BEIS ICF Mitigation Investment Options: Opportunity Assessment Reports

Final report prepared for BEIS

9 November 2020

:vivideconomics
putting economics to good use

Adam Smith International

Factor
Ideas for change

PBL Netherlands Environmental Assessment Agency

Contents

Acknowledgements

This research was conducted by Vivid Economics, in partnership with Adam Smith International, Factor and PBL. Vivid Economics led the project and analysis, with support from Adam Smith International and Factor who provided expert input and co-authored the Opportunity Assessment reports. PBL provided critical analysis on climate impacts, investment gaps and cost-effectiveness of mitigation measures through climate modelling using the IMAGE model.

Authors and contributing experts for the work include:

Organisation	Authors	Contributing Experts
Vivid Economics	Deven Azevedo, James Bragg, Maarten Hage, Nick Kingsmill, Aurore Mallon, Cor Marijs, Leire Sarasola, Shahbano Soomro, Bryan Vadheim, John Ward (Pengwern Associates)	Simon Dietz, Jason Eis, Sam Fankhauser, Alex Kazaglis, Penny Mealy
Adam Smith International	Andreas Beavor, Devanshi Gupta, Nicholas Haslam, Hans Verolme	Mansoor Ali, Alina Averchenkova, Ian Barrett, Adam Brown, John Cantrill, Federica Chiappe, Michael Cowing, Alekya Datta, Patrick Hardcastle, Gilberto Jannuzzi, Asier Larretxea Barja, Jon Macartney, Darius Nassiry, Katrina Pielli, Shri Prakash, Sharif Qamar, Milan Rusnak, Ian Tellam, Tali Trigg, David Shelley, Jan van den Akker, Maria Yetano
Factor	Iker Larrea, Craig Menzies, Asier Sopelana	Elena Aguirre, John Cantrill, Alexandre Fernandes, Germán García, Jiangwen Guo, Nils Hempelmann, Jules Siedenberg, Kepa Solaun, Paul Stevenson, Carolina Trimiño, Ángel Valverde, Maria Yetano
PBL		HsingHsuan Chen, Oreane Edelenbosch, Andries Hof, Nicole van den Berg, Kaj-Ivar van der Wijst, Detlef van Vuuren

The authors would like to thank the contributions of the UK BEIS steering group and all those who provided input and feedback throughout the process, guidance, the contributing experts who helped shape and steer the work, and all interviewees and workshop participants for contributing their time and expertise to this research.

Introduction

This report provides 15 Opportunity Assessment Reports for mitigation options for potential UK Department for Business, Energy and Industrial Strategy (BEIS) investment within the UK International Climate Finance (ICF). These reports are the output of a research programme that provides BEIS with robust evidence to feed into the strategic approach to deploying UK ICF in support of global climate mitigation. The aim of these reports is to support decision making about future BEIS ICF mitigation investments, with a particular focus on expanding BEIS's evidence base by focusing on areas of high importance where prior evidence or research within BEIS was (relatively) limited. For a set of 15 research priorities across the energy sector, the land use sector, transport and cross cutting technology and policy opportunities, the analysis identifies the mitigation potential, investment need, development co-benefits, cost-effectiveness, barriers that hold back autonomous action, and the UK's comparative advantage arising from its decarbonisation expertise and strengths in providing development assistance. Each opportunity area is considered using a consistent approach and against a common scoring rubric. The results of the assessment were validated through expert workshops and expert elicitation.

The analysis considers each opportunity area according to six key themes to inform strategic decision making on where and how to prioritise funding. Individual opportunity reports are structured around six critical themes for prioritisation of climate finance, agreed in consultation with key BEIS stakeholders. These themes include:

Climate impact: The relative importance of an opportunity in leading to a reduction in greenhouse gas (GHG) emissions, through the opportunity's direct impact on decarbonisation and its potential to support transformational change.

Development impact: The degree to which an opportunity provides significant co-benefits within a region through enabling the achievement of 2030 SDGs.

Investment need: The magnitude of investment need and the degree to which that need is likely to be unmet to 2050 by both public and private sector funding sources.

Cost-effectiveness: The long-term effectiveness of investments in reducing greenhouse gas emissions via an opportunity, in terms of emissions per British Pound Sterling (GBP) of investment. Differences in cost-effectiveness can help to distinguish between otherwise similar opportunity-region combinations.

Barriers to adoption: The extent to which business-as-usual support for an opportunity is likely to remain insufficient in the future by judging the strength of barriers in the political economy, the strength of market failures and the conditions in the broader enabling environment.

UK additionality: The degree to which UK funding or support specifically is likely to be beneficial, either because of the ability to harness UK expertise or the existence of strong existing UK partnerships in an opportunity area.

In addition to the main criteria assessment, the analysis identifies and prioritises interventions to support mitigation within each opportunity area. Two final sections within each opportunity report consider:

Intervention opportunities: The most suitable interventions for future ICF investment, based on the preceding assessment.

Intervention case studies: Examinations of one to three previous or ongoing interventions within each opportunity area, to provide real-world context on potential interventions, and identify how interventions have addressed identified barriers and the lessons that can be taken from these investments.

The assessment considers climate impact and investment need under a 1.5-degrees Celsius scenario, several 2-degrees Celsius scenarios and a 'stated policies' business-as-usual scenario. Scenarios referred to in this work include:

The *stated policies scenario* (also referred to as "NPI" scenario or "business-as-usual" scenario) is one in which only current implemented energy and climate policies are considered. This scenario is considered the business-as-usual scenario.

2-degrees scenarios. Carbon budgets for these scenarios are set to align with "well below 2 degrees" i.e. a probability of 66% of staying below 2°C. There are various plausible pathways to reaching 2 degrees. To capture this uncertainty, we consider the following scenarios:

A *"Default 2 degree" scenario*. In this scenario it is assumed that national climate and energy policies were implemented until 2020, after which emission reduction measures are implemented in a cost-optimal manner across greenhouse gases, regions, and over time.

A *"NDC 2-degrees" scenario*, in which decarbonisation actions follows current NDCs until 2030, after which decarbonisation intensifies to meet a 2°C target.

A *"lifestyle" scenario*, in which consumers change their habits towards a lifestyle that leads to lower greenhouse gas emissions. This includes a less meat-intensive diet, less CO_2-intensive transport modes, less intensive use of heating and cooling and a reduction in the use of several domestic appliances.

A *"renewables" scenario* (otherwise known as the "central power scenario"), with higher electrification rates in all end-use sectors, in combination with relatively ambitious assumptions on the integration of variable renewables and on costs of transmission, distribution and storage.

1.5-degrees scenario. A 1.5 °C carbon budget is less than half that of the available 2°C budget, which dramatically increases the depth and rate of decarbonisation required. All mitigation options need to be deployed to (close to) their maximum potential.

Assessments across each criteria area and intervention assessments are based on quantitative evidence, literature review, and expert inputs. These assessments provide rankings of how individual opportunities perform in each of the six key criteria themes – and how individual regions rank within each opportunity – through consolidation of quantitative and qualitative evidence and elicitation across experts. Note that these assessments aim to capture relative differences within and between prioritised opportunities rather than provide an absolute assessment across all potential mitigation investment areas.

When considering summary opportunity-level scorings, it is important to bear in mind that scores are intended to convey an average across different issues. There is often high diversity of strengths and weaknesses within criteria for individual opportunities – for example, across different regions or intervention areas.

The full methodology applied in each opportunity assessment is provided in the companion Synthesis Report.

Variable Grid Renewables

Summary

The on-grid variable renewable electricity opportunity considers a range of grid-connected variable renewable energy sources expected to provide large climate impact at high cost-effectiveness. The assessment of on-grid variable renewables includes grid-connected onshore wind, offshore wind, solar photovoltaics (PV) and concentrated solar power (CSP). As variable low-carbon power generation technologies, they deliver similar benefits, and face similar barriers to deployment, in low- and middle-income countries. Their key benefit is low-carbon, cost-effective, electricity. Variable renewable electricity is often cost-competitive with non-renewable electricity sources in many regions. There are, however, significant barriers to deployment, particularly market and institutional structures to deal with intermittency in supply, and the costs of finance.

Interventions to encourage adoption of on-grid variable renewables in focus regions include measures to de-risk investments and reform electricity market regulation. Given the largest barriers to adoption for variable renewables, example interventions include:

Financial and technical support to de-risk investments, to address the higher costs of capital that renewable energy investments face and the unfamiliarity of local financial institutions.

Technical assistance to reform electricity market regulation, with current regulatory systems often not allowing intermittent renewable energy to compete fairly with other generation sources.

Table 1 Variable grid renewables assessment summary

Criteria	Assessment	Notes
Climate impact	High	• Critical to power sector decarbonisation in every region, helping to avoid around 50% of power sector CO2 emissions (7.3 gigatonnes of carbon dioxide [$GtCO_2$]) in 2050 beyond business-as-usual (BAU).[1,2] • Large positive spillovers on all other sectors through the provision of low-cost and low-carbon electricity, particularly via onshore wind and solar PV which can be cost competitive with non-renewable electricity today.
Development impact	High	• Substantial and long-lasting positive development impact. Variable renewables are critical to achieving Sustainable Development Goal (SDG) 7, access to low-carbon reliable energy, as well as improving progress towards SDG 3, good health and wellbeing, and SDG 8, decent work and economic growth.
Investment gap	High	• Total investment gap in the opportunity is high, USD 9 trillion by 2050, given the capital intensity of renewables and scale of deployment required. • Investment will need to double relative to BAU. • Over 70% of investment required is in solar PV and onshore wind.
Cost-effectiveness	High	• PV and onshore wind are a highly cost-effective mitigation opportunity across all regions, often able to deliver CO2 emissions for GBP at no additional cost. • Regional cost-effectiveness impacted by the emissions intensity of the current power generation mix, natural endowments, local supply chain, and financing costs and cost of renewable integration for the local grid.
Barriers to adoption	Medium	• Despite increasing cost-competitiveness, several moderate political economy, market failure, and enabling environment barriers slow down the adoption of variable renewables. Most significant barriers include presence of fossil fuel subsidies, weak or non-existent power transmission infrastructure, and the poor

[1] This figure reflects emissions reductions in the IMAGE renewables decarbonisation scenario vs the BAU scenario. The percentage reduction in emissions is calculated relative to 2050 BAU emissions from the power sector.
[2] All figures in this report will reflect mitigation potential beyond BAU – the BAU is taken to be IMAGE's new policies scenario.

Criteria	Assessment	Notes
		financial capacity of local utilities and governments to enter into power purchasing agreements.
UK additionality	High	• The UK has leading expertise in feasibility assessments and financing of variable renewable energy domestically and internationally. Compared to other international donors, UK additionality is greatest in offshore wind energies.

Source: Vivid Economics, ASI & Factor

Key lessons for supporting mitigation through variable renewables:

- South Asia (including India), Indonesia, and South Africa are likely to deliver the largest mitigation opportunity, due to their high grid emissions intensity and availability of low-cost solar and wind.
- Despite declining technology costs, significant barriers continue to reduce the profitability of variable renewables for investors, including the risks of a public electricity off-taker not being able to pay for the power it purchases over the lifetime of the generation asset
- Government intervention can most cost-effectively crowd-in private sector investment by:
  - Taking on market risks, through credit or power purchase guarantees.
  - Reducing market risks over the longer term, by assisting utilities on tracking and improving their financial sustainability.
  - Or lowering financing costs, through concessional finance.[3]
- Amongst regions with the largest mitigation potential, the UK can leverage its strong Official Development Assistance (ODA) ties with South Asia and Southern Africa.

[3] World Bank. (2019). "The role of the public sector in mobilising commercial finance for grid-connected solar". https://openknowledge.worldbank.org/bitstream/handle/10986/32185/The-Role-of-the-Public-Sector-in-Mobilizing-Commercial-Finance-for-Grid-Connected-Solar-Projects-Lessons-Learned-and-Case-Studies.pdf?sequence=1&isAllowed=y

Introduction to the opportunity

Role of the opportunity in decarbonisation of developing countries

The power sector emitted 7.4 Gt CO_2 in low- and middle-income countries in 2015, rising to 16 GtCO_2 in 2050 under a BAU scenario. The power sector accounts for approximately 40% of total emissions from low- and middle-income countries today.[4] To reach the 1.5 °C target, the sector needs to nearly fully decarbonise. While decarbonising, capacity will also need to substantially expand to meet rising demand. On-grid variable renewables are will have a critical role in the future of the power sector, expected to provide 68% of electricity by 2050 in our central power decarbonisation scenario.[5]

Currently, annual deployment of on-grid variable renewables is far lower than what a world compatible with the Paris Agreement would require - approximately 220 gigawatt (GW) additions per annum by 2050.[6] Capacity of wind and solar would need to grow to approximately 7,800 GW by 2050 in the central power decarbonisation scenario.[7] This reflects the need to electrify, decarbonise, and meet economic growth. As Table 2 shows, this will require around a 3x increase in annual capacity additions.

Table 2 Approximate annual capacity additions required across low-and middle-income regions

Technology	2018 capacity additions (GW)	Annual average capacity additions up to 2050, depending on scenario (GW) – forecast	
		BAU	Renewables (2 degrees)
Onshore wind	28	0.71	45
Offshore wind	1.8	1.8	8.7
Solar PV	62	23	120
Solar CSP	0.7	2.4	56

Source: Vivid Economics, ASI and Factor based on PBL's IMAGE model (renewables scenario) for future capacity additions and International Renewable Energy Agency (IRENA) (2019) for past capacity additions

Scope considered in this assessment

The on-grid variable renewable electricity opportunity is defined as grid-connected solar PV, solar CSP, onshore wind, and offshore wind. Grid connection implies that energy generation sources are connected to a national or regional electricity transmission grid, through which they supply electricity. In other words, we do not consider off-grid or mini-grid connected renewable power.[8]

The assessment considers all ODA-eligible regions, given the large mitigation potential of on-grid renewable electricity within each of them. Nonetheless, a subset of regions are focused on in consideration of their relatively large mitigation potential and in consultation with the BEIS steering group. Selected regions include:

- India, which has the second largest GtCO_2 abatement from variable renewables in 2050 (following China).

[4] International Energy Agency. (2017). "Energy Technology Perspectives". https://www.iea.org/reports/energy-technology-perspectives-2017
[5] From IMAGE (considering PV, CSP, Wind onshore, and Wind offshore).
[6] Under a1.5-degree scenario, annual additions are 26 GW.
[7] Under a1.5-degree scenario, this value is 980 GW.
[8] This opportunity also does not consider: a) on-grid non-variable energy sources, such as hydropower and geothermal, b) off-grid renewable electricity, which uses wind and solar power to provide energy directly to households. For instance, solar home systems, c) The integration of on-grid renewable electricity on a grid network, via energy storage or demand-side response measures. These measures are captured in the Energy System Flexibility Opportunity Report.

East Africa, which has the largest relative mitigation potential from variable renewables in 2050 (as a share of 2015 power sector emissions).

South America (excluding Brazil), henceforth ‘South America’, which has close to 100% variable renewable powered electricity in 2050 and is amongst the largest contributors to $GtCO_2$ abatement from the opportunity.

South-East Asia, where deployment of variable renewables is expected to scale up significantly relative to 2015.

South Africa, which was included after consultation with BEIS steering group, however is expected to have lower relative and absolute emissions reduction from variable renewables.

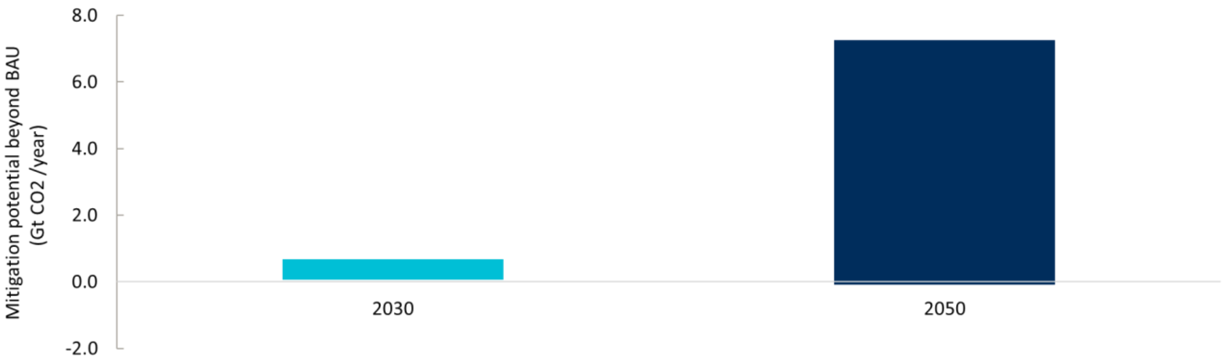
This assessment focuses on the benefit of supporting the opportunity as a whole and does not aim to comprehensively assess the effectiveness of specific investment opportunities or interventions. However, for context, specific investment opportunities are detailed in Section 0.

Climate impact

Mitigation potential and urgency

Across low- and middle-income countries, variable renewables can help avoid around 50% of power sector CO_2 emissions (7.3 $GtCO_2$) in 2050 beyond BAU.[9,10] In the central decarbonisation scenario, power sector emissions will need to decrease by 100% in 2050, relative to BAU. Even higher emissions reductions, 140% relative to BAU, could be required in a 1.5-degrees scenario where negative emissions technologies (e.g. BECCS) are deployed at scale. On-grid renewables will be key to meet growing electricity demand without increasing emissions, at the same time as displacing emissions from coal-fired power stations. Some on-grid variable renewables are already cost-competitive with fossil generation, so are expected to be deployed at scale in a BAU scenario. As Figure 1 shows, in some scenarios this implies there is 0 additional mitigation from renewables relative to BAU, particularly in the near term. In the longer term, the scale of additions and emissions reductions expected from variable renewables in a decarbonised power sector still far exceeds expectations in BAU. Notably, this will be affected by uncertainty in the BAU scenario (see Figure 1).

Figure 1 Range of mitigation potential compared to BAU in 2030 and 2050



Note: The bars indicate the range of mitigation potential estimates across the five IMAGE decarbonisation scenarios. Mitigation potential in each scenario is calculated relative to the BAU one, which is taken to be IMAGE's national policies scenario. Mitigation potential in 2030 is therefore calculated as emissions reductions in 2030 in one decarbonisation scenario minus the emissions reductions in 2030 in the national policies scenario.

Source: Vivid Economics, ASI and Factor based on PBL's IMAGE model

The largest mitigation potential in 2050 occurs in regions with the largest power sector emissions today: China, India, and Eastern Europe and Central Asia. China, India, and Eastern Europe and Central Asia are expected to account for 75% of $GtCO_2$ abated by low and middle-income countries in 2050. This reflects the sheer size of power sector emissions in these countries today. In 2015, they account for 80% of total emissions across low and middle-income countries. Nearly 60% of power sector emissions in low- and middle-income countries result from China alone in 2015. In comparison, the focus regions together account for around one-third of $GtCO_2$ abated in 2050.

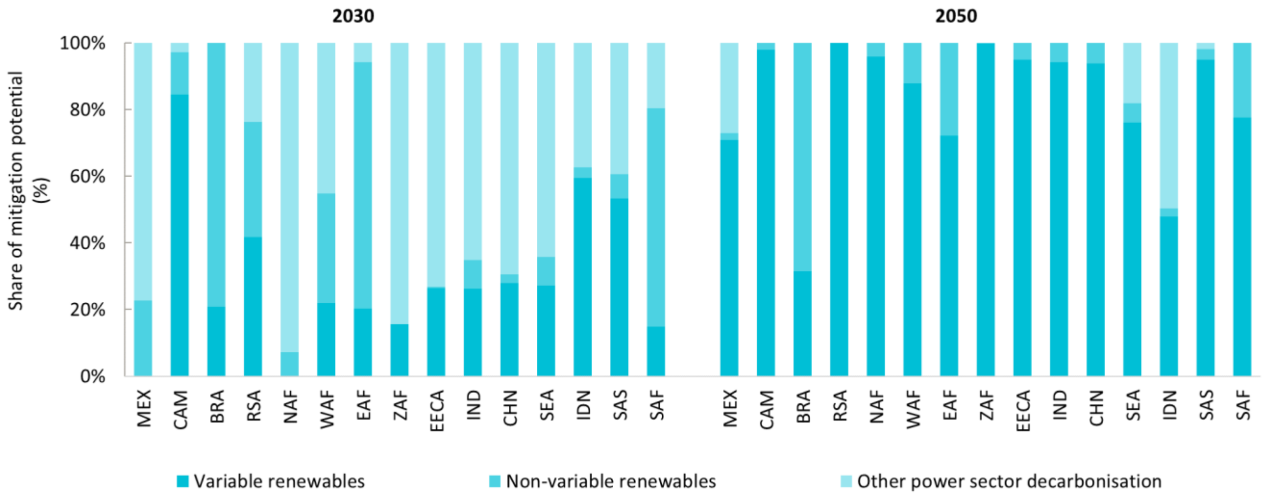
Nevertheless, in every region, variable renewables contribute significantly to local power sector decarbonisation - 85% of GtCO2 abated in the focus regions in 2050 beyond the BAU. As Figure 2 shows, variable renewables account for between 30% to 100% of power sector emissions reductions beyond BAU in 2050, depending on region. Higher relative mitigation potential in Mexico, North Africa, and South Asia is influenced by the cost-competitiveness of renewables in these regions, and the lack of competition from

[9] This figure reflects emissions reductions in the IMAGE renewables decarbonisation scenario vs the BAU scenario. The percentage reduction in emissions is calculated relative to 2050 BAU emissions from the power sector.

[10] All figures in this report will reflect mitigation potential beyond BAU – the BAU is taken to be IMAGE's new policies scenario.

non-variable renewable energy. Hydropower in Brazil results in a smaller role for variable renewables, in comparison.

Figure 2 On-grid variable renewable electricity contributes, on average, to 31% of power sector abatement in 2030, 75% in 2050



Note: The bars reflect the mitigation potential in IMAGE's renewables decarbonisation scenario minus mitigation achieved in IMAGE's new policies scenario (BAU scenario). Abbreviations correspond to the following: MEX= Mexico, CAM = Central America, BRA = Brazil, RSA = South America excluding Brazil, NAF = North Africa, WAF = West Africa, EAF = East Africa, ZAF = South Africa, EECA = Eastern Europe and Central Asia, IND = India, CHN = China, SEA = South-East Asia excluding Indonesia, IDN = Indonesia, SAS = South Asia excluding India, SAF = Southern Africa excluding South Africa. Mitigation potential from 'Other' includes energy efficiency and fossil fuel Carbon Capture and Storage (CCS). Mitigation potential from Non-variable Renewables (RE) includes hydropower, geothermal, and biomass with and without CCS.

Source: Vivid Economics, ASI and Factor based on PBL's IMAGE model (renewables scenario)

To 2030, the absolute mitigation potential is expected to be highest in regions shifting from coal-powered generation to renewables, such as in China, Indonesia, and India. Renewable electricity is a significant contributor to decarbonisation up to 2030 across all regions, as power is a relatively cheap sector to decarbonise, and low-carbon electricity is required to decarbonise other sectors. However, the largest absolute mitigation potential up to 2030 is expected to be in regions with emissions-intensive electricity (proxied by the kilograms of carbon dioxide per kilowatt-hour [$kgCO_2$/kWh]), such as China, Indonesia and South Asia, where coal-fired generation is prevalent. Coal's share of the power mix was approximately 75% in India, 70% in China, and 60% in Indonesia in 2017.[11] Together these countries account for nearly 80% of $GtCO_2$ abatement in 2030. Notably, the emissions intensity of South's Africa power sector (90% of power is coal fired) does not translate to large mitigation in the modelling.[12] This could reflect the imperfections of the modelling in forecasting regional mitigation. Regardless, South Africa's power sector provides a large short-term mitigation opportunity based on the status of the sector today.

Onshore wind and solar PV will be the key technologies to deliver emissions reductions. Onshore wind and solar PV will account for most of the abatement by renewable technologies in 2050, with additional cumulative capacity additions of 1,500 GW and 3,200 GW expected to 2050 respectively.[13] This is far greater than offshore wind or CSP, which are together expected to increase by 2,100 GW to 2050. These differences

[11] IEA. (2019). "World Energy Balances".

[12] Relative mitigation potential from variable renewables in South Africa is 6% in 2030. In other words, the mitigation potential achieved in 2050 beyond the BAU is a small share of 2015 power sector emissions. In comparison, relative mitigation potential from variable renewables is 60% in 2030.

[13] These figures reflect a renewables decarbonisation scenario. Onshore wind and solar PV capacity additions under the 1.5-degree scenario are 25 GW and 805 GW respectively. The 0% emissions reductions relative to 2015 reflects Brazil, which has limited power sector emissions today.

are primarily driven by expectations on relative technology costs, which are 30% lower for onshore wind and solar PV than alternative on-grid renewables.[14]

Box 1 Modelling uncertainty

There is large uncertainty over the exact magnitude of emissions reduction from the opportunity, stemming from cost assumptions of on-grid renewable electricity. Cost optimised modelling will rely more or less heavily on different renewable technologies depending on cost assumptions, which often do not reflect changing costs of less mature technologies. For example, in a low-cost renewables scenario, the emissions reduced by solar in 2050 are 6.5 times more than under the 1.5-degrees scenario.

The availability of biomass for bio-energy with carbon capture and storage (BECCS) as well as assumptions on BAU also heavily impact assessments of the abatement potential of on-grid renewables. High levels of BECCS replace the need for renewable electricity generation in the 1.5-degrees scenario. However, levels of BECCS deployment predicted by IMAGE ought to be treated with caution. They rely on an ambitious assumption of bioenergy supply of approximately 200 exajoules (EJ)/year, far higher than the 14-84 EJ/year predicted by the Committee on Climate Change (CCC).[15] Optimistic BAU scenarios assume coal will be largely displaced by low cost renewables purely driven by economics. This is likely optimistic (given other barriers to deployment as well), but the degree of additionality is important to consider both when assessing the need for public support, and when interpreting estimates of abatement potential.

To capture the expected role of variable renewables, and the uncertainty of future BECCS deployment, we choose to use IMAGE's renewables scenario as our "central power scenario". As discussed further in Box 2 of the Non-variable Renewables Opportunity Report, elicitation with experts on likely deployment of variable renewables, as well as research on planned or existing investment, suggest additions of solar and wind to be far higher than predicted under IMAGE's 1.5 degrees scenario.

To capture uncertainty over BAU investment, we consider how cost-competitiveness is expected to evolve under current investment levels. To inform our assessment of the BAU we rely on market-led assessments of expected costs of solar and wind, and cost-competitiveness relative to thermal power generation. Examples include: IRENA's "Future of Solar PV", "Future of Wind", and "Global Renewables Outlook", as well as BloombergNEF (BILLIONEF) and Carbon Tracker estimates of relative cost-competitiveness.[16] However, these studies notably do not account for political and market barriers, which we recognise may slow down deployment in the BAU scenario despite increasing competitiveness. Even BAU estimates therefore ought to be viewed as contingent on efforts to decrease barriers to action.

Transformational change

Variable renewable energy offers substantial opportunities for transformational change. Interventions that help to create the right regulatory enabling environment or that can de-risk or catalyse private sector investment in resources such as solar PV or onshore wind are likely to encourage uptake at scale. This will particularly be the case if those projects pave the way in terms of refining appropriate legislation and providing reassurance to investors that a viable model is possible. Transformational change can also be realised in terms of enabling the decarbonisation of other sectors, such as electric vehicles and many

[14] IRENA. (2019). "Renewable Power Generation Costs in 2018". https://www.irena.org/-/media/Files/IRENA/Agency/Publication/2019/May/IRENA_Renewable-Power-Generations-Costs-in-2018.pdf
[15] Committee on Climate Change. 2018. "Biomass in a low-carbon economy". https://www.theccc.org.uk/publication/biomass-in-a-low-carbon-economy/
[16] IRENA. (2019). "Future of solar PV". https://www.irena.org/-/media/Files/IRENA/Agency/Publication/2019/Nov/IRENA_Future_of_Solar_PV_2019.pdf; IRENA. (2019). "Future of wind". https://irena.org/-/media/Files/IRENA/Agency/Publication/2019/Oct/IRENA_Future_of_wind_2019.pdf ; IRENA. (2020). "Global Renewables Outlook". https://www.irena.org/-/media/Files/IRENA/Agency/Publication/2020/Apr/IRENA_Global_Renewables_Outlook_2020.pdf; Carbon Tracker. (2020). "Powering down coal". https://carbontracker.org/reports/coal-portal/

industrial processes, by providing low-cost and low-carbon electricity. Many of the drivers of transformational change in non-variable renewable energy are common across the target regions but several specific aspects can be identified. For example, the decarbonisation of energy can really drive a transformational uptake of zero-carbon vehicles and cleaner industrial processes in **India**, which will have significant development spillover in areas such as air quality and health. The support on identifying renewable resources and crowding in private sector investment is likely to have a particularly high transformational impact in **East Africa** and certain countries in **South America**, where there is strong potential but a poor enabling environment in terms of financial and regulatory risk.

Table 3 Transformational change assessment

Transformational change criterion	Interventions to support change	Regional potential
	Sensitive intervention points	
Improvement of local capacities and capabilities	Building capacity of government and stakeholders in appropriate regulatory frameworks and investment enabling environment. Developing integrated strategies for attracting and deploying variable renewables, across specific sectors such as wind or PV.	East Africa., South-East Asia East Africa, South America
Local ownership and strong political will	Awareness raising and training for government and utilities, relating to the potential of non-variable renewables in the local context. Developing a database of variable renewable energy resources in the target regions.	East Africa, South America
Leverage / creation of incentives for others to act	Support in enabling reliable power purchasing agreements helps to incentivise variable renewables generation. Supporting the development of a pipeline of bankable projects. Supporting governments to de-risk investment via financial and policy-based measures.	All regions
	Spillovers	
Broad scale and reach of impacts	Support enables decarbonisation of other sectors, such as electric vehicles and many industrial processes, by providing low-cost and low-carbon electricity.	India, South Africa
Sustainability (continuation beyond initial support)	Establishing durable and well-supported policy measures to enable renewable investment at scale. Improving the enabling environment and market conditions, allowing more commercially led projects to thrive.	All regions
Replicability by other organisations or actors	Investment and development process could enable renewable energy installation, results in replication by other donors and/or private sector entities.	India, South America, South-East Asia
	Innovation	
Catalyst for innovation	Blended finance initiatives to catalyse private sector investment. De-risking investment via financial incentives or policy measures.	All regions
Evidence of effectiveness is shared publicly	Importance of sharing learning and evidence of what works well and what has failed, or could be improved.	All regions

Source: Vivid Economics, ASI and Factor

Development impact

SDG impacts

Improved access to on-grid clean energy has notable positive impacts on achieving SDGs in all regions. On-grid renewable electricity helps countries achieve several sustainable development goals, as set out in Table 4.

Table 4 SDG impacts

SDG	Strength of impact	Most relevant region	Rationale
Positive Impacts			
SDG 1 – No poverty	High	East Africa, India, South Africa, South America	Access to electricity is a key driver of income generation, better education, and more efficient use of time otherwise spent on gathering fuel wood etc., all of which help to reduce poverty.
SDG 3 – Good Health and well being	Moderate	India, South-East Asia, South Africa	The opportunity has a potential to decrease air pollution, thereby reducing pollution-related diseases and deaths. Decreased coal and other fossil fuel power generation, as well as displacing diesel generators and wood or kerosene burning stoves, would also contribute to health and wellbeing.
SDG 7 – Affordable and clean energy	High	All regions	The opportunity is essential in order to increase renewable energy in the global energy mix and improve energy efficiency.
SDG 8 – Decent work and economic growth	Moderate	India, South Africa, South America	The opportunity has potential to create jobs in the renewable energy sector. If grid-connected renewables can reduce power outages, this would in turn contribute to productivity of enterprises.
Negative Impacts			
SDG 9 – Industry, Innovation and Infrastructure	Low	East Africa, South-East Asia	If renewable energy is not integrated properly into grids, it can lead to fluctuations and blackouts, with severe impacts on industry. For example, the Philippines has historically avoided renewables due to such energy security concerns.
SDG 15 – Life on Land	Low	All regions	PV, wind arrays, and CSP plants require land and can have negative environmental impacts if not managed appropriately.

Note: Low positive impacts on SDGs are not included in this table.
Source: Vivid Economics, ASI and Factor

Demand in target regions

Table 5 Summary assessment of demand in target regions

Region	Demand	Rationale
India	High	Ambitious targets and improving regulatory environment evidenced by efforts of the National Institution for Transforming India (NITI Aayog) and recent investments in the sector.
East Africa	Low – Moderate	Variable ambition and plans across countries, increasing share of renewables only a priority in some.
South Africa	High	Aims to increase renewable energy in the energy mix as evidenced by nationally determined contributions (NDC), national plans, and policies.
South-East Asia	Low - Moderate	The potential to increase on-grid renewables is high but varying regulatory and policy environment across countries.
South America	Low – High	Variable policy and regulatory environment across counties. Chile and Colombia are particularly promising.

Source: Vivid Economics, ASI and Factor

India: According to its NDC commitments, the Government of India has set an ambitious target of achieving 175 GW of renewable energy capacity by 2022. These include 100 GW of solar capacity addition and 60 GW of wind power capacity. As of December 2019, India's on-grid renewable energy capacity stood at 85.9 gigawatts (GW)[17] and in 2018, India's investment in solar PV was greater than in all fossil fuel sources of electricity generation combined.[18] India has pledged to promote renewable energy in its NDCs[19] and has very ambitious renewable energy targets, aiming for 450 GW by 2030, compared to a current total of 369GW installed across all energy sources.[20] The draft National Energy Policy by NITI Aayog, currently under consultation, is an excellent framework and should be adopted swiftly to guide policy making, implementation, and enforcement across central and state governments.[21]

East Africa: All Eastern African countries mention energy-related policies and measures in their NDCs and the majority have stated their goal to enhance their ambition or action in the 2020 NDCs.[22] Eight East African nations have introduced National Energy Plans or Policies (NEPs) to meet growing energy demand with affordable, sustainable energy services that enable socio-economic development.[23] Kenya and Ethiopia have more developed and ambitious energy policies as compared with others. Ethiopia's National Electrification Programme aims to achieve 100% electrification in 2025, with 35% off-grid and 65% on-grid by 2030.[24] The present contribution of wind to the total energy mix is marginal but there is high potential.[25] Kenya has one of the highest potentials for wind generation in Africa and Ethiopia aims to increase overall generating capacity by 25,000 megawatt (MW) by 2030, of which wind would account for 2,000 MW by 2030. In 2016, Sudan, Madagascar, Ethiopia, Kenya, and Mauritius all set wind energy targets. Somalia is considered to have high onshore potential,

[17] Institute for Energy Economics and Financial Analysis. (2020). "India's Renewable Energy Policy Headwinds". Source: https://ieefa.org/wp-content/uploads/2020/02/Indias-Renewable-Energy-Policy-Headwinds_February-2020.pdf
[18] IEA. (2020). India is going to need more battery storage than any other country: https://www.iea.org/commentaries/india-is-going-to-need-more-battery-storage-than-any-other-country-for-its-ambitious-renewables-push
[19] Haque et al. (2019). NDC pledges of South Asia: are the stakeholders onboard? Climatic Change, Vol 155.
[20] India's Ministry of New and Renewable Energy. Accessed July 2020: http://mnre.gov.in
[21] IEA. (2020). India 2020: Energy Policy Review: https://www.iea.org/reports/india-2020
[22] Cabre & Sokona. (2016). Renewable Energy Investment in Africa and Nationally Determined Contributions (NDCs). Global Economic Governance Initiative, Working Paper 010. University of Boston, USA.
[23] IRENA. (2015). Africa 2030: Roadmap for a Renewable Energy Future. IRENA, Abu Dhabi.
[24] IEA. (2019). Ethiopia Energy Outlook. https://www.iea.org/articles/ethiopia-energy-outlook
[25] Kazimierczuk, Agnieszka H. (2019). Wind energy in Kenya: A status and policy framework review. Renewable and Sustainable Energy Reviews. Volume 107. https://www.sciencedirect.com/science/article/pii/S136403211830861X

followed by Sudan, Madagascar, and Kenya.[26] However, despite progress in several countries (e.g. Kenya, Ethiopia, Ghana, and Rwanda), current and planned efforts to provide access to clean energy barely outpace population growth.[27]

South America: All South American countries in the focus region identify energy as a mitigation sector in their NDCs/intended nationally determined contributions (INDCs). In addition to identifying it in NDCs, there are increasingly well-developed energy related national polices and laws. Renewable energy investment has surged recently in the region, with Chile, Colombia, and Argentina leading the way. Colombia launched its Energy Plan 2050 in 2016, which aims to diversify the country's energy resources and ensure a reliable energy supply. The Plan also aims to include wind power plants, solar PV, and geothermal energy generation in the country's electric mix.[28] Other countries, such as Ecuador, Peru, and Uruguay, show strong commitment to encouraging renewable energy in both their NDCs and national energy policies.

South-East Asia: All South-East Asian countries identify energy as a mitigation pathway in their NDCs. While, in the first half of 2019, approvals of new coal-fired capacity were exceeded by capacity additions of solar PV for the first time,[29] there is still a clear risk that the region will become locked into a high-carbon development pathway.[30] Despite falling costs, the contribution of solar PV and wind remains small, though some markets are now putting in place frameworks to better support their deployment. South-East Asia has considerable potential for renewable energy, but (excluding the traditional use of solid biomass) it currently meets only around 15% of the region's energy demand and under current policy the share is forecast to be 20% by 2040. In South-East Asia, the share of coal in the power mix increased in 2018 and, based on today's policy settings, coal demand is projected to rise steadily over the coming decades, although this is likely to change in light of rapidly falling costs for renewable energy.[31]

South Africa: South Africa is seen as a key emerging market for renewables[32] and its NDC proposes a significant increase in renewables-based generation from wind and solar, as well as gas-based generation capacity, by 2030 (an additional 15.8 GW for wind and 7.4 GW for solar).[33] In its Nationally Appropriate Mitigation Action (NAMA) the South African Renewables Initiative aims to mobilise domestic and international funding, and sector expertise, to support South Africa to scale up renewable energy.[34] South Africa's Integrated Resource Plan sets out a diverse energy mix and nine policy decisions to ensure the security of its national electricity supply.

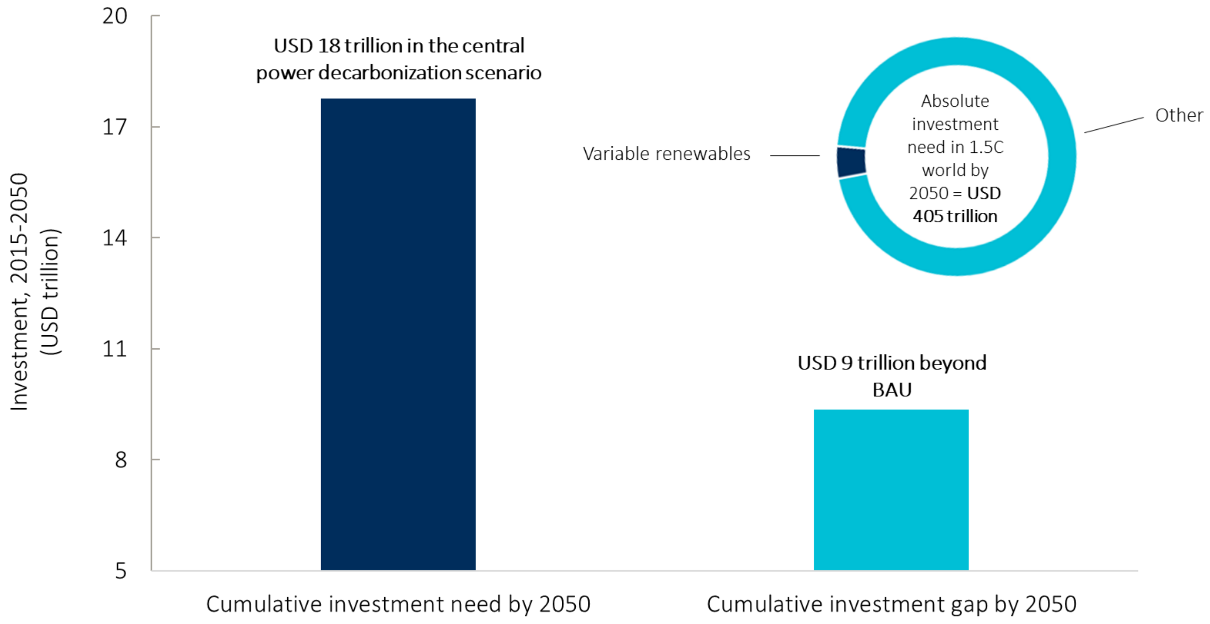
---

[26] Ibid.
[27] IEA. (2019). Africa Energy Outlook 2019. https://www.iea.org/reports/africa-energy-outlook-2019
[28] International Energy Agency. Colombia: https://www.iea.org/countries/Colombia
[29] IEA. (2019). Southeast Asia Energy Outlook 2019. https://www.iea.org/reports/southeast-asia-energy-outlook-2019
[30] Ibid.
[31] World Economic Forum. (2019). "Can Southeast Asia keep up with growing energy demand?". https://www.weforum.org/agenda/2019/12/asean-southeast-asia-energy-emissions-renewables/
[32] IRENA. (2020). Renewable Energy Finance Brief: Institutional Capital. https://www.irena.org/-/media/Files/IRENA/Agency/Publication/2020/Jan/IRENA_RE_finanace_Institutional_capital_2020.pdf
[33] Action Climate Tracker: South Africa. https://climateactiontracker.org/countries/south-africa/
[34] NAMA Database: South Africa. Accessed July 2020. http://www.nama-database.org/index.php/South_Africa

Investment need

Investment in the opportunity in low- and middle-income countries will need to scale up to a cumulative USD 18 trillion by 2050, twice the investment expected under BAU. Overall, the scale of investment required in the opportunity is relatively large. Renewables are capital intensive, and hence require substantial upfront investment to deploy. Annual investment requirements are multiple 100s of billions. The exact scale of investment needs beyond BAU depends on assumptions on BAU. In our BAU scenario, average annual investment is approximately 0.25 trillion – equal to the level of global investment levels witnessed in 2019, and around 40% higher than current renewables investment levels in low- and middle-income countries.[35,36] Relative to BAU, investment would need to double each year to 2050 in a high renewables decarbonisation scenario. In absolute terms, cumulative additional investment needs (beyond BAU) are moderate compared to other opportunities - approximately USD 9.3 trillion.

Figure 3 Despite large investment need in on-grid renewable electricity, only 50% additional investment is required beyond BAU



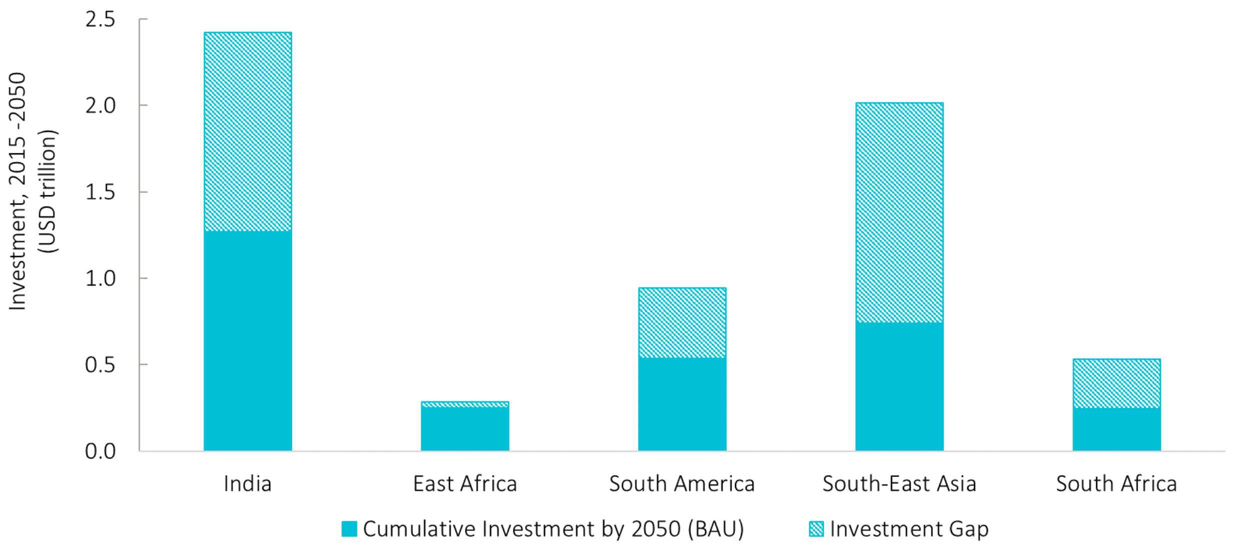
Notes: Investment need calculations are calculated from the International Energy Agency's (IEA) investment levels on renewables capital expenditures (capex) in the Beyond 2 Degrees scenario and Reference Technology Scenario; IEA investment need calculations are approximately 10% higher than IMAGE capacity additions, resulting in a small degree of inconsistency.

Source: Vivid Economics, ASI and Factor using IEA. (2017). Energy Technology Perspectives.

Across focus regions, the cumulative investment gap to 2050 is between 11% to 60% of the investment needed in a pathway compatible with the Paris Agreement. There is a large range in the scale of investment need across regions, depending on the scale of capacity additions required. This ranges from USD 2.4 trillion cumulative investment need in India to USD 0.3 trillion in East Africa. The investment gap is expected to be largest in absolute and relative terms in Southeast Asia (excluding Indonesia), over 60% of investment required (USD 1.3 trillion), reflecting less ambitious stated policies.

[35] IEA. (2020). "World Energy Investment 2020". https://www.iea.org/reports/world-energy-investment-2020
[36] IEA. (2020). "Global Renewables Outlook 2020". https://www.irena.org/-/media/Files/IRENA/Agency/Publication/2020/Apr/IRENA_Global_Renewables_Outlook_2020.pdf

Figure 4 Relative scale of capacity additions required across regions is one key driver of relative investment needed



Notes: Forecast investment is calculated from IEA's investment levels on renewables capex in a BAU scenario. Unmet investment need = forecast investment – investment need.

Source: Vivid Economics, ASI and Factor using IEA. (2017). Energy Technology Perspectives.

Over 70% of investment need is in solar PV and onshore wind. Table 6 sets out the global investment need by technology. While there will be small differences at a regional level, the cost-competitiveness of solar and onshore wind imply they will account for the majority of investment need in nearly all regional contexts. A few exceptions include Southeast Asia, due to large offshore wind potential.[37]

Table 6 Investment need is largest in onshore wind and solar PV globally

Technology	Investment need in 2030 (USD billion)	Investment need in 2050 (USD billion)
Onshore wind	140	120
Solar PV	160	150
Offshore wind	30	30
CSP	90	80

Source: Vivid Economics, ASI and Factor using IEA. (2017). Energy Technology Perspectives

Investment within the opportunity reflects the expansion of on-grid power plant capacity and, to a smaller degree, the creation of supporting infrastructure and personnel, such as trained technicians. Most of the investment required reflects the physical installation of additional on-grid power, given that capacity additions will need to scale up significantly (to over 220 GW per year, set out in Section 1.4). Significant uncertainty in costs, however, result from regional and site differences. The average solar PV plant cost in 2018 ranged from USD 790/kilowatt (kW) in India in 2018 compared to 1,700/kW in South Africa. Offshore wind installed costs vary even more significantly, both across regions and sites, with costs between 3,000 USD/kW and under 1,000 USD/kW, in parts of Africa and South America, respectively.[38] Given these

[37] In Southeast Asia, the expected cumulative increase in offshore wind capacity is 19 GW to 2030 and 53 GW to 2050. The average capacity increase across regions is 6 GW to 2030 and 20 GW to 2050. All figures correspond to a renewables decarbonisation scenario.
[38] IRENA. (2018). *"Renewable power generation costs in 2018"*.

contextual considerations, investment within a region can only show the relative scale of need, rather than the likely investment required.

The climate financing need is expected to be far smaller than the overall investment need estimates, due to the cost-competitiveness of on-grid renewable technologies. Given the cost declines of solar PV and onshore wind, power generation is increasingly attractive for private sector investors, as shown by increasing levels of investment in recent years. Annual investment in solar PV increased by 50% between 2013 and 2015, while that in onshore wind increased by 30% between 2013 and 2016, with more recent fluctuations in investment reflecting falling technology costs.[39,40] This trend is largely explained by falling capital costs and improvement in average load factors, which help to make investment more attractive and reduce the need for the public sector. Despite the commercial maturity of the market for solar PV and onshore wind, project profitability continues to be hindered by unfavourable financing costs influenced heavily by local market risks, including the risks of a public off-taker being able to pay for the power it purchases over the lifetime of the generation asset.[41] In recognition of the fact that reducing the weighted average cost of capital will be a key driver of increased uptake of renewables, benefits of public sector investment are likely to be greatest when taking on market risks (such as through credit or power purchase guarantees), reducing market risks over the longer term (for instance, policy support to create financially sustainable power utilities), or lowering costs through provision of concessional finance.[42] As a result of the evolving role of the public sector, total financing need by governments is expected to be a fraction of the overall capital expenditure figures highlighted above.

[39] IRENA. (2019). Future of Solar Photovoltaic. https://irena.org/publications/2019/Nov/Future-of-Solar-Photovoltaic#:~:text=Solar%20PV%20project%20costs%2C%20already,solar%20PV%20investment%20until%202050.

[40] IRENA. (2019). Future of Wind. https://www.irena.org/publications/2019/Oct/Future-of-wind#:~:text=To%20fulfil%20climate%20goals%20and,USD%20100%20billion%20in%202050.

[41] IEA. (2020). "World Energy Investment 2020". https://www.iea.org/reports/world-energy-investment-2020

[42] World Bank. (2019). "The role of the public sector in mobilising commercial finance for grid-connected solar". https://openknowledge.worldbank.org/bitstream/handle/10986/32185/The-Role-of-the-Public-Sector-in-Mobilizing-Commercial-Finance-for-Grid-Connected-Solar-Projects-Lessons-Learned-and-Case-Studies.pdf?sequence=1&isAllowed=y

Cost-effectiveness

On-grid variable renewable electricity is a highly cost-effective mitigation opportunity. Overall cost-effectiveness of on-grid renewable electricity is relatively high compared to other opportunities, due to rapidly declining costs stemming from ongoing innovation and efficiency gains. The levelized cost of electricity (LCOE) of utility-scale solar PV plants has decreased by nearly 80% since 2010 and is expected to decrease further, to as low as 0.02/kWh by 2030.[43] Onshore wind has also seen large cost declines of 30% since 2010, with a global weighted average LCOE of 0.06/ kWh in 2018. Its cost is expected to continue falling, reaching USD 0.03 - 0.05/kWh by 2030.[44]

Across the focus regions, renewable power is often competitive with thermal power generation today, delivering CO_2 emissions for GBP at no additional cost. In India, 17% of operating coal capacity is already uncompetitive with local renewables.[45] In other words, the long-run costs to operate 17% of coal plant capacity exceeds the levelised costs to build and operate new solar and onshore wind plus storage. The share of uncompetitive coal rises to 85% in 2025. By 2030, the share of uncompetitive coal capacity is expected to reach 89% in South Africa, 80% in Vietnam, and 48% in the Philippines.[46]

Cost-effectiveness varies across regions due to four principal characteristics:

- Natural endowments. Cost-effectiveness is highest in regions with high onshore wind and solar endowments and lowest where endowments only allow offshore wind development. Onshore wind energy potential varies from 8,900 petajoule (PJ)/year to 76,000 PJ/year across the focus regions.
- Grid capacity. Variable renewables impose costs on the rest of the system, because of the need for grid balancing. Some grids have more or less robust structures in place for this (or different levels of current renewable penetration) and hence face different integration costs.
- Alternative power generation investments. There are significantly greater mitigation benefits from shifting away from coal to on-grid renewables, resulting in higher cost-effectiveness in regions where there is a high share of coal electricity generation today, such as India and South Africa. Coal-powered generation was approximately 75% in India and 90% in South Africa in 2017.[47] Further, the relative cost-effectiveness of variable renewables will depend on the scope for low- to zero-cost energy efficiency improvements; where efficiency improvements are possible, the relative cost-effectiveness of renewables is lower.
- Supply chain costs. As technology costs decline, the 'soft' costs associated with the supply chain and costs of capital are an increasingly large cost driver. In South America, supply chain costs are nearly 40% of installed on-grid renewable electricity costs (USD/kW) compared to 25% in parts of South Asia.[48]

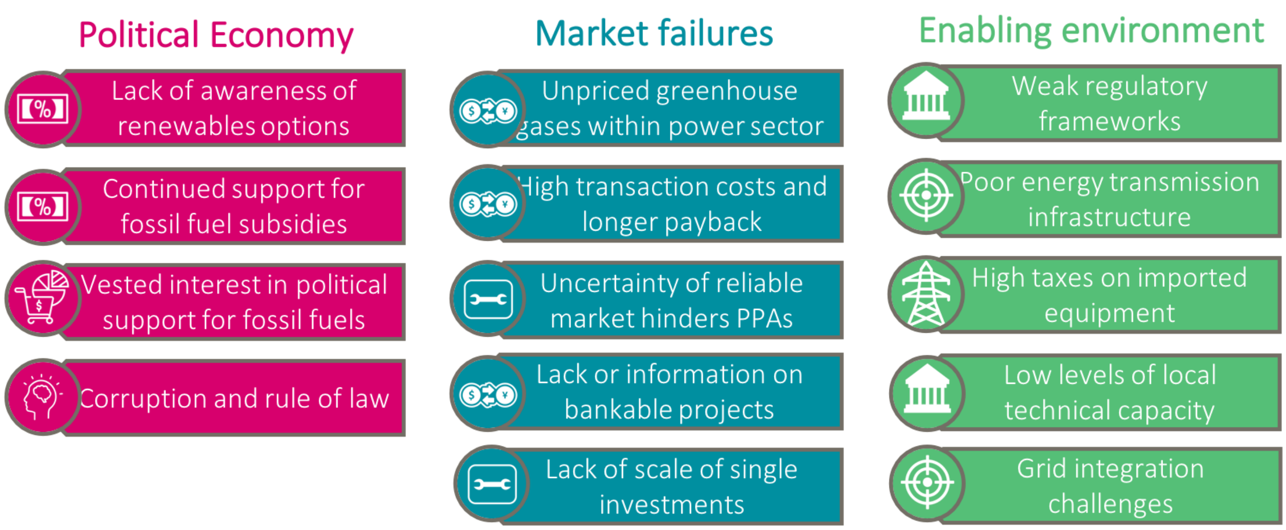
---

[43] IRENA renewable energy dashboard, available at: http://resourceirena.irena.org/gateway/dashboard/index.html?topic=4&subTopic=54
[44] IRENA. (2019). "Future of Wind". https://www.irena.org/-/media/Files/IRENA/Agency/Publication/2019/Oct/IRENA_Future_of_wind_2019.pdf
[45] Rocky Mountain Institute. (2020). "How to retire early".
[46] Carbon Tracker Initiative. (2018). "Power down on coal". https://carbontracker.org/wp-content/uploads/2018/11/CTI_Powering_Down_Coal_Report_Nov_2018-1.pdf?fbclid=IwAR2j-DnSFBhAIxTCVm_KS9hn16RclR2ZIxj2GgtlQ3M-rS8zLmFuLKc3TPM
[47] IEA. (2019). World Energy Balances.
[48] IRENA. (2018). "Renewable power generation costs".

Barriers to adoption

The largest barriers to on-grid renewable electricity in regions where the opportunity offers the greatest mitigation potential are those related to i) political economy challenges, ii) market failures, and iii) enabling environment. These barriers are not critical to inhibiting investment, as the potential of on-grid clean energy is recognized and investment levels growing in all regions. However, if not addressed they are likely to slow down the potential growth of this opportunity, particularly in sub-Saharan Africa. Our typology of barriers is provided in the Methodology chapter in the Synthesis Report.

Figure 5 Barriers to on-grid variable renewable energy.



Source: Vivid Economics, ASI and Factor

The moderate <u>political economy barriers</u> to investment or adoption are likely to be:

- Strong political support for fossil fuel subsidies, either due to strong relationships between government and the fossil fuel industry (producer and marketing subsidies) or to pressure from population groups dependent on affordable energy (consumer subsidies), that diminish renewables' competitiveness.
- Decision-making inertia towards fossil fuels. The Energy Information Administration (EIA) suggests that without more transformational change, fossil fuels are expected to supply 78% of the global energy used in 2040, with countries often not ready to commit more fully to clean energy investment if their electrification rate is low and fossil fuels offer more rapid energy provision. This is a particular challenge in South-East Asia.
- The perception that renewables cannot be integrated into an existing grid without significant investment is a moderate barrier, particularly in South-East Asia. While there are technical challenges that must be overcome, this can usually be achieved with appropriate regulatory frameworks.
- Government fatigue from initial failed attempts to install and integrate renewables is sometimes a barrier. For example, in the past, governments in East Africa and other African regions have frequently been poorly advised on aspects such as deregulation of the sector with often unintended consequences. Other sources of fatigue include use of public-private partnership (PPP) vehicles for investment without mitigating the well-known risks; and indebtedness in the sector creating a moral hazard problem for governments who cannot afford it to collapse (examples include Eskom in South Africa and Nigeria's DisCos).

Community opposition to renewable power. Proposals have faced opposition from individual citizens, political leaders, grassroots organisations, national interest groups and, in some cases, even environmental groups. However, there is likely to be significantly more resistance to new fossil fuel-based plants.

UK Export Finance (UKEF) still provides significant support for fossil fuel-based energy generation investment in developing countries, sending out mixed messages that may reduce the incentive for governments in target regions to fully support low-carbon pathways.[49] However, tackling climate change is a central part of UK Aid and the Government is committed to aligning UK Aid spending with the objectives of the Paris Agreement.

Moderate market failure barriers to investment or adoption are likely to be:

Insufficient information amongst investors, banks, project developers, and governments regarding: 1) ecological and financial benefits, 2) renewable energy technologies, and 3) the financial feasibility of renewable energy installation projects.

A range of risks deter renewable energy investors, such as high initial capital cost per MW, longer pay back periods (because of the lower efficiency of renewable technology), a lack of bankable projects and a lack of scale of investments, and high transaction costs between international capital markets and domestic renewable energy project developers.[50] This is the case in the majority of countries in the target regions although risks decrease with stable regulations as demonstrated in countries such as Chile and India.

The lack of a secure income stream from renewable energy projects, and the poor ability of governments to afford power purchasing agreements or a lack of capacity in shaping feasible contractual agreements, is often a significant barrier, particularly in East Africa and lower-income countries in South-East Asia and South America. If there is a well implemented long-term power purchase agreement (PPA) with a financially secure counterparty then confidence in consistent future income would be much stronger.

The unpriced greenhouse gases of the power sector of most countries, which distorts incentives to invest in renewable power. This is exacerbated by government subsidies provided to conventional energy, which are often much higher than the subsidies awarded to renewable energy. For example, a recent Overseas Development Institute (ODI) study highlights how South Africa subsidises coal by USD 3.2 billion per year, despite considerable evidence that a renewable energy transition is the country's lowest-cost energy pathway.[51]

Moderate enabling environment / absorptive capacity barriers to investment or adoption are likely to be:

Confusion in regulatory and institutional frameworks is often cited as a major barrier. Policy inconsistency and change is prevalent across many of the countries in the high mitigation potential regions.[52] This is a significant barrier in many East African and South-East Asian countries.

There have not been enough measures by governments to remove tax on imports of the equipment and parts required for renewable energy plants. This is a particular problem in South-East Asia.

Lack of information on potential sources of renewable energy in the target regions, can be a significant barrier, particularly if a government wishes to actively encourage renewables investment. Information could be strengthened in all lower-income countries across the target regions.

[49] See for example: https://www.desmog.co.uk/2020/07/09/uk-offered-760m-support-overseas-fossil-fuel-projects-last-year
[50] Climate Policy Initiative. 2018. "Blended Finance in Clean Energy: Experiences and Opportunities".
[51] ODI. 2019. "G20 Coal Subsidies: South Africa". https://www.odi.org/publications/11369-g20-coal-subsidies-south-africa
[52] Adams & Asante. 2019. "Politics of Renewable Energy in Africa: Nature, Prospects, and Challenges". DOI: 10.5772/intechopen.89019

Transmission infrastructure barriers are also very challenging in all regions with high mitigation potential. Sites of clean energy generation often do not match with current grid configurations and in many countries with low energy coverage, such as across East Africa and lower-income countries in South-East Asia and South America, there are large regions not covered by the grid.

Technical barriers on integrating variable renewable sources into an existing grid can be a challenge, particularly once the proportion of renewables goes above 10% of a specific network. Countries in the target regions are at varying stages. India has made strong progress, while this barrier is still particularly high in East Africa and South-East Asia.

Lack of operations and maintenance expertise in many of the target regions, particularly India, East Africa, and lower-income countries in South America, is a barrier to investor confidence as well to the sustainability of renewables investment.

UK additionality

The UK's additionality is particularly strong in offshore wind energy resulting from extensive domestic experience. However, the UK can also harness expertise in international consulting and financing experience directed to all technologies in this opportunity.

The UK is a world leader in offshore wind energy, with 7.6 GW installed capacity and a target to increase that to 40GW by 2030, which will play a key role in decarbonising the UK power sector.[53]

The UK has substantial sector expertise in on-grid renewables. The UK can provide expertise in onshore wind and solar installation and grid integration, and project development and financing services, although its domestic supply chain for solar and onshore wind is limited.[54]

Extensive expertise is provided by the UK in both developing appropriate policy and regulations and in financing clean energy domestically and internationally.

The UK has made a strong contribution to bilateral and multilateral donor investment in the target regions in relation to on-grid variable renewable energy.

According to OECD-Development Assistance Committee (DAC) data, the UK funded USD 252m out of a DAC total of USD 2,187m between 2015 and 2018:

DAC members spent USD 1,152m in India, of which the UK has spent approximately USD 244m.

DAC members spent USD 291m in Eastern Africa, of which the UK spent USD 6.5m.

DAC members spent USD 200m in South Africa, with no contribution from the UK.

DAC members spent USD 242m in South-East Asia, while the UK has spent less than a million.

DAC members spent USD 302m in South America, while the UK has spent less than a million.

The largest drivers of donor support in this area are Department for International Development (DFID), the World Bank, African Development Bank, Asian Development Bank, Germany (The German Agency for International Cooperation [GIZ]), USA (USAID), Japan (JICA) and the EU.

Despite the prevalence of donor activity in this sector, there remains a significant demand from governments to help overcome constraints and the UK's expertise can add strong value.

In the regions with the largest mitigation potential, the UK typically has strong ODA ties with South Asia and South Africa.

Between 2010 and 2017, the UK's ODA support for renewable energy totalled GBP 1.032bn or 32% of total ODA support for energy. Of all UK support for energy in developing countries, including non-ODA sources, 1.31bn, or 17%, was for renewables.[55]

In the same period Brazil, Ghana, Nigeria, Turkey, India, and Bangladesh were in the top ten highest recipients of overall UK energy-related assistance. In ODA terms, Nigeria, Bangladesh, Pakistan, Ghana, and Ecuador were in the top ten.

---

[53] AURORA Energy Research. (2020). "Reaching the UK Government's target of 40GW of offshore wind by 2030 will require almost GBP 50bn in investment". https://www.auroraer.com/insight/reaching-40gw-offshore-wind/

[54] https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/755218/Renewables_Toolkit_Web_Accessible.pdf Ibid.

[55] Catholic Agency for Overseas Development. (2019). "UK support for energy 2010-2017". https://cafod.org.uk/content/download/49429/623388/version/4/file/UK%20Support%20for%20Energy%202010-17%20Policy%20Briefing%20web%20version3.pdf

BEIS and DFID have been the major conduits of the ICF and renewables-centred ODA. Two-thirds of the ICF is channelled via multilateral development banks (MDBs).[56] This includes the GBP 200m BEIS UK Climate Investment initiative, established in 2015 with ICF funding and with a mandate for transformational green energy investments in some of the world's most carbon-intensive economies, mobilising additional private sector capital on a sustainable basis.[57]

Most programmes of support focus on energy access, policy and regulatory reform, addressing market failures, and support private sector green finance.

DFID is currently funding substantial programmes in renewable energy access, policy and regulatory reform, addressing market failures, and green finance mobilisation, including via the Africa Clean Energy Fund, Solar Nigeria Programme, Ayrton Fund (a joint DFID and BEIS fund), the Private Infrastructure Development Group (PIDG) and the UK-Africa Investment Summit.[58] The Foreign and Commonwealth Office (FCO) is implementing Prosperity Fund support via Energy and Low Carbon programmes in China, Mexico, and Indonesia. Another key UK Government institution is the CDC Group, for example the recent GBP 150m investment into the renewable energy platform Ayana in India, to develop utility-scale solar and wind generation projects across high-growth states.[59]

[56] Independent Commission for Aid Impact (ICAI). (2019). "International Climate Finance: UK aid for low-carbon development". https://icai.independent.gov.uk/report/international-climate-finance/
[57] Green Investment Group: UK Climate Investments. https://www.greeninvestmentgroup.com/what-we-do/uk-climate-investments.html
[58] Development Tracker: Aid by Sector. https://devtracker.dfid.gov.uk/sector/14/projects#page-1
[59] Gov.UK. (2019). " UK commits over £150 million to power India's energy ambitions". https://www.gov.uk/government/news/uk-commits-over-150-million-to-power-indias-energy-ambitions

Intervention opportunities

To alleviate the barriers set out in Section 1.7, there is substantial opportunity across all regions for the UK to draw on its core strengths and areas of additionality, to deliver on-grid variable renewable energy interventions in the following areas:

Opportunities to encourage uptake of variable renewable energy:

- Improve renewable energy enabling environments. For example, technical assistance to improve policy and regulation and overcome market failures, e.g. reducing transaction costs, addressing information asymmetries, and reducing currency risks, and thereby facilitate private investment.
- Provide technical assistance around improving the policy and regulatory environment, relating to power purchasing guarantees and agreements and feed-in tariffs, which would be particularly beneficial in East Africa, South America, and South-East Asia.
- Build the capacity of public and private sector organisations and staff, including assisting governments to understand and implement the most suitable policy levers to encourage investment in variable renewable energy within their local context. This could include establishing auctions for developers to take forward viable sites for solar or wind, as demonstrated by the case below.
- Provide support on leveraging and de-risking private sector green finance. For instance, investing climate finance to leverage further private debt or equity finance via BEIS investments such as UK Climate Investments (UKCI), the PIDG, the CDC, credit lines, MDBs, or bespoke debt or equity funds. There are significant opportunities for blended finance across all target regions, to meet the demand set out by ambitious renewable energy targets. Blended finance is likely to be most helpful for investment in solar PV and wind in India, East Africa, and South America.
- Support governments to de-risk investment across the lifecycle of renewable investments via specific policy measures, such as:
  - Encouraging reduced interest rates for initial investments, to counter initial periods of uncertainty and a long rate of return.
  - Reducing risks relating to siting of turbines or PV arrays, by supporting the development of policy that can reduce uncertainty, by pre-zoning land which has been shown to have strong potential for wind and solar energy, and engaging stakeholders early.
  - Helping governments set up systems on requirements and timeframes for permits relating to construction standards, environmental impacts, and other requirements can also reduce uncertainty, costs, and risk for investors.
- Help improve the availability of information and evidence on possible investments, via a database of potential resources, helping to develop a pipeline of bankable projects. This would add great value in East Africa, South America, and South-East Asia in particular.
- Support governments to develop green infrastructure bonds, such as that recently developed in Nigeria,[60] helping to provide investment across a wider range of small-scale projects. This can help overcome critical investment constraints in East Africa, India, and South America in particular.
- Influence groups such as UK Export Finance to stop investing in fossil fuel projects (GBP 760 million invested in 2019) as this reduces the impact of UK support for a green energy transition on the global stage.

[60] DLA Piper. (2019). Renewable Energy in Africa: https://www.dlapiper.com/en/africa/insights/publications/2019/06/renewable-energy-in-africa/

Influence multilateral investment banks. For example, using substantial UK contributions to MDBs to influence their agendas towards greater use of loan guarantees, investment in clean technology, and backing national banks.[61] The CDC is an important player to consider in this space.

Opportunities to support variable renewable system integration:

Technical assistance to support improved integration of variable renewable energy to grids and between renewable and non-renewable sources. This is particularly critical in East Africa, South Africa, and South America. For example, a workshop facilitated by IRENA in 2017 for South American representatives, focused on exchanging best regional and global practice for planning, modelling, and integrating variable renewable energy as the region looks to further develop its renewable energy generation capacity.[62] A range of IRENA guidance on this topic is also useful.[63]

Support for regional grid integration to allow international power purchasing, particularly in South America and East and South Africa, so that power generated with renewables abundantly available in one country (e.g. Chile, Colombia, or Argentina) can be exported to another that lacks the resources. For example, the Eastern Africa Power Pool (EAPP) was established in 2005 and now comprises ten countries that have signed an Inter-Governmental Memorandum of Understanding (IGMOU) to foster power system interconnectivity. The EAPP has received guidance and technical assistance from various donors including Power Africa, funded by USAID.

Support governments or utilities to plan and implement utility-scale storage to help grids to maintain a more even level of power over a 24-hour period, reducing fluctuations and the possibility of curtailment. Often this can be done in an integrated way with renewable investment. For example, recent Asian Development Bank (ADB) support in Thailand is developing wind energy along with a battery energy storage system, and in South Africa there are several examples of CSP plants constructed in co-location with molten salt thermal storage plants (See the Energy Storage Opportunity Report, Section 0 for case studies).

Support governments and utilities to consider demand-side management (DSM) integrated with planning and implementation of variable renewable energy sources. DSM has an important role to play in terms of reducing peaks in demand and flattening the load during a 24-hour period. Demand response functions can go even further, by reducing the usage of electricity in households and businesses at times of peak demand, via smart meters, which can be particularly useful to balance variable generation with demand. (Refer to the DSM Opportunity Report for examples of smart, green grid, and demand-response interventions, Section 0)

[61] Overseas Development Institute. (2017). Briefing Paper: Six development finance proposals to expand climate investment. Available at: https://www.odi.org/publications/10746-six-development-finance-proposals-expand-climate-investment

[62] IRENA. (2017). "South America Plans for its Renewable Energy Future". https://www.irena.org/newsroom/pressreleases/2017/Aug/South-America-Plans-for-its-Renewable-Energy-Future

[63] See, for example, IRENA. (2017). Planning for the renewable future: Long-term modelling and tools to expand variable renewable power in emerging economies. https://www.irena.org/publications/2017/Jan/Planning-for-the-renewable-future-Long-term-modelling-and-tools-to-expand-variable-renewable-power

Intervention case studies

These case studies provide real-world insights into intervention design and challenges. Each case study provides an overview of the context, the aim of interventions, and the challenges faced.

Box 2 USAID Clean Power Asia Technical Assistance for a Solar Auction Pilot in Lao People's Democratic Republic (PDR), 2017 – 2019

Lao PDR has set a target to increase the share of renewable energy (RE) to 30% of total energy consumption in 2025. The Renewable Energy Development Strategy specifies individual targets (in MW) for RE technologies, in which solar power potential is estimated at a 14% share of the energy mix, up from less than 1% in 2018.[64] In August 2017, the Ministry of Energy and Mines (MEM) and USAID Clean Power Asia entered into a cooperation framework agreement to provide technical assistance in the promotion and implementation of renewable energy in Lao PDR. Under USAID's Clean Power Asia programme, one of the key activities was developing and formalising the Solar Auction process in Lao PDR via an initial pilot. Solar power auctions are seen as a fundamental process to catalyse cost-effective solar energy investment in the country. For example, the auction of a 60MW solar project in neighbouring Cambodia in August 2020 has resulted in the lowest PV power purchase tariff reportedly seen in South-East Asia to date, at USD 38.77 per MWh.[65]

With the assistance of USAID, the objectives of the solar auction pilot were to:[66]

- Identify the tariff level that triggers private solar development.
- Assist government stakeholders to learn and replicate the auction process.
- Engage with the private sector and try to foster a more active domestic market in the generation of solar power with a potential scale-up of the solar PV auction process.
- Learn from the procurement mechanism process and assess the potential for scaling up solar auctions.
- Potentially reduce the need for electricity imports near load centres with a focus on increasing the available capacity during the dry season (when there is less hydro capacity).

In pursuit of those objectives, the activities of the programme were:

- A policy workshop was conducted to discuss and identify policy goals and market and regulatory analysis.
- Followed by the policy workshop, an auction design workshop was conducted to design the PPA template, undertake a reference price study, and finalise the design of the auction.
- Auction documents were prepared by the technical assistance (TA) facility, drawing on international best practice.
- A bidders' conference (the auction itself) was conducted for a hypothetical project to reveal market prices and gauge the interest of the private sector in solar generation in Lao PDR.
- Lastly, a post-auction assessment workshop was held to evaluate the process and discuss auction opportunities with government- and utility-related stakeholders.

The above activities resulted in:

---

64 USAID. (2017). "Designing Renewable Energy Incentives and Auctions: Lessons for ASEAN". https://pdf.usaid.gov/pdf_docs/PA00SVK9.pdf

65 PVTECH. (2019). "Cambodia's 60MW solar auction draws record-low bid". https://www.pv-tech.org/news/cambodia-solar-auction-draws-record-low-bid

66 USAID. (2018). "Designing a Solar Pilot Auction for Lao PDR". http://usaidcleanpowerasia.aseanenergy.org/event/designing-a-solar-pilot-auction-for-lao-pdr/

- The TA facility enabled the government and utility stakeholders to understand and prepare for a solar auction process, developing a template for future bidders' conferences and related documentation.
- Increased private sector awareness and confidence in the opportunities to bid for solar power generation prospects.

Relevant stakeholders involved were:

- Lao PDR government and utilities, private sector independent power producers.

The risks and challenges include:

- High upfront transaction costs, such as for feasibility studies and land use permits, need to be carried by the government or utility to make a viable site available that can then be auctioned. This is a disincentive for governments but must be weighed up against the advantages of an auction.
- There is a risk of under-bidding and delays. For example, the auction may result in an agreed price for a developer that is actually too low to realise the projects. This is unlikely to happen if developers are well prepared and have carried out their own assessments of the potential opportunity.

For BEIS, the primary lesson from the programme in determining ICF investment is:

- Auctions are being adopted by an increasing number of countries, becoming a preferred policy tool for catalysing cost-effective renewable energy generation with remarkable rates of adoption.[67] There is a role for ICF support to foster auctions in countries where they are not yet taking place.

Box 3 CDC Concessional Financing for Solar PV in Malindi, Kenya

Kenya's per capita electricity consumption is well below the Sub-Saharan average and 44 per cent below the level that would be expected for its gross domestic product (GDP) per capita.[68] However, the country's potential to generate power from renewable sources is substantial, including solar, wind, and geothermal. One such project is the Malindi solar PV array in the East of Kenya, near the coastal town of Malindi. The Malindi plant is designed to provide 52 megawatt peak (MWp) of clean generation capacity to the Kenyan grid. Located in a region where load shedding is widespread and power demand is increasing, it is expected most of the generation will be consumed locally. It is estimated that the power generated will support the creation of jobs through direct employment and indirect job creation due to a more consistent supply of electricity.

The project, which is being taken forward as the Malindi Solar Group, has received USD 52m in debt financing from the UK's development finance institution CDC. This includes a USD 20m contribution from the German Development Finance Institution (DEG). Together with the commercial partner, Globeleq, this amounts to a USD 66 million debt investment in Malindi Solar Group. The long-term, 16-year financing will provide much needed power in the Malindi area, which currently struggles with regular power shortages and relies largely on expensive thermal plants.

With the assistance of CDC, the objectives were to:

[67] Source: http://usaidcleanpowerasia.aseanenergy.org/resource/overview-of-a-solar-pilot-auction-in-lao-pdr/
[68] CDC. (2019). Malindi Solar Project. https://www.cdcgroup.com/en/our-impact/investment/malindi-solar-project/

- Raise public and private finance, sign a PPA with the appropriate utility in Kenya, and reach financial close of the Malindi Solar Power plant, enabling the construction phase to begin.
- Provide a stable, long-term involvement to give confidence to other private sector investors and to provide additional technical expertise in address planning and construction challenges, as well as interaction with government and utility stakeholders.

In pursuit of those objectives, the activities and results of the programme were:

- The financing allowed Malindi Solar Group to progress with feasibility studies and prepare technical reports, such as the Environmental Impact Assessment on the project,[69] as a prerequisite for government planning approval and entering into a PPA.
- A 20-year PPA was signed with the Kenya Power and Lighting Company (KPLC) in 2019, which provides the public electricity service in Kenya.[70]
- The Malindi plant was able to move into the construction phase; engineering, procurement, and construction contractors moved on site during 2019 with the company having already started the project's civil and electrical construction works. Globeleq will oversee construction, operation, and maintenance of the power plant. [71]

Relevant stakeholders involved were:

- KPLC, Government of Kenya, local communities, and non-governmental organization (NGOs).

The challenges faced were:

- Governance- and regulatory-related risks, such as complex bureaucracy, corruption, changing regulations, and political risks, like low political stability or the risk of conflict, are challenges that affect renewable energy generation in East Africa, including Malindi. This has been mitigated by a proactive approach from the CDC in applying their experience from around the world and engaging frequently with relevant stakeholders.
- Several disputes between the entities involved have arisen, including the intention of a Kenyan firm to sell its share of the project without covering the costs of an international consultancy working on the feasibility studies. These were resolved with a mix of legal action and internal agreement.[72]

For BEIS, primary lessons from the programme in determining ICF investment are:

- Providing concessional, equity, or grant financing can have a transformational impact in enabling variable renewable energy projects to progress. This is particularly crucial during the early project preparation phase, where funding can cover feasibility and technical studies that are necessary for a PPA to be signed.
- Relatively high upfront costs, compared to fossil fuel plant, can be a challenge for financing solar energy in Africa. However, once in place, the operation and maintenance costs are low. This emphasises the importance of concessional or equity financing support from institutions like the CDC group or the ICF.

[69] Malindi Solar Group Ltd. (2015). Environmental Impact Assessment Study Report for the proposed Malindi Solar Power Plant. https://nema.go.ke/images/Docs/EIA-1240-1249/EIA-1244_%20Malindi%20solar%20power%20study%20report.pdf
[70] Construction Review Online. (2019). "Construction of 40 MW Malindi solar photovoltaic project in Kenya begins". https://constructionreviewonline.com/2019/06/construction-of-40-mw-malindi-solar-photovoltaic-project-in-kenya-begins/
[71] Globeleq. "Globeleq and CDC to Develop Kenyan Solar Plant" : https://www.globeleq.com/globeleq-and-cdc-to-develop-kenyan-solar-plant/
[72] Source: http://karibu.mambozuri.com/2018/02/sh6bn-malindi-solar-power-plan-risk-companies-feud/

Glossary

Acronym / Term	Definition
ADB	Asian Development Bank
Aggregators	Aggregators are a grouping of agents in a power system (e.g. consumers, producers, prosumers) which act as a single entity when engaging in power markets.
AI	Artificial intelligence
AMI	Advanced metering infrastructure
Ancillary services	Services that maintain the proper flow and direction of electricity e.g. synchronised regulation, contingency reserves, black-start regulation, flexibility reserves
Baseload	The minimum amount of electric power delivered or required over a given period
BAU	Business as usual
Behind the meter storage	Storage connected at the consumer side of the utility meter for commercial, industrial or residential power customers (and is therefore grid-connected).
BEIS	UK government Department for Business, Energy & Industrial Strategy
BESS	Battery energy storage systems
BMZ	Germany's Federal Ministry for Economic Cooperation and Development
BTM	Behind the meter
BUG	Back-up generator
C&I	Commercial and Industrial
CCC	Committee on Climate Change
CIF	Climate Investment Funds
CSP	Concentrated solar power
CTF	Clean Technology Fund
Curtailment	A reduction in output from a power generator from what it could otherwise produce using available resources
DAC	Development Assistance Committee
DEG	German Development Finance Institution
DER	Distributed energy resource
DFID	UK government Department for International Development
Dispatchable	A source of electric energy production whose output can be switched off or on or otherwise moderated according to demand.
DR	Demand response
DSM	Demand side management
EE	Energy efficiency
EIA	Energy Information Administration
EJ	Exajoules

Acronym / Term	Definition
Electrical storage	Storage of energy in electrical fields e.g. supercapacitor
Electrochemical storage	Storage of chemical potential energy e.g. lithium-ion batteries
Energy storage	A device that captures energy for later use, with categories of storage including electrochemical, electrical, mechanical, and thermal forms of storage
EnMS	Energy management system
EPC	Energy Performance Certificate
EPSRC	Engineering and Physical Sciences Research Council
ESCO	Energy Service company
ESMAP	Energy Sector Management Assistance Programme
ESO	Energy systems optimisation
ESS	Energy storage systems
ETP	Energy Technology Perspectives
EU	European Union
EUR	Euro
Flexibility	The ability of a power system to respond to changes in electricity demand and supply
GBP	British pound sterling
GDP	Gross domestic product
GESP	Global Energy Storage Program
GHG	Greenhouse gas
GIZ	Deutsche Gesellschaft fur Internationale Zusammenarbeit GmbH
Grid	An electricity grid
Grid storage	Storage connected to a distribution or transmission networks, or alongside a power generation asset, such as a wind turbine
Gt CO2	Gigatonnes of CO2
Gt CO2e	Gigatonnes of CO2 equivalent
GW	Gigawatt
GWh	Gigawatt hours
IADB	Inter-American Development Bank
IEA	International Energy Agency
IESA	India Energy Storage Alliance
IFC	International Finance Corporation
IGMOU	Inter-Governmental Memorandum of Understanding
IoT	Internet of Things

Acronym / Term	Definition
IPCC	Intergovernmental Panel on Climate Change
IPP	Independent Power Producer
IRENA	International Renewable Energy Agency
IT	Information technologies
JICA	Japan International Cooperation Agency
KPLC	Kenya Power and Lighting Company
LCOE	Levelized Cost of Electricity
Load	The energy demand experienced on a system
MAGC	Market Accelerator for Green Construction
MDBs	Multilateral Development Banks
MW	Megawatt
NAMA	Nationally Appropriate Mitigation Action
NDC	Nationally Determined Contribution
NDCs	Nationally Determined Contributions
NEP	National Energy Plans or Policies
NEPs	National Energy Plans or Policies
ODA	Official Development Assistance
ODI	Overseas Development Institute
OECD	Organisation of Economic Cooperation and Development
Ofgem	Office of Gas and Electricity Markets
PDR	People's Democratic Republic
PIDG	Private Infrastructure Development Group
PJ	Petajoule
PPA	Power purchase agreement
PPP	Public-Private Partnership
RD&D	Research, development & demonstration
RE	Renewable Energy
REPP	Renewable Energy Performance Platform
SDG	Sustainable Development Goal
Stationary storage	Electrical storage designed for stationary applications
System costs	Total costs to the electricity system to supply electricity at a given load and security of supply
TA	Technical Assistance

Acronym / Term	Definition
TCP	Technology Collaboration Programme
TRL	Technology readiness levels
UKCI	UK Climate Investments
UNIDO	United Nations Industrial Development Organisation
USAid	United States Agency for International Development
USD	United States Dollar
Variability	The changes in power demand and/or output of a generating source due to underlying fluctuations in resource or power consumption
Virtual Power Plants	VPP operators aggregate DERs to behave like a traditional power plant and engage in a power market to sell electricity or ancillary services

Non-variable Grid Renewables

Summary

The non-variable renewable electricity opportunity considers a range of non-variable renewable energy sources, which could provide large climate impact, but are subject to high levels of uncertainty. The assessment of non-variable renewable electricity includes grid-connected small- to medium-scale hydropower, geothermal generation, and biomass-fired power (with and without carbon capture and storage (CCS)). As firm low-carbon power generation technologies, a common benefit within each region is low-carbon, reliable, electricity – competing with alternative forms of firm generation, demand-side response, and nuclear. Biomass energy with CCS (BECCS) also provides a further benefit: negative emissions. As a result, BECCS could be key to driving higher climate impact from the opportunity. However, uncertainty over the technical and economic potential of BECCS contribute to uncertainty in the opportunity as whole. Additional barriers to the opportunity include a lack of data on the economically exploitable geothermal and small- to medium-scale hydropower potential.

Interventions to encourage adoption of on-grid non-variable renewable electricity in focus regions include provision of better data on resource potential and policy support on electricity market design. Given the largest barriers to adoption, example interventions include:

Policy support for the design of electricity market regulation that recognises the value of firm and dispatchable[73] low-carbon energy, to address the lack of clear revenue streams for power system flexibility or baseload generation.

Technical assistance in resourcing mapping and feasibility assessments, with a lack of spatially fine data inhibiting investment by the private sector and impairing the capacity of local policy makers to make effective policy roadmaps.

Table 7 Non-variable grid renewables assessment summary

Criteria	Assessment	Notes
Climate impact	Medium	• Importance to power sector decarbonisation is highly variable, helping to avoid between 3% to 40% of power sector CO_2 emissions in 2050 beyond business-as-usual (BAU), depending on the mitigation scenario.[74,75] • Increasing BECCS deployment by 2050 is both the main source of CO_2 emission abatement, as well as the driver of high uncertainty. Upper bound estimates of emissions reduction should be treated with caution – explaining the medium climate impact assessment.
Development impact	Medium	• Significant positive contribution to achieving Sustainable Development Goal (SDG) 7, access to low-carbon, reliable energy, SDG 3, good health and wellbeing and SDG 8, decent work and economic growth. However, impact is more variable across regions and less certain than in the case of variable renewables. • Potential negative impacts on SDG 15, life on land, where use of land for geothermal energy, hydropower, and biomass crops displaces local communities and existing industries.
Investment gap	Medium	• Cumulative investment gap ranges between USD 1.7 – 5.7 trillion by 2050, as investment need is 1.5x – 3x the investment expected under business-as-usual. • Uncertainty in the levels of BECCS deployment and declining availability of cost-competitive hydropower are key sources of uncertainty.

[73] Defined as: "Of or relating to a source of electric energy production whose output can be switched off or on or otherwise moderated according to demand". Source: https://www.thefreedictionary.com/dispatchable
[74] This figure reflects emissions reductions in the IMAGE renewables decarbonisation scenario vs the BAU scenario. The percentage reduction in emissions is calculated relative to 2050 BAU emissions from the power sector.
[75] All figures in this report will reflect mitigation potential beyond BAU – the BAU is taken to be IMAGE's new policies scenario

Criteria	Assessment	Notes
Cost-effectiveness	Medium	• Small-scale hydro and geothermal power can be highly cost-effective, but costs are highly variable by region. • BECCS, as an immature technology, is likely to see cost reductions which make it an increasingly effective mitigation method by 2050.
Barriers to adoption	High	• Moderate political economy barriers to uptake include fossil fuel subsidies and community opposition to geothermal drilling or use of land for bioenergy crops. • Significant market failures relating to lack of information on resource potential, capital mismatch between high capital costs and delayed returns, and a missing market for firm or dispatchable power. • Enabling environment barriers include the poor financial capacity of local utilities to enter into power purchase agreements (PPAs).
UK additionality	Medium	• Strong expertise in developing regulatory frameworks to incentivise non-variable low-carbon power and financing of renewables domestically and internationally. • Amongst the non-variable renewable energies, the UK's relative expertise lies in BECCS deployment.

Source: Vivid Economics, ASI & Factor

Key lessons for supporting mitigation through non-variable renewables:

To realise the potentially large climate impact from non-variable renewables will require:

Better data on resource potential for small to medium scale hydropower and geothermal.

Regulatory frameworks that recognise the value of firm or dispatchable power.

The cost-effectiveness of an intervention ought to consider the relative costs of deploying variable renewables within a region, accounting for the system integration costs of each type of energy. In many regions, increasing solar and wind generation could deliver emissions reductions at a lower GBP/ton of carbon dioxide (tCO_2.)

China, India, and Brazil are expected to deliver the largest absolute mitigation potential due to their economically exploitable hydropower endowments and large power sectors today – notably, more information is required to understand the split in small- to medium-scale hydropower in each region.

UK government official development assistance (ODA) can support the potential climate impact of BECCS by providing technical assistance towards the development of a local, sustainable biomass feedstock supply chain. Meanwhile, domestic BECCS deployment can help to decrease international technology costs.

Introduction to the opportunity

Role of the opportunity in decarbonisation of developing countries

Non-variable renewables will play a substantial role in decarbonising the power sector, although their share of electricity generated is substantially lower than variable renewables. The power sector emitted 7.4 gigatonnes of carbon dioxide (Gt CO_2) in low- and middle-income countries in 2015, rising to 16 GtCO_2 in 2050 under a BAU scenario. In a 1.5-degrees scenario, the power sector needs to act as a major emissions sink (providing several GtCO_2 negative emissions through BECCS). On-grid non-variable renewables are expected to provide around 15 - 62% of electricity, with the range mostly driven by uncertainty in BECCS deployment.[76] Nevertheless, it is worth noting that the share of non-variable renewables in electricity generation is expected to be substantially lower than that of variable renewables (around 70% in the central power decarbonisation scenario).

Estimates of the scale-up in non-variable renewables capacity required for a world compatible with the Paris Agreement, with large differences in the expectations of the future deployment of BECCS. As Table 8 highlights, annual deployment of non-variable renewables in a 2-degree (high renewable) decarbonisation scenario is not vastly different to that witnessed in 2018, approximately 17 gigawatt (GW) additions per annum to 2050. However, in most 1.5-degree scenarios (including the IMAGE one used in this project), BECCS needs to scale up rapidly to supply large-scale negative emissions.[77] See **Box 4** for further details on the differences between scenarios.

Table 8 Approximate annual power capacity additions required under a Renewables and 1.5 degrees scenario across low-and middle-income regions

Technology	2018 capacity additions (GW)	Annual average capacity additions up to 2050, depending on scenario (GW) – forecast		
		BAU	Renewables (2 degrees)	1.5 degrees
Geothermal	0.4	0	2	0
Large-scale hydro	15	11	10.5	11
Small- and Medium-scale hydro	5	4	3.5	4
Biomass power (without CCS)	4.2	6	0.13	0
Biomass power with CCS	0	0	0	25

Note: IMAGE does not model the breakdown of large- to medium- and small-scale hydro. To estimate the relative split of capacity additions in each type to 2050, we make the simplifying assumption that the future split will mirror the current one, such that large hydropower is approximately 75% of total capacity. This is based on US Department of Energy figures for 2017.[78]

Source: Vivid Economics, ASI and Factor using PBL's IMAGE model and IRENA (2019)

[76] From IMAGE, under renewables scenario, considering hydropower, biomass, and other renewables.

[77] From IMAGE: Annual capacity additions under 1.5-degree scenario (40GW) relative to annual capacity additions under the renewable scenario (1GW).

[78] US Department of Energy. (2017). "2017 Hydropower Market Report". https://www.energy.gov/sites/prod/files/2018/04/f51/Hydropower%20Market%20Report.pdf

Scope considered in this assessment

The non-variable renewable electricity opportunity is defined as grid-connected small- to medium-scale hydropower, geothermal generation, and biomass-fired power (with and without CCS). The assessment excludes potential small-scale hydro mini grids, as well as large-scale hydropower, >100 megawatt (MW), due to its potential negative social and environmental impacts.[79] It also excludes detailed considerations around the supply of biomass feedstock. Biomass from waste is considered in the Waste and Wastewater Opportunity Report and bioenergy crops were excluded after consultations with the UK Department of Business, Energy and Industrial Strategy (BEIS) International Climate Finance (ICF). Similarly, it excludes considerations on the development of CCS technologies and supporting infrastructure following these consultations. As in the Variable Renewable Energy Opportunity Report, grid connection implies that energy generation sources are connected to a national or regional electricity transmission grid, through which they supply electricity.[80]

The assessment focuses on a subset of ODA-eligible regions, in consideration of their relatively large mitigation potential and in consultation with the BEIS steering group. Selected regions include:

- China, which has the largest absolute emissions reductions from non-variable renewables, partially as non-variable renewables will help shift the country away from coal power generation, which accounts for 70% power generation currently. [81]
- India, which has the third-largest absolute emissions reduction from non-variable renewables (after China and Brazil), around 75% of current generation from coal power, and is expected to see power generation increase by 200% to 2040.[82,83]
- East Africa, which has the largest relative mitigation potential from non-variable renewables in 2050 (as a share of 2015 power sector emissions), to a large extent due to significant growth in electricity consumption. Kenya, for instance, is expected to see a 230% increase in electricity generation to 2040, under stated policies.[84]
- West Africa, which has relatively large mitigation potential from non-variable renewables in 2050, similar to East Africa, due to growing demand for grid-connected power.
- Eastern Europe and Central Asia, which has the fourth-largest absolute emissions reduction from non-variable renewables beyond BAU (after India).

This assessment focuses on the benefit of supporting the opportunity as a whole and does not aim to comprehensively assess the effectiveness of specific investment opportunities or interventions. However, for context, potential investment opportunities to support non-variable renewable electricity are detailed in Section 0.

---

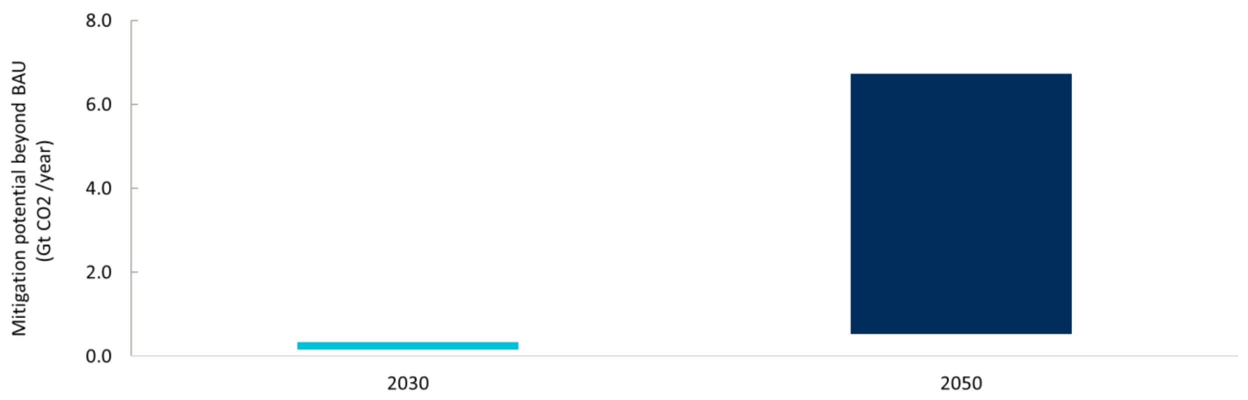
[79] International Renewable Energy Agency (IRENA). (2012). "Renewable Energy Technologies: Cost Analysis Series. Hydropower".
[80] This opportunity also does not consider: a) on-grid variable energy sources, such as solar and wind or b) off-grid non-variable renewable electricity, which uses non-variable renewables to provide energy directly to households.
[81] International Energy Agency (IEA). (2010). "World energy balances".
[82] Ibid.
[83] BP. (2019). "Insights from the evolving transition scenario – India". https://www.bp.com/content/dam/bp/business-sites/en/global/corporate/pdfs/energy-economics/energy-outlook/bp-energy-outlook-2019-country-insight-india.pdf
[84] International Energy Agency (IEA). (2020). "Kenya energy outlook". https://www.iea.org/articles/kenya-energy-outlook

Climate impact

Mitigation potential and urgency

Across low- and middle-income countries, non-variable renewables can help avoid around 3% of power sector CO_2 emissions (0.5 Gt CO_2) in 2050 beyond business-as-usual.[85] Non-variable grid renewables are important to meet growing electricity demand in a low carbon way and help displace large-scale emissions from coal-fired power stations. However, they are often higher cost than solar photovoltaic (PV) and wind energy. As a result, mitigation potential to 2050 in the central power scenario is moderate, 91% lower than the abatement provided by variable renewables.[86] Figure 6 shows, however, that there is significant variation in mitigation potential achievable by non-variable renewables between scenarios - see Box 4 for an explanation on the differences in mitigation potential between scenarios and relationship with the analysis in the Variable Renewables Opportunity Report. For instance, in a high BECCS 1.5-degrees scenario, non-variable renewables can help to avoid around 40% (6.7 Gt CO_2) of power sector CO_2 emissions in 2050 beyond BAU.

Figure 6 Range of mitigation potential compared to BAU in 2030 and 2050



Note: The bars indicate the range of mitigation potential estimates across the five IMAGE decarbonisation scenarios. Mitigation potential in each scenario is calculated relative to the BAU, which is taken to be IMAGE's national policies scenario. Mitigation potential in 2030 is therefore calculated as emissions reductions in 2030 in one decarbonisation scenario minus the emissions reductions in 2030 in the national policies scenario.

Source: Vivid Economics, ASI and Factor using PBL's IMAGE model

Estimates of deployment, and hence mitigation potential, are uncertain.

- *Uncertainty around BECCS* is the major driver of uncertainty in mitigation potential. **Box 4** sets out the uncertainties related to expectations of BECCS deployment, which drive differences in the climate impact between scenarios.

- Hydro and geothermal deployment is uncertain due to incertitude in resource potential, as well as the uncertainty around the value of non-variable power. The scale of economically exploitable resource is not thoroughly mapped. This reflects a lack of information on both resource availability and the highly location-specific nature of costs, as well as the benefits (and hence value) of non-variable power compared to variable generation. Typically, estimates of potential resource

[85] This figure reflects emissions reductions in the IMAGE renewables decarbonisation scenario vs the BAU one. The percentage reduction in emissions is calculated relative to 2050 BAU emissions from the power sector.

[86] In a 1.5-degrees decarbonisation scenario, mitigation potential from non-variable renewables is 10x higher than from variable renewables due to large-scale deployment of BECCS.

availability do suggest it to be far smaller than for variable renewables. In the case of small-scale hydro, there is around 230 GW potential estimated, two-thirds of which is not yet utilised.[87]

Box 4 Uncertainty in BECCS deployment

There is significant variation in the magnitude of mitigation potential from non-variable renewable power across modelling scenarios, stemming largely from different expectations of BECCS deployment. As Figure 6 shows, estimates of mitigation potential from non-variable renewables varies from close to 0 $GtCO_2$ in 2050 (versus BAU) to nearly 7 $GtCO_2$. As highlighted in the Variable Renewable Opportunity Report, variation between power scenarios to a large degree reflects assumptions on the availability of biomass for BECCS and cost declines in BECCS.

In IMAGE's 1.5-degrees scenario, high levels of BECCS deployment drives higher abatement potential from the non-variable renewables opportunity as a whole and displaces other forms of non-variable/variable renewable power. IMAGE's 1.5-degrees scenario estimates approximately 850 GW additions of BECCS to 2050, which provide approximately 6.5 $GtCO_2$ abatement in 2050 (versus BAU). The emissions reductions provided by BECCS reduces the need for other forms of low-carbon power. Estimates of variable renewable capacity additions are only 30 GW per year on average in a 1.5-degrees scenario, for instance; in comparison, under IMAGE's renewables scenario, estimates increase to 220 GW per year.

Levels of BECCS deployment predicted by IMAGE need to be treated with caution. Estimates of BECCS deployment are always subject to uncertainty due to the technological immaturity of BECCS and uncertainty over the availability of sustainable biomass feedstock. IMAGE relies on an ambitious assumption of bioenergy supply of approximately 200 exajoule (EJ)/year, far higher than the 14-84 EJ/year expected by the UK's Committee on Climate Change (CCC).[88] Notably, much of this biomass will face competition from transport and industry, implying even greater limits to the quantity of finite biomass feedstock available for power.[89]

To capture the far higher expected role of variable renewables, and the uncertainty of future BECCS deployment, we choose to use IMAGE's renewables scenario as our "central power scenario". In IMAGE's renewables decarbonisation scenario, BECCS deployment is minimal (around 5 GW). The vast majority of capacity additions to 2050 instead come from solar PV and wind - approximately 220 GW per year to 2050. Though neither scenario perfectly represents the future of BECCS in low- and middle-income countries, the renewables scenario is generally more reflective of expert opinion on the relative mitigation potential from variable versus non-variable renewables as a whole. It is used as the central power scenario in all power sector Opportunity Reports.

The largest absolute mitigation potential in 2050 occurs in regions with economically exploitable hydropower endowments and large power sectors today: China, India, and Brazil. These countries are expected to account for nearly 80% of $GtCO_2$ abated by low- and middle-income countries in 2050 beyond BAU. In each of these countries, close to 100% of abatement from non-variable renewables will come from hydropower. The availability of low-cost hydropower resources also implies these regions account for most of the near-term abatement potential, approximately 60% in 2030. In comparison, the focus regions together account for 17% of $GtCO_2$ abated within the opportunity in 2050, and 40% in 2030.

Non-variable renewables contribute around 11% of power sector decarbonisation beyond the BAU in the focus regions in 2050.[90] As Figure 7 shows, non-variable renewables account for between close to 0% to 70%

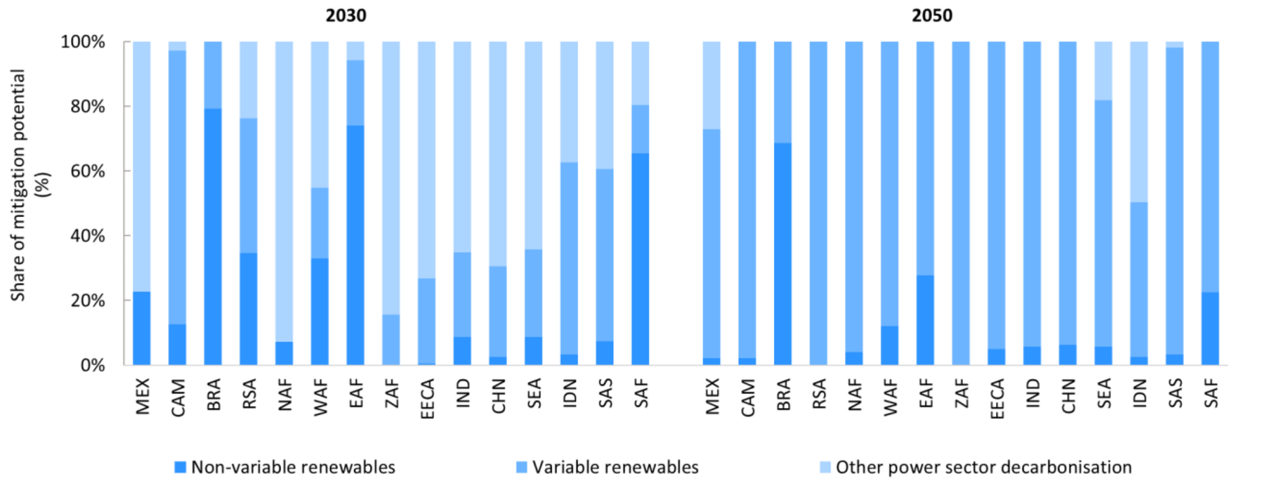
---

[87] UNIDO. (2019). "World Small Hydro Development Report 2019". https://www.unido.org/sites/default/files/files/2020-05/Global%20Overview.pdf
[88] CCC. (2018). "Biomass in a low-carbon economy".
[89] Use of biomass in power (without CCS) is typically less cost-effective on a GBP/tCO_2 avoided basis then biomass use in transport or industry.
[90] This figure reflects the mitigation from non-variable renewables in IMAGE's renewables decarbonisation scenario minus the mitigation from non-variable renewables in BAU.

of power sector decarbonisation beyond BAU, depending on the region. Higher relative mitigation potential in Brazil and East Africa is largely influenced by the relative abundance of low-cost hydropower resources in each country and relative costs of solar and wind.

Hydropower is the dominant technology in 2030 and 2050, across regions. Though IMAGE does not distinguish the role of small- and medium-scale hydro vs large-scale hydropower, estimates suggesting approximately 25% of economically exploitable capacity is from the former suggest most forecast additions are in large scale hydro. Excluding large-scale hydropower, small- and medium-scale hydropower have the highest forecast capacity additions required amongst the technologies in this Non-variable renewables Opportunity Report. In practical terms, there is estimated to be around 150 GW of small hydropotential globally, around 3x smaller than the hydropower capacity which is expected to be needed across low- and middle-income countries by 2050.[91] Geothermal, though competitive in comparison to hydropower, is far less equally distributed globally. Therefore, only in Southeast Asia are there capacity additions expected.

Figure 7 On-grid non-variable renewable electricity contributes, on average, to 20% of abatement in 2030 and 11% in 2050 beyond BAU



Note: The bars reflect the mitigation potential in IMAGE's renewables decarbonisation scenario minus mitigation achieved in IMAGE's new policies scenario (BAU scenario). Abbreviations correspond to the following: MEX= Mexico, CAM = Central America, BRA = Brazil, RSA = South America excluding Brazil, NAF = North Africa, WAF = West Africa, EAF = East Africa, ZAF = South Africa, EECA = Eastern Europe and Central Asia, IND = India, CHN = China, SEA = Southeast Asia excluding Indonesia, IDN = Indonesia, SAS = South Asia excluding India, SAF = Southern Africa excluding South Africa. Mitigation potential from 'Other' includes energy efficiency and fossil fuel CCS. Mitigation potential from non-variable renewable energy (RE) includes hydropower, geothermal, and biomass with and without CCS

Source: Vivid Economics based on PBL's IMAGE modelling (renewables scenario)

Transformational change

Non-variable renewable energy offers substantial opportunities for transformational change, as set out in Table 9. Interventions that help to create the right regulatory enabling environment, or that can de-risk or catalyse private sector investment in resources such as geothermal or small-scale hydro, are likely to encourage uptake at scale. This will particularly be the case if those projects pave the way in terms of refining appropriate legislation and providing reassurance to investors that a viable model is possible. Transformational change can also be realised in terms of enabling the decarbonisation of other sectors, such as electric vehicles and many industrial processes, by providing low-cost and low-carbon electricity. Many of

[91] UNUDO. (2019). "World Small Hydro Development Report 2019". https://www.unido.org/sites/default/files/files/2020-05/Global%20Overview.pdf

the drivers of transformational change in non-variable renewable energy are common across the target regions but several specific aspects can be identified. For example, the decarbonisation of energy can really drive a transformational uptake of zero-carbon vehicles and cleaner industrial processes in China and India, which will have significant development spillover in areas such as air quality and health. The support for identifying renewable resources and crowding in private sector investment is likely to have a particularly high transformational impact in East and West Africa, where there is strong potential but a poor enabling environment in terms of financial and regulatory risk.

Table 9 Assessment of transformational change

Transformational change criterion	Interventions to support change	Regional potential
Sensitive intervention points		
Improvement of local capacities and capabilities	Building capacity of government and stakeholders in appropriate regulatory frameworks and investment enabling environment. Developing integrated strategies for attracting and deploying non-variable renewables, or specific sectors such as biomass.	India, East Africa, West Africa, Eastern Europe and Central Asia
Local ownership and strong political will	Awareness raising and training for government and utilities, relating to the potential of non-variable renewables in the local context. Developing a database of non-variable renewable energy resources in the target regions.	East Africa, West Africa
Leverage / creation of incentives for others to act	Support in enabling reliable power purchasing agreements helps to incentivise geothermal, biomass, and medium hydro energy generation. Supporting the development of a pipeline of bankable projects. Supporting governments to de-risk investment via financial and policy-based measures.	East Africa, West Africa, Central Asia India, East Africa, West Africa
Spillovers		
Broad scale and reach of impacts	Supporting clean energy enables decarbonisation of other sectors, such as electric vehicles and many industrial processes, by providing low-cost and low-carbon electricity.	China, India, East Africa
Sustainability (continuation beyond initial support)	Establishing durable and well-supported policy measures to enable renewable investment at scale. Improving the enabling environment and market conditions, allowing more commercially led projects to thrive.	All regions
Replicability by other organisations or actors	Demonstration of investment and development process could enable renewable energy installation, results in replication by other donors and/or private sector entities.	All regions
Innovation		
Catalyst for innovation	Blended finance initiatives to catalyse private sector investment. De-risking investment via enabling insurance for geothermal exploration.	India, East Africa, West Africa
Evidence of effectiveness is shared publicly	Leveraging relevant communities of practice in which the UK has international presence and influence to disseminate learning.	All regions

Source: Vivid Economics, ASI and Factor

Development impact

SDG impacts

Improved access to on-grid non-variable renewable energy has notable positive impacts on achieving SDGs in all regions with a particularly high impact in South Asia and Southern Africa. On-grid non-variable renewable electricity has clear linkages with several sustainable development goals, as set out in Table 10.

Table 10 SDG impacts

SDG	Strength of impact	Most relevant region	Rationale
Positive Impacts			
SDG 1 – No poverty	High	East Africa, West Africa	Access to electricity is a key driver of income generation, better education, and more efficient use of time otherwise spent on gathering fuel wood etc., all of which help to reduce poverty.
SDG 3 – Good Health and wellbeing	Moderate	India, Southeast Asia, South Africa	The opportunity has a potential to decrease air pollution via decreased coal power generation, as well as displacing diesel generators and wood or kerosene burning stoves, thereby reducing pollution related diseases and deaths.
SDG 7 – Affordable and clean energy	High	All regions	The opportunity is essential in order to increase renewable energy in the global energy mix and improve energy efficiency.
SDG 8 – Decent work and economic growth	Moderate	All regions	The opportunity has potential to create jobs in the renewable energy sector. Further, grid-connected renewables would likely reduce power outages. This would in turn contribute to productivity of enterprises.
Negative Impacts			
SDG 9 – Industry, Innovation and Infrastructure	Low	All regions	If renewable energy is not integrated properly into grids it can lead to fluctuations and blackouts, with severe impacts on industry, although this shouldn't be a problem for dispatchable renewables if there are clear grid connection codes etc.
SDG 15 – Life on Land	Low	All regions	Bioenergy and BECCS can have significant negative environmental impact, if not appropriately managed. They require significant feedstock which could detract from biodiversity, as well as agriculture. In terms of carbon emissions, The UK CCC recommended in 2018 that the UK should move away from biomass for domestic energy generation, unless it is supported by carbon capture and storage technologies (becoming a BECCS approach).[92] Hydropower can also be very damaging to river and water body ecosystems if not planned and managed appropriately.

Source: Vivid Economics, ASI and Factor

[92] CarbonBrief. (2018). "CCC: UK should 'move away' from large-scale biomass burning". https://www.carbonbrief.org/ccc-uk-should-move-away-from-large-scale-biomass-burning

Commitment by governments and expected demand in target regions

Table 11 Summary assessment of demand in target regions

Region	Demand	Rationale
China	High	Ambitious targets and demonstrated commitment by national government to promote non-variable on-grid renewables.
East Africa	Moderate	Variable policy across countries but some ambitious targets in Ethiopia and Kenya on hydro and geothermal.
Eastern Europe and Central Asia	Low	Not many countries in the region prioritise non-variable on-grid RE or have ambitious targets for the same.
India	High	Ambitious targets set by the national government, improving regulatory and policy environment.
West Africa	Low - Moderate	Variable policy and regulatory environment across counties. For example, Nigeria has more advanced policy and regulatory environment, compared to low levels in countries such as Niger and Sierra Leone.

Source: Vivid Economics, ASI and Factor

China: A global leader in driving forward the domestic use of non-variable renewable energy, China attracted 33% of global renewable energy investment (including variable renewables) in 2018. It has the world's greatest share of installed hydropower capacity, including globally recognised projects such as the Three Gorges Dam, as well as many small hydropower resources and is expected to add 140 GW of hydro capacity between 2020 and 2030. China is also a leader in biomass energy generation, including waste-to-energy. By the end of 2017, China had the largest installed waste-to-energy capacity of any country globally, with 7.3 GW across 339 plants.[93] This lead has been growing rapidly since then.

East Africa: Eight East African nations have introduced National Energy Plans or Policies (NEPs) to meet growing energy demand with affordable, sustainable energy services that enable socio-economic development.[94] Kenya and Ethiopia have more developed and ambitious energy policies, compared to others in the region. One non-variable related Nationally Appropriate Mitigation Action (NAMA) project is being implemented in the region; the facilitation of grid-connected renewable energy generation through a feed-in tariff and through carbon credit generation in Uganda.[95] Kenya is the most advanced country in the region in terms of geothermal power generation.

Eastern Europe and Central Asia: Countries in Eastern Europe and Central Asia demonstrate varying levels of commitment to non-variable renewables, with the strongest focus on hydropower. At least two NAMAs are currently being implemented in the energy sector in the region, including construction of 10 hydropower plants in the Kakheti region of Eastern Georgia.[96]

India: The Indian government has pledged to promote renewable energy in its nationally determined contributions (NDCs)[97] and has very ambitious renewable energy targets and is aiming for 450 GW by 2030, compared to a current total of 369GW installed across all energy sources.[98] India has drafted a

[93] IEA. (2019). Will energy from waste become the key form of bioenergy in Asia? Available at: https://www.iea.org/articles/will-energy-from-waste-become-the-key-form-of-bioenergy-in-asia#:~:text=Will%20energy%20from%20waste%20become%20the%20key%20form,cities%20must%20rapidly%20develop%20new%20waste%20management%20solutions.
[94] IRENA. (2015). Africa 2030: Roadmap for a Renewable Energy Future. IRENA, Abu Dhabi.
[95] NAMA Database. Accessed July 2020: http://www.nama-database.org/index.php/Special:RunQuery/QueryData
[96] Ibid.
[97] Haque. et al. (2019). NDC pledges of South Asia: are the stakeholders onboard? Climatic Change, Vol 155.
[98] India's Ministry of New and Renewable Energy. Accessed July 2020: http://mnre.gov.in

national geothermal policy, which aims to make it a global leader in the geothermal power sector, by generating 1,000 MW in its primary phase by the year 2022.[99] India also demonstrates strong commitment to hydropower.[100]

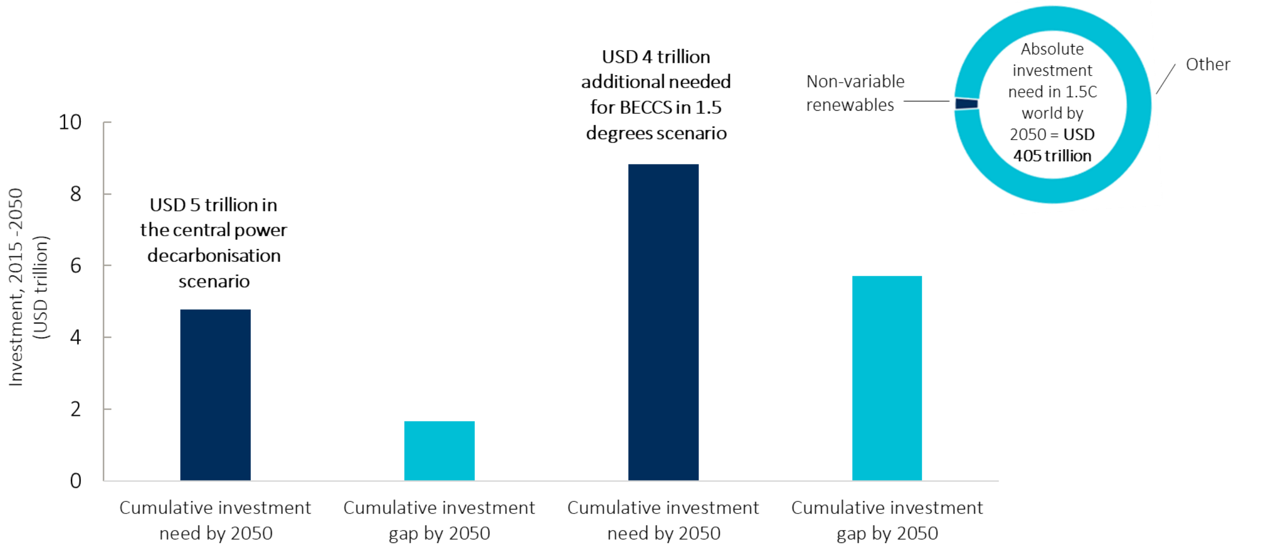
West Africa, In West Africa, Nigeria's Renewable Energy Plan aims for renewable electricity to account for 10% of Nigerian total energy consumption by 2025. It increases capacity of small-scale hydro to 2,000 MW by 2025 and biomass-based power plants to 400 MW by 2025.[101] At least two NAMAs are currently being implemented in the energy sector in West Africa, including in Mali and Sierra Leone.

[99] Geoenergy Marketing Services. (2020). Geothermal Country Overivew: India. Available at: https://www.geoenergymarketing.com/energy-blog/geothermal-country-overivew-india/
[100] IndiaSpend. (2019). 'Only Hydro Projects Can Feed India's 24×7 Power Needs'. https://www.indiaspend.com/only-hydro-projects-can-feed-indias-24x7-power-needs/
[101] IEA. (2013). Nigeria Renewable Energy Master Plan. Available at: https://www.iea.org/policies/4974-nigeria-renewable-energy-master-plan

Investment need

Investment in the opportunity in low- and middle-income countries will need to scale up to a cumulative USD 4.8 trillion by 2050, one and a half times the investment expected under BAU. Overall, the scale of investment required in the opportunity is small relative to other energy opportunities, reflecting uncertainty in levels of deployment. Though Figure 8 reflects our central power scenario, estimates of cumulative investment need would be twice as large in a high BECCS scenario, for example. Estimates of the investment gap are also subject to some uncertainty, depending on assumptions on BAU. Figure 8 reflects a BAU scenario where there continues to be substantial build-out of large-scale hydropower – average annual investment is approximately USD 90 billion.[102] The declining availability of cost-competitive large-scale hydro puts expectations of BAU investment to 2050 into question, highlighting that the cumulative investment gap could be significantly larger than the USD 1.7 trillion estimate shown below. In recent years, there has already been a decline in hydropower additions, with development in higher cost areas – for instance, capacity additions for hydropower (of all sizes) within 2019 final investment decisions (FIDs) was more than half the capacity additions approved in 2010 and small-scale hydropower investment was 70% lower in 2019 relative to 2010. [103,104,105]

Figure 8 Investment need in on-grid non-variable renewable electricity is small compared to other opportunities



Notes: Investment need calculations are calculated based on analysis of IMAGE's renewables scenario, new policies scenarios, and the International Energy Agency's (IEA) Beyond 2 Degrees and Reference Technology Scenarios. Cumulative investment gap is calculated as investment need in a decarbonisation scenario minus the investment need in a BAU scenario.

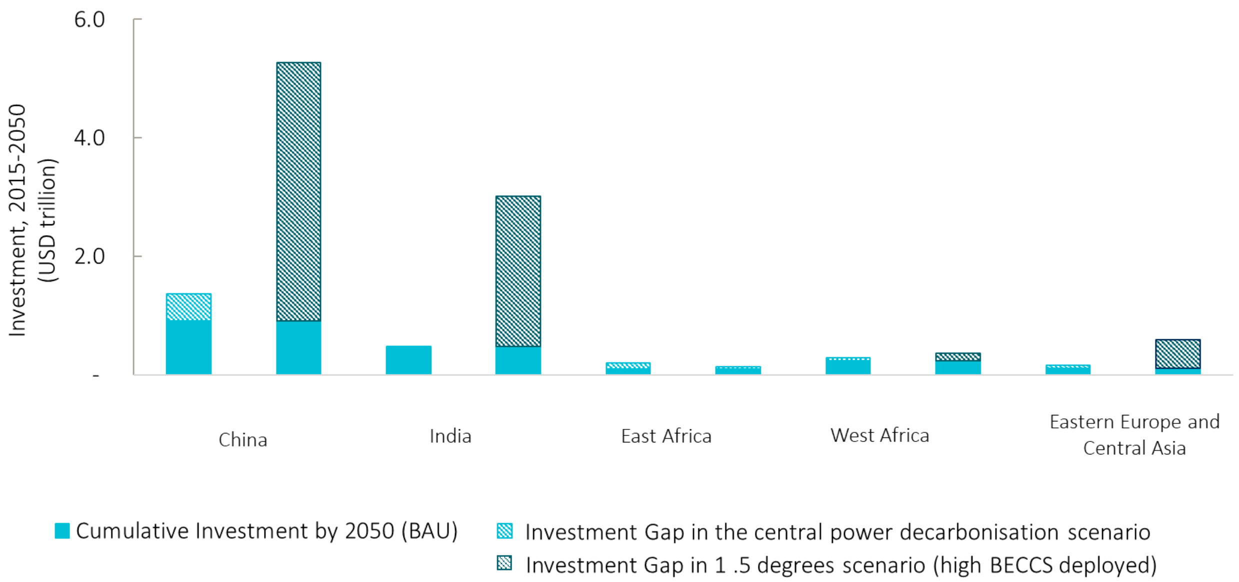
Source: Vivid Economics, ASI and Factor using PBL's IMAGE model and IEA. (2017). Energy Technology Perspectives.

Across the focus regions, the cumulative investment gap to 2050 in the central power decarbonisation scenario is between 0% to 50% of the investment needed in a pathway compatible with the Paris Agreement. There is a large range in the scale of investment need across regions, depending on regional variation in the cost-competitiveness of geothermal and hydro versus variable renewables, as well as the

[102] IEA. (2020). "World Energy Investment 2020". https://www.iea.org/reports/world-energy-investment-2020
[103] Ibid.
[104] Frankfurt School -UNEP. (2020) "Global trends in renewable energy investment 2020" https://www.fs-unep-centre.org/global-trends-in-renewable-energy-investment-2020/
[105] Over the same period, the global weighted average levelised cost of electricity (LCOE) of newly commissioned hydropower projects increased by 27%, from USD 0.037/kWh in 2010 to USD 0.047/kWh in 2019. Source: IRENA. (2020). "Renewable Power Generation Costs in 2019". https://www.irena.org/publications/2020/Jun/Renewable-Power-Costs-in-2019

expected deployment of BECCS. In the central power decarbonisation scenario, this ranges from USD 480 billion in 2050 in India to USD 160 billion in 2050 in Eastern Europe and Central Asia, for example. In the central decarbonisation scenario, Figure 9 shows that there is far less variation expected in the investment gap across the focus regions, which reflects the expectation that future deployment will occur in relatively mature technologies (e.g. large-scale hydropower, geothermal) which are likely to see deployment even under BAU. East Africa is expected to have the largest investment in relative terms – equivalent to USD 100 billion by 2050, 50% of its total investment need. China, on the other hand has the largest absolute investment gap, around USD 450 billion. In a 1.5-degree scenario with high BECCS deployment, the size of the investment gap widens significantly, to around USD 4.4 trillion in China and USD 2.5 trillion in India.

Figure 9 Forecast investment need and gap across regions



Notes: Investment need calculations are calculated based on analysis of IMAGE's 1.5-degrees, renewables, and new policies scenarios. These are scaled to meet the IEA's Beyond 2 Degrees and Reference Technology Scenarios. Cumulative investment gap is calculated as investment need in a decarbonisation scenario minus the investment need in a BAU scenario. EE&CA = Eastern Europe and Central Asia

Source: Vivid Economics calculated from PBL's IMAGE modelling and IEA. (2017). Energy Technology Perspectives

Unsurprisingly, nearly 90% of investment need is expected to occur in hydropower, the most available form of low-cost non-variable renewable power across low and middle-income countries. Investment in hydropower, specifically large-scale hydro, vastly outweighs other technologies in the short and long term in IMAGE's renewables decarbonisation scenario (the central power decarbonisation scenario), reflected in Table 12. However, under a scenario where BECCS is required at scale for decarbonisation, both total and relative investment levels could look significantly different – BECCS would require around USD 310 billion in 2030, 80% of total non-variable power investment in a 1.5-degrees scenario.

Table 12 Investment need is largest in hydropower

Technology	Investment need in 2030 (USD billion)		Investment need in 2050 (USD billion)	
	Renewables (2 degrees)	1.5 degrees	Renewables (2 degrees)	1.5 degrees
Geothermal	9	<1	23	<1
Hydro (large)	85	49	42	38
Hydro (small and medium)	29	16	14	13
Biomass (without CCS)	<1	<1	<1	<1
Biomass with CCS	<1	310	<1	34

Note: IMAGE does not model the breakdown of large, medium, and small scale hydro. To estimate the relative split of capacity additions in each type to 2050, we make the simplifying assumption that the future split will mirror the current one, such that large hydropower is approximately 75% of total capacity. This is based on US Department of Energy figures for 2017.[106]

Source: Vivid Economics, ASI and Factor using PBL's IMAGE model and IEA. (2017). Energy Technology Perspectives

Investment within the opportunity reflects the expansion of non-variable renewable power plant capacity. Most of the investment required reflects the physical installation of additional power capacity, given that capacity additions will need to be around 17 GW per year to 2050, set out in Section 0. Like the Variable Renewables Opportunity Report, significant uncertainty in costs results from regional and site differences. The cost of geothermal extraction, for example, typically ranges from 2,000 - 5,000 USD/kW.[107]

The climate financing need is expected to be far smaller than the overall investment need estimates. Given the cost-competitiveness of geothermal and hydropower in some contexts today, many of the potential investment opportunities are cost-effective over the lifetime of the investment. Public sector investments can therefore achieve high rates of leverage through targeted interventions. For example, by increasing information on resource availability and financing exploration of resource potential.

[106] US Department of Energy. (2017). "2017 Hydropower Market Report". https://www.energy.gov/sites/prod/files/2018/04/f51/Hydropower%20Market%20Report.pdf
[107] IRENA. (2020). "Renewable Power Generation Costs in 2019". https://www.irena.org/publications/2020/Jun/Renewable-Power-Costs-in-2019

Cost-effectiveness

Cost-effectiveness of hydropower and geothermal electricity is highly variable. The cost-effectiveness of non-variable renewable electricity can be relatively high compared to other opportunities, as geothermal and hydropower can be cost-competitive with variable renewables and thermal power. The levelised cost of electricity (LCOE) of small-scale hydropower can be as low as 0.03 – 0.12 USD/kilowatt-hour (kWh) in developing countries. Geothermal power can be as inexpensive as 0.04 USD/kWh.[108,109] However, these costs have high variation between both regions and sites within a region.

Cost-effectiveness varies from across regions due to three principal characteristics:

- Natural endowments. Cost-effectiveness is highest in regions with economically exploitable geothermal endowments and hydropower endowments, such as Indonesia, the Philippines, and Kenya – these countries have the highest geothermal power capacity, around 5 GW in 2016.
- Grid capacity. Non-variable renewables can impose costs on the rest of the system when extraction of energy occurs far from power consumption. Some grids have more or less robust structures to transmit energy across large distances and hence face different transmissions losses.
- Alternative power generation investments. As discussed in the Variable Renewables Opportunity Report, there are significantly greater mitigation benefits from shifting away from coal to on-grid renewables, resulting in higher cost-effectiveness in regions where there is a high share of coal electricity generation today, such as India and South Africa. Coal-powered generation was approximately 75% in India and 90% in South Africa in 2017.[110]

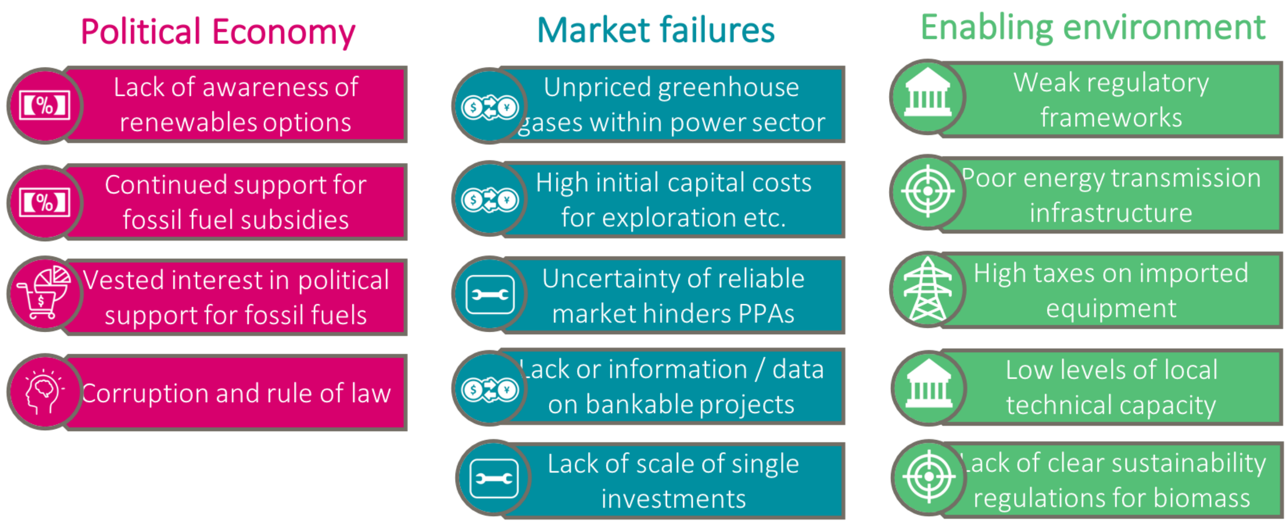
Cost-effectiveness of BECCS is far lower than other non-variable renewables today. Cost-effectiveness of BECCS on a GBP/tCO_2 basis is very low today, approximately GBP 170/tCO_2, due to the high costs of CCS technology and the limited supply chain for biomass feedstocks. As an immature technology with no large-scale deployment to date, there are substantial opportunities for reducing technology costs to 2050, however. Further, as emissions reductions in other sectors become increasingly costly to 2050, BECCS could provide a relatively cost-effective method of achieving mitigation efforts across the energy system.

[108] IRENA. (2020). "Power Generation Costs – Hydropower". https://www.irena.org/costs/Power-Generation-Costs/Hydropower
[109] IRENA. (2020). "Power Generation Costs – Geothermal Power". https://www.irena.org/costs/Power-Generation-Costs/Geothermal-Power
[110] IEA. (2019). World Energy Balances. https://www.iea.org/reports/world-energy-balances-overview

Barriers to adoption

The largest barriers to on-grid non-variable renewable electricity in regions where the opportunity offers the greatest mitigation potential are those related to i) political economy challenges, ii) market failures, and iii) enabling environment. Our typology of barriers is provided in the Methodology chapter in the Synthesis Report.

Figure 10. Barriers to non-variable renewable energy



Source: Vivid Economics, ASI and Factor

Moderate <u>political economy barriers</u> to investment or adoption are likely to be:

Strong political support for fossil fuel subsidies, either due to strong relationships between government and the fossil fuel industry (producer and marketing subsidies) or to pressure from population groups dependent on affordable energy (consumer subsidies), that diminish renewables' competitiveness.

Decision-making inertia towards fossil fuels. The IEA suggests that without more transformational change, fossil fuels are expected to supply 78% of the global energy used in 2040, with countries often not ready to commit more fully to clean energy investment if their electrification rate is low and fossil fuels offer more rapid energy provision. This is a particular challenge in countries that have made fewer commitments to renewables such as in Eastern Europe and Central Asia.

Community opposition to renewable power. Proposals have faced opposition from individual citizens, political leaders, grassroots organisations, national interest groups and, in some cases, even environmental groups. This is particularly relevant for large-scale hydropower, geothermal drilling, and bioenergy that relies on large areas of land dedicated to feedstock. However, there is also likely to be significant local resistance to new fossil fuel-based plants.

Moderate <u>market failure</u> barriers to investment or adoption are likely to be:

Insufficient information amongst investors, banks, project developers, and governments regarding: 1) ecological and financial costs and benefits, 2) renewable energy technologies, and 3) financial feasibility of non-variable renewable energy projects.

The lack of a secure income stream from renewable energy projects. If there is a well implemented long-term PPA with a financially secure counterparty, then confidence in consistent future income would be much stronger.

Unpriced greenhouse gases is a barrier. Given the higher costs of non-variable renewable technologies, the lack of a carbon price further weakens their cost-competitiveness and the case for investment. This is exacerbated by government subsidies provided to conventional energy, which are often much higher than the subsidies awarded to renewable energy. Subsides remain particularly high in China, India and Central Asian countries and Nigeria in West Africa.

The high capital requirements for non-variable renewable energy investments, such as dam construction or early-stage development for geothermal exploration and development, is prohibitively risky and has been a barrier to private sector investment in the target regions.[111]

High transaction costs between international capital markets and domestic renewable energy project developers. This is particularly the case for small renewable energy projects, although this can be overcome by clustering projects together, as demonstrated in India.

Moderate enabling environment / absorptive capacity barriers to investment or adoption are likely to be:

Lack of information and data on potential sources of non-variable renewable energy such as geothermal resources. For example, in East Africa, Malawi and Rwanda have not gone far beyond initial identification of potential resources, while Ethiopia, Kenya, Tanzania, and Uganda are at the exploration stage or beyond.[112]

The suitability of physical assets will shape the nature of opportunities for non-variable renewables in the target regions. Geothermal is more widely available in the regions of interest, but still limited to specific regions in the majority of countries, which often do not correspond to the presence of existing grid infrastructure.

Environmental and social barriers are a significant challenge to uptake. Hydro projects have a mixed environmental record and arguably small- and medium-scale hydro can have a larger cumulative environmental impact than large-scale hydro, per Kw generated.[113] Resettlement of displaced communities is a complex process that can often derail hydro projects.

Climate change and more extreme fluctuations in rainfall and drought can also be a significant barrier to hydro, resulting in more costly design and construction to accommodate greater seasonal fluctuations in water flow. Glacier melt will also increasingly threaten the reliability of water for run-of-the-river hydro operations. This is likely to be higher in China, India, and Central Asia.

Risk aversion amongst banks and investors is a significant barrier. Investors regularly express concerns over the volatility of developing economy currencies; the risks of policy and political change; the reliability of renewable energy buyers, whether utilities or individuals, to pay for the services; and the lack of scale of investments.[114] There are additional concerns about the investment readiness, i.e. internal corporate and financial capacity, of non-variable renewables development projects, often manifested in a limited availability of power purchasing agreements (PPAs) from financially secure power companies. This is a particularly high barrier in East Africa and West Africa.

Confusion in regulatory and institutional frameworks in many countries is often cited as a major barrier. Policy inconsistency and change is prevalent across many of the countries in the high mitigation potential regions, relating particularly to feed-in tariffs and grid integration.[115] This is a particularly high barrier in East Africa and West Africa.

---

[111] ESMAP. (2018). "Geothermal Energy is on a Hot Path to Ending Energy Poverty". https://www.esmap.org/geothermal_energy_is_on_a_hot_path_to_ending_energy_poverty
[112] Kombe & Muguthu. (2018)." Geothermal Energy Development in East Africa: Barriers and Strategies. Journal of Energy Research and Reviews, 2(1), 1-6". https://doi.org/10.9734/jenrr/2019/v2i129722
[113] Opperman, Jeff. (2018). "The Unexpectedly Large Impacts of Small Hydropower". https://www.forbes.com/sites/jeffopperman/2018/08/10/the-unexpectedly-large-impacts-of-small-hydropower/#206835467b9d
[114] Climate Policy Initiative. (2018). "Blended Finance in Clean Energy: Experiences and Opportunities".
[115] Adams & Asante. (2019). "Politics of Renewable Energy in Africa: Nature, Prospects, and Challenges". DOI: 10.5772/intechopen.89019

Transmission infrastructure barriers are also very challenging in all regions with high mitigation potential. Sites of clean energy generation often do not match with current grid configurations and in many countries with low energy coverage, such as across sub-Saharan Africa, there may be very little transmission network in place anywhere. India also still has large areas isolated from the grid.

BECCS has considerable environmental barriers. Large quantities of biomass would be required to expand BECCS to an industrial scale. Biomass production is subject to a range of sustainability constraints, such as: scarcity of arable land and fresh water, loss of biodiversity, competition with food production, deforestation, and the application of fertiliser to overcome scarcity of phosphorus. BECCS should only use biomass that can be produced while meeting sustainability criteria and within the limits of the global sustainable supply potential.

Furthermore, as with other carbon capture and storage technologies, a significant challenge is to find suitable geographic locations to build combustion plants and to sequester captured CO_2 back into bedrock formations. The lack of clear sustainability regulations for biomass generation and the sourcing of feedstock is a constraint to investment.

UK additionality

The UK's additionality is particularly strong in bioenergy, resulting from its rapidly growing domestic experience. However, the UK can also harness expertise in international consulting and financing experience directed to all technologies in this opportunity.

- Biomass makes up a significant proportion of the UK's renewable energy mix, resulting in significant expertise that can be exported to the target regions. The UK also has solid expertise in waste-to-energy planning and implementation.
- The UK also has considerable expertise in CCS which should continue to grow in line with a large potential domestic market and international opportunities, ideally connected to bioenergy such that it is a combined BECCS approach.
- While the UK does not have significant domestic experience in geothermal and hydropower, the private sector has considerable international consultancy and engineering experience in the sector.
- Extensive expertise is provided by the UK in developing appropriate policy and regulations, financing clean energy domestically and internationally, and de-risking renewable investments via financial or policy measures.
- The UK provides extensive expertise in integrating renewable energy sources into existing and new grids.

The UK has made a strong contribution to bilateral and multilateral donor investment in the target regions in relation to on-grid non-variable renewable energy.

- According to Organization for Economic Co-operation and Development – Development Assistance Committee (OECD-DAC) data, the UK funded USD 179m out of a DAC total of USD 2,833m between 2015 and 2018:
  - DAC members spent USD 37m in China in total, while the UK spent less than a million USD.
  - DAC members spent USD 964m in India, out of which the UK spent approximately USD 145m.
  - DAC members spent USD 867m in Eastern Africa, out of which the UK spent USD 7m.
  - DAC members spent USD 194m in Eastern Europe and Central Asia, out of which the UK's contribution was negligible.
  - DAC members spent USD 771m in West Africa, out of which the UK spent around USD 26m.
- The largest drivers of donor activity in support of non-variable renewable energy are the World Bank, European Union (EU), Asian Development Bank (ADB), Japanese International Cooperation Agency (JICA), German Agency for International Cooperation (GIZ) and German Development Bank (KfW). Chinese investment in the African power sector has also been significant.
- World Bank support focuses principally on financial instruments for governments to unlock renewable energy opportunities, as demonstrated in its Central Asia strategy.[116] Particularly notable donor programmes are the World Bank's Energy Sector Management Assistance Program (ESMAP)[117] and the EU's Sustainable Energy for All Facility.[118]

---

[116] Motohashi, M. (2017). Presentation on World Bank's Engagement on Renewable Energy in Central Asia. IRENA. https://www.irena.org/eventdocs/Central%20Asia%20Regional%20Workshop/14%20Session%20IV%20Mapping%20the%20RE%20Support%20in%20the%20Region%20Mits%20Motohashi.pdf
[117] ESMAP - Website: https://www.esmap.org
[118] Sustainable Energy for All. Website: https://www.seforall.org

Much of the UK's ODA support to hydropower has been channelled through the German Federal Ministry for Economic Cooperation and Development and KfW bank, which seems to be a particularly active partnership in the sector. Generally, donor investments are targeted much more frequently at larger or mini-grid hydro, leaving a gap for medium-scale projects.

The Geothermal Risk Mitigation Facility was established by the African Union Commission, the German Federal Ministry for Economic Cooperation and Development, and the EU-Africa Infrastructure Trust Fund via KfW.

Despite the prevalence of donor activity across non-variable clean energy, there remains a significant demand from governments to help overcome constraints and UK expertise can add strong value.

In regions with the largest mitigation potential, the UK typically has strong ODA ties with East and West Africa, India, and China.

Between 2010 and 2017 the UK's ODA support for non-variable and variable renewable energy totalled GBP 1.032bn or 32% of total ODA support for energy. Of all UK support for energy in developing countries, including non-ODA sources, GBP 1.31bn, or 17%, was for renewables.[119]

BEIS and Department for International Development (DFID) have been the major conduits of the ICF and renewables-centred ODA. Two-thirds of the ICF is channelled via multilateral development banks (MDBs).[120]

Of the five regions, East and West Africa (particularly Ethiopia, Kenya, Nigeria, and Ghana) have been the major recipients of ODA, India has received significant ODA support, whilst China and several Eastern Europe and Central Asian countries (Kyrgyzstan, Tajikistan, and Ukraine) have received limited ODA and non-ODA assistance.

In the same period, Ghana, Nigeria, Turkey, and India were in the top ten highest recipients of overall UK energy assistance.

Most of the UK's ODA support to hydropower has been delivered outside of the prioritised regions, in countries such as Afghanistan, Indonesia, Nepal, and Pakistan.

Most programmes of support related to non-variable renewable energy focus on access, policy and regulatory reform and addressing market failures, and supporting private sector green finance.

DFID is currently funding substantial programmes in broader renewable energy access, policy and regulatory reform, addressing market failures, and green finance mobilisation, for example, the *Africa Clean Energy Fund*, *Solar Nigeria Programme, Ayrton Fund (jointly funded with BEIS), Private Infrastructure Development Group (PIDG), UK-Africa Investment Summit,*[121] and the Foreign & Commonwealth Office (FCO) Prosperity Fund is implementing an *Energy and Low Carbon* programme in *China.*

DFID recently implemented the *East Africa Geothermal Energy Technical Assistance Facility*[122] and has also provided exploratory services for geothermal in Montserrat, in the Caribbean. UK support in this area typically covers reducing the risk of exploratory test drilling, leading to increased investor confidence in underexploited geothermal energy; and improving geothermal strategy, policy, and regulations that facilitate investment.

---

[119] Catholic international development charity (CAFOD). (2019). UK support for energy 2010–2017: Protecting the climate and lifting people out of poverty? Available at: https://cafod.org.uk/content/download/49429/623388/version/4/file/UK%20Support%20for%20Energy%202010-17%20Policy%20Briefing%20web%20version3.pdf

[120] Independent Commission for Aid Impact (ICAI). (2019). "International Climate Finance, UK aid for low-carbon development, A performance review".

[121] UK Development Tracker. "Aid by Sector". https://devtracker.dfid.gov.uk/sector/14/projects#page-1

[122] UK Development Tracker. "East Africa Geothermal Energy (EA-Geo) ". https://devtracker.dfid.gov.uk/projects/GB-1-203153

From 2012 to 2016, BEIS implemented a GBP 60 million *International Carbon Capture and Storage programme,* which included support to many of the focus regions, including China. In particular, it funded the incremental financing required for CCS planning and pre-investment, capital costs for CCS units and components, and CCS-related post-completion and operation activities.[123]

DFID programmes such as the *Nigeria Infrastructure Advisory Programme (NIAF*) have provided robust support on aspects such as a feasibility and business case for hydropower proposals, as well as supporting on wider power sector reform.[124]

[123] Department of Energy & Climate Change. (2015). International Carbon Capture and Storage Programme: Annual Review. Available at : https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/471695/International_Carbon_Capture_and_Storage_Second_Annual_Review.pdf

[124] ICF International. (2015). Formative Evaluation of NIAF II. DFID. Available at: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/497629/Evaluation-NIAFII-March-2015.pdf

Intervention opportunities

To alleviate the barriers set out above, there is substantial opportunity across all regions for the UK to draw on its core strengths and areas of additionality, to deliver non-variable renewable energy interventions in the following areas:

- Provide technical assistance to improve policy and regulation and overcome market failures, e.g. reducing transaction costs, addressing information asymmetries, reducing currency risks, and thereby facilitate private investment. This is greatly needed in countries in East and West Africa and Eastern Europe and Central Asia that are lagging behind in renewables policy.

- Technical assistance to improving integration of grids between renewable and non-renewable sources, particularly in East Africa and West Africa.

- Support on regional grid integration to allow international power purchasing, particularly in East Africa and South Africa, so that power generated with renewables that are abundantly available in one country can be exported to another one that lacks the resources.

- Technical assistance around improving the policy and regulatory environment, relating to power purchasing guarantees and agreements and feed-in tariffs. This would help overcome critical constraints in East Africa and West Africa.

- Building the capacity of public and private sector organisations and staff, including assisting governments to understand and implement the most suitable policy levers, again particularly in East and West Africa.

- Helping to improve the availability and quality of information relating to energy resources and benefits, targeted at governments, utilities, and investors, helping to raise awareness, providing information and evidence on possible investments, via a database of potential resources, and helping to develop a pipeline of bankable projects. This would be valuable in Eastern Europe and Central Asia, and East and West Africa.

- Leveraging and de-risking private sector green finance. For instance, investing climate finance to leverage further private debt or equity finance via PIDG, CDC, credit lines, MDBs, or bespoke debt or equity funds. There are greatest opportunities for blended finance in clean energy in India, East Africa, and West Africa.

- Influence multilateral investment banks. For example, using substantial UK contributions to MDBs to influence their agendas towards greater use of loan guarantees, investment in clean technology, and backing national banks.[125]

- Enable more sustainable biomass energy generation by:

  - Supporting government to formulate a BECCS roadmap followed up by implementation support on specific aspects such as feedstock sources and value chains, sustainability, and financing. It is important to consider that each country will have specific comparative advantages to build on.

  - Supporting concessional finance towards bioenergy projects, helping to de-risk projects. This can achieve particularly high impact at the project preparation phase or during early construction. When blended with commercial finance, ICF concessional finance should seek to promote

[125] Overseas Development Institute. (2017). "Six development finance proposals to expand climate investment". https://www.odi.org/publications/10746-six-development-finance-proposals-expand-climate-investment

adherence to high standards of conduct, including in the areas of corporate governance, environmental impact, social inclusion, transparency, integrity, and disclosure.[126]

Help governments develop biomass sustainability regulations at the national level, with a focus on feedstock sourcing and implementing appropriate carbon capture and storage techniques.

Support Research & Development (R&D) in bioenergy techniques and processes suitable to the target regions and use the outcome of research to inform actionable steps.

Enable geothermal energy generation by:

Giving technical assistance in developing a database on local geological resources, which would add strong value in East Africa and Central Asia.

Support innovation and knowledge sharing in areas such as geothermal drilling techniques.

Provide or raise concessional finance to enable the de-risking of public or private sector investments, such as in exploratory drilling for geothermal resources. For example, between 2013 and 2018, the World Bank financed Global Geothermal Development Plan (GGDP) raised USD 235 million in concessional funding through the Clean Technology Fund (CTF), which has been made available to MDBs, including the World Bank, to support upstream geothermal activities.[127]

Support governments and power company stakeholders to develop power purchasing agreements and loan guarantees, particularly in India, and East and West Africa.

[126] Development Finance Institutions. (2018). "DFI Working Group on Blended Concessional Finance for Private Sector Projects: Joint Report, October 2018 Update"

[127] The World Bank. (2018). "Geothermal Energy is on a Hot Path" https://www.worldbank.org/en/news/feature/2018/05/03/geothermal-energy-development-investment

Intervention case studies

These case studies provide real-world insights into intervention design and challenges. Each case study provides an overview of the context, the aim of interventions, and the challenges faced.

Box 5 Restoring run-of-the-river Hydropower in Remote Regions of Tajikistan, 2002 to date

The Aga Khan Fund for Economic Development (AKFED), in partnership with the International Finance Corporation, formed the Pamir Energy company in 2002 as Tajikistan's first public-private partnership (PPP). Tajikistan's electrical infrastructure was in need of major investment after the collapse of the Soviet Union and a five-year-long civil war. Among the most affected areas was the Gorno-Badakhshan Autonomous Oblast (GBAO), where people and businesses suffered during the cold winter months. The lack of electricity for heating resulted in the closure of schools, health centres, and businesses. Many of the region's 220,000 residents resorted to wood fuel for their heating and cooking needs during the winter, which resulted in 70% of the region's forests being destroyed within a decade. Smoke inhalation from fuelwood caused an increase in respiratory illnesses.[128] Pamir Energy continues to expand its power generation capacity through rehabilitation of the small hydro plants and connecting them to the main grid where appropriate. It is expected that by 2027, the Company will have invested USD 50 million in electrical infrastructure, producing a total economic benefit of USD 85 million for the region.[129]

The objectives of the project have been to:

- Restore small-scale hydropower across the region to be able to meet the electricity demand for every day economic and social activities in the GBAO region.
- Improve the affordability and reliability of electricity for local communities, as well as health and environmental outcomes.

In pursuit of those objectives, the activities of the project were:

- Rehabilitating 11 abandoned, small and medium run-of-the-river hydropower plants and upgrading 4,300km of old transmission and distribution lines.
- Smart meters were installed for households and businesses in 2014 which allow the company to monitor usage and regulate supply to match demand and can also be used to cut off supply remotely for defaulting customers. In addition, the system is ready to accept mobile payments when the technology comes to the area.

As a consequence, the results of partnership are:

- It has refurbished or built 11 small and medium run-of-the-river hydropower plants that range in capacity from 130 kW to 28 MW, with a total capacity of 43.4 MW. They produce about 170 GWh of electricity per year and supply over 33,000 customers, representing some 254,000 people: 220,000 in Tajikistan and 34,000 in Afghanistan. A twelfth hydro plant is under construction.
- It has upgraded 4,300 km of old transmission and distribution facilities and reduced transmission losses from 39% to 12%.
- Electricity coverage has expanded from 13 % of households receiving 12 hours of electricity per day in 2002 to 96 % of households receiving electricity 24 hours per day in 2016.
- It has improved livelihoods by providing employment opportunities to over 600 local residents and 200 contractual opportunities. Commercial enterprises are also flourishing; today there are

[128] Thomson Reuters Foundation. (2016). "Mountainous Pakistan cuts forest loss, disaster risk with river power ". https://news.trust.org/item/20160314070911-3jowc

[129] The Aga Khan Development Network (AKDN). (2012). Tajikistan. Pamir Energy. https://3ga4b0g2bmm2x0mm4aptur1d-wpengine.netdna-ssl.com/wp-content/uploads/2012_tajikistan_pamir.pdf

more than 2,100 businesses in the region, up from some 600 in 2006. This has all been achieved with clean power, which is also reducing pressure on the region's natural environment.[130]

- Women and girls are able to continue education and participate in economic activities as they are no longer spending hours collecting fuelwood and household air quality has improved with the replacement of diesel generators, wood, and kerosene, and average household energy costs have been cut substantially.
- Due to its limited greenhouse emissions, PamirEnergy has been able to generate revenue by selling carbon credits abroad, in line with the terms of the Kyoto Protocol.

Key stakeholders and clients include:

- Local government departments, local community groups, other non-governmental organizations (NGOs), and special interest groups.

The risks and challenges that the project faced were:

- The ability of residents to afford power has been a significant challenge. To address cost issues, AKFED developed a pioneering subsidy scheme, making electricity both affordable to residents and financially viable for PamirEnergy. One of the subsidies ensures provision of a minimum 'lifeline' monthly power supply to all households served by the company at a rate of USD 0.25/kilowatt-hour, one of the lowest in the world among privately owned utilities. Subsidies are generously funded by two grants, one from the Swiss Government (SECO) and the other from the Government of Tajikistan through financing by the International Development Association (IDA), a member of the World Bank Group.[131]
- Despite subsidies, cost recovery can be a significant challenge for PamirEnergy in a region where 40 % live below the poverty line. To help solve the problem, they established a Customer Service Centre in Khorog in 2009 and plan to open similar centres in other districts, enabling representatives to more efficiently and effectively respond to customer difficulties and inquiries.
- PamirEnergy has faced issues with maintenance, durability of equipment, and transportation and logistics of equipment and workers in a remote and mountainous region where temperatures can fall to minus 30°C and that threatens many different types of natural hazards.
- The small hydro plants depend on glaciers and snowmelt. Once the glaciers reach a critical melting point, the system will lose access to their outflow, which will reduce reliability, so PamirEnergy are also considering wind and solar options to create hybrid networks.[132]

For BEIS, the primary lessons from this programme in determining ICF investment are:

- Small-scale run-of-the-river hydro can provide reliable, clean, and affordable electricity over the long term and can be the best solution for certain regions such as southern Tajikistan, given the topography, climate, distribution of resources, and remoteness.
- Transformational impact has been achieved by the AKFED and IFC in creating a PPP for PamirEnergy as a sustainable, responsible, and well-run energy company, which will hand back the power assets to the Government after a 25-year period. For the success of a public private partnership in a challenging region, robust local contextual knowledge and building on local capacity are of utmost importance.

[130] Ashden. (2017). Pamir Energy / Bringing power to the people of Tajikistan and Afghanistan. https://www.ashden.org/winners/pamir-energy
[131] The Aga Khan Development Network (AKDN). (2012). Tajikistan. Pamir Energy. https://3ga4b0g2bmm2x0mm4aptur1d-wpengine.netdna-ssl.com/wp-content/uploads/2012_tajikistan_pamir.pdf
[132] AKDN. Pamir Energy and the future of clean electricity in Central Asia. https://www.akdn.org/our-stories/pamir-energy-and-future-clean-electricity-central-asia

- In regions of extreme poverty, clean energy operations may need to be supported by public sector loans or grants to ensure affordability for local communities. This should become less necessary over time as access to energy improves livelihoods and income generation. Indeed, the utilities section of PamirEnergy now breaks even but concessional or grant financing is required to further expand the network.[133]

Box 6 InfraCo Africa Financing Support for the Corbetti Geothermal Plant in Ethiopia, 2017 to date.

Ethiopia's geothermal potential has long been recognised as a potential solution to low levels of energy generation and access across the country. In 2019, the Government of Ethiopia (GoE) released an updated National Electrification Plan with the target of achieving universal access through a combination of on- and off-grid supplies by 2025. This requires 13.5 GW of new on-grid generation, of which 840 MW is geothermal. Situated in the Corbetti Caldera 250km south of Addis Ababa, Corbetti Geothermal will be a pioneering project. It will prove a new geothermal resource and be one of the first pairs of privately developed, owned, and operated geothermal Independent Power Producers (IPPs) in Ethiopia, which is only the second country in sub-Saharan Africa to develop geothermal privately. To manage the early stage development risks and costs, Corbetti will be developed in two phases over a four-year period. The first phase, wholly equity funded, will drill up to six exploratory wells and build a small power plant. This initial phase will demonstrate the viability of the geothermal resource and the PPA, enabling the project to raise further investment. The second phase will raise debt financing to drill a further 9-13 wells and construct a 50-60 MW commercial-scale power plant and facilities. Totalling 150 MW, the full Corbetti programme will enable the government to meet 18% of its ambition to generate 840 MW from geothermal sources by 2025.[134]

InfraCo Africa, part of the PIDG which is funded by UK Aid as well as other donors, made an initial commitment to Corbetti because of the potential for geothermal power to transform Ethiopia's energy mix and the enormous challenge faced by the project in being the first private sector-led development of an unproven resource.[135] CDC Group have also invested in Corbetti, through the Africa Renewable Energy Fund.[136]

The objective of the project was to:

- Raise finance and achieve financial close for the first stage of proving the geothermal resource, enabling the project to move onto more comprehensive drilling and realising full power generation by 2023.

In pursuit of those objectives, the activities of the intervention were:

- In 2015, InfraCo Africa formed a joint venture company with Berkeley Energy to jointly become the majority shareholder in Corbetti Geothermal. At the time, InfraCo Africa committed up to USD 15m to the project. This was extended to USD 30m in 2020.
- Undertaking a process of studies and exploratory drilling to prove the resource, culminating in the signing of a PPA and Implementation Agreement (IA) in early 2020 with Ethiopian Electric Power, which allows the Corbetti geothermal project to move into the next phase of implementation and to commence the final drilling and then power generation.

[133] AKDN. Pamir Energy and the future of clean electricity in Central Asia. https://www.akdn.org/our-stories/pamir-energy-and-future-clean-electricity-central-asia
[134] ESI Africa. (2020). Ethiopia breaking ground in geothermal vision. https://www.esi-africa.com/industry-sectors/generation/ethiopia-breaking-ground-in-geothermal-vision/
[135] InfraCo Africa. (2018). InfraCo Africa increases its commitment to US$30 million for Ethiopia's first private geothermal projectSource: https://infracoafrica.com/infraco-africa-increases-commitment-ethiopias-first-private-geothermal-project-us30-million/
[136] CDC Group. Corbetti Geothermal. https://www.cdcgroup.com/our-impact/underlying/corbetti-geothermal/

- Relevant stakeholders worked to support the Government in drafting the regulatory frameworks and legislation required to unlock private sector provision of geothermal energy potential in the country.

As a consequence, the results of the intervention have been:

- Totalling 150 MW, the full Corbetti programme will enable the GoE to meet 18% of its ambition to generate 840 MW from geothermal sources in 2025.[137]
- The impact is substantial in terms of proving what is possible and enabling other IPPs to follow the lead. The Ministry of Water and Energy forecasts an increase in geothermal generation from 7 MW in 2012, to over 1,000 MW by 2030.[138]
- The project is expected to have significant community benefits with interventions focused on health, education, agriculture, and water, with the intention to supply potable water for humans and livestock in a very dry region of Ethiopia.[139]

Key stakeholders and clients include:

- Government of Ethiopia, Ethiopian Electric Power, various private and public sector financing entities, local NGOs and communities.

The risks and challenges that the project has faced are:

- Financing and unproven resource is the greatest challenge in realising geothermal energy. The role of donor funded investment vehicles like InfraCo Africa is vital in de-risking geothermal exploration and investment. Much of the debt associated with financing the second phase is also expected to come from Development Finance Institutions.
- A PPA was first anticipated for Corbetti in 2012 and has been delayed due to a range of factors, including investor and regulatory uncertainty. These challenges had been addressed by 2020, which shows that things can move slowly if the necessary elements are not aligned.
- The geothermal project is a long way from the electricity grid and as such will need to include a sub-station and an 11km transmission line.

For BEIS, the primary lessons from this programme in determining ICF investment are:

- De-risking geothermal energy via concessionary, grant, or equity financing can create a transformational impact in moving forward a particular project and breaking a trail for other private sector investors to follow.
- The process involved technical assistance in refining the necessary legislation, which should pave the way for much rapid development of subsequent geothermal projects.

[137] InfraCo Africa. Ethiopia: Corbetti. https://infracoafrica.com/project/corbetti/
[138] Ethiopia Semonegna. (2018). InfraCo Africa increases its commitment to US$30 million for Ethiopia's first private geothermal project. https://semonegna.com/infraco-africa-us30-million-commitment-ethiopia-corbetti-geothermal/
[139] Berkeley Energy. Corbetti. https://www.berkeley-energy.com/project/corbetti/

Glossary

Acronym / Term	Definition
ADB	Asian Development Bank
AKFED	Aga Khan Fund for Economic Development
BAU	Business as usual
BECCS	Biomass energy with carbon capture and storage
BEIS	UK government Department of Business, Energy and Industrial Strategy
BMZ	Germany's Federal Ministry for Economic Cooperation and Development
BMZ	Germany's Federal Ministry for Economic Cooperation and Development
BUG	Back-up generator
CCC	UK's Committee on Climate Change
CCS	Carbon capture and storage
CIF	Climate Investment Funds
CTF	Clean Technology Fund
CTF	Clean Technology Fund
DAC	Development Assistance Committee
DFID	UK government Department for International Development
Dispatchable	A source of electric energy production whose output can be switched off or on or otherwise moderated according to demand.
EJ	Exajoule
ESCO	Energy Service company
ESMAP	Energy Sector Management Assistance Program
ESO	Energy systems optimisation
ESS	Energy storage systems
ETP	Energy Technology Perspectives
EU	European Union
EUR	Euro
FCO	Foreign & Commonwealth Office
FID	Final investment decision
Flexibility	The ability of a power system to respond to changes in electricity demand and supply
GBAO	Gorno-Badakhshan Autonomous Oblas
GBP	British pound sterling
GET FiT	Global Energy Transfer Feed in Tariff

Acronym / Term	Definition
GGDP	Global Geothermal Development Plan
GIZ	German Agency for International Cooperation
GoE	Government of Ethiopia
Grid	An electricity grid
Grid storage	Storage connected to a distribution or transmission networks, or alongside a power generation asset, such as a wind turbine
GtCO2	Gigatonnes of CO2
Gt CO2e	Gigatonnes of CO2 equivalent
GW	Gigawatt
GWh	Gigawatt hours
IA	Implementation Agreement
IADB	Inter-American Development Bank
ICF	International Climate Finance
IDA	International Development Association
IEA	International Energy Agency
IPP	Independent Power Producer
IRENA	International Renewable Energy Agency
IT	Information technologies
JICA	Japanese International Cooperation Agency
KfW	German Development Bank
kWh	kilowatt-hour
Load	The energy demand experienced on a system
LCOE	Levelised Cost of Electricity
MDB	Multilateral Development Bank
MW	Megawatt
NAMA	Nationally Appropriate Mitigation Action
NDC	Nationally Determined Contribution
NEPs	National Energy Plans or Policies
NGO	Non-governmental organizations
NIAF	Nigeria Infrastructure Advisory Programme
ODA	Official Development Assistance
ODI	Overseas Development Institute
OECD	Organization for Economic Co-operation and Development

Acronym / Term	Definition
PPA	Power Purchase Agreements
PPP	Public-private partnership
PV	Solar Photovoltaic
RD&D	Research, development & demonstration
RE	Renewable Energy
REPP	Renewable Energy Performance Platform
SDG	Sustainable Development Goal
SECO	Swiss Government
Stationary storage	Electrical storage designed for stationary applications
TA	Technical Assisstance
USAid	United States Agency for International Development
USD	United States Dollar
Variability	The changes in power demand and/or output of a generating source due to underlying fluctuations in resource or power consumption
Virtual Power Plants	VPP operators aggregate DERs to behave like a traditional power plant and engage in a power market to sell electricity or ancillary services

Energy storage

Summary

Energy storage considers a range of interventions to encourage the adoption of electrochemical (battery) and non-electrochemical storage, to support an increase in renewable integration and demand side response. The assessment of energy storage considers the utilisation of stationary storage by industrial, commercial and household users with connection to a grid network.[140] It focuses on how storage can support grid flexibility and renewable integration, including 'smart grid' demand side response opportunities.

Interventions to encourage adoption of energy storage in focus geographies include financial incentives, pilot projects and reform of electricity market regulation. Given the largest barriers to adoption for storage technologies, example interventions include:

- Financial support to pilot storage technologies, to demonstrate viability of relatively new storage technologies in the local context and build a local supply chain of skilled technicians; and,
- Technical assistance to support electricity market regulation, with current systems often not incentivising storage's value as a provider of flexibility services to the grid, due to the lack of an ancillary service market, time of use electricity prices, or net metering legislation.

Table 13 Energy storage assessment summary

Criteria	Assessment	Notes
Climate impact	Medium	• Sizeable indirect impact on power sector emissions by enabling integration of variable renewables (which could help to reduce around 50% of power sector emissions by 2050), reducing dependence of polluting forms of back-up power, and increasing opportunities for demand side flexibility
Development impact	High	• Critical impact on SDG 7 by enabling greater access to reliable, clean energy, as well as subsequent additional positive impacts on health and well being and economic growth. Potential negative impact on local environment due to poor end-of-life management practices, and the extraction of raw minerals for electrochemical storage technologies.
Investment gap	Low	• Investment gap of USD 0.45 trillion is low compared to other opportunities, due to lower overall investment need of USD 1.1 trillion. • Largest forecast investment gap in India, approximately USD 70 billion.
Cost effectiveness	Medium	• Increasingly cost effective in markets which integrate storage as part of a 'smart grid' and allow storage to provide multiple flexibility services to the grid. • Relative cost effectiveness will depend on local availability of alternative firm low carbon power and centralised demand side response (to provide flexibility)
Barriers to adoption	High	• Multiple barriers to adoption, including lack of trust and understanding amongst policymakers (and industry) on the use of storage; high costs of investment; and, minimal financial incentives for the services that storage can provide (such as demand flexibility necessary for renewable integration or grid ancillary services for reliable grid power)

[140] The assessment does not consider storage for mobility e.g. electric vehicle storage (which is considered in the passenger vehicle report) or off-grid storage (which was considered out of scope following Phase 1 of the analysis)

Criteria	Assessment	Notes
UK additionality	High	• UK is active and influential in the international donor landscape, with strong expertise in research of emerging electrochemical storage technologies and the recycling of lithium-ion batteries. Further expertise in the integration of energy storage and smart grid design, including 'energy as a service' business models can be harnessed in interventions.

Source: Vivid Economics, ASI & Factor

Key lessons for supporting mitigation through energy storage:

Behind the meter storage has the potential to provide the largest and most immediate climate impact opportunity, particularly in countries with an unreliable grid network or a high reliance on back-up generators (BUGs).

India, West Africa and South Africa are likely to have the largest mitigation opportunity due to weak grid capacity, reliance on BUGs and high grid emissions intensity today.

Adoption of storage will only increase if two fundamental barriers are overcome:

policymakers and local industries are aware of the value that storage can provide and the relative costs of storage technologies versus alternatives, such as diesel generators; and,

the payback period for storage technologies is minimised, either through RD&D to reduce technology costs, business models which allows storage to stack revenue streams or financing which reduces consumer borrowing constraints.

Technical constraints of storage technologies, particularly lithium-ion batteries, must also be overcome to ensure faster and more sustainable adoption of energy storage. Key concerns are the recyclability and safe disposal of lithium-ion batteries, and their degradation under high temperatures (relative to lead acid or non-electrochemical storage).

The UK is well placed to harness its expertise in academic research and testing surrounding storage technologies, and knowledge on business models to monetise the benefits of storage.

Introduction to the opportunity

Role of the opportunity in decarbonisation of developing countries

The power sector emitted 7.4 gigatonnes of carbon dioxide (Gt CO_2) in low- and middle-income countries in 2015, rising to 16 GtCO_2 in 2050 under a business as usual (BAU) scenario.[141] The power sector accounts for approximately 40% of total emissions from low- and middle-income countries today.[142,143] To reach a 1.5 degrees Celsius target, the sector needs to nearly fully decarbonise, which is expected to require large-scale additions of variable renewable energy. Variable renewable energy is expected to supply around 68% of electricity in low- and middle-income countries in 2050, compared to only 1% in 2015.[144]

Energy storage will have an important role in power decarbonisation, by helping to integrate renewables at a lower overall cost and reduce consumption of back-up generators. Power system flexibility will become increasingly necessary to handle the variability that solar and wind introduce into the system, helping to ensure reliability of supply, reduce the cost of renewable integration (by reducing the need for transmission and distribution (T&D) investment and back-up generation), and reduce renewable power curtailment.[145] Storage has a particularly important role in providing power flexibility because, unlike some alternatives, storage can help to balance demand and supply in the short and long-term (across seconds, minutes, hours and days). Further, storage enables increased demand side response, discussed further in the Demand-Side Management Opportunity Report. Alongside providing flexibility, storage can also help to reduce power emissions of industry and households by reducing reliance on polluting back-up generators. In sub-Saharan Africa alone, back-up generator capacity is approximately equal to that of power plants on the grid, around 50% of which is medium to large generators (>60kW) owned by businesses, critical infrastructure (e.g. hospitals) and industry.[146]

Currently, storage additions are far lower than what would be required in a Paris Agreement compatible pathway - approximately 58 gigawatts (GW) per annum by 2050. In 2015, storage capacity was only 27 GW across low and middle-income countries. Under stated policies, capacity rises by over 150 GW in 2050. To support the renewables uptake expected in decarbonisation scenarios, capacity would need to increase by 13x more to 2050 than is expected under stated policies, however.[147]

Scope considered in this assessment

The energy storage opportunity considers both electrochemical and non-electrochemical storage technologies in stationary applications. The assessment considers the utilisation of stationary storage by industrial, commercial and household users with connection to a grid network,[148] focusing on how storage can support 'smart grid' demand-side response opportunities and renewable integration. Non-electrochemical storage technologies are also considered, including mechanical storage technologies (e.g. compressed-air energy storage and flywheels), thermal storage technologies and electrical storage

---

[141] Figures correspond to the IMAGE Planned Policies decarbonisation scenario
[142] IEA (2017). *"Energy Technology Perspectives"*. https://www.iea.org/reports/energy-technology-perspectives-2017
[143] Figures correspond to the renewables decarbonisation scenario. Variable renewables includes solar photovoltaic (PV), concentrated solar power (CSP), onshore wind and offshore wind
[144] IRENA (2018). "*Global Energy Transformation. A Roadmap to 2050*". https://www.irena.org/-/media/Files/IRENA/Agency/Publication/2018/Apr/IRENA_Report_GET_2018.pdf
[145] Variability is defined as the fluctuating nature of solar and wind resources, which translate into rapid changes in electricity generation. Uncertainty is defined as the inability to perfectly predict the future output of variable renewable generation. Based on Irena. (2019). "Innovation landscape preview" https://www.irena.org/-/media/Files/IRENA/Agency/Publication/2019/Jan/IRENA_Innovation_Landscape_preview_2019.pdf?la=en&hash=10221885865D12F47747356D9F6290283B205210
[146] IFC (2019). "The Dirty Footprint of the Broken Grid". https://www.ifc.org/wps/wcm/connect/2cd3d83d-4f00-4d42-9bdc-4afdc2f5dbc7/20190919-Full-Report-The-Dirty-Footprint-of-the-Broken-Grid.pdf?MOD=AJPERES&CVID=mR9UpXC
[147] From IMAGE, under the renewables scenario
[148] The assessment does not consider storage for mobility e.g. electric vehicle storage

technologies (e.g. supercapacitors).[149] Considerations of batteries as part of smart grids and the potential for vehicle-to-grid charging are discussed in the Demand Side Management Opportunity Report.

The assessment focuses on regions where the balancing requirements created by variable renewable energy uptake and local demand profiles necessitate greater uptake of storage. On-grid renewable variable energy will be critical to emissions reduction in all low and middle-income countries, and therefore our analysis of storage considers all regions to some degree. However, the regions of focus in this assessment include:

India, where large expected additions of solar photovoltaic (PV) and grid emissions intensity (75% power was coal-fired in 2017) imply storage will be an important enabler of India's large mitigation opportunity. As such, India is expected to require the second-largest absolute increase in storage to 2050 (after China).

East Africa, where (similar to India) storage presents an opportunity to avoid grid congestion and defer transmissions and distribution upgrades required throughout the region.

South America (excluding Brazil), henceforth 'South America', which is expected to increasingly rely on alternatives to pumped hydro for flexible power, resulting in one of the largest increases in storage capacity relative to 2015 levels (third-largest after China and Indonesia's relative increase in capacity).

South-East Asia, where storage is increasingly recognised as an important enabler of increased renewables deployment in government policies, with the Philippines recently publishing a comprehensive and ambitious framework for storage systems in 2019.[150]

South Africa, a country which is reliant on coal for 90% of power generation despite significant solar and wind resources presents a great opportunity for storage and renewables.151 South Africa's state-owned utility Eskom unveiled a Distributed Battery Storage Programme, committing to 1,400 megawatt-house (MWh) of storage projects.[152]

This assessment focuses on the benefit of supporting the opportunity as a whole and does not aim to comprehensively assess the effectiveness of specific investment opportunities or interventions. However, for context, potential investment opportunities to support on energy storage are detailed in Section 0.

[149] Pumped hydropower is not considered in the energy storage category, but small-to medium-scale pumped hydropower opportunities are considered in the Non-variable Renewables Opportunity Report

[150] Energy storage news. (2019a). New DoE framework puts energy storage at heart of Philippines' energy reforms. https://www.energy-storage.news/news/new-doe-framework-puts-energy-storage-at-heart-of-philippines-energy-reform; Energy storage news. (2019b). Meralco and Hitachi inaugurate 2MW / 2MWh BESS in Philippines. https://www.energy-storage.news/news/meralco-and-hitachi-unveil-2mw-2mwh-bess-in-philippines

[151] IEA. (2020) "World Energy Balances".

[152] Energy storage news. (2018). South Africa makes huge distributed energy storage commitment. https://www.energy-storage.news/news/south-africa-makes-huge-distributed-energy-storage-commitment

Climate impact

Mitigation potential and urgency

Energy storage indirectly helps to reduce emissions across low and middle-income countries by supporting the uptake of variable renewable energy, which can help to avoid around 50% of power sector CO_2 emissions (7.3 $GtCO_2$) in 2050 beyond business as usual.[153] As discussed in the Variable Renewables Opportunity Report, on-grid variable renewables are key to meet growing electricity demand whilst lowering power sector emissions. In a high renewables' scenario, 68% of electricity in low- and middle-income countries is provided by variable renewables. However, the integration of these variable renewables will place increased pressures on the grid to balance supply and demand, both in the short-term (due to minute by minute variations in energy supplied) and in the longer-term (to shift energy supplied to times of peak demand). Energy storage can provide both short and long-term services to maintain the quality of the grid connection.

Energy storage can help to reduce emissions through enabling renewables deployment, reducing dependence of polluting forms of back-up power, and increasing opportunities for demand-side flexibility. There are three main pathways through which storage can support emissions reductions:

Enabling renewables deployment. The largest pathway for storage to reduce emissions is through increasing the penetration of renewables into the electricity system. On-grid transmission or distribution-connected storage helps support increased consumption of on-grid renewables, for example, by managing variability in supply, reducing power curtailment and shifting energy supplied to times of peak demand. BTM storage meanwhile can increase self-consumption from distributed variable renewable energies, such as solar home systems154. In the Central African Republic, for example, the CAR Emergency Electricity Supply and Access Project is expected to catalyse the development of solar PV by incorporating a 25 MWh battery electricity storage system to a site suitable for large-scale PV development. The use of battery storage will enable consumers to harness energy produced with PV, cost-effectively tackling the local power supply deficit despite fluctuations in solar energy during the rainy season.155

Reducing emissions from back-up generators (BUGs). Storage can help to displace BUGs either by reducing the frequency and duration of grid outages, thereby reducing the reliance on them as a common form of back-up power by industry and households; or, by providing back-up power services to power consumers during in replacement of diesel generators. BUGs currently account for a sizeable share of emissions, approximately 100 megatonnes (Mt) CO2 across low and middle-income countries. Their contribution to power sector emissions is particularly high in Africa and South Asia. For instance, in Africa BUGs contribute to over 10% of power emissions. 156

Increasing level of demand flexibility to the grid. As discussed in the Demand-Side Management Opportunity Report, BTM storage can help enable an active demand-side in the power sector, allowing consumers to shift an increasing share of their demand to non-peak times and provide electricity back to the grid. See the Demand-Side Management Opportunity Report Box 11 for detail

[153] From IMAGE: 7.3 Gt CO2 corresponds to the renewables scenarios. The lower is negative (-0.09 Gt CO2), corresponding to the 1.5-degrees scenario estimate

[154] Behind-the-meter storage is connected at the consumer side of the utility meter for commercial, industrial or residential power customers (and is therefore grid-connected). Throughout the report, we differentiate between BTM and on-grid storage as two forms of grid-connected storage. The latter are connected to a distribution or transmission networks, or alongside a power generation asset, such as a wind turbine. While on-grid storage typically provides ancillary services (e.g. frequency response) and power system flexibility to the grid network operator, BTM storage typically increases self-consumption of distributed generation assets (solar home systems) and reduces electricity bills of customers. The exact split in services that each type of storage provides will depend on market environment, however, as BTM storage can also provide ancillary support services and power system flexibility. Source: IRENA. 2019. "Behind-the-Meter batteries innovation landscape brief"

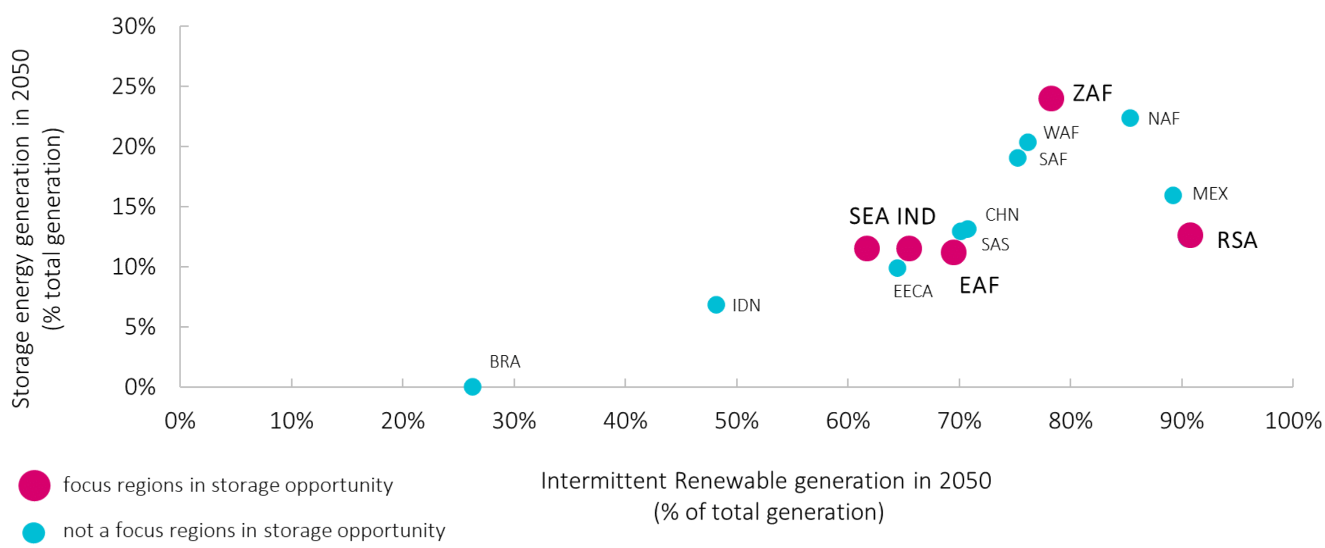
[155] World Bank. (2020). "Deploying Storage for Power Systems in Developing Countries". http://documents1.worldbank.org/curated/en/738961598380536870/pdf/ESP-Policy-Manual-Aug-2020.pdf

[156] IFC (2019). "The Dirty Footprint of the Broken Grid". https://www.ifc.org/wps/wcm/connect/2cd3d83d-4f00-4d42-9bdc-4afdc2f5dbc7/20190919-Full-Report-The-Dirty-Footprint-of-the-Broken-Grid.pdf?MOD=AJPERES&CVID=mR9UpXC

on the efficiency benefits of storage within a smart grid. This can reduce the need to run baseload fossil generation on the grid, and hence reduce emissions.

Storage is expected to scale up significantly in all low and middle-income regions. Variable renewables will be important to power sector decarbonisation in all low and middle-income regions (see Variable Renewables Opportunity Report). As a form of demand-side flexibility that has witnessed rapid cost declines in recent years, significant increases in storage capacity will likely be required within each region. Figure 11 demonstrates that higher levels of variable renewable generation are correlated with increased need for storage. Beside Brazil, which relies on pumped hydropower to integrate variable renewables, energy generated from storage in 2050 ranges from 7 to 24% of total electricity generation in a region.[157]

Figure 11 Higher shares of variable renewable generation are one driver of storage's climate impact



Source: Vivid Economics, ASI and Factor based on PBL's IMAGE model (renewables scenario).

Note: The abbreviations correspond to the following: MEX (Mexico), CAM (Central America), BRA (Brazil), RSA (Rest of South America), NAF (North Africa), WEF (West Africa), EAF (East Africa), ZAF (South Africa), EECA (Eastern Europe and Central Asia), IND (India), CHN (China), SEA (Southeast Asia), IDN (Indonesia), SAS (Rest of South Asia), SAF (Rest of South Africa).

The relative mitigation potential from storage will be highest in regions where emissions-intensity of the grid is high and grid capacity is low, such as South Africa. The relative mitigation potential from storage will be influenced by three principal factors:

Grid emissions intensity, which is an important driver of the mitigation potential of variable renewables. Grid emissions intensity, proxied by the share of coal-powered generation, is highest in South Africa, India and Southeast Asia. For instance, approximately 90% of electricity is coal-powered in South Africa, 75% in India and 25%, on average, across Southeast Asia.[158] These regions all witness renewable generation increase to above 60% of total electricity, supported by storage.

The capacity of the grid. Countries with less robust grid structures are both most in need of storage to allow for renewables integration and most reliant on polluting forms of back-up power today, which storage can displace. Amongst our focus regions, India and East Africa both have weaker grid

[157] From IMAGE. Figures correspond to a renewables decarbonisation scenario.
[158] IEA. (2019). World Energy Balances. Figures reflect 2017 data.

structures, reflected in the frequency of power outages in a typical month – 14 for India and 9 in Tanzania, relative to less than one for countries in Southeast Asia, South America and South Africa.[159]

Cost competitiveness of alternative forms of power flexibility and availability of unutilised fossil fuel generation. South America, for example, can achieve higher levels of renewable integration with similar levels of storage generation due to availability of non-variable renewable power – mainly hydropower.

Table 2 Capacity in 2050 required beyond the business as usual

Focus regions	2015 capacity (GW)	2050 capacity, BAU (GW)	2050 capacity, Ren (GW)
India	3.4	27	330
Rest of Southeast Asia	0.96	14	140
Rest of South America	0.62	3.9	160
South Africa	1.1	9.0	68
East Africa	0.17	5.5	38

Note: BAU reflects IMAGE's stated policies scenario; Ren reflects IMAGE's renewables scenario. All estimates reflect the capacity increase in the renewables decarbonisation scenario relative to the BAU scenario.
Source: Vivid Economics, ASI and Factor

Lithium-ion (Li-ion) batteries will be the key technology to 2030, in GW additions, but a range of technologies will be required to meet different energy storage needs. Excluding pumped hydro, lithium-ion batteries supply approximately 90% of stored energy to the grid today.[160] The dominance of lithium-ion batteries is expected to continue due to their cost-competitiveness to 2030, driven by their large-scale adoption in electric vehicles.[161] However, as with power generation, a variety of technologies will likely be required to provide the range of storage services needed in the future. For instance, super capacitors and flywheels will be best suited to grid support services (e.g. frequency response, voltage support) due to their rapid response and high power density. Compressed air energy storage (CAES), thermal storage and redox flow batteries, meanwhile, are better suited to support daily peak shifting due to competitiveness in larger energy applications. Notably, CAES has not been widely tried at grid-scale.[162] Thermal molten salt technologies could also be a cost-competitive means to provide seasonal storage, a role that hydrogen could fulfil in the future.[163]

Though emerging technologies such as zinc-air and sodium-ion batteries are promising in terms of their technical characteristics, cost declines will continue to be largest in battery chemistries supplying the electric vehicle (EV) market. Emerging storage technologies with lower inputs and end-of-life management costs could, in theory, undercut dominant lithium-ion technologies in the longer term. Recent pilots of zinc-air claim, for instance, to be able to provide energy for as low as USD 45/kWh.[164] The reliability and duration of low-cost zinc-air batteries in utility-scale applications is still to be tested, however. Moreover, despite the

[159] World Bank. (2020). Ease of Doing Business Indicators. Figures reflect the latest year of available data.
[160] EESI (2019). "Fact Sheet: Energy Storage (2019)". https://www.eesi.org/papers/view/energy-storage-2019
[161] Schmidt et al (2019). "Projecting the future levelised cost of electricity storage technologies"
[162] Vivid Economics, The Faraday Institution (2019). "Rapid market assessment of energy storage in weak and off-grid contexts of developing countries." https://www.vivideconomics.com/wp-content/uploads/2019/11/191025-Rapid-market-assessment-of-storage-in-developing-countries.pdf
[163] Grantham Institute (2018). "Electrical energy storage for mitigating climate change" https://granthaminstitute.atavist.com/electrical-energy-storage-technologies
[164] NYPA (2020). "*NYPA Announces New Energy Storage Demonstration Project Supporting Further Integration of Renewable Power Sources Into the Grid*". https://www.nypa.gov/news/press-releases/2020/20200117-zinc

advantages alternative battery chemistries provide, cost declines and performance improvements of storage are most likely to be driven by large-scale manufacturing, specifically the manufacturing of batteries for electric vehicles – which account for 70% of storage additions to 2030.[165]

Box 7 Modelling uncertainty

There is large uncertainty over the exact demand for storage, due to the inability of modelling to capture the value of both short-term or behind-the-meter flexibility. Measuring the value of smart or flexible technologies is a weakness of integrated assessment models (IAMs), such as IMAGE, as they do not have a fine time breakdown and do not explicitly model short-term flexibility. It is expected that they may therefore undervalue storage and DSM. IAMs similarly do not have a fine spatial breakdown of where flexibility is coming from, and do not model the relative value of demand-side management opportunities, resulting from behind-the-meter storage installed at the consumer end of the grid network or load shedding by power consumers. They therefore fail to capture crucial elements of the future potential market for flexibility as whole, and particularly the market for BTM storage, in low- and middle-income countries.

Uncertainty in the scale of variable renewable technologies forecast by IMAGE, particularly in the 1.5-degrees scenario, creates additional uncertainty over the role of storage. Expected deployment of variable renewables and storage in IMAGE's 1.5-degrees scenario are driven by assumptions on the relative technology costs of BECCS and renewables, and the availability of biomass for BECCS. These assumptions ought to be treated with caution (as discussed in the Variable Renewables Opportunity Report).

Transformational change

Energy storage offers substantial opportunities for transformational change, as set out in Table 14 .

Table 14 Assessment of transformational change

Transformational change criterion	Interventions to support change	Regional potential
	Sensitive intervention points	
Improvement of local capacities and capabilities	Support in the development of appropriate regulatory frameworks to enable utility-scale and behind-the meter (BTM) storage solutions.	High potential in India, Southeast Asia and South America
Local ownership and strong political will	Support in taking stock of integrated electricity generation and storage needs and developing strategy and clear steps to progress. Supporting renewable and storage solutions allows developing countries to be less exposed to oil price fluctuations, reducing dependency.	East Africa, Southeast Asia, South America. East Africa, South America
Leverage / creation of incentives for others to act	Support on regulatory incentives such as feed-in-tariffs for consumers to sell power back to the grid. Financial incentives for innovators to develop new energy solutions or business models.	All regions
	Spillovers	

[165] Vivid Economics, The Faraday Institution. (2019). "Rapid market assessment of energy storage in weak and off-grid contexts of developing countries."

Transformational change criterion	Interventions to support change	Regional potential
Broad scale and reach of impacts	Storage allows a faster electrification of regions, including rural areas and providing stability, reliability for industrial development Energy storage can bring about transformation change in all areas of life, providing benefits in health, education, transportation, agriculture and other sectors.	India, East Africa, South Africa
Sustainability (continuation beyond initial support)	Institutional capacity building and regulatory support for storage can enable long-term impact. Enable commercial models that can deploy BTM storage solutions at scale.	All regions
Replicability by other organisations or actors	Demonstration and pilot projects can help prove various approaches and technologies.	All regions
Innovation		
Catalyst for innovation	Initiatives such as supporting thermal storage links to CSP generation, such as in South Africa and South America.	India, South Africa, South America
Evidence of effectiveness is shared publicly	Leveraging UK communities of practice and influence in international groups and fora, relating to energy storage, to disseminate best practice and learning.	All regions

Source: Vivid Economics, ASI and Factor

Development impact

SDG impacts

In combination with renewable energy, energy storage would contribute to achieving SDGs in all regions but would have even greater development impact in East Africa, India and Southeast Asia.

Table 15 SDG impacts

SDG	Strength of impact	Most relevant region	Rationale
Positive Impacts			
SDG 3 – Good Health and well being	Moderate	Southeast Asia, India, East Africa (Particularly high usage of diesel generators in these regions due to less reliable or extensive grids.)	Energy storage can reduce use of diesel generators, and the associated diseases/deaths caused by air pollution. International Finance Corporation (IFC) research finds that users spend USD 30 billion to USD 50 billion annually on fuel for generators in 167 countries with significant negative health impacts. For example, in Sub-Saharan Africa, the nitrogen oxides (NOx) from back-up generators accounts for 15% of all NOx emitted in the region, and emissions of fine particles with a diameter of 2.5 micrometres or less ($PM_{2.5}$) are equal to 35% of emissions from all motor vehicles.[166]
SDG 7 – Affordable and clean energy	High	India, East Africa (where energy access is particularly lacking)	Energy storage would significantly contribute to more reliable and affordable electricity, particularly due to lower peak load generation requirements and costs and linkages between storage and feed-in tariffs at the household level.[167]
SDG 8 – Decent work and economic growth	Moderate	All regions	Potential to help increase formal employment in the renewable energy sector, particularly related to installation and maintenance. Initiatives to reuse and recycle batteries can help create employment opportunities, improve access to more reliable power and support a just transition. For example, the cost of repurposing lithium-ion batteries for second-life applications could go down to as little as USD 49 per kWh, compared to a cost of roughly USD 300 per kWh for new batteries at the moment, and USD 160 for lowest-cost battery chemistries such as the zinc hybrid cathode technology.[168]
SDG 9 – Industry, Innovation and Infrastructure	High	India, East Africa, South Africa (due to challenge of less reliable grids)	Storage can reduce exposure to power outages, by supporting the grid or providing back-up power during grid outages, which is crucial for industrial processes. For example, power cuts cost South Africa up to USD 8.3 billion in 2019.[169]

[166] International Finance Corporation. (2019). The Dirty Footprint of the Broken Grid. https://www.ifc.org/wps/wcm/connect/industry_ext_content/ifc_external_corporate_site/financial+institutions/resources/dirty-footprint-of-broken-grid
[167] IRENA (2019) Behind the Meter Batteries: Innovation Landscape Brief. https://www.irena.org/publications/2019/Sep/Behind-the-meter-batteries
[168] BNEF (2018) Used EV Batteries for Stationary Storage: Second-life Supply & Costs
[169] Reuters. (2020). Power cuts cost South Africa up to $8.3 bln in 2019, research shows. https://www.reuters.com/article/safrica-eskom/power-cuts-cost-south-africa-up-to-83-bln-in-2019-research-shows-idUSL8N29R1W7

SDG	Strength of impact	Most relevant region	Rationale
SDG 12 – Sustainable Consumption and Production	Moderate	India, South Africa, South America (due to more advanced economies and opportunities to integrate innovative storage solutions)	Opportunities to integrate the circular economy with a wide range of storage technologies, including thermal storage linkages to information and communications technology (ICT) cooling and chilled storage uses. As mentioned above, there is also potential for second-life EV batteries to be deployed as household storage units in the target regions.
Negative Impacts			
SDG 12 – Sustainable Consumption and Production	Low	All regions	Electrochemical storage impacts on the SDGs need to be carefully managed, to ensure they do not work against sustainable consumption and production.
SDG 15 – Life on Land	Medium	East Africa, South Africa, South America (where mining activity is higher in the target regions)	Negative environmental impact from mining rare earth metals if demand for lithium-ion batteries soars. For example, a recent report by the World Bank estimates that mineral demand will soar by 50% by 2050 due to renewable energy and storage expansion.[170]

Source: Vivid Economics, ASI and Factor

Demand in target regions

Table 16 Summary of policy support for energy storage in target regions

Region	Demand	Rationale
East Africa	Low – Moderate	Poor but improving regulatory environment as demonstrated by National Energy Plans and Policies (NEPs) and governments looking at ways to electrify rural areas
India	Moderate	Ambitious renewable energy targets and subsequently, greater demand for energy storage, which is manifesting itself with increasing numbers of storage tenders from utilities.[171]
South Africa	Moderate – High	Good policy and regulatory environment with ambitious targets as demonstrated by NDCs and other national level commitments. This is manifested in several utility-scale storage projects currently under construction.
South America	Low – Moderate	Variable commitment and targets across countries. For example, demand in Colombia is high, particularly at the utility-scale level, while Peru and Ecuador demonstrate little commitment to storage investment.
Southeast Asia	Low – Moderate	Variable commitments and targets across countries. For example, there is moderate policy commitment and progress in the Philippines, Thailand and Vietnam, whereas policy commitment in Myanmar is lower.

Source: Vivid Economics, ASI and Factor

[170] Prasad, Nithin. (2020). By 2050, Mineral Demand to Soar by 500% Pushed by Renewable Expansion: World Bank https://mercomindia.com/mineral-demand-soar-renewable-world-bank/

[171] Deign, Jason. (2019). India's Energy Storage Market Is Finally Starting to Grow. https://www.greentechmedia.com/articles/read/indias-energy-storage-market-finally-starts-to-grow

All regions: The IEA notes that more efforts are needed to promote and incentivise energy storage globally, as the rate of energy storage installation fell for the first time in 2019 (30% less than in 2018).[172]

East Africa: In East Africa, blackouts and power cuts are often considered a part of everyday life, as the current grid and supply cannot keep up with demand. Along with significant investment into the grid, energy storage, paired with low-carbon energy sources such as solar, particularly in a mini-grid or off-grid context, could transform the energy availability for East African countries, bringing both economic and social benefits with it. [173] East African countries are looking for solutions for electrification of rural areas, where grid-tied mini-grids with storage are potential solutions. Eight East African nations have introduced NEPs to meet growing energy demand with affordable, sustainable energy services that enable socio-economic development. Kenya has announced its plan to provide electricity to all its citizens by 2022 and energy storage has the potential to provide reliable and regular power to its residents. Rwanda set a target of having 100% electricity access by 2030.[174]

India: Storage interest in India is high, as indicated by the India Energy Storage Alliance (IESA) which since 2012 has been working to "focus on the advancement of advanced energy storage and e-mobility technologies in India" and includes members across manufacturing, research, renewable energy companies, EV companies and others.[175] India has pledged to promote renewable energy in their NDCs[176] and has very ambitious renewable energy targets, aiming for 450 GW by 2030, compared to a current total of 369 GW installed across all energy sources.[177] In 2018, India's investment in solar PV was greater than in all fossil fuel sources combined. However, to take full advantage of this investment, batteries and storage solutions are required. The IEA estimate that the energy storage needs in India are amongst the highest in the world.[178] India uses hydro-pumped storage and demonstrates some early example of thermal storage solutions, as well as electrochemical storage.

South Africa: On a national level, South Africa is strongly committed to utility-scale energy storage, with up to 1.44 gigawatt-hours (GWh) of battery storage planned in two phases, which were scheduled to start in mid-2019.[179] There are also a number of thermal storage plant coming online, often co-located with CSP generation (See case study in Section 0). South Africa's NDC proposes a significant increase in renewables-based generation from wind and solar as well as gas-based generation capacity by 2030 (an additional 15.8 GW for wind and 7.4 GW for solar. The country currently has several examples of molten salt thermal storage projects.

South America: South America currently holds the greatest regional share of thermal storage capacity in non-OECD global regions, often co-located with CSP plant.[180] Underground / borehole thermal storage was first tested in the region via a partnership between Argentina and Chile in 2003.[181] The region is expected to significantly expand its demand for energy storage solutions, in response to greater investment in renewables and increased need for flexible grids. Pumped hydro storage tied to wind energy generation is a particularly promising area. Colombia is a leader in this area, reflecting a more advanced stage in renewable energy generation.

[172] IEA. (2020). Energy Storage Tracking Report. Available at: https://www.iea.org/reports/energy-storage
[173] Business Week. (2020).Energy Storage Technology Will Make Blackouts In Africa Ancient History: https://www.busiweek.com/energy-storage-technology-will-make-blackouts-in-africa-ancient-history/
[174] SEforALL. (no date). Rwanda: At a glance. https://www.se4all-africa.org/seforall-in-africa/country-data/rwanda/
[175] India Energy Sotrage Alliance. Accessed July 2020. https://indiaesa.info/about
[176] Haque, A. *et al* (2019) NDC pledges of South Asia: are the stakeholders onboard? Climatic Change, Vol 155.
[177] India's Ministry of New and Renewable Energy. Accessed July 2020: http://mnre.gov.in
[178] IEA (2020) India is going to need more battery storage than any other country. Available at : https://www.iea.org/commentaries/india-is-going-to-need-more-battery-storage-than-any-other-country-for-its-ambitious-renewables-push
[179] IEA (2020) Energy Storage Tracking Report. Available at: https://www.iea.org/reports/energy-storage
[180] Envision Intelligence (2018) South America Thermal Energy Storage Market – Size, Outlook, Trends and Forecasts (2018 – 2024). Available at: https://www.envisioninteligence.com/industry-report/south-america-thermal-energy-storage-market/
[181] Busso et al. (2003). Underground Thermal Energy Storage – First Thermal Response Test in South America. Paper produced for RIO 3 - World Climate & Energy Event. http://www.rio12.com/rio3/proceedings/RIO3_189_A_Busso.pdf

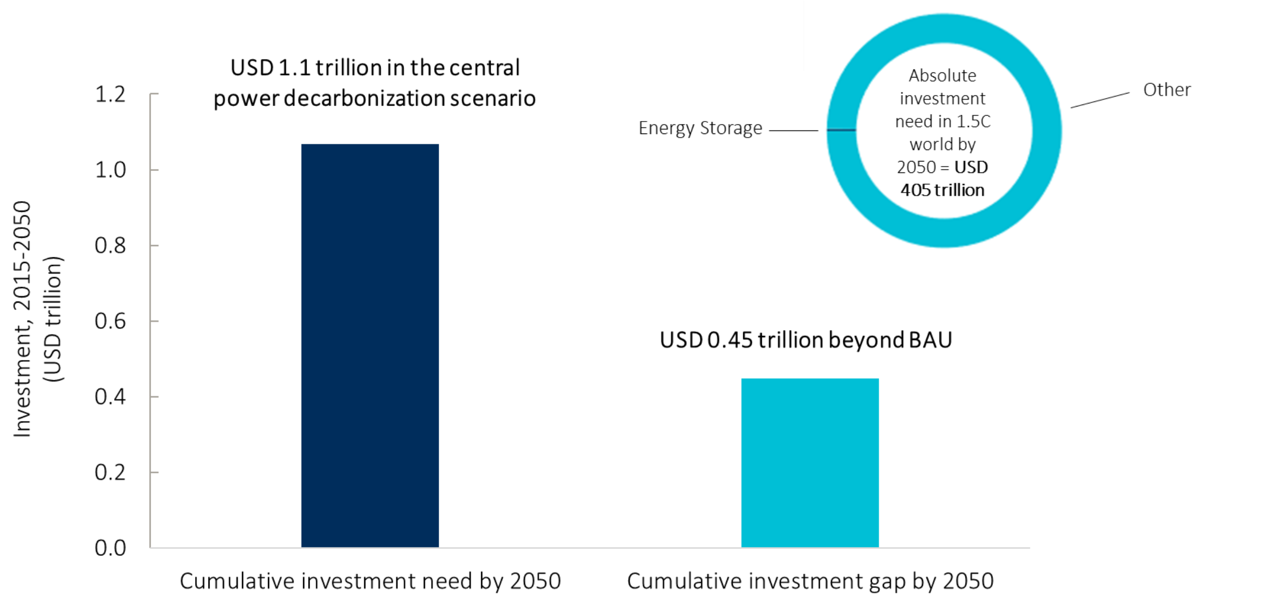
Southeast Asia: In Southeast Asia, Vietnam has focused on solar energy to fuel its growth and provide electricity to citizens, however, several of their efforts have come under criticism due to the lack of encouraging solar-plus-storage solutions, instead focusing on pure solar energy generation.[182] In 2019, the Philippines's Department of Energy issued a circular notifying the framework for energy storage systems (ESS) in the country to address the growing adoption of renewable energy systems. Under the circular, ESS technologies include battery energy storage systems (BESSs) that are capable of storing electric energy electrochemically from which they are able to charge or discharge electric energy. Thailand's latest Power Development Plan aims to source 35% of the energy mix from non-fossil sources by 2037 and there is potential for increased energy storage. In line with Thailand's ambition, The Asian Development Bank has approved a USD 7.2 million loan to fund a 10 MW wind energy and 1.88 MWh battery storage project in Thailand (See Section 0).

[182] Energy Storage News. (2019), Storage omission in Vietnam solar FiT draft a 'serious mistake'. 03/10/2019: https://www.energy-storage.news/news/storage-omission-in-vietnam-solar-fit-draft-a-serious-mistake

Investment need

Across low and middle-income countries investment will need to scale up to approximately USD 1.1 trillion to 2050, over 90% which is additional to the BAU scenario. Overall, the scale of investment required in the opportunity is relatively low compared to other energy opportunities- approximately 10 trillion investment required in solar, for example. Less than 60% of investment needed in storage is expected to occur in the BAU scenario, however. The exact scale of investment beyond BAU will depend on assumptions around cost declines in storage and the associated level of storage uptake in the BAU. Against our BAU assumptions, approximately 3,000 GW of additional capacity will be required by 2050.[183] There is therefore a sizeable investment gap, USD 13 billion per year to 2050. It is worth treating these numbers with caution, given that modelling of storage will systematically underestimate power flexibility needs (see Box 7).

Figure 12 Investment need in energy storage is low compared to other opportunities



Source: Vivid Economics based on PBL's IMAGE modelling

Investment need is highly uncertain because each region is likely to have a different technology mix and each technology's costs will depend on how and where it is used. In theory, cost-competitiveness will influence the choice of technology. However, cost-competitiveness will vary between each site and region, leading to differences in the optimal technology mix. For instance, the cost of electricity provided by storage will depend on how it is used (multiple times per day or once every two weeks, for instance) and location-specific factors (such as temperature and presence of supporting infrastructure e.g. underground taverns can reduce costs of compressed air energy storage). Table 17 shows the wide range of costs within each technology. For thermal and CAES, only the most competitive costs are shown, as in non-ideal conditions these technologies would not even be deployed.[184,185] It is therefore difficult to predict which technologies will be deployed and how costly they will be. For instance, a recent study comparing CSP thermal storage and lithium-ion battery storage found that despite higher initial costs associated with CSP, investing in CSP rapidly decreases the total system cost by 33% in 2035 as compared to a scenario without storage and would be more competitive in the local context than battery storage.[186] Solutions must be tailored to the local context. Notably, costs in Table 17 are based on historic examples (mostly in high-income countries). Lower

[183] Under a "Renewable" scenario
[184] CAES is cheapest when situated next to an underground cavern for storing the compressed air. In all other locations, its costs increase
[185] IRENA (2017). "Electricity Storage and Renewables: Costs and Markets to 2030". https://www.irena.org/-/media/Files/IRENA/Agency/Publication/2017/Oct/IRENA_Electricity_Storage_Costs_2017.pdf
[186] ESMAP (2020) "Deploying storage for power systems in developing countries" http://documents1.worldbank.org/curated/en/738961598380536870/pdf/ESP-Policy-Manual-Aug-2020.pdf

labour costs in focus regions could drive lower installation costs and systems costs. In the case of lithium-ion batteries, labour accounts for approximately 15% of project costs and could drive significant differences between regions. Regional differences in labour cost are less likely to affect CAES, on the other hand, as construction costs account for only 3% of the total.[187]

Large expected declines in the costs of technologies also creates uncertainty in terms of future investment need. Across nearly all storage technologies, lab innovation and learning from doing is expected to lead to large cost declines (see Table 17). The demand for storage and associated investment need will depend on the speed and extent of these cost reductions.

Table 17 Each technology exhibits a wide range of costs, both today and in 2030

Technology	Levelised Cost of Electricity (LCOE) (USD/kWh)	Forecast LCOE in 2030 (USD/kWh)
Lithium-ion	200 –1260	77 – 574
Redox Flow	315 – 1,680	108 – 576
Lead acid battery	105 – 475	50 – 240
CAES	53	44
Flywheels	1,500 – 6,000	143
Supercapacitors/ Superconducting magnetic energy storage (SMEs)	10,000	160
Thermal storage	17 – 77	<15

Note: Cost estimates reflect global variation in costs and are not specific to low and middle-income countries. Cost estimates for thermal storage refer to thermal storage used for AA-CAES systems, including sensible high-temperature heat storage in liquids, sensible high-temperature heat storage in solids, high-temperature storage (not specified), molten salt storage and thermocline with quartzite.

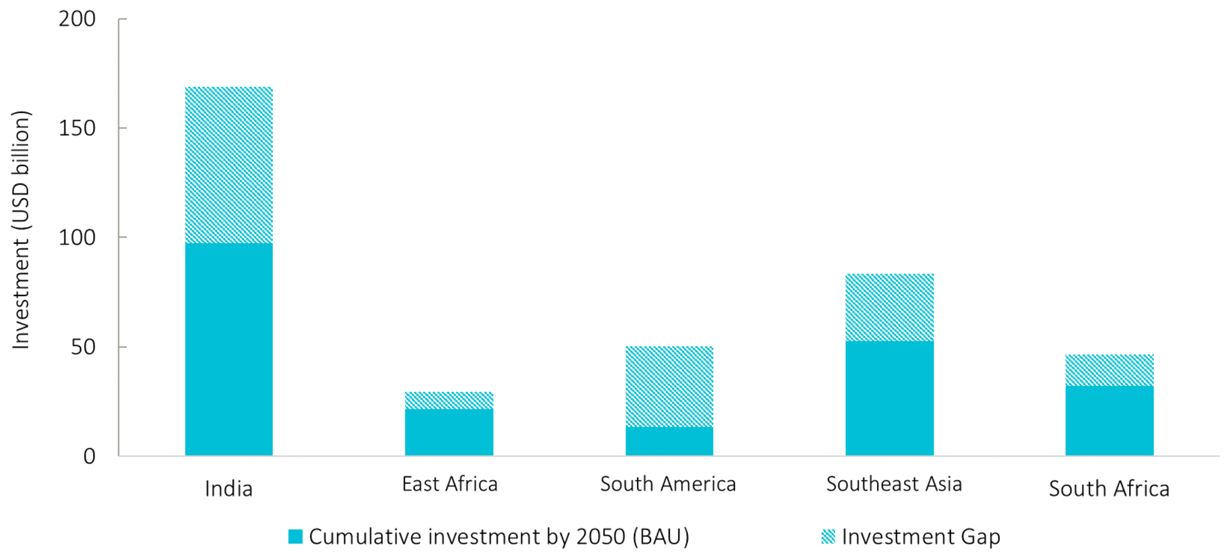
Source: IRENA (2017). “Electricity Storage and Renewables: Costs and Markets to 2030”. https://www.irena.org/-/media/Files/IRENA/Agency/Publication/2017/Oct/IRENA_Electricity_Storage_Costs_2017.pdf
Deloitte (2014). “Energy storage: Tracking the technologies thatat will transform the power sector”. https://www2.deloitte.com/content/dam/Deloitte/us/Documents/energy-resources/us-er-energy-storage-tracking-technologies-transform-power-sector.pdf.at will transform the power sector”. https://www2.deloitte.com/content/dam/Deloitte/us/Documents/energy-resources/us-er-energy-storage-tracking-technologies-transform-power-sector.pdf.
IRENA (2017). “Electricity Storage and Renewables: Costs and Markets to 2030”. https://www.irena.org/-/media/Files/IRENA/Agency/Publication/2017/Oct/IRENA_Electricity_Storage_Costs_2017.pdf
Deloitte (2014). “Energy storage: Tracking the technologies thatat will transform the power sector”. https://www2.deloitte.com/content/dam/Deloitte/us/Documents/energy-resources/us-er-energy-storage-tracking-technologies-transform-power-sector.pdf.
IRENA (2017). “Electricity Storage and Renewables: Costs and Markets to 2030”. https://www.irena.org/-/media/Files/IRENA/Agency/Publication/2017/Oct/IRENA_Electricity_Storage_Costs_2017.pdf
Deloitte (2014). “Energy storage: Tracking the technologies that

However, it is certain there will be significant variation in investment need between regions, due to differences in the size of the power sector and scale of capacity additions required. As shown in Figure 13, the size of the cumulative investment gap across our focus regions could vary between USD 7.8 billion in East

[187] BEIS, Vivid Economics. (2019). “Energy Innovation Needs Assessment. Sub-theme report: Smart systems”. https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/845664/energy-innovation-needs-assessment-smart-systems.pdf

Africa to USD 71 billion in India when considering only the differences in storage capacity required. Overall, total investment required could vary from USD 29 billion in East Africa to USD 170 billion in India. As investment estimates are calculated based on forecast GW capacity additions in each region, they do not reflect the location-specific technology costs that will also influence the exact investment required.

Figure 13 Forecast investment need across regions will vary due to differences in capacity, reflected here, as well as other contextual factors



Note: The figure intends to show the scale of differences in investment need rather than provide an exact forecast of investment required in each region. Investment need is calculated by multiplying average cost of storage per kW and forecast kW capacity additions. We assume an average cost of USD 150/kW. Forecast capacity additions are based on IMAGE's 2 degrees renewables scenario, which reflects our central power decarbonisation scenario (see Variable Renewables Opportunity Report for further information).

Source: Vivid Economics based on PBL's IMAGE modelling

Cost-effectiveness

Energy storage is an increasingly cost-effective mitigation opportunity, particularly when coupled with 'smart grid' demand-side response opportunities. The cost-effectiveness of storage (on a GBP/tCO2 basis) is typically lower than alternatives which provide similar levels of system flexibility, such as non-variable low-carbon energy and centralised forms of demand-side response, such as bilateral contracts with industrial power consumers to reduce demand at peak times. Relative cost-effectiveness is expected to increase, however, because of declining costs of storage technologies (the key driver in creating cost-effective applications of storage today).[188] For instance, the costs of lithium-ion batteries on a USD/kW basis are expected to fall by as much as 60% to 2030 (from 2017), due to efficiency improvements in the production of lithium-ion EV batteries and innovations in battery chemistry.[189] Large cost reductions are also forecast in non-electrochemical storage, with installed costs of flywheels expected to fall by 35% and costs of CAES expected to fall by 17% by 2030.[190] Cost-effectiveness is also expected to increase as countries develop business models and regulatory frameworks that maximise the services that storages provide, allowing it to 'stack' revenue streams and reduce it's per unit cost. The creation of a capacity market for storage, for instance, can increase the cost-effectiveness of BTM storage by increasing its opportunities to support emissions reductions and demand-side management – both by enabling greater distributed renewable generation and by providing flexibility for grid-level renewable integration.

Cost-effectiveness will vary significantly across regions due to:

- System flexibility options. The relative cost-effectiveness of storage will depend on the alternative forms of system flexibility. Where non-variable low-carbon power or demand-side management (e.g. capacity market design) can be exploited it will typically be far more cost-effective than storage, as it requires minimal capital investments. For instance, studies of West Africa's power supply found a large cost-effective opportunity to balance the energy mix by creating interconnections between existing solar and wind power capacity in the north of West Africa and hydropower capacity in the south (spatial synergies effectively displaced the need for energy storage). In contrast, low spinning reserve and inadequate frequency regulation capacity in Senegal makes energy storage critical to the cost-effective integration of renewables on the grid;[191]

- Grid capacity. The ability of storage to cost-effectively integrate renewables into the grid will depend on the capacity of the grid to shift stored energy to where it is needed. Grids with more robust structures in place will be able to use storage more effectively to balance supply and demand.

- Regulatory environment. The electricity market design will determine the extent to which storage technologies can be utilised. The potential for storage to provide a variety of services to the grid can significantly increase the cost-effectiveness of investments. For instance, across US regions the value of storage is shown to be greatest where there are opportunities for value-stacking.[192] In India, in contrast, an inconsistent regulatory framework prevents distribution utilities from investing in certain applications of energy storage, limiting potential returns from the utility's investment.[193]

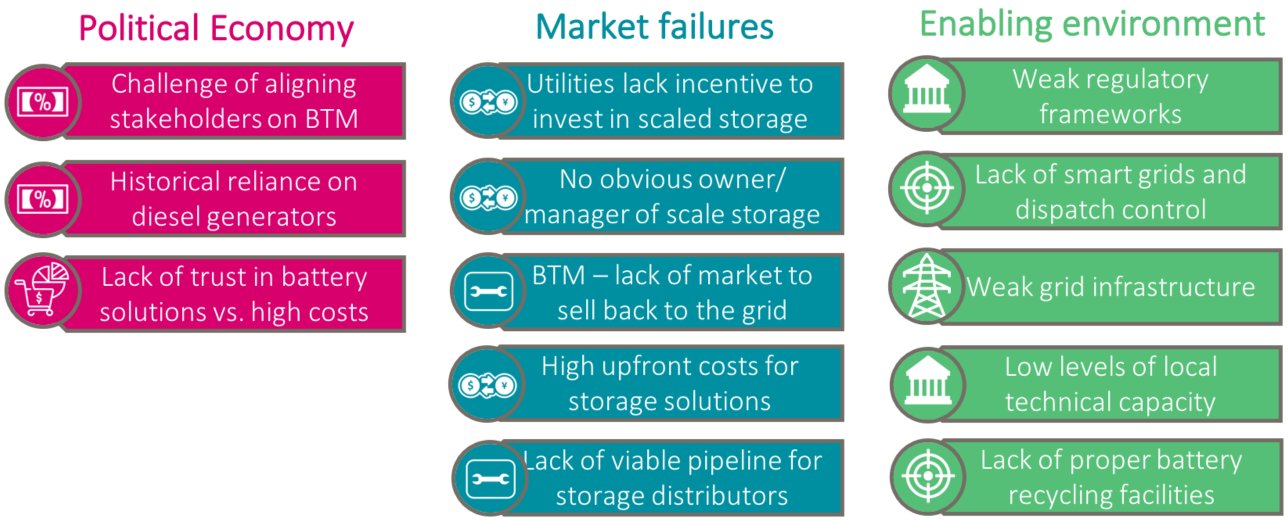
---

[188] Arbabzadeh et al. (2019) "The role of energy storage in deep decarbonisation of electricity production" https://www.nature.com/articles/s41467-019-11161-5
[189] IRENA, 2017 *"Electricity storage and renewables: costs and markets to 2030"*. https://www.irena.org/-/media/Files/IRENA/Agency/Publication/2017/Oct/IRENA_Electricity_Storage_Costs_2017.pdf
[190] Ibid.
[191] ESMAP (2020) "Deploying storage for power systems in developing countries" http://documents1.worldbank.org/curated/en/738961598380536870/pdf/ESP-Policy-Manual-Aug-2020.pdf
[192] NREL. (2016) "Capturing the impact of storage and other flexible technologies on electric system planning" https://www.nature.com/articles/s41467-019-11161-5
[193] ESMAP (2020) "Deploying storage for power systems in developing countries" http://documents1.worldbank.org/curated/en/738961598380536870/pdf/ESP-Policy-Manual-Aug-2020.pdf

Barriers to adoption

The largest barriers to energy storage are those related to ii) market failures and iii) enabling environment (Figure 14). These barriers are not critical to inhibiting investment, as the potential of energy storage is widely recognized and investment levels growing in all regions. However, if not addressed they are likely to slow down the potential growth of this opportunity. Our typology of barriers is provided in the Methodology chapter in the Synthesis Report.

Figure 14 Barriers to an opportunity



Source: Vivid Economics, ASI and Factor

Moderate <u>political economy</u> barriers to investment or adoption are expected.

To coordinate investment across transmission connected, distribution connected and BTM storage, there is a need for stakeholders to align on a range of issues and policies. For example, utilities may be against storage if there is no financial incentive to run more efficient and reliable grids.

Historical dependency on, and trust in, generators is likely to slow down the uptake of battery storage solutions. This is a problem in East African countries where widespread blackouts and power outages are the norm.

A lack of trust in new battery companies can be a significant barrier to uptake at a wider scale. For example, several battery companies have recently gone out of business in East Africa, which made their warranties worthless. This explains why even considering long delays in delivery, well known brands such as Tesla were in high demand.

Moderate <u>market failure</u> barriers to investment or adoption are likely to be:

As the use of renewables is still low across the target regions, there are currently very few on-grid situations where storage can make a difference in terms of capturing generated electricity beyond the capacity of the grid.[194] Exceptions include regional grids that have a high and rapidly growing proportion of renewables, such as in Chile.[195] Therefore, utilities are unlikely to invest in large-scale storage in a short to medium time horizon, until renewables make up a greater proportion of their grids. The case for storage in developing countries is currently more compelling for off-grid systems

[194] Insight from expert interview. (2020).
[195] Source: https://www.globaldata.com/renewable-energy-is-expected-to-comprise-50-of-chiles-power-mix-by-2030/

or mini-grids, which could have a particularly transformational impact in East Africa, India and South America.

For utility-scale grid storage a critical barrier in that there is often no obvious manager of the storage who would benefit financially.[196] Neither system operator nor power generator are able to recoup investment costs for storage if there is no time and use pricing and there is no incentive to add storage to the grid if they can always sell power during the day. In more advanced markets such as the USA, third party operators often take responsibility for installing, owning and operating utility-scale storage, relying on well-developed business cases. In countries like South Africa, the new 1.4 GWh battery energy storage system that is currently under construction, with World Bank and African Development Bank financing, will be owned by Eskom, the national utility, with a third party responsible for its design, construction, operation and maintenance for its first five years.[197]

The energy storage sector currently experiences fragile growth, as it continues to depend heavily on policy intervention through direct support or market creation. The impact of COVID-19 is also expected to damage market prospects during 2020.

For BTM storage, the lack of a market whereby customers can sell back to the grid is a critical barrier. The electricity tariff structure is also weak with unclear grid costs for customers, which makes it difficult to define the profitability created by using storage. BTM is more likely to be feasible in middle-income countries such as Argentina, Thailand, Malaysia and South Africa, rather than low income countries where the regulatory and cost barriers are rather high.

High unit costs for both large-scale utility storage and BTM storage units is a barrier for uptake, particularly in rural areas where storage and off-grid solutions could have a significant development impact. It is likely that the majority of households in developing countries would find it difficult to afford, although this can potentially be overcome by incentive schemes, payment by instalments or low interest loans. High prices are partly due to competition with high-income countries including the UK for energy storage solutions, in the early stages of market development.[198]

Unaccounted for carbon emissions from battery storage. In the case of wind power, energy storage could potentially be double the emissions of wind power without storage.199 These emissions will need to be considered in the wider context of low-carbon and net-zero plans. Because of its effect on coal and natural gas–fired generation, introducing a carbon dioxide emissions price may increase the likelihood that lower storage costs will reduce emissions.[200]

Relatively high costs of emerging technologies such as thermal energy storage and mechanical storage, such as flywheels, are a barrier to investment. However, these will continue to drop as techniques and equipment becomes used at a greater scale. Typically, feasible examples such as utility-scale thermal storage integrated with CSP in South Africa have been subsidised by international donors such as the German Agency for International Cooperation (GIZ), IFC, or the African Development Bank.

The lack of private finance deployed due to uncertainty of investment security is a moderate barrier, although purely commercial investment is still not widespread and storage solutions often rely on public or blended financing. This is the case in all regions with greater risks in East Africa and lower-income Southeast Asian and South American countries.

[196] IEA. (2020). Energy Storage : Tracking report – June 2020. https://www.iea.org/reports/energy-storage
[197] Energy Storage News. (2020). South Africa's Eskom opens tender for 80MW / 320MWh battery storage. https://www.energy-storage.news/news/south-africas-eskom-opens-tender-for-80mw-320mwh-battery-storage
[198] Insight from expert interview. (2020).
[199] Forbes. (2020). Estimating the Carbon Footprint of Utility-Scale Battery Storage. https://www.forbes.com/sites/rrapier/2020/02/16/estimating-the-carbon-footprint-of-utility-scale-battery-storage/#3af8b89f7adb
[200] Linn & Shih (2018). Does Electricity Storage Innovation Reduce Greenhouse Gas Emissions? Resources for the Future Discussion Paper.

Moderate enabling environment / absorptive capacity barriers to investment or adoption are likely to be:

The need for stable policy environments. This includes the importance of standards and grid connectivity regulations for grid-connected energy storage. For example, the IEA reported that energy storage efforts slowed in 2019 partly due to delay or changes in regulation and rules around use and deployment of both utility-scale and BTM storage.[201] For example, following a change of regulations in China in 2019, grid companies are no longer permitted to include storage costs in their transmission and distribution fees, which led to a freeze on new projects to installations in 2019 shrinking by one-third.[202]

Lack of grids in which to integrate utility-scale storage or BTM storage technology, particularly in rural areas is a barrier. This can be overcome by developing new mechanisms, potentially through mini-/micro-grids or off-grid systems. For example, in East Africa, this is a large constraint, but solutions are being driven forward by innovative entrepreneurs. Kenya is considered to be an 'innovation lab for microgrids', often tied to microgrid scale storage, and accounts for 40% of all microgrids in East Africa.[203] Much of this investment is being driven by the private sector with a remarkably dynamic range of business models being tested in the country. These include selling access to microgrid energy along with other desirable items such as a fridge for cold storage or a TV, to encourage greater uptake. An example of an innovative microgrid is the community of Entesopia in Kenya, powered by an 8.5 kW modular solar microgrid, owned by Vulcan Philanthropy and managed by SteamaCo. Demand-side management measures are also actively being discussed and trialled by some minigrid operators, including alerting users by short message services (SMS) when the battery storage is at capacity and energy can be offloaded at a cheaper rate.[204]

Lack of capacity in grids that are in place. Overcoming this barrier requires large storage facilities in urban centres where population density is high, and land is at a premium. This is likely to be a challenge in India and Southeast Asia, where population density is particularly high, and sprawling cities leave very little land available for large-scale storage facilities.

Many countries in the target regions don't have dispatch control integrated into grids, which makes it hard to create a space for utility-scale storage. This is the case in much of East Africa.

The need for battery companies to have a viable BTM storage pipeline to focus on a market is a significant barrier. Without a viable pipeline, through a mix of commercial and industrial (C&I), mini-grid, or tourism (for example at safari park lodges), companies are unlikely open an office and distribute storage units. Battery storage markets are improving in India and parts of Southeast Asia, but this remains a challenge throughout most low-income countries in the target regions.

The innovation and costs needed to implement specific solutions to avoid overheating is a barrier as batteries can be damaged in especially hot regions, such as parts of India and East Africa.

Thermal storage solutions that could be integrated into buildings are constrained by a lack of both stakeholder awareness and lack of a joined-up approach between building design, building codes and energy storage. This is particularly severe in East Africa and South Africa. However, there are increasing examples of thermal energy storage integrated into buildings in South America and India, with linkages to the information technology (IT) sector, where cooling of ICT equipment is a cost-effective side effect. For example, in 2015, thermal energy storage equipment was already storing over 12MW of cooling in Indian cities like Nagar, Bangalore, New Delhi and Chennai. Adoption in in

[201] IEA (2020) Energy Storage Tracking Report. Available at: https://www.iea.org/reports/energy-storage
[202] Ibid.
[203] TFE Consulting (2017) Kenya: The World's Microgrid Lab. https://sun-connect-news.org/fileadmin/DATEIEN/Dateien/New/TFE_Report-Microgrids-Kenya.pdf
[204] Vulcan Impact Investing (2016) Powering Productivity: Early Insights into Mini Grid Operations in Kenya. https://sun-connect-news.org/fileadmin/DATEIEN/Dateien/New/Kenya-Mini-Grids-White-Paper-VI2.pdf

the country's commercial sector has been steadily occurring for over a decade, particularly in the IT sector.[205]

The assessment of Li-ion batteries for local applications is often carried out without consideration for how other storage technologies at lower technology readiness levels (TRLs), including other battery types, may perform or integrate with wider economic development considerations, often due to lack of awareness in the target regions.[206] For example, utility-scale thermal storage solutions may be more appropriate in contexts with high-level sunlight patterns, where batteries may not be the most cost-effective or best option from end-user perspective to deploy.[207] Lower TRL batteries, including sodium sulphur, lead-acid and redox-flow battery types, could also offer opportunities for companies in target regions to manufacture and export solutions, such as industry interest in South Africa around Vanadium-based redox flow batteries.[208] This could be increasingly viable if appropriate minerals are extracted in those countries or the region, whereby logistics costs would be reduced and local job creation could result from the supply chains and manufacture of storage solutions.[209]

Potential limited availability of technicians for the installation and maintenance of household or commercial use of battery storage, especially for rural household use. Maintenance and upkeep are needed to ensure storage interventions are sustainable throughout their life cycle. This is a particular barrier for "smart" batteries (including digital /high tech. intelligence systems).

Although not a barrier to initial uptake, a barrier to more sustainable use of battery storage is a lack of adequate reuse or recycling facilities / logistics. This will be particularly difficult in East African countries.

[205] CALMAC. (2015). Thermal energy storage sees ongoing development in India. http://www.calmac.com/energy-storage-article-thermal-energy-storage-sees-ongoing-development-in-india-1
[206] Insight from expert interview. (2020).
[207] Insight from expert interview. (2020).
[208] ESI Africa. (2019a). The vanadium redox flow battery, a leading technology in energy storage. https://www.esi-africa.com/industry-sectors/generation/the-vanadium-redox-flow-battery-a-leading-technology-in-energy-storage/
[209] ESI Africa. (2019b). Webinar recording: Battery Storage: Africa's energy metals market and supply chain. https://www.esi-africa.com/regional-news/africa/battery-storage-africas-energy-metals-market-and-supply-chain/

UK additionality

The UK's additionality is strong within innovation and proof of concept of energy storage solutions. By leveraging this expertise and experience, together with efforts by other organisations and through collaborations, UK support could realise true acceleration in this space.

The UK has strong academic and private sector-driven research expertise in energy storage, as well as knowledge sharing network sand forums such as The Energy Storage Research Network (ESRN), the Energy SUPERSTORE and the Science and Technology Facilities Council (STFC) Network in Battery Science and Technology, all funded by the Engineering and Physical Sciences Research Council (EPSRC). The UK Energy Storage Research Conference has been running since 2015.

UK private sector expertise is strong in the integration of energy storage and grids, including smart grid design and operations. See for example the UK's 2017 Smart Systems and Flexibility Plan.[210]

Through its BEIS Energy Innovation Portfolio, BEIS has invested GBP 70 million in the smart energy systems innovation theme.[211] This experience can be drawn upon for interventions in the target regions.

Under the Green Growth Strategy (2017), GBP 265m is allocated to "innovations in smart systems (including energy storage)", accounting for almost 10% of the full budget.[212]

Experience in private sector-led 'energy-as-a-service' models that could help in the introduction of energy storage in the target regions.

The UK is active and influential in the international landscape, for example due to involvement in IEA Technology Collaboration Programmes (TCPs), including the Energy Storage TCP and the former demand-side management TCP. UK government donors and the UK private sector have extensive experience in assisting developing country governments in energy distribution and transmission (e.g. GridWorks, backed by CDC),[213] as well as some energy storage initiatives, including the development of standards.

There is significant export potential for UK business to implement energy storage solutions internationally, including the regions of interest.

Donor activity relating to energy storage is currently driven by the World Bank, Germany and the US.

The *World Bank's Battery Storage Initiative* was set up in 2018, as well as the *Energy Storage Partnership*, both of which the UK has joined (the UK provided GBP 200m last year to the Battery Storage Initiative and joined as a member of the Energy Storage Partnership). The Battery Storage Initiative aims to finance 17.5 GWh of battery storage by 2025 – more than triple the 4-5 GWh currently installed in all developing countries – via direct assistance and concessional climate financing and public and private investments.

The World Bank has been investing in energy storage over the past few years, via the wider *Energy Sector Management Assistance Programme* (ESMAP), for which the involved partners have contributed USD 26.8billion and leveraged another USD 15.8billion in private finance across all the energy interventions covered by the programme.

---

[210] HMG and Ofgem (2017) Upgrading our Energy System: Smart Systems and Flexibility Plan. https://www.gov.uk/government/publications/upgrading-our-energy-system-smart-systems-and-flexibility-plan

[211] HMG (2017) Funding for innovative smart energy systems. https://www.gov.uk/guidance/funding-for-innovative-smart-energy-systems

[212] HMG (2017) The Clean Growth Strategy: Leading the way to a low carbon future. https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/700496/clean-growth-strategy-correction-april-2018.pdf

[213] https://www.gridworkspartners.com

The US Trade and Development Agency (USTDA) has invested in a number of storage projects in Africa and also supported an energy storage standards workshop in Southern Africa. The United States Agency for International Development (USAID) has also partnered with the National Renewable Energy Laboratory (NREL) on 'Greening the Grid' which includes work on storage.

Storage is part of the Sustainable Energy for All (SEE4ALL) UN Initiative's Alliance for rural electrification.

GIZ provides significant support in the target regions on energy storage. For example in Chile it is supporting the government to integrate molten salt thermal storage with CSP generation.[214]

Within Europe, there is the European Clean Energy package from the European Commission and several pilot projects in Germany, France, the Netherlands and the UK. These countries in particular are in a stronger position to contribute to donor activity in energy storage.[215]

Efforts in energy storage are more recent in adoption and focus and have seen national governments and the private sector complementing donor funding and projects.

In regions with the largest mitigation potential, the UK typically has strong ODA ties related to technical assistance programming, with an initial focus on innovation programming.

There is a real opportunity for the UK to enable the uptake of energy storage in countries in the target regions, where there are strong ODA relationships, involving both the national government and private sector to maximise impact.

Beyond the GBP 200 million contribution in 2019 to the World Bank's Battery Storage Initiative the UK Department for International Development (DFID, now part of the Foreign, Commonwealth & Development Office (FCDO)) and BEIS recently allocated an initial GBP 20 million to create the *Faraday ODA Energy Storage Challenge*, building on the foundation created by the Industrial Strategy Challenge Fund (ISCF) Faraday Battery Challenge.

Most UK ODA programmes of support focus on smaller scale interventions and leveraging private finance into the sector. In recent years, DFID and other government departments have increased their focus on innovation programming, and exploring ways to ensure maximum value for money, through global programmes such as *Frontier Technologies Livestreaming*, the *Global Innovation Fund* and *Ideas to Impact* which tests innovation prizes as a development tool, among others.

Energy storage experimentation is benefiting from UK ODA through the *Frontier Technology Livestreaming programme* which is currently testing a system to provide sustainable energy to health clinics in Zimbabwe, facilitated through solar power and solar energy storage, which is showing great initial results and promise for scale across the country.[216] Through connecting the solar energy systems, a tenfold increase in out-of-hours procedures has been enabled, which brings significant health improvements to those who live in rural Zimbabwe.[217]

Under DFID's Ideas to Impact programme, The *Global LEAP Off-Grid Cold Chain Challenge* (OGCCC) "aimed to identify and reward the most appropriate technologies for off-grid cold storage, and by promoting the technologies and their associated business models, stimulate appropriate support from donors, investors and government."[218] As part of the competition, funding was provided to 10

---

[214] GIZ (2019) Ready for Change: Chile is on course for a future with renewables. Available at: https://www.giz.de/en/workingwithgiz/81233.html
[215] IEA (2020) Energy Storage Tracking Report. Available at: https://www.iea.org/reports/energy-storage
[216] Rahman, A. (2018) Blog: Notes from the field: Zimbabwe. Available at: https://medium.com/frontier-technology-livestreaming/notes-from-the-field-zimbabwe-a8a557ef65b1
[217] Rahman, A. (2019) Play #8: For Learning, More is More. Available at: https://medium.com/frontier-technology-livestreaming/play-8-for-learning-more-is-more-578d42af5a82
[218] Brown, C. (2020) Review Report: 2018-19 Global Leap Off-Grid Cold Chain Challenge. Itad. Available at: http://www.ideastoimpact.net/sites/default/files/doc_research/Global%20LEAP%20OGCCC%20Review%20Report_0.pdf

organisations working on new forms of cold storage in Sub-Saharan Africa. Of the ten, seven explicitly mention the use of batteries, either thermal or electrical batteries.[219]

In relation to off-grid solar linked to storage, DFID has funded some e-waste work that could be relevant and considered for expanding, with a focus on how to encourage battery reuse and recycling.[220]

[219] Ideas to Impact website. Accessed July 2020: http://www.ideastoimpact.net/content/spotlight-10-finalists-uk-aid-funded-grid-cold-chain-challenge
[220] DFID. (2016). Electronic waste (e-waste) impacts and mitigation options in the off-grid renewable energy sector. https://www.gov.uk/dfid-research-outputs/electronic-waste-e-waste-impacts-and-mitigation-options-in-the-off-grid-renewable-energy-sector

Intervention opportunities

To alleviate the barriers set out in Section 0, there is substantial opportunity across all regions for the UK to draw on core strengths and areas of additionality, to deliver energy storage interventions in the following areas.

Assist governments to take stock of needs and opportunities and plan and implement energy storage in a coherent approach, with linkages to a range of development objectives.

Help governments take stock of energy generation and storage needs in a holistic way, with close linkages to renewable energy generation, as well as identifying ties between aspects such as thermal storage and other sectors such as chilled goods storage. Develop subsequent storage sector strategies with clear implementation steps and investment needs, drawing on resources such as *IRENA's Electricity Storage Valuation Framework*.[221] This helps assess where each country or region is in terms of the proportion of variable renewable energy (VRE) in power supply and relating the need for storage to that. For instance, at low levels not much need except to test out technologies, then as levels rise the need to have an integrated integration plan and to put in place market mechanisms to incentivise investment. Priority measures will be context-specific in each case but could include:

Grid planning for anticipated levels of deployment and testing of storage solutions on the grid and to help over-come over conservative reactions from grid operators.

Putting in place an independent grid authority, help with appropriate grid management regulations, and development of polices to incentivise investment in storage and other flexibility mechanisms

Support governments to expand the role of storage in ancillary service and flexibility markets, which are markets used to compensate flexible generating resources for services used to balance generation and load on the power grid in real time.

Consider how flexible sector coupling can be integrated to energy storage strategy and investments as this can drastically change the development and investment opportunities. For example, the role of excess hydrogen from gas, integrated grids with integrated heat and cooling, or thermal storage combined with cold storage facilities for produce. This is most relevant in more advanced economies such as India and South Africa and in specific countries such as Thailand, Malaysia, or Argentina.

Help governments to focus on smart green grids as one of the most effective ways of maximising the value of current energy generation and integrating storage, considering the following interventions:

Provide technical assistance to help governments understand, in an integrated way, how they need to develop their grids to move to lower-carbon forms of generation, and how storage can help in this.

Support government to improve technical capacity in grid planning to tie together demand-side management, dispatch control, and storage all together.

Focus support for smart green grids on countries that use a high proportion of coal, such as in Southeast Asia. Reducing losses in the grid is also seen as very attractive to a wide range of stakeholders, including those who perhaps do not see climate change mitigation as their job.

Behind-the-meter storage solutions:

Provide technical assistance to governments to develop regulatory systems, such as feed-in-tariffs, which can help to catalyse the uptake of BTM storage solutions. Consider the lack of regulations in target

[221] IRENA (2020) Electricity Storage Valuation Framework. Available at: https://irena.org/publications/2020/Mar/Electricity-Storage-Valuation-Framework-2020

regions as an opportunity that allows for a more streamlined approach to adopting recent best practice. There are different levels of maturity of electricity markets that call for different interventions and different opportunities to by-pass traditional stages of the electricity market. As promoted by the IEA it is important to place flexibility rather than specific technologies at the heart of policy support.[222]Also consider providing support to utilities to help develop offerings that include BTM storage solutions.

Consider how to catalyse the important role of warranties in de-risking storage investments and quantifying the financial value of storage. Warranties can cover the products as a guarantee against defects. They can also cover the performance of the product in terms of aspects such as consistent capacity, energy and availability over time. It is important to consider the potential downsides of warranties from an average life-of-SME-perspective in developing countries. For example, if the warranty is for 5 years and the average life expectancy of an SME is 3 years, it can be a bit meaningless. Furthermore, warranties for battery storage in developing countries may need to give special consideration for aspects such as high temperatures, fluctuating grids and difficulties for logistics in remote areas, which may lead to damage during transportation. A recent World Bank Battery Storage Partnership report on this subject, can offer useful guidance.[223]

Investment in pilot and demonstration projects to highlight the technical viability, robustness and reliability of new technologies. As a first step, implement batteries in public infrastructure (such as telecommunications infrastructure, municipal buildings, military/police infrastructure, and hospitals) to demonstrate profitability and correct implementation. For example, cool thermal storage has been deployed in public buildings such as city halls in cities like Durban, Pretoria, and Johannesburg in South Africa, to test and demonstrate the concept.

Support on catalysing financing mechanisms for energy users to encourage uptake and industry investment in BTM storage solutions. This could either be through grants or small interest-free loans, initiatives that spread out the cost over time so the upfront price isn't prohibitive, or supporting business models, such as pay-as-you-go energy access or storage-as-a-service. For example, a DFID programme is helping fund loans to provide low-carbon cookstoves to semi-urban and rural households in sub-Saharan Africa. Households pay off the loan through monthly salary sacrifice, which is offset by the fuel cost savings.[224] It is possible to develop similar mechanisms for energy storage technologies to encourage uptake, across all geographic regions.

Support initiatives that make use of second-life batteries. For example, lithium-ion batteries from EVs in developed countries could be used as household storage packs in countries in the target regions. It is important to note that the falling costs of lithium-ion batteries for second-life uses, make it harder for other battery chemistries to compete in the BTM storage sector.[225] Notable examples of vehicle manufacturer-led initiatives (albeit in high-income countries) include: General Motors' used-battery electric storage system project with ABB; BMW's used-battery electric storage system project with Bosch; and Renault's used-battery project with Powervault.[226]

Support the awareness and knowledge sharing of the benefits and possibilities of energy storage for a range of audiences including government, industries, businesses and households, helping to create more demand for storage services.

---

[222] IEA (2020) Energy Storage Tracking Report. https://www.iea.org/reports/energy-storage
[223] World Bank Group (2020) Warranties for Battery Energy Storage Systems in Developing Countries. Washington, D.C. https://www.esmap.org/report-warranties-for-battery-energy-storage-systems-in-dev
[224] Climate Care. (no date). Arup Joins Initiative to Provide Cleaner and Safer Cooking Technology to Communities in Kenya. Accessed July 2020. https://climatecare.org/arup-joins-initiative-to-provide-cleaner-and-safer-cooking-technology-to-communities-in-kenya/
[225] Energy Storage Report. (2016). The second-life threat to non-lithium batteries. http://energystoragereport.info/the-second-life-threat-to-non-lithium-batteries/
[226] Asian Development Bank (2018) Handbook on Battery Energy Storage System. https://www.adb.org/sites/default/files/publication/479891/handbook-battery-energy-storage-system.pdf

Focus on sectors where there are likely to be big savings in cost and GHG emissions, such as replacing BUGs in East Africa. Support here could be transformational. For example, an ongoing IFC initiative has carried out research to understand the true costs of diesel generators in terms of emissions, health and other impacts, using data from 167 countries, finding that users spend USD 30 billion to USD 50 billion annually on fuel in those countries and that utilities are struggling to keep up with surging demand. This is informing the next stage of the initiative which is to displace diesel generators with viable solar plus storage solutions.[227]

Support specific to development of utility-scale on-grid or mini-grid storage.

Help governments to set and plan implantation roadmaps for utility-scale storage capacity additions, followed up by appropriate implementation support. For example, the Philippines recently released an *Energy Storage Framework* which assesses the potential of storage systems such as various electro-chemical and flow battery technologies, compressed air, pumped-hydro and flywheel, as well as clearly setting out guidance on who should own, operate and ultimately benefit from the deployment of energy storage systems.[228] Another example is South Africa's 2019 Integrated Resources Plan, which sets the 10-year strategy for the country's energy mix, with a focus on renewables plus storage.[229] To support the implementation of energy storage in a coordinated way, the World Bank and African Development Bank are supporting Eskom to deliver a pilot 1.4 GWh battery energy storage system, expected to be the largest in sub-Saharan Africa.[230] India, South Africa, and countries in South America and Southeast Asia are more likely to require assistance in developing and implementing such strategy, before East Africa, which has a stronger focus on increasing generation capacity.[231]

Provide technical assistance to ensure utility-scale energy storage, smart grids and grid integration policy and regulation is fit for purpose and robust enough to encourage private investment.

Consider providing concessional finance to help to unlock potential utility-scale storage projects. Funding can cover project preparation phases such as feasibility studies, as well as early construction phases. A recent BloombergNEF (BILLIONEF) study shows that concessional finance could incentivise new storage capacity globally by lowering capital costs of the technology.[232]

Support research and development in utility-scale and BTM energy storage solutions.

Continue to support research and development in the energy storage sector, such as more efficient thermal storage techniques, including testing pilot interventions and obtaining proof of concepts for solutions that can easily be scaled, especially when it comes to working with the private sector.

Encourage wide ranging and holistic research and development (R&D) related to energy storage to ensure that storage technologies at lower TRLs, which may be more appropriate in certain contexts than better known Li-ion batteries, are advanced.

Aim to feed research outcomes into actionable and practical interventions and disseminate findings to a wide audience of relevant stakeholders.

---

[227] International Finance Corporation. (2019). The Dirty Footprint of the Broken Grid. https://www.ifc.org/wps/wcm/connect/industry_ext_content/ifc_external_corporate_site/financial+institutions/resources/dirty-footprint-of-broken-grid

[228] Energy Storage News. (2019). New DoE framework puts energy storage at heart of Philippines' energy reforms. https://www.energy-storage.news/news/new-doe-framework-puts-energy-storage-at-heart-of-philippines-energy-reform

[229] Government of the Republic of South Africa (2019) Integrated Resources Plan (Link)

[230] Construction Review Online. (2020). South Africa to construct battery energy storage system (BESS) in Vredendal. https://constructionreviewonline.com/2020/08/south-africa-to-construct-battery-energy-storage-system-bess-in-vredendal/

[231] Insight from expert interview. (2020).

[232] BNEF. (2019). The Clean Technology Fund and Concessional Finance: Lessons Learned and Strategies Moving Forward. (Link)

Intervention case studies

These case studies provide real-world insights into intervention design and challenges. Each case study provides an overview of the context, the aim of interventions, and the challenges faced.

Box 8 Project Financing Support to the Redstone Concentrated Solar Power (CSP) Plant with Molten Salt Thermal Storage in South Africa, 2015 – 2018, US$ 794 (IFC contribution of US$ 72 million)

The Redstone CSP plant in South Africa is a flagship renewable energy and utility-scale storage project for the continent. Co-developed by ACWA Power and SolarReserve, the 100MW CSP tower project will enable 12 hours of molten salt storage, helping to distribute power more evenly through a 24-hour period. It is designed to power more than 200,000 homes during peak demand, day and night. Due to high project development costs of approx. USD 794 million, club loans (a blend of development finance institutions and commercial banks) were required, including a blended finance component of USD 50 million from the Clean Technology Fund (CTF) and a further USD 192 from the African Development Bank.[233] As such the International Finance Corporation (IFC) provided overall coordination and guidance. The Redstone CSP project is one of 27 renewable energy Independent Power Producer (IPP) projects under the South Africa Renewable Energy Independent Power Producer (REIPPP) programme.

The objectives of the intervention were to:

- Raise sufficient financing for the project and enable the process to progress smoothly to financial close and then construction.
- Support the developers to formulate and sign at an appropriate power purchasing agreement (PPA) with Eskom, the national utility company.
- Ensure best practice financing standards and environmental and social safeguarding are adopted and followed throughout the process.

In pursuit of those objectives, the intervention's activities were to:

- Provide USD 72 million soft loan financing to contribute to the overall amount.
- Provide overall coordination and guidance to all parties involved in the process, from the developer, government stakeholders, CTF and private finance. This is also referred to as the 'honest broker role'.
- Provide sector expertise through in-house technical and country context advice, in-house CSP market experts, advice and best practice on environmental and social best practice and the Equator Principles, as well as advice on access to carbon credits.
- IFC's commitment to the project helped sponsors weather volatile international lending markets and a depreciating local currency, while also offering IFC's global expertise and experience in renewable energy production.

As a consequence the results of the intervention were:

- The PPA was signed in 2018 between the South African utility Eskom and the developers, following delays related to the replacement of the Zuma government. Full financing is now in place and construction is likely to start during 2020, subject to Covid-19.
- A ground-breaking application of thermal storage is being deployed, which should prove to be significantly more cost-effective solution than battery enabled storage. Indeed, estimates suggest

233 NS Energy. (no date). Redstone Concentrated Solar Project. https://www.nsenergybusiness.com/projects/redstone-concentrated-solar-project/

that molten salt thermal storage is 33 times more cost-effective than lithium-ion battery-based storage.[234]

- The Project is expected to create up to 1,400 new construction jobs, as well as dozens of permanent jobs in South Africa, where the current unemployment rate is 24 %.[235]

Key stakeholders included:

- Eskom utility company.
- Northern Cape Province Government.
- Local residents and businesses, although the proposed location is very sparsely inhabited.

Key risks and the steps taken to mitigate them were as follows:[236]

- Delays to the planning and construction process: Mitigating actions include Energy Performance Certificate (EPC) delay LDs, a strong insurance package, stringent construction supervision & progress reporting, using an EPC contractor with experience including local experience.
- Relatively untested technology: Mitigating actions include: Demystifying the technology risk associated with these complex projects, EPC performance LDs, extended performance measuring period (2-3 years), performance ramp-up, experienced & solid EPC contractor, sponsor completion support, stringent performance testing protocol for provisional & final acceptance under EPC
- Cost over-runs: Mitigating actions include: Fully wrapped all-in EPC contracts, fully back-to-back with the PPA, adequate contingencies, stringent construction supervision & progress reporting
- A lack of appropriate grid connection required the construction of a new 132kV switching station and a 34km-long 132kV transmission line are proposed to be constructed to connect the project with the national grid.

For BEIS there are several primary lessons of the intervention in determining ICF investment:

- Large utility-scale storage projects often require complex financing arrangements and the coordination of multiple stakeholders.
- The presence of a trusted and honest broker, usually a development finance institution plays an important role in galvanising financial support and commitment for the project.
- All major contracts are arranged as back-to-back with the overarching PPA, to minimise risk and exposure.

[234] Source: https://www.solarthermalworld.org/news/molten-salt-storage-33-times-cheaper-lithium-ion-batteries
[235] https://www.dfc.gov/sites/default/files/2019-08/PublicSummary_RedstoneCSP.pdf
[236] http://pubdocs.worldbank.org/en/574031489525897517/Day-II-4-2-IFCs-Project-Financing-of-Concentrated-Solar-Power-Plants-Dana-Younger.pdf

Box 9 Asian Development Bank's Support for Utility Scale Battery Storage in Thailand

The Asian Development Bank (ADB) recently approved a loan of approximately USD 7.2 million to Lomligor Company Limited (Lomligor), a subsidiary of BCPG Public Company Limited (BCPG) for a 10 MW wind power project with an integrated 1.88 MWh pilot battery energy storage system (BESS) project in Southern Thailand. The project will also leverage a USD 4.75m concessional loan provided by the CTF.[237] This is the country's first example of wind generation connected to battery storage and is located in one of the country's least developed regions, which suffers from a lack of investment, job opportunities, and access to basic services. The lack of economic activity in the region has led to underinvestment in the local power system, which continues to experience energy shortages. The project will provide additional generation capacity to the region, help make the power network more resilient, and thus support economic growth. The project should also generate job opportunities for the local community, including for women; and support the growth of the local and national economy.

With assistance of the ADB, the objectives of the project are to:

- Expand the amount of renewables capacity delivered into the main grid.
- Contribute to Thailand's Power Development Plan targets for clean energy.
- Contribute to job creation, including for women, and support growth of the economy.

In pursuit of those objectives, the activities of the programme are:

- The project company entered into a PPA with the Provincial Electricity Authority (PEA), the Thai state-owned utility handling all distribution and retail sales outside the greater Bangkok area, for up to 8.965 MW under the Ministry of Energy's very small power producer (VSPP) programme.[238]
- The PPA is to be automatically renewed every five years, and in addition to the wholesale tariff, the project receives a tariff incentive (the so-called "adder") of B3.5 per kWh, applicable for 10 years from the commercial operations date.
- Assisting Lomligor to align its labour and gender policies with the applicable regulatory requirements, ADB's Social Protection Strategy, and internationally recognised core labour standards.
- Facilitating meetings and discussions with community and village heads, and other members in the area where the project is located, to enable stakeholder consultation and resolution of community and stakeholder grievances or concerns linked to the projects development.
- Facilitating liaison with state and provincial regulatory authorities.

As a consequence, the results the programme aims to achieve are:

- When operational, the wind power plant with integrated pilot battery energy storage system will have an installed electricity generation capacity of 10 MW with battery energy storage capacity of 1.88 MWh, helping to provide energy over a longer timeframe in each 24-hour period.
- Supply of renewable energy to Thailand's domestic grid will be increased and the pilot use of integrated battery energy storage system is being demonstrated.
- At least seven permanent jobs will be created during operation and the project is providing almost 700 jobs during construction, at least 100 of which were occupied by women, or 15% of the total.

[237] Asian Development Bank. (2019). Report and Recommendation of the President to the Board of Directors: https://www.adb.org/sites/default/files/project-documents/53174/53174-001-rrp-en.pdf

[238] The government has allowed small-scale power projects of up to 10MW to connect to the grid and directly sell electricity to Metropolitan Electricity Authority (MEA) and Provincial Electricity Authority (PEA) since 2002.

- Provide beneficiaries with access to more affordable and reliable electricity and better opportunities to raise their income and improve their livelihoods.
- The concessional loan provided by the CTF has been critical in overcoming the risk-related bankability challenges that such a project might otherwise face in debuting an innovative technology. The benefits stand to be substantial, including the annual generation of at least 14,870 MWh of electricity and the reduction of 6,364 tonnes of carbon dioxide emissions, beginning in 2020.[239]

In the course of the programme, key clients and stakeholders are:

- Provincial Electricity Authority.
- Ministry of Energy.
- Local communities impacted by the project.

The risks and challenges that the project faces are:

- Potential changes in the regulatory environment or power purchase agreement.
- Technology risk relating to the relatively untried battery energy storage system and possible future maintenance costs.
- Inflation and other unexpected market changes leading to cost overrun.
- Weak power demand as a result of adverse macroeconomic shock.

For BEIS the lesson from the programme in determining ICF investment are:

- In many parts of Southeast Asia, the lack of pilot projects and a lag in regulatory regimes prevent widespread commercial deployment of the battery storage technology seen in other parts of the world.

[239] https://www.climateinvestmentfunds.org/news/innovative-battery-technology-boosts-renewable-energy-supplies-thailand

Glossary

Acronym / Term	Definition
ADB	Asian Development Bank
Aggregators	Aggregators are a grouping of agents in a power system (e.g. consumers, producers, prosumers) which act as a single entity when engaging in power markets.
AI	Artificial intelligence
AMI	Advanced metering infrastructure
Ancillary services	Services that maintain the proper flow and direction of electricity e.g. synchronised regulation, contingency reserves, black-start regulation, flexibility reserves
Baseload	The minimum amount of electric power delivered or required over a given period
BAU	Business as usual
Behind the-the-meter storage	Storage connected at the consumer side of the utility meter for commercial, industrial or residential power customers (and is therefore grid-connected).
BEIS	UK government Department for Business, Energy & Industrial Strategy
BESS	Battery energy storage systems
BMZ	Germany's Federal Ministry for Economic Cooperation and Development
BTM	Behind the-the- meter
BUG	Back-up generator
C&I	Commercial and Industrial
CAES	Compressed Air Energy Storage
CIF	Climate Investment Funds
CSP	Concentrated solar power
CTF	Clean Technology Fund
Curtailment	A reduction in output from a power generator from what it could otherwise produce using available resources
DER	Distributed energy resource
DFID	Former UK government Department for International Development (now part of the Foreign, Commonwealth and Development Office (FCDO)) UK government Department for International Development
DR	Demand response
DSM	Demand side -side-management
EE	Energy efficiency
Electrical storage	Storage of energy in electrical fields e.g. supercapacitor
Electrochemical storage	Storage of chemical potential energy e.g. lithium-ion batteries
Energy storage	A device that captures energy for later use, with categories of storage including electrochemical, electrical, mechanical, and thermal forms of storage
EnMS	Energy management system
EPC	Energy Performance Certificate
EPSRC	Engineering and Physical Sciences Research Council

Acronym / Term	Definition
ESCO	Energy Service company
ESMAP	Energy Sector Management Assistance Programme
ESO	Energy systems optimisation
ESRN	Energy Storage Research Network
ESS	Energy storage systems
EU	European Union
EUR	Euro
Flexibility	The ability of a power system to respond to changes in electricity demand and supply
GBP	British pound sterling
GDP	Gross domestic product
GESP	Global Energy Storage Program
GHG	Greenhouse gas
GIZ	Deutsche Gesellschaft fur Internationale Zusammenarbeit GmbH
Grid	An electricity grid
Grid storage	Storage connected to a distribution or transmission networks, or alongside a power generation asset, such as a wind turbine
Gt CO2	Gigatonnes of CO2
Gt CO2e	Gigatonnes of CO2 equivalent
GW	Gigawatt
GWh	Gigawatt hours
IADB	Inter-American Development Bank
IEA	International Energy Agency
IESA	India Energy Storage Alliance
IFC	International Finance Corporation
IoT	Internet of Things
IPCC	Intergovernmental Panel on Climate Change
IPP	Independent Power Producer
IT	Information technologies
LEDs	Light emitting diode lights
Load	The energy demand experienced on a system
MAGC	Market Accelerator for Green Construction
Mechanical storage	Storage of mechanical potential energy e.g. pumped hydropower
NDC	Nationally Determined Contribution
NEP	National Energy Plans or Policies
ODA	Official Development Assistance
OECD	Organisation of Economic Cooperation and Development
Ofgem	Office of Gas and Electricity Markets

Acronym / Term	Definition
PPA	Power purchase agreement
RD&D	Research, development and demonstration
SDG	Sustainable Development Goal
Stationary storage	Electrical storage designed for stationary applications
System costs	Total costs to the electricity system to supply electricity at a given load and security of supply
TCP	Technology Collaboration Programme
Thermal storage	Storage of energy as heat (or cold) for later use, either directly or to generate electricity
TRL	Technology readiness levels
UNIDO	United Nations Industrial Development Organisation
USAidUSAID	United States Agency for International Development
USD	United States Dollar
Variability	The changes in power demand and/or output of a generating source due to underlying fluctuations in resource or power consumption
VPP / Virtual Power Plant	VPP operators aggregate DERs to behave like a traditional power plant and engage in a power market to sell electricity or ancillary services

Demand Side Management

Summary

The demand side management opportunity is defined as measures to increase power system flexibility and encourage power demand reduction, using both price and non-price signals. In this assessment, demand-side management focuses on the power sector. It includes measures to influence the consumer use of electricity (households, commercial users and industry), either in the time pattern of use or magnitude of demand (e.g. energy efficiency and energy conservation). It also includes measures to improve the operation of grid assets, to improve system flexibility and increase efficiency of generation. There are numerous strategies to achieve the outlined types of DSM considered in this report, including electricity market design, customer self-generation, behavioural change policies, and use of digital, smart technologies by consumers and network operators within a smart grid.

Interventions to encourage adoption of demand side management include technical assistance to local utilities and policymakers, advisory support to businesses and financing of smart grid infrastructure. Given the largest barriers to adoption of demand side management, example interventions include:

<u>Technical assistance</u> in the development of electricity market regulation and design of effective behavioural change policies; and,

<u>Financing of capital and software</u>, including data management systems and remote smart metering systems throughout a grid network.

Table 18 Demand side management assessment summary

Criteria	Assessment	Notes
Climate impact	Medium	• Large indirect impact on power sector emissions by enabling integration of variable renewables (which could help to reduce around 50% of power sector emissions by 2050), reducing dependence on polluting forms of back-up power and reducing overall energy demand • Transformational impact on all sectors in the long-term through increased efficiency of energy consumption across transport, buildings, industry etc
Development impact	High	• Substantial positive impact on SDG 7, access to low carbon, reliable power, and SDG 3, good health and wellbeing, by supporting renewables integration. Further positive impacts on economic growth and industry can be achieved through system wide impact of DSM
Investment gap	Low	• Investment need, and therefore gap is low (around USD 2 trillion) compared to other opportunities, reflecting lower levels of infrastructure required for centralised DSM • Costs are not negligible, however, and can be high in the case of payments to industrial users to reduce demand, or deployment of metering units and smart end-use appliances in the transition to a smart grid
Cost effectiveness	High	• DSM is in principle a low-cost measure but there are costs associated with overcoming barriers to delivery, and this is poorly understood. • Cost effectiveness is greatest where behavioural inertia can be overcome, through behavioural change policies, or circumvented, through automation and use of AI
Barriers to adoption	High	• Substantial barriers to greater DSM include policy inertia, resulting from poor understanding of the ability of DSM to achieve energy access and climate goals; the missing market associated with the provision of 'flexible power' to integrate renewables; and, the lack of technical capacity to implement DSM measures e.g. a poor digital ecosystem.

Criteria	Assessment	Notes
UK additionality	High	• Extensive domestic experience in implementing DSM measures, both through effective regulatory design and private sector business models, such as aggregators.

Source: Vivid Economics, Adam Smith International & Factor

Key lessons for supporting mitigation through demand side management:

The nature of the local electricity demand will influence the ease of rolling out DSM. In countries with large industrial demand, such as South Africa, incentives-based mechanisms targeted at industrial users could provide a large degree of the flexibility needed.

DSM policies can increase their climate impact through measures to:

Increase the price responsiveness of consumers, through behavioural change policies, or

Increase the participation rate of consumers by automating decision-making, through use of artificial intelligence and smart appliances.

To increase local support for a DSM strategy, policies should seek to leverage the tangible monetary benefits from DSM, such as the potential to increase revenues of electricity operators through AI.

India and South Africa both have significant regional demand for DSM and can deliver large climate mitigation potential.

Introduction to the opportunity

Role of the opportunity in decarbonisation of developing countries

Demand-side management will be essential to the decarbonisation of the power sector, and the energy sector as a whole, through its role in providing demand-side flexibility to meet rising electricity demand, reducing total electricity demand by encouraging behaviour change, and supporting the integration of variable renewable energy. The power sector emitted 7.4 gigatonnes of carbon dioxide ($GtCO_2$) in low- and middle-income countries in 2015, rising to 16 $GtCO_2$ in 2050 under a business-as-usual (BAU) scenario.[240] Variable renewable energy is expected to supply 68% electricity in low- and middle-income countries in 2050, compared to only 1% in 2015. This will require the capacity of wind and solar power to increase, on average, by 220 gigawatts (GW) per year to 2050.[241] Power system flexibility will be increasingly necessary to handle the variability and uncertainty that these variable renewables introduce into the system, helping to ensure renewables integration occurs at low cost and avoiding renewable power curtailment.[242] Flexibility and demand reduction are maximised to the extent that a smart grid is combined with increased digitalisation of the energy system, to automate optimisation of grid assets, and behaviour change policies to increase responsiveness of consumers. Notably, grid flexibility delivers emissions reductions benefits across other sectors besides the power sector, such as industry and transport, by allowing for more efficient integration of electric vehicles (EVs) and improved efficiency at which industries consume and generate power.[243]

Currently, most forms of demand-side management in place in low and middle-income countries focus on improving energy efficiency of power consumption. Measures to manage demand by increasing the efficiency of power consumption are by far the most common form of DSM, with over 230 energy efficiency labelling policies present globally – including in, India, Vietnam, the Philippines, Mexico, Peru, Colombia, South Africa and Kenya among other low- and middle income countries. Contracts to curtail industrial demand are the second most common form of DSM in place across low- and middle-income countries. [244] However, the scale of power flexibility they supply is still relatively small. Decentralised DSM and 'smart grid' opportunities, including the use of digital technologies and artificial intelligence, are scarce, with grid modernisation only at a pilot stage in high-income countries. There is therefore little precedence in terms of how countries can transition to a smarter grid, and substantial room for innovation.

Box 10 The future of demand side management, the 'smart grid' and energy storage

A smarter grid is viewed as a key step to realising increased demand-side management, both via active participation of energy consumers and increasing use of automation and smart systems. A grid is 'smart' to the extent that it can optimise generation, distribution and consumption of electricity.[245] Though its exact composition will vary, all smart grids will rely on the introduction of information and communication technologies – sensors and smart meters –to provide real-time measurement of grid activity and provide signals that consumers, producers and network operators can respond to. One core aspect will be the increased role of energy consumers, who will be empowered with the information and incentives to modulate demand in response to real-time price signals; and supply energy back to the grid, utilising distributed energy resources (e.g. solar home systems or electric vehicles). Smart grids will not only rely

---

[240] Figures correspond to the IMAGE Planned Policies decarbonisation scenario

[241] Figures correspond to the renewables decarbonisation scenario. Variable renewables includes solar photovoltaic (PV), concentrated solar power (CSP), onshore wind, and offshore wind.

[242] Variability is defined as the fluctuating nature of solar and wind resources, which translate into rapid changes in electricity generation. Uncertainty is defined as the inability to perfectly predict the future output of variable renewable generation. Based on Irena. (2019). "Innovation landscape preview" https://www.irena.org/-/media/Files/IRENA/Agency/Publication/2019/Jan/IRENA_Innovation_Landscape_preview_2019.pdf?la=en&hash=10221885865D12F47747356D9F6290283B205210

[243] International Energy Agency. (2020). Demand Response: Tracking Report – June 2020. https://www.iea.org/reports/demand-response

[244] ESMAP (2011). "*Implementing Energy Efficiency and Demand Side Management – South Africa's Standard Offer Model*". https://openknowledge.worldbank.org/bitstream/handle/10986/12508/690330ESM0P1180SouthAfrica0WebFinal.pdf?sequence=1&isAllowed=y

[245] Daki et al. (2017). "Big Data Management in Smart Grids: concepts, requirements and implementation"

on energy consumers to provide flexibility, however, but also on smart appliances and network operation systems that can automatically optimise operation based on digital signals.

The effects of increased data collection on the grid can be transformational at the system-wide level. A smarter grid will also allow for the optimisation of generation and distribution across the electricity system. For instance, artificial intelligence techniques are increasingly applied to the vast amount of grid data, energy consumption data and weather data to help decide when and how to utilise renewable power sources. Applications have so far been concentrated in high-income countries, Norway and the USA for example, but could equally benefit low and middle-income countries – pilots for improved grid data collection and real-time optimisation are, for instance, underway in Argentina and Colombia.[246][247] This supports the increased utilisation of renewable energy assets, improving the profitability of these assets and reducing emissions on the grid. In its most advanced form, the smart grid will allow optimisation across the entire energy system, providing data that allows for flexibility and integration across the power, transport and building sectors.

One of the key benefits of the smarter grid is the low-cost integration of renewables. By increasing the responsiveness of the entire power system, a smarter grid can increase the efficiency at which assets are utilised. It therefore both helps to support higher levels of renewable integration and to reduce the costs of meeting rising power demand – by reducing levels of renewable energy curtailment, for example. There are numerous other benefits of the smarter grid, including increased reliability of generation and reduced risks of electricity theft.

There are several components necessary to realise the benefits provided by a smart grid. Installation of sensors and smart meters will not be enough to catalyse the increased efficiency opportunities highlighted above. The benefits of grid modernisation will also rely on three interconnected factors:

- Digitalisation and artificial intelligence. Smart meters and sensors will inevitably create a surplus of information. For example, one million smart meters with a sampling rate of four times per hour will generate over 35 billion records. Information in itself is not valuable, however, and will only be useful if combined with advanced data analytics software, to translate vast amounts of information into meaningful signals; and, internet of things (IoT) technologies able to communicate and automatically respond to these digital signals – smart thermostats, smart substations etc.

- Decentralisation, via distributed energy resources (DERs) at the consumer end of the utility grid. Increasing deployment of DERs – including solar home systems, behind-the-meter (BTM) energy storage systems, electric heat pumps and electric vehicles – effectively decentralises power generation, blurring the line between power consumer and producer. They are core to increasing DSM. DERs increase the ‘flexible power’ capacity by allowing for both self-consumption, when electricity prices are low, and the supply of energy back to the grid when prices rise. Importantly, the associated revenue streams created by this process simultaneously increases the value of DERs.

- New business models. Regulatory frameworks that value flexibility and associated business models which seek to profit from DERs and the surplus of digital information are a necessary condition to achieve a smarter, more responsive grid. In the UK and Germany, the design of capacity market auctions has been effective at stimulating ‘aggregator’ and ‘virtual power plant’ (BPP_ business models, for example, which utilise DERs to create revenue-generating grid assets. China has also demonstrated the viability of virtual power plants through a series of pilots, with as much as 55MW was gathered through a VPP project focused on air-conditioning resources in commercial

[246] IFC. (2020). “Artificial intelligence in the Power Sector”
[247] energy & meteo systems. (no date.) Virtual Power Plant for South America. https://www.energymeteo.com/customers/customer_projects/virtual-power-plant_south-america.php

buildings.[248] In 2020, the controllable load managed by the state grid Jiangsu Electric Power Company is targeted to be 10 GW.[249] Countries in South America are also advancing towards deployment of VPPs, with a project currently underway in Argentina and Colombia, having been co-financed by Germany's Federal Ministry for Economic Cooperation and Development (BMZ).[250]

Scope considered in this assessment

The demand-side management opportunity is defined as measures to increase power system flexibility and encourage power demand reduction, using both price and non-price signals. In this assessment, demand-side management focuses on the power sector. It includes measures to influence the consumer use of electricity (households, commercial users and industry), either in the time pattern of use or magnitude of demand (e.g. energy efficiency and energy conservation). It also includes measures to improve the operation of grid assets, to improve system flexibility and increase efficiency of generation. There are numerous strategies to achieve the outlined types of DSM considered in this report, including electricity market design, customer self-generation, behavioural change policies, and use of digital, smart technologies by consumers and network operators. Box 11 sets out our approach to classifying the variants of DSM discussed in this report specifically.

Box 11 Forms of demand-side management

In this assessment, we classify DSM according to two dimensions, which together affect how DSM is introduced into a country's electricity market design. The two dimensions used to distinguish between types of DSM are:

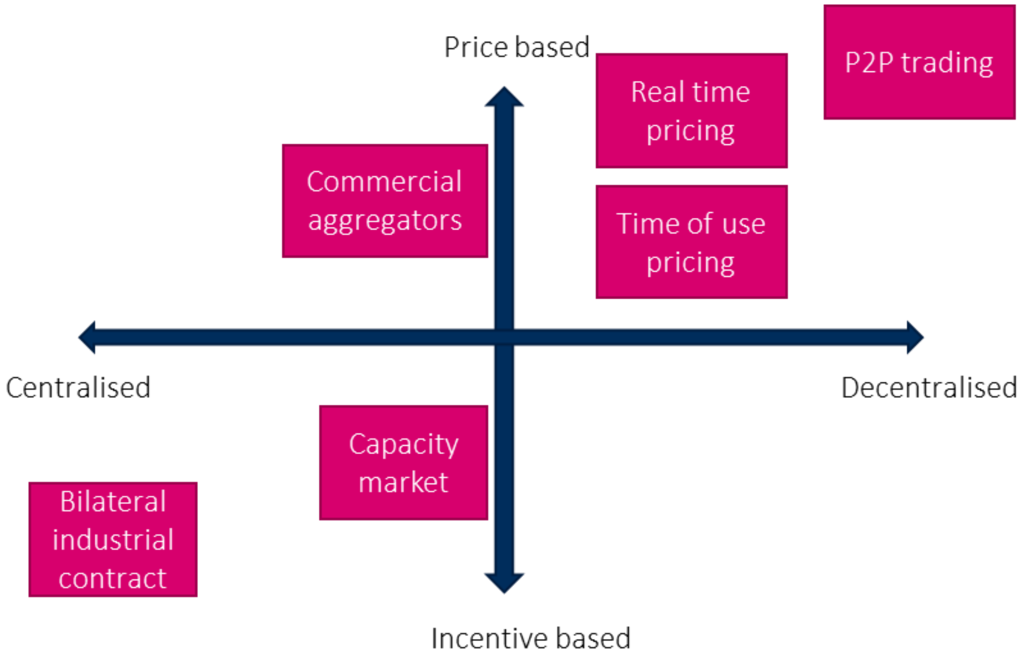
- *Centralised vs. Decentralised DSM.* This dimension captures the level of coordination required. Centralised DSM typically involves bilateral coordination between system operators and large industrial/commercial electricity consumers, and it is often categorised as demand-side response (DSR). Decentralised DSM includes small-scale (household) electricity users, and could be achieved on market-based platforms.

- *Price- vs. incentive-based DSM.* This dimension captures the type of incentive provided. Price-based mechanisms provide incentives through the price of electricity (GBP/kilowatt-hour (kWh)) itself. This can be in the form of time-of-use (TOU) tariffs, critical peak pricing, variable peak pricing, extreme day pricing, real-time pricing, peak time rebates, etc. On the other hand, incentive-based mechanisms provide incentives beyond those included in the electricity price itself. This could include direct load control, interruptible load, emergency demand response programmes, capacity markets, demand bidding programmes, ancillary service markets, etc.[251] Notably, price-based DSM will require the uptake of digital, smart technologies that can automatically respond to a vast quantity of information, and data processing systems that can streamline the information provided.

As set out in Figure 15, different DSM mechanisms sit on a spectrum. For example, bilateral industrial contracts are highly centralised, and incentive based.

[248] Dena. (2019) "Industrial demand side flexibility in China"
[249] GIZ (2019) "Opportunities for virtual power plants in India" https://www.energyforum.in/fileadmin/user_upload/india/media_elements/publications/20191121_Virtual_Power_Plants/Virtual_Power_Plants__Report.pdf
[250] energy & meteo systems. (no date). Virtual Power Plant for South America. https://www.energymeteo.com/customers/customer_projects/virtual-power-plant_south-america.php
[251] Thakur & Chakraborty. (2016). Demand side management in developing nations: A mitigating tool for energy imbalance and peak load management. Available from: https://www.sciencedirect.com/science/article/abs/pii/S0360544216311331

Figure 15 Types of DSM discussed in the report can be characterised along two dimensions



Note: Not all possible forms of DSM are shown in the above figure; P2P refers to peer-to-peer trading.
Source: Vivid Economics, ASI and Factor

DSM is typically most beneficial to achieving emissions reductions in regions where a large proportion of future supply will be highly variable, hence this assessment focuses on similar regions as the Renewable Opportunity Report:[252]

India, where DSM can help to integrate renewables and improve the energy efficiency of consumption, as well as improve energy access outcomes through reduced grid outages. Given these local benefits, a nationwide roll-out of 250 million smart meters is planned.253

East Africa, where there is a large increase in variable renewable generation relative to today, with more than 2GW of solar PV and wind power projects announced over the next two to three years. DSM opportunities are likely to be far smaller than other regions, however, given the potential to provide power system flexibility via alternative firm power generation, specifically pumped hydro;254

South Africa, where there are large opportunities to achieve low-cost forms of centralised DSM through contracts with industrial users (who account for 70% of electricity consumption). This is demonstrated by the Integrated Demand Management Programme's success in establishing savings capacity equivalent to a full year's electricity consumption by the capital city.[255]

South America (excluding Brazil), henceforth 'South America', which is expected to have amongst the highest levels of variable renewable generation, stimulating demand for DSM. A recent study by the

[252] CCC (2019) "Technical Annex: Integrating variable renewables into the UK electricity system" https://www.theccc.org.uk/wp-content/uploads/2019/04/Technical-Annex-Integrating-variable-renewables-into-the-UK-electricity-system.pdf
[253] Bloomberg Quint. (2020). India Plans to Spend $21 Billion on Smart Power Meter Rollout. https://www.bloombergquint.com/business/india-plans-to-spend-21-billion-on-smart-power-meter-rollout
[254] Renewable Energy World. (2020). Energy Storage is the key to energy access in East Africa. https://www.renewableenergyworld.com/2020/04/03/energy-storage-is-the-key-to-energy-access-in-east-africa/#gref
[255] International Smart Grid Action Network (2020). "DSM Case/ South Africa" http://www.iea-isgan.org/dsm-case-south-africa/

Economic Commission for Latin America and the Caribbean estimated that approximately 25% of energy consumption could be avoided by an active demand-side in the region.[256]

South-East Asia, where, like in India, DSM provides opportunities to increase energy efficiency of electricity consumption and help integrate renewables across the region. Opportunities are already being explored in Malaysia and Vietnam, for instance.[257,258]

This assessment focuses on the benefit of supporting the opportunity as a whole and does not aim to comprehensively assess the effectiveness of specific investment opportunities or interventions. However, for context, potential specific investment opportunities are detailed in Section 0.

[256] Martinez and Rudnick (2012). "Design of demand response programs in emerging countries" http://hrudnick.sitios.ing.uc.cl/paperspdf/PID2455963.pdf
[257] Demand Side Management Energy Commission (2014). "Demand side management" https://www.st.gov.my/en/contents/presentations/EPC_2014/Demand%20Side%20Management.pdf
[258] ESMAP. (2007) "Vietnam Demand Side Management and Energy efficiency Programme" https://www.esmap.org/sites/default/files/esmap-files/39.%20Vietnam_CFL_Proghram_Evaluation_Report.pdf

Climate impact

Mitigation potential and urgency

Demand-side management indirectly helps to reduce emissions across low and middle-income countries by supporting the uptake of variable renewable energy on the grid, which can help to avoid around 50% of power sector CO_2 emissions (7.3 $GtCO_2$) in 2050 beyond business-as-usual.[259] As discussed in the Variable Renewables Opportunity Report, on-grid variable renewables are key to meet growing electricity demand whilst lowering power sector emissions. In a high renewables' scenario, 68% of electricity in low- and middle-income countries is provided by variable renewables. However, the integration of these variable renewables will place increased pressures on the grid to balance supply and demand, both in the short-term (due to minute by minute variations in energy supplied) and in the longer-term (to shift energy supplied to times of peak demand). Demand-side management can help to provide flexibility to the power system, ensuring this balance is achieved and grid quality maintained.

Demand-side management can also help to reduce emissions by reducing dependence of polluting forms of back-up power and by reducing power demand by increasing the efficiency of both consumption and generation. Though the largest pathway for demand-side management to support emissions reductions is through enabling renewables deployment, it can also reduce emissions through two alternative pathways.

Reducing emissions from back-up generators (BUGs). DSM can help to reduce the frequency and duration of power outages, thereby reducing the reliance on BUGs as a common form of back-up power. BUGs currently account for a sizeable share of emissions, approximately 100 megatonnes (Mt) CO2 across low- and middle-income countries. Their contribution to power sector emissions is particularly high in Africa and South Asia. For instance, in Africa BUGs contribute to over 10% of power emissions.[260]

Reducing power demand by increasing efficiency of consumption. By exposing power consumers to the real price of electricity DSM can help encourage efficiency improvements, particularly in countries with electricity subsidies.[261] Through information campaigns, energy audits and feedback measures, among other behavioural change policies, DSM can also increase the adoption of new energy conservation practices and increase the responsiveness of consumers to price signals. In Porto, Portugal, energy audits on municipal assets (e.g. street lights, buildings and vehicles) and real-time consumption monitoring has led to total annual savings of EUR 210,000 - resulting from a reduction in the number of energy contracts and an identification of energy conservation measures.[262] In India, effective behavioural change policies have enabled energy efficiency and demand reduction by 'changing the default', for instance changes to the default temperature setting of air conditioners has achieved energy savings of around 24%.[263] Similar successful experiments have been conducted in a number of Organisation for Economic Co-operation and Development (OECD) countries, with reductions in the default temperature settings from washing machines resulting in energy savings of 24% per wash amongst those with a low-temperature default setting versus those with a high default temperature settings. Emerging evidence suggests the exact choice of the default can influence the later scale of energy savings. A randomised control trial amongst office workers suggests that a

[259] From IMAGE: 7.3 Gt CO2 corresponds to a renewables scenarios. The lower is negative (-0.09 Gt CO2), corresponding to the 1.5-degrees scenario estimate

[260] IFC (2019). "The Dirty Footprint of the Broken Grid". https://www.ifc.org/wps/wcm/connect/2cd3d83d-4f00-4d42-9bdc-4afdc2f5dbc7/20190919-Full-Report-The-Dirty-Footprint-of-the-Broken-Grid.pdf?MOD=AJPERES&CVID=mR9UpXC

[261] The top 25 countries providing energy (including electricity subsidies) are listed by the IEA here: https://www.iea.org/topics/energy-subsidies

[262] Interreg Europe (2018). "Behaviour change for energy efficiency". https://www.interregeurope.eu/fileadmin/user_upload/plp_uploads/policy_briefs/PolicyBrief_Behavioural_Change.pdf

[263] MoneyControl. (2019). "Explained: Why you should keep the AC at 24°C". https://www.moneycontrol.com/news/business/economy/explained-why-you-should-keep-the-ac-at-24c-4711541.html. Note: from early 2020, a 24 degree Celsius default setting was made mandatory on all room air conditioners covered under the ambit of BEE star-labelling program.

smaller change in the default settings on office thermostats (a 1 degree reduction versus 2 degrees reduction) resulting in a subsequent lower temperature setting and greater energy savings.[264]

Reducing power demand by improving efficiency of grid generation and distribution. Smart grids enable more accurate real-time monitoring of generation and consumption, which can help network operators to better manage electrical networks and optimise the use of current grid assets. For instance, machine learning algorithms can learn how variable renewables are best absorbed on the grid to reduce renewable power curtailment- an estimated 25% reduction in curtailment, a 10% reduction in operation costs, and an 8% increase in renewable energy generation is expected from digital system implementation.[265] Crucially, a smarter grid allows for efficient investment decisions in future capacity and reduces reliance on surplus fossil fuel capacity to provide flexibility. Application of machine learning to wind powered generation in the US has boosted the value of wind energy by around 20%; in the European Union, integration of digitally enabled DSM and increase storage could reduce curtailment of solar PV and wind from 7% to 1.6% in 2040, avoiding 30 million tonnes of CO_2 emissions in the same year.[266][267] In recognition of these benefits, Argentina has invested in the automation of power distribution and use of remote energy meters as part of its grid modernisation strategy.[268]

DSM's ability to provide flexibility and efficiency gains substantially increases through measures that either increase the price responsiveness of power consumers or reduce the need for deliberate consumer decision-making, through a smart grid. Despite latent flexibility in a power system, DSM is often inhibited by price inelastic power consumers. Behavioural barriers can inhibit all types of DSM shown in Figure 17, but particularly affects centralised DSM, which relies exclusively on power consumers to make deliberate decisions to reduce or shift demand. Two approaches can help maximise the provision of flexibility under a DSM strategy:

Behavioural change policies, which can help to increase responsiveness of power consumers to price signals and unlock greater flexibility. The flexibility benefits of energy-saving behaviour is substantial - in Bangladesh, it has been estimated that changes in household behaviour could reduce residential power demand by an average of 10%, and by up to 22% during peak demand hours.[269]Policies targeting behavioural change include the provision of information to identify cost-saving options (e.g. energy audits on historic energy consumption information), feedback measures (e.g. real time displays, benchmarking consumption against peer group) and training and awareness raising, among others.[270] A randomised control trial in the UK recently showed that coupling behavioural levers alongside the installation of smart meters delivered larger energy savings – with the provision of a real-time display proven to result in energy savings that were 2% - 4% higher.[271] Policies are increasingly being trialled in low and middle-income countries, but it is still too early to evaluate their impact. In the Western Cape of South Africa, for example, energy consumption in office building is being tackled through a range of behavioural interventions, including information provision via

---

264 McCalley. (2016). "From motivation and cognition theories to everyday applications and back again". https://www.sciencedirect.com/science/article/pii/S030142150400268X?casa_token=j0mbgwS081IAAAAA:kdMDL5_6V-JGOH6jwZllbg-ViHUT8Xllbgd_Rmwgx1tJYVu7RQcG-UmzRmuN9k9rlXt8di13Y6g

265 IRENA (2019). "Innovation landscape for a renewable powered future" https://www.irena.org/-/media/Files/IRENA/Agency/Publication/2019/Feb/IRENA_Innovation_Landscape_2019_report.pdf

266 Elkin & Witherspoon. (2019). Machine learning can boost the value of wind energy. https://deepmind.com/blog/article/machine-learning-can-boost-value-wind-energy

267 International Energy Agency. (2017). Digitalisation and Energy: Technology report — November 2017. https://www.iea.org/reports/digitalisation-and-energy

268 IFC. (2020). "Artificial Intelligence in the Power Sector" https://www.ifc.org/wps/wcm/connect/publications_ext_content/ifc_external_publication_site/publications_listing_page/artificial+intelligence+in+the+power+sector

269 Khan (2019). "Energy-saving behaviour as a demand-side management strategy in the developing world: the case of Bangladesh". https://link.springer.com/article/10.1007/s40095-019-0302-3

270 Interreg Europe (2019). "Behaviour change for energy efficiency - A Policy Brief from the Policy Learning Platform on Low-carbon economy" https://www.interregeurope.eu/fileadmin/user_upload/plp_uploads/policy_briefs/PolicyBrief_Behavioural_Change.pdf

271 OECD (2017). "Tackling Environmental Problems with the Help of Behavioural Insights". https://www.oecd-ilibrary.org/docserver/9789264273887-en.pdf?expires=1598601277&id=id&accname=guest&checksum=52D9923391356A4C7D7153681992058E

emails, inter-floor competitions on energy savings and identification of "champions of energy efficiency".

Smart systems and artificial intelligence techniques, such as machine learning, which can increase flexibility by reducing the need for conscious consumer participation.[272] Smart home energy management systems, for example, direct energy appliances and distributed generation sources to automatically respond to price signals. Azuri Technologies Home Smart solution is built on AI, for instance, learning each home's energy needs and adjusting power output accordingly—by automatically dimming lights, battery charging, and slowing fans—to match the customer's typical daily requirements.[273] Machine learning and use of smart meters throughout the grid also improve the flexibility of the system as a whole. In Baja California, AI algorithms are being trialled to allow the electricity system operator to react in seconds to changes in cloud coverage, and its effect on solar generation. Adoption of smart technologies, such as blockchain, can also compliment behavioural change initiatives. For instance, use of blockchain technologies can lead to better information on power consumption and increase trust in energy transactions, facilitating decentralised energy trading. Energy Bazaar, which focuses on India, provides one example of how blockchain technology is being used to facilitate peer-to-peer (P2P) trading.[274] A second example involves the P2P trading pilot project in Medellin, part of the Transactive Energy Colombia Initiative under the IEA Users Technology Collaboration Programme (TCP). The project's aim is threefold: to implement a transactive energy pilot based on blockchain platform with DERs; to provide technical and regulatory recommendations for transactive energy (TE) models in Colombia; and to define a scaling route for TE models and design a business model for the Colombian case. The pilot, running from October 2019 to September 2020, is intended to demonstrate P2P as a way of enabling the democratisation of energy.[275]

The role of DSM, and hence its mitigation potential, will vary per region. The relative mitigation potential from any provision of flexibility (including DSM, but also storage) is highest in regions where the emissions intensity of the grid is high and grid capacity is low, such as India, South Asia and sub-Saharan Africa, and particularly Western Africa. All of these regions currently share experience of frequent black-outs, as well as using substantial levels of diesel generation, which DSM could help reduce.[276] DSM's potential is greatest where grid emissions intensity and the required roll-out of renewables is large, while alternative options to provide flexibility are limited:

High grid emissions intensity implies enabling renewable penetration has the greatest benefit. Virtually all regions will see over 60% variable renewable penetration by 2050. Hence, regions which currently have high levels of coal generation (and hence grid emissions intensity) such as South Africa (90%) and India (75%) will all require transformative changes to their power sectors, where DSM can play a large role.

Limited alternative supplies of flexibility. Flexibility can be provided through various means, both on the supply and demand side. DSM is most valuable where these alternative forms of flexibility are limited.

Weak transmission and distribution infrastructure means the grid itself cannot be used to help balance variable supply and demand. Amongst our focus regions, India and East Africa both have

---

[272] IFC. (2020). "Artificial Intelligence in the Power Sector" https://www.ifc.org/wps/wcm/connect/publications_ext_content/ifc_external_publication_site/publications_listing_page/artificial+intelligence+in+the+power+sector

[273] Ibid.

[274] Adoni et al. (2019) "Blockchain technology in the energy sector: A systematic review of challenges and opportunities" https://reader.elsevier.com/reader/sd/pii/S1364032118307184?token=88DE6C58632901939D666A5CFEC3D4913263F210859B979E806048C22D4AA34DAD9949A08523759BB8918979E9A55F9E

[275] EnergyRev and Technology Collaboration Programme (2019). "Summary of the Global Observatory on Peer-to-Peer, Community Self-Consumption and Transactive Energy Models". https://userstcp.org/wp-content/uploads/2019/10/191004-SummaryGlobalObservatoryLaunchEvent.pdf

[276] Percentage of firms experiencing power outages in a typical month are 25.5% in South Asia (2019), and 8.8% in sub-Saharan Africa.

weaker grid structures, reflected in the frequency of power outages in a typical month – 14 for India and 9 in Tanzania, relative to less than one for countries in Southeast Asia, South America and South Africa.[277]

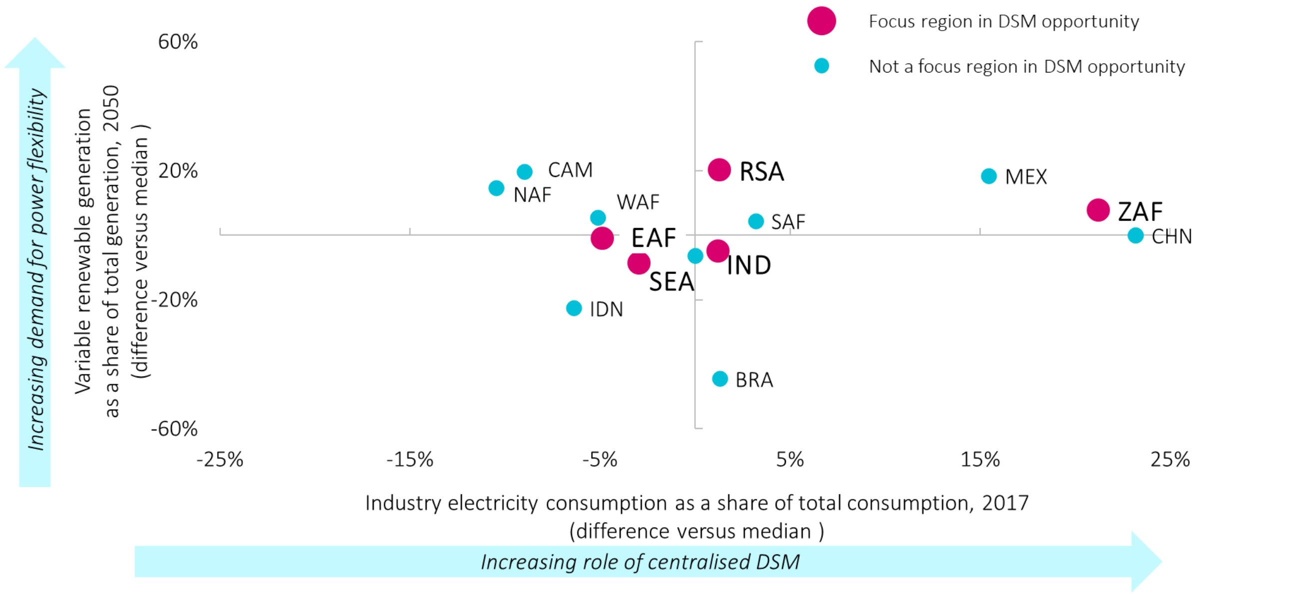
Cost-competitiveness of alternative forms of power flexibility, such as firm renewable generation and underutilised thermal power generation. South America, for example, can achieve higher levels of renewable integration with similar levels of DSM due to availability of firm renewable power – mainly hydropower.

The scale and type of DSM across regions, will vary according to the need for power system flexibility, as well as the composition of local electricity consumers. As set out above, the greater the roll-out of variable renewables, the greater the potential need for DSM. Given that nearly all low and middle-income countries, except for Brazil, are expected to have upwards of 50% variable renewables in their electricity generation, it is evident that demand for power system flexibility will be sizeable in all regions. The nature of the local electricity demand will influence the ease of rolling out DSM and the exact type of the DSM that is required (see Box 11 on DSM categories).

In countries with large industrial demand, such as South Africa, incentives-based mechanisms targeted at industrial users could provide a large degree of the flexibility needed. Figure 16 shows which regions will have a greater demand for power flexibility on the y-axis, proxied by the share of variable renewable generation that is forecast in 2050. Regions which have above the median level of renewable generation are shown in the top two quadrants. It also shows which regions may rely predominantly on centralised vs decentralised DSM on the x-axis, proxied by the increasing share of industry in power consumption today. Regions which have above the median level of industry electricity consumption are shown in the two quadrants on the right. This analysis highlights South Africa as one example where centralised DSM could be rolled out at scale. Countries with a small industrial base, on the other hand, may need to rely primarily on price-based mechanisms targeted at household consumers. Households and businesses account for 60-70% of regional electricity consumption in Central America, Northern and Western Africa, for example. The investment and coordination required to implement these decentralised mechanisms also reduce the scale of the DSM opportunity in the near term.

[277] World Bank. Ease of Doing Business Indicators. Figures reflect the latest year of available data.

Figure 16 Regional demand for DSM will depend on levels of variable renewable generation to 2050 and composition of the electricity consumption



Note: Variable renewable generation in 2050 axis is calculated based on each's regions projected% of variable renewable electricity generation minus the median projected% of variable renewable electricity generation across regions. Projections reflects IMAGE's renewables decarbonisation scenario; Industrial electricity consumption in 2017 axis is calculated based on each region's percentage of industrial electricity consumption minus the median percentage of industrial electricity consumption.

Source: Vivid Economics, ASI and Factor based on IEA World Energy Balances 2019 and PBL's IMAGE model

Transformational change

Demand-side management offers substantial opportunities for transformational change. The greatest potential for transformational change lies with large demand loads, such as in the demand for large industrial needs, heating and cooling in buildings, or the increased demand for EV charging and battery storage. Linking energy storage and DSM to electric vehicles also has significant potential to enable smart and flexible grids. Overall, the scale of change related to DSM is likely to be highest in the near-term where the scope for improving energy efficiency is greatest, such as in South Asia and East Africa, where more focus has been placed on energy generation than efficiency, and where there are significant peak time loads from industry or agriculture that could be flattened with demand management interventions. This is likely to be particularly high in India, and South Asian countries such as Bangladesh and South America, where the efforts on DSM and load spreading has been minimal or only focused in specific sectors such as on industry in India. Regional differences are also driven by the maturity of ICT infrastructure which is necessary to support smart grids and demand response measures. Examples in the target regions of where this is well-developed are Thailand, Vietnam and parts of India, whereas most East African countries should focus on more basic DSM strategies such as reducing transmission losses and improving behavioural change of households and the private sector.

Table 19 Assessment of transformational change

Transformational change criterion	Interventions to support change	Regional potential
Sensitive intervention points		
Improvement of local capacities and capabilities	Support in institutional capacity building and regulatory reform related to DSM, as well as electricity market reform.	India, East Africa, South Africa
Local ownership and strong political will	Demonstrating the cost-effectiveness and environmental impact of DSM, particularly for interventions that rely on process improvement and behavioural change rather than capital expenditure.	East Africa, Southeast Asia, South America
Leverage / creation of incentives for others to act	Electricity market reform and implementation of smart grids, allows industry and households to become more active participants in efficient use of electricity. Behavioural change-focused interventions can help improve the energy efficiency actions of households, business and industry, even without regulatory change or financial incentives.	India, South Africa, South America
Spillovers		
Broad scale and reach of impacts	Potential to reduce large electricity loads at peak times, particularly from industrial and agricultural sectors. Behavioural change initiatives can achieve broad scale in terms of reducing overall energy demand or load spreading, at relatively low cost.	India, East Africa, South Africa
Sustainability (continuation beyond initial support)	Regulatory improvements combined with behavioural change help to ingrain DSM measures for households and the workforce.	All regions
Replicability by other organisations or actors	Improving consumer awareness is an important aspect to promote DSM, helping allow uptake, scale, and replication.	India, East Africa
Innovation		
Catalyst for innovation	Supporting the implementation of smart and flexible grids can enable innovation on digital solutions, integration with electric vehicles and, other energy efficient measures. Smart grids and demand response measures allows linkages to energy storage innovation.	India, Southeast Asia, South America
Evidence of effectiveness is shared publicly	Importance of sharing learning and evidence of what works well and what has failed, or could be improved.	All regions

Source: Vivid Economics, ASI and Factor

Development impact

SDG impacts

DSM would significantly contribute to achieving SDGs in all regions, as set out in Table 20.

Table 20 SDG impacts

SDG	Strength of impact	Most relevant region	Rationale
Positive Impacts			
SDG 7 – Affordable and clean energy	High	India, East Africa, South America (where energy access is lacking to a greater extent)	DSM would enable more reliable energy, helping to reduce power outages. Increased access to affordable power would lead to creation of economic opportunities. DSM also helps to reduce the unnecessary expansion of supply systems, with a positive impact on tariff evolution and energy affordability. For example, studies in a European context show that demand response could result in a 3-4% reduction in electricity wholesale prices.[278]
SDG 8 – Decent work and economic growth	Moderate	All regions	There is a role for energy service companies (ESCOs) and other DSM-related measures to create additional jobs.
SDG 9 – Industry, Innovation and Infrastructure	Moderate	All regions	DSM would support industrial productivity by reducing exposure to power outages, which often hinder businesses and enterprises in many of the target regions. For example, World Bank data shows that in Zambia, this equates to 18% reduction in sales in 2019. For Bangladesh the figure is 5.5% and in India it is 3.7%.[279]
SDG 13 – Climate Change	High	Southeast Asia, South Africa (where a greater proportion of energy is generated from fossil fuels)	More efficient grids and use of electricity should reduce the generation needs, thus reducing fossil-fuel related greenhouse gas emissions.
Negative Impacts			
SDG 13 – Climate Change	Low	All regions	Unintended consequences from increased use of data processing, requiring energy intensive data centres, could lead to substantial additional emissions, if data centres are not powered by clean energy.
SDG 16 - Peace, Justice and Strong Institutions	Low	All regions	Demand response often requires handing over personal or commercial data and even control of devices, at which point there are a set of privacy and control issues that arise and must be handled with appropriate processes and law. There are also ethical considerations regarding the loss of individual control of devices or systems due to automation as part of demand response systems.[280]

Source: Vivid Economics, ASI and Factor

[278] COWI (2016) Impact Assessment Study on Downstream Flexibility, Price Flexibility, Demand Response and Smart Metering. European Union. https://ec.europa.eu/energy/sites/ener/files/documents/demand_response_ia_study_final_report_12-08-2016.pdf

[279] World Bank. (no date). Value lost to electrical outages (% of sales for affected firms). https://data.worldbank.org/indicator/IC.FRM.OUTG.ZS?view=map

[280] European Commission. (no date). Data protection impact assessment for smart grid and smart metering environment. https://ec.europa.eu/energy/topics/markets-and-consumers/smart-grids-and-meters/smart-grids-task-force/data-protection-impact-assessment-smart-grid-and-smart-metering-environment_en

Demand in target regions

Regions such as India, Southeast Asia and South Africa show strong commitment to DSM, evidenced by DSM and energy efficiency policies, but effective and successful implementation has been rare.

Table 21 Demand for DSM

Region	Demand	Rationale
India	Moderate - High	Varied and evolving regulation across states with many past initiatives that have not had the desired impact but can be learned from.
East Africa	Low - Moderate	Varied and improving regulatory environment. Kenya and Ethiopia appear to be more advanced than other countries in energy efficiency policy and strategy.
South Africa	High	Strong regulatory environment driven by government evidenced by various programmes and favourable policies.
Southeast Asia	Moderate	Variable regulatory and policy environment across countries. Efforts by Thailand and Malaysia are promising and Vietnam is making rapid progress in developing policy and initiatives, often with donor support.
South America	Low - Moderate	Peru, Colombia, Uruguay and Ecuador have made limited DSM-related progress, but this has often been done without proper articulation of strategy or coordination between stakeholders.

Source: Vivid Economics, ASI and Factor

East Africa: Eight East African nations have introduced National Energy Plans or Policies (NEPs) to meet growing energy demand with affordable, sustainable energy services that enable socio-economic development. Besides increasing generation capacity and grid coverage, all countries in the region would benefit greatly from improving the efficiency and reliability of grids through demand-side management and smart grids. Kenya's recent laws and policies such as the National Energy Policy[281] and the Energy Act[282] outline efforts and measures to champion energy efficiency. Kenya has also set up the Centre for Energy Efficiency and Conservation. Ethiopia's Growth and Transformation Plan II, identifies energy efficiency as a vehicle to promote economic growth.[283] Rwanda's Energy Policy highlights measures that need to be undertaken to promote energy efficiency.[284]

India: In India, the focus on DSM varies depending on states, with just over half of 36 states and union territories passing regulation while others have issued directives to distribution companies to make it part of day-to-day operations.[285] However, this is happening in a non-uniform way and there are many barriers to state level uptake of effective measures. Industrial sector demand response has been addressed more comprehensively, but there is huge need for DSM, specifically demand response and efficiency in the agricultural sector. Utilities in India have previously been mandated to draw up cost-effective demand-side management action plans and programmes and prioritise them as per their specific needs. The resulting changes have generally been slow and not uniform across the utilities and there is significant demand for support that results in practical and implementable approaches.[286] As India increases its production and generation of energy through solar PV which

281 Republic of Kenya Ministry of Energy. (2018). National Energy Policy. https://kplc.co.ke/img/full/BL4PdOqKtxFT_National%20Energy%20Policy%20October%20%202018.pdf
Republic of Kenya. (2019). Kenya Gazette Supplement: Acts, 2019. http://kenyalaw.org/kl/fileadmin/pdfdownloads/Acts/2019/EnergyAct__No.1of2019.PDF
283 International Energy Agency. (2017). Growth and Transformation Plan II (GTP II) 2016-2020. https://www.iea.org/policies/6372-growth-and-transformation-plan-ii-gtp-ii-2016-2020
284 The Rwanda Energy Policy (REP, 2015) highlights measures that need to be undertaken to promote energy efficiency
285 Chunekar, A. et al (2014) Demand Side Management in India: An Overview of State Level Initiatives. Available at: https://www.prayaspune.org/peg/publications/item/281-demand-side-management-in-india-an-overview-of-state-level-initiatives.html
286 TERI (2015) Demand Side Management in Indian Power Utilities. Available at : : https://www.teriin.org/research-paper/demand-side-management-indian-power-utilities

was higher than all fossil fuel investments in 2018,[287] a focus on demand management is going to be required, as generation cannot increase indefinitely, especially as India's energy use is expected to more than double by 2040.[288]

South Africa: In 2004, South Africa brought in the 'Energy Efficiency Demand Side Management' programme, under the Department of Energy. The programme focuses on regulations, institutional governance structures and targeted financial incentives.[289] South Africa has focused energy efficiency (EE)/DSM efforts predominantly on manufacturing as it accounts for around a third of energy use. This includes energy management systems, behaviour change, and implementing ISO50001. Behavioural changes of household consumers and industry customers are important elements of this initiative. DSM initiatives have also been implemented by members of the Southern African Power Pool (SAPP), of which South Africa is an influential member, since 2009. These generally comprise energy efficiency measures implemented by participating utility companies, such as Compact Florescent Lamps, Commercial Lighting, Hot Water Load Control and Solar Water Heaters.[290]

South America: several South American countries have National Energy Efficiency Laws in place (Peru, Colombia, Uruguay and Ecuador – Argentina is preparing one). The market in Colombia allows some indirect demand response, but it is not a strong example of a DSM programme. While Peru seems to have robust, although outdated mechanisms and laws in place to promote energy efficiency, via Peru's Efficient Use of Energy Promotion Law, published in 2000. [291] Other measures which Peru has in place include Directorate General for Energy Efficiency and its Energy Policy 2010-2040. Argentina has taken some recent measures to promote energy efficiency. An example of this is an energy efficient labelling regulation for new social housing, which states that the calculation of the Energy Performance Index for all social housing built with national government funds must be submitted for approval via an online tool provided through the national residential building labelling programme Some of the other measures taken by the Argentinian government include the National Programme for Rational and Efficient Use of Energy, Argentinean Energy Efficiency Fund and Programme to Promote Use of Renewable Energy in Electricity Generation.[292] Energy Service Companies (ESCO's) - service providers that help clients to save energy by evaluating their energy use, developing and designing a project to lower the client's energy bills, and implementing the project - are still incipient agents in South America as legislation and regulation do not facilitate necessary contracts with the public sector, in particular. Other instruments, such as mandatory codes and minimum efficiency standards, are still not a common practice in South America, apart from a limited range of electrical appliances in Argentina and Ecuador.

Southeast Asia: The region's growth in electricity demand, at an average of 6% per year, has been among the fastest in the world and met largely by fossil-fuel generation. There is a vital role for DSM to play an improving the efficiency of electricity distribution and reducing peak load and related fossil-fuel generation. Within Southeast Asia, Thailand has made great strides and been an early adopter of DSM. It initiated a USD 189m programme in 1993. Since then, the electricity authority has developed a portfolio of 19 programmes and substantially surpassed its original targets.[293] In Malaysia DSM was

[287] IEA (2020) India is going to need more battery storage than any other country. Available at : https://www.iea.org/commentaries/india-is-going-to-need-more-battery-storage-than-any-other-country-for-its-ambitious-renewables-push
[288] IEA (2020) Energy Efficiency in India. https://www.iea.org/articles/energy-efficiency-in-india
[289] IEA. (2019.) Energy Efficiency and Demand Side Management (EEDSM) Programme. https://www.iea.org/policies/578-energy-efficiency-and-demand-side-management-eedsm-programme
[290] ESI Africa. (2009), Implementation of Demand Side Management in the Southern African Power Pool. https://www.esi-africa.com/industry-sectors/energy-efficiency/implementation-of-demand-side-management-in-the-southern-african-power-pool/
[291] Asia-Pacific Economic Cooperation. (2020). Follow-Up Peer Review on Energy Efficiency in Peru https://aperc.or.jp/file/2020/4/7/Follow-Up_PREE_Peru.pdf
[292] International Energy Agency. (no date). Policies Database: Argentina. https://www.iea.org/policies?country=Argentina
[293] Electricity Generating Authority of Thailand. Accessed July 2020. Available at: https://www.egat.co.th/en/sustainable-development/demand-side-management

given focus in the 11th Malaysia Plan.[294] More generally, the Asian Development Bank is focusing on boosting investment in user demand energy efficiency.[295]

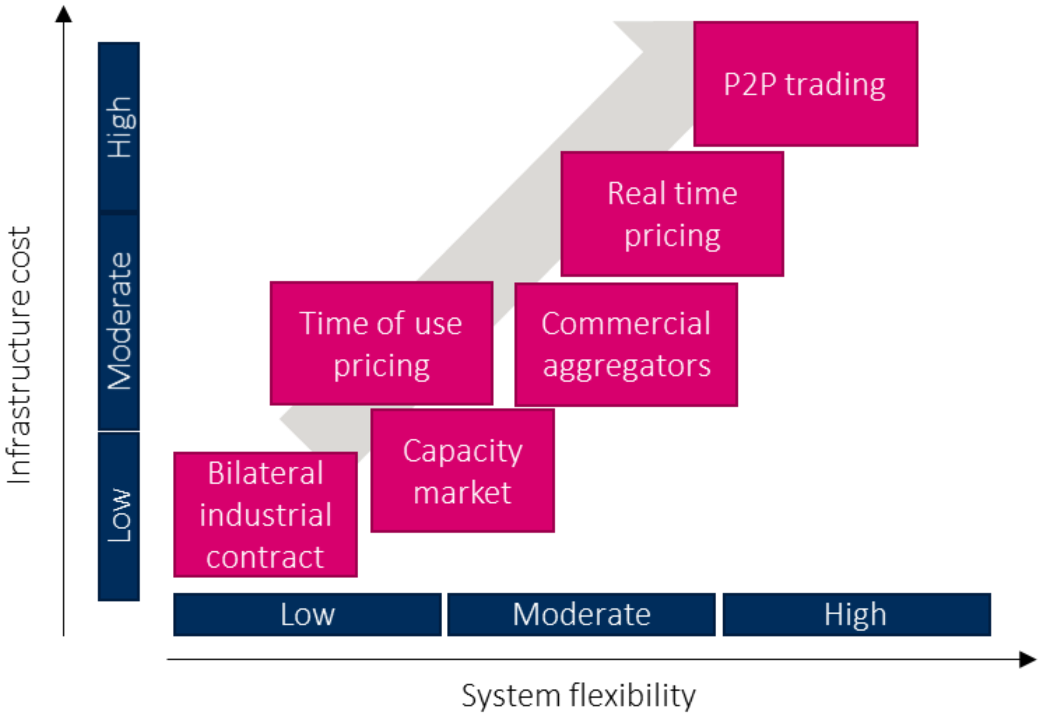
---

[294] Eleventh Malaysia Plan (2016-2020) available at: https://policy.asiapacificenergy.org/sites/default/files/11th%20Malaysia%20plan.pdf
[295] ADB (2013) ADB Aims to Accelerate Demand-side Energy Efficiency Investments. Available at: https://www.adb.org/news/adb-aims-accelerate-demand-side-energy-efficiency-investments

Investment need

Capital investment need for centralised DSM is typically negligible, but significant costs are incurred through the payments to curtail power demand and, to a lesser extent, encourage behavioural change. Centralised DSM, such as bilateral contracts with industry and time-of-use pricing will typically require no infrastructure investment and can therefore be rolled out with extremely low levels of capital investment (as shown in Figure 17). Nevertheless, some investment is typically needed to design an appropriate incentive mechanism and ensure appropriate metering and monitoring infrastructure is in place. Further, high costs will often be incurred in the delivery of centralised DSM to effect a shift in behaviour of power consumers. In the case of bilateral industrial contracts there are often high costs related to contracted payments provided to industrial units upon an agreed reduction in their demand. Time-of- use pricing will often need to be complemented by investment in behavioural change policies (e.g. energy audits, feedback measures, and educational sessions) to effect a change in demand, though associated costs of behavioural policies are small, in the hundreds of thousands.[296]

Figure 17 Investment need increases the greater the level of flexibility and decentralisation



Source: Vivid Economics, ASI and Factor

More substantial levels of infrastructure investment will be required to enable decentralised DSM, requiring greater deployment of smart metering and smart end-use systems, as well as improved data processing. Approximate cumulative investment needs are upwards of USD 2 trillion by 2050.[297] This investment is necessary to deliver smart grids. The degree to which grids are transformed into smart grids will vary per region. Broadly this will be guided by a trade-of between the level of flexibility required, and the cost of the necessary infrastructure (see Figure 17). Despite these higher infrastructure costs, smart grids may deliver

[296] For instance, a cost of EUR 115,000 was associated with Durham City Council's training and awareness program on energy conservation, which allowed schools to access energy consumption data and attend educational sessions. See: OECD (2017). "Tackling Environmental Problems with the Help of Behavioural Insights".

[297] Calculated based on forecast of cumulative investment need in global electricity networks in the IEA's beyond 2-degrees (B2DS) scenario. To arrive at a rough estimate of investment required in smart grids in low- and middle-income regions, this number is a) scaled to reflect investment need in low- and middle-income regions and b) multiplied by the share of current investment in smarts grids (https://www.iea.org/reports/smart-grids). As this estimate is based on historical spending on smart grid infrastructure it is likely an underestimate of future investment required.

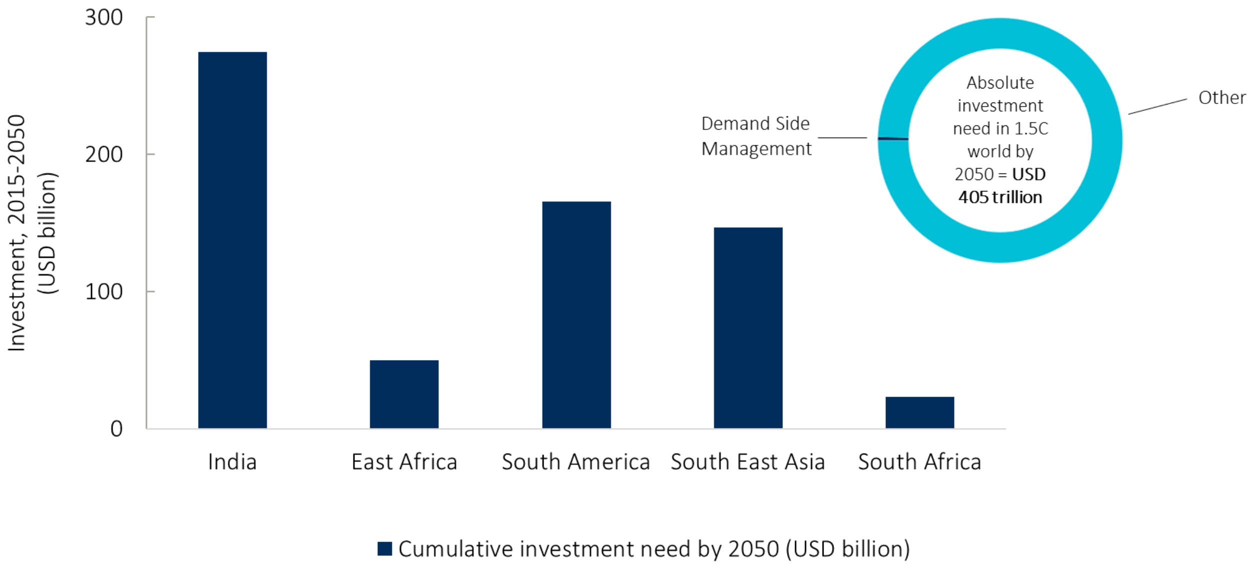
flexibility at a lower cost than centralised DSM due to the costs associated with changing consumer behaviour outlined above. Amongst others, investments include:

- Consumer infrastructure. To increase demand-side flexibility by consumers will require infrastructure that allows the bi-directional flow of information to and from the grid, such as advanced metering systems; smart end-use systems that are able to respond in real-time to price signals provided by the grid, such as smart heat pumps; and distributed energy resources, including BTM storage systems, that allow consumers to provide energy to the grid.
- Grid infrastructure. Required grid infrastructure can broadly be split into two areas:
  - Widespread deployment of sensors to allow for real-time monitoring of grid assets. Typically, this is already in place at the transmission and high voltage substation levels, but this will also be required at the distribution level to enable decentralised DSM.
  - Deployment of advanced control systems at the distribution level. This includes digitalised transformers and other key smart grid technologies such as fault current limiters.
- IT and Communications. To utilise the flows of information and allow real-time optimisation of the grid will require a range of interconnected information systems that gather and process data to create signals for the grid electricity network and power consumers. Investments will be needed in machine learning algorithms, for instance, that can provide meaningful signals to a grid operator on an optimal generation or distribution based on historical performance and current data. The influx of information created by communicating equipment (e.g. smart meters) is only as valuable as the quality of the data management systems in place.

Box 12 provides some specific examples of DSM related investments, and their costs.

Electricity demand and renewable penetration will drive different levels of regional investment in DSM. Figure 18 provides a rough indication of the regional investment needed to support DSM. This only coarsely considers the different choices different regions can make around flexibility delivery. The scale of investment in a region is reflective of the relative size of household electricity consumption - highest in India, which could require nearly USD 300 billion in smart grid infrastructure to 2050. South America and Southeast Asia are also likely to require relatively larger smart grid investments, approximately USD 150 billion in each region. Far lower levels of investment are expected in East Africa and South Africa, due to far smaller household electricity networks – here, investment need is in the tens of billions.

Figure 18 Scale of investment need is in the order of hundreds of billions within focus regions



Note: Investment need calculations are projected based on a) total investment need required in a 1.5 degrees scenario b) current proportion of investment in smart grid infrastructure, and c) relative demand for smart grid infrastructure in a region, which is calculated based on the share of household electricity demand (TWh) in that region relative to low and middle-income countries as a whole.

Source: Vivid Economics, ASI and Factor based on IEA Energy Technology Perspectives (2017) and IEA World Energy Balances (2019)

Box 12 Examples of the types and magnitude of investment needed

Costs of a smart meter rollout have been estimated to be in the tens of billions. In the UK, costs associated with the Smart Metering Implementation Programme, which has overseen the installation of 17 million smart meters to data, are estimated to be approximately GBP 13 billion (USD 17 billion).[298] France's roll-out of 35 million smart meters is estimated to cost EUR 4.5 billion (USD 5.3 billion).[299] This gives an approximation of the scale of investment needed to initiate a smart meter roll-out, which will, of course, vary significantly depending on the scale of residential users and country specific costs of installation. Per smart meter installation costs in France are estimated to be EUR 150 to 200 (approximately USD 180 to 240). Far lower installation costs are likely in low and middle-income countries. In India, for example, it is estimated to cost USD 21 billion for the country's planned 250 million meter roll-out, which would imply costs of around USD 80 per smart meter installed (which would in this case include factors besides assets and installation). Similarly, Vinte, a large-scale developer of affordable green homes in Mexico, has installed smart meters in its solar-powered residences – and each of these meters costs Vinte as little as USD 40.

Historically, most investment has been associated with costs of infrastructure and installation, while a smaller share of around 20% has been invested in IT and data management systems. Out of the UK's estimated costs of a smart meter rollout, 56% are expected to be related to installation and asset costs,

[298] BEIS (2019). "Smart Meter Roll-out. Cost-Benefit Analysis 2019". https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/831716/smart-meter-roll-out-cost-benefit-analysis-2019.pdf

[299] Smart Energy International (2018). "Smart meters 101: France's Linky electricity meters". https://www.smart-energy.com/features-analysis/smart-meters-101-frances-linky-electricity-meters/

and 21% to the costs of the UK's data and communications company (DCC).[300] A similar breakdown has been estimated in France, whereby 80% of smart meter roll-out costs are associated with procurement and installation of meters, 10% with data concentrators and 10% with an IT system.[301] As of early 2019, 55 million smart meters were installed across 50 emerging countries in Latin America, the Middle East, Africa, Central and Eastern Europe, South Asia, and Southeast Asia. Between 2019 and 2023, 270 million smart meters or Advanced Metering Infrastructure (AMI) devices will be deployed in emerging markets.[302]

In the long term it is likely that data management systems and IT networks take an increasing share of investment need. Examples of investment are associated with relatively nascent smart meter systems, which have typically chosen to prioritise the physical installations of household metering infrastructure rather than the data systems to control and manage information. There is therefore large room to increase investment in data management systems in the future, as countries move towards a more automated and price-based DSM, at the top right of Figure 18.

[300] BEIS (2019). "Smart Meter Roll-out. Cost-Benefit Analysis 2019". https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/831716/smart-meter-roll-out-cost-benefit-analysis-2019.pdf

[301] Smart Energy International (2018). "Smart meters 101: France's Linky electricity meters". https://www.smart-energy.com/features-analysis/smart-meters-101-frances-linky-electricity-meters/

[302] IFC (2020). "Artificial Intelligence and the Future of Smart homes". https://www.ifc.org/wps/wcm/connect/6fc5b622-05cb-4ee9-b720-ab07591ac90e/EMCompass-Note-78-AI-Smart-Homes.pdf?MOD=AJPERES&CVID=n0S3dro

Cost-effectiveness

DSM is in principle a low-cost measure but there may be a cost associated with overcoming barriers to delivery, and this is poorly understood. Centralised DSM requires minimal capital investment, and so in theory is relatively cost-effective (on a GBP/tCO2 basis) compared to other energy opportunities, which require large amounts of capital infrastructure. This does not imply, however, that there are zero costs of DSM. Non-negligible costs associated with the payments to industrial users to curtail demand ought to be considered, and these have been high historically. The cost-effectiveness of decentralised DSM will be relatively lower, due to substantially higher costs of setting up a 'smart grid'. However, considering the energy service provided and the costs of alternative forms of power flexibility on a large scale (such as the build out of additional renewable capacity), decentralised DSM is still relatively cost-effective mitigation opportunity.

The benefits of DSM will vary per region, and extend beyond its climate benefits, affecting the cost-effectiveness of DSM measures. The climate benefits of DSM will depend on the level of variable renewable penetration to 2050, and hence demand for power system flexibility. It will also depend on the potential to use DSM to encourage greater energy efficiency among consumers. DSM will therefore be most cost-effective on a GBP/tCO_2 basis in regions with lower energy efficiency and higher variable renewable generation expected to 2050. Non-climate impacts could also increase the relative cost-effectiveness of DSM measures. For example, in regions where grid outages are frequent, such as India and the rest of South Asia, DSM is relatively cost-effective for both reducing emissions and improving energy access simultaneously.

Similarly, decentralised DSM's relative cost-effectiveness varies across regions depending on the costs associated with achieving demand flexibility:

Alternatives forms of power system flexibility, specifically the availability and costs of storage and firm power will affect relative cost-effectiveness of DSM opportunities. South America (particularly Brazil) and East Africa are two regions where pumped hydropower could, for example, provide the power flexibility required to integrate higher variable renewables.

Behavioural inertia, with effectiveness of any intervention dependent on the degree to which it can encourage significant changes in demand of power consumers. These changes will depend on the regulatory incentives to change behaviour, the communication of benefits from DSM and the ease of DSM transactions (for example, lengthy contractual procedures are likely to lead to lower uptake). For instance, experiments in the USA suggest that non-price interventions could help deliver energy savings equivalent to a short-run electricity price increase of 11 to 20%, highlighting that price-based interventions will, by themselves, be a costly method to achieved desired changes in behaviour due to behavioural inertia.[303] Given this inertia, the effectiveness of behavioural change policies will be the key driver of cost-effectiveness. A South African company, International Housing Solutions, helps deliver savings equivalent to one month's rent each year by educating its customers on how to use pre-installed smart meters.[304]

Latent flexibility, with some regions having an inherently larger capacity for providing power flexibility, depending on the key sources of consumption. Some industries and businesses, such as data centres, can more freely optimise demand without affecting output. On the other hand, some industries could find it far more costly to modulate demand, such as textile or manufacturing industries. Household appliances will also differ in their ability to optimise demand in response to price signals -

[303] The experiment refers to programs run by OPOWER in the USA, to send Home Energy Report letters to residential customers comparing their electricity use to that of their neighbours. The average program reduces energy consumption by 2%, but the effect is heterogenous across households of different income levels. See Allcott. (2011). "Social norms and energy conservation". https://www.sciencedirect.com/science/article/abs/pii/S0047272711000478?via%3Dihub

[304] IFC (2020). "Artificial Intelligence and the Future of Smart homes". https://www.ifc.org/wps/wcm/connect/6fc5b622-05cb-4ee9-b720-ab07591ac90e/EMCompass-Note-78-AI-Smart-Homes.pdf?MOD=AJPERES&CVID=n0S3dro

air conditioners, for example, are well suited to modulate demand at regular intervals without affecting the service they provide.

Level of supporting 'smart grid' infrastructure, such as the degree to which a region already has deployed advanced metering and management systems. Gradual deployments of infrastructure in some regions may increase the cost-effectiveness of future interventions. Brazil, South Africa, and Southeast Asian countries (Thailand, Malaysia and Vietnam) are among the countries who have begun to use smart grids.[305]

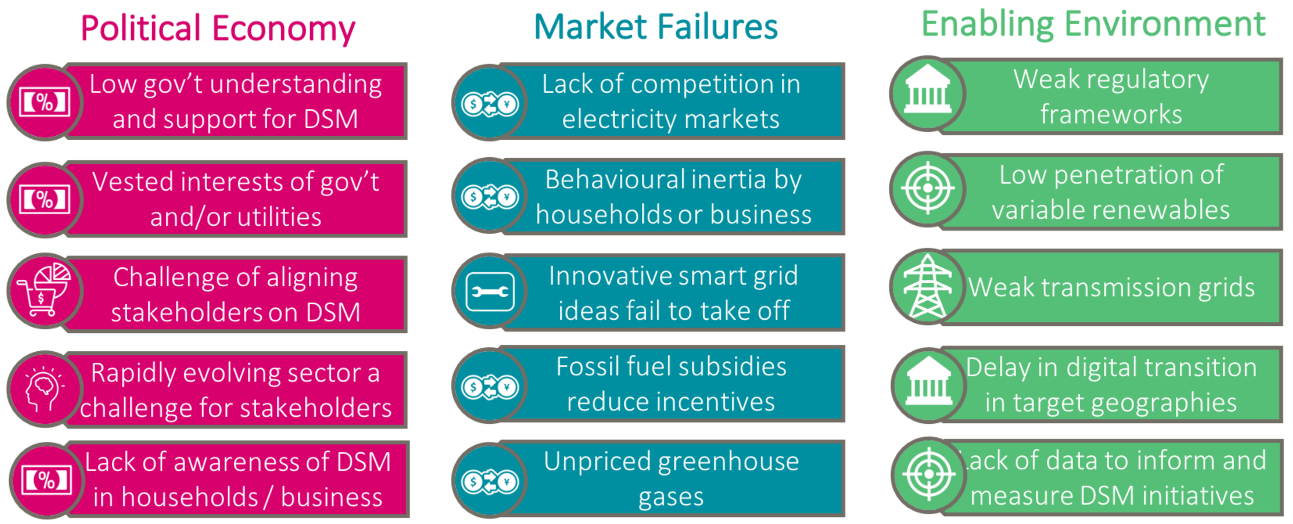
Regulatory and policy inertia. More than other energy opportunities DSM requires the creation of a new market for flexibility and grid optimisation via concerted policies and regulation. The costs of achieving required policy changes will affect the cost-effectiveness of nearly all forms of DSM.

[305] IEA. (2019). Smart grids https://www.iea.org/fuels-and-technologies/smart-grids

Barriers to adoption

The largest barriers to DSM in regions where the opportunity offers the greatest mitigation potential are those related to i) political economy challenges, ii) market failures and iii) enabling environment. These barriers are not critical to inhibiting investment, as the potential of DSM is widely recognised and investment levels growing in all regions. However, if not addressed they are likely to slow down the potential growth of this opportunity. Our typology of barriers is provided in the Methodology chapter in the Synthesis Report.

Figure 19 Barriers to an opportunity



Source: Vivid Economics, ASI and Factor

<u>Political economy</u> barriers to implementation are likely to be:

- Implementing DSM initiatives can require alignment between a wide range of stakeholders including regulators, utility companies, distributors and customers. This can be challenging, as demonstrated with South Africa's Energy Efficiency and DSM programme. The Standard Offer approach, proposed in 2008 and already practised in Australia, India, the U.S., and other countries, would allow Eskom to purchase energy savings from ESCOs and customers using a pre-determined and pre-published price. However, the first round of negotiations failed to agree on pricing and terms. Since then the model has been successfully adopted.[306]

- The required leadership and investment by national and municipal governments in providing incentives for consumers to engage in DSM can be a critical barrier. Often there is a clear disincentive for municipalities to lead or participate in energy efficiency measures, as they are heavily reliant on the revenue from the sale of electricity. In South Africa, for example, revenue from electricity sales can account for 24 to 35 % of total municipal revenues.[307]

- Poor government awareness of the benefits and unintended consequences that could be realised from DSM, and how it fits into the wider global goals of increased energy access and reduced emissions can be a barrier. Traditionally, most focus in the target regions has been on energy generation as opposed to demand-side management. The two are different sides of the same coin and must be considered in unity, as DSM can reduce network investment costs and improve reliability of electricity supply. However, the potential 'rebound effect' of DSM measures must be

[306] ESMAP. Implementing Energy Efficiency and Demand Side Management: South Africa's Standard Offer Model. http://documents1.worldbank.org/curated/en/763421468008714696/pdf/690330ESM0P1180SouthAfrica0WebFinal.pdf

[307] Covary, T. (2016) Overview and assessment of the energy efficiency and energy conservation policies and initiatives of the Republic of South Africa

considered as greater efficiency makes an energy-consuming technology less expensive to use, so people use it more often. This can offset the energy saved by efficiency measures, which highlights the importance of behavioural change interventions to also help reduce electricity usage. This has been observed particularly strongly in the Indian context.[308]

- There is also often a lack of governance structure for planning, implementing and evaluating DSM efforts. In South America, for example, it is common to see that several agencies promote and implement DSM efforts without coordination and articulation. This is particularly the case in Colombia and Uruguay.[309]
- Furthermore, lack of awareness or thorough analysis means that government-led DSM policies that are put in place, can miss key sectors or approaches that can yield significant energy savings at minimal costs. For example, a recent study showed that while literature suggests that energy-saving behaviour could reduce energy demand by a maximum of 21.9 %, Bangladesh's 2015 Energy Efficiency and Conservation Master Plan (EECMP) does not consider energy-saving behaviour at all.[310]
- Even if DSM policy is implemented at the national level, there is often a lack of government capacity at state or regional level to cascade this into local level policy and mandates for utility companies, industry and other stakeholders. For example, in India around half of 36 states have passed regulations on DSM but only a six or seven have issued directives to distribution companies to make it part of day-to-day operations.[311]
- There is often a general lack of awareness and understanding of DSM measures in companies and industries in the target regions. Most companies do not have dedicated resources to scrutinise energy use and potential for efficiency. For example, a study on Ugandan and Indian small enterprises found that managers often lacked basic business skills and were thus unable to correctly calculate payback periods and savings potential, which presented a strong barrier to energy efficiency investments.[312]
- As such a rapidly evolving energy sector is challenging for stakeholders to keep up with. As energy generation switches to a greater proportion of variable renewables and distributed energy resources, DSM programmes will also need to align with distributed energy management and resource flexibility goals. Furthermore, even when DSM measures become higher profile, the concept of 'tunnelling' can help explain why managers in business and industry may not engage with them or take them forward. This mindset causes changes in decision-making methods, causing people to magnify costs while minimising benefits.[313]

Severe market failure barriers to investment or adoption are likely to be:

- Immature and uncompetitive electricity markets that exist in many countries, particularly in East Africa and South America, do not incentivise DSM investments by households or the private sector.
- Behavioural inertia and the 'attitude-behaviour gap' at household and industry levels can be a barrier as people tend to stick with what they know and are used to, rather than making changes that could be beneficial to their finances and the environment. For example, research by Ofgem in the UK[314] found that UK consumers tend to stick with the default service plan option, even if it is substantially

[308] Thapar, S. (2020) Energy consumption behavior: A data-based analysis of urban Indian households. Energy Policy Volume 143 (Link)
[309] Gilberto De Martino, J. (2017) 'Energy Efficiency and Renewable Energy in Latin America: Policies towards Sustainable Development'. International Area Studies 21 (2): 9–22. (Link)
[310] Khan, I. (2019)Energy-saving behaviour as a demand-side management strategy in the developing world: the case of Bangladesh. International Journal of Energy and Environmental Engineering, 493-510. (Link)
[311] Chunekar, A. et al (2014) Demand Side Management in India: An Overview of State Level Initiatives. Available at: https://www.prayaspune.org/peg/publications/item/281-demand-side-management-in-india-an-overview-of-state-level-initiatives.html
[312] Pegels, A, Figueroa, A, Never, B. (2018) The Human Factor in Energy Efficiency: Lessons for Developing Countries. German Development Institute.
[313] Mullainathan, S. and Shafir, E. (2013): Scarcity. Times Books: New York.
[314] Ofgem (2019) Applying behavioural insights to forward looking charging reform: Results from a literature review by Ofgem's Behavioural Insights Unit. Link

more expensive than the alternatives. Instead, behaviour can be influenced via non-financial incentives and clear information and messaging. A study by Never (2014) finds that many of the behavioural factors proven to be barriers in developed economies, which may be relevant for energy efficiency in developing countries, remain untested at this point.[315] Never does highlight some relevant examples related to energy efficient lighting in Ghana, Uganda and Rwanda, finding that behavioural levers are only likely to work in a policy package that addresses wider technical, market and institutional barriers to energy efficiency. Not many developing country behavioural examples have been identified in more recent literature, although a study by Tavares da Silva and Gabriela Prata Dias (2020)[316] on energy efficiency in developing countries provides some useful analysis and evidence. Examples from other sectors such as more hygienic practices for drinking water delivery in Kenya, can also offer some behavioural change insights.[317]

- There are high costs and investment risks (such as currency volatility and political stability particularly in East African countries), involved in smart meter roll-out programmes, which is the infrastructure that allows consumers to reduce their demand in response to higher prices during peak periods.

- Internal competition for capital and resources can limit the potential for industry-focused DSM measures. Manufacturers often have limited capital available for end-use efficiency projects and frequently require very short payback periods (one to three years).[318] Financial matters are still the driving force behind energy efficiency investment decisions, meaning no- and low-capital improvement options, often based on behavioural change strategy, are still preferred.[319] Furthermore volatile energy prices can create uncertainty in investment returns, leading to delayed decisions on DSM projects.

- Unpriced carbon leads to a lack of the true cost being reflected in energy use, reducing incentives for generators and consumers to support more flexible and cost-effective solutions.[320] This is further compounded by continued fossil fuel subsidies. For example, a recent Overseas Development Institute (ODI) study highlights how South Africa subsidises coal by USD 3.2 billion per year.[321]

- Innovation support is also needed to support inventions related to ICT and digitalisation, including AI and blockchain, and linking with smart grids. While many good ideas exist, in relation to smart grids and the use of digital innovation, these can sometimes be expensive and difficult to test, and therefore never reach full potential, particularly when many stakeholders need to align on the process and agree on the rationale for upfront investment.[322]

Moderate enabling environment / absorptive capacity barriers to investment or adoption are likely to be:

Lack of government institutional capacity to develop policy and regulations to enable DSM measures to be implemented and enforced, such as in regions like East Africa or much of Southeast Asia. Alternatively, existing policy may be in place but is not the most appropriate framework for flexible solutions. A lack of regulation of industry to support behaviour change and DSM may present barriers to adoption, especially for countries which rely heavily on manufacturing and selling at low cost, such as India, The Philippines, Vietnam and Ethiopia. In some cases, this could be mitigated by an ESCO model, although in India, EESL, the world's largest ESCO, is working in every dimension of EE and DSM and yet inefficiencies and barriers still exist. However, it should be noted that regulation and

[315] Never, B (2014) Making Energy Efficiency Pro-Poor: Insights from Behavioural Economics for Policy Design. Deutsches Institut fur Entwicklungspolitik. Discussion Paper 11/2014. (Link)
[316] Tavares da Silva, S. and Prata Dias, G. (2020) Energy Efficiency in Developing Countries: Policies and Programmes. Routledge. (Link)
[317] Source: https://www.unenvironment.org/news-and-stories/story/nudge-action-behavioural-science-sustainability
[318] Pegels, et al. (2018) The Human Factor in Energy Efficiency: Lessons for Developing Countries. German Development Institute.
[319] Ibid.
[320] CMS Law Now. (2016). DSR, Energy Storage and Smart Grids: Key proposals for the UK's Smart Energy System
Available at: https://www.cms-lawnow.com/ealerts/2016/01/dsr-energy-storage-and-smart-grids--key-proposals-for-the-uks-smart-energy-system
[321] ODI. 2019 *"G20 Coal Subsidies: South Africa"* https://www.odi.org/publications/11369-g20-coal-subsidies-south-africa
[322] Kappagantu & Arul Daniel. (2018) Challenges and Issues of Smart Grid Implementation: A case of an Indian scenario. Journal of Electrical Systems and Information Technology. Volume 5, Issue 3.

financial incentives are not the only solutions for DSM and a range of behavioural change methods can also be effective, as highlighted in the case studies in Section 0.

The absence of good and reliable statistical information on electricity customer use, including disaggregated load curves, hampers a proper evaluation of DSM interventions and resources, as well as the evaluation of DSM programmes. This is a typical constraint in India, East Africa and many lower-income Southeast Asian and South American countries.

In relation to smart grids and enabling technology for some demand response measures, a poor digital ecosystem and lack of awareness of ICT -based solutions (including AI and blockchain) is a major barrier in many of the target regions, particularly in East Africa and South America. A strong enabling environment for ICT innovation and smart grids is important to maximise DSM opportunities. For example, a lack of widespread adoption of interoperability and open standards can be a barrier if many different devices and systems need to communicate in a robust demand response programme. Demand response is hindered if technologies from different vendors do not interoperate seamlessly.

Weak transmission grids, particularly in East Africa, India South Africa and lower-income countries in Southeast Asia such as Myanmar, is a significant barrier to the uptake of smart grids, as well as effective demand response measures.

Lack of an informed workforce or public can be a major barrier to the successful uptake of DSM measures, particularly related to industry or household-scale initiatives to shift peak demand with TOU pricing or other behavioural change focused incentives. For example, India has found widespread consumer awareness to be a key enabler of effective DSM measures in the industrial sector, along with measures such as TOU pricing.

UK additionality

The UK's additionality is particularly strong in knowledge sharing from the UK domestic experience

- The UK's private sector has extensive experience in smart grid research, development and implementation and there are opportunities for partnerships, local assembly and accelerators that leverage UK private sector and academic expertise. The UK also convenes an annual forum on smart grids, working with Ofgem, and key stakeholders which works across nine workstreams focusing on issues including frameworks, networks, and commercial and regulatory challenges.[323]

- The UK has focused on demand-side management with increased national campaigns over recent years, including the focus on smart meter installations. In addition to encouraging households to request smart meters, the government placed targets upon energy suppliers for uptake, which encouraged the uptake. This dual approach to both consumer and supplier could be replicated in some of the target regions and place strong additionality in helping other governments learn from the UK experience.

- The UK has provided considerable support to innovation in clean and efficient energy, for example through *Carbon Limiting Technologies*, the largest clean tech incubator in the UK, which has supported over 350 companies as well as managing BEIS's GBP 72m *Energy Entrepreneurs Fund* for the past several years. Establishing funds and extending similar incubation support to companies working in, or looking to expand, into other regions could be very valuable and provide strong additionality.

- The Behavioural Insights Unit at Ofgem was established in 2016 to apply behavioural science to the regulation of the British energy market.[324] Relevant learning and processes of analysis could be drawn on in support for target regions.

- The UK demonstrates strong investment and expertise in energy efficiency, including the Energy Company Obligation Scheme (ECO) and efficiency in buildings.

Donor activity in this opportunity is principally driven by the World Bank, the European Union (EU), the Asian Development Bank, United States Agency for International Development (USAID), MCC, Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ), KfW, the Inter-American Development Bank, and United Nations Industrial Development Organisation (UNIDO). Some notable interventions include:

- The World Bank has active programmes that feature DSM to some extent across Asia and Africa,[325] including the "Demand-Side Management and Energy Efficiency Project" in Vietnam (USD 18m),[326] as well as continued interventions and projects under the the Energy Sector Management Assistance Program (ESMAP).

- The Asian Development Bank's investment in large DSM programmes in India, one which is due to close in 2021 and the other in 2025. These combine loans for capital expenses with technical assistance grants to support the development and implementation of energy efficiency measures.[327]

---

[323] Ofgem. (no date). DECC and Ofgem Smart Grid Forum. https://www.ofgem.gov.uk/electricity/distribution-networks/forums-seminars-and-working-groups/decc-and-ofgem-smart-grid-forum

[324] Ofgem (2019) Applying behavioural insights to forward looking charging reform: Results from a literature review by Ofgem's Behavioural Insights Unit.

[325] World Bank. (no date). Projects. https://projects.worldbank.org/en/projects-operations/projects-list?searchTerm=%22demand%20side%20management%22

[326] World Bank. (2002). Viet Nam - Demand-Side Management and Energy Efficiency Project (English). https://documents.worldbank.org/en/publication/documents-reports/documentdetail/434891468780588320/viet-nam-demand-side-management-and-energy-efficiency-project

[327] Asian Development Bank. (2019a). India: Demand-Side Energy Efficiency Sector Project. https://www.adb.org/projects/48224-002/main#project-pds and Asian Development Bank (2019b). India: Scaling Up Demand-Side Energy Efficiency Sector Project. https://www.adb.org/projects/52196-001/main#project-pds

- The EU's EUR 4 million programme to support Argentina's Energy Efficiency Plan.
- USAID's Jordan "Energy Capacity Building Activity" (2013-2017), which includes a focus on demand-side mechanisms. [328]
- GIZ's 'Smart Grids for Renewable Energy and Energy Efficiency' programme, which includes DSM.[329]

In regions with the largest mitigation potential, UK typically has moderate experience in delivering DSM related support, with most programmes of support focusing on smart green grids and integration with storage.

- Most programmes of support focus on combining loans for large-scale interventions alongside technical assistance. Fewer programmes and donors have focused on smaller scale programmes, particularly those that look at AI, smart-grids and behaviour change policies, although an exception is an innovation fund on AI solutions run through the ICF. Given the UK's strong experience in innovation programming, there could be real additionality in continuing to foster new solutions in the smart grid space.
- For example, the the UK Department for International Development (DFID, now part of the Foreign, Commonwealth and Development Office (FCDO)) funds the *Africa Clean Energy Programme* (2016-2021, budget of GBP 65 million) works across 14 priority countries to catalyse a market-based approach for private sector delivery of solar products and services.[330]
- DFID's global *Low Energy Inclusive Appliances Programme* is a research and innovation programme that seeks to double the efficiency and half the cost of a range of electrical appliances suited for off- and weak-grid household, small business, and industrial consumers. It deploys a range of interventions from market stimulation to education and awareness raising.
- The DFID *Transforming Energy Access programme* in sub-Saharan Africa is also providing relevant support in relation to DSM opportunities, mainly increasing the uptake of efficient appliances.[331]
- In India, the *Supporting Structural Reform in the Indian Power Sector* programme which aims to support structural reforms in the Indian power sector has created a *Smart Grid Readiness Assessment Tool*, to assess utility readiness.[332]
- In a 2016 survey on top ICT for development trends among DFID advisors, household/community-scale batteries and smart grids were placed second and third, respectively. [333] The *Frontier Technologies Livestreaming programme* has piloted ideas suggested by DFID staff as they relate to these overarching areas.

[328] https://escb-jordan.org/
[329]GIZ. (no date). Smart Grids for Renewable Energy and Energy Efficiency. https://www.giz.de/en/worldwide/62816.html
[330] FCDO. (2020). Africa Clean Energy Programme (ACE). https://devtracker.dfid.gov.uk/projects/GB-1-204637
[331] DFID (2016) Business Case: Transforming Energy Access for Households and Improved Livelihoods (TEA)
[332] DFID (2019) Annual Review 2019 for Supporting Structural Reform in the Indian Power Sector. Available at : http://iati.dfid.gov.uk/iati_documents/46047872.odt
[333] Simpson, L. (2019) Blog: Frontier Technologies Tech Survey Results. Available at: https://medium.com/frontier-technology-livestreaming/frontier-technologies-tech-survey-results-24be0eaae18d

Intervention opportunities

To alleviate the barriers set out in Section 0, there is substantial opportunity across all regions for the UK to draw on core strengths and areas of additionality, to deliver demand-side management interventions in the following areas:

General support to government to set up appropriate DSM strategy, policy and regulations

- Help governments define a holistic DSM strategy with a focus on key sectors that are likely to yield high energy savings. For example, in India, DSM measures have been applied to heavy industry and now the agricultural sector has significant potential to improve efficiency across a wide range of appliances including irrigation pumps. Such a strategy requires needs-based research, for example, exploring high potential for distributed DSM through off-grid renewables (mini-grids, interconnected mini-grids, and standalone home systems) helping to meet significant demand in the micro and small and medium enterprises (SME) sector. Data collection surveys are also often necessary to develop a robust picture of the existing consumer baseline, such as appliance ownership, equipment models and sizes, current practices, etc. Resulting intervention support could include technical assistance to national governments on regulatory, financial, or tax-related mechanisms improvement and DSM measures, across household, business and industry levels, time-of-use tariffs to shift demand, connected with an understanding of behavioural change aspects and industrial energy efficiency. These and other interventions are explored below.

- Consider supporting utility companies and grid operators with interventions on tariffs that closely reflect the price at any given point in time. This includes time-of-use tariffs that target households and-or businesses and help to shift demand away from peak times, reducing the overall grid capacity needs. For example, in Tanzania, given the large peak demand in the early evening, when farmers return home from the fields, and low demand in the day, mini-grid developer JUMEME has attempted to shift commercial demand away from the evening, and stimulate demand in the day.[334] Based on the fact that irrigation pumps used to be used in early morning, through a partnership with drinking-water business, water pumps were switched on automatically when there was excess supply, and lower rate tariffs given to the business for this energy usage. The impacts of the strategy were:

The time-of-use tariff ‘nudged’ farmers to use irrigation systems in the day while there is cheaper energy, reducing evening demand.

The productive use partner filled the gaps in electricity demand during the day, and increased demand.

- Consider support to foster an ESCO market, which can help deliver energy efficiency solutions to industrial and commercial customers. It is important that ESCOs are seen as credible and trustworthy, if users are willing to invest money upfront and realise energy efficiency gains down the line. GIZ helped fund the enabling components for this in South Africa, helping the South African National Energy Development Institute to set up the register of accredited ESCO’s. The register includes ESCO’s across the value chain of energy services offered, e.g. Auditing, Measurement & Verification, Technology Installers, Consulting Engineers as well as full ESCO’s that provide energy services and financing. The greater participation of ESCOs will help to advance and attract private investments in DSM efforts.

- If a country does not yet have a conducive environment for ESCOs, consider supporting appliance and equipment labelling programs. The US MCC Energy Efficiency and Demand Side Management (EEDSM) in Ghana is a good example of this. Project interventions include (1) a rollout of energy efficiency standards, (2) implementation of the pre-tertiary school curriculum and public information on use of efficient appliances with standards and labels via different media platforms, (3)

[334] https://www.energy4impact.org/file/2100/download?token=9k2uhkpD

implementation of an energy auditing and retrofitting activity and an intervention to establish two sustainable energy services centers (SESCs) that will train and certify energy auditors for the country, and (4) installing energy-efficient LED street lights.[335]

- Energy efficiency indicators are crucial to measuring the impact of interventions and benchmark the level of efforts. A platform should be in place so that the impact of DSM efforts can be monitored, and investments can be accounted for as well as to quantify energy savings or emissions mitigation.

- Industrial DSM initiatives can be high impact in terms of reducing emissions and balancing the grid. For industrial EE, high-potential actions include developing and energy management (EnMS), equipment standards labelling (for motors in particular), and incentives from local/state/national governments and utilities and combined heat and power. Adoption of ISO 50001 by leading industries can set examples and help make it an industrial norm, with supporting communications and behavioural change inputs. Consider providing support to regional governments to implement national regulations that may already be in place but are poorly understood. For example, in India, implementation of DSM policy in states and union territories has strong potential for support and impact.

- Enable knowledge sharing programmes, allowing countries to learn from each other's interventions and programming to leapfrog in adoption. Leverage UK private sector and academic expertise to create or support partnerships, local assemblies and accelerators related to DSM initiatives.

Specific support regarding behavioural change at the industry and household level

- Methods to understand and promote behavioural change can be powerful as either the main focus or a component of DSM interventions. Interventions could provide advisory support for behaviour change programming, assisting government to address knowledge gaps and help to ensure these are designed as effectively as possible. For example, support the setting up of behavioural science insights in electricity market regulators, as demonstrated by the *UK's Ofgem Behavioural Insights Unit*, to apply behavioural science to the regulation of the energy market. Insights can better understand consumer choices, supplier conduct and other business decision-making, which can then inform the most effective energy saving initiatives.[336] It is important to note that research on energy efficiency in Ghana, Rwanda and Uganda finds that behavioural levers are only likely to work when included as part of a policy package that addresses wider technical, market and institutional barriers to energy efficiency.[337]

- Consider supporting voluntary energy efficiency programmes for heavy industry. The aim is to demonstrate the value and cost-effectiveness to businesses of adopting more efficient processes, as well as the environmental and climate benefits. This could be independent from or integrated with a time-of-use tariff that industries can also respond to. A good example of behavioural change in industry efficiency is the UNIDO Industrial Energy Efficiency Project (IEEP)'s support to the steel industry in South Africa, where it was found that any meaningful package of DSM measures would have to include skills development for those working on the 'shop floor'. See the case study in Section 0.

- Consider providing advisory support on voluntary energy efficiency programmes for households, through implementing strong communication of the rationale for flexible and more efficient energy use based on a strong understanding of behavioural change factors. Based on UK experience, Ofgem found that the current evidence pointed to three particular strategies of how best to help residential consumers be demand-flexible: automated response to price signals; simplicity in tariff design or the

[335] Data.Gov. (2019). Ghana - Energy Efficiency and Demand-side Management. https://catalog.data.gov/dataset/ghana-energy-efficiency-and-demand-side-management
[336] Ofgem (2019) Applying behavioural insights to forward looking charging reform: Results from a literature review by Ofgem's Behavioural Insights Unit. Link
[337] Never, B (2014) Discussion Paper: Making Energy Efficiency Pro-Poor Insights from Behavioural Economics for Policy Design. Link

user experience; and providing information about price and tips on how to respond.[338] This could be particularly effective in countries with frequent blackouts and high reliance on generators, such as East Africa.

Specific support on smart and flexible grids and wider smart technologies and digitalisation

- Build stakeholder awareness on the benefits of smart grids that are smart allow for two-way communication between the utility (supplier) and customer (user) of energy, and often utilise digital solutions, including artificial intelligence and other mechanisms to predict demand and help regulate supply. The main benefits associated with smart grids are increased efficient transmission of electricity, and reduced peak demand.[339]

- Support government with utilities-led programmes to install metering, including smart metering, to help lay the foundations for more smart and flexible grids. For example, in Chile, the Ministry of Energy has prioritised the development of a net-metering system that allows interaction of demand with the system, allowing in principle: (i) decision making on the demand side, (ii) the sale of energy on the demand-side, iii) user awareness in relation to price. Despite this, the current rate structure for residential customers does not reflect the cost in peak hours. Apart from this, distribution companies themselves have developed demand management programmes based on system reliability criteria.[340]

- Support government capacity building and catalyse investment in local data management systems, that underpin smart grids and demand response. There is large potential for transformational change, and ability to leverage growing UK expertise. As segments of the grid become 'smart' and their data start to flow, questions that have emerged for operators and regulators in developed countries, such as in the UK, include: What should the data processing chain be and what are the technological issues associated with each of its stages? How can data aspects (production, security, etc.) be better controlled? How can we make best use of the data? What constitutes data quality? How does data affect operations? What staff resources and skills are required for a specific context?[341] These questions are relevant for a variety of stakeholders in the electricity sector in relation to flexible grids and DSM measures: network operators, suppliers, associations and regulatory authorities/licensors. Interventions that work with such stakeholders to assess their needs can lead to a range of data-related solutions.

- Support innovators to increase the range of smart technologies focused on metering, appliances and integration with communication systems. Enable collaboration on R&D and innovation in relation to smart grids, storage and DSM. Decentralised innovation is quite 'bottom up', helping to identify the best solutions in each local context, and is particularly relevant to many of the more advanced target regions such as India, Southeast Asia, and South America where there are many opportunities to leapfrog traditional stages of centralised grid development.

- Provide advisory and regulatory support to encourage smart grid implementation, combining distributed generation incentives/regulation with tariffs, storage and smart technologies.

- Consider implementing pilot projects to demonstrate specific techniques and technologies that can enable smart grid performance, including digital-based solutions that draw on frontier technologies such as AI and blockchain. Special attention can be paid to DSM for local distribution grid congestions

---

[338] Ofgem (2019) Applying behavioural insights to forward looking charging reform: Results from a literature review by Ofgem's Behavioural Insights Unit. https://www.ofgem.gov.uk/system/files/docs/2019/12/behavioural_insights_and_forward_looking_charging_report_0.pdf
[339] US Dept. Of Energy. (no date). The Smart Grid. https://www.smartgrid.gov/the_smart_grid/smart_grid.html
[340] Martinez & Rudnick. (2012). Design of demand response programs in emerging countries. http://hrudnick.sitios.ing.uc.cl/paperspdf/PID2455963.pdf
[341] de Buttet et al. (2018). Study: The digital transformation of utilities. https://extranet.thinksmartgrids.fr/?get_group_doc=9/1543222684-ThinkSmartgrids_report_data_nov2018.pdf

and/or isolated-island type of meso-grids. Market design and platforms can be a good opportunity for integration of DSM measure in a bottom up approach.

- Support governments to enable the integration of EVs into flexible grids, with appropriate regulations and standardisation of charging infrastructure.
- These interventions are likely to be particularly relevant to countries and regions that have a more advanced energy sector and a more mature ICT infrastructure and digital economy, such as India, South American countries such as Colombia and Argentina, and Southeast Asian countries such as Malaysia, Thailand and Vietnam.

General support to addressing Investment and finance needs to enable DSM:

- Leverage UK private sector and academic expertise to create or support partnerships, local assemblies and accelerators related to DSM initiatives.
- There are opportunities for ODA funding to provide financing support to ESCOs, which rely on the payback through energy savings over several years, so rely heavily on cheap loans to make their business model work. See for example, a World Bank livewire note on the emerging possibilities of ESCOs.[342] The same principle applies to aggregators, whose business model relies on paybacks over time and hence would be helped by cheap loans.
- Consider providing grant and incubation support to innovators working in the DSM space, especially for application at household and industry level. Supporting blended financing to smart meter programmes could be an important aspect of this, helping utilities to overcome initial capital expenditure where the benefits lead to substantial energy efficiency gains. For example, the US Trade and Development Agency (USTDA) funded the Spark Meter pilot project in Port Harcourt, in Nigeria. This could be particularly relevant to urban centres in East Africa and South America.
- Support governments to explore and implement energy efficiency financing policy, tailored to the maturity of the financial market. For example, an energy efficiency fund, which could, be generated via a tariff levy established by the energy regulator and collected by the utility via the customers' bills. Other funding mechanisms have included a tariff levy on electricity consumption, special taxes, general state tax revenues, revenue bonds and certification fees, etc.[343]
- Providing funding for innovation in the smart grid space, taking full advantage of AI based solutions as they develop.
- Help UK innovators and companies who have received domestic support to expand their offerings to new regions, through grant and challenge funding. Considering BEIS' Energy Entrepreneurs Fund, there are likely to be some ideas which could transfer to other regions and provide true value for money.
- Support government in exploring and utilising the role of new agents (aggregators) which can have an impact if they succeed in combining the individual DSM/EE potential of smaller consumers. New commercial models and improved regulation can stimulate these initiatives.

[342] Sarkar, A. and Moin, S. (2018) World Bank Transforming Energy Efficiency Markets in Developing Countries: The Emerging Possibilities of Super ESCOs. Livewire Knowledge Note 2018/92 by the World Bank Group.
http://documents1.worldbank.org/curated/en/536121536259648570/pdf/129781-BRI-PUBLIC-VC-ADD-SERIES-6-9-2018-12-9-31-LWLJfinalOKR.pdf

[343] ESMAP (2011) Implementing Energy Efficiency and Demand Side Management: South Africa's Standard Offer Model. Low carbon growth country studies program. Briefing Note 007/11.

Box 13 UNIDO Industrial Energy Efficiency Project (IEEP): Support to the steel industry in South Africa via behavioural change and process innovation, 2010 – 2011

UNIDO's IEEP first engaged with ArcelorMittal Saldanha Works (AMSW) in South Africa's Western Cape region in 2010. The plant had 548 permanent employees and focused on hot rolled coil (HRC) steel products with a thickness of less than 1.6 mm, which are primarily for export to West and East African markets.[344] The case study demonstrates that behavioural insights, along with process innovation, can contribute significant near-term and low-cost opportunities for energy savings and emissions reductions.

The objectives of the intervention were to:

- Enhance the plant's competitiveness and efficiency alongside generating considerable financial, economic and environmental returns.
- Build a sustained institutional culture of energy efficiency, supported from the senior management down to the 'shop floor'.

In pursuit of those objectives, the intervention's activities were:

- Firstly, the project provided training to the senior management on an energy management system (EnMS) along with energy systems optimisation (ESO) measures in line with the international energy management standard ISO 50001.
- An Energy Manager was appointed to develop and implement an energy strategy for the plant. An energy audit was then initiated to update the list of already identified initiatives with new and additional energy saving opportunities. The Energy Manager was later joined by a further three engineers, forming an 'Energy Team'. The energy team's main focus was the identification of potential energy saving opportunities and the development and implementation of such projects. This was implemented via an 'Energy Matrix Structure' to identify new energy savings opportunities and monitor the effectiveness of the initiatives being implemented. Not only was the position of Energy Manager created, but 25% of the plant's budget was allocated to energy performance improvement. Thirteen energy saving projects were then implemented, under a combination of awareness raising and ESO initiatives, with most of these projects not requiring capital investment.
- The project provided AMSW with the tools to introduce and implement a system which integrates energy efficiency into daily management and operational practices, changing the enterprise's culture in a simple and sustainable manner. This included identifying 'energy champions' in different teams, who were made responsible for raising energy awareness and encouraging sustained action. The dedicated energy coordinators at each plant helped champions to become more capable energy custodians in their respective work areas.
- UNIDO-IEEP assisted AMSW plant engineers to acquire EnMS and ESO expertise by providing training, technical and advisory support in the implementation and installation of the EnMS along with other energy performance optimisation measures.[345] There was a greater emphasis on capacity-building over mere instruction in order to empower employees with the ability to identify opportunities rather than to simply implement top-down directives.
- The engineers in the plant were technically capacitated with respect to EnMS and ESO methodologies implementation, through the IEE Project training courses

[344] Pegels, et al. (2018) The Human Factor in Energy Efficiency: Lessons for Developing Countries. German Development Institute.
[345] UNIDO-IEEP (2013) Introduction and implementation of an energy management system and energy systems optimization. https://open.unido.org/api/documents/3294411/download/SA%20IEE%20Case%20Study%20-%20Arcelormittal%20Saldanha%20Works_01%20July%202013.pdf

- AMSW implemented a communication strategy through poster drives, hosting competitions for innovative savings ideas, replacing light bulbs from home with LEDs, and organising outreach events at work. Committing to saving energy was also made public by displaying a poster bearing employee signatures. The efforts were designed to create a link between actions and implications and elicited greater resolve across the workforce to improve efficiency.

As a consequence the results of the intervention were:

- AMSW reduced its average energy demand by 5.3% against their 2010 baseline values, including a 26% reduction in Liquefied Petroleum Gas (LPG) consumption being achieved
- From an initial expenditure of just ZAR 500,000 by AMSW, the intervention resulted in savings of approximately ZAR 89 million within one year. This investment was offset in less than four production days.
- In the first year, energy savings of 80 GWh was achieved, corresponding to a 77,222 tonnes GHG emission reduction.
- The EnMS instilled an energy savings culture across the AMSW workforce, which became closely integrated with the company culture, helping to maintain energy efficiency and costs and GHG savings during the following years.

Key risks and the steps taken to mitigate them were as follows:

- Initial process optimisation was implemented in silos and no coordination or overall optimisation strategy was in place, limiting the efficiency of the initiatives put in place. The IEE Project assisted AMSW in analysing the plant's energy consumption in a systematic and holistic manner and building capacity of the plant's engineers on how to optimise across processes throughout the systems. The energy manager also manages projects that cross boundaries – for example, efficiency improvement at the water treatment plant.
- High staff turnover makes it difficult to maintain high skill levels throughout the company. Training was therefore instilled as an ongoing process rather than a one-off process delivered by the UNIDO project.
- Formal training can be problematic because it takes people out of the workplace and has an opportunity cost – both notable challenges in a production context. UNIDO therefore implemented on-the-job and active learning to develop staff members' skills to independently identify energy efficiency opportunities and allow instructors to identify unforeseen training opportunities.
- Another obstacle may arise if a technology (such as energy metering devices) is deemed to be an unjustified expenditure by financial officers who may not understand its potential impact on energy efficiency. However, measurement of performance and impact is key to behavioural change. This can be overcome by strong communication to all staff and departments on the rationale and process for energy efficiency improvements.
- Constant reporting to top management on the achievements and challenges encountered helped reinforce the commitment.

For BEIS there are several primary lessons of the intervention in determining ICF investment:

- Interventions based on behavioural change and corporate culture transformation can achieve significant energy efficiency savings and GHG emissions reduction, particularly in the heavy industry sector. However, they should be part of a coherent package of measures which address the most important barriers in a holistic manner.

- The specific intervention factors which impacted energy efficiency at AMSW were the EnMS that was established, training, the social norms of AMSW, management involvement, finance, and communication.
- Implementing an EnMS was seen as the only way in this context to ensure that the knowledge and practices are captured and institutionalised within the corporate culture and not reliant on any specific individual.[346]
- Senior management commitment is vital. behavioural change in a company requires demonstrated senior leadership and a range of cascading initiatives that communicate and encourage active participation throughout the workforce.
- Knowledge and understanding similarly contribute to ownership. Employees who understand the goals, mission, and performance of their organisation may develop psychological ownership, whereas imposed change may provoke resistance.
- Identifying and making use of a 'window of opportunity' is important for energy efficiency interventions. In 2010, the employees of AMSW were particularly open to changing their energy-wasting habits since their factory was in a financial crisis.
- The status quo and areas for improvement in energy efficiency are often not visible from within an organisation, which often justifies external involvement, such as engagement in a programme like UNIDO-IEEP

Regions/countries where this intervention is likely to be applicable

- The industrial sector accounts for roughly one-third of global final energy consumption and related emissions. This proportion is often much higher in industrialising economies, where it may exceed 50 %.[347]
- Energy efficiency that requires management commitment and behavioural change rather than capital expenditure can be replicated in a wide range of contexts globally, with particular relevance across sub-Saharan Africa, in India, and Southeast Asia.

Box 14 Smart Grids for Renewable Energy and Energy Efficiency Project in Vietnam, 2017 – 2021, US$5.5 million

Vietnam's rapid economic development is restrained by shortages in power supply. Increasing power generation, grid capacity and energy efficiency are necessary to solve this problem. Through funding from the German government, GIZ has been supporting the Government of Vietnam since 2009 in achieving its targets on renewable energy. The ***Smart Grids for Renewable Energy and Energy Efficiency Project (SGREE)*** project is the latest phase of this support, working closely with Electricity Regulatory Authority of Vietnam (ERAV) to support the Vietnamese power sector in developing a smart grid i.e. the digitalisation and flexibility of the power supply system, which allows integration of an increasing share of variable renewable energy and supports greater energy efficiency.[348] The Smart Grid introduces a two-way

[346] UNIDO-IEEP (2013) Introduction and implementation of an energy management system and energy systems optimization. https://open.unido.org/api/documents/3294411/download/SA%20IEE%20Case%20Study%20-%20Arcelormittal%20Saldanha%20Works_01%20July%202013.pdf
[347] International Energy Agency (2013) Energy Efficiency Market Report. OECD: Paris.
[348] GIZ. (no date). Smart Grids for Renewable Energy and Energy Efficiency (SGREEE). http://gizenergy.org.vn/en/project/smart-grids-for-renewable-energy-and-energy-efficiency

interchange where both electricity and information can be exchanged - in both directions - between the power utilities and the consumers.

The objectives of the GIZ intervention are:

- To promote the participatory development of smart grid solutions via three main action areas of the intervention: i) legal and regulatory framework, ii) capacity development and iii) technology cooperation.[349] To contribute to Vietnam's emissions reduction strategy and green growth strategy by improving the existing regulatory framework for renewable energy (RE) and EE;
- Increase the professional and organisational capacities of key institutions and stakeholders.[350]
- Through legal and regulatory framework action area, the programme aims to provide ERAV with information for improving the regulatory framework for a Smart Grid, which facilitates RE and increases EE.
- Through the capacity development action area, the programme aims to establish a Smart Grid Knowledge Hub, which helps Vietnamese experts and stakeholders to exchange knowledge about the development and management of Smart Grids, state-of-the-art technologies and international approaches.
- Via the technical cooperation action area, the programme aims to promote exchange on available technology solutions for an intelligent power supply system, which facilitates the integration of RE and improves EE.[351]

In pursuit of those objectives, the activities of the programme are to:

- Provide strategic advice on future power system development and establishment of a sector-wide stakeholder dialogue, to inform appropriate legal and regulatory frameworks
- Support the development of regulations, with the emphasis on the grid integration of renewable energies as well. This includes promulgating regulations to incentivise investment; working on international co-operation; setting up an "energy valley" to test new technologies; installing smart meters and specifying a quantifiable target; defining minimum operational ranges for distributed energy resources; considering international smart grid standardisation roadmaps, and aligning the national standardisation activities with international best practices.
- Intensify national research and testing of smart technologies that can increase the flexibility and digitalization of the power system. The intervention gave a high priority to renewable energy forecasting; smart inverters, virtual power plant tools, and high voltage direct current transmission system. Feasibility tests for smart technology system configurations are often carried out in laboratories.[352]
- Establish a Knowledge Network on smart grid technologies for Vietnamese power system experts.
- Conduct training on Smart Grid technologies, innovative power system operation and planning with high shares of renewable energies.
- Organise the ***Smart Grid Week Vietnam***, a series of events and workshops that deal with specific topics and target groups within the project's focus. It was hosted by MOIT, GIZ and ERAV. Government officials, national and international professionals, and partners, as well as associations, discuss trends and vision for a future sustainable power system of Vietnam at a

---

[349] GIZ. (2019). Smart Grids for Renewable Energy and Energy Efficiency. http://gizenergy.org.vn/media/app/media/GIZ_Smart%20Grids%20for%20Renewable%20Energy_10Apr2019.pdf
[350] http://gizenergy.org.vn/en/
[351] GIZ. (no date). Smart Grids for Renewable Energy and Energy Efficiency. https://www.giz.de/en/worldwide/62816.html
[352] GIZ. (no date). Utilizing smart grids for optimum power results. http://gizenergy.org.vn/en/article/utilizing-smart-grids-optimum-power-results

series of conferences and workshops. Stakeholders recommended smart energy solutions that enable high shares of renewable energy and energy efficiency and showcase innovative emerging technologies and applications for the power system of the future. The four-day event covered different topics namely "Power System Innovation Day", "Smart Grid Symposium Vietnam", and "Future Lab: Internet of Energy".

As a consequence, the results that the intervention is aiming to achieve are:

- The introduction of feasible smart grid technologies and solutions for the integration of renewable energy sources into the power system of Vietnam.[353]
- Expert knowledge on Smart Grids will be enhanced and the regulatory framework for Smart Grids is expected to be improved, leading to the introduction of Smart Grid solutions, which include an advanced metering infrastructure and demand-side management.
- Enable increased integration of variable renewable energies into the existing power grid, helping to reduce the reliance on fossil fuel generation.
- Improved efficiency, reliability, and sustainability of electricity services across Vietnam, helping to reduce overall need for power generation and reduce GHG emissions.[354]

In the course of the programme, key clients and stakeholders are:

- Government and policy makers; Businesses; Research institutes and civil society

The challenges that project has faced are:

- Several practical challenges have arisen on the topic of implementing smart grids in Vietnam. This includes challenges of connectivity and interoperability of smart metering systems for households and businesses. These types of challenges are part of the learning experience on smart grids that the SGREE is aiming to explore and advise on.

For BEIS the lesson from the programme in determining ICF investment are:

- Interventions that seek to support government progress on smart grids should ensure that the enabling environment is suitable, particularly in terms of government policy (this programme builds on a government directive taken in 2012 to push forward smart grids across the country) and in terms of ICT infrastructure, as well as other aspects such as a reasonably high level of grid reliability.

[353] GIZ. (2019). Plans for Viet Nam's Smart Grid Development in 2019. http://gizenergy.org.vn/en/article/plans-viet-nams-smart-grid-development-2019

[354] GIZ. (no date). Smart Grids for Renewable Energy and Energy Efficiency. https://www.giz.de/en/worldwide/62816.html

Glossary

Acronym / Term	Definition
ADB	Asian Development Bank
Aggregators	Aggregators are a grouping of agents in a power system (e.g. consumers, producers, prosumers) which act as a single entity when engaging in power markets.
AI	Artificial intelligence
AMI	Advanced metering infrastructure
Ancillary services	Services that maintain the proper flow and direction of electricity e.g. synchronised regulation, contingency reserves, black-start regulation, flexibility reserves
Baseload	The minimum amount of electric power delivered or required over a given period
BAU	Business as-as- usual
Behind the-the-meter storage	Storage connected at the consumer side of the utility meter for commercial, industrial or residential power customers (and is therefore grid-connected).
BEIS	UK government Department for Business, Energy & Industrial Strategy
BESS	Battery energy storage systems
BMZ	Germany's Federal Ministry for Economic Cooperation and Development
BTM	Behind the-the- meter
BUG	Back-up generator
C&I	Commercial and Industrial
CAES	Compressed Air Energy Storage
CIF	Climate Investment Funds
CSP	Concentrated solar power
CTF	Clean Technology Fund
Curtailment	A reduction in output from a power generator from what it could otherwise produce using available resources
DER	Distributed energy resource
DFID	UK government Department for International Development (now part of the Foreign, Commonwealth and Development Office (FCDO)
DR	Demand response
DSM	Demand- side management
EE	Energy efficiency
Electrical storage	Storage of energy in electrical fields e.g. supercapacitor
Electrochemical storage	Storage of chemical potential energy e.g. lithium-ion batteries
Energy storage	A device that captures energy for later use, with categories of storage including electrochemical, electrical, mechanical, and thermal forms of storage
EnMS	Energy management system
EPC	Energy Performance Certificate
EPSRC	Engineering and Physical Sciences Research Council
ESCO	Energy Service company

Acronym / Term	Definition
ESMAP	Energy Sector Management Assistance Programme
ESO	Energy systems optimisation
ESRN	Energy Storage Research Network
ESS	Energy storage systems
EU	European Union
EUR	Euro
Flexibility	The ability of a power system to respond to changes in electricity demand and supply
GBP	British pound sterling
GDP	Gross domestic product
GESP	Global Energy Storage Program
GHG	Greenhouse gas
GIZ	Deutsche Gesellschaft fur Internationale Zusammenarbeit GmbH
Grid	An electricity grid
Grid storage	Storage connected to a distribution or transmission networks, or alongside a power generation asset, such as a wind turbine
Gt CO2	Gigatonnes of CO2
Gt CO2e	Gigatonnes of CO2 equivalent
GW	Gigawatt
GWh	Gigawatt hours
IADB	Inter-American Development Bank
IEA	International Energy Agency
IESA	India Energy Storage Alliance
IFC	International Finance Corporation
IoT	Internet of Things
IPCC	Intergovernmental Panel on Climate Change
IPP	Independent Power Producer
IT	Information technologies
LEDs	Light emitting diode lights
Load	The energy demand experienced on a system
MAGC	Market Accelerator for Green Construction
Mechanical storage	Storage of mechanical potential energy e.g. pumped hydropower
NDC	Nationally Determined Contribution
NEP	National Energy Plans or Policies
ODA	Official Development Assistance
OECD	Organisation of Economic Cooperation and Development
Ofgem	Office of Gas and Electricity Markets
PPA	Power purchase agreement

Acronym / Term	Definition
RD&D	Research, development and demonstration
SDG	Sustainable Development Goal
Stationary storage	Electrical storage designed for stationary applications
System costs	Total costs to the electricity system to supply electricity at a given load and security of supply
TCP	Technology Collaboration Programme
Thermal storage	Storage of energy as heat (or cold) for later use, either directly or to generate electricity
TRL	Technology readiness levels
UNIDO	United Nations Industrial Development Organisation
USAidUSAID	United States Agency for International Development
USD	United States Dollar
Variability	The changes in power demand and/or output of a generating source due to underlying fluctuations in resource or power consumption
Virtual Power Plants	VPP operators aggregate DERs to behave like a traditional power plant and engage in a power market to sell electricity or ancillary services
VPP	Virtual Power Plant

Industrial Decarbonisation Policy

Summary

Industrial decarbonisation policy includes policies that incentivise energy intensive industries to decarbonise, through supply side incentives as well as through boosting demand for low carbon products, and that help ensure industrial decarbonisation does not hinder competitiveness. Given the heterogeneity of potential mitigation measures across industrial sectors, this opportunity does not attempt to prioritise the merits of supporting specific technical interventions (e.g. hydrogen use in cement production over hydrogen use in steelmaking). Instead, cross sectoral interventions are considered. The opportunity will focus on energy and emission intensive industries.

Policies to enable industrial decarbonisation in focus geographies include:

- Regulatory standards for industries such as emission standards or requirements on recycled content in products;
- Carbon pricing for industries such as carbon taxes or emissions trading schemes; and,
- Policy to support low carbon industrial business models.

Table 22 Industrial decarbonisation policy assessment summary

Criteria	Assessment	Notes
Climate impact	High	• Helps to avoid around 28% of direct industry sector CO_2 emissions (3.4 Gt CO_2) in 2050 beyond business as usual • Though improvements in energy efficiency will be the key mitigation opportunity to 2030, CCS will become the dominant industrial mitigation opportunity across all regions by 2050
Development impact	Low	• Development impact is greatest in supporting SDG 9, by improving innovation in industry, and SDG 12, by helping increase demand for and supply of low-carbon production. • Potential negative impacts on gender equality (SDG 5) could result from automation and digitalisation.
Investment gap	High	• Investment need of USD 39 trillion by 2050, which will vary substantially between regions depending on scale of industrial sector and relative split in efficiency improvements versus more capital-intensive interventions • An investment gap of around USD 5 - 6 trillion by 2050 is expected, relative to BAU investment levels, which implies an average annual investment of USD 180 billion.
Cost effectiveness	High	• There are substantial industrial abatement opportunities which are cost effective on a marginal £/tCO_2 basis. • CC(U)S is relatively cost effective, within the range of 30-60 £/tCO_2
Barriers to adoption	Medium	• Political economy barriers range from entrenched (fossil fuel) subsidy systems, to entrenched vested interests, and limited transparency. • Market failures include unpriced GHG emissions and investment cycles. • Enabling environment issues include policy (dis)continuity, workforce and skillsets availability, and inadequate knowledge sharing networks.
UK additionality	Medium	• Moderate-to-high synergies with the UK's approach to industrial decarbonisation policy, including: designing and negotiating minimum carbon pricing systems, voluntary standards and agreements; assessing policy and financial mechanisms to address cross-border competitiveness issues; developing climate finance accelerators.

Source: Vivid Economics, ASI & Factor

Key lessons for supporting mitigation through industrial decarbonisation policy:

- There is a substantial gap between average industrial energy productivity in low and middle -income regions relative to the EU and US - India and Eurasia's industrial energy productivity is 75% lower than European energy productivity (measured in USD/GJ). [355][356] A substantial amount of total mitigation potential can be achieved by closing this gap.
- The largest absolute mitigation opportunities are in India and China, due to their large industrial base.
- Which measures are more or less cost effective in regions will heavily depend on the availability of CCS, particularly the availability of low-cost storage, and local energy prices.
- The UK has a large opportunity to harness expertise from domestic industrial policy, particularly around the deployment of CC(U)S in industry and the design of policy and financial mechanisms to address cross-border competitiveness issues.

[355] IEA (2020). "Tracking Industry 2020". https://www.iea.org/reports/tracking-industry-2020

[356] Eurasia includes Russian Federation, Kazakhstan, Uzbekistan, Turkmenistan, Azerbaijan, Georgia, Kyrgyzstan, Tajikistan

Introduction to the opportunity

Role of the opportunity in decarbonisation of developing countries

The industrial sector is a major emitter: it currently emits approximately 9 $GtCO_2$ in low and middle-income countries, rising to 12 $GtCO_2$ in 2050 under a BAU scenario.[357] The industrial sector accounts for about a quarter of total emissions from low- and middle-income countries today.[358,359]As populations grown and economies develop, demand for industrial products is expected to grow substantially. For example, demand for buildings floor space is expected to increase by 2-3x in developing regions, and the associated construction will drive large increases in demand for emissions intensive products such as cement and steel.[360] In a 1.5-degrees scenario, the industrial sector will need to meet large increases in demand, while reducing emissions. There are a myriad of technologies and business model changes that can accommodate this. These can broadly be split into two groups:

Technologies to reduce industrial emissions including CC(U)S, fuel switching to hydrogen, energy efficiency measures, new chemical processes to manufacture cement.[361] The technological options available for this supply-side mitigation are relatively well understood, and can be captured well in techno-economic modelling. Given the scale of industrial emissions, several $GtCO_2$ can be mitigated through implementation.

Technology and business models to reduce demand for emission-intensive products including increased recycling, and increased material efficiency (e.g. light weighting vehicles to reduce steel demand). Analysis of demand-side mitigation opportunities in developing countries in key downstream sectors such as construction (responsible for approx. 50% of steel demand, 100% of cement demand, and 20% of plastics demand) is at an early stage.[362] Economic and market barriers, rather than technical ones, are often critical. Nevertheless, technical estimates suggest reductions in the order of 30% are feasible, which would imply $GtCO_2$ scale reductions may be achieved through material efficiency.[363]

While mitigation opportunities are large, achieving industrial decarbonisation is particularly challenging, and lags behind other sectors for several reasons

There are limited economies of scale compared to other sectors (e.g. in cement kilns compared to wind turbines), which increases the cost of decarbonisation.

Integrated production processes often imply the need for wholesale changes across the production process. There is a lack of viable and sustainable business models that incentivise the development of new processes and sustainable supply chains.

Most industrial products are traded internationally, so increased costs due to decarbonisation threaten to reduce international competitiveness and raise exposure to trade. Addressing this head on may require international policy coordination to develop markets for low carbon products, which is currently underdeveloped.

High industry concentration, including state monopolies, reduce incentives for change and innovation.

---

[357] From IMAGE, NPI scenario
[358] IEA (2017). Energy Technology Perspectives 2017. "https://webstore.iea.org/download/direct/1058"
[359] Rissman et al (2020). Technologies and policies to decarbonize global industry: Review and assessment of mitigation drivers through 2070. Applied Energy. https://www.sciencedirect.com/science/article/pii/S0306261920303603
[360] IEA (2017). Towards a zero-emission, efficient, and resilient buildings and construction sector. Available from: https://www.worldgbc.org/sites/default/files/UNEP%20188_GABC_en%20%28web%29.pdf
[361] The IEA's Clean Energy Technology Guide (2020) provides an extensive list of technologies for industrial decarbonization. Available from: https://www.iea.org/articles/etp-clean-energy-technology-guide
[362] Based on IEA (2019). Material Efficiency in Clean Energy Transitions; World Steel (2020). World Steel in Figures 2020; Greyer, Jambeck and Law (2017). Production, use and fate of all plastics ever made.
[363] Vivid Economics (2020). Technology innovations in industrial decarbonization in developing countries. Forthcoming report for the World Bank.

Scope considered in this assessment

The Industrial decarbonisation policy opportunity will cover policy which incentivises energy-intensive industries to decarbonise, through supply-side incentives as well as boosting demand for low-carbon products, and helps ensure industrial decarbonisation does not hinder competitiveness. Given the heterogeneity of potential mitigation measures across industrial sectors, this opportunity does not attempt to prioritise the merits of supporting, for example hydrogen use in cement production over hydrogen use in steelmaking. Instead, cross-sectoral interventions are considered. The opportunity will focus on the energy and emissions-intensive industries. The scope of the activities included in the analysis includes

- **Design of regulatory standards for industries** such as emission standards or requirements on recycled content in products.
- **Design of carbon pricing for industries** such as carbon taxes or emissions trading schemes.
- **Support for developing country specific low-carbon industrial innovation.**
- **Design of policy to support low-carbon industrial business models** through, for example, subsidies or grants for particular low-carbon business models (e.g. payments per tCO2 captured through CCS) or government procurement standards to provide baseline demand for low-carbon industrial products.
- **Support to maintain industrial competitiveness**

This assessment focuses on the benefit of supporting the opportunity as a whole and does not aim to comprehensively assess the effectiveness of specific investment opportunities or interventions. However, for context, case studies on some of the potential investment opportunities are detailed in Section 0.

The assessment focusses on selected official development assistance (ODA) eligible regions, in consultation with the BEIS steering group, and the scale of potential industrial mitigation. The included regions are

India, like China, is a large industrial emitter and is expected to see rapid industrial growth

East Africa, while currently a minor industrial player, is expected to see its industrial sector grow and hence has large relative (as a percentage of current industrial emissions) reductions available

South Africa, which has the largest industrial base in Africa

Both Southeast Asia and the South Asia (excluding India), (henceforth, 'South Asia') are rapidly growing manufacturing hubs. They already have major textile industries, and substantial growth in more emissions-intensive industry is expected.

Climate impact

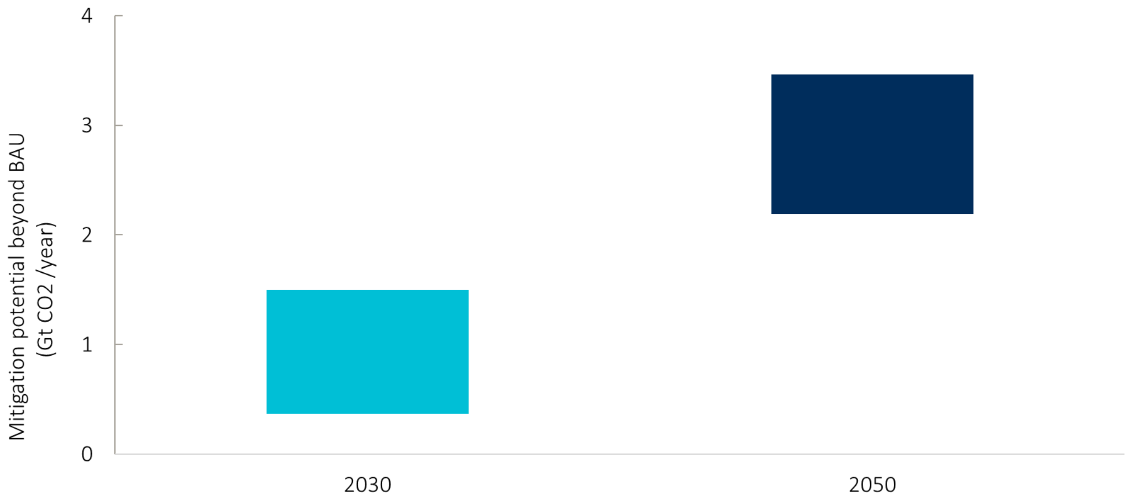
Mitigation potential and urgency

Across low and middle-income countries, industrial decarbonisation can help avoid around 28% of direct industry sector CO_2 emissions (3.4 Gt CO_2) in 2050 beyond busines-as-usual.[364] Direct industrial emissions can be categorised as direct energy emissions (from combusting fuel for energy) and process emissions (emissions from the chemical reactions in, for example, cement production). For this report, the mitigation of indirect emissions (increasing efficiency of electricity use) is captured in opportunities related to the power sector. Energy emissions are roughly two-thirds of industrial emissions, and represent the greatest mitigation opportunity, across 3 major groups:

- **Energy efficiency:** Approximately 0.2 – 1.2, by 2030, and 0.9 – 1.9 $GtCO_2$, by 2050, of the industrial mitigation opportunity comes through energy efficiency.[365] Note, many energy efficiency opportunities are (in theory) cost saving, and also taken up in BAU.
- **Fuel switching,** primarily away from coal, accounts for approximately 0.08 – 0.36 $GtCO_2$ of abatement by 2030, and up to 0.65 $GtCO_2$ by 2050. Natural gas is expected to play an increasingly large role, as well as electricity and biomass (although biomass use in industry may not be the most effective use of this scarce resource). Hydrogen is not expected to play a major role in the industrial energy mix in non-Organisation for Economic Co-operation and Development (OECD) countries in cost-optimal modelling. An expected heavy reliance on CCS, and limited hydrogen, means mitigation potential from fuel switching in industry is relatively modest. However, hydrogen clusters could develop in, for example, China, and drive mitigation substantially beyond modelled levels.
- **CCUS** is the primary driver of mitigation of combustion emissions, and is mostly deployed beyond 2030, 0.14-0.42 GtCO2 could be captured by 2030, growing to 1.6 – 2.2 $GtCO_2$ by 2050. Used in conjunction with biomass, industry could provide negative emissions (although biomass availablity is limited and can have unintended land use consequences).[366]

[364] From IMAGE, reflecting mitigation potential from combustion emissions in the 1.5-degrees scenario.
[365] From IMAGE modelling. The range of estimates reflects differences between 1.5- and 2-degree scenarios.
[366] Use of biomass with CCS in industry is likely one of the most efficient uses of limited biomass particularly if used in applications where high quality heat is needed. In these instances, biomass is typically significantly cheaper than alternative abatement options Furthermore, with CCS the negative emissions provide a 'double dividend' for the used biomass. This compares favourably to other uses of biomass e.g. in road transport. Although analysis on optimal biomass use in developing countries is limited, the Committee on Climate Change (CCC) has analysed the comparative value of biomass use for the UK extensively in its *Biomass in a low carbon economy* report (2018).

Figure 20 Range of mitigation potential compared to BAU in 2030 and 2050



Source: Vivid Economics, ASI and Factor based on PBL's IMAGE model

Note: The bars indicate the range of mitigation estimates from IMAGE across the six scenarios run. The national policies scenario is used as the BAU scenario, and so "vs. BAU" mitigation estimates are calculated as the emissions reduction from 2015 in one scenario minus the emissions reductions from 2015 in the national policies scenario.

Abating process emissions often requires immature technologies, and is costly, compared to combustion emissions. Although process emissions represent a sizeable share of industrial emissions (approximately one-third), abatement is often costly as wholesale process changes or CCS are required. For example, in the cement industry, responsible for approximately 30% of non-OECD industrial emissions,[367] approximately 60% of emissions are from the calcination reaction required to produce clinker.[368] CCS can be used in instances with technoeconomic assessments suggesting an abatement cost of GBP 50/tCO_2 is achievable.[369] However the technology is substantially less mature (with only one demonstration project in the EU) than retrofitting post-combustion CCS units in the power sector or combustion processes in industry.[370]

To 2030, the key mitigation opportunity across low and middle-income countries is improving energy efficiency. For example, India and Eurasia's industrial energy productivity is 75% lower than European energy productivity (measured in USD/GJ).[371] Closing this substantial gap between average industrial energy productivity in non-OECD countries and the EU and US provides a large mitigation opportunity. Between 2015 and 2030, industrial energy use in a 1.5-degrees C=celsius scenario needs to drop by around 20%, while industrial value added grows by over 50%, hence industrial energy productivity needs to approximately double.[372] As shown in Figure 21, the majority of mitigation is provided through energy efficiency in 2030. Notably, around 70% of the energy efficiency opportunities are estimated to be in the less-energy intensive manufacturing sectors, rather than the traditionally considered energy intensive sectors like iron and steel, cement and aluminium.[373] Some of this is likely because in the most energy intensive sectors, fuel is a major cost, and hence there is a clear profit incentive to improve efficiency. In other sectors, the relative importance of fuel costs are lower, leaving (in aggregate) large energy efficiency opportunities. For example,

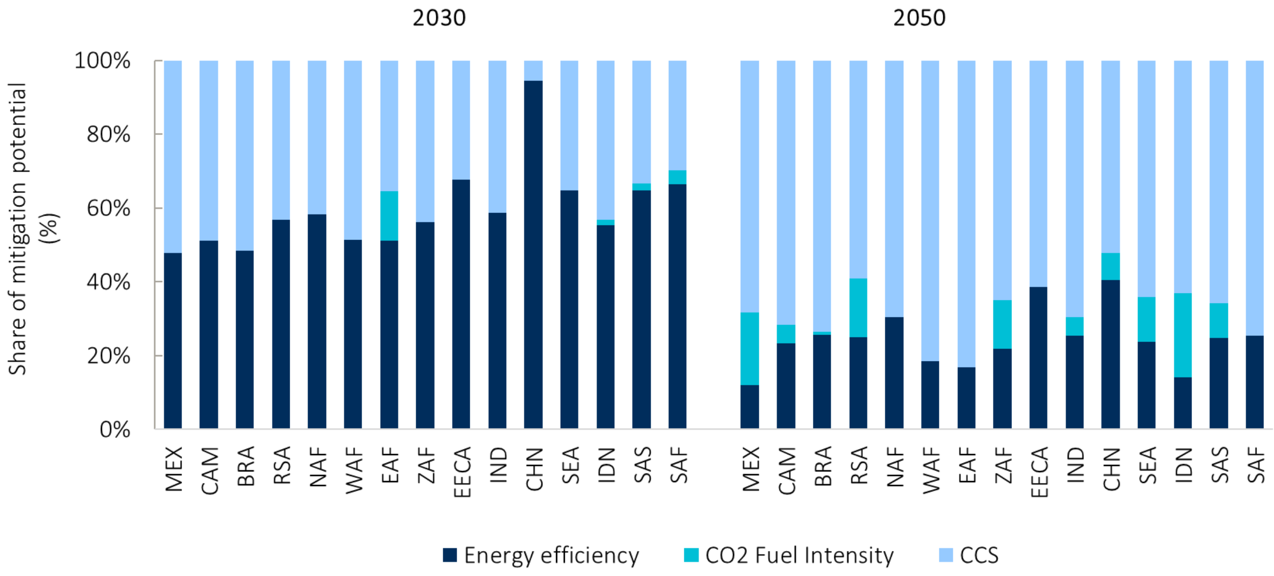
[367] Vivid Economics (2020). *Technology innovations in industrial decarbonization in developing countries*. Forthcoming report for the World Bank.
[368] OECD (2020). Low and zero emissions in the steel and cement industries. https://www.oecd-ilibrary.org/environment/low-and-zero-emissions-in-the-steel-and-cement-industries_5ccf8e33-en
[369] De Lena et al. (2017). Process integration study of tail-end Ca-Looping process for CO_2 capture in cement plants. Int. J. Greenh. Gas Control, 67 (2017), pp. 71-92, 10.1016/j.ijggc.2017.10.005
[370] The Leilac project. See https://www.project-leilac.eu/
[371] IEA (2020). "Tracking Industry 2020". https://www.iea.org/reports/tracking-industry-2020
[372] IMAGE modelling using a 1.5C scenario based on SSP2 pathway
[373] Energy Efficiency Analysis and Outlook 2040. IEA (2018). https://webstore.iea.org/download/direct/2369

in mining, evidence suggests the gap between the best operators and others is up to 44% for dragline operations.[374]

By 2050, CCS becomes the dominant industrial mitigation opportunity across all regions. Despite substantially different industrial bases, CCS is expected to be the dominant mitigation technology across all regions. Note, this is predicated on the assumption that sufficient storage space is economically available in all regions.

Ensuring new industrial stock is constructed with long term decarbonisation targets in mind will be crucial. For example, in the iron and steel sector, steel can be produced using scrap fed electric arc furnaces (EAFs). In countries like India, which are expected to see large rises in steelmaking capacity, by far the most cost-effective abatement strategy will be to support steel recycling and EAFs, rather than the construction of emission intensive blast furnaces which will require costly CCS retrofitting.[375]

Figure 21 Timing of deployment and mitigation opportunity vs BAU



Note: Abbreviations correspond to the following: MEX= Mexico, CAM = Central America, BRA = Brazil, RSA = South America excluding Brazil, NAF = North Africa, WAF = West Africa, EAF = East Africa, ZAF = South Africa, EECA = Eastern Europe and Central Asia, IND = India, CHN = China, SEA = Southeast Asia excluding Indonesia, IDN = Indonesia, SAS = South Asia excluding India, SAF = Southern Africa excluding South Africa

Source: Vivid Economics, ASI and Factor based on PBL's IMAGE model

Local conditions will materially affect technology choice. Relative energy costs affect the optimal decarbonisation option. For example, low electricity prices (around 35 USD/megawatt-hour (MWh) or lower) would make hydrogen use (produced through electrolysis) more attractive than CCS in many regions.[376] Wholesale electricity prices at this level are significantly below current prices in low- to-middle-income countries. However, these levels are plausible in future systems with high renewable penetration. Aside from electricity prices, local availability of bioenergy and/or waste may provide an attractive (and high Technology Readiness Level (TRL)) means of decarbonising cement production, for example.

[374] Awuah-Offei, Kwame. (2016). Energy efficiency in mining: a review with emphasis on the role of operators in loading and hauling operations. Journal of Cleaner Production. https://doi.org/10.1016/j.jclepro.2016.01.035

[375] Vivid Economics (2020). *Technology innovations in industrial decarbonization in developing countries*. Forthcoming report for the World Bank.

[376] McKinsey. (2019). How industry can move toward a low-carbon future. Available from: https://www.mckinsey.com/business-functions/sustainability/our-insights/how-industry-can-move-toward-a-low-carbon-future

The largest absolute mitigation opportunities are unsurprisingly in India and China, while Africa has large relative reduction opportunity.

The largest emission reductions are available in regions with large industrial basis. Globally, two-thirds of industrial emissions are from only three sectors: iron and steel, cement, and chemicals.[377] China currently produces approximately 50% of global steel, and 50% of global cement, and hence has particularly large mitigation opportunities. India has substantial existing industry, and is also expected to have large growth in key emitting sectors, providing a potential opportunity to ensure these new industrial sites are low-emissions ones.

The largest relative emission reductions are in Africa. Africa currently does not have much energy-intensive heavy industry. However, over the coming decades heavy industry is expected to grow on the continent. For example, cement is not economic to transport over long distances, hence expected large scale construction in Africa will drive substantial growth in the cement industry. Mitigating emissions from these new sites will be important to avoid large increases in African industrial emissions.

Box 15 Modelling uncertainty

Industrial mitigation potential as estimated through integrated assessment models (IAMs) is uncertain for several reasons. Fundamentally, an IAM drastically simplifies what is a complex and heterogenous sector and as a result cannot capture all the dynamics in an industrial decarbonisation pathway. Three key aspects not included are:

1. *Overestimation of energy efficiency opportunities.* Energy efficiency is often highlighted as a large and cost-effective opportunity. Given that IAMs cost optimise, energy efficiency opportunities are always taken up due to their fuel savings. However, this ignores potentially large real-world barriers to deployment. For example, some energy efficiency improvements would require substantial plant downtime, which implies large costs (not taken into account by IAMs).

2. *BAU assumptions on industrial demand and industry location.* IAMs project out demand assuming (broadly) BAU, as well as assuming global industrial production patterns remain as they are today (i.e. China continues to dominate steel production, and Africa will remain a net importer of industrial products). Neither of these assumptions are necessarily true. For example, increased material efficiency in construction could substantially lower steel demand, reducing the size of the mitigation opportunity in industry as presented here.

3. *Economies of scale and network effects.* Some industrial decarbonisation interventions can become significantly cheaper if infrastructure (e.g. hydrogen production) is shared across an industrial cluster. These spatial effects are not considered in an IAM, and could imply the potential for hydrogen uptake, for example, is underestimated.

Transformational change

Overall, industrial decarbonisation has significant potential for facilitating and inducing transformational change. In each of the considered regions, industrial activities constitute a large proportion of overall economic activity, account for significant proportions of total energy demand and net consumption of industrial products is significant (constituting a large proportion of consumer spend). Industrial decarbonisation can yield substantial cost and GHG emission savings, through reducing energy demand and switching to low-carbon energy alternatives and encouraging the use of innovative technologies and

[377] IEA (2020). "Tracking Industry 2020". https://www.iea.org/reports/tracking-industry-2020

approaches based on circular economy theory. If adequately designed, industrial decarbonisation policies could promote positive change and innovation throughout entire supply and value chains. Table 23 below assesses the potential for interventions within Industrial Decarbonisation Policy support to support transformational change, within these themes.

Table 23 Assessment of transformational change

Transformational change criterion	Interventions to support change	Regional potential
Sensitive intervention points		
Improvement of local capacities and capabilities	Support in upskilling, education and training is needed to create the workforce required to facilitate industry decarbonisation (e.g. auditors, energy managers, etc.). Training recipients acquire new skills and knowledge, expand their skillsets, and consequently can undertake additional and more specialist tasks (which are key for facilitating industrial decarbonisation).	All regions, and especially Indonesia and South Africa.[378]
Local ownership and strong political will	Support in strategy development, including industry engagement and target setting can help ensure that strategies fit local conditions, adequately deal with legitimate cross-border competitiveness concerns related to carbon pricing, are achievable, have industry "buy-in" and that stakeholders understand the potential benefits. Political will is likely to be higher when the path to decarbonisation is clear, realistic, achievable and industry is engaged.	All regions, especially South Africa, East Africa (with the exceptions of Ethiopia and Kenya) and South Asia where low levels of political will and interest to decarbonise industry[379] can be severely limiting.
Leverage / creation of incentives for others to act	Support in the design and application of carbon pricing instruments may result in industry players receiving tangible economic signals and incentives to improve efficiency and decarbonise, throughout supply chains. Incentives can also be created for industry players to export low-carbon products to international markets, via the reduction or removal of barriers to trade for low-carbon product manufacturers.	All regions, including in particular those countries of focus with large-scale industry bases. India, Indonesia, Thailand and Vietnam are particularly relevant in Asia. As a regional economic centre in East Africa, Kenya also shows high potential. Similarly, South Africa has strong potential, as a hub of industrial activity in Southern Africa.
Spillovers		
Broad scale and reach of impacts	Support to stimulate demand for low-carbon products (e.g. through standards, labelling, supply chain development, promoting reputational advantages, etc.) may have scope to incentivise large swathes of industrial sectors to decarbonise, whether through compliance obligations or through sea-changes in industrial competitiveness.	All regions. Countries with particularly high potential include India, Indonesia, Thailand and Vietnam in Asia, as well as Kenya and South Africa in Africa. This is due to those countries' status as key industrial produce trading blocks and regional economic centres.

[378] On the basis that both Indonesia and South Africa currently have overall reasonable governance capacities (as reflected by their World Bank Governance Indicator ranking, for example), and whilst key institutions and industry players also have some capabilities in developing early-stage policy and regulation promoting industry decarbonisation, considerable scope remains to improve those capacities, especially in relation to energy efficiency, industrial symbiosis, CCUS and other key industrial decarbonisation approaches. The issue of governance is discussed in detail in the barriers section of this report, in the context of country-level enabling barriers to the adoption of effective and timely industrial decarbonisation policy.

[379] These (low) levels of ambition around industry decarbonisation are measured against, and reflected within, the considered countries' NDC pledges. (Source: Climate Tracker, 2020. Countries. Accessed via: https://climateactiontracker.org/countries/)

Transformational change criterion	Interventions to support change	Regional potential
Sustainability (continuation beyond initial support)	Support to stimulate demand for low-carbon products (e.g. through standards, labelling, supply chain development, promoting reputation advantages, etc.) because "critical mass" levels of demand will help establish markets of scale, which industry players will be incentivised to enter and operate in. Support in upskilling, education and training for key decarbonisation facilitation roles can help to permanently remove a key barrier to decarbonisation progress, as newly trained workers can then remain active in the workforce over the mid- to long-term.	All regions
Replicability by other organisations or actors	Support for the design and application of standards for (low-carbon) products have considerable scope for replicability by other organisations and countries. This is especially the case where some countries work to harmonise their product standards with those of key target export markets.[380] Hence, support for product standard development in one country can also induce and catalyse product standard improvements in other (non-targeted) countries.	All countries, and especially those with significant imports of industrial products and which operate as key industrial produce trading blocks, such as India, Pakistan, Indonesia, Thailand and Vietnam, Kenya and South Africa in Africa.
Innovation		
Catalyst for innovation	Support in the design of carbon intensity limits, standards, regulations and rules can lead to markets within which industry players have strong incentives to comply, by adopting more efficient and lower-carbon technologies and processes throughout supply chains.	All regions, especially in India and Southeast Asia, where productivity is low and requirements to use more efficient technologies are often absent.
Evidence of effectiveness is shared publicly	Support in the development of industry reporting protocols can ensure that key data, information and evidence on the effectiveness of low-carbon systems and processes are publicly accessible. Support for projects that demonstrate the technical and economic viability of key emerging low-carbon technologies (e.g. CCUS, hydrogen, digitalisation and automation solutions, etc.), can also help demonstrate effectiveness to broad audiences. This includes showcasing effective business models for such projects through, for example, full disclosure of project costs and revenue streams.	All regions

Source: Vivid Economics, ASI and Factor

[380] This can be observed in the case of various countries which neighbour the EU trading block, and which have worked to replicate product standards in force in the EU, to facilitate exports to it.

Development impact

SDG impacts

Overall, the net overall long-term impact on SDGs is likely to be highly positive, recognising its role in decoupling industrial activities and GHG emissions,[381] and considering that current industrial activities often stymie progress to meeting SDGs (e.g. pollution, human health effects, etc.). In the short term, the implementation of industrial decarbonisation policy is expected to create both positive and negative impacts on key SDGs. However, the timely uptake of industrial decarbonisation policy will help countries and industrial sectors to avoid significant negative impacts and shocks over the longer term.[382] Salient positive impacts on SDGs include industry, innovation and infrastructure (SDG9), responsible consumption and production (SDG12), and climate action (SDG13). Positive impacts on SDGs will accrue over both the short and long terms. Short-term negative impacts are expected regarding progress towards gender equality (SDG5) and ensuring decent work and economic growth (SDG8). In addition, industrial decarbonisation can leverage significant positive impacts on several other SDGs. Table 24 offers a summary of the anticipated impacts of Industrial Decarbonisation Policy support on progress towards meeting the relevant SDGs.

Table 24 SDG impacts

SDG	Strength of impact	Most relevant region	Rationale
Positive impacts			
SDG 3 – Good health and well being	Moderate	All regions, especially in India	Reduced use of fossil fuels has a positive impact on air quality Large industrial process hubs and coal-fired power generation plants are often located close to large urban population centres. Hence, air and water quality improvements can have significant positive impacts for large proportions of populations.
SDG5 – Gender equality	Moderate	All regions, especially East Africa	The creation of strong supply chains can improve industrial competitiveness, which in turn could improve job security, and vice versa.[383] This could help improve job security for women in certain industrial sectors (e.g. manufacturing) and contexts wherein women tend to undertake less secure roles and receive lower remuneration compared to men.
SDG 6 – Clean water and sanitation	Moderate	All regions	Lower water footprints of certain low-carbon energy technologies (e.g. solar and wind power), compared to fossil fuel fired energy alternatives
SDG 7 – Affordable and clean energy	Moderate	All regions	Policies that internalise the social cost of GHG emissions incentivise the use of low-carbon and clean energy sources and promote the efficient use of energy (energy savings)

[381] Energy cost savings can be achieved when an existing industrial installation is retrofitted with low-carbon technologies, as well as in the event that low-carbon technologies are applied in a site or project which had previously planned to use carbon-intensive energy sources and processes.
[382] Key shocks would include, for instance, serious difficulties to comply with increasingly stringent climate change mitigation targets and industry standards, mass job losses and a lack of new job creation within emerging low-carbon industries.
[383] UN Women. (2017). What women's economic empowerment means for companies and actions for companies to advance women's economic empowerment: a brief. https://www2.unwomen.org/-/media/hlp%20wee/attachments/other-materials/briefing-papers/womens%20economic%20empowerment%20and%20companies_unhlp%20brief_2.pdf?la=en&vs=1938

SDG	Strength of impact	Most relevant region	Rationale
SDG 8 – Decent work and economic growth	Moderate	All regions, and especially in South Africa (related to high chronic unemployment)	Significant scope for promoting economic growth, improved competitiveness, industry development, stimulating the creation of low-carbon jobs of the future
SDG 9 – Industry, innovation and infrastructure	High	All regions	Policies encourage technology and process innovation, improved process control, and investments in low-carbon infrastructure
SDG 12 – Responsible consumption and production	High	All regions	Policies stimulate consumer demand, markets and supply chains for low-carbon products
SDG 13 – Climate action	High	All regions, and especially in India, Southeast Asia and South Africa	Scope for reducing a significant proportion (~30%) of total global GHG emissions, and decoupling industrial growth from GHG emissions
Negative impacts			
SDG5 – Gender equality	High	All geographies, and especially those of East Africa, South Asia (especially Pakistan); India; and Bangladesh, Cambodia and Myanmar in Southeast Asia	Increased automation and digitalisation will replace low-skilled jobs, which overall tend to be undertaken by women (as opposed to men).
SDG7 – Affordable and clean energy	Medium	All regions	Certain early stage industrial decarbonisation technologies (such as CCUS or hydrogen energy systems) have energy penalties, thereby increasing the overall energy costs for industry players that develop such projects[384] and/or industrial entities that consume energy downstream, (e.g. within industry hubs).
SDG 8 – Decent work and economic growth	High	All regions	Some industries (e.g. hydrocarbon fuel refining) and jobs based on high-carbon industrial processes could become increasingly redundant (i.e. prohibited or non-cost-competitive), and automation and digitalisation will replace low-skilled jobs.[385] If the workforce and industry transition is not carefully planned and managed, there will be risks of mass unemployment and social unrest. Most initiatives targeting deeper decarbonisation can increase costs, especially in the short-term with relatively low carbon prices, which has a negative impact on economic competitiveness.

Source: Vivid Economics, ASI and Factor

[384] IFRI, 2019. Carbon capture, storage and utilization to the rescue of coal? Global perspectives and focus on China and the United States. Accessed via: https://www.ifri.org/sites/default/files/atoms/files/etude_cornot_carbon_coal_2019.pdf

[385] PWC, 2018. Will robots really steal our jobs? An international analysis of the potential long term impact of automation. Accessed via: https://www.pwc.co.nz/pdfs/2018pdfs/impact-of-automation-on-jobs-Feb-2018.pdf

Demand in target regions

The considered countries and regions show varying levels of commitment to industrial decarbonisation. Countries' industrial development (and, sometimes, decarbonisation) strategies, binding targets and political commitments (including nationally determined contributions (NDCs)), and strategies to explore and rollout decarbonisation technologies such as CCUS suggest different levels of demand for support to promote industrial decarbonisation. Table 25 provides a summary, followed by a brief discussion of key indicators of demand in respective countries and regions.

Table 25 Demand in target regions for support to promote industrial decarbonisation policy

Region	Demand	Rationale
East Africa	Low-moderate	Key regional industrialisation strategy contains no measures or targets for decarbonisation. Initial steps taken on GHG emission pricing.
India	High	Clear industry decarbonisation target in NDC (reducing overall gross domestic product (GDP) emission intensity by 35% below 2005 levels), and Roadmaps for Industrial Decarbonisation, and Hydrogen development. Participation in CCUS initiatives. Substantial levels of industry-led initiatives on digitalisation and smart solutions (but not driven by binding official targets).
South Africa	Medium	Recent carbon tax established in law, industrial development strategy has limited focus on decarbonisation, coal use remains entrenched. Ambitions to develop CCUS and initial testing undertaken.
Southeast Asia	Medium	Most countries lack decarbonisation targets for industry, regional interest in exploring CCUS development. Initial scoping on CCUS in some countries.
South Asia	Low-moderate	Fossil fuel consumption remains high and heavily subsidised, very limited binding decarbonisation targets. Initial scoping on CCUS in some countries.

Source: Vivid Economics, ASI and Factor

In East Africa, several countries are already experimenting with market mechanisms to facilitate implementation of their NDCs. Regional industrial development is guided via the East African Industrialisation Strategy (2012-2032), which aims to enhance industrial production and productivity and accelerate the structural transformation of the economies of the region. The strategy seeks the attainment of sustainable wealth creation, improved incomes and a higher standard of living for the Community. However, it includes no provisions or targets for decarbonisation.[386] The East African Alliance on Carbon Markets and Climate Finance was launched in 2019. It seeks to promote a common regional vision on carbon markets and climate finance for decarbonisation. Overall, support to maintain industrial competitiveness is diverse in East Africa and includes investments in capacity building and research and development (R&D) of financial infrastructure and local market development.[387]

India's NDC establishes the unconditional target of reducing overall GDP emission intensity by 35% below 2005 levels. Whilst remaining heavily dependent on fossil fuel energy sources, India has strong ambitions to rapidly scale up its use of renewable and low-carbon energy sources, to help facilitate the decarbonisation of its industrial sector, and has recently published a national level Roadmap for Industrial Decarbonisation. Whilst India has no official policy or legal requirements on industry for the uptake of digitalisation, smart solutions and industrial symbiosis; some industry player-led initiatives are currently underway,[388] exploring and trialling innovative solutions in these fields.

---

[386] EAC. 'Industrialisation and SME Development'. https://www.eac.int/industry.
[387] EAC. (2017). 'EAC Industrial Competitiveness Report 2017'.
[388] Based on the findings of an interview undertaken with a key external expert, as part of the methodological approach used in this present analysis.

India has had a carbon tax on coal in place since 2010 and is considering the introduction of broader carbon pricing measures. Many Indian companies already use an internal carbon pricing system. The country is also engaging with and thinking about circular economy in industry,[389] which is relatively rare for an emerging/developing country.

Some of the key specific industry sector and decarbonisation technology measures in place in India include:

- India's NDC establishes the conditional target of raising the non-fossil fuel share of cumulative power generation capacity to 40% by 2030.
- The use of various industry sub-sector level decarbonisation (and sustainable development) roadmaps and plans (e.g. the *Cement Sector SDG Roadmap*).[390]
- Participation in several international CCUS initiatives, including the Carbon Sequestration Leadership Forum. Since 2007, R&D activities are led by the Indian CO_2 Sequestration Applied Research network.[391]
- A Hydrogen Roadmap to guide the development of a future hydrogen fuel energy sector.
- The Perform, Achieve and Trade (PAT) scheme is currently the key policy driving efficiency gains in the industry sector: it is a market-based mechanism to enhance cost-effectiveness of energy efficiency improvements within industrial plants.[392]

In South Africa, industrial decarbonisation strongly depends on breaking the link to coal consumption, scaling up renewable energy use, and upgrading the power grid infrastructure. [393] Despite recent policy and legal measures, government industrial strategy sometimes appears more focused on addressing challenges around the concentration of ownership and control; overcoming high private sector input costs; tackling high electricity prices; upskilling the workforce; and addressing transport and logistics constraints.[394] However, there is only limited explicit focus on decarbonisation. A recent push for the uptake of decarbonisation incentives and policies can be observed in South Africa. For example, the South African government passed its Carbon Tax Act in 2019, which has clear implications for emitting entities in the industrial sector.

Some of the key specific industry sector and decarbonisation technology measures in place in South Africa include:

- The National Energy Efficiency Strategy passed in 2019, focused on improving energy intensity and decoupling economic growth from energy demand.
- Historically, South African industry has largely been powered by electricity via coal-powered plant. The country has set out a national level energy transition strategy and is pioneering in the African country context in the use of renewable energy auctions, with strong focus on achieving a just energy transition. Many industrial processes are already electric. Natural gas has only recently been introduced into the country (mostly imported). However, most thermal energy is derived from either coal, oil-based fuels or electricity. Politically, South Africa has focused on providing power (and heat via small-scale renewable energy, solar thermal) to domestic users rather than industry.[395]

---

[389] Ellen MacArthur Foundation. (2016). Circular economy in India: rethinking growth for long-term prosperity. http://sites.ellenmacarthurfoundation.org/india

[390] WBCSD, 2019. Indian cement Sector Roadmap. https://www.wbcsd.org/Programs/People/Sustainable-Development-Goals/SDG-Sector-Roadmaps/News/Indian-Cement-Sector-SDG-Roadmap

[391] S. Shackley and P. Verma, 2008. "Tackling CO2 reduction in India through the use of CO2 capture and storage (CCS): Prospects and challenges."

[392] The goal is to set energy efficiency targets and issue market tradable permits for certification of energy savings. IEA, 2018. Energy efficiency in India. https://www.iea.org/articles/energy-efficiency-in-india

[393] SDSN, 2015. Pathways to deep decarbonisation in South Africa.: http://deepdecarbonization.org/wp-content/uploads/2015/09/DDPP_ZAF.pdf

[394] South African Government. (2018). Industrial policy action plan 2018/2019 – 2020/2021. https://www.gov.za/sites/default/files/gcis_document/201805/industrial-policy-action-plan.pdf

[395] This trend of focusing on providing energy to domestic consumers over industry is somewhat driven by the fact that people vote and industry doesn't. This has sometimes induced associated economic harm because poorer people cannot pay for the energy they consume.

National GHG emissions reporting regulations passed into law in 2017.

CCUS developments in South Africa are guided by the South African CCS Roadmap.[396]

In Southeast Asia, most countries have no long-term economy-wide or industry sector specific decarbonisation goals or targets enshrined in law.[397] However, most Southeast Asian countries have set NDC emission reduction targets for 2030, both conditional and unconditional.[398] Overall, industry decarbonisation policy is framed around the continued use of coal as a primary fuel source and the progressive decoupling of GHG emissions and coal consumption, facilitated by the uptake of CCUS solutions. There are currently no official and binding policy or legal requirements on industry for the uptake of key deep decarbonisation solutions, such as digitalisation, smart solutions and industrial symbiosis.

Some initial scoping work on CCUS has been undertaken in Indonesia and Vietnam via the international CCUS programme. The Association of Southeast Asian Nations (ASEAN)'s Plan of Action for Energy Cooperation explicitly aims to enhance the image of coal through the promotion of clean coal technologies.[399] Within the programme, countries pledge to share technical capacity to explore CCUS opportunities and deploy low-emission coal solutions. Some five intensive industrial sectors (cement, chemicals, petrochemicals, paper and steel) together account for around 40% of the energy consumption of industry in Southeast Asia.[400]

In South Asia, countries diverge substantially with respect to their respective long-term decarbonisation targets and NDC ambition levels. Several South Asian countries remain firmly reliant on coal and other fossil fuels as energy inputs (to industrial activities, as well as meeting broader electricity demand). As regards the use of specific energy sources in industry, ambition on fossil fuel (mainly coal) phase out is often very limited or lacking. For example, Pakistan plans to add 35.9 GW of new power generation capacity in the period to 2025, of which over 30% will be coal-fired capacity.[401]

In Bhutan, on the other hand, the country's Draft Energy Efficiency Roadmap identifies measures in the industrial sector to further reduce emissions, and the Government launched its National Energy Efficiency and Conservation Policy in 2019. The latter emphasises capacity building measures to promote energy efficiency in the industry sector, especially through Demand-Side Management (DSM) interventions, the development of energy efficiency codes, energy audit capacities, and energy use reporting guidelines. Nepal has high demand for decarbonisation via renewables – especially wind power and hydropower – and energy storage for electricity (in particular, via pumped hydro storage).[402] For thermal energy applications in South Asian industry sectors, bioenergy is currently the most common renewable energy application. Initial scoping work on CCUS has been undertaken in Pakistan and Bangladesh via the international CCUS programme.

---

[396] The key coordinating entity is the South African Centre for Carbon Capture and Storage (SACCCS), and in 2017 it undertook a CO_2 test injection project Rebecca Cameron. (2019). "Is carbon capture and storage still a feasible option for South Africa? https://www.iea-coal.org/is-carbon-capture-and-storage-still-a-feasible-option-for-south-africa/

[397] The exception to the trend is Singapore, which has a target to cut absolute emissions by 50% by 2050. Singapore's Long-Term Low-Emissions Development Strategy (2020), for instance, calls for the significant scale up of CCUS and carbon markets, driven by clear decarbonisation policy and strategy.

[398] The exception to the trend is Vietnam, which excludes industry coverage in its targets.

[399] Climate Analytics. Decarbonising south and Southeast Asia. https://climateanalytics.org/media/decarbonisingasia2019-fullreport-climateanalytics.pdf

[400] REEEP. (2014). Regional energy efficiency policy recommendations. SE Asia. Accessed from: https://www.reeep.org/sites/default/files/FINAL_SEA_Recommendations_Brochure.pdf

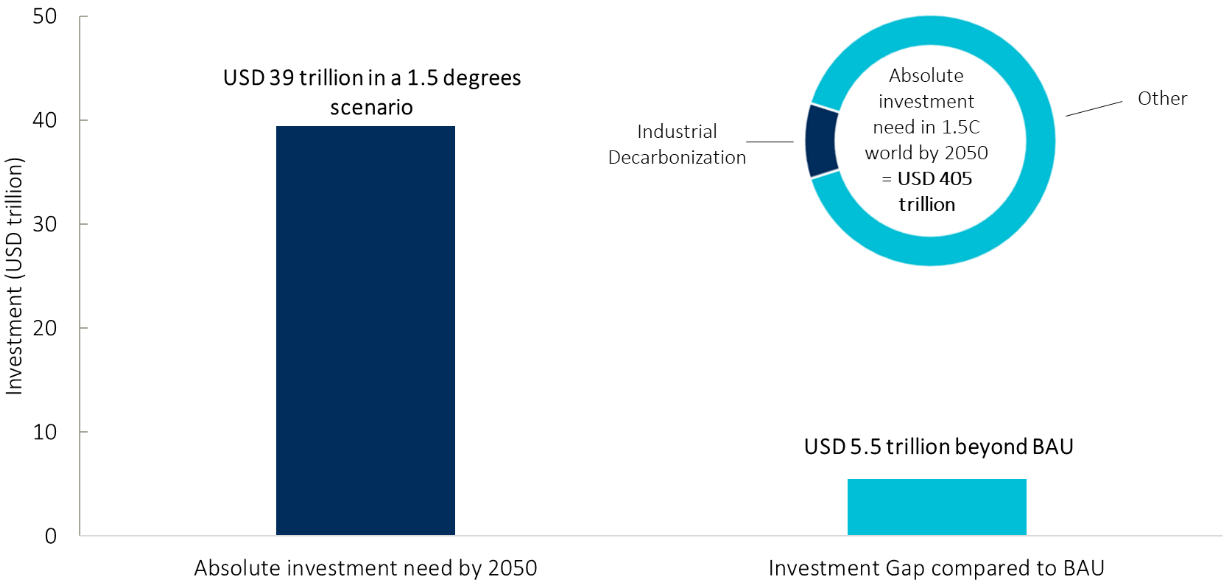
[401] Pakistan's State of the Industry Report from the National Electric Power Regulatory Authority (NEPRA) includes a summary of planned generation capacity additions out to 2025. Pakistan plans to add 35.9 GW of generation capacity, of which over 30% is coal-fired capacity, until 2025.

[402] Principally to address the chronic pattern of planning via "flood-drought syndrome" (wherein a single relatively large-scale project was selected and built, resulting in immediate excess power; this was then followed a few years later by scheduled load shedding as the excess capacity was absorbed by fast growing domestic demand. Some industry players responded by installing inverters and battery backups, rooftop solar PV, etc.

Investment need

Industrial decarbonisation will require around USD 5-6 trillion of additional cumulative investment to 2050, which implies an average annual investment of USD 180 billion.[403] This will be required to reach the absolute investment need by 2050, USD 39 trillion. To provide a sense of scale, global industrial capital costs was approximately USD 800 billion in 2018.[404] There is limited evidence on current industrial decarbonisation spending in non – OECD countries; however, it is reasonable to assume most of the estimated investment need will be additional. In other words, the annual investment gap is in the order of USD 180 billion. At the same time, decarbonisation investment should be viewed within the context of existing large capital investment flows in industry. Broadly a 10-20% increase in annual existing flows would suffice, highlighting the importance of supporting policies that encourage this additional investment during natural replacement cycles.

Figure 22 Investment need in industrial decarbonisation



Notes: Investment need calculations are calculated from IEA's investment levels on renewables capital costs in a BAU and a 1.5-degrees scenarios

Source: Vivid Economics, ASI and Factor using IEA. (2017). Energy Technology Perspectives

Industrial decarbonisation investment will vary significantly across regions, driven by the size of industrial local industries, as well as the balance of interventions required. As shown in **Error! Reference source not found.**, the size of the cumulative investment need across our focus regions could vary between USD 0.6 trillion in South Africa to USD 9.5 trillion in India. Naturally, regions with large industrial sectors will require substantial investment to decarbonise. However, the make-up of local industry is also important to consider. It is helpful to broadly consider 2 types of investment need:

Energy efficiency and other investments with an existing business case. The vast majority of energy efficiency investment has a positive net present value, given the associated fuel savings. However, investment often does not happen because payments periods are 10 years or longer. Hence, most energy efficiency improvements occur within natural capital replacement cycles, when the additional

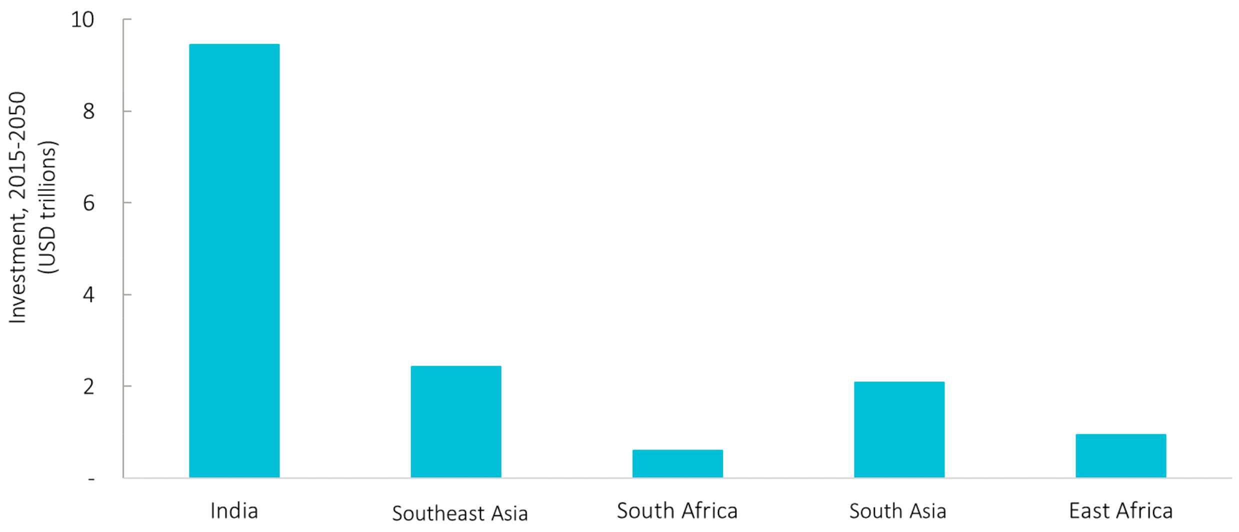
[403] IEA (2017). Energy Technology Perspectives. Available from: https://www.iea.org/reports/energy-technology-perspectives-2017

[404] S&P (2019). Global Corporate Capex Survey. Available from: https://www.spratings.com/documents/20184/1481001/Global+Corporate+Capex+Study+2019+Curbed+Enthusiasm/086812c1-e10f-e2e7-2be0-89c7e34d8bc7

investment need is limited. [405] The primary challenge here is to incentivise earlier action and improve financing availability, rather than increasing levels of funding.

Additional investment need, with no existing business case. On the other hands, CCS retrofits and other deep decarbonisation measures are capital intensive and a purely additional investment, and can add several USD 10's of millions to around USD 200 million to the capital cost for industrial facilities.[406] Using CCS deployment as a proxy, Figure 4 provides an indication for the distribution of industrial decarbonisation investment needs across the focus regions.

Figure 23 Forecast investment need across focus regions



Notes: Investment needs based on IEA ETP 2017, scaled by the distribution of IMAGE emissions reductions for costly interventions

Source: Vivid Economics, ASI and Factor using PBL's IMAGE model and IEA.(2017). Energy Technology Perspectives

[405] For example, replacing end-of-life gas turbines with best available technology will typically yield substantial energy efficiency improvements at limited extra cost

[406] John Wood Group plc. (2018). Assessing the Cost Reduction Potential and Competitiveness of Novel (Next Generation) UK Carbon Capture Technology. Available from: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/864688/BEIS_Final_Benchmarks_Report_Rev_4A.pdf

Cost-effectiveness

There are substantial industrial abatement opportunities which are cost-effective on a marginal GBP/tCO_2 basis. Although dependent on local energy prices, energy efficiency measures can often have negative abatement costs (i.e. money is saved in the long term). Similarly, some opportunities to abate process emissions are very low cost. For example, non-clinkered cement which reduce cement emissions by 40-80%, is already cost competitive in some areas (although highly dependent on input costs).[407] However, despite low or negative marginal abatement costs, implementation can nevertheless be costly. Marginal cost estimates neglect the risks of delays to installation and associated downtime, or the costs associated with scaling up necessary supply chains (e.g. large volume supply of clinker substitutes in cement).

CC(U)S is relatively cost-effective, and is expected to be the marginal industrial technology deployed in developing countries. Costs vary per sector, but are broadly GBP 30-60/tCO_2. Beyond CC(U)S, abatement costs typically increase substantially. For example, using hydrogen in industry has an abatement cost of around GBP 100-200 t/CO_2 (depending on the industry and hydrogen price).[408] Based on current technology costs, technologies to reach zero industrial emissions (e.g. hydrogen use) are not expected to be taken up at scale in developing countries given they substantially exceed CCS costs, and hence they are not considered cost-effective.

Which measures are more or less cost-effective in regions will heavily depend on the availability of CCS, and relative local energy prices.

Availability of CCS: The distribution of global storage availability is uncertain, and some regions (particularly India) may not have sufficient low cost storage sites available.[409] CCS is widely thought to be the most cost-effective measure to achieve deep decarbonisation across large emitting sectors including steel, cement, and chemicals. Limited CCS availability would substantially increase the average GBP /tCO_2 cost.

Local fossil fuel prices: Local coal and gas deposits and prices (oil is more expensive and less relevant as an industrial fuel) impact the attractiveness of decarbonisation measures. High fossil fuel prices make energy efficiency and potential fuel switching more attractive. Conversely, low prices make decarbonisation less attractive. Furthermore, there are often incentives to maintain industrial fossil fuel demand, to support domestic fossil fuel industries.

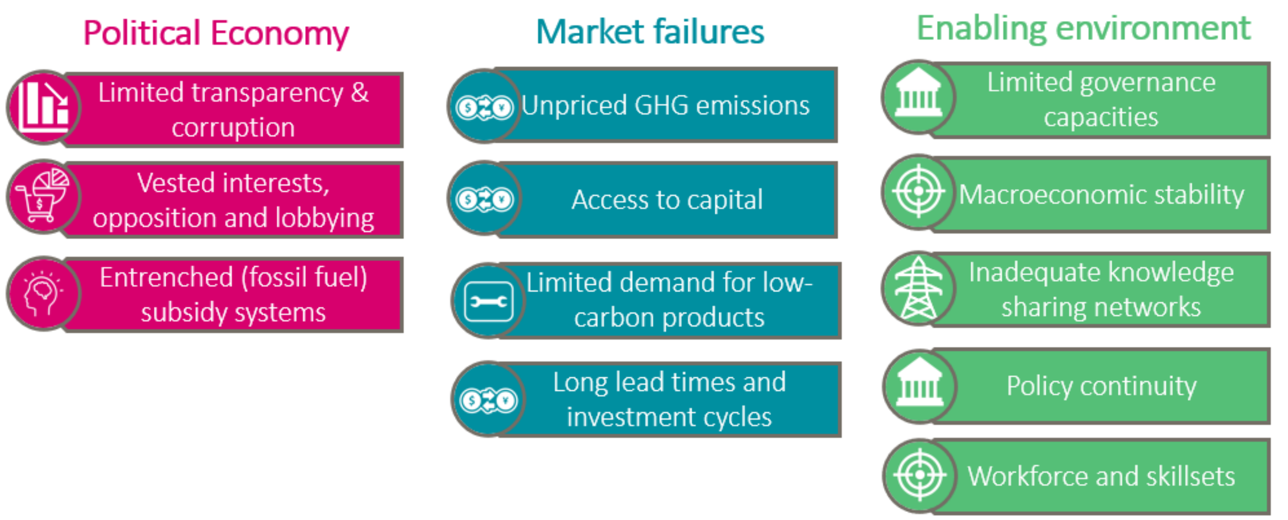
Local renewable energy prices: Local electricity prices substantially impact the attractiveness of electrification, and (indirectly) hydrogen use in industry. Early and large-scale renewable deployment would help lower long-term power prices, and hence potentially make industrial decarbonisation more attractive. This is particularly true in regions with high solar potential (and hence low cost).

[407] Provis (2018). Alkali-activated materials. https://www.sciencedirect.com/science/article/pii/S0008884616307700#s0060
[408] IEA (2019). The Future of Hydrogen. https://www.iea.org/reports/the-future-of-hydrogen
[409] Assessment of CCS Technology in a Climate Mitigation Portfolio (2019). MIT Joint Program. Available from: https://globalchange.mit.edu/publication/17251

Barriers to adoption

Barriers to the uptake of industrial decarbonisation policy relate to i) political economy challenges ii) market failures, and iii) enabling environment. The five priority regions were selected for their relatively high levels of net industrial sector GHG emissions in the international context, their heavy reliance on carbon-intensive energy and fuel sources, the prevalence of relatively inefficient industrial processes and technologies; and the significant industrial sector growth forecasted within their respective economies. As a result, they may respond very positively to UK interventions to support industrial decarbonisation policy uptake, especially when there is significant ambition to switch to a low-carbon development path. Most if not all of the barriers apply to all the countries under analysis, albeit to varying degrees.

Figure 24 Barriers to an intervention opportunity



Source: Vivid Economics, ASI and Factor

The key barriers to industry decarbonisation policy implementation are described below, along with an indication of the relative strength of key barriers within the target regions.

<u>Market failures</u>

- **Unpriced GHG emissions are a moderate to critical barrier to encouraging decarbonisation across the target regions, with a couple notable exceptions (including South Africa and India).**[410] South Asia and East Africa have virtually no disincentives for GHG emissions.

- **Access to affordable capital for energy efficiency and industrial renovation investments can directly block industrial organisations' capacity to implement low-carbon technologies and certain energy saving measures.** At best, capital is often offered under highly unattractive repayment conditions and is available only to a select few organisations. Industry players and financial lending institutions are often unaware of the various business models and financing options that can be used for industrial decarbonisation investments, meaning that those options can be overlooked. This is a critical barrier in much of East Africa and South Africa and a moderate barrier in India and South Asia.[411] Access to capital in South Africa is a low-level barrier due to its relatively advanced financial services sector.

[410] South Africa introduced a carbon tax in 2019. India has a carbon tax on coal and is considering the introduction of broader carbon pricing measures. Many Indian companies already use an internal carbon pricing system. There is some degree of carbon pricing in Singapore.

[411] In addition to capital costs, it is worthwhile underlining that appropriate models for financing energy efficiency require careful design, tailored to the maturity of the market. Source: IPEEC, 2018. G20 Energy Efficiency Finance Task Group. Accessed from: https://ipeec.org/taskgroup/12-Energy%20Efficiency%20Finance%20Task%20Group%20(EEFTG).html

- **Lack of demand for low-carbon industrial products and services if they entail higher final costs for consumers compared to high-carbon alternatives.** This can result from several factors, including a lack of willingness on the part of purchasers and organisations to pay more for non-substitutable commodities. This issue is likely to be further compounded where levels of industrial competition are high and where profit margins are tight.[412] Overall demand for low-carbon industrial products is shaped by the extent to which the social cost of carbon is adequately reflected, through economy-wide carbon pricing, for example.[413] It is also driven by perceptions around exposure to future carbon price risks, organisational and corporate social responsibility commitments to use low-carbon products, and end-consumers' willingness (and ability) to pay a premium for certain products.
- **Overall, the existence of an adequate level of demand for low-carbon industrial products and services is an essential pre-requisite for decoupling industrial activities and GHG emissions.**[414] It is also worth underlining that progress towards addressing this barrier (i.e. scaling up demand for low-carbon industrial products) would create a more conducive environment to address many of the other barriers described in this section. The lack of demand for low-carbon industrial products and services if they entail higher final costs for consumers compared to high-carbon alternatives is a critical barrier in all regions.
- **Long lead times and investment cycles, and low profit margins, may provide few (i.e. infrequent) windows of opportunity for technology switching in certain parts of industrial process cycles**. If technology or process replacement is not undertaken during a given period of industrial process "downtime", then the next replacement opportunity may not arise for around 15-20 years. In industries where profit margins are low (e.g. cement manufacture), the limited ability of industry players to invest in technology switching may be prohibitive to action. This is a moderate-critical barrier in all considered regions.

<u>Political economy barriers</u>

- **Fossil fuel prices are often subsidised by government, meaning that they are not on a level playing field with low-carbon energy alternatives.** The use of subsidy systems can limit the business case for industrial firms to implement process system overhauls, for investments in low-carbon energy supply systems, etc. Consequently, there is often a lack of viable and sustainable commercial frameworks that enable investment, innovation and cost reductions. A related and important aspect concerns the cross-border influence between countries that trade industrial products, but where differences exist related to the extent of industrial decarbonisation policy requirements in force in the respective countries.[415] (Please refer to case studies in Section 0, for a more detailed description of this barrier

---

412 The issue could be particularly challenging in the context of macroeconomic stagnation (e.g. resulting from economic slow-down related to the COVID-19 pandemic).

413 Within the EU ETS, for instance, it is estimated that carbon prices need to be at least EUR 50/tCO2 in order to generate demand for the use of currently-available carbon neutral technologies for cement manufacture, and EUR 60/tCO2 for aluminium production. (Source: IDDRI, 2019. Decarbonising basic materials in Europe: how carbon contracts-for-difference could help breakthrough technologies to market. https://www.iddri.org/sites/default/files/PDF/Publications/Catalogue%20Iddri/Etude/201910-ST0619-CCfDs_0.pdf)

414 For example, a 2019 OECD study on the barriers, technologies and policies for low and zero emissions in the steel and cement industries underlined the critical role of stimulating market demand for low-carbon industrial products, as a vital component part of overall efforts to decarbonise industry. The report authors emphasise, for instance, the importance of "market demand creation for early "green" commercial plants through guaranteed markets that reflect the higher production costs and investment risk, for example via green public procurement (e.g. preferred or minimum market shares for green materials), low emissions material "feed-in tariffs" (or "contracts for difference") or private buyer coalitions." (Source: OECD, 2019. Low and zero emissions in the steel and cement industries. Barriers, technologies and policies. https://www.oecd.org/greengrowth/GGSD2019_Steel%20and%20Cemement_Final.pdf).

415 If not addressed properly, significant differences in carbon content rules and decarbonisation commitments between countries that trade industrially produced goods, can result in reduced competitiveness for some, and an increase in the risk of "carbon leakage", i.e. production moving to countries that are less strict about emissions. In these instances, total global GHG emissions would not reduce but may in fact increase. Furthermore, the economies of the "responsible" countries would suffer. Tighter legislation (including related to energy and the environment), plus stricter enforcement, are often cited as a key reasons why many energy-intense industries have moved away from Europe.

and possible mitigation options). Entrenched subsidies for fossil fuels, and the lack of a level playing field between countries, are a moderate barrier in all considered regions.[416]

Industry players often enjoy considerable lobbying power over policy makers and government. There can be strong resistance to change, especially where industry captains also hold high political positions, and resist changes to the status quo. This is a barrier in all considered regions.

A lack of transparency and the existence of corruption can severely impact the correct and consistent enforcement of regulation and rules across a sector, which in turn can lead to an unlevel playing field. Industrial organisations are unlikely to engage fully with rules and regulations for decarbonisation if they consider that not all market players are held to the same standard of compliance with those rules. This is a moderate barrier in South Africa. That country ranks 73rd on Transparency International's 2018 Global Corruption Transparency Index.[417] This is a moderate barrier in India (78th); overall, it is a moderate barrier in Southeast Asia (key countries: Vietnam (33rd), Myanmar (132nd), Thailand (99th), etc.), but that region shows significant inter-country variation. It is a critical barrier in South Asia (key countries: Pakistan (117th), Afghanistan (172nd)).

Enabling environment

Industry sectors can be negatively affected by governments' poor capacities to develop policy and to design and implement industrial decarbonisation strategies. Changes in governments can also result in major policy shifts over relatively short periods of time. This can create levels of uncertainty for industry players with regard to future policy directions, which may cause them to postpone taking key decisions related to decarbonisation (e.g. technology switching) and/or can negatively-affect investments already made. Poor leadership by governments is often driven by concerns that industrial decarbonisation will make sectors less competitive. By contrast, relatively bold policies that seek to strengthen industrial decarbonisation could theoretically make industrial sectors more competitive.[418]

This barrier is compounded by the issue that governments, regulatory authorities and industry watchdogs may also lack both sufficient power to implement change and the ability and resources needed to adequately enforce regulations and rules and monitor compliance. Governments may have poor understanding of commercial frameworks for industrial decarbonisation. The limited capacities of the governments is a moderate barrier in South Africa, which scores 66.4% on the World Bank's Governance Indicator analysis (2018). It is a moderate barrier in India (64%); overall, it is a moderate barrier in Southeast Asia (key countries: Vietnam (53.4%), Myanmar (12.5%), Thailand (66.8%), etc.), and that region shows very large inter-country variation. It is a critical barrier in South Asia (key countries: Pakistan (26.9%), Afghanistan (7.7%)).

There is a risk of heightened macroeconomic instability in the immediate future, in the context of economic stagnation, principally because of the COVID-19 induced economic slowdown effects. This may reduce ambition for decarbonisation, a many industrial organisations' focus shifts to merely avoiding bankruptcy. On the other hand, recovery packages that prioritise green investments could be targeted towards industrial energy efficiency investments. This is a moderate to critical barrier in all considered regions.

---

[416] For example, 17.2% of the Indian government's revenue is dependent on taxation of fossil fuel production and consumption. India has reduced petrol and diesel subsidies, but still subsidises liquefied petroleum gas (LPG).

[417] Transparency International, 2020. Corruption perceptions index. Accessed from: https://www.transparency.org/en/cpi/2018/results/ken

[418] An example of such a policy measure is the European Union's current deliberation on implementing a "carbon border adjustment mechanism". Under this scheme, EU importers of products with high carbon footprints would have to buy carbon allowances, as EU producers do under the EU ETS. The central objective of the policy is to dismantle incentives for EU companies to outsource production to non-EU countries which lack carbon content rules. Moreover, goods produced by EU industry could become more competitive, as the mechanism would effectively act as an import tax (raising the price of imported good). Please refer to case studies in Section 0, for further background information on this policy mechanism.

Industry associations and knowledge sharing networks are sometimes undeveloped and uncoordinated, which can mean that opportunities and benefits associated with industrial decarbonisation are not widely understood and taken up. There is limited development of demonstrably viable innovative and sustainable business models to incentivise low carbon processes, products, share risks and effectively share by-products between industrial organisations, across the full industrial supply chain and processes. Consequently, industry players have limited understanding of, and experience in the use of, viable innovative business models can unlock deep decarbonisation of industry. This is a moderate to high barrier in most of the considered geographies.

Policy continuity can be a barrier. Continuity is important not least in order to offer industry players long-term signals and avoid situations where major policy and decarbonisation changes become a regular feature, and wherein major changes to decarbonisation strategy are subject to political election cycles (every 4 years for example). Lack of policy continuity is a moderate barrier in most of the considered regions.

Suitable skillsets are critical to unlocking industrial decarbonisation opportunities. Energy efficiency policies need to be accompanied by the build-up of a skilled workforce, making use of existing institutions, curricula and facilities. Suitably skilled and trained experts (e.g. in energy auditing and energy management) are often lacking, or at least not present in sufficient numbers. This can be a moderate barrier in South Africa, and a moderate to critical barrier in East Africa, India, Southeast Asia, and South Asia.

A summary of the severity of key identified barriers across target regions is provided in Table 26.

Table 26 Barriers to industrial decarbonisation: severity across target geographies

Type of barrier	East Africa	India	South Africa	South Asia	Southeast Asia
Political economy barriers	**Critical** Fossil fuel price subsidies, industry lobbying (blocking change), low transparency and poor regulatory enforcement	**Moderate** Fossil fuel price subsidies, industry lobbying	**Moderate-critical** Fossil fuel price subsidies, powerful industry lobbies (blocking change)	**Critical** Fossil fuel price subsidies, industry lobbying (blocking change), low transparency and poor regulatory enforcement	**Critical** Fossil fuel price subsidies, industry lobbying (blocking change), varied transparency and patchy regulatory enforcement
Market failures	**Critical** Unpriced GHG emissions, limited access to affordable capital for investments	**Moderate** Patchy access to affordable capital, low demand for low-carbon products	**Low-moderate** Limited demand for low-carbon products and long investment cycles	**Critical** Unpriced GHG emissions, limited access to affordable capital, limited demand for low-carbon products	**Moderate** Unpriced GHG emissions, patchy access to affordable capital, limited demand for low-carbon products

Type of barrier	East Africa	India	South Africa	South Asia	Southeast Asia
Enabling environment barriers	**Critical** Missing workforce skillsets, knowledge sharing networks, and governance issues	**Moderate** Key issue of suitable skillsets in the workforce and government leadership	**Moderate** Macroeconomic stability	**Critical** Limited government capacity for policy and strategy development, poor knowledge sharing networks and critical lack of skillsets	**Moderate** Governments' capacities for strategy design is variable, limited access to required skillsets,

Source: Vivid Economics, ASI and Factor

UK additionality

In the national context, the UK has considerable experience in several areas that are critically important for facilitating and promoting industrial decarbonisation through coherent policy.

The UK has had moderate ties with priority regions in relation to supporting the design and uptake of industrial decarbonisation policy. Given the extent of UK relationships in the countries of focus it is likely that UK additionality is high. The UK has longstanding ODA relationships with India and South Africa in particular. For example, DFID has previously supported private sector uptake of industrial energy efficiency in South Africa through the Private Sector Energy Efficiency programme. The UK also participates in the international CCUS programme which is supporting CCUS R&D, scoping studies, and demonstration project development in several target region countries (e.g., India, Indonesia, Pakistan, South Africa and Vietnam).

The UK can take advantage of several moderate-to-high synergies with its approach to UK industrial decarbonisation policy. The key aspects of relevance are described below. It is important to note that the UK industrial base is relatively limited in scale compared to certain industrialised countries and providers of development assistance in this opportunity area.

It is worth underlining that industrial decarbonisation policy is a relatively new area of international development support. By comparison, there is substantial and long-term experience in the provision of international development support in the field of industrial energy efficiency. To date, most of the assistance provided to support industrial decarbonisation policy design and uptake, is understood to have comprised relatively minor (sub-component) parts of broader industrial energy efficiency programmes. Overall, international donor support activity in the industrial decarbonisation policy opportunity area is driven by UNIDO and the World Bank. The key ODA donor countries in the emerging field of industrial decarbonisation policy support are understood to include Denmark, Germany (via KfW and GIZ), Sweden and the US (via USAID).

Some aspects of UK additionality are likely to be highest in relation to the industry sub-sectors in which the UK continues to have significant ongoing activity (e.g. chemicals production and refining), as well as within sectors in which the UK has growing experience (e.g. CCUS).

- The UK has considerable experience in designing and negotiating minimum carbon pricing systems, voluntary standards and agreements for UK industry to promote decarbonisation. In this context, the UK is well placed to provide guidance and support on stakeholder engagement processes, quantifying industry decarbonisation potentials, to communicate benefits and share information.

- Another area of expertise is policy and financial mechanisms to address cross-border competitiveness issues. The UK previously addressed this issue at the start of the UK Climate Change Agreement (CCA), and then again with the initiation of the EU Emissions Trading Scheme (ETS).[419] The UK could leverage its experience with Border Carbon Adjustments (BCAs) to support target regions to design and implement similar arrangements. Support in this area could go some way towards providing target country governments with some of the tools they need in order to address legitimate concerns around industrial competitiveness when creating markets for low-carbon industrial products (e.g. implementing emissions trading systems). Whilst the specific contexts of the target regions are quite different to the UK-EU context, the UK could provide target regions with valuable support around BCA system design (e.g. assessing the benefits, opportunities, difficulties and risks associated with BCA system implementation; setting appropriate BCA price / tax levels; and consulting and engaging with key industrial sector stakeholders to canvass opinions and obtain feedback on proposed system designs, etc.)

[419] More recently, BEIS and the UK CCC have revisited the topic of Border Carbon Adjustments (BCAs), in the context of evaluating future UK ETS options (i.e. from January 2021 onwards, following the UK's departure from the EU). Source: UK CCC. (2019). The future of carbon pricing in the UK. Accessed from: https://www.theccc.org.uk/wp-content/uploads/2019/08/Vivid-Economics-The-Future-of-Carbon-Pricing-in-the-UK.pdf

The UK has considerable strengths in the design of regulation and industry standards. Some of the key achievements include CCAs;[420] the EU ETS;[421] the Carbon Reduction Commitment (CRC) scheme; and the Energy Saving Opportunity Scheme (ESOS).[422] Further examples include instruments such as the "12L Income Tax for Energy Efficiency Savings," the Carbon Tax Act and the Carbon Offset regulations.

A further area of UK additionality relates to the design and promotion of markets for low-carbon products. One example of this is the UK's successful creation of significant demand for energy efficient products, to help meet some of the (above-mentioned) UK domestic energy efficiency targets and comply with binding energy efficiency standards and product labelling requirements, etc. The UK successfully grew its market for energy efficient products (reaching GBP 16.7 billion in 2018, up from GBP 12.6 billion in 2015).[423] The UK can draw on first-hand experience and lessons learned with respect to developing its domestic market for both energy efficiency and other low-carbon products; to support target regions in the creation of markets and critical mass levels of demand for low-carbon products.

The UK can build on its experience as an early mover with its national-level decarbonisation strategy and successfully developing, negotiating and obtaining industry sector buy-in to binding climate change agreements. The UK also has significant experience and capacities related to developing sub-sector specific industrial decarbonisation approaches.[424]

To help overcome access to capital barriers, the UK can leverage its experience with climate finance accelerators, such as the development of the UK Green Investment Group (previously Bank). The UK was an early mover in the international context, in developing a Green Investment focused bank.[425]

The development of skills sets, education and training in industrial decarbonisation analysis, auditing, energy management planning, etc. is a crucial part of unlocking industrial decarbonisation, and this is also an area in which the UK can provide additionality, drawing on its experience in setting up and delivering industrial decarbonisation skills programmes and training courses.

The UK has strengths related to developing government platforms promoting industrial decarbonisation. One such example is the UK Industrial Decarbonisation Programme (funded with GBP 170 million from the Industrial Strategy Challenge Fund)[426] which aims to accelerate the cost-effective decarbonisation of industry by developing and deploying low-carbon technologies. The programme involves planning and coordinating the development of (low carbon) industrial hubs that can facilitate large-scale and coordinated industrial decarbonisation. One example is the Clean Growth Grand Challenge: Industrial Clusters Mission,[427] which has the objective of creating at least one low-carbon cluster by 2030 and at least one net zero carbon industrial cluster by 2040.

---

[420] The UK was one of the first countries to introduce an emission trading scheme with industrial sectors. CCAs started in 2001 and pre-dates the EU ETS; this scheme is ongoing.

[421] However, it is unclear how the UK's involvement in the EU ETS will continue after Brexit.

[422] For "large" UK organisations – to address the EU EE Directive Article 8 obliging either ISO50001 certification or 4-yearly cycles of site energy audits.

[423] Office of National Statistics, 2020. Low carbon and renewable energy economy, UK: 2018. Accessed via: https://www.ons.gov.uk/economy/environmentalaccounts/bulletins/finalestimates/2018

[424] This expertise goes back nearly 40 years to the early "energy-efficiency demonstration scheme" (EEDS), followed by the energy efficiency best-practice programme and, most recently, the Carbon Trust Programme. More recently, specific activities include 2050 Roadmaps for 9 key industrial sectors (by DECC / BEIS); Industrial Heat-Recovery support programme; and UK food and drinks sector decarbonisation action plan (plus other sectoral plans).

[425] It has much to offer in terms of sharing the lessons learnt and assisting other countries / regions in designing, setting up and operating similar institutions. One key role of such investment banks includes ensuring that capital support mechanisms for low-carbon investments are fit-for-purpose in terms of allowing industry players to comply with industrial decarbonisation policies (in a timely and efficient way).

[426] The Programme is expected to be matched by funding of up to GBP 261 million from industry UKRI, 2020. Industrial Decarbonisation. Received from: https://www.ukri.org/innovation/industrial-strategy-challenge-fund/industrial-decarbonisation/

[427] Funded via the Industrial Strategy Challenge Fund. Key industrial clusters will be developed in Grangemouth, Teeside, Merseyside, Humberside, South Wales, and Southampton. Decarbonisation will be achieved through well-coordinated strategic planning; the use of market mechanisms; maximising economy of scale benefits; and promoting effective collaborations between the public and private sector, local communities and R&D.

The development of low-carbon industrial hubs allows the application of innovative business models for low-carbon processes often spanning the full supply chain. Moreover, such developments can yield significant economy of scale benefits and help spread investment risks. The UK can draw on its growing experience in this topic area, to advise on and help rollout similar initiatives, innovative business models, risk-sharing approaches and industrial symbiosis arrangements[428] in the international context.

Whilst the development of a zero carbon industrial cluster by 2040 is ambitious and would be a world first, it is important to note that the development of low-carbon industrial hubs in the UK is currently in a relatively nascent stage compared to in some other locations (e.g. Rotterdam) in the international context.

The UK government and industry partnership, via the new CCUS Council, seeks to put the UK on a path to deploying CCUS at scale in the UK, and maximising the associated socio-economic benefits of this industrial opportunity. The CCUS Council is the UK's primary forum for engaging the CCUS sector and addressing key strategic issues to allow CCUS targets to be achieved. Drawing on this experience, the UK can provide support in the establishment of bodies, as well as sharing the benefits of lessons learnt, in target geographies.

In the hydrogen fuel research area, the UK is actively involved R&D, for example through the Network-H2 project.[429] This is a GBP 1million collaboration across government, industry and UK universities, that works to advance R&D and act as a forum to maximise impact, communicate, share best-practice, and disseminate information and data for research projects. The UK could export its experience, develop international level collaborations in these topic areas, and assist other target regions in establishing similar such forums.

The UK can draw on various strengths and capacities, and growing experience, around promoting industrial decarbonisation policy uptake internationally. Significant experience has been gained through, for instance:

The UK's collaboration with global partners in CCUS to invest in leading CCUS technologies and industrial innovation to drive down costs in this technology area. The UK is the largest multilateral ODA investor into CCUS globally, having provided GBP 70 million ODA support since 2012. The international CCUS programme provides technical assistance for industry and power applications and has primarily supported technical assistance activities in Mexico, South Africa, China, Indonesia and India, as well as scoping work in Bangladesh, Pakistan, Vietnam and Mongolia.[430] Through its participation the UK has gained valuable experience that can be leveraged and exported, including in relation to planning CCUS demonstration projects, analysing risks, coordinating project development and possible business models for projects.[431]

The UK participates in the World Bank's Energy Sector Management Assistance Programme (ESMAP), and in 2019 made the largest contribution of donor countries (with total ICF support of GBP 41.5 million, of which GBP 20 million was provided by BEIS). ESMAP works to help scale up the efficient use of energy and low-carbon energy technologies (and with certain focus on industrial energy). At the time of writing, BEIS is providing a total of GBP 15 million to specifically support industrial

Accessed from: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/803086/industrial-clusters-mission-infographic-2019.pdf

[428] Industrial symbiosis includes the intelligent linking of industrial processes through supply chains, efficient processing of waste streams and sharing industrial process by-products where possible and efficient to do so.

[429] Durham University. (2019). Durham UK lead on hydrogen fuel research. https://www.dur.ac.uk/research/news/item/?itemno=39771

[430] Gov-UK, 2020. CCS Annual report.: https://www.gov.uk/government/publications/crown-commercial-service-annual-report-and-accounts-2019-to-2020

[431] However, the experience of the CCUS programme has also demonstrated the substantial difficulties encountered in achieving transformation change in CCUS in developing countries. On the positive side, such insights can be drawn upon to help inform future work and collaborative initiatives in CCUS in developing countries. This may help ensure that future programme objectives are optimally-designed, realistic and achievable and benefit from the myriad lessons learned to date.

decarbonisation innovation (technology innovation and technology-agnostic solutions) within the ESMAP programme.

The Clean Energy Innovation Facility is a new programme for accelerating the commercialisation of innovative, clean energy technologies in developing countries. The aim is to advance TRLs 3-7)and encourage potential scale-up of innovative technologies through RD&D. Within this a GBP 15 million fund focused on industrial decarbonisation has been established, which is housed within the WB's ESMAP.

A considerable part of UK ODA support (recent and ongoing) for the promotion of industrial decarbonisation tends to be provided to the European Bank for Reconstruction and Development (EBRD) programme and budget. The UK makes an important financial contribution to EBRD initiatives promoting industrial decarbonisation, benefits from participating in ongoing regional initiatives for industrial decarbonisation and can continue to shape programme activities and share the benefits of its growing experience.

With its expertise in the design and application of industrial decarbonisation policy, the UK is well-placed to address critical market failures and enabling environment challenges. It can build on its international experience, ongoing partnerships, and key upcoming opportunities (such as hosting the COP26 and holding the presidency of the Group of Seven (G7) in 2021), to address political economy challenges to industrial decarbonisation. Overall, the UK's key strengths and areas of additionality fall into three broad categories. The first relates to the creation of government-led platforms focused on promoting industrial decarbonisation, through strategic planning and the promotion of integrated low-carbon industry hubs. The second area derives from the UK's involvement in international partnerships to scale-up and de-risk decarbonisation projects (including CCUS). The third key area of additionality is the UK's international collaborative work to address cross-border competitiveness issues and achieve common carbon prices (e.g. via BCAs), drawing on its experience in evaluating the impacts of such systems, setting appropriate price levels, and consulting with industry on proposals.

Intervention opportunities

There is substantial opportunity across all regions for the UK to address identified barriers and support the design and use of effective industrial decarbonisation policy.

Based on analysis of the core UK strengths and areas of additionality, strong intervention opportunities for the UK include:

Provision of technical assistance to define and negotiate carbon intensity limits, standards, regulations and rules. Specific interventions in this area would include:

Mapping industrial activities and quantifying the carbon intensities of those activities and sub-sectors. Supporting regulatory authorities to define and negotiate carbon intensity limits and standards.

Strengthening human capacities within enforcement agencies to improve their abilities to enforce, monitor, report and verify compliance with carbon intensity regulations and rules.

Supporting the design and application of industry voluntary agreements on carbon limits.

This intervention is in demand within each of the considered regions. South Africa and India are understood to have made initial progress on several of these topics and therefore support would be used to continue strengthening existing measures, whereas in East Africa, and South Asia and Southeast Asia, support would be focused on laying the groundwork and undertaking more initial steps.

Support the creation, introduction and application of carbon pricing instruments. Support in this intervention area would involve:

Provision of strategic support to governments in evaluating and screening options for implementing carbon taxes, ETSs, and other fiscal measures which incentivise low-carbon and efficient energy use in industry.[432] Assisting in the design of effective BCAs,[433] to support ETS development.

Creating dedicated platforms to support carbon markets in focus countries.

Assist industry associations to promote the uptake of company-level internal carbon pricing systems.

Supporting RD&D on carbon pricing instruments, with particular focus on critical measures such as the design of suitable BCA mechanisms, and to help protect industrial competitiveness, avoid carbon leakage, and address industry concerns.

Continuing to support key Multilateral Development Bank (MDB) programmes, including the EBRD's work on industrial decarbonisation, and the World Bank's Partnership for Market Readiness (PMR) and ESMAP.

This intervention is understood to be most appropriate for Southeast Asian region countries, which have certain ambition for exploring the use of carbon pricing instruments, but which have yet to take concrete steps in that direction. South Africa is not considered to be a relevant target region given its recent uptake of dedicated carbon pricing instruments.

Technical assistance for the development of tailor-made industrial decarbonisation hubs, tools and strategies. Support in this intervention area would involve:

Supporting governments and industry to work together to establish and agree strategic objectives, action plans, and timelines of industrial decarbonisation strategies. Ensuring that industrial decarbonisation

[432] The design of specific instruments always needs to be strongly tailored to the maturity of the specific market.
[433] Support in this field could build on the lessons learned through certain similar initiatives undertaken to date, including e.g. the EBRD's Green Trade Facilitation Programme, which is described in Case Study 2 (section 0 of this report).

strategy is coherently aligned with other related strategies (e.g. RE and power sector development strategy, strategies for industrial development and economic growth, etc.).[434]

Supporting RD&D and strategic planning for low-carbon industry hubs,[435] including the facilitation, where possible, of high rates of (RE-powered) electrification, digitalisation, use of smart systems, industry symbiosis, zero-carbon hydrogen and CCUS infrastructure.

Supporting RD&D on innovative and sustainable business models, commercial frameworks, de-risking and risk-sharing approaches, in order to incentivise low-carbon investments.[436] Designing and applying ad-hoc and country-specific industrial decarbonisation financing models;[437] these should be accompanied by regulation, institutional capacity, skills, and awareness policies.

Given their relative lack of industrial decarbonisation strategies to date, the countries of South Asia and East Africa are strong candidates for support in this intervention area. India (given its proven interest and grass-roots efforts to design and test innovative approaches) and South Africa may be stronger candidates for support related to industry hubs, and large-scale CCUS and hydrogen energy projects; this is because, in general terms, they already have the key foundations of industrial decarbonisation in place.

Support the design and delivery of industrial decarbonisation upskilling, education and training courses.
Support in this intervention area would involve:

Designing and delivering specialised education, training and skills development courses focused on (amongst other things) energy auditing, energy management and decarbonisation strategy, to prepare the workforce that is needed in order to unlock industrial decarbonisation at scale.

Promoting just and equitable transitions, characterised by skills retention, by identifying and planning ways to support the worst affected industry players, to avoid significant job and competitiveness losses, and to maximise new job creation.

All target regions are considered to be strong candidates for support in this intervention area, as significant numbers of workers will need to be trained and educated across industrial decarbonisation topics in all regions, ranging from technicians, to policy-makers, and more vocational roles such as workers within financial institutions (whom will finance decarbonisation investments).

Provision of capital investments to support the deployment of demonstration projects.

Demonstration projects can provide multiple benefits, such as indicating political support for, key innovative technologies and approaches. Demonstration projects can also serve to bring together different donors and investors and stimulate buy-in from a wide group of stakeholders. Most critically, demonstration projects can showcase the functionality and technical viability of key

---

[434] Develop and test frameworks and pathways for resource efficiency, circularity, and integration of natural infrastructure.
[435] Future ICF support for the development of low-carbon industry hubs may draw on examples of best practice and lessons learnt within similar initiatives that are currently underway.
For instance, the Baltic Industrial Symbiosis (BIS) project is a multi-country Baltic Sea region initiative that works to promote and coordinate the development of low-carbon industry hubs in the Baltic region. This is undertaken through developing new business and finance models for industrial symbiosis; identifying new symbiotic business development opportunities; and providing capacity building and training necessary for the design, management and facilitation of low-carbon industrial hubs. (https://symbiosecenter.dk/project/bis/).
Important lessons and examples of good practice can also be drawn from the programme to decarbonise the port and industrial complex of Rotterdam. For instance, one aspect of the wider programme includes the development of CCUS infrastructure that will be accessible to multiple industrial actors. Specifically, the port will contain a CO_2 transport and storage infrastructure connected to offshore empty gas fields under the North Sea. The infrastructure is being developed with a view to being expandable, to eventually be able to transport and store CO_2 from other regions of the Netherlands (i.e. beyond Rotterdam) and neighbouring countries such as Belgium and Germany. (Port of Rotterdam. (2019). https://www.portofrotterdam.com/sites/default/files/por_priorities_energy_transition_european_elections_2019.pdf)
[436] It is recommendable that technical assistance provided within this context be accompanied by grant funding, which could be used to implement the first stage of the technical assistance's recommendations. For instance, grant funding could be used to finance one training scheme, one pilot hydrogen or heat capture installation, one pilot energy efficiency network, and one round of grant funding for innovative start-ups, etc.
[437] Finance models should be specifically designed to fit countries' particular contexts (e.g. level of maturity of financial markets, governance, etc).

innovative technologies and systems, often alleviating doubts around their effectiveness and providing important data that support further improvements through RD&D.

Support in this intervention area would involve making capital investments in selected industrial decarbonisation demonstration projects.

It is recommended that support for CCUS projects be targeted to countries in which the UK has previously supported CCUS uptake efforts, including in Bangladesh, India, Indonesia, Mongolia, Pakistan, South Africa, and Vietnam. It is recommended that UK Government capital investment support for demonstration projects focused on digitalisation, hydrogen networks, smart systems and the development of industrial hubs / symbiosis networks be prioritised for initiatives in India.

Stimulate demand for low-carbon industrial products. The overall driver for this intervention is to create significant ("critical mass") levels of demand for low-carbon and industrially produced products. Key activities would include:

Assisting in creating standards and labels (e.g. covering the carbon footprints of industrially made products) and accompanied by robust enforcement and compliance systems.

Developing and rolling out (industry and/or industry sub-sector specific) information and awareness raising campaigns on the multiple benefits of low-carbon industrial goods targeted towards end-consumers, industrial organisations, governments and others. Such initiatives would provide evidence-based information around the economic, environmental and social benefits; the business opportunities and options to enter and prosper in emerging low-carbon market niches; and any measures that can be accessed to support switching to the use of low-carbon processes and systems.

Strengthening trade networks for low-carbon products, helping those products reach points of demand.[438] Stimulating the development of low-carbon supply chains; for example, via the establishment of integrated low-carbon industry hubs. Low-carbon supply chains can also be supported through more detailed analysis and public disclosure of the carbon footprints of processes up and down industrial supply chains.

Promoting the reputational advantages for those industry organisations that decarbonise. Progress in this direction can be made, for example, through supporting the design of industrial energy efficiency rankings and award schemes.

Support in this intervention area could be provided in all considered regions, given the significant need to stimulate demand for low-carbon products in each.

[438] If industrial organisations can see a clear downstream demand for low-carbon products, they are more likely to take the necessary steps to be able to meet (supply) that demand.

Box 16 GEF's Long-Term Programme on Technology Transfer: Climate Technology Centres and Networks, Pilot Projects. Global Environmental Facility – 2008 –ongoing.

Introduction

While most energy efficiency options are likely to bring about cost savings for firms, certain investments associated with industrial decarbonisation (such as CCUS) are likely to reduce the competitiveness of emissions-intensive and trade-exposed sectors.

Innovation and technology-transfer programmes represent one possible approach to addressing cross-border competitiveness issues, in particular in the context of emerging and developing and emerging economies. While it is complex to evaluate their impact, they are potentially complementary to trade-related policy, such as cross-border regulations and carbon border taxes, which are in themselves very challenging to implement and require multi-lateral agreements and action.

This case study focuses on the Global Environmental Facility's (GEF) Long-term Programme on Technology Transfer[439], as an instrument that addresses innovation and technology transfer holistically, without a specific focus on industrial decarbonisation (though with a strong energy and energy efficiency focus). Although addressing cross-border competitiveness is not explicitly addressed in this programme's goals, it is considered a useful model of an integrated approach to innovation and technology transfer which could address a variety of competitiveness aspects for energy-intensive industry in developing and emerging economies.

Goals of the programme

Two of the six goals of the GEF climate change mitigation objectives address industrial decarbonisation technologies:

- Goal 1: Promote the demonstration, deployment, and transfer of innovative, low-carbon technologies.
- Goal 2: Promote market transformation for energy efficiency in the industrial and buildings sectors.

Since its inception in 1991, the entire GEF climate change mitigation portfolio has supported innovation and technology transfer. Specifically, in its fourth programme cycle the GEF launched the Long-term Programme on Technology Transfer. Since then, the GEF has supported and financed a range of priority technical assistance activities and pilot projects related to innovation technology transfer. The most recently concluded programming cycle of the GEF (GEF-6) prioritised the promotion of innovation and technology transfer as a cross-cutting theme.

The role of GEF's finance within its technology transfer programme include[440]:

- Supporting the Climate Technology Centre and Network (CTCN).
- Piloting priority technology projects to foster innovation and investments.
- Building Private Public Partnership for tech transfer.
- Supporting Technology Needs Assessments (TNAs).
- Positioning GEF as a catalytic supporting Institution for tech transfer.

[439] GEF. (2020). Technology transfer. Accessed from: https://www.thegef.org/topics/technology-transfer
[440] CTCN. (2019). GEF update on technology transfer. Accessed from: https://www.ctc-n.org/sites/www.ctc-n.org/files/item_4c_-_gef7_update.pdf

Resulting outcomes from the first two elements of the programme (Climate Technology Centre and Network, and pilot projects) in the field of industrial decarbonisation are outlined in the next section.

High level results and outcomes

The **Climate Technology Centre and Network (CTCN)** supports country efforts to enhance the transfer of low-carbon technologies. One of the CTCN's core services is the provision of technical assistance (TA) at the request of developing countries. This technical assistance is provided up to a value of USD 250,000, at local, national, or regional levels and at all stages of the technology cycle. The CTCN's own evaluation indicates that the bulk of the requests for TA is for decision-making tools (26%), technology feasibility assessment (21%), technology identification and prioritisation (15%), as well as sectoral roadmaps and strategies (12.5%)[441].

Some examples of CTCN technical assistance and other technology transfer projects that are relevant to industrial decarbonisation include:

- Vietnam: Pilot demonstration of Energy Service Company (ESCO) model for greenhouse gases emission reduction in the cement sector (2016)
- Thailand: Benchmarking Energy & GHG Intensity in Thailand's Metal Industry (2015)
- South Africa: Substantial GHG emissions reduction in the cement industry by using waste heat recovery combined with mineral carbon capture and utilization (2015)

In addition to the technical assistance request described above, the CTCN provides so-called Fast Technical Assistance (FTA) with a limited value of USD 15,000, and a timeframe of up to 2 months. FTA also addresses technology prioritisation and technology assessments that are of immediate interest to the requesting country.

With regards to the GEF's **pilot projects**, the GEF supports "innovation and technology transfer at key early and middle stages, focusing on the demonstration and early deployment of innovative options". The financial support aims at "mitigating the barriers of technology transfer, and piloting promising approaches". A review of 61 GEF-6 climate change mitigation projects indicated that over a quarter included support for technology transfer[442,443].

These are some examples of finance for projects in industrial decarbonisation in the GEF portfolio, which included or will include demonstration of technology (chiefly related to energy efficiency and fuel switching):

- China: Environmentally Sustainable Development of the Iron and Steel Industry (2020 start, GEF-7)
- Brazil: Production of Sustainable, Renewable Biomass-based Charcoal for the Iron and steel Industry in Brazil (2012-2015, GEF 5)
- Cambodia: Climate Change Related Technology Transfer: Using Agricultural Residue Biomass for Sustainable Energy Solutions (2011–2015, GEF 4). (Industry relevance: Replacement of diesel oil with biomass in industrial captive power generation).
- India: Removal of Barriers to Energy Efficiency Improvement in the Steel Rerolling Mill Sector (2003-2015, GEF-3)

[441] CTCN. (2020). Request visualizations. https://www.ctc-n.org/technical-assistance/request-visualizations
[442] GEF. (2017). Climate change focal study area. https://www.thegef.org/sites/default/files/council-meeting-documents/EN_GEF.ME_C.53_Inf.02_Climate_Change_F_A_Study_Nov2017.pdf
[443] IISD. (2016). http://sdg.iisd.org/news/unfccc-technology-executive-committee-evaluates-technology-transfer-poznan-programme/ https://unfccc.int/resource/docs/2015/sbi/eng/16.pdf

This is a high-level analysis of a long-standing and highly integrated programme. Thus, it is challenging to reach conclusions on the level of investments that it has leveraged in climate technologies in developing and emerging economies, or on the extent to which it has strengthened countries' capacity to innovate and transfer technology. In general, the effect of technology transfer and innovation programmes competitiveness at the firm, sector and economy level are difficult to quantify and attribute. Nevertheless, the GEF's technology transfer programme is a good example of a needs-driven approach to innovation and technology transfer which has provided multiple lessons over the years. Elements of it can be adapted to industrial decarbonisation programmes, where technology innovation and transfer are key levers when addressing cross-border competitiveness issues.

Promotion of gender equality

The GEF has a series of policies on gender and supports the mainstreaming of gender aspects in all its projects, including those in its technology transfer programme. In addition, all GEF implementing agencies have their own policies related to gender.

Partnership

The two technology innovation and transfer elements of the GEF programme examined here have different governance, partnership and co-financing models. Some of the key aspects related to partnership include (drawing from their 2015 evaluation) include:

- The programme needs-driven approach has proven successful: for example, GEF-supported pilots were found to be more effective and smooth-running when they responded to a demand from the technology users. Projects that had taken a "technology-push" approach resulted in less relevance for country stakeholders and a difficulty in finding partners willing to invest.
- The existence of regional centres promoted the creation of dialogue with local institutions.
- The programme has succeeded at engaging financial institutions on climate technology issues. The regional centres have created strong links with domestic and regional financial institutions.

Main risks of the programme

Some of the programme's key risks and lessons learnt (drawing from their 2015 evaluation) include:

- There is a need to complement technical assistance efforts with innovative finance instruments that address investment risk.
- Technology transfer projects are complex processes that are subject to changes in political conditions, implementation delays and changes to project scope. Flexibility to make amendments to plans subsequent to project approval is critical to success.
- The speed of the GEF project cycle can be a barrier to engaging the private sector on technology transfer.

Box 17 Ongoing initiatives to support the production and international trade of low-carbon products

The following analysis considers a selection of international level initiatives to support the production and international trade of low-carbon products. An initial discussion is provided of the current thinking around the possible uptake of carbon border adjustment mechanisms in the EU and North America. The analysis then presents two examples of effective initiatives to support the cross-border trade of industrial (including low-carbon) products, as undertaken by the EBRD and Asia-Pacific Economic Cooperation (APEC), respectively.

Proposed carbon border adjustments mechanisms

The authors are currently unaware of any existing cross-border regulations and/or carbon border taxes in effect. Some have been considered or are in the late planning stage – these are discussed later in this review. However, no such systems have been in-situ for a suitable period of time and for which an impact analysis has been made – which would naturally be the basis for a Case Study.

The main idea of carbon border taxes is to protect energy-intensive industries located in countries with strict CO_2 / GHG emission legislation, by eliminating any competitive advantage enjoyed by exporters from countries that don't tax emissions. If adopted, carbon border adjustment systems could incentivise non-carbon taxing countries (or, indeed, those with subsidised energy) to adopt carbon taxes and/or tighter environmental controls. The idea is to eliminate any "unfair" advantage offered to such importers.

The European Union

The EU is currently considering the implementation of a carbon border adjustment mechanism.[444] Under this scheme, EU importers of products with high carbon footprints (generally, energy-intensive sectors such as steel, aluminium, cement, glass and others) would have to buy carbon allowances, as EU producers do under the EU ETS. In effect, this could be considered an import tax that raises the price of imported goods, boosting the competitiveness of similar goods produced in the EU.

The main rationale is that EU's efforts to go climate-neutral by 2050 could be undermined by a lack of ambition by others. It could also mean increased risk of "carbon leakage", i.e. production moving to countries that are less strict about emissions. In these instances, total global emissions would not reduce but may in fact increase. Furthermore, the economies of the "responsible" countries would suffer. Tighter legislation (including on energy, environment and health and safety), plus stricter enforcement, are often cited as being key reasons why many originally-European energy-intensive industry market players have relocated to countries outside of Europe.

This new carbon border adjustment mechanism would counteract the risk of relocation of market players to countries outside of Europe, mainly by putting a carbon price on imports of certain goods from outside the EU.[445] However, a key concern is that such a move may risk breaching World Trade Organization (WTO) rules, which require equal treatment of similar products and no discrimination between domestic and foreign producers. There are also concerns about reprisals and trade-wars. However, other authors, including from the US, suggest that this is not discriminatory and is in fact "levelling the playing field".

North America

As mentioned above, professional opinions are divided on whether WTO law would permit border tax adjustments for taxable inputs that are not physically incorporated into the final product. Also, it is not clear if an import tax could vary based on the amount of CO_2 emitted during its production. For instance, in terms of kWh/t or $kgCO_2$/t: (1) primary steel from ore is substantially more energy intense than (2) secondary steel (re-melted scrap), which in turn is more energy-intense than (3) steel rolling mills. WTO

[444] Reuters(2019). https://www.reuters.com/article/us-climate-change-eu-carbontax-explainer/explainer-what-an-eu-carbon-border-tax-might-look-like-and-who-would-be-hit-idUSKBN1YE1C4; FT. (2018). EU's carbon border taxi s risky but needed. https://www.ft.com/content/28bbb54c-41b5-11ea-a047-eae9bd51ceba

[445] European Commission. (2020). EU Green Deal (carbon border adjustment mechanism). https://ec.europa.eu/info/law/better-regulation/have-your-say/initiatives/12228-Carbon-Border-Adjustment-Mechanism

rules would have to be interpreted in a way that considers products not to be 'like' each other, based on their carbon footprints.

Several US experts have concluded that WTO trade rules permit countries with carbon taxes to adopt non-discriminatory harmonising tariffs.[446] [447]

The US itself already recognises this principle, but on a food source, by prohibiting the import of Thai shrimp that had been caught in "turtle unfriendly" nets. The WTO sustained the principle that global environmental concerns are more important than narrow commercial interests, setting a precedent. Stiglitz concluded that if one can justify restricting the importation of shrimp in order to protect turtles, certainly one can justify restricting imported goods produced by technologies that excessively pollute the atmosphere.

Non-legislative green trade mechanisms

EBRD – Green Trade Facilitation Programme

The EBRD's **Green Trade Facilitation (TFP) Programme** supports investments in, and the supply of, climate change mitigation and adaption technologies in countries of EBRD focus. The programme aims to promote foreign trade to, from and within the EBRD regions and offers a range of products to facilitate this trade, indulging guarantees and trade-related cash advances. Under the programme, the EBRD offers access to an established network of banks for financing the cross-border supply of key green technologies.

A key aspect of the TFP is that the EBRD provides guarantees to international confirming banks, taking the political and commercial payment risk of international trade transactions undertaken by banks in its regions of focus. In particular, guarantees can be used to support the use of several instruments that are issued or guaranteed by local banks, including:

- Letters of credit and standby letters of credit.
- Deferred payment and 'red-clause' letters of credit.
- Advance payment guarantees and bonds, and other payment guarantees.
- Bills of exchange and trade-related promissory notes.
- Bid and performance bonds and other contract guarantees.
- Letters of credit with post-financing to cover the finance of imported capital equipment.
- Other types of trade finance instruments can also be considered.[448]

In terms of practicalities, either the issuing bank or the confirming bank may apply for financial support (guarantee). If the confirming bank applies, the consent of the issuing bank is required before a transaction can be covered.[449] Under the programme, the issuing banks are responsible for managing their exposure.

---

[446] Carbon Tax Centre, 2020. Border adjustments. Accessed from: https://www.carbontax.org/issues/border-adjustments/(2015)

[447] In 2013, a former WTO officer, Jennifer Hillman, concluded that both the letter and spirit of WTO trade rules would permit countries with carbon taxes to adopt non-discriminatory tariffs. Hillman concluded that: "… *provided policymakers carefully design a [carbon] tax, keeping in mind the basic requirements of the WTO not to discriminate in favour of domestic producers or imports from certain countries over others … the threat of WTO challenges should not present a barrier to policymakers wishing to adopt a carbon tax system now.*"
Earlier, in 2006, Nobel Laureate Joseph Stiglitz wrote, "*Not paying the cost of damage to the environment is a subsidy, just as not paying the full costs of workers would be*." He and others urge adoption of carbon border adjustments to eliminate the artificial advantage given to firms that manufacture goods or provide services for world markets from countries that fail to tax CO_2 emissions. In fact, Stiglitz was critical of energy subsidies for US manufacturers and suggested that "*other countries should prohibit the importation of US manufactured goods produced using energy intensive technologies, or, at the very least, impose a high tax on them, to offset the subsidy that those goods currently are receiving*."

[448] EBRD, 2020. Trade Facilitation Programme. Accessed via: https://www.ebrd.com/work-with-us/trade-facilitation-programme/products.html

[449] EBRD, 2020. Trade facilitation programme. FAQ. Accessed via: https://www.ebrd.com/work-with-us/trade-facilitation-programme/faq.html

Under the TFP, and in addition to guarantees, the EBRD extends short-term cash advances to selected banks and factoring companies in the EBRD regions for on-lending to local exporters, importers and distributors.

A further aspect of the TFP is its trade finance e-learning programme. This programme was launched in 2010 and is run by the EBRD and the International Chamber of Commerce (ICC), with the objective of helping issuing banks involved in the EBRD's TFP to achieve best international practice in trade finance. The e-Learning Programme covers all of the ICC traditional trade finance products and Incoterms® rules. These are key features of international commercial contracts involving the shipment of goods and provision of services. Since 2010, training has been provided to over 300 trade specialists within around 80 banks throughout Eastern Europe and Central Asia.

With the central objective of promoting the trade of industrial products to, from, and within EBRD regions, the TFP has significant potential to help facilitate and encourage international trade in low-carbon products in a timely and efficient way.

The EBRD recently reported that "as importers and exporters grapple with increasingly complex supply routes, there has been a rapid rise in demand for trade finance that is vital to keeping the channels of trade open",[450] especially during March and April of 2020 during the initial stages of the coronavirus pandemic. Amongst other things, this increased demand for trade finance support has shown that such mechanisms can make a tangible difference as regards the viability of international trade under challenging conditions. Such mechanisms have strong potential to support scaling up international trade in emerging low-carbon industrial products, especially where those markets' development is at a nascent (and rapidly evolving) stage.

The TFP was launched in 1999 and has received a variety of awards in recognition of the effectiveness of its activities.

The TFP works to promote gender equality through adherence to the EBRD's overall organisational Strategy for the Promotion of Gender Equality 2016-2020, which sets the Bank's commitment to promoting gender equality and equality of opportunities in the countries where the EBRD invests, as an important contributor to well-functioning market economies and inclusive societies.

Measures taken by the Asian-Pacific Economic Cooperation to promote trade in low-carbon and environmentally friendly products

The APEC region covers 21 national economies largely bordering the Pacific Ocean and accounts for around 60% of total global energy demand. In 2016, the APEC economies consumed the equivalent of 8,043 Mtoe/yr.[451]

Following several years of negotiations, in 2012 APEC implemented tariff cuts on a list of 54 Environmentally-friendly Goods (EGs).[452] This initiative was undertaken with the objective to lower the purchase costs of EGs, such as solar panels, wind power turbines and air pollution control equipment. Alongside efforts to support service providers that utilise clean technologies, those tariff reductions also helped position the APEC region to:

- Meet its target of doubling renewable energy by 2030.
- Reduce overall energy intensity by 45% by 2035.

Transparent, easy-to-access information on tariff cuts help businesses take advantage of new trade opportunities while promoting the efficient use of clean and low-carbon energy in the region. The tariff reductions on the APEC list of 54 EGs also promoted trade worth around USD 300 billion within the APEC region and USD 500 billion worldwide, whilst also giving impetus to the "Environmental Goods

[450] EBRD, 2020. Trade facilitation programme: overview. Accessed from: https://www.ebrd.com/work-with-us/trade-facilitation-programme.html
[451] 1 million tonnes of oil equivalent = 1 Mtoe = 11.63 MWh
[452] APEC, 2016. APEC cuts environmental goods tariffs. Accessed from: https://www.apec.org/Press/News-Releases/2016/0128_EG.aspx

Agreement" negotiations in the WTO. Unfortunately, very little recent information, updates or impact assessment could be found regarding progress with this initiative from 2016 onwards.

A second initiative is the APEC Green Supply Chain Cooperation Network. Initiated in 2014, this initiative seeks to facilitate the reduction of pollution and environmentally-damaging waste linked to manufacturing and logistics networks in the Asia-Pacific region, whilst boosting trade and economic growth.[453]

An expert group was formed to help advance the network, through strategically reviewing green supply chain practices in specific industry sectors, as well as within key segments of international production and supply chains.

In order to bridge the significant gaps in the uptake of green and low-carbon supply chains between the diverse economies across the APEC region, the Green Supply Chain Cooperation Network organises annual dialogues and cooperation conferences, capacity building activities (such as stakeholder training workshops), and has developed online information resource and dissemination networks.

Some examples of green supply chain practices include the use of easily disposable and low impact materials, recycling infrastructure and networks, and industrial operational efficiency enhancements.

[453] APEC, 2015. Green trade boosted as network takes shape. Accessed from: https://www.apec.org/Press/News-Releases/2015/0904_green.aspx

Glossary

Acronym / Term	Definition
ADB	Asian Development Bank
AI	Artificial intelligence
APEC	Asian-Pacific Economic Cooperation
BAU	Business as usual
BCA	Border carbon adjustment
BEIS	UK government Department for Business, Energy & Industrial Strategy
BESS	Battery energy storage systems
BMZ	Germany's Federal Ministry for Economic Cooperation and Development
BTM	Behind-the-meter
BUG	Back-up generator
CCA	Climate change agreement
CCS	Carbon capture and storage
CCUS	Carbon capture utilisation and storage
C&I	Commercial and Industrial
CIF	Climate Investment Funds
CRC	Carbon Reduction Commitment scheme
CSP	Concentrated solar power
CTF	Clean Technology Fund
DER	Distributed energy resource
DFID	UK government Department for International Development
DR	Demand response
EBRD	European Bank of Reconstruction and Development
EE	Energy efficiency
ESMAP	Energy Sector Management Assistance Programme
ESO	Energy systems optimisation
ESOS	Energy Saving Opportunity Scheme
ESRN	Energy Storage Research Network
ESS	Energy storage systems
ETS	Emissions Trading Scheme
EU	European Union
EUR	Euro
GBP	British pound sterling
GDP	Gross domestic product
GEF	Global Environmental Facility
GESP	Global Energy Storage Program
Gt CO2	Gigatonnes of CO2

Acronym / Term	Definition
Gt CO2e	Gigatonnes of CO2 equivalent
GHG	Greenhouse gas
GIZ	Deutsche Gesellschaft fur Internationale Zusammenarbeit GmbH
GW	Gigawatt
GWh	Gigawatt hours
IADB	Inter-American Development Bank
ICC	International Chamber of Commerce
IEA	International Energy Agency
IT	Information technologies
NDC	Nationally Determined Contribution
NEP	National Energy Plans or Policies
ODA	Official Development Assistance
OECD	Organisation of Economic Cooperation and Development
PAT	Perform, Achieve and Trade scheme
PPA	Power purchase agreement
RD&D	Research, development and demonstration
SDG	Sustainable Development Goal
TRL	Technology Readiness Level
UKCI	UK Climate Investments
UNIDO	United Nations Industrial Development Organisation
USAid	United States Agency for International Development
USD	United States Dollar
WTO	World Trade Organisation

Mass Transit

Summary

The mass transit opportunity considers all interventions related to the movement of individuals using group travel, primarily buses and trains, and is expected to be a cost-effective pathway to decarbonising transport in densely populated urban areas. The mass transit assessment will consider the role of group travel in reducing passenger transport emissions, either by increasing mass transit's share of passenger transport activity or reducing the emissions intensity of transit by buses and trains. It will focus on buses and trains, as they are the most prevalent forms of group travel. The rationale for mass transit relates to its potential to deliver emissions reductions at a lower cost than other transport interventions (e.g electrification of passenger vehicles) and provide additional development benefits, such as congestion relief. Uptake and climate impact are therefore dependent on the local context, and will be highest in densely populated urban areas where a high utilisation rate is more likely.

Interventions to encourage adoption of low-carbon mass transit in the focus regions include financial support to subsidise large upfront infrastructure costs and technical assisstance to ensure more effective, integrated mass transit solutions. Examples of such interventions include:

Financial support towards mass transit infrastructure, such as in the purchase of low-carbon bus fleets, installation of charging infrastructure and, in fewer cases, financing of rail infrastructure.

- Technical assistance to improve the planning and design of mass transit systems, with the current quality of service delivery often inhibited by ineffective urban planning, non-integrated transport solutions, and a limited use of digital technologies to maximise efficiency.

Table 27 Mass transit assessment summary

Criteria	Assessment	Notes
Climate impact	Low	• Mass transit can help avoid around 11% of passenger transport CO2 emissions (0.7 gigatonnes of carbon dioxide [CO2]) by 2050, beyond business as usual (BAU), with impact potentially greater under more ambitious mode-switching assumptions. • Climate impact is highest in regions with densely populated urban areas, where mass transit is particularly cost-effective at meeting increasing mobility demand, while reducing emissions and delivering additional co-benefits e.g. time savings.
Development impact	High	• Significant potential for mass transit to help achieve several Sustainable Development Goals (SDGs), including the ability to create sustainable cities, which improve levels of gender equality, economic growth, and help ensure improved health outcomes through reductions in local air pollution.
Investment need	High	• Investment need of USD 63 trillion by 2050 is amongst the largest across the opportunities considered, driven by the capital intensity of infrastructure provision. • An investment gap of around USD 39 trillion by 2050 is expected, relative to BAU investment levels, which will vary substantially across regions depending on their required infrastructure provision.
Cost-effectiveness	Medium	• Mass transit can be a highly cost-effective opportunity, due to the value of the transport service obtained, together with the efficiency in its provision. • The largest driver of cost-effectiveness will be the subsequent utilisation rate and the extent of mode-shifting away from other more polluting forms of transport.

Criteria	Assessment	Notes
Barriers to adoption	High	• Adoption is slowed by many political economy, market failure, and enabling environment barriers, including: lack of public sector capacity to budget and plans for mass transport investment, non-existent urban planning frameworks which reduce viability of mass transit projects, and capital mismatch from the delayed returns to significant, upfront capital costs.
UK additionality	Low	• Despite relatively lower potential to harness existing UK expertise, UK Official Development Assistance (ODA) has been effectively used for building capacity related to urban planning. The UK can also readily deploy relevant expertise in bus rapid transit (BRT) infrastructure and smart ticketing systems.

Source: Vivid Economics, ASI & Factor

Key lessons for supporting mitigation through mass transit:

Mass transit will deliver the largest climate impact in regions with large, densely populated urban agglomerations, due to their ability to achieve higher utilisation rates and deliver co-benefits of reduced congestion and air pollution.

West Africa and India are regions where climate impact (GtCO_2 abated) is likely to be largest.

In nearly all regions, except India (where train travel is more prevalent), interventions ought to focus on decarbonising bus travel, which is the most widely adopted mass transit mode. To enable this transition, a large share of investment need is expected in enabling infrastructure for electric buses, where the private sector is likely to continue to underinvest.

The full benefits of mass transit interventions are only achieved in a holistic transport and urban development strategy, which ensures that pricing and system-wide operational efficiency are optimised to encourage mode-shifting.

Introduction to the opportunity

Role of the opportunity in decarbonisation of developing countries

The transport sector currently emits 1.2 Gt CO_2 in low- and middle-income countries, rising to 3.1 GtCO_2 in 2050 under a BAU scenario. Passenger transport accounts for 16% of total emissions from low-and middle-income countries today.[454] Buses and trains represent approximately 5% of total emissions.[455] In the near-to-medium term, emissions from passenger transport as a whole are expected to grow significantly due to an increase in passenger kilometres (km) travelled – expected to be 4.5x larger in 2050.[456]

Bus and train travel account for 20% of total passenger km today, but in a Paris Agreement compatible pathway this could increase to 35%.[457] Within mass transit, over 90% of total activity occurs on buses in low- and middle-income countries. Some studies show that mass transit's share of total passenger activity is expected to grow to around 35-40% by 2050 in a 1.5-degrees scenario.[458] The extent of mode-shift necessary to reach 1.5-degrees could be arguably smaller or larger, however, depending on the relative effectiveness of using mass transit versus alternative transport interventions to decarbonise urban transport activity (e.g. electrification of passenger vehicle fleet, urban planning measures to encourage active travel). As such, the opportunity assessment in any region should be considered alongside parallel opportunities in passenger vehicles (set out in the Passenger Vehicles opportunity).

Scope considered in this assessment

Mass transit is defined as the movement of individuals within and between urban areas using group travel, primarily buses and trains. Throughout, this report will consider both activities that increase adoption or reduce emissions intensity of transit by buses and trains. It will not consider the following: freight transport, international transport, aviation, or maritime transport.

The assessment focusses on a subset of ODA-eligible regions, in consideration of their relatively large mitigation potential and in consultation with the BEIS steering group . Selected regions include:

- India, which has the largest absolute mitigation potential in GtCO2 from mass transit, and is one of the few regions with higher levels of passenger activity by rail versus buses.
- South Asia (excluding India), hereafter 'South Asia', where large urban agglomerations are likely to increase the cost-effectiveness of mass transit.
- South America (excluding Brazil), hereafter 'South America', a vehicle-oriented region, with large potential benefits from mode-shifting.
- Western Africa, which has the third largest absolute mitigation potential in GtCO2 from mass transit (after India and China).
- Southern Africa (excluding South Africa), hereafter 'Southern Africa'), where relative emissions reductions from mass transit are highest, relative to 2015 transport emissions.

---

[454] International Energy Agency. (2019). *CO_2 Emissions from Fuel Combustion Highlights (2019 edition).*
[455] Given that bus and train correspond to 30% of passenger sector emissions, by IMAGE.
[456] Based on Reference Technology (BAU) scenario from New Climate Economy (NCE); adding light duty vehicle (LDV), Bus and Rail. Calculated as 2050 passenger km divided by 2015 passenger km.
[457] International Energy Agency. (2017). Energy Technology Perspectives 2017. https://www.iea.org/reports/energy-technology-perspectives-2017
[458] Ibid.

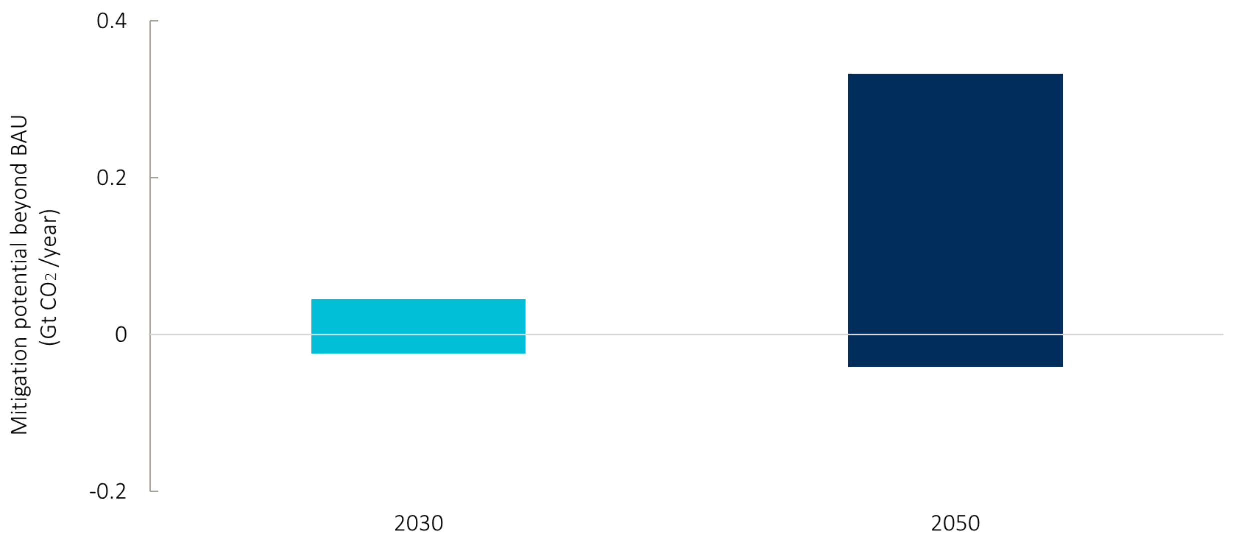
This assessment focuses on the benefit of supporting the opportunity as a whole and does not aim to comprehensively assess the effectiveness of specific investment opportunities or interventions. However, for context, potential investment opportunities are detailed in Section 0.

Climate impact

Mitigation potential and urgency

Across low- and middle-income countries, mass transit can help avoid around 11% of CO_2 emissions (0.7 $GtCO_2$) beyond business as usual in 2050.[459,460] In a 1.5-degrees scenario, passenger transport emissions will need to decrease by 70% in 2050, relative to BAU. Mass transit could be essential to meeting growing mobility demand while reducing total transport emissions. To reach the higher end of abatement would require a widespread change in preferences and a shift away from passenger vehicles. As models often cannot fully account for the factors that influence consumer behaviour (see Box 18) estimates of mass transit's climate impact shown in Figure 25 are on the lower end of potential climate impact, with only a small% (<10%) of mode-switching even in the most optimistic scenario. Some studies suggest that as much as 20% of passenger vehicle activity could switch to mass transit.[461] In reality, this is likely to vary by region, with examples of a cost-effective two-wheeler market in Southeast Asia suggesting limited incentives for mode-shift. In comparison, thriving informal markets for group travel, such as in Kenya, suggest large latent demand for mass transit– in Nairobi informal minibuses account for around 36% of total traffic.[462]

Figure 25 Range of mitigation potential compared to BAU in 2030 and 2050



Source: Vivid Economics, ASI and Factor using PBL's IMAGE model

Note: The bars indicate the range of mitigation estimates from IMAGE across the six scenarios run. Figures reflect mitigation potential relative to the BAU scenario (IMAGE's national policies scenario), and so are calculated as the emissions reduction in 2030/2050 in one scenario minus the emissions reductions in 2030/2050 in BAU.

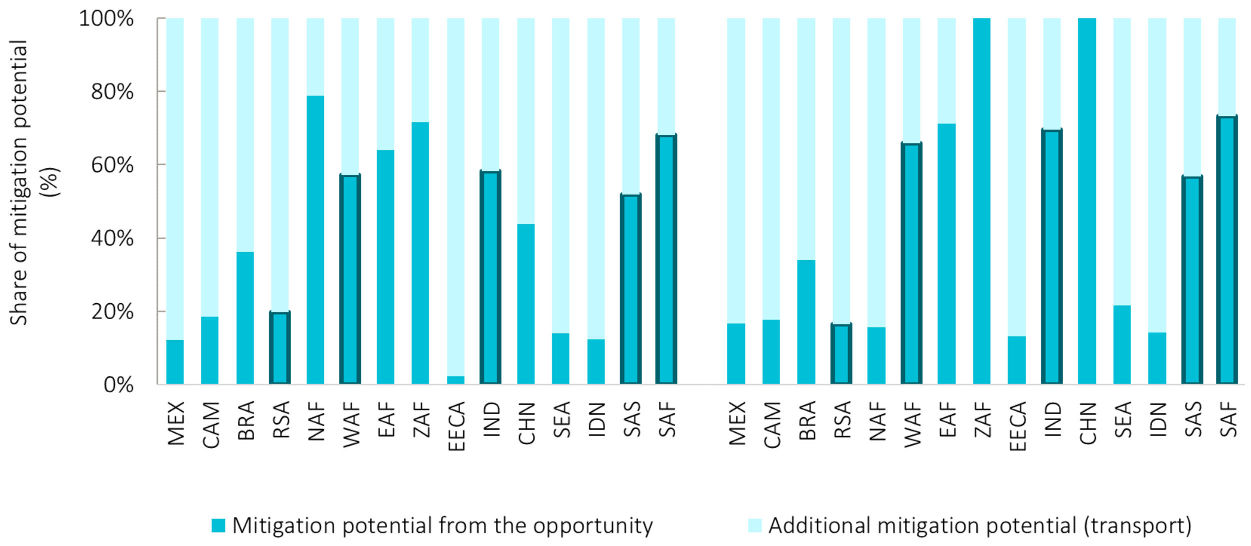
To 2030, climate impact is expected to be highest in countries with large and growing passenger vehicle fleets, where there is a large opportunity for mode-shifting. Across the analysed regions, mass transit contributes to between 13% and 100% of a region's passenger transport mitigation potential in 2050. The most immediate gains will occur in countries where there are significant emissions from internal combustion engine (ICE) vehicles and/or mass transit availability is currently very limited. The largest opportunities are

---

459 This figure reflects emissions reductions in the IMAGE renewables decarbonisation scenario vs the BAU scenario. The percentage reduction in emissions is calculated relative to 2050 BAU emissions from the transport sector.
460 All figures in this report will reflect mitigation potential beyond BAU – the BAU is taken to be IMAGE's new policies scenario.
461 Commission on the Economy and Climate (2015). "Accelerating Low-Carbon Development in the World's Cities". https://newclimateeconomy.report/2015/wp-content/uploads/sites/3/2015/09/NCE2015_workingpaper_cities_final_web.pdf
462 NCE. (2016). "Unlocking the Power of Urban Transport Systems for Better Growth and a Better Climate". http://newclimateeconomy.report/workingpapers/workingpaper/unlocking-the-power-of-urban-transport-systems-for-better-growth-and-a-better-climate/

thought to be in countries such as China, India, and Western Africa (as shown in Figure 26). Mass transit in India is expected to abate 64 $MtCO_2$/year in 2050, 25% of the mass transit's total mitigation potential across all low- and middle-income countries. West Africa also has a large mitigation potential of 25 $MtCO_2$/year.

Figure 26 Mass transit's contribution to passenger transport's total mitigation potential varies between 2% to 79% in 2030, and between 13% and 100% in 2050



Source: Vivid Economics, ASI and Factor using PBL's IMAGE model

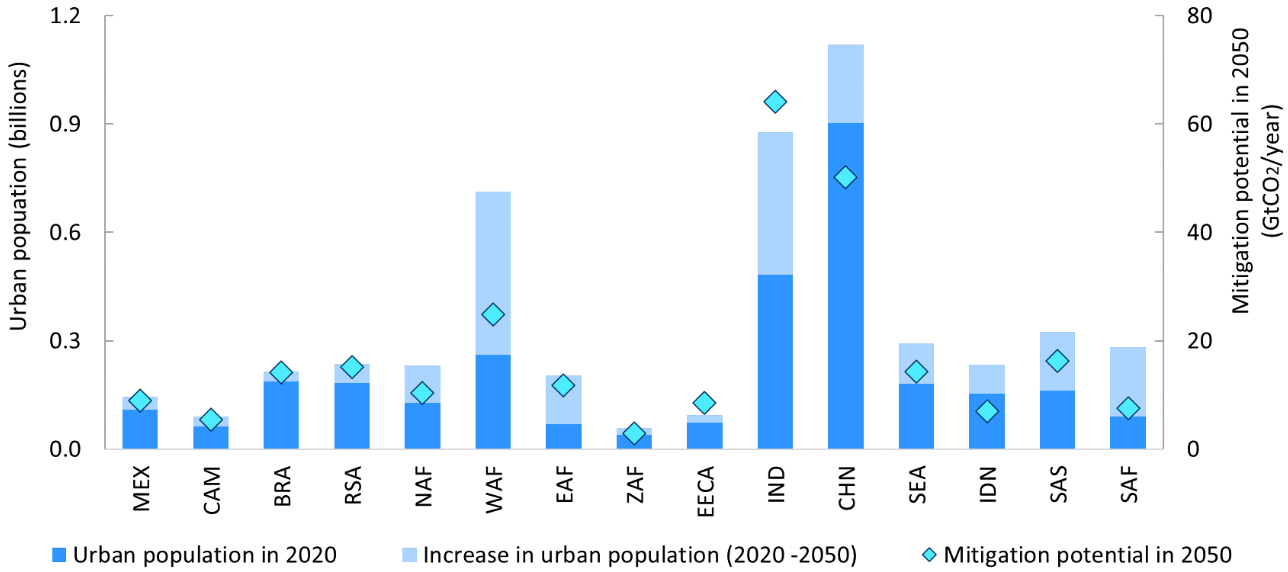
Note: The bars reflect mitigation potential in IMAGE's 1.5-degrees decarbonisation scenario minus mitigation achieved in IMAGE's new policies scenario (BAU scenario). Dark borders represent focus regions. Abbreviations correspond to the following: MEX= Mexico, CAM = Central America excluding Mexico, BRA = Brazil, RSA = South America excluding Brazil, NAF = North Africa, WAF = West Africa, EAF = East Africa, ZAF = South Africa, EECA = Eastern Europe and Central Asia, IND = India, CHN = China, SEA = Southeast Asia excluding Indonesia, IDN = Indonesia, SAS = South Asia excluding India, SAF = Southern Africa excluding South Africa.

Another key driver of mass transit's climate impact will be the urban population size and density in 2050. In the longer term, countries could opt to decarbonise their passenger vehicle fleet through electric vehicles (EVs) rather than mode-switching. The rationale for mass transit investment will therefore be its cost-effectiveness relative to vehicle decarbonisation. Cost-effectiveness is particularly high in regions where there is a large urban population, today and in 2050, as this increases the utilisation rate of large infrastructure investments and reduces per passenger investment need. Urban population density is also a strong predictor of urban mobility choices, with denser cities shown to have an increasing proportion of trips taken by public transport, walking, and cycling.[463] As Figure 27 shows, the urban population in 2050 is highest in India, West Africa, and China, regions where mitigation potential is also larger in 2050. Notably, these regions also have larger urban agglomerations, where the co-benefits of mass transit are particularly high. In 2035, 24% of India's urban population is expected to live in urban settlements greater than 10 million. Six of the world's 30 largest cities will be in India, three in South Asia, and three in Western Africa.[464]

[463] Union Internationale des Transports Publics. (2015). "Mobility in cities database" https://www.uitp.org/sites/default/files/MCD_2015_synthesis_web_0.pdf

[464] United Nations, Department of Economic and Social Affairs, Population Division. (2018). "World Urbanisation Prospects: the 2018 revision."

Figure 27 Mitigation potential will be largest in regions with increasing urban populations



Note: The abbreviations correspond to the following: MEX (Mexico), CAM (Rest of Central America), BRA (Brazil), RSA (Rest of South America), NAF (North Africa), WEF (West Africa), EAF (East Africa), ZAF (South Africa), EECA (Eastern Europe and Central Asia), IND (India), CHN (China), SEA (Southeast Asia), IDN (Indonesia), SAS (Rest of South Asia), SAF (Rest of South Africa).

Source: Vivid Economics, ASI and Factor using UN population forecasts and PBL's IMAGE model

Buses are expected to provide over 90% of mass transit's emissions reductions, serving as the primary alternative to vehicle travel across low- and middle-income countries. Buses are the primary provider of mass transit in our focus regions today – they accounted for 91% of mass transit passenger km travelled in 2015.[465] The preference for bus travel (versus rail) is expected to continue to 2050. Mode-switching to buses is expected to deliver 40% of emission reductions from mass transit as a whole, by reducing light duty vehicle (LDV) use, specifically for short-distance trips in urban areas.[466] Electrification of buses is equally important, also delivering around 40% of emissions reductions from mass transit in 2050.

The exception is India, where large climate mitigation is expected from continued expansion and electrification of rail transport. Rail passenger traffic in India has increased by almost 200% since 2000, reflecting the country's strong commitment to rail transport as a means to connect populations between urban centres, and move people within densely populated urban areas.[467] India has the second-highest absolute level of passenger rail activity today, but only approximately 50 - 60% of rail activity is on electric trains.

Box 18 **Modelling uncertainty**

There is large uncertainty over the exact magnitude of emissions reductions from mass transit, due to uncertainties surrounding the level of mobility demand and extent of mode-shift to mass transit. The mitigation potential of mass transit depends on expectations about how passengers will choose to travel, specifically on the extent of mode-shifting away from passenger vehicles. This, in turn, is affected by a host of local non-cost considerations, such as the quality of mass transit provision, concerns over safety, and the severity of congestion and pollution. It can also be influenced by global, difficult-to-predict

[465] International Energy Agency (2017). Energy Technology Perspectives 2017. https://www.iea.org/reports/energy-technology-perspectives-2017
[466] Ibid.
[467] International Energy Agency (2019). The future of rail. https://www.iea.org/reports/the-future-of-rail

changes in the level of passenger mobility in future, following increasing trends in digitalisation and decentralisation of work.

Integrated assessment models (IAMS) underestimate the potential non-monetary benefits of mass transit and subsequently underestimate the extent of mode-shifting. As a cost optimisation model, IMAGE and other IAMS only consider cost considerations when estimating the level of mode-shifting, ignoring changes in travel preferences due to non-cost factors. Therefore, far greater adoption of mass transit could be expected due to consumer preferences for low-carbon transport, changes in the quality of the mass transit journey, and increased levels of working from home, among other factors.

Expectations of mass transit's climate impact are therefore triangulated with wider literature to inform more reliable and robust assessments. We rely on a range of modelling results, including International Energy Agency (IEA) Energy Technology Perspectives Sustainable Development Scenario and The International Transport Forum's Transport outlook to inform forecasts of future passenger transport activity.[468] Further we use insights from the IEA,[469] New Climate Economy[470] and World Resources Institute[471,472] to highlight relative potential of different modal options across regions.

Transformational change

Mass transit offers substantial opportunities for transformational change, as set out in Table 2. With the right conditions for planning and rapid delivery of buses in particular, whether conventional ICEs or EVs, mass transit can be provided that displaces private vehicle use and greatly reduces emissions, while also providing a wide range of co-benefits, such as better access to education and employment and other services and amenities. Interventions can also enhance and take forward the opportunities for efficient light rail, metro, or full rail infrastructure and services, via technical assistance or concessional financing to support project preparation activities. Providing the enabling conditions for private sector delivery of mass transit is a particularly vital consideration, supporting procurement of bus fleets or upgrades to zero-carbon vehicles for example, much of which is constrained by upfront costs. While such measures are required in all of the target regions, there is particular need for mass transit in the rapidly growing cities of India, sub-Saharan Africa, and South Asia, where there is a danger of chaotic urban planning and poor transport locking countries into more carbon-intensive pathways.

Table 28 Assessment of transformational change

Transformational change criterion	Interventions to support change	Regional potential
Sensitive intervention points		
Improvement of local capacities and capabilities	Support to governments in integrated urban and transport planning, with capacity building related to policy and strategy. Enabling the better use of data and digital solutions for planning.	Southern Africa, West Africa

[468] International Energy Agency. (2017). Energy Technology Perspectives 2017. https://www.iea.org/reports/energy-technology-perspectives-2017; International Transport Forum. (2019). "Transport Outlook." https://www.oecd-ilibrary.org/transport/itf-transport-outlook-2019_transp_outlook-en-2019-en;jsessionid=L-HvhVR5S_N9u1R4twhJilYP.ip-10-240-5-172
[469] International Energy Agency. (2019). "The Future of Rail". https://webstore.iea.org/download/direct/2434
[470] New Climate Economy. (2016). "Unlocking the power of urban transit systems for better growth and a better climate". https://newclimateeconomy.report/workingpapers/wp-content/uploads/sites/5/2016/04/Unlocking-the-power-of-urban-transport-systems_web.pdf
[471] World Resource Institutes. (2019). "How to Enable Electric Bus Adoption in Cities Worldwide". https://files.wri.org/s3fs-public/how-to-enable-electric-bus-adoption-cities-worldwide.pdf
[472] World Resource Institutes. (2010). "Modernizing Public Transportation". https://files.wri.org/s3fs-public/pdf/modernizing_public_transportation.pdf

Transformational change criterion	Interventions to support change	Regional potential
Local ownership and strong political will	Engaging with all stakeholders to develop practical solutions, including informal paratransit service providers.[473]	India, Southern Africa, West Africa
Leverage / creation of incentives for others to act	Transformational change can be realised via pre-feasibility studies (PFS) and Feasibility Studies (FS) which can evaluate alternatives, propose and evaluate a preferred option, and then prepare the Business Case for bankability. Provision of concessional loans for upgrades to low-carbon fleets or tax-based and financial incentives to informal paratransit operators to switch to low-carbon vehicles.	All regions
Spillovers		
Broad scale and reach of impacts	Support in implementing or upgrading local bus transit (inc. with efficient ICE vehicles) in a wide range of urban areas, including secondary and tertiary cities.	India, Southern Africa, West Africa
Sustainability (continuation beyond initial support)	Improving institutional capacity and evidence base with data relating to the demand for travel, as well as current systems and factors such as population density, as well as new methods of data collection such as Geographical Information Systems (GIS) can provide the necessary basis for planning, regulating, and investing in mass transit solutions.	Southern Africa, West Africa
Replicability by other organisations or actors	Demonstration of how public and private sector bus fleets could be decarbonised, particularly for informal paratransit services.	India, South Asia, West Africa, Southern Africa
Innovation		
Catalyst for innovation	Support on integrated route identification and digital payment apps,that could be used by a range of service providers, helping to make mass transit more efficient and attractive. The powertrain, battery, and motors, for buses can offer a potential leapfrog technology with dramatically lower energy consumption. Support new mobility innovations in technology and business models to provide on-demand and shared mobility services for last mile transport, helping provide access to mass transit.	West Africa, Southern Africa, South America
Evidence of effectiveness is shared publicly	Importance of sharing learning and evidence of what works well and what has failed, or could be improved.	All regions

Source: Vivid Economics, ASI and Factor

[473] Paratransit is defined as a transportation service that supplements larger public transit systems by providing individualized rides without fixed routes or timetables. Source: https://www.merriam-webster.com/dictionary/paratransit

Development impact

SDG impacts

Increasing the mode-share of low-carbon mass transit helps countries achieve several sustainable development goals, as set out in Table 29.

Table 29 SDG impacts

SDG	Strength of impact	Most relevant region	Rationale
Positive Impacts			
SDG 1 – No Poverty	High	South Asia, Southern and West Africa.	Increase in access to mass transit would have a positive impact on economic growth. Improved and more equitable access to education, healthcare, and employment.
SDG 3 – Good Health and wellbeing	High	India, West Africa, Southern Africa, South America	Air pollution-related deaths are high and will be significantly reduced as sustainable mass transit is adopted. With efficient mass transit systems, there would likely be a shift from private vehicles to mass transit transportation thereby reducing air pollution and transport emissions. Road accidents and related costs and fatalities should also be significantly reduced.
SDG 5 – Gender and Inclusion	High	All regions	Accessible, safe, and comfortable transport that enables more efficient urban transit allows the more vulnerable and poorer groups to benefit from a wider range of opportunities.
SDG 11 – Sustainable Cities and Communities	High	All regions	Mass transit options would improve mobility across and within cities, as a key pillar of sustainable cities. It is also proven to improve road and pedestrian safety.
SDG 13 – Climate Action	High	All regions	Promotion of mass transportation would result in a decreased number of vehicles on the road and would also result in reducing greenhouse gases (GHG) emissions.
Negative impacts			
SDG 15 – Life on Land	Low	All regions	Negative environmental impact from mining rare earth metals if demand soars for lithium-ion batteries in e-buses and other EVs. For example, a recent report by United Nations Conference on Trade and Development (UNCTAD) reveals that in Chile, lithium mining uses nearly 65% of the water in the country's Salar de Atamaca region.[474] For new rail routes in particular, the planning and construction process must take environmental impact considerations into account and provide appropriate mitigating measures.

Note: Low positive impact on SDGs are not included in this table.
Source: Vivid Economics, ASI and Factor

[474] United Nations. (2020). UN highlights urgent need to tackle impact of likely electric car battery production boom. https://news.un.org/en/story/2020/06/1067272

Demand in target regions

Table 30 shows the respective levels of demand, by target regions, for support to promote industrial decarbonisation policy through strategy development, the design of regulation and carbon pricing instruments, and promoting demand for low-carbon products.

Table 30 Demand in target regions

Region	Demand	Rationale
India	Moderate – High	High demand and policy evident from India's initiatives, such as the Smart Cities Mission, and recent investment in metro lines across the country.
South Asia	Low – Moderate	Variable policy and regulatory environment across countries against as measured against Nationally Determined Contributions (NDCs), national plans, and policies.
Southern Africa	Low – Moderate	Variable demand across countries, favourable regulatory environment for mass transit is just emerging.
West Africa	Low - Moderate	Few countries have transport-related policies and plans in place and the regulatory environment is still in its infancy.
South America	Moderate – High	Variable policy and regulatory environment across counties and progress as evidenced by NDCs, Nationally Appropriate Mitigation Action (NAMAs), and national plans and policies.

Source: Vivid Economics, ASI and Factor

All regions: Of the 166 NDC submissions in 2015, representing 193 countries, 76% highlighted the transport sector as a mitigation source, but only 8% included transport-specific greenhouse gas mitigation targets. However, it is clear that improved mass transit is widely supported in principle by governments across the majority of countries in the target regions, albeit with a particular focus on decarbonising the passenger fleet.

India: In its NDC, India recognises transport as a mitigation pathway. India has a National Urban Transport Strategy which aims to ensure safe, affordable, quick, comfortable, reliable, and sustainable access for the growing number of city residents to jobs, education, recreation and such other needs within our cities. In addition, India's Smart Cities Mission has the potential to make mass transit more efficient. India isn't implementing a NAMA for transport. Despite India's strong rail network and high ridership, almost 90% of movement of passengers in India is currently catered for by road transport and a modal shift to low-carbon public transport is increasingly urgent. Increasing market share in rail-based passenger transport systems, improved fuel efficiency, use of alternative fuels, and promoting electric mobility are key strategies in India.

South Asia: In South Asia, all countries cover transport as a mitigation sector in their NDCs/INDCs. Despite recognising transport as a mitigation sector in NDCs, most South Asian countries do not have defined targets in plans or policies pertaining to mass transit. Bangladesh and Pakistan seem to be more developed in terms of existing policies in the sector, as compared to the others. Pakistan's National Transport Policy promotes low-carbon public transport, Bangladesh's Draft Integrated Multi-modal Transport Policy (IMTP) and 20-Year Strategic Transport Plan (STP) for greater Dhaka are notable too. Sri Lanka is implementing a NAMA for transport. [475]

Southern Africa: In Southern Africa, all countries except Angola identify transport as a mitigation sector in their NDCs/Intended Nationally Determined Contributions (INDCs). Lesotho's National Climate

[475] NAMA Database. Accessed 03/08/2020. Available at: http://www.nama-database.org/index.php/Transport

Change Policy (CCP) promotes low-carbon transport systems. Malawi's National Transport Master Plan provides a clear framework for delivering sustainable interventions to enhance the transport sector across Malawi for the period between 2017 and 2037. Zambia, Namibia, and Tanzania recently launched National Transport Policy frameworks while Angola's National Plan for Transportation is in draft form. Zimbabwe also has a National Transport Policy in place while Botswana has a Transport Master Plan. However, mass transit remains severely underdeveloped across the region.

West Africa: Nigeria, Ghana, and Sierra Leone identify transport as a mitigation sector in their NDCs, while Cameroon, Chad, Republic of the Congo, Mali, Niger, and Togo do not. National transport related laws and policies are in place In some countries, including Nigeria's National Transport, Sierra Leone's Integrated Transport Policy, Strategy and Investment Plan, and Ghana's National Transport Policy, which recognises the important role of intermodal transport for sustainable national development but gives very little attention to environmental pollution and adverse human health. Sierra Leone is implementing a NAMA for transport.[476] Similarly to Southern Africa, mass transit remains severely underdeveloped across all countries in West Africa.

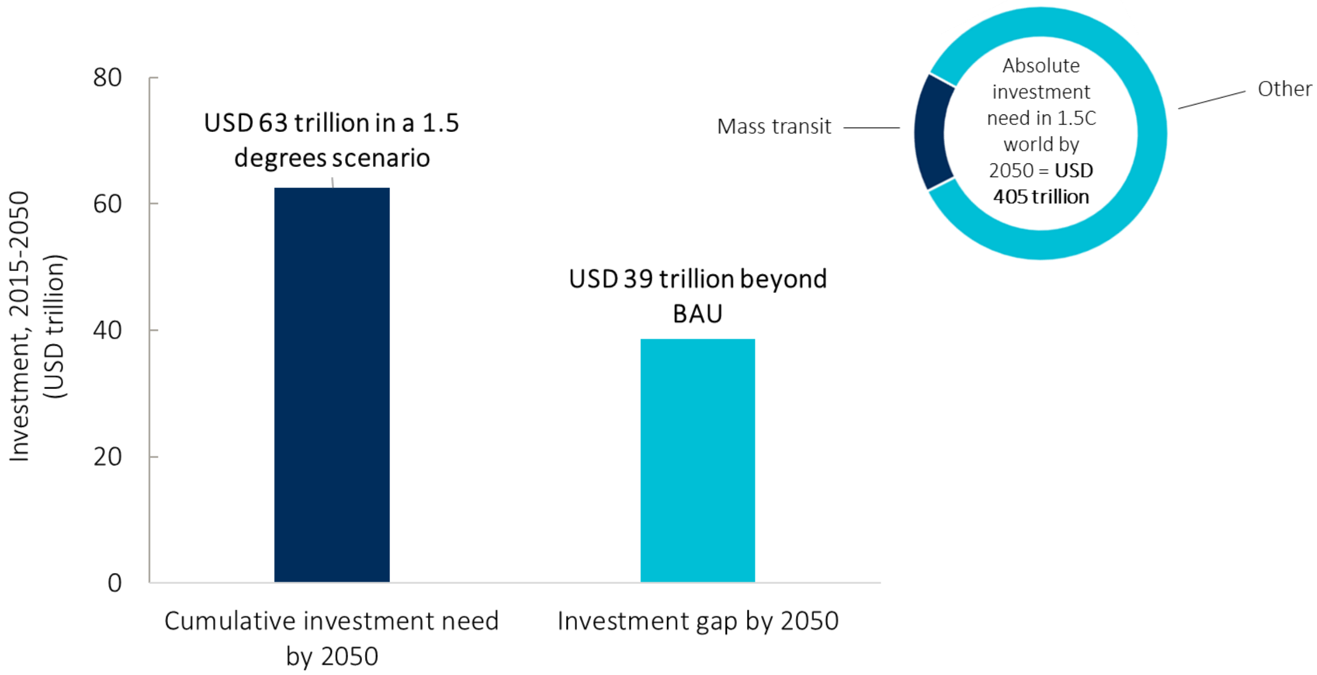
South America: Chile, Colombia, and Uruguay identify transport as a mitigation sector in their NDCs, while Ecuador, Bolivia, Guyana, Paraguay, and Peru do not. Colombia, Chile, and Ecuador are implementing NAMAs for transport.[477] These programmes help to overcome challenges and offer valuable lessons about how to link 'on the ground actions' with national GHG-reduction commitments. South America is a global leader in bus transit, with the highest ridership figures for any global region.[478] Pioneering BRT schemes have been implemented in the region such as the *Transmilenio*, in Bogota, Colombia, and effective systems in Chile and Argentina. The region also boasts a range of metro systems such as in Santiago, Chile and Medellin, Colombia.

[476] Ibid.
[477] Ibid.
[478] Red Green and Blue. (2020). Renewable Roundup: Electric buses sweeping South America, equipped with new battery tech. Available at: http://redgreenandblue.org/2020/06/10/renewable-roundup-electric-buses-sweeping-south-america-equipped-new-battery-tech/

Investment need

Across low- and middle-income countries investment will need to scale up to USD 63 trillion by 2050 in a 1.5-degrees scenario, 60% larger than investment expected in BAU.[479] The scale of investment required is very high; amongst the highest across all opportunities. The magnitude of rail investment reflects the large upfront capital costs of infrastructure expansion, while bus investment need is driven by the high cost of fleet turnover (see Box 18 for examples of relative costs of each). Many of these investments would have to occur in BAU, where growing passenger transport demand will fuel infrastructure rollouts and purchase of ICE bus fleets. Nonetheless, to support mode-switch on the scale expected in a 1.5-degrees scenario will require investment of USD 39 trillion by 2050 beyond investment expected in BAU.[480] Annual investment in rail infrastructure to 2050 is estimated to be 20% of investment in road infrastructure, leading to a cumulative investment of USD 10 trillion in rail, and USD 53 trillion in road.[481]

Figure 28 Cumulative investment need in mass transit is high compared to other opportunities



Source: Vivid Economics, ASI and Factor using IEA. (2017). Energy Technology Perspectives.

Across focus regions, the expected investment need is in the order of billions per annum in 2050. Across regions, the scale of infrastructure required is consistently large, due to a combination of the low levels of provision to date and growing mobility demand that will need to be supported.

The exact magnitude of the investment need will vary significantly by local construction costs and transit preferences. Clear differences in investment need between regions are partially driven by differences in current and future level of passenger transport activity, reflecting the scale of economic activity in a region and population density. Considering activity levels for passenger transport alone, far higher investment need will be expected in India, Western Africa, and South America. However, even when focusing on these regions a host of far more local factors will influence the magnitude of investment required, including the highly site-specific costs of civil works and the current preference for mass transit. Rail costs, for instance, will be influenced by local costs of land acquisition, labour, and materials, the number of tracks per line, the need

[479] International Energy Agency (2017). Energy Technology Perspectives 2017. https://www.iea.org/reports/energy-technology-perspectives-2017
[480] Ibid.
[481] International Energy Agency (2019). The Future of Rail. https://webstore.iea.org/download/direct/2434

for tunnels (such as in metro rail), and the operating speed (see Box 18 for indicative costs). Most countries already prefer a certain type of mass transit, which must be embedded into cost considerations. Furthermore, countries also typically exhibit differing preferences on whether to rely on mass transit to decarbonise or whether to simply decarbonise passenger vehicles. Given the high levels of coordination and path-dependency associated with mass transit investment, local policy will ultimately be the single largest driver of investment need.

The climate financing need is expected to be smaller than the overall investment need estimates, due to the potential to crowd-in private finance towards large infrastructure projects. Though there are high costs of infrastructure provision, there are also opportunities for private companies to achieve profits from these investments in the long term. Public sector investments can therefore focus on co-financing large infrastructure investments and creating reliable demand for mass transit to crowd-in private sector activity.

Box 18 Illustrative investment needs in mass transit

Decarbonising bus transport could require approximately USD 900 million for a city the size of Kolkata. Kolkata currently has approximately 10,000 diesel-powered buses, equivalent to 0.0003 buses per resident of the city's metropolitan area. Under ambitious plans to have 5,000 e-buses and 240 charging stations in the city by 2030, total upfront investment need is estimated to be USD 900 million.[482]

Much of this investment is additional to the BAU scenario, resulting from the large upfront costs of EV charging infrastructure and higher costs of e-buses. Costs of an inner-city e-bus today are approximately USD 190,000 in India, twice as high as the costs of a comparable diesel bus. For a large fleet, with frequent turnover, this divergence in costs creates substantial investment requirements. Further, the transition to e-buses requires investment in charging infrastructure – development of 70 charging stations in Kolkata cost approximately USD 120 million. Costs of a charger are USD 13,000 to USD 20,000, hence most costs arose from civil and electrical works.

Costs of rail investment will vary by type of rail and local costs of labour and land. Type of rail in itself will have a significant impact on costs for the same scale of infrastructure rollout, shown in Table 31.

Table 31 Indicative costs of rail

Type of rail	Costs per line-kilometre (USD million)
Conventional rail	0.5 - 20
Urban light rail	10 - 25
High speed rail	20 - 80
Metro rail	50 - 350

Source: Vivid Economics; IEA. (2019). Future of rail.Vivid Economics; IEA. (2019). Future of rail.Vivid Economics; IEA. (2019). Future of rail.Vivid Economics; IEA. (2019). Future of rail.Vivid Economics; IEA. (2019). Future of rail.Vivid Economics; IEA. (2019). Future of rail.uture of rail.Vivid Economics; IEA. (2019). Future of rail.Vivid Economics; IEA. (2019). Future of rail.Vivid Economics; IEA. (2019). Future of rail.Vivid Economics; IEA. (2019). Future of rail.Vivid Economics; IEA. (2019). Future of rail.Vivid Economics; IEA. (2019). Future of rail.Vivid Economics; IEA. (2019). Future of rail.Vivid Economics; IEA. (2019). Future of rail.Vivid Economics; IEA. (2019). Future of rail.Vivid Economics; IEA. (2019). Future of rail.Vivid Economics; IEA. (2019). Future of rail.Vivid Economics; IEA. (2019). F

Urban rail extension could cost around USD 6 billion for a city like Lima. The *Lima Metro Line Two Project for Peru* project is currently underway, with the objective of providing a mass transit system serving the east-west axis of the Lima-Callao Metropolitan Region. In practice, this includes the roll-out of 35 km of

[482] The Energy and Resources Institute. (2020). Successful operation of Electric bus fleet – "A Case Study of Kolkata".

new urban rail infrastructure, as well as the construction and integration of 35 new stations; construction of approximately 27 km of tunnel; and, the provision and installation of the necessary rolling stock, electrical, control, telecommunications, and fare systems for operation of the Metro Line two.[483]

Regional rail development in a country such as Tanzania could be achieved for a similar scale of funding required, approximately USD 8 billion, despite the larger distances covered. The Government of Tanzania is implementing a major railway revitalisation programme throughout the country, rehabilitating and constructing new railway line links. It includes the construction of a Standard Gauge Railway track of approximately 1,200km between Dar es Salaam to Isaka. Although still underway, total costs of completion are estimated at USD 7.6 billion.[484]

[483] The World Bank. (2020). "Peru Lima Metro Line 2 Project". https://projects.worldbank.org/en/projects-operations/project-detail/P145610?lang=en

[484] Kiruga, Morris. (2020). Tanzania: the race for regional rail supremacy. https://www.theafricareport.com/24195/tanzania-the-race-for-regional-rail-supremacy/

Cost-effectiveness

Mass transit is a highly cost-effective mitigation opportunity in transport, from a system perspective, particularly when targeting improved utilisation and efficiency of existing networks. It can be highly cost-effective when focused on encouraging a change in behaviours (e.g. mode-shifting) or a change in operation of existing systems (e.g. route optimisation). It is less cost-effective (on a GBP/tCO_2 basis,) when it requires substantial infrastructural change or rollover of fleets, due to higher capital costs. Subsidising hybrid buses results in costs of 100 - 250 USD/tCO_2, and this same figure can reach 750USD/tCO_2 for electric buses.[485] Nevertheless, the value of the transport service obtained, together with the efficiency in its provision, implies even these interventions are cost-effective at reducing emisisons relative to alternative investments in transport decarbonisation e.g. household purchase of private electric vehicles.

Cost-effectiveness varies across regions due to four principal characteristics:

Existing level of infrastructure. Wherever interventions include infrastructure provision or rollover of fleets, costs will increase significantly.

Cost of urban land. Wherever land purchase is required in urban areas it will be a sizeable cost component.

Cost of civil works. Costs of building new infrastructure can vary across countries and sites within a country due to the difficulty or scale of provision. Costs of metro rail, for example, can cost up to 14x more per line-kilometre than urban rail - cost differences driven by speed of operation and the need for bridges or underground infrastructure in metro rail (see Table 31).

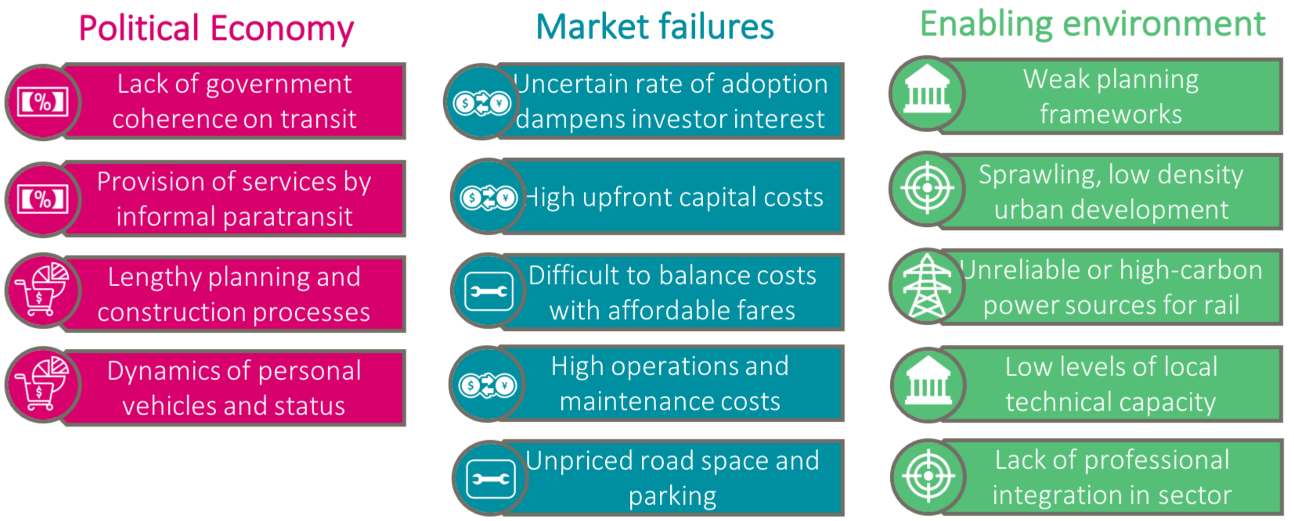
Behavioural change. The cost-effectiveness of all interventions will be affected by the subsequent utilisation rate and the extent of mode-shifting away from more polluting forms of transport. Cultural norms and safety concerns could result in vastly different rates of mode-shift across regions.

[485] World Bank Blogs. (2017). "Are hybrid and electric buses viable just yet?" https://blogs.worldbank.org/transport/are-hybrid-and-electric-buses-viable-just-yet

Barriers to adoption

There are barriers to more widespread and efficient mass transit across all three areas of i) political economy challenges, ii) market failures, and iii) enabling environment (Figure 29). These barriers are not critical to inhibiting investment, as the potential of mass transit is widely recognised and investment levels are growing in all regions. However, if not addressed they are likely to slow down the potential growth of this opportunity. Our typology of barriers is provided in the Methodology chapter in the Synthesis Report.

Figure 29 Barriers to an opportunity



Source: Vivid Economics, ASI and Factor

A wide range of political economy barriers to investment or adoption constrain mass transit development in all of the target regions:

Lack of public sector coherence on budgeting and planning for urban planning or transport investment, as a result of transport services having been taken over by paratransit operators over the past decades. There is also a common failure to allow cities to spend the taxes they raise, particularly in Southern African and West African countries, leading to a poor level of urban transport investment.

Personal vehicle dependence is often built into a culture and legal barriers that can exist to prevent the building of dense, mixed-use community centres and transit-oriented development (TOD) that reduce car dependence.[486] This is a significant constraint in West Africa and Southern Africa.

Successful urban transport investment requires a long-term vision and consistent political support, which is often undermined by short-term political cycles and a culture of undoing the legacy of a previous political leader, as it often the case in sub-Saharan African politics. Politicians are unwilling to commit where there is a high risk of key stakeholder opposition.

Mass transit reform and investment inevitably affect the roles and livelihoods of incumbent para-transit system operators and their unions and associations. Unless these stakeholders are brought into the concept design for more formal mass transit projects from the beginning and are offered appropriate incentives to participate (or compensation should they choose not to), then they can effectively block outcomes. This is a significant barrier in all target regions. In many countries, such as India and

[486] Intergovernmental Panel on Climate Change (IPCC). (2014). Climate Change 2014: Mitigation of Climate Change. Contribution of Working Group III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change (Transport chapter). Available at: https://www.ipcc.ch/site/assets/uploads/2018/02/ipcc_wg3_ar5_chapter8.pdf

those in West Africa and Southern Africa, informal paratransit is likely to continue to provide valuable services for last mile connectivity.

New mobility options such as ride-hailing and car-pooling are causing many decision-makers to question the benefits of spending large amounts on mass-transit infrastructure.[487] Examples include ride-hailing apps such as Grab in South and Southeast Asia, Ride in Ethiopia, and SWVL in Kenya. However, recent studies have showed that personal vehicle ride-hailing is actually a net contributor to congestion.[488] While ride-hailing plays an important last mile solution, mass transit is required to move significant numbers of people within the required carbon emission parameters.

There are often low levels of urban autonomy and decision-making in the target regions, particularly in South Asia, West Africa, and Southern Africa, with particularly severe impacts on a lack of integrated land-use and transport planning. It is important that interventions have the ability to affect change at this level of government.

Inertia in behavioural change in terms of switching to public transport modes. This is particularly challenging in countries with high safety concerns related to public transport, such as West Africa, Southern Africa, and India and South Asia, or where the personal status demonstrated by a private vehicle is a strong cultural phenomenon, in all the target regions.

The Covid-19 crisis has dealt the mass transit sector a severe blow globally, due to restricted services and social distancing, which has greatly reduced capacity. This will hopefully be a short-to-medium-term constraint, but must be considered for potential mass transit interventions.

Moderate market failure barriers to investment or adoption are likely to be:

The rate of adoption of public mass transit is uncertain. Many people with greater income in the target regions prefer to use their own cars as it is associated with status and personal success, as well as the advantages of safety and comfort. However, transit solutions could partly overcome this by adopting a two-class approach, where a premium service is provided alongside a more affordable but less comfortable service. This has been successfully implemented with minibuses in Nairobi in Kenya.

Infrastructure-heavy projects such as metro or light rail require very high investment costs and often yield a slow rate of return, although they do attract the investment support of development partners. Their benefits must be quantified in terms of carbon reduction, time efficiencies, and other social development factors, which many governments struggle to convey in a typical cost-benefit analysis. There are recent examples of capital infrastructure projects in the regions of interest, such as the Dhaka metro in Bangladesh, but these are heavily funded by donors such as the Japan International Cooperation Agency (JICA) and the World Bank, which ICF support is not designed to contribute to.

Mass transit systems must be affordable to the vast majority of residents in order to achieve related sustainable development objectives. As such, to cover the costs of initial investment, operations, and maintenance, there is often a need for public sector subsidisation, although other mechanisms exist such as public service obligations (PSO) which regulate the subsidisation of a less financially viable route by more financially viable ones within a private sector operator's portfolio.

Public / private partnerships are not required for the structuring of large transport infrastructure projects but rather for the harnessing of the advantages of each form respectively in planning, infrastructure, and regulation, and in rolling stock investment, operation, and maintenance. Within that scenario, rolling stock investment is the greatest challenge as no return can usually be earned on this while

[487] McKinsey. (2020) Transit Investments in an Age of Uncertainty. Available at: https://www.mckinsey.com/industries/public-sector/our-insights/transit-investments-in-an-age-of-uncertainty
[488] See, for example: Hawkins, Andrew J. (2019). Uber and Lyft finally admit they're making traffic congestion worse in cities. Available at: https://www.theverge.com/2019/8/6/20756945/uber-lyft-tnc-vmt-traffic-congestion-study-fehr-peers

vehicles are under commercial finance without also raising fares above those currently observed. This is common to all target regions.

Mass transit projects are hampered by unpriced GHG emissions, unpriced road space, and capital market imperfections, which are prevalent across all countries in the target regions.

Network effects are particularly strong for mass transit given the need to coordinate provision across diverse range of potential customers. Enabling effective and attractive public transport services requires coherent implementation of aspects such as inter-modal terminal and stop infrastructure, including the integration of feeder and last mile services, real-time digital information on services and delays, and the rapid and affordable maintenance of vehicles. This has been done very well in cities such as Medellin, Colombia, but is severely lacking in West Africa and Southern Africa.

In terms of upgrading mass transit fleets to low-carbon vehicles, capital costs often prove prohibitive without external support. Many cities do not have the funds to pay for e-buses with higher upfront costs, even with additional support from the government. This is currently slowing down e-bus adoption in all of the target regions.[489] However, once the upfront costs are overcome, there can be significant benefits in lessened fuel consumption in urban mass transit, including from hybrid technologies for the vehicle powertrain, or EVs, depending on the levels of traffic congestion. For now, conventional ICE buses still remain the most effective way of implementing mass transit and reducing GHG emissions.

Legacy vehicles in bus fleets can be a barrier to upgrading to more efficient vehicles. Many operators are faced with scarce resources to maintain their vehicles properly. Fleet renewal can replace the oldest and dirtiest vehicles in the fleet with new ones, but any such programme will need to take into consideration the economic challenges of the low-income population.[490] This is a particular barrier in West Africa, and Southern Africa and South Asia, whereas many countries in South America are starting to scale up the upgrade of fleets to EVs and other low-carbon options.[491]

Moderate enabling environment / absorptive capacity barriers to investment or adoption are likely to be:

Weak planning frameworks and urban development strategies are a significant constraint to the effective implementation of mass transit, particularly where there is a failure to guide the integration of land use with transport service provision, supporting infrastructure, and a more holistic approach to sustainable urban mobility planning. This is a severe constraint in Southern Africa, West Africa, and many South Asian countries.

Institutional weakness in how to catalyse and manage the implementation of mass transit services is a barrier at all levels of government in many of the regions, particularly in Southern Africa, West Africa, and South Asia, although it is generally not the case in India. This is often a result of a delegation of this responsibility to the private or informal transit sector, resulting in large government knowledge gaps. In some of the target countries this process is starting to reverse with public transport focused departments being established, such as the proposed Kathmandu Valley Transport Authority in Nepal, which is likely to require strong capacity building support.

Chaotic urban planning that enables low-density urban sprawl and reduces the economic viability for mass transit projects, as there are fewer potential passengers living near to planned stations. This is a severe constraint in the rapidly urbanising countries of Southern Africa and West Africa, for example Lagos and Accra, and across India and South Asia.

---

[489] BNEF. (2018). Electric Buses in Cities: Driving towards Cleaner air and lower CO2. Bloomberg New Energy Finance.

[490] Posada et al. (2018). 2018 South America Summit on Vehicle Emissions Control: Summary Report and Regional Workplan. Available at: https://theicct.org/sites/default/files/publications/ICCT_SouthAmerSummit2018_rpt.pdf

[491] Red Green and Blue. (2020). Renewable Roundup: Electric buses sweeping South America, equipped with new battery tech. Available at: http://redgreenandblue.org/2020/06/10/renewable-roundup-electric-buses-sweeping-south-america-equipped-new-battery-tech/

There is often little professional integration in all target regions, at the level of government, academia, and the private sector, between urban planning, transport planning and engineering, and financing infrastructure projects, resulting in lost opportunities to develop cities and transport in a holistic and sustainable way.

To gain the full mitigation potential from mass transit, rail, and ideally BRT systems, they should be electrified. However, unreliable power sources in many countries in the target regions severely constrain the feasibility of such options. Improving power reliability has been a strong consideration for the planned light rail in Colombo, Sri Lanka, which should be operational in 2025.

There is a lack of robust data or data management and analysis systems, such as GIS, available to help decision-makers and planners in many of the target regions to understand the nature of mass transit challenges. This is a greater challenge in the lower-income countries of sub-Saharan Africa and South Asia.

UK additionality

The UK's additionality is very strong in integrated transport and urban planning, financing arrangements for large transport infrastructure projects, research and design for new mass transit technology, and experience in commercial operations in developing countries.

The UK is a European leader in BRT infrastructure, with systems in over 8 cities and active knowledge sharing forums such as BRTUK.492

UK transport planning consultancies have had proven success in many overseas markets that include sub-Saharan Africa, South and Southeast Asia, and Eastern Europe and Central Asia in particular.

The UK provides expertise in fare collection and smart ticketing systems with proven application across a range of countries with differing levels of technical sophistication. London's Oyster Card is a global standard of best practice in this regard.

The UK is a global leader in finance and contract management for mass transit infrastructure, including Public-Private Partnership (PPP) and Build Operate Transfer (BOT) arrangements.

The UK is strong in designing and deploying technology for hybrid powertrains in bus mass transit, based on proven operating experience in London in particular.

Improving inclusion aspects in mass transit are key strengths of the UK's private sector, for example improving accessibility for persons with disabilities and safety and comfort for women and families.

The UK has contributed less than 0.5 % of historical bilateral and multilateral donor activity related to mass transit between 2015 and 2018.

According to OECD-DAC data, between 2015 and 2018, DAC members, including the UK, spent approximately USD 10,049m out of which the UK has spent USD 51m in sectors related to rail transport, road transport, and transport policy and administrative support.

DAC countries (including UK) have spent approximately USD 8,118m in India from 2015-18 in the transport sector, while the UK has spent USD 1.6m.

In South Asia, DAC members spent USD 1,500m in the transport sector, while the UK spent approximately USD 2.9m from 2015-18.

In West Africa, DAC members spent USD 141m in the sector, while the UK spent USD 0.08m.

In South America, DAC members have spent USD 352m in the sector, while the UK hasn't spent any.

In Southern Africa, DAC members have spent approximately USD 61m, out of which the UK has spent USD 46m between 2015-2018.

The World Bank is a leader in funding large capital mass transit projects, whereas the UK is not well set up to provide this type of support. Examples include BRT systems in Tanzania and the twin cities of Hubballi-Dharwad, the second-largest urban cluster in Karnataka, India;[493] light rail in Manila, Philippines;[494] and urban planning and development programmes in Mumbai. The World Bank also

492 BRTUK website: http://www.brtuk.com
493 Gupta, Nupur. (2020). India: New Bus Rapid Transit System makes travel faster, safer and more convenient in Hubballi-Dharwad. https://blogs.worldbank.org/endpovertyinsouthasia/india-new-bus-rapid-transit-system-makes-travel-faster-safer-and-more
494 McCormack et al. (2017). Betting on Bankability: Picking up the pace of Manila's Light Rail Transit system. https://blogs.worldbank.org/ppps/betting-bankability-picking-pace-manila-s-light-rail-transit-system

produces and disseminates useful resources such as the *Urban Transport; Fares Collection; Intelligent Transport Systems; and Transportation PPP Toolkits*.[495]

The JICA is also particularly active in mass transit in the target regions, including currently facilitating the first phases of the Dhaka metro in Bangladesh and the Colombo light rail in Sri Lanka.

The Asian Development Bank (ADB) is a key player in sustainable transport in South Asia, helping national and municipal governments to incorporate TOD into urban planning and to plan and finance mass transit infrastructure and upgrade vehicle fleets to reduce carbon emissions.

Many other bilateral donors, such as Germany, France, Sweden, the Netherlands, and Australia, provide technical assistance related to planning, financing, and delivery of mass transit solutions, as well as reducing reliance on personal vehicles and improving the mode share of more sustainable options.

In regions with the largest mitigation potential (particularly India, South Asia, and West Africa), the UK typically has strong ODA ties related to developing sustainable and inclusive transport infrastructure, blended finance, and capacity building related to urban transport and urban planning. Some of the most notable programmes are:

- The DFID-funded *High Volume Transport (HVT) Facility*,[496] which is focused on applied research to contribute to more efficient and low-carbon transport in national and regional corridors and within cities in low-income countries in Africa and South Asia.
- ODA-funded facilities, such as the *Infrastructure and Cites for Economic Development (ICED)*[497] and *Evidence on Demand* (both DFID-funded), have provided considerable technical assistance in mass transit infrastructure planning and delivery to governments in the target regions.
- UK ODA has supported the *Private Infrastructure Development Group (PIDG)* in African countries since 2004, creating investment-ready, bankable, infrastructure opportunities as well as building local capability and capacity, via over USD 3 billion in disbursed blended financing funds.[498]
- *The Foreign and Commonwealth Office (FCO) Prosperity Fund* is currently implementing a number of programmes relevant to mass transit across the Infrastructure and the Future Cities portfolios. These include the Nigeria Future Cities Programme, the Global Future Cities programme, which operates across South and Southeast Asia, and the Sustainable Cities for Shared Prosperity in India.
- *DFID Cities and Infrastructure for Growth (CIG) programmes* operate in several sub-Saharan African countries and are likely to start up in Nepal and Bangladesh in 2021.

Most UK ODA programmes of support focus on technical assistance to governments in integrated city and transport planning, gender and inclusion aspects, financing infrastructure and capacity building related to maintenance and operations.

UK ODA has traditionally played a strong role in using public sector funding to leverage private sector investment in mass transit.

UK Government programmes are particularly strong in promoting the sustainability and inclusive development aspects of mass transit projects, helping to influence governments as well as multilateral donors such as the World Bank, which typically provide larger capital investments.

[495] Toolkits available here: https://ppp.worldbank.org/public-private-partnership/sector/transportation/toolkits
[496] HVT website: https://transport-links.com
[497] ICED website: http://icedfacility.org
[498] Source: https://infracoafrica.com/pidg/

Intervention opportunities

To alleviate the barriers set out above, there is substantial opportunity across all regions for the UK to draw on core strengths and areas of additionality in order to deliver energy storage interventions in the following areas:

Focus on improving bus transport in urban centres, including secondary and tertiary cities

- Technical assistance and demonstrations of integrated fare collection using electronic payment, vehicle location, and communication technologies.
- Support governments to prepare comprehensive sustainable urban mobility plans (SUMP), which can provide a fundamental basis for transport infrastructure development and related finance, based on broad participation and support.
- Providing support to city governments and stakeholders on the integration of informal and paratransit systems with existing or planned formal mass transit systems.
- Promoting a two-class transit approach for bus or minibus transit, in which a premium, more comfortable service is provided alongside a more affordable standard service.
- Supporting the planning and implementation of conventional bus service development and BRT-Lite applications on a network, rather than corridor, basis.
- These interventions are likely to be particularly effective in all target regions, with specific need in India, South Asia, and Southern and West Africa, where urban centres are rapidly growing, often in a chaotic way and transport demand is rapidly growing. Interventions should seek to engage primarily with city governments, with the buy-in of national or state level governments, to ensure maximum support is provided at the level at which transformational change should be achieved

Focus on decarbonising existing or growing bus fleets and paratransit fleets

- Support governments in designing and implementing mechanisms to scrap and improve highly polluting paratransit vehicles to low-carbon models via appropriate policy and financial incentives.
- Support rolling stock operating lease entities, including contract maintenance capability, which will help bus transit operators to upgrade vehicle fleets to low-carbon options.
- Support concessional finance to enable government purchase of low-emission bus fleets. This can reduce the upfront cost to achieve cost parity with conventional diesel buses, overcoming the cost related barrier to uptake. One option is to provide concessional financing directly to city authorities to allow purchase of bus assets. Another option is to raise awareness or existing model concessional agreements or help to create a new bespoke model for a specific context. For example, in 2019 the National Institute for Transforming India (NITI) Aayog created a model concession agreement for public-private partnership (PPP) aimed at the operation and maintenance of electric buses in cities across India. The objective of the model concession agreement is to provide better Operations and Maintenance (O&M) efficiency of city bus fleets for the authority while ensuring bankability of the project for the private sector.[499]
- Raise awareness, or support the implementation of, other initiatives such as battery leasing and long-term maintenance contracts through Original Equipment Manufacturers (OEMs), to enable government purchase of electric bus fleets. These arrangements also reduce the upfront cost to achieve cost parity with conventional diesel buses, overcoming the cost-related barrier to uptake. For

[499] Prateek, Saumu. (2019). NITI Aayog Introduces Model Concession Agreement for Electric Bus Fleets in Cities. https://mercomindia.com/niti-aayog-model-concession-agreement-electric-buses/

battery leasing, payments for the battery are included in fixed service payments for the lifetime of an asset.[500]

Provide concessional finance to fund increased use of renewable energy at bus stations, depots, stops, and charging points. This should make use of off-grid or on-grid solar photovoltaics energy, potentially with the option of feeding excess electricity back into the grid.

Consider financing lighter infrastructure works related to bus transit, such as implementation of priority bus lanes, and bus stop and terminus infrastructure. It is advised that financing of larger infrastructure projects such as light rail, metro or rail, is not usually the domain of UK Aid. However, financing of the project preparation process, such as feasibility studies and early design work, is a possible area of support.

Support to government with the wider transition to electric buses, which requires proper planning, including bus and route selection, fleet and e-charging systems analysis and design, procurement support, duty cycle determination, and maintenance.

Integration of informal and paratransit systems with existing or planned formal mass transit systems. It is particularly important to establish or maintain integration with last mile transit services, often provided by 2- and 3-wheelers.

These interventions are likely to be most effective and implementable in more advanced transport contexts such as India, South Asia, and South America, although there is also great demand across West Africa and Southern Africa.

Support to governments in demand management to reduce private car use and shift passenger preference towards safe and efficient and low-carbon mass transit.

This could include public awareness campaigns as well as more substantial planning for congestion charging zones, low-emissions zones, and improved cycling infrastructure.

Many areas of synergy with the Passenger Vehicles opportunity.

These opportunities are likely to be more effective in India and South America, building on strong public sector demand to improve mass transit systems, and helping to mitigate rapidly growing personal vehicle use. The need is also rapidly growing in South Asia countries, such as Pakistan, and countries in West Africa, such as Ghana and Nigeria.

Interventions to catalyse wider integrated urban development and low-carbon mass transit

Technical assistance to improve capacity and resources of governments to carry out or manage private sector consultancy in mass transit planning, which must be focused on identifying and developing the least-cost mode or size of transit.

Developing sustainable transport strategies and costed implementation plans. The UK has significant expertise in transport planning, modelling, and development of integrated strategy. This can be combined with advisory services on how to finance and deliver priority sub-projects.

Support in the design of the legal, regulatory, institutional, organisational, and financial frameworks for the operation of mass transit in a region or urban area.

Support governments to implement and use ICT and GIS and data-based systems for planning, design, and operations of cities and mass transit.

[500] BNEF. (2018). Electric Buses in Cities: Driving Towards Cleaner Air and Lower CO2. Bloomberg Finance. London.

Technical assistance to develop smart city solutions and software that can maximise the efficiency of mass transit services and thereby increase popularity, capacity, and uptake.

Improving the capacity and resources of municipal governments in integrated urban planning and transport planning that is based on TOD.

Expertise in accessible, safe, and comfortable transport can be mainstreamed across all interventions. The UK has considerable expertise in designing and enabling transport services that are accessible for everyone, including women and persons with disabilities. Promoting accessible and comfortable transport will play an important role in enabling a mode-shift to mass transit.

These interventions could apply in countries that have more advanced urban planning capabilities as well as digital infrastructure, such as South America and India.

Intervention case studies

Box 19 C40 Cities Finance Facility's support to Bangalore Metropolitan Transport Corporation to transition to an electric fleet

With an estimated 2020 population of over 12 million, Bangalore is the fifth largest city in India and the most rapidly growing Indian metropolis. It is one of India's most congested cities and suffers from high levels of air pollution, largely from transport-related emissions.[501] Bangalore joined the C40 Cities Finance Facility (CFF) in the second phase to help realise a range of low-carbon and climate-resilient projects for the city. CFF, along with the German Agency for International Cooperation (GIZ), is supporting the Bengaluru Metropolitan Transport Corporation (BMTC) by providing technical assistance and capacity building to help the city implement a full transition to electric buses by 2031. The bus fleet is projected to increase from 6,634 in 2019 to 15,134 by 2031.[502] As highlighted by a recent BILLIONEF report, e-buses now have lower total cost of ownership than comparable diesel or compressed natural gas (CNG) buses. Operational savings are one of the more important arguments supporting e-buses' introduction in many cities, as well as the environmental outcomes. Noise reduction and reduced maintenance requirements are also strong benefits.[503] The Cities Finance Facility (CFF) receives its funding from the German Federal Ministry for Economic Cooperation and Development (BMZ), BEIS, the United States Agency for International Development (USAID) as well as the Children Investment Fund Foundation.

The objective of the project is:

- To support the replace the whole fleet of 6,500 buses in the next ten years.
- Build the business case to transition the entire bus fleet to electric.

While the city of Bangalore is leading the project's planning and implementation, CFF is undertaking the following support activities:

- CFF's dedicated technical adviser is based within the BMTC administration and advises on capacity development in urban development issues and electric mobility with BMTC.
- Financing the feasibility studies needed to make the project bankable.
- Structuring a scalable business model to transition all buses within the city.
- Conducting technology analysis to ensure the right technology is selected for the city.
- Developing technical capacity and knowledge in the city administration, including municipal institutions and staff.

Activities undertaken would contribute to achieving the following results:

- Help to support public transport usage, which is forecast to increase to at least 60% by 2031, by providing modern and zero-emissions buses.
- Pollution levels will be reduced by 50 % by 2031 (against 2019 levels).
- USD 700,000 per day in fuel costs will be saved.
- 51,460 metric tonnes of CO_2 will be eliminated per year.

Key stakeholders and clients include:

- City administration, transport, and non-transport departments at city and state levels.

[501] Infrastructure Development Corporation. (2019). Bengaluru Comprehensive Mobility Plan. Government of Karnataka. https://opencity.in/documents/bengaluru-comprehensive-mobility-plan-cmp-draft-october-2019
[502] C40 Cities Finance Facility. (2019). Bengaluru - Leading the electrification revolution in India. https://www.c40cff.org/projects/bengaluru-electric-bus
[503] BNEF. (2018). Electric Buses in Cities: Driving Towards Cleaner Air and Lower CO2. Bloomberg Finance. London.

The challenges that the C40 CFF faced are:

- Changes in senior management at BMTC led to problems associated with turnover and project support.
- Existing bus depots, terminals, or bus stops are often located in places where the power supply is not adapted to charge bigger fleets of e-buses. It was important to involve local utilities and grid operators from the beginning of the process of planning e-bus deployment.

For BEIS, these are the primary lessons of the C40 CFF programme in determining ICF investment:

- It is important to identify capacity needs adequately before planning capacity development exercises to ensure that the technical assistance provided fits the need of the beneficiaries.
- Coordination between different levels of the government is helpful; the C40 CFF project team acts as the coordinator between the city and state governments.
- Deploying a technology without factoring in local needs and context defeats the purpose of the support.

Box 20 The BRT-Lite in Lagos, Nigeria, 2006-2008

The Ikorodu Road BRT in Lagos was Africa's first BRT scheme. It became operational in March 2008 following support from the World Bank and a concerted effort between various city and government stakeholders. Termed "BRT-Lite," this new form of BRT focuses on the delivery of improved quality of life within a modest budget. The implementation programme, from conception to operation, was collapsed into a 15-month timeframe; that, together with its delivery cost of USD 1.7m/km, made its development unique and its experience relevant to cities throughout the world. Before the service, passengers relied purely on 75,000 slow and uncomfortable, highly polluting minibuses and midibuses of low quality, with variable fares.[504] They plied their transport services over relatively short distances to maximise profit rather than serve demand. Significant improvements were needed, and following initial discussion and consultation there was a quick recognition that BRT was not necessarily a long-term aspiration but something that was readily deliverable.

The objective of the World Bank Lagos Urban Transport Project (LUTP) was:

- To support the planning and implementation of BRT-Lite along a key 19.2 km radial highway that connects Mile 12, a newly emerging central business district (CBD) in the north, to Lagos Island, the traditional CBD.
- To take up and move forward concepts identified in earlier studies.
- To build city government capacity to manage the transport system and identify the priority actions, investments, and enabling measures for its improvement.

The intervention undertook the following activities:

- A feasibility study and the design of a low cost, high frequency, high speed, high occupation, high safety, low-emissions BRT-Lite system.
- Light infrastructure works along the existing roadway, complemented by new bus shelters and ticket kiosks, as well as the design of a simple pre-boarding ticketing system.

[504] Kaenzig et al. (2010). Africa's First Bus Rapid Transit System. Journal of the Transportation Research Board.

- Amendments and additions to policy and regulations for the prohibition of vehicles other than those franchised for the BRT-Lite scheme (and certain emergency services) in the designated infrastructure.
- Amended regulations designed to facilitate the free movement of traffic in the reduced roadway capacity alongside the BRT-Lite running lanes, principally through the restriction of other commercial buses to the service lanes only and a total prohibition on heavy commercial traffic in the peak hours.
- Stakeholder and public consultation: a wide range of groups were consulted and the scheme explained as a means to solve their own particular problems—not those problems identified by others—and without the imposition on them of alien solutions. Through this approach a sense of local ownership was developed, which resulted in BRT-Lite being seen as a user's project.
- Support on procurement of a mix of new and used buses, to be operated by existing transport operators, represented by transport unions.
- A public relations strategy was adopted throughout development and construction and consisted of advertising within the corridor, in newspapers, radio, and on TV, including a 90-second demonstration on how to use BRT (i.e., how to get and pay for a ticket, and how to wait, board, and alight).

Activities undertaken contributed to achieving the following results:

- BRT-Lite runs 7 days a week, from 06:00 a.m. to 22:00 p.m. on weekdays, with reduced hours of operation at weekends. Weekday service frequency is approximately 90 seconds.
- Six million people live within the catchment and patronage of BRT-Lite was observed to reach 195,000 passengers on an average weekday in 2009 and more than 1,150,000 passengers in a full week. The system carried 10,000 passengers per hour in the peak direction.[505]
- The service represented a saving of 25 minutes on the same journey taken before the BRT became operational.
- The BRT-Lite currently accounts for more than a quarter of all trips recorded along the corridor, although its vehicles make up just 4% of those on the route.
- The majority of those surveyed "strongly agreed" that BRT was superior in terms of journey time, safety, reliability, price, and comfort.

Key stakeholders and clients include:

- The Lagos Metropolitan Area Transport Authority (LAMATA); Lagos State Government inc. Ministry of Works; the National Union of Road Transport workers and Transport Industry; and the Road Transport Employers Association of Nigeria.

The challenges faced were:

- Delivery of BRT-Lite involved the cooperation of multiple agencies. First, BRT-Lite needed to be considered within the context of land use and spatial development in the state. Ongoing master plan development was to feed from - and BRT was to feed off - this plan. To ensure that synergy was maximised, appropriate representation was made within the BRT Steering Group. Second, transfer of the control of the federal highway, under which BRT-Lite operates, to Lagos State would involve the relevant ministries of transportation and of works.
- Public coordination and cooperation with the new scheme was a challenge and to solve this a state initiative called "Kick Against Indiscipline" was made available to help with public

[505] Ibid.

management within the BRT-Lite system, such as to deal with trading and hawking on the walkways, and to maintain orderly queuing at the bus stops and vehicle parks.

- Disability access was not considered for the BRT-lite design. While a fully accessibly system would require significantly more design, there are a number of cost-effective things that could be done to factor universal design at least into the bus stop and terminal infrastructure.

For BEIS, these are the primary lessons of the programme in determining ICF investment:

- BRT-Lite is rooted in established BRT practice but also grounded in a detailed understanding of local user needs, with the key requirement being efficient and rapid delivery, based on a flexible approach that works for the local context.
- Existing public transport operators were able to benefit from involvement in delivery of a new transport system.
- Success was largely due to a dedicated public transport authority, LAMATA, that has the capabilities to plan, regulate, and form relationships to enforce and operate public transport with appropriate expertise, energy, and desire to succeed.
- Political commitment and support with a clear focus was vital, especially when difficult decisions are required and opposition is felt.
- Transport union support was enabled with stakeholder engagement that educated, defined roles, and demonstrated the benefits and links in a cross-sector delivery that involves both public and private participation.

Glossary

Acronym / Term	Definition
ADB	Asian Development Bank
Baseload	The minimum amount of electric power delivered or required over a given period
BAU	Business as usual
BEIS	UK government Department for Business, Energy & Industrial Strategy
BESS	Battery energy storage systems
BMZ	Germany's Federal Ministry for Economic Cooperation and Development
BOT	Build operate transfer
BRT	Bus rapid transit
CIF	Climate Investment Funds
CIG	Cities and Infrastructure for Growth
CNG	Compressed Natural Gas
CSP	Concentrated solar power
CTF	Clean Technology Fund
DFID	UK government Department for International Development
Energy storage	A device that captures energy for later use, with categories of storage including electrochemical, electrical, mechanical, and thermal forms of storage
EU	European Union
EUR	Euro
EVs	Electric vehicles
FCO	UK government Foreign and Commonwealth Office
GBP	British pound sterling
GDP	Gross domestic product
GHG	Greenhouse gas
GIS	Geographic Information System
GIZ	Deutsche Gesellschaft fur Internationale Zusammenarbeit GmbH
Gt CO2	Gigatonnes of CO2
Gt CO2e	Gigatonnes of CO2 equivalent
GW	Gigawatt
GWh	Gigawatt hours
HVT	High Volume Transport Facility
IADB	Inter-American Development Bank
ICE	Internal combustion engines
ICED	Infrastructure and Cities for Economic Development
IEA	International Energy Agency
IFC	International Finance Corporation
IoT	Internet of Things

Acronym / Term	Definition
IPCC	Intergovernmental Panel on Climate Change
IT	Information technologies
MAGC	Market Accelerator for Green Construction
NAMA	Nationally Appropriate Mitigation Action
NDC	Nationally Determined Contribution
NEP	National Energy Plans or Policies
O&M	Operations and maintenance
ODA	Official Development Assistance
OECD	Organisation of Economic Cooperation and Development
PPP	Public-private partnership
PSO	Public service obligation
RD&D	Research, development and demonstration
SDG	Sustainable Development Goal
System costs	Total costs to the electricity system to supply electricity at a given load and security of supply
TOD	Transit-oriented development
UNIDO	United Nations Industrial Development Organisation
USAid	United States Agency for International Development
USD	United States Dollar

Passenger Vehicles

Summary

The passenger vehicles opportunity considers all low emissions passenger vehicles except those used for mass transit and is expected to provide a low climate impact given the scale of electric vehicle (EV) deployment already expected under the business-as-usual (BAU) scenario. Broadly, we consider two vehicle categories: cars and two-wheelers. Cars includes fuel cell and battery electric vehicles (FCEV/BEVs), and fuel efficiency internal combustion engine vehicles (ICEVs). Both two- and three- wheelers are considered, as they represent a significant share of passenger kilometres (km) in ODA-eligible countries- often over 60%. This includes all motorised two wheelers, ranging from low power e-bikes and mopeds to motorcycles and rickshaws. Notably, large emissions reductions are forecast from this opportunity in the BAU scenario due to fuel efficiency improvements and increasing uptake of EVs, both cars and two-wheelers.

Interventions to encourage adoption of low-carbon passenger vehicles in focus regions include financial support to install charging stations and technical assisstance to support EV-friendly urban planning. Examples of such interventions include:

- Financial support towards enabling infrastructure, specifically the provision of electric vehicle charging stations, which is often underinvested in by the private sector until the market is mature.
- Technical assistance to improve urban planning and help integrate EVs into the smart grid, with poor urban planning and concerns over EV charging's impact on the grid network often leading to lower levels of uptake or public sector interest.

Table 32 Passenger vehicles assessment summary

Criteria	Assessment	Notes
Climate impact	Low	• Additional investment in passenger vehicles decarbonisation can help avoid around 20% of total passenger transport sector emissions by 2050, beyond the BAU. The relatively low climate impact is due to already high emissions reductions expected under a BAU scenario, due to energy efficiency improvements and adoption of electric vehicles. • In regions with large two-wheeler markets, most notably India, the transition to EVs (and the climate impact) could be faster compared to markets with mostly four-wheelers.
Development impact	Low	• Largest development impact results from reductions in local air pollution and the consequent positive impact on Sustainable Development Goal (SDG) 3, good health and wellbeing. • Potential negative impact on SDG 12, sustainable consumption and production, if end-of-life management practices for electric vehicle batteries are not in place.
Investment gap	Low	• Investment gap is negative, around USD 19 trillion less is required relative to BAU due to the considerable investment forecast to occur under BAU and the declining costs of EVs, which are expected to become cheaper than ICEVs. • The key additional investment to support low-carbon vehicles is enabling infrastructure e.g. charging stations.
Cost-effectiveness	Medium	• Cost-effectiveness of EVs improves over time, as they are expected to reach cost parity with ICEVs by the mid-2020s; they will soon deliver CO2 abatement at GBP no additional cost.[506] • Electric two-wheelers are already cost-effective for certain vehicle classes.

[506] Jürg et al. (2019). E-Mobility Options for ADB Developing Member Countries. https://www.adb.org/sites/default/files/publication/494566/sdwp-060-e-mobility-options-adb-dmcs.pdf; BNEF (2020) Electric Vehicle Outlook 2020 https://about.bnef.com/electric-vehicle-outlook/

Criteria	Assessment	Notes
Barriers to adoption	Low	• Coordination challenges and network effects associated with the provision of enabling infrastructure (e.g. charging stations) for low-carbon vehicles continues to be the most significant barrier. • Though low-carbon vehicles have historically faced barriers related to the unpriced carbon externality and policy bias towards incumbent automotive and oil distribution sectors, these barriers are reducing in many regions (e.g. India) due to EV cost declines and planned ICE phase-outs
UK additionality	High	• The UK has substantial experience in increasing uptake of low emissions vehicles and implementing demand management measures to both reduce personal vehicle use and integrate vehicles into the grid network. • There is substantial international influence that can be leveraged within ongoing activities, including work by BEIS's COP26 team on overcoming barriers to transition to EVs across an extensive network of countries.

Source: Vivid Economics, ASI & Factor

Key lessons for supporting mitigation through decarbonising passenger vehicles:

Electric vehicles are expected to be an increasingly cost-effective mitigation opportunity, forecast to reach cost parity with internal combustion vehicles in the 2020s. EV deployment could therefore be significantly faster than climate modelling suggests. However, to realise the full benefit of cost declines will require EV adoption to be paired with rapid renewable deployment by 2030.

India and South America deliver a particularly large mitigation opportunity, due to their large and fast-growing passenger vehicle fleets. In India, the mitigation opportunity will be delivered through the decarbonisation of the large two-wheeler market, more so than in South America (excluding Brazil).

Public sector intervention will be most cost-effective when:

Targeting the provision of enabling infrastructure, such as EV charging stations.

Supporting low emission vehicle (LEV)-friendly urban planning.

Ensuring the efficient integration of LEVs into the grid network.

The UK has a substantial opportunity to harness its expertise in the design and implementation of demand management mechanisms, and installation and integration of charging infrastructure.

Introduction to the opportunity

Role of opportunity in decarbonisation of developing countries

Passenger vehicles (cars and two-wheelers) currently emit 1.2 gigatonnes of carbon dioxide ($GtCO_2$) in low- and middle-income countries, rising to 3.1 $GtCO_2$ in 2050 under a BAU scenario. Passenger vehicles account for approximately 14% of total emissions in non-OECD countries, and the majority of transport emissions.[507] To reach 1.5 degrees, emissions from passenger vehicles need to reduce to around 0.5 $GtCO_2$ in 2050 (a 70% reduction versus BAU), while supporting a large increase (potentially 2-3x increase) in road transport demand.[508] This large increase in demand is expected to come hand in hand with substantial increases in passenger vehicle fleet sizes, with four-wheelers increasing from 0.5 to 0.8 billion in non-OECD countries, and two wheelers continuing to play a large role as well. Given the scale of the vehicle fleet, low-carbon pathways with EV adoption will not only have a large direct impact in reducing transport emissions, they will also have large indirect impacts, helping to further reduce the cost of batteries and disrupting oil industry revenues.

Two-wheelers currently play a crucial role in road transport in non-OECD countries, but cars are expected to gradually become more important. Currently, up to 70% of passenger km in non-OECD countries are travelled using 2-wheelers (compared to 10% in the OECD).[509] Although their relative importance is expected to continue, it is expected to decline to around 50% of passenger km travelled by mid-century. This is driven by a structural shift in transport demand, from heavily urban transport to more non-urban road transport, as well as increasing wealth making cars more affordable.[510]

The passenger vehicle market is materially different to the UK's market in many developing countries, which impacts how mitigation opportunities can be achieved. The large expected growth in demand for vehicles as populations and wealth grow underscores the importance of decarbonising the sector. However, despite rises in demand, the majority of vehicle sales in developing countries are second-hand. Hence, changing the make-up of the vehicle stock takes longer than, for example, in the UK. The specific challenges and opportunities for low- and middle-income countries to capture the mitigation potential in passenger vehicles are set out in this opportunity report.

Scope considered in this assessment

The passenger vehicle opportunity considers all low emissions passenger vehicles except those used for mass transit. Broadly, we consider two vehicle categories:

Cars: This includes FCEVs and BEVs, and fuel efficiency ICEVs.

Two wheelers: The passenger vehicles category includes two and three-wheelers, as they are a significant share of passenger km in non-OECD countries- often over 60%. This includes all motorised two wheelers, ranging from low power e-bikes and mopeds to motorcycles and rickshaws.

Across both cars and two wheelers, individually owned and rented business models are considered.

[507] International Energy Agency. (2019). CO_2 Emissions from Fuel Combustion Highlights (2019 edition). https://www.iea.org/reports/co2-emissions-from-fuel-combustion-2019
[508] Measured in passenger km, based on SSP2. Data available from Integrated Assessment Modelling Consortium (IAMC) 1.5C scenario explorer here: https://data.ene.iiasa.ac.at/iamc-1.5c-explorer/#/workspaces
[509] International Energy Agency. (2017). Energy Technology Perspectives. Available from: https://www.iea.org/topics/energy-technology-perspectives
[510] International Transport Forum and Organization for Economic Co-operation and Development. (2019). ITF Transport Outlook 2019. Available from: https://www.oecd-ilibrary.org/docserver/transp_outlook-en-2019-en.pdf?expires=1595426275&id=id&accname=ocid75017725&checksum=4F15D0FE09C14B4DB96E31FA1EE5C365

The assessment focuses on selected Official Development Assistance (ODA)-eligible regions, based on the scale of emission reductions in passenger vehicles expected within these regions. The included regions are:

- India, the largest global market for two-wheelers, and a large potential market for electric two-wheelers (following the transition that has already occurred in China).
- South America (excluding Brazil), hereafter 'South America', is a more car-focused region, and has the largest absolute mitigation opportunity after China, at 73 $MtCO_2$/year (versus BAU).
- North Africa, where passenger vehicles account for 85% of mitigation potential in 2050 beyond BAU.
- Central America. Like North Africa, passenger vehicles in this region are responsible for most mitigation beyond BAU, approximately 90% in 2050.
- Eastern Europe and Central Asia has both a sizeable absolute as well as relative mitigation opportunity, of 65 MtCO2/year (versus BAU).

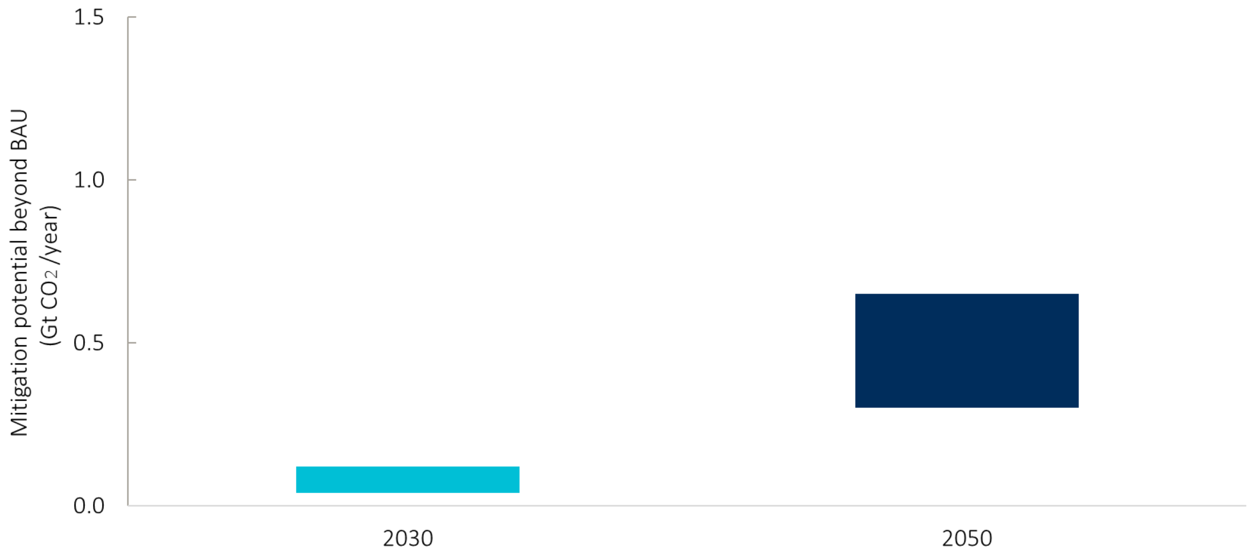
This assessment focuses on the benefit of supporting the opportunity as a whole and does not aim to comprehensively assess the effectiveness of specific investment opportunities or interventions. However, for context, potential specific investment opportunities are detailed in Sections 0.

Climate impact

Mitigation potential and urgency

Across low- and middle-income countries, decarbonising passenger vehicles can help avoid around 20% (0.6 $GtCO_2$) of CO_2 emissions in the transport sector by 2050, beyond BAU.[511] Most mitigation up to 2030 is expected to come from energy efficiency (0.12 GtCO2), with near zero mitigation from EV or FCEV deployment, compared to BAU, until later in the century. The minimal short-term mitigation from EVs is a result of limited short-term take-up of EVs (four-wheelers and two-wheelers) in climate modelling, as well as the relatively high continued emissions intensity of electricity in non-OECD countries (lowering the mitigation potential of EVs). Consequently, EVs are expensive from a GBP/tCO_2 perspective in the short term, and hence not taken up at scale in most climate models. By 2050, EVs are expected to drive over half of the mitigation opportunity in passenger transport. Energy efficiency of ICEs, as well as biofuels, also play a role, with little to no deployment of hydrogen expected in passenger transport.

Figure 30 Range of mitigation potential compared to BAU in 2030 and 2050



Note: The bars indicate the range of mitigation estimates from IMAGE across the six scenarios run. The national policies scenario is used as the BAU scenario, and so "vs. BAU" mitigation estimates are calculated as the emissions reduction from 2015 in one scenario minus the emissions reductions from 2015 in the national policies scenario.

Source: Vivid Economics, ASI and Factor using PBL's IMAGE model

EV deployment could be significantly faster than climate modelling suggests, but would need to be paired with rapid renewable deployment to support large-scale emissions reductions (several 100 $MtCO_2$) by 2030. It is plausible the number of EV sales, and hence the mitigation opportunity, is significantly higher (particularly in China) than expected in climate modelling, driven by rapid cost reductions, as well as additional policy action motivated by non-climate factors (e.g. industrial strategy and air pollution). Rapid policy developments like, for example, planned ICE phase-outs in India, as well as faster than expected cost reductions, are not fully captured in the modelling. Bloomberg expects 116 million EVs on the road by 2030, which implies approximately 70 million are on the road in non-OECD countries.[512] Assuming a rapid coal

---

[511] Measured against BAU, emission reductions are significantly lower. This is because energy (fuel) efficiency is a major driver of the mitigation opportunity, and substantial energy efficiency improvements compared to today are expected in BAU as well.
[512] BloombergNEF. (2020). Electric Vehicle Outlook 2020. Available from: https://about.bnef.com/electric-vehicle-outlook/

phase-out, this would be equivalent to around 140 $MtCO_2$ annual abatement by 2030.[513] Similarly, the market for electric two-wheelers is growing very rapidly, driven by cost and the ease of recharging small e-moped and/or e-bicycle batteries. An earlier switchover to EVs would have a knock-on impact on the EV fleet size by 2050, driving the mitigation opportunity up beyond the estimated 0.3 $GtCO_2$/year against BAU as estimated in IMAGE.

FCEVs are not expected to play a major role. Current cost projections suggested FCEVs are likely to be more expensive than EVs in the passenger vehicle segment. As a result, FCEVs are not expected to play a major role in mitigating passenger emissions.

Achieving large-scale mitigation in passenger vehicles requires significant changes in the vehicle fleet in the short term, and hence high sales penetration of electric vehicles and fuel-efficient vehicles. In non-OECD countries, there are approximately 0.5 billion cars on the road today. By 2030, this is expected to increase to 0.8 billion and to around 1.2 billion by 2050.[514,515] While by 2030 EV penetration may still be low in non-OECD countries, achieving large-scale emissions savings mid-century will require a rapid transition, and around 50% (or above) sales penetration by the late 2030s in many markets. Notably, the Indian government aims for fast adoption of electric four-wheelers, 30% penetration by 2030, but the ability to achieve government targets is called into question by the availability of very low cost cars and consumer readiness.[516] Across most regions, rapidly turning over the vehicle stock will be a substantially larger challenge than in developed countries, given the importance of the second-hand market.

In regions with large two-wheeler markets, most notably India, the transition to EVs could be faster compared to markets with mostly four-wheelers. Although short-term climate mitigation from this transition is limited (given high grid intensity), electric mopeds and bicycles are relatively cheap, potentially accessible through sharing platforms, and easy to charge in the home. This means the technology is relatively well positioned (compared to cars) to reach very high penetration rates, as has been demonstrated in China already.

Fleet size, the current average emissions intensity and fuel economy (gCO2/km and Lge/100 km), mode-switching opportunities, and the likely electrification potential also play a major role in determining the mitigation opportunity:

- Fleet size and associated transport demand unsurprisingly drive the mitigation opportunity. The largest opportunities in passenger transport occur in regions with the largest passenger fleets. For instance, China has a mitigation potential from passenger vehicles of 150 $MtCO_2$/year in 2030 and is expected to have a fleet of 200 million vehicles.[517]

- Current average fleet fuel economy varies substantially by region. For example, in Italy fuel economy is approximately 5.2 litres gasoline-equivalent (Lge)/100 km, in China it is 7.6 Lge/100 km, and in Chile it is 8 Lge/100 km.[518] Regions where fuel economy is currently poor have numerous relatively easy mitigation opportunities available.

- Mode-switching opportunities to mass transit vary substantially across regions, as set out in the Mass Transit opportunity report. To illustrate, 8% of all passenger transport mitigation in China is expected

---

513 The yearly mitigated emissions from EVs will vary by make and model, as well as the grid intensity in the country of use. In the UK, the yearly emissions saved are estimated at about 2 tonnes of CO_2 per EV (Hausfather. 2019. Carbonbrief. https://www.carbonbrief.org/factcheck-how-electric-vehicles-help-to-tackle-climate-change).
514 Bloomberg New Energy Finance. (2020). Electric Vehicle Outlook 2020. https://about.bnef.com/electric-vehicle-outlook/
515 OECD. (2012). Transport Outlook. https://www.oecd.org/greengrowth/greening-transport/Transport%20Outlook%202012.pdf
516 https://www.bbc.co.uk/news/world-asia-india-48961525
517 Bloomberg New Energy Finance. (2020). Electric Vehicle Outlook 2020. https://about.bnef.com/electric-vehicle-outlook/
518 International Energy Agency. (2019). Fuel Economy in Major Car Markets: Technology and Policy Drivers 2005-2017. https://www.iea.org/reports/fuel-economy-in-major-car-markets

to come through mode-switching to mass transit, compared to just 3% in Eastern Europe and Central Asia. [519]

The EV take-up is expected to vary substantially by region. This is driven by likely differences in the availability of enabling infrastructure, as well as by characteristics of vehicle markets in different regions. For example, EV penetration will be slower in markets which heavily depend on second-hand imports (particularly Africa). By contrast, it will likely be faster in large two-wheeler markets (particularly Asian regions).

Box 22 **Modelling uncertainty**

The uncertainty around passenger vehicle mitigation is primarily driven by uncertainty around the relative costs between EVs and ICEs. EV costs have reduced rapidly in the past years. It is plausible that costs reduce below those of ICEs, in which case mitigation potential may become significantly larger than estimated.

Uncertainty around mode switching is also significant but does not substantially change the mitigation potential in passenger vehicles. Urban planning policy etc. can discourage the use of passenger vehicles, particularly in urban areas.[520] This is a sizeable mitigation opportunity (analysed separately), but is likely to represent a smaller uncertainty around passenger vehicle mitigation potential.

Transformational change

The Passenger Vehicles opportunity offers substantial scope for transformational change, as set out in Table 2. The uptake of zero-carbon vehicles including two- and three-wheelers can be massively scaled up with a suitable framework of policy that sets out incentives to purchase and operate such vehicles, as well as enabling infrastructure, such as public charging points and building codes that mainstream the provision of private charging, as well as behavioural change considerations. This is likely to accelerate faster in India and South American countries where the uptake of EVs is gaining speed, but with a range of suitable interventions, transformational change can be achieved across the other target regions including Central America, North Africa, and Eastern Europe and Central Asia. It is also important to remember that achieving the Paris Agreement targets also relies to a significant extent on limiting the uptake of private vehicles and instead shifting demand to active transport, such as walking and cycling, and mass transit solutions, such as bus and rail. As such, International Climate Finance (ICF) interventions should also consider demand management interventions to achieve transformational change via reducing the use of private vehicles.

Table 33 Assessment of transformational change

Transformational change criterion	Interventions to support change	Regional potential
Sensitive intervention points		
Improvement of local capacities and capabilities	Capacity building for governments to implement and enforce vehicle emissions standards. Support policy and regulation that incentivise uptake of zero-carbon vehicles. Strengthening urban planning and building code legislation to incentivise EVs.	North Africa, Central America, South America

[519] By 2050, under a 1.5°C scenario.
[520] Jones, Peter. (2014). The evolution of urban mobility: The interplay of academic and policy perspectives. https://doi.org/10.1016/j.iatssr.2014.06.001

Transformational change criterion	Interventions to support change	Regional potential
Local ownership and strong political will	Creating stronger understanding of the rationale and the levers to improve the uptake of more efficient and low-carbon vehicles can improve political will.	Eastern Europe and Central Asia, North Africa, Central America
Leverage / creation of incentives for others to act	Support financial incentives for EVs or efficient ICEs, such as tax rebates and subsidies. Support in developing widespread EV charging infrastructure, helping to encourage uptake. Support for demand management incentives such as low-emission zones, paired with more efficient mass transit, safer cycling lanes, etc. helps reduce reliance on personal vehicles.	Eastern Europe and Central Asia, North Africa, Central America
Spillovers		
Broad scale and reach of impacts	Supporting disruptive business models for electric vehicles and two- and three-wheelers can achieve rapid growth and scale. Support to integrate EVs in providing grid balancing services, as smart and flexible electricity grids are developed. Potential for EV deployment to decrease costs of stationary storage / provide second life batteries for the grid. Charging infrastructure for passenger vehicles can reduce future costs of decarbonising heavy duty freight transport	India, North Africa, Central America, South America
Sustainability (continuation beyond initial support)	Support implementing urban planning measures to help integrate EVs and to manage demand for personal vehicle use.	All regions
Replicability by other organisations or actors	Support the dissemination of demonstration projects or pilots to other countries and contexts.	All regions
Innovation		
Catalyst for innovation	Support innovative development of mini-grid solar to power EV two- and three-wheelers in off-grid locations. Enabling more widespread EV charging infrastructure. Encouraging local manufacturing of two- and three-wheelers	North Africa, Central America
Evidence of effectiveness is shared publicly	Importance of sharing learning and evidence of what works well and what has failed or could be improved.	All regions

Source: Vivid Economics, ASI and Factor

Development impact

SDG impacts

Cleaner passenger vehicles significantly help countries in the target regions achieve several sustainable development goals, as set out in Table 34.

Poor air quality in most cities in the target countries is connected to many thousands of early deaths per year and many governments are actively seeking to decarbonise vehicle fleets to reduce this.

Health-related SDG benefits are likely to be greater in the near-term in countries with large urban centres, where negative health impacts of air pollution are concentrated.

Table 34 SDG impacts

SDG	Strength of impact	Most relevant region	Rationale
Positive Impacts			
SDG 3 – Good Health and wellbeing	High	All regions	Promoting low emission passenger vehicles would reduce air pollution, thereby reducing pollution and contamination-related deaths and illnesses.
SDG 7 – Affordable and Clean Energy	Moderate	China, South America (Chile)	EVs have an important role to play in smart and flexible electricity grids, helping to store power and feed back into the grid during times of high demand.
SDG 9 – Industry, Innovation and Infrastructure	High	All regions	More sustainable passenger vehicles would promote innovation and innovative infrastructure, such as EV integration with flexible grids. Local battery or two- or three-wheeler production could also lead to greater industry and employment.
SDG – 10 Equity	Moderate	China, India, South America	Access to mobility options is a key consideration, including the role of autonomous vehicles in the longer term.
SDG 12 - Responsible Consumption and Production	Moderate	All regions	More sustainably produced passenger vehicles that are more efficient or emissions free.
SDG 13 – Climate Action	High	All regions	Promotion of energy-efficient passenger vehicles would result in reducing greenhouse gases (GHG) emissions.
Negative Impact			
SDG 12 – Responsible Consumption and Production / SDG 15 – Life on Land	Low	All regions	Impacts of EV batteries on the environment need to be carefully managed. For instance, mineral extraction for batteries ought to meet environmental and ethical standards and batteries should be recycled appropriately. The production of land-competitive biofuels can also have direct and indirect impacts on biodiversity, water, and food.

Source: Vivid Economics, ASI and Factor

Demand in target regions

Table 35 Demand in target geographies

Region	Demand	Rationale
India	Moderate-High	Recent roll-out of plans and policies by national and sub-national governments, sales of Passenger Electric Vehicles PEVs) increasing year by year.
Eastern Europe and Central Asia	Low-Moderate	Variable regulatory environment and policies across different countries, mostly limited to tax exemptions.
North Africa	Low-Moderate	Variable regulatory environment and policies across different countries.
Central America	Moderate-High	Variable policy and regulatory environment, countries are developing or have developed targeted EV policies.
South America	Moderate-High	Variable policy and regulatory environment, countries are developing or have developed EV targeted policies led by Chile and Colombia.

Source: Vivid Economics, ASI and Factor

India: India has a vision to make EV sales at least 30% of all passenger vehicle sales by 2030, and in April 2019 the government launched the second phase of FAME (Faster Adoption and Manufacturing of Hybrid & Electric Vehicles), although progress against targets during 2019-2020 has been hampered by a range of factors, including Covid-19.[521] In India more than ten state governments have rolled out EV Policy with both fiscal and non-fiscal incentives. The fleet operators across the different segments are exploring, and are tying up with, original equipment manufacturers (OEMs) to develop low cost and agile solutions for the EV market. Total EV sales surpassed 750,000 vehicles in 2018, including electric two-wheelers (growth of 130% year-on-year), electric three-wheelers, and electric passenger vehicles.[522] Finally, India has recently introduced the BS6 standard for ICE vehicle efficiency, which is equivalent to Euro VI.

Eastern Europe and Central Asia: Six out of nine countries mention transport as one of the mitigation sectors in their Nationally Determined Contributions (NDCs) or Intended Nationally Determined Contributions (INDCs). Further, seven out nine countries recognise transport in their domestic climate laws and policies. However, countries rarely directly refer to EVs. For example, in Central Asian countries such as Kyrgyzstan, Kazakhstan, Turkmenistan, Tajikistan, Uzbekistan, no policies or incentives exist for EVs.[523] In Ukraine, there are value-added tax (VAT) exemptions on imports of EVs.[524] Many Eastern European countries benefit from knowledge sharing and resources within the European Union (EU) and also demonstrate commitment to the uptake of more efficient and less polluting passenger vehicles via policy and financial incentives.[525]

North Africa: Several North African countries, such as Egypt and Morocco, are actively seeking to improve the efficiency of their passenger vehicle fleets and have applied a total ban on the import of

[521] Dwivedi, Shivali. (2020). Impact of COVID-19 on the Indian e-mobility sector. https://www.icf.com/insights/transportation/impacts-covid19-emobility-sector?utm_medium=emp-social&utm_source=linkedin&utm_campaign=1978-India-Next-Energy&utm_content=article
[522] International Energy Agency. (2019). India and IEA hold workshop on EV charging infrastructure. https://www.iea.org/news/india-and-iea-hold-workshop-on-ev-charging-infrastructure
[523] Grütter and Kim. (2019). E-Mobility Options for ADB Developing Member Countries. https://www.adb.org/sites/default/files/publication/494566/sdwp-060-e-mobility-options-adb-dmcs.pdf
[524] Eastern Partnership. (2018). Eastern Partnership 14th Panel on Transport: Electric Vehicles in Ukraine. http://eap-csf.eu/wp-content/uploads/EVs-in-Ukraine.pdf
[525] See, for example: European Automobile Manufactures Association. (2019). Electric Vehicles: Tax Benefits & Incentives in the EU. https://www.acea.be/uploads/publications/Electric_vehicles-Tax_benefits_incentives_in_the_EU-2019.pdf

used cars as a first step.[526] There is a need for further assistance in improving the regulations and standards governing the efficiency of ICEs and the integration of new energy vehicles.

Central America: Approximately 90% of countries identify transport as a mitigation pathway in their NDCs/INDCs. Generally, there is very little policy in terms of fuel economy, but there are some promising moves within electric mobility, partly due to advances in clean grids. To provide a few examples: There are comprehensive EV regulations in Costa Rica – the first in the region - and it has set an ambitious target to get 37,000 PEVs on the road by 2022. Guatemala locally produces electric three-wheelers. Panama is implementing a National Strategy for Electric Mobility, along with the Inter-American Development Bank, and has introduced 1,500 e-taxis. Jamaica is developing an Electric Vehicle Policy and a strategic framework for electric mobility to inform policy and support a seamless transition to battery electric vehicles.

South America: Chile, Colombia, and Uruguay identify transport as a mitigation sector in their NDCs, while Ecuador, Bolivia, Guyana, Paraguay, and Peru do not. There is significant demand by a range of stakeholders from the public and private sectors in South America for a range of policies and technologies that reduce vehicle emissions, as demonstrated by the 2018 South America Summit on Vehicle Emissions Control, which culminated in a draft regional workplan for more efficient vehicles.[527] Chile is taking a regional lead in ambition for clean mobility, with targets to increase the number of electric vehicle tenfold by 2022 and to transform the private vehicle fleet to 60% electric by 2050, [528] as well as shifting modes from private to public transport and increasing the use of green hydrogen for buses.[529] Chile also made a further commitment in their revised NDC, to reduce total carbon emissions by 25% in 2030 compared to 2016 levels.[530] In Colombia, the Ministry of Transport has taken steps to move the NDC forward by creating a new division called the Group for Environmental Affairs and Sustainable Development (GAADS), to coordinate mitigation measures in the transport sector.

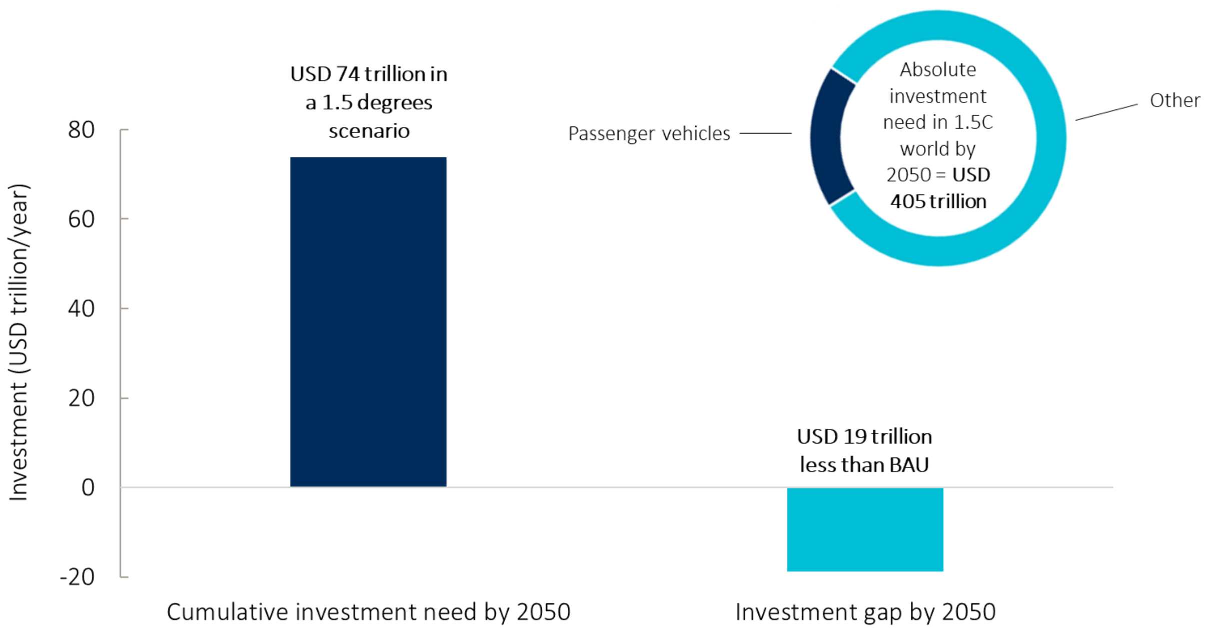
[526] Baskin, Ariadne. (2018). Africa Used Vehicle Report. https://wedocs.unep.org/bitstream/handle/20.500.11822/25233/AfricaUsedVehicleReport.pdf
[527] Posada et al. (2018). 2018 South America Summit on Vehicle Emissions Control: Summary Report and Regional Workplan. Available at: https://theicct.org/sites/default/files/publications/ICCT_SouthAmerSummit2018_rpt.pdf
[528] Changing Transport: Chile submits New Nationally Determined Contribution (NDC). Available at: https://www.changing-transport.org/chile-submits-new-ndc/
[529] Ramos Miranda, Natalia A. (2018). Chasing China: Chile drives Latin America's electric vehicle revolution. https://www.smh.com.au/world/south-america/chasing-china-chile-drives-latin-america-s-electric-vehicle-revolution-20181210-p50l7a.html
[530] Climate and Clean Air Coalition. (2020). Chile Increases Climate Change Ambition with Targets that Simultaneously Improve Air Quality and Health. https://breathelife2030.org/news/chile-increases-climate-change-ambition-targets-simultaneously-improve-air-quality-health/

Investment need

Total investment need in decarbonising passenger vehicles is an order of magnitude larger than that for renewables; however, much of this investment will occur in BAU. The passenger vehicle market is very large. Car sales alone in non-OECD countries accounted for approximately USD 1 trillion revenues in 2017. [531,532] Data on the full two-wheeler market is less available, but total market value is of a similar magnitude (more sales, but lower unit value). Given the market size, even relatively small percentage increases in average vehicle costs can have a substantial impact on investment needs. Although these investments are mostly distributed across a large number of households, mass market sales for EVs in both cars and two-wheelers are not expected before these become cheaper, and hence additional investment is limited.

Electric cars are expected to become cheaper than ICE cars in the next decade, while some electric 2-wheelers are already cost-effective to purchase. Electric cars currently represent an additional (upfront) investment of approximately USD 10,000/vehicle, however this is expected to reduce to USD 0 in 5-10 years.[533] While electric vehicles remain more expensive now, at the point of mass take-up in developing countries, electric vehicles will be at cost parity and do not represent a substantial additional investment. Electric two-wheelers, particularly mopeds and e-bikes, are already cost-competitive in many countries, and seeing substantial take-up alongside growing wealth. This cost inversion implies investment needs against BAU are expected to be negative, as shown in Figure 31.

Figure 31 Investment needs to turn over the fleet to low-carbon vehicles in a 1.5-degrees scenario could be lower than in the BAU, driven by lower EV costs as well as mode-shifting



Notes: Investment need calculations are calculated from the International Energy Agency's (IEA) investment levels on transport capital expenditure in the BAU and 1.5-degrees scenarios. Investment gap is calculated as investment need in a 1.5-degrees scenario minus investment in a BAU scenario.

531 Statista. (2019). Revenue - automotive industry worldwide 2017-2030. https://www.statista.com/statistics/574151/global-automotive-industry-revenue/
532 Bullard, Nathaniel. (2019). Bullard: China's Hunger for Electric Vehicles is Driving Manufacturing. https://about.bnef.com/blog/bullard-chinas-hunger-electric-vehicles-driving-manufacturing/
533 Grütter and Kim. (2019). E-Mobility Options for ADB Developing Member Countries. https://www.adb.org/sites/default/files/publication/494566/sdwp-060-e-mobility-options-adb-dmcs.pdf

Source: Vivid Economics, ASI and Factor using IEA. (2017). Energy Technology Perspectives.

The key additional investment to support low-carbon vehicles is the enabling infrastructure. For example, public charging networks will be required to support large-scale EV deployment. Investment needs for this will vary by country and depend on local factors such as population density. To give an indication, investment requirements for public EV chargers in the UK are estimated at USD 1 billion by 2030.[534] Scaling this by fleet size suggests approximate investment needs of USD 6 billion across all non-OECD countries. A key difference between regions is the importance of the two-wheeler fleet. Many electric two-wheelers can easily be charged using home electricity, whereas the larger battery size of cars requires specialist chargers (to achieve practical charging times).[535]

---

534 Vivid Economics. (2018). Accelerating the EV transition – Part 1: environmental and economic impacts. https://www.wwf.org.uk/sites/default/files/2018-03/Final%20-%20WWF%20-%20accelerating%20the%20EV%20transition%20-%20part%201.pdf

535 Rajper & Albrecht. (2020). Prospects of Electric Vehicles in Developing Countries: A literature review. Available from: https://www.mdpi.com/2071-1050/12/5/1906

Cost-effectiveness

Cost-effectiveness of low-carbon vehicles will improve over time.

- In the short term, direct investment in (FC)EVs is unlikely to be cost-effective given the existing price gap between EVs and ICEs and the limited emission savings per EV. A typical EV saves approximately 10 tCO_2 of carbon compared to ICEs over its lifetime (although this is heavily dependent on the carbon intensity of electricity).[536] Given that the difference in capital cost between EVs and ICEs is typically around GBP 10,000, upfront investment is costly for limited CO_2 savings. EVs compare more favourably to ICEs on a total cost of ownership basis (and hence on lifetime GBP/tCO_2). By contrast, measures to encourage fuel efficient ICEs are cost-effective from a GBP/tCO_2 point of view, given the fuel savings.
- In the long term, as set out above, electric cars are expected to become cheaper than ICE ones (first on a lifetime basis, and later on a showroom cost basis), and hence electric cars would have negative abatement cost, and measures to support their uptake would typically be highly cost-effective.

Unlike cars, supporting electric two-wheelers is already cost-effective for certain vehicle classes. E-bikes and low power electric mopeds can be cost competitive with two-stroke ICEs (partly because cheap, small batteries can be used). Over their lifetime, replacing two-stroke ICEs with electric substitutes saves approximately 1 tCO_2, hence small cost differences between the alternatives imply cost-effective investments.[537]

The cost-effectiveness of enabling infrastructure will be context-specific, but is likely to be high. In many cases, enabling infrastructure is likely to be a cost-effective investment in terms of GBP/ tCO_2. This is because, without the enabling infrastructure present, countries would not be able to benefit from high take-up from EVs when these become cheaper than ICEs.

---

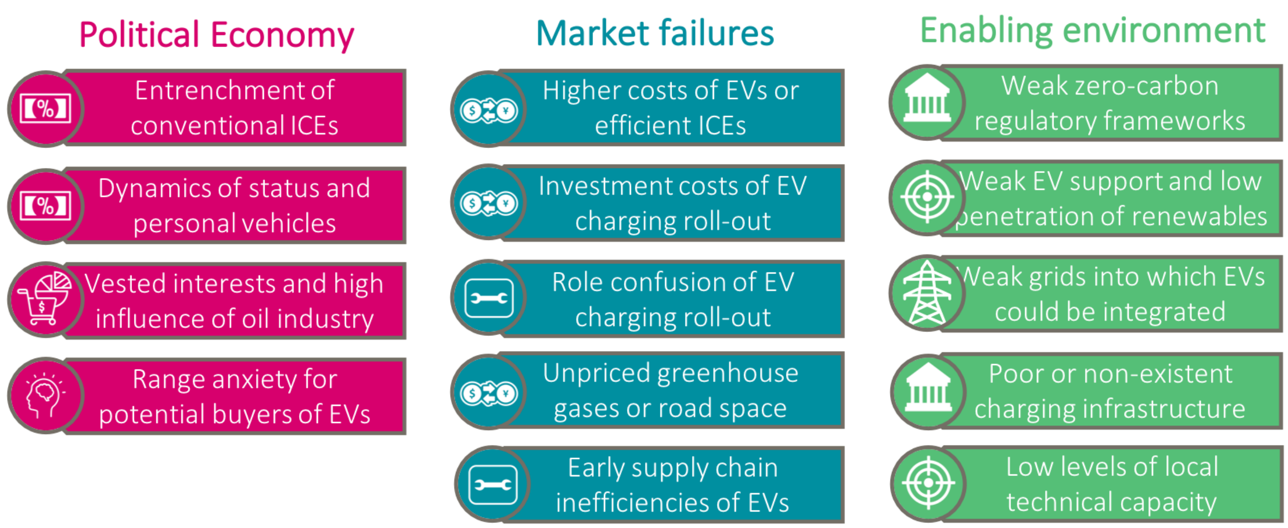
[536] International Energy Agency. (2019). Global EV Outlook 2019. https://www.iea.org/reports/global-ev-outlook-2019

[537] Assuming 50,000 lifetime km driven, approximately 20 gCO_2/km difference in emissions and similar material emissions intensity. Detailed lifecycle assessments are available from Cherry et al. (2009). Comparative environmental impacts of electric bikes in China. Available from: https://www.sciencedirect.com/science/article/pii/S1361920908001387

Barriers to adoption

The largest barriers to the adoption of cleaner private passenger vehicles in the target regions are related to political economy challenges, market failures and the enabling environment. Our typology of barriers is provided in the Methodology chapter in the Synthesis Report.

Figure 32 Barriers to an opportunity



Source: Vivid Economics, ASI and Factor

Moderate political economy barriers reduce the uptake of more efficient ICE vehicles or EVs and other zero-emissions vehicles.

Governments in the target regions can be strongly influenced by the conventional oil distribution sectors, particularly if they provide financial support to political parties in advance of elections. This is likely to be higher in North Africa and Central Asia, weakening political support for zero-carbon vehicles.

The cultural dynamics of personal status associated with owning a larger vehicle, such as an sport utility vehicle (SUV), can often act as a barrier to the uptake of more efficient vehicles and reduce the incentive to cut down personal vehicle use and switch to mass transit. There are now over 200 million SUVs around the world, up from about 35 million in 2010, accounting for 60% of the increase in the global car fleet since 2010. Around 40% of annual car sales today are SUVs, compared with less than 20% a decade ago. As a consequence, SUVs have been the second-largest contributor to the increase in global CO2 emissions since 2010 after the power sector, but ahead of heavy industry.[538]

There may also be affordability and equity issues in some regions, particularly India and North Africa, where higher-cost EVs and more efficient ICEs are only accessible to a minority of high-income households. However, affordability is to some degree an issue worldwide, and as EVs develop along a market penetration curve, costs will come down and a higher share of cleaner and more efficient vehicles will become affordable enough for most, which is another reason why shared mobility and fleets are key targets for initial electrification.

Range anxiety for potential buyers of EVs can be a significant barrier to uptake, in all target regions, although perceptions are changing rapidly along with development in battery efficiency and the

[538] International Energy Agency. (2019). Growing preference for SUVs challenges emissions reductions in passenger car market. Available at: https://www.iea.org/commentaries/growing-preference-for-suvs-challenges-emissions-reductions-in-passenger-car-market

increased sharing of positive experiences of EV owners. Nevertheless, awareness-raising campaigns are essential to make sure that technological advances translate into common knowledge.

Moderate market failure barriers to investment or adoption are likely to be:

Battery costs are reducing at a relatively fast pace but still make the price of EVs comparatively higher than conventional ICEs. Bridging this gap for consumers, until cost parity occurs, must rely on financial and regulatory incentives as well as public awareness and support of the importance of less polluting vehicles.[539]

High investment costs in implementing charging infrastructure is a significant barrier to the uptake of EVs in all of the target regions. There is also often confusion between government and private sector entities, such as auto manufacturers and utility companies, over who should take responsibility for implementing charging infrastructure and where and for how long in terms of phases of deployment. This is an evident problem in regions that are more advanced in pursuing the uptake of EVs, such as India and South America.

Complementary aftermarket supply chains for parts and services is key to increasing the attractiveness of EVs and is generally lacking in the target regions until a more coherent policy approach enables greater uptake and commercial commitment to specific national or regional markets.

In terms of managing demand and encouraging a shift away from private vehicles to public transport, a critical market failure is unpriced access to urban road space, followed by under-priced access to parking space (often taken from road space). The challenge is for funds derived from charging for these to be retained at the municipal, rather than national, level so that these can be used for the development of clean and efficient urban mobility.

Moderate enabling environment / absorptive capacity barriers to investment or adoption are likely to be:

While developing countries have the fastest growing fleets of private passenger vehicles, in terms of cars and two- or three-wheelers, many have no, or rather weak, vehicle emissions standards or mechanisms to enforce them, which undermines the incentives to invest in EVs. This is particularly lacking in Central Asia, Central America, and South America, although the latter region is taking steps to implement more robust vehicle efficiency standards.[540]

There is very little local data available on emissions and environmental impact of passenger vehicles in many countries in the target regions, particularly South and Central America and North Africa, reducing the incentive for public sector intervention.

Many countries in the target regions lack policy frameworks, national roadmaps, and incentives to promote zero-emission vehicles, to bring the relevant stakeholders together, and to unlock the barriers to their deployment.[541] This is particularly the case in North Africa and Central Asia.

A major barrier to the uptake of EVs is the lack of charging infrastructure. EVs and FCEVs, as well as electric two- and three-wheelers, become increasingly attractive as a comprehensive charging infrastructure is available, which is currently severely lacking across all regions. For example, Chile, which is a frontrunner in terms of ambition and targets for electric vehicle uptake, only has 40

[539] McKinsey and Company. (2018). Making Electric Vehicles Profitable: *https://www.mckinsey.com/industries/automotive-and-assembly/our-insights/making-electric-vehicles-profitable*

[540] Posada et al. (2018). 2018 South America Summit on Vehicle Emissions Control: Summary Report and Regional Workplan. Available at: https://theicct.org/sites/default/files/publications/ICCT_SouthAmerSummit2018_rpt.pdf

[541] UNEP. Why Does Electric Mobility Matter? Accessed 24/07/2020. Available at: https://www.unenvironment.org/explore-topics/transport/what-we-do/electric-mobility/why-does-electric-mobility-matter

charging stations in the country, half of which are in the capital, Santiago.[542] India, with a population of almost 1.4 billion, had under 1,000 public charging points at the start of 2020.[543]

Lack of reliable electricity in some less-developed countries is a major constraint to the uptake of electric vehicles, where charging is likely to be disrupted and unreliable. There are also significant rural areas that remain off-grid, particularly in India and South America, although off-grid renewable energy solutions for charging is a potentially high-impact area of new development.[544]

Limited public awareness and public debate exists in many of the target regions, particularly in India and Central Asia, on the issues of the climate- and air quality-related costs of polluting vehicles, and around the benefits of a shift to cleaner transportation. An under-informed public will not have the information it needs to judge the benefits or costs of public actions, which is crucial in enabling a shift to less polluting private vehicles.[545]

Battery swapping initiatives, more predictable to manage and thus often more effective for fleet vehicles, including three-wheeler urban freight vehicles, are hindered by a lack of standardisation on battery specifications. This has been noted as a barrier in India, where this mode could rapidly be implemented, whereas many other regions such as North Africa and Eastern Europe and Central Asia have not progressed far in this area.

[542] Ramos Miranda, Natalia A. (2018). Chasing China: Chile drives Latin America's electric vehicle revolution. https://www.smh.com.au/world/south-america/chasing-china-chile-drives-latin-america-s-electric-vehicle-revolution-20181210-p50l7a.html

[543] Kwatra, Sameer. (2020). Mobilizing Finance for Electric Vehicle Charging in India. https://www.nrdc.org/experts/sameer-kwatra/mobilizing-finance-electric-vehicle-charging-india#:~:text=March%2027%2C%202020%20Sameer%20Kwatra%20Of%20the%20one,finance%20is%20critical%20to%20achieving%20the%20required%20scale.

[544] Silverstein, Ken. (2020). Solar-Powered Electric Vehicle Charging Stations Are Just Around The Corner. https://www.forbes.com/sites/kensilverstein/2020/02/10/solar-powered-electric-vehicle-charging-stations-are-just-around-the-corner/#27c0a706320f

[545] Posada et al. (2018). 2018 South America Summit on Vehicle Emissions Control: Summary Report and Regional Workplan. Available at: https://theicct.org/sites/default/files/publications/ICCT_SouthAmerSummit2018_rpt.pdf

UK additionality

The UK's additionality is strong across the design and implementation of demand management mechanisms, financial and tax-based incentives, and installation and integration of charging infrastructure.

Via the Office for Low Emissions Vehicles (OLEV), the UK is continuing to strengthen its expertise in encouraging the uptake of EVs, integrating EVs into the power sector, and rolling out charging infrastructure; areas where non-OECD countries require significant assistance.

The BEIS COP26 team is building extensive international networks to overcome barriers to transition to EVs in different countries, which can be leveraged for influence and knowledge sharing.

The UK has strong experience in designing domestic policy and contributing to EU initiatives and policy on financial and tax-based incentives for scrapping old vehicles and encouraging the uptake of more efficient ICEs and zero-emissions vehicles.

In general, there is high potential for UK additionality given the UK's recently announced fossil-fuel vehicle phase-out. This should drive down costs and lead to innovation in solving the challenges of the rapid uptake of EVs.

The UK has strong experience in implementing demand management measures to reduce the use of personal vehicles, or increase uptake of low emissions vehicles, including congestion charging zones (London is a global study of best-practice) and low emissions zones and attractive mass transit.

International donor activity in support of passenger vehicles is focused on ICE efficiency and the uptake of EVs:

The United Nations Environmental Programme's (UNEP) *Electric Mobility Programme* supports electric mobility for developing and transitional countries.[546] The UNEP, supported by the IEA and several other partners, is also implementing the *Global Fuel Economy Initiative,*[547] which aims to help stabilise greenhouse gas emissions from the global light duty vehicle fleet through a 50% improvement of vehicle fuel efficiency worldwide by 2050.[548]

The EV30@30 Campaign, implemented by the *Clean Energy Ministerial*, to which the UK government contributes to the budget, sets a collective aspirational goal to speed up deployment and reach a 30% sales share for electric vehicles by 2030 among the participating countries.[549] The campaign supports the market for electric passenger cars, light commercial vans, buses, and trucks (including battery-electric, plug-in hybrid, and fuel cell vehicle types). It also works towards the installation of charging infrastructure to supply sufficient power to the vehicles deployed.

In the five regions with the largest mitigation potential, the UK typically has strong ODA ties with India, Colombia, Ukraine, and the British Overseas Territories in the Caribbean but limited ODA links with most of the other high-potential countries, such as in North Africa or Eastern Europe.

Very few UK Government ODA programmes focus specifically on increasing the uptake of EVs and more efficient passenger vehicles. A greater number have focused on reducing private vehicle use through promoting active transport, such as walking and cycling, as well as supporting the implementation and improvement of mass transit. Several notable examples include:

---

546 UNEP. Why Does Electric Mobility Matter? Accessed 24/07/2020. Available at: https://www.unenvironment.org/explore-topics/transport/what-we-do/electric-mobility/why-does-electric-mobility-matter
547 GFEI Website: https://www.globalfueleconomy.org
548 UNEP. Global Fuel Economy Initiative: https://www.unenvironment.org/explore-topics/transport/what-we-do/global-fuel-economy-initiative
549 Clean Energy Ministerial website: http://www.cleanenergyministerial.org/campaign-clean-energy-ministerial/ev3030-campaign#:~:text=The%20EV30%4030%20campaign%20aims%20to%20gather%20commitments%20from,private%20sector%2C%20and%20the%20involvement%20of%20civil%20society%3B

The Department for International Development (DFID)-funded *High Volume Transport (HVT) Facility* is focused on applied research to contribute to more efficient and low-carbon vehicles in national and regional mass transport corridors and within cities in low-income countries in Africa and South Asia.[550]

The Foreign and Commonwealth Office (FCO) is currently implementing a range of interventions in India via the Prosperity Fund, several of which relate to smart cities, sustainable urban development, and a low-carbon economy.

In Colombia, the FCO Prosperity Fund is focused on sustainable agriculture and some sustainable cities and infrastructure support.[551]

[550] HVT website: https://transport-links.com
[551] Foreign and Commonwealth Office. (2020). Annual Review for the Colombia Prosperity Fund Programme 2019-2020. Whitehall, London.

Intervention opportunities

Global intervention opportunities

To alleviate the barriers set out in above, there is substantial opportunity across all regions for the UK to draw on core strengths and areas of additionality in order to deliver passenger vehicles interventions in the following areas:

Supporting the uptake of zero-emissions vehicles:

Technical assistance to develop a national zero-emissions vehicle strategy.[552] There is often strong value in setting governments a roadmap with a series of coordinated targets and recommendations, especially to help bring together the relevant stakeholders to start the necessary discussions. Complementary to a roadmap would be implementing guidelines to help answer on-the-ground questions of what implementation looks like in reality. ICF can build on BEIS's world-class OLEV to help build the capacity of governments in the target regions. OLEV provides an innovative and effective institutional model to help incentivise the uptake of ultra-low emissions vehicles.

Support governments on the implementation of appropriate financial incentives, helping to make the cost of electric vehicle ownership and use cheaper than conventional vehicles by enabling appropriate price differentials in the capital and operating costs of these vehicles.

Support the development of new business models for deployment of EVs, particularly for fleet vehicles. Without the emergence of new business models that create novel relationships between private drivers, fleet managers, city managers, energy providers, the auto industry, and central government, it will be difficult to scale up the ownership of electric vehicles.[553] Examples include demand aggregation or bulk procurement for adoption of electric vehicles for a public or private fleet. Car sharing models can also significantly reduce the payback period.

Technical assistance for accelerating the roll-out of charging infrastructure. There is high potential to leverage UK experience in successfully establishing country-wide charging networks, which can help to address a critical barrier to greater EV deployment. This could include support on standardisation of infrastructure, setting up interoperable networks and concomitant business models, or catalysing investments in charging infrastructure, until the industry reaches a commercial scale.

Support innovative solutions, such as linking off-grid solar to charging infrastruture. In areas that are remote from grids and have strong renewable energy potential, there is an opportunity to leapfrog more conventional routes and provide decentralised clean energy for electric vehicles, particularly two- and three-wheelers that require less electricity per charge. This is particularly promising in India, North Africa, and Central and South America.

Technical assisstance towards EV-friendly urban planning. There is strong value for money in designing urban centres to encourage low emissions vehicles, through zoning for instance, with clear co-benefits to local communities, such as in air quality improvements and noise reduction. This should also include engaging with utilities to enable building codes to become "EV ready", particulalry to enable charging at home, or other destinations. This could be achieved through supporting National Urban Mobility Programmes (NUMPs) as recently done in Colombia and India, and currently in Uruguay through an "e-NUMP".[554]

Supporting smart grid and EV integration. Draw on the UK's growing expertise in this area, bringing together aspects of smart and flexible grids, energy storage, demand side management, and EVs. This will be feasible in countries or cities where there is a more developed digital ecosystem, which is

[552] IEA. (2019). Global EV Outlook 2019. Available at: https://www.iea.org/reports/global-ev-outlook-2019#executive-summary
[553] United Nations Industrial Development Organization. (2020). Best Practices in Electric Mobility. https://www.unido.org/sites/default/files/files/2020-08/UNIDO_Electric_Mobility_Paper.pdf
[554] Euroclima+. Uruguay: electric urban mobility. http://euroclimaplus.org/movilidadurbana/item/221-nump-uruguay

necessary as an enabling factor for distributed, smarter, and more flexible grids that draw on frontier technologies such as artificial intelligence (AI) for demand management and blockchain for peer-to-peer trading of electricity.[555]

Promote the recently accepted methodology for selling carbon credits from electric vehicle charging.[556] This could be used to offset the costs of building and maintaining the infrastructure network required.

Support governments to increase domestic innovation and production of batteries for EVs. There could also be synergies with the energy storage sector.

The potential for these interventions is likely to be greatest in India, North Africa and some Central American and South American markets.

Electric two- and three-wheeler interventions:

Support governments to implement appropriate policy and financial incentives to encourage the uptake of electric two- and three-wheelers.

Support governments in planning and implementation of safe and segregated road space for two- and three-wheelers. There is strong correlation between safe cycling infrastructure and the penetration of e-bikes. Examples of dedicated cycle highways could be drawn upon, including in Beijing.[557]

Support the development of building codes to integrate weatherproof parking and charging for electric two-wheelers.

Support the development of policy and initiatives to enable battery swapping, which is most effective for three-wheeler urban freight, where fleet vehicles can swap batteries at a depot. This is most suitable for India, North Africa and Central and South America.

Encourage and support governments to create the right conditions to develop manufacturing or assembly for two- and three-wheelers in the target regions, with spill-over linkages to local economic growth.

There is an opportunity to incentivise the uptake of electric two-wheelers to reduce car use as a replacement for restricted mass transit during the time of Covid-19. This has been deployed in Italy following the Covid-19 crisis, with successful initial results.

Overall, these interventions could be particularly valuable in India (helping to overcome challenges in the current relevant initiatives), North Africa, and Central and South America.

Demand management to reduce private ICE vehicle use:

An important area of policy support is to focus on a reduction in the use of private passenger vehicles via demand management. Possible measures include supporting governments to undertake initial consultation and planning for congestion charging and parking control and payment initiatives.

However, these are only politically possible where there are attractive mass transit or cycling alternatives – and this provides a synergy with Mass Transit opportunities under ICF. Interventions could include promoting the use of electric two- and three-wheelers to help solve the first/last mile problem and connecting to public transit corridors. Another is to support better integration between public

---

[555] Green, Jemma. (2020). The distributed grid explained. https://www.forbes.com/sites/jemmagreen/2020/08/27/the-distributed-grid-explained/#10e741716518

[556] Verra – Verified Carbon Standards. VM0038 Methodology for Electric Vehicle Charging Systems, v1.0. Accessed 24/07/2020. Available at: https://verra.org/methodology/vm0038-methodology-for-electric-vehicle-charging-systems-v1-0/

[557] Sustainable Transport in China. (2019). Beijing's First Cycle Highway. Accessed 05/08/2020. Available at: https://www.sustainabletransport.org/archives/7269

transport and land use planning, which could yield transit-oriented development and thus obviate much private car use in the first place.

Supporting behavioural change interventions to raise public awareness and popularity of zero-carbon mobility solutions, including active transport and mass transit that helps switch journeys away from private vehicles, should be considered.

Demand management programmes are likely to be relevant in all regions, and most effective in the larger Indian, North African and South American cities.

Interventions to encourage a transition to clean vehicles:

Support governments to develop regulations for vehicles efficency and fuel standards, helping to encourage the uptake of greener vehicles. Technical assistance can be provided in setting local vehicle safety and emissions standards, and structuring import tariffs to penalise the dirtiest vehicles, with a 'feebate' mechanism, which could be fiscally neutral. Policy support to draft national fuel and vehicle standards, to anticipate the phasing out of ICEs, especially for two-wheelers, or to implement a fuel economy roadmap and introduce electric mobility.

Data collection and strengthening the evidence base of vehicle emissions and impact in terms of climate, environment, and poor health. Demonstrating how the uptake of zero-emission vehicles can improve the baseline will help to support public sector funding to encourage the uptake of zero-carbon vehicles, including through investing in charging infrastructure. Implementing robust air quality monitoring in relation to the contribution of transportation is also important to demonstrate the impact of low-emission vehicles, helping to create further public, private sector, and government buy-in to the low-carbon transition.

Intervention case studies

Box 21 UNEP Electric Mobility Programme for Two- and Three-wheelers, 2017 – ongoing

Two- and three-wheelers are the fastest growing transport mode in many low- and middle-income countries. An estimated 270 million motorcycles are on the road today and by 2050 the global fleet of motorcycles is projected to account for more than 400 million vehicles, representing a 50% increase. However, many of these internal combustion engine two- and three-wheelers are old and inefficient, thus emitting substantial amounts of particulate matter (PM) and black carbon (BC), a potent short-lived pollutant. Two-stroke scooters, for example, produce more particle emissions than a passenger car.[558] In India, for instance, two-wheelers account for 60-65 per cent of the country's total petrol consumption.[559]

As such, experts agree that in most developing countries, two- and three-wheelers are the first priority in moving to electric mobility.[560] The UNEP programme is the first global effort to introduce electric two- and three-wheelers in non-OECD countries, and will start the transition from internal combustion engine to electric and non-motorised two- and three-wheelers. Currently, with funding from several other institutions, the programme is supporting electric two- and three -wheeler projects in eight countries in Africa and Asia: Ethiopia, Morocco, Kenya, Rwanda, Uganda, the Philippines, Thailand, and Vietnam.

The objectives of the programme are to enable transformative integration of electric two- and three-wheelers into existing urban transport modes via a comprehensive policy framework and a range of other technical assistance support.

In pursuit of those objectives, the activities of the programme are to:

- Understand the lessons learned in other countries throughout the sub-regions, as a first step towards a general shift to electric mobility.
- Support to governments on planning and project baseline setting, including the characterisation of fleets, and policies to inform the creation of a state-of-the-art electric grid.
- Use the UNEP's eMob Calculator to estimate costs and benefits of a large-scale deployment of electric motorcycles. This can be used for regional and national assessments of energy reduction as well as of the greenhouse gas and air pollutant emission reduction potentials of shifting to electric motorcycles. It can also be used by governments to develop a first order of magnitude cost-benefit analysis including technology costs as well as fuel and maintenance savings stemming from a large-scale introduction of electric motorcycles.[561]
- Design policy based on technical assessments, leading to bespoke policy development that is suitable for each country of a sub-region.
- Pilot the resulting policy initiatives with a process that includes stakeholder engagement and mobilisation, awareness raising, and behavioural change initiatives to encourage the uptake of electric vehicles.
- Facilitate knowledge management and policy replication – through communications, global studies, training tools development, and policy best practices etc.

[558] UNEP. Electric two and three wheelers. https://www.unenvironment.org/explore-topics/transport/what-we-do/electric-mobility/electric-two-and-three-wheelers
[559] Nangia, Pratishtha. (2019). How Indian two-wheeler market will pan out with electrification of upto 150cc? https://auto.economictimes.indiatimes.com/news/industry/how-will-indian-two-wheeler-market-pan-out-with-electrification-of-upto-150cc/69832001
[560] UNEP. Electric two and three wheelers. https://www.unenvironment.org/explore-topics/transport/what-we-do/electric-mobility/electric-two-and-three-wheelers
[561] Ibid.

Key stakeholders and clients include:

- National and local government departments.

As a consequence, the expected results of the programme are:

- At a global level, scenario calculations using the UN Environment eMob calculator show that a steep shift to 90% battery electric motorcycles sales by 2030 and 100% by 2050 could result in CO_2 emissions reductions of about 11 billion tonnes between now and 2050.
- At the same time, overall monetary savings stemming from lower fuel and maintenance costs and taking into account a higher purchase price of electric motorcycles could amount to about USD 350 billion by 2050.
- The specific interventions carried out so far have resulted in policy improvements in a number of countries, as well as much greater levels of knowledge sharing and awareness between the beneficiary governments and other stakeholders, such as donors and the private sector.

The challenges faced by the programme are:

- A general lack of awareness and understanding of the technologies, both in government and the general population, is a challenge when trying to implement e-mobility infrastructure.
- Policy coordination among ministries and key stakeholders can be a barrier, particularly in relation to charging infrastructure.
- A lack of infrastructure and standards can constrain the uptake of electric mobility. The programme aims to diagnose the specific barriers to each country and help implement the most effective solutions.
- High upfront costs of electric two- and three-wheelers remains a constraint. This is slowly being alleviated by the market but can also be aided by government tax relief and other incentives.

Learnings for BEIS include:

- Focusing on two- and three-wheelers is likely to be a high-impact entry point for ICF interventions that seek to improve the uptake of electric mobility in the target regions.
- Technical assistance that supports governments to assess and quantify the economic, environmental, and social benefits of a transition to electric two- and three-wheelers is valuable and can be followed by assistance to implement appropriate policy and other incentives to improve uptake.

Box 22 EUROCLIMA + and German Agency for International Cooperation (GIZ) Support for Electric Three-wheelers in Guatemala, 2018-Ongoing

EUROCLIMA + is the EU's flagship programme on environmental sustainability and climate change with Latin America. Its objective is to reduce the impact of climate change and its effects in Latin America by promoting mitigation and adaptation to climate change, resilience, and investment.[562] Under EUROCLIMA+, GIZ is promoting the uptake of electric three-wheelers for social transport, freight transport, and the replacement of units in the municipality of San Juan Comalapa in Guatemala.

The objectives of the project are to:

- Support the city to procure and demonstrate the use of zero-carbon transport for passengers and freight.
- Reduce greenhouse gas emissions and improve air quality in the city.

In pursuit of those objectives, the activities of the programme are:

- Devising a model to encourage the uptake of electric tricycles.
- Replacing 'tuck tucks' (tricycles that use gasoline) that have exceeded their useful life and are in poor condition with electric tricycles.
- Establishing a series of pilot charging stations for the fleet.
- Improving the mobility of persons with disabilities and elderly populations through access to electric tricycles.
- Collecting and transporting refuse using electric tricycles in the narrow streets across the city that are inaccessible to larger waste collection vehicles.
- Train electric tricycle drivers and mechanical workshop personnel at the recharging stations.

Key stakeholders and clients include:

- Municipality of San Juan Comalapa – Commission on Urbanism, Security and Infrastructure, Carrier trade unions, Council of Urban and Rural Development of the Municipality, Ministry of Education, Climate Change Directorate of the Ministry of Environment and Natural Resources.

As a consequence the expected results of the programme are:[563]

- To have supported city to acquire 50 electric three-wheelers: 10 to transport elderly people, 13 to transport freight, and 27 to replace old conventional tricycles.
- To have used the electric three-wheelers for collection and transportation of trash and solid wastes in inaccessible sectors (narrow streets).

Lessons for BEIS include:

- Small-scale pilot projects such as this can raise awareness of the benefits of electric vehicles and demonstrate a successful procurement and operation process for a city government or private sector fleet.

[562] Euroclima+. EUROCLIMA+ : A flagship programme of the European Union in Latin America. http://euroclimaplus.org/en/home-en/about-the-programme
[563] Euroclima+. Guatemala: Electric tricycles. http://www.euroclimaplus.org/en/projects-urban/item/447-guatemala-electric-tricycles

Glossary

Acronym / Term	Definition
ADB	Asian Development Bank
Baseload	The minimum amount of electric power delivered or required over a given period
BAU	Business as usual
BEIS	UK government Department for Business, Energy & Industrial Strategy
BESS	Battery energy storage systems
BMZ	Germany's Federal Ministry for Economic Cooperation and Development
BOT	Build operate transfer
BRT	Bus rapid transit
CIF	Climate Investment Funds
CIG	Cities and Infrastructure for Growth
CNG	Compressed Natural Gas
CSP	Concentrated solar power
CTF	Clean Technology Fund
DFID	UK government Department for International Development
Energy storage	A device that captures energy for later use, with categories of storage including electrochemical, electrical, mechanical, and thermal forms of storage
EU	European Union
EUR	Euro
EVs	Electric vehicles
FAME	Faster Adoption and Manufacturing of Hybrid & Electric Vehicles
FCEV	fuel cell electric vehicles
FCO	UK government Foreign and Commonwealth Office
GAADS	Group for Environmental Affairs and Sustainable Development
GBP	British pound sterling
GDP	Gross domestic product
Gt CO2	Gigatonnes of CO2
Gt CO2e	Gigatonnes of CO2 equivalent
GHG	Greenhouse gas
GIS	Geographic Information System
GIZ	Deutsche Gesellschaft fur Internationale Zusammenarbeit GmbH
GW	Gigawatt
GWh	Gigawatt hours
HVT	High Volume Transport Facility
IADB	Inter-American Development Bank
ICE	Internal combustion engines
ICED	Infrastructure and Cities for Economic Development

Acronym / Term	Definition
IEA	International Energy Agency
IFC	International Finance Corporation
IoT	Internet of Things
IPCC	Intergovernmental Panel on Climate Change
IT	Information technologies
LEV	Low emission vehicle
MAGC	Market Accelerator for Green Construction
NAMA	Nationally Appropriate Mitigation Action
NDC	Nationally Determined Contribution
NEP	National Energy Plans or Policies
NUMPs	National Urban Mobility Programmes
ODA	Official Development Assistance
OECD	Organisation of Economic Cooperation and Development
O&M	Operations and maintenance
OEM	Original Equipment Manufacturers
OLEV	Office for Low Emissions Vehicles
PEV	Passenger Electric Vehicles
PM	Particulate Matter
PPP	Public-private partnership
PSO	Public service obligation
RD&D	Research, development and demonstration
SDG	Sustainable Development Goal
System costs	Total costs to the electricity system to supply electricity at a given load and security of supply
SUV	Sport Utility Vehicle
VAT	Value-added tax
TOD	Transit-oriented development
UNEP	United Nations Environmental Programme
UNIDO	United Nations Industrial Development Organisation
USAID	United States Agency for International Development
USD	United States Dollar
VAT	Value-added tax

Forests

Summary

The forests opportunity considers all interventions that affect rates of deforestation, forest degradation, reforestation, restoration of degraded woodlands, and afforestation as well as the use of improved forest management techniques. The mitigation potential from this opportunity is very large and primarily in avoided deforestation and reforestation interventions. The high cost-effectiveness of the opportunity leads to a modest investment need relative to other opportunities considered in this series of reports. However, global investment in forest mitigation must still increase substantially under a 2-degree compliant scenario. Development impacts are large, driven by the preservation of biodiversity and ecosystem services that come with avoided deforestation and the potential to generate these benefits through re/afforestation. Barriers to adoption are significant, largely due to difficulties in monitoring interventions and weak property rights in many regions experiencing deforestation, and have proven difficult to overcome for a variety of past development aid interventions. Some of the many existing programmes in this opportunity space have overcome these barriers to have substantial impact, reinforcing the importance of careful, long-term intervention design should BEIS choose to pursue investment in this area.

The interventions considered here to increase forest mitigation activity in focus regions include:

Transform the political narrative, ensure complementarity rather than competitiveness between forests and other land uses and infrastructure, support the enhancement of forests policy and ambition, and strengthen the enforcement of the law at national, state, and local levels.

Support large-scale re/afforestation in regions with sizeable amounts of secondary forest and degraded land as well as sustainable forest management via the deployment of bilateral public finances to incentivise private investment, and establish comprehensive payment for ecosystem services (PES) models and initiatives including all forest goods and services.

Enact improvements to reduced deforestation and forest degradation ‘plus’ (REDD+) in all regions, in partnership with other donors, including progression towards jurisdictional and national initiatives, coordination with other forestry initiatives, measurement, reporting, and verification (MRV), REDD+ readiness, and adaptation to dry forest countries.

Secure and clarify land tenure and land rights between government, business, smallholders, and forest and indigenous communities, offer long-term training and capacity development within national, state, and local governments, and strengthen decentralised and participatory forest management.

Where high political economy issues are apparent, channel support to state and local government, international and domestic business, civil society, and indigenous and forest communities.

Support countries, states, and municipalities to form sustainable partnerships with international business interests to strengthen deforestation-free commodity supply chains and improve domestic forest carbon policies and standards to establish offset markets and increase private investment.

Table 36 Forests assessment summary

Criteria	Assessment	Notes
Climate impact	High	• According to IMAGE modelling results, forests may support up to 4 gigatonnes CO2 equivalent per year (Gt CO2e/year) of land use emissions mitigation in low- and middle-income countries by 2050. • Recent literature suggests the mitigation potential of forests could be even higher.
Development impact	High	• Impact on Sustainable Development Goals (SDGs) is high, including SDGs 1, 2, 3, 6, 8, 12, 13 and 15, focused on the non-monetised goods and services that forests provide including no poverty, zero hunger, health and air quality, the quality and supply of water, jobs and employment, responsible consumption and production, and land-based biodiversity. • If interventions are implemented insensitively there are potential negative SDG impacts as well, including loss of livelihoods, food shortages and higher food prices, particularly for women and indigenous groups, water availability, and biodiversity via monocrop plantations.
Investment gap	Low	• Global investment in the opportunity will need to scale up to, on average, USD 58 billion per year between now and 2050, an order of magnitude above today's levels. • While the cumulative investment gap of USD 1.7 trillion by 2050 appears large, this is a comparatively smaller investment gap than many other opportunities, such as variable renewables at USD 9 trillion.
Cost-effectiveness	High	• Forests are one of the most cost-effective mitigation opportunities. • The cost of reforestation and afforestation is significantly smaller than the present-day cost of bio-energy with carbon capture and storage (BECCS), the only other negative emissions technology with a currently clear potential pathway to at-scale deployment.
Barriers to adoption	High	• In all regions, high political economy barriers, moderate to high market failures, and high enabling environment barriers exist • Barriers include political commitment, entrenched interests, fiscal support, funding shortfalls, carbon accounting, lack of carbon price and recognition of forest goods and services, REDD+ MRV and transaction costs, REDD+ suitability to dry forests, weak and competitive policy, unclear and insecure land tenure, judicial systems and law enforcement, technical capacity, horizontal and vertical coordination, fragility of benefits to indigenous and forest communities, and REDD+ influence on governance. • Moreover, competition for land use from agriculture, infrastructure growth, mining, and food consumption is a major barriers.
UK additionality	Moderate	• Domestic value is moderate to high resulting from good technical expertise in re/afforestation, sustainable forest management (SFM), support to forest governance, markets and private sector engagement, REDD+, and opportunities arising from the UK's hosting of the 26th UN Climate Change Conference (COP26). • The UK has good ties in Indonesia and Southern and West Africa and moderate ties in Brazil and South America with recent support focused on REDD+.

Source: Vivid Economics, ASI & Factor

Key lessons for supporting mitigation through investment in forests include:

Combining REDD+, re/afforestation and SFM, forests represent one of the single largest mitigation opportunities explored in this series of reports. While the literature presents a wide range of values for the exact scale, location, and type of land that needs to be protected or reconverted into forested area, scenarios universally agree that much more land area, hundreds of millions of hectares, needs to be forested than is the case today. Sources generally also agree that, in principle, forests represent some of the cheapest mitigation opportunities available, and that natural forested habitats offer a variety of development co-benefits, including biodiversity, disaster resilience and water and climatic systems, the scale of which can hardly be overstated.

Forest investments and development programmes are not new and seem to have had mixed success over their long history due primarily to the scale of barriers faced. Despite the numerous goods and services that forests bring, the barriers to improvement are substantial, relating to issues of political will, technical capacity, availability of funding, law enforcement, land tenure and the economic incentive to keep or restore forests – as well as wider concerns about political and the influence of agriculture, transport and energy systems on forests.

In response interventions must be well designed and substantially funded, have political buy-in, and incorporate a long-term plan. Mitigation efforts in the forests sector take time to mature and yield benefits, and one common feature of past interventions with sub-optimal outcomes has been donor planning horizons that are too short for the long-lived nature of forest interventions. Experts interviewed over the course of this work have suggested that donors must be prepared to make long-term commitments of 20 years or more, respecting the long timeframe for forest interventions to generate impact.

The UK has decades of bilateral ODA experience in forested countries and continued presence in all priority regions via historic support to forest governance, law enforcement, markets, and indigenous and forest communities. Interventions to address barriers should consist of a combination of technical assistance and exchange of expertise and of sizeable results-based payments for forests mitigation. Programmes should also be aware of technical and financial absorptive capacity issues in forest countries, especially in Southern and West Africa. The funding channels for interventions will vary – a combination of bilateral and multilateral channels will be necessary based on UK additionality and the strengths of existing multilateral mechanisms. Donor and programme coordination need to improve.

The time profile of the intervention need favours avoided deforestation efforts in the short term, transitioning to large-scale re/afforestation efforts in the medium term of 2030 and beyond. In order for re/afforestation interventions to be ready at the scale required, intervention design should be considered and tested early where possible.

Introduction to the opportunity

Role of the opportunity in decarbonisation of developing countries

Low- and middle-income countries must radically change their relationship to forests in order to be consistent with 1.5- and 2-degree pathways. Deforestation currently contributes emissions of approximately 3 Gt CO_2/year in low- and middle-income countries. In East Africa, West Africa, Southern Africa, and Brazil, deforestation is equivalent to over 100% of each region's economy-wide emissions.[564] [565] While current commitments in low- and middle-income countries promise to reduce forest sector emissions, zero-deforestation policy and implementation must be strengthened in order to reach mitigation targets. Model results presented here suggest that in a 2-degree scenario a minimum of an additional 0.6 Gt CO_2/year of mitigation from avoided deforestation is required on top of the commitments already made – but not yet implemented – by low- and middle-income countries. In parallel, substantial re/afforestation efforts sufficient to reduce emissions by between 0.1 and 3.6 Gt CO_2/year on average between 2020 and 2050, depending on the scenario, are required.[566] Re/afforestation efforts will require testing and piloting early but will likely be first deployed at scale later in the period. Mitigation through avoided deforestation will likely be the focus of most early funding due to the urgency of need and greater donor experience in the area.

Avoiding deforestation provides greater mitigation at low costs compared to re/afforestation, but the total mitigation potential of re/afforestation is greater. Reducing tropical deforestation provides about 55.1 Gt CO_2 of abatement between 2020 and 2050 at a cost of less than USD 20/t CO_2 .[567] For this same cost, re/afforestation gives only 5.7 Gt CO_2 of mitigation over this same period.[568] However, IMAGE modelling results, as well as Griscom et al. (2017), suggest that the maximum mitigation potential of re/afforestation is much higher than avoided deforestation. In tropical and subtropical regions, Griscom et al. (2017) find that reforestation has a mitigation potential of 8.0 Gt CO_2/year, more than double that of avoided deforestation, at 3.6 Gt CO_2/year.[569] However, the authors also find that the uncertainty in these estimates are much higher for reforestation, having a 95% confidence interval of 2.7 – 17.9 Gt CO_2/year, than for avoided deforestation, with a 95% confidence interval of 3.0 – 4.2 Gt CO_2/year.[570] This high uncertainty comes from concerns over the permanence of new forests, related to climate tipping points, as well as land competition with agriculture and energy crops. Additionally, in a subsequent paper, Griscom et al. (2020) highlight that only slightly over 1 Gt CO_2/year of this reforestation potential is available at under USD 100/t CO_2 in tropical regions.[571]

The exact mitigation contribution of forests, however, will be significantly influenced by the development of the bioeconomy and potential improvements in agricultural productivity. Significant growth of the bioenergy sector would increase competition for forested land or land with the potential to be re/afforested. This would increase land value, making forest interventions more expensive. By contrast, increases in agricultural productivity have the potential to have the opposite effect. Greater productivity means less land is required

[564] Note that deforestation can account for over 100% of a region's emissions because forests that are not cut down act as carbon sinks, making net emissions substantially lower than total positive emissions.
[565] Calculated using net forest conversion data from FAOSTAT (2020) and economy-wide emissions data from the World Bank (2020). Using emissions from net forest conversion may underestimate emissions from deforestation if forests are expanding in areas where deforestation is not taking place.
[566] Differing assumptions on food demand and agricultural productivity lead to large differences in land used for agriculture across scenarios, which leads to large differences in the area available for re/afforestation. There are also notable differences across scenarios in the amount of land used for cultivating biofuel crops; however, this range is notably smaller than the range in agricultural land demand across scenarios.
[567] While this report considers forests in all low- and middle-income countries, not just tropical forests, the vast majority (>80%) of forested land in official development assistance (ODA)-eligible countries lies in tropical regions. Additionally, the regions considered in this report include nearly all of the world's tropical forests (except northern Australia which account for less than 7% of the world's tropical forest) and so results from the literature on tropical forests can be considered a minimum bound for the regions considered here. Subtropical regions are also discussed occasionally in this report. These regions partially overlap with forest in the United States, Japan, and Australia, but the vast majority still lie in ODA-eligible countries.
[568] Busch et al. (2019). Potential for low-cost carbon dioxide removal through tropical reforestation. https://www.nature.com/articles/s41558-019-0485-x.
[569] Griscom et al. (2017). Natural climate solutions – supporting information appendix. https://www.pnas.org/content/pnas/suppl/2017/10/11/1710465114.DCSupplemental/pnas.1710465114.sapp.pdf
[570] The Intergovernmental Panel on Climate Change (IPCC) (2019) Special Report on Climate Change and Land finds a similar difference in uncertainty between reforestation and avoided deforestation mitigation potential estimates.
[571] Griscom et al. (2020). National mitigation potential from natural climate solutions in the tropics. https://royalsocietypublishing.org/doi/10.1098/rstb.2019.0126.

per tonne of crops, reducing land competition. However, productivity enhancements can also lead to additional deforestation if legislation and enforcement to constrain further agricultural expansion are not put in place. The impact of growing the circular economy to reduce demand for timber products, increasing agricultural productivity, and reducing demand for forest-risk commodities are covered in more detail in the Sustainable consumption and Agricultural productivity reports.

Scope considered in this assessment

The Forests opportunity includes all interventions that affect rates of deforestation, forest degradation, reforestation, restoration of degraded woodlands, and afforestation as well as the use of improved forest management techniques. Aquatic ecosystems, such as mangroves, are not assessed in this opportunity. The definitions of forests and forest intervention types used throughout the report are aligned with Griscom et al. (2020) and are summarised below:

Forest: an ecosystem with greater than 30% tree cover.

Avoided deforestation: forest loss which occurs in the baseline scenario but does not take place in the low-carbon scenarios.

Re/afforestation: the shift of non-forest cover to forest cover at the 30% tree cover threshold (includes afforestation with native trees).[572]

Natural forest management: includes reduced impact logging for climate, extended harvest cycles, increased post-harvest sequestration rates, and set-asides from logging activity. Does not include avoidable illegal logging emissions.

The assessment focuses on a subset of ODA-eligible regions: Indonesia, West Africa, South America (excl. Brazil), Southern Africa (excl. South Africa), and Brazil. These regions were chosen based on IMAGE modelling results. Regions with the largest mitigation potential in the forest sector, in terms of both absolute mitigation potential and mitigation potential relative to today's emissions, were selected. The only exception to this methodology was in the case of China, where IMAGE results suggested that re/afforestation would be extremely large. Due to both uncertainty in this result and a desire to include Indonesia in the list after consultation with the steering group China was replaced by Indonesia. This list was created in consultation with BEIS ICF stakeholders.

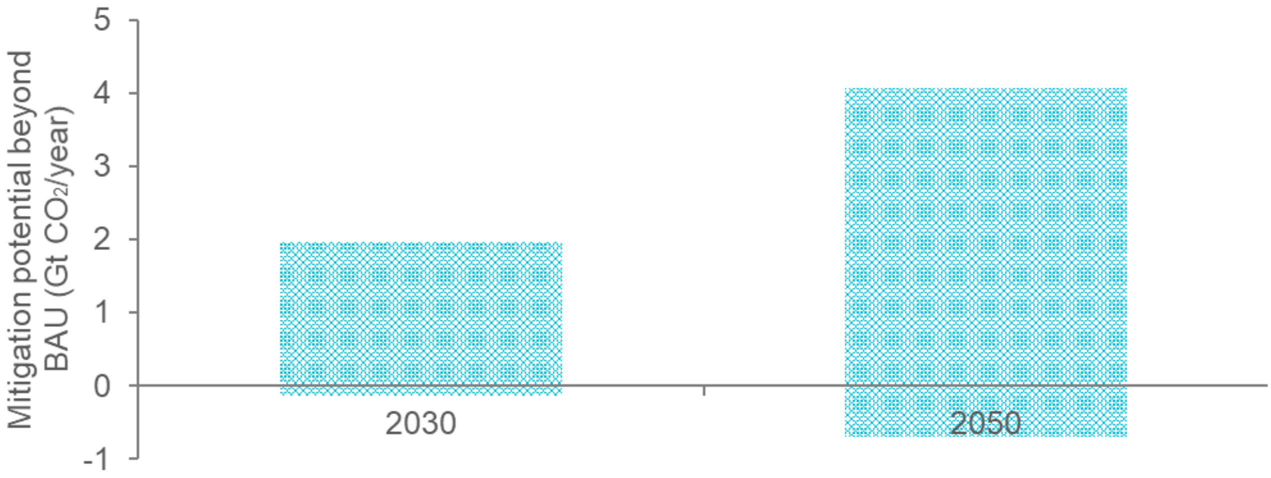
[572] Note that Griscom et al. (2020) also combine reforestation with afforestation using native trees. Here, this intervention is labelled as "re/afforestation" to be transparent about the conflation of these two terms.

Climate impact

Mitigation potential and urgency

Across all ODA-eligible regions, forest interventions support -0.7 – 4.0 Gt CO_2/year of land use emissions abatement in 2050 and -0.1-2.0 Gt CO_2/year of abatement in 2030 from current emissions of about 5.7 Gt CO_2/year.[573 574] Mitigation via avoided deforestation is urgent and forests are the cheapest and most readily scalable source of negative emissions. Hence, this opportunity is available at scale in the short term, and so mitigation potential in the more ambitious land scenarios is relatively high by 2030. Other literature identifies a similar or higher mitigation potential. For example, Griscom et al. (2017) suggest the maximum mitigation potential of reforestation alone in tropical regions is about 5.6 Gt CO_2/year, although subsequent analysis from the same group of authors suggest cost-effective mitigation from tropical forests totals slightly over 4.0 Gt CO_2/year, at the upper range of IMAGE estimates presented here (Griscom et al. (2020)).

Figure 33 Land use: range of mitigation potential compared to BAU in 2030 and 2050, which is primarily driven by changes in forests.



Source: Vivid Economics, ASI and Factor based on PBL's IMAGE model results (1.5-degree scenario excluded).
Note: The bars indicate the range of land use emissions mitigation estimates from IMAGE across five scenarios. The national policies scenario is used as the business-as-usual (BAU) scenario, and so mitigation estimates are calculated relative to the national policies scenario.

The forests mitigation potential calculated by IMAGE is likely underestimated, as the baseline scenario used is relatively optimistic and does not account for tipping points. The baseline applied in the IMAGE modelling assumes that all countries' commitments to reduce deforestation will be implemented, leading the estimated mitigation potential of avoided deforestation, additional to the baseline, to be relatively low. However, some countries are not currently on track to meet targets for reductions in deforestation. For example, in Indonesia and Brazil current rates of deforestation are 450,000 hectare (ha)/year and 970,000 ha/year, respectively, whereas the baseline scenario assumes these numbers will fall to an average of 81,000

[573] Calculated from 2017 Food and Agriculture Organisation of the United Nations (FAO) land use emissions data. Note that negative mitigation potential (positive emissions) can result because current emissions from deforestation are substantial. Interventions that limit net deforestation can be useful while still resulting in net carbon emissions.

[574] Unlike in the other energy and land use opportunity reports, the IMAGE results included in the forests report do not include the 1.5-degree pathway. This is because in order to get IMAGE to solve for a 1.5-degree pathway, land use assumptions that were more optimistic than in the 2-degree pathways had to be implemented. Therefore, land use results from the IMAGE 1.5-degree scenario are not comparable with land use results from the rest of the scenarios. While other opportunity reports primarily discuss the results of the 1.5-degree pathway, in the forests report, the 2-degree lifestyle changes pathway is given most attention as it is the most ambitious pathway from a forest conservation perspective.

ha/year and 21,000/year between now and 2030, respectively, in line with their Nationally Determined Contributions (NDCs) and stated commitments. Additionally, IMAGE does not account for tipping points in forest ecosystems. Tipping points, as they pertain to forests, are critical thresholds beyond which irreversible change occurs in a forest ecosystem, such as the proposed Amazon forest dieback, where reduced evapotranspiration due to deforestation leads to decreased precipitation in the region, which in turn leads to additional tree mortality.[575]

There is large and urgent mitigation potential from avoided deforestation in West Africa, Indonesia, Brazil, and South America. IMAGE provides estimates of net forest cover change but does not produce estimates of how much of this forest cover change is due to avoided deforestation versus re/afforestation. However, forest cover loss in the baseline scenario gives an indication of the minimum potential mitigation from avoided deforestation by region, and the forest cover gain in the mitigation scenarios provides the minimum potential of mitigation through re/afforestation in each region. These measures are minimum estimates only because in every region there may be, and likely is, both deforestation and afforestation occurring simultaneously. These variables are presented in Figure 34 for each of the focus regions. The results suggest that the opportunity in avoided deforestation in West Africa is much larger than in the other four focus regions. However, the small mitigation potential in Indonesia, Brazil, and South America is likely due in large part to the optimistic baselines in these regions, as discussed above. This is corroborated by a comparison with other literature. For example, using regional conversion factors from Kindermann et al. (2008) to convert these results to Mt CO_2e mitigated per year, IMAGE results suggest that Brazil and South America have the potential to collectively mitigate 80 Mt CO_2e/year through avoided deforestation on average between 2020 and 2050. By contrast, Roe et al. (2017) propose that 1,010 Mt CO_2e/year should be mitigated by 2050 in Latin America.[576] Similarly, Griscom et al. (2020) find that there is over 800 Mt CO_2e/year of cost-effective mitigation from avoided deforestation in Brazil alone and over 1,250 Mt CO_2e/year in Latin America. Combining all the above evidence together, and given current high rates of deforestation in the focus regions, it is clear that the mitigation potential from avoided deforestation is substantial and urgent.

The mitigation potential of re/afforestation is potentially large but highly uncertain, particularly in Brazil and South America. Figure 34 suggests that in all but West Africa, the mitigation potential of re/afforestation in some or all scenarios is higher than that of avoided deforestation. However, it also illustrates the uncertainty of these estimates. While in Southern Africa and Indonesia there is significant re/afforestation in all scenarios, in South America, Brazil, and West Africa there is a large amount of re/afforestation in the 2-degrees lifestyle changes scenario but zero re/afforestation in other scenarios. The results from Griscom et al. (2017) also suggest that reforestation potential is highest in South America and Brazil;[577] although they are much higher than the results presented here. IMAGE results indicate that Brazil and South America combined have a maximum mitigation potential of about 1.2 Gt CO_2e/year, whereas results from Griscom et al. (2017) suggest the regions' reforestation mitigation potential is as high as 2.5 Gt CO_2e/year. However, Griscom et al. (2020), looking only at cost-effective reforestation, suggest there are about 500 Mt CO_2e/year worth of mitigation in Latin America.

Natural forest management provides smaller mitigation potential than avoided deforestation and reforestation and is heavily concentrated in Indonesia. IMAGE does not provide estimates of the mitigation potential of natural forest management. Estimates from Griscom et al. (2020) suggest that Indonesia has the largest cost-effective mitigation potential from natural forest management out of all tropical countries, at approximately 200 Mt CO_2/year. West Africa and South America have natural forest management mitigation potentials of 81 and 30 Mt CO_2/year, respectively.

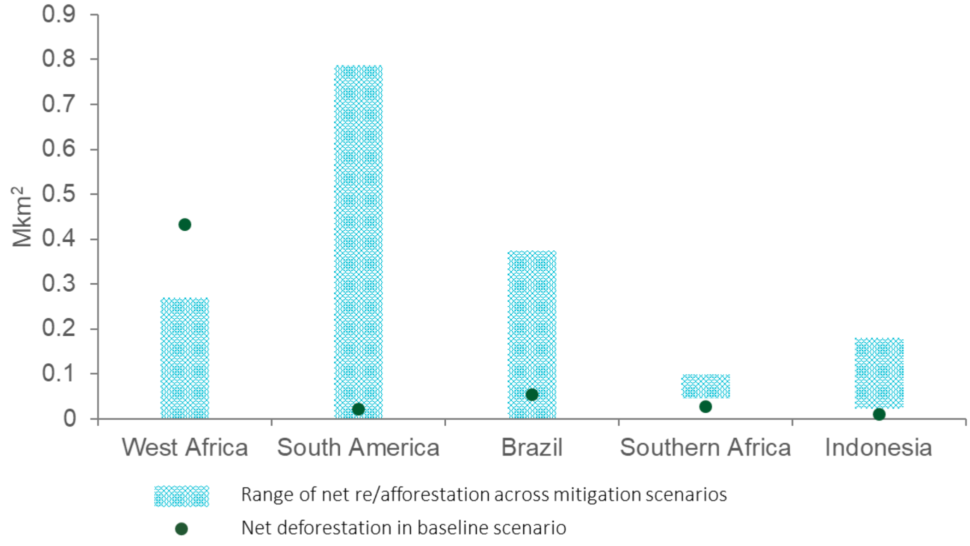
---

[575] Reyer et al. (2015). Forest resilience and tipping points at different spatio-temporal scales: approaches and challenges. https://besjournals.onlinelibrary.wiley.com/doi/pdf/10.1111/1365-2745.12337#:~:text=A%20tipping%20point%20describes%20a,Friend%201999%3B%20Cox%20et%20al.

[576] Roe et al. (2017). How improved land use can contribute to the 1.5C goal of the Paris Agreement. https://www.climatefocus.com/sites/default/files/CIFF%20Report.pdf.

[577] Griscom et al. (2017) estimates reforestation potential only (not afforestation) but uses a fairly broad definition of reforestation. The authors include expanding forests on grazing land as reforestation, as long as it takes place in a forested ecoregion. They do not differentiate grazing lands, and whether they can be reforested, based on how long ago they were cleared.

Figure 34 Change in re/afforestation and deforestation of forest cover in 2050 compared to BAU.



Source: Vivid Economics, ASI and Factor based on PBL's IMAGE model

Notes: Forest cover loss in the baseline scenario gives an indication of the minimum potential mitigation from avoided deforestation by region, and the forest cover gain in the mitigation scenarios provides a minimum potential of mitigation through re/afforestation in each region. These measures are minimum estimates only because in every region there may be, and likely is, both deforestation and afforestation occurring simultaneously.

Box 23 Modelling uncertainty

There is large uncertainty over the pathway of forest cover change and associated land use change emissions, largely due to uncertainty over what land competition will look like in the future.

- The amount of BECCS deployed in the power system has a strong impact on forest cover change. In scenarios where BECCS provides cheaper negative emissions than forestry, bioenergy crops are planted instead of forests in some regions, leading to substantially less forest cover. However, levels of BECCS deployment predicted by IMAGE ought to be treated with caution. In the most ambitious BECCS scenario, it relies on an ambitious assumption of bioenergy supply of approximately 200 exajoules (EJ)year, far higher than the 14-84 EJ/year predicted by the Committee on Climate Change (CCC).[578]

- Forest cover is also heavily impacted by competition from food production. Forest cover in the 2-degrees lifestyle changes scenario, which sees a significant curtailment of meat consumption per capita, is substantially higher than in the rest of the 2-degree scenarios.

Assumptions on BAU also heavily impact the abatement potential of forests.

- The BAU scenario used here assumes countries implement current climate legislation. In some regions, particularly Southeast Asia, this is likely optimistic as countries are currently not on track to meet deforestation goals set by domestic policy.

[578] UK Committee on Climate Change. (2018). Biomass in a low-carbon economy. https://www.theccc.org.uk/publication/biomass-in-a-low-carbon-economy/.

Transformational change

Transformational change involves actions that themselves catalyse further change, leading to broader, faster, or more ambitious climate action. Interventions may deliver transformational change in a number of ways:

They may target *sensitive interventions points* to encourage further changes in socioeconomic/ technological/ political systems to advance climate change mitigation by improving the enabling environment.

They may create *spillovers* that increase efficiency of the overall system, either nationally or globally, and so increase the speed or depth of mitigation action.

They may support *innovation* in new or improved ideas/methods/products that reduce costs or increase mitigation impact within opportunity areas.

Forests are both an outcome and a potential driver of transformational change. Increased forest cover is a likely outcome of interventions that spark virtuous circles in the agriculture and food system, or in improved governance. Forest interventions that successfully increase the range and health of forest cover can help prevent substantial negative spirals related to biodiversity and ecosystem loss, as both are susceptible to tipping points at which they are unable to sustain themselves.

Table 37 Assessment of transformational change

Transformational change criterion	Interventions to support change	Regional potential
Sensitive intervention points		
Improvement of local capacities and capabilities	Raising national capabilities to undertake integrated, long-term, forest sector planning can reconcile trade-offs between different land uses and promote national objectives aligned with forest preservation and restoration. Overcoming constraints in carbon accounting, e.g. in quality, scope, and accuracy, and reducing the costs of MRV in all forest types will ensure current forest preservation models are scalable and can attract private investment.	All regions
Local ownership and strong political will	Given the dearth of political will in many forested countries, the alignment of plans and policies for reducing deforestation and degradation, re/afforestation and SFM with plans for agriculture, transport, mining, and energy, and the reduction or elimination of perverse fiscal and regulatory incentives would transform forest sector ambitions and effectiveness.	All regions
Leverage / creation of incentives for others to act	Establishing broad consensus between national and sub-national government, large and small businesses, and forest communities can alter norms around forests and raise ambition	All regions
Spillovers		
Broad scale and reach of impacts	Donor willingness to fund comprehensive reduced deforestation, re/afforestation, and SFM initiatives at scales far higher than exist presently will transform ambition and effectiveness	All regions

Transformational change criterion	Interventions to support change	Regional potential
Sustainability (continuation beyond initial support)	Designing and implementing PES models that can adequately compensate for a range of forest goods and services – including those commercial products such as timber, pulp, and paper, as well as undervalued services such as carbon sequestration, water, air quality, and medicines – at scale would enable sustainable and comprehensive action Related to this, understanding the true opportunity cost of avoided deforestation, degradation, and re/afforestation in terms of alternative land uses will enable sustainable initiatives	All regions
Innovation		
Catalyst for innovation	Accessing credible and transparent oversight of forest product supply chains and enacting standards and certification of products within supply chains will incentivise businesses, as well as national and sub-national government, to reduce deforestation and SFM	All regions
Evidence of effectiveness is shared publicly	Raising awareness of the relationship between consumer products and forests via standards, certification and labelling can change consumer demand and offer commercial incentives for reducing deforestation and SFM	All regions

Source: Vivid Economics, ASI and Factor

Development impact

Sustainable Development Goal impacts

Forests have substantial net positive impacts on achieving SDGs across the focus countries:

Impact on SDGs is likely to be high, focused on the non-monetised goods and services that forests provide. These include no poverty (SDG 1), zero hunger (SDG 2), supporting health and air quality (SDG 3), the quality and supply of water (SDG 6), jobs and employment (SDG 8), responsible consumption and production (SDG 12), climate action (SDG 13), and the substantial benefits to land-based biodiversity (SDG 15).

However, if interventions are implemented insensitively and without regard to a just rural transition there are potential negative SDG impacts as well. Reduced access to forests and the conversion of agricultural land to forests could lead to loss of livelihoods, food shortages, and higher food prices (SDGs 1 and 2). Limitations on local population access to forests can also lead to the loss of livelihoods (SDG 8), particularly for women and indigenous groups. Re/afforestation can have detrimental effects on water availability (SDG 6) and biodiversity (SDG 15) via monocrop plantations, the use of non-native trees, and the conversion of biomes into forests.

Table 38 SDG impacts

SDG	Impact	Most relevant region	Rationale
Positive Impacts			
SDG 1 – No poverty	Moderate	All regions, especially Indonesia, Southern Africa, West Africa	Positive potential of forestry exists in providing local livelihoods, employment, and agricultural productivity from the provision of forest goods and services.
SDG 2 – Zero hunger	Moderate	All regions, especially Indonesia, Southern Africa, West Africa	Forests support agriculture by providing fodder for livestock, nutrients for crops, rainfall, prevention of soil erosion, insect and bird pollination, and regulation of local climatic conditions. Agroforestry offers direct benefits to food security.
SDG 3 – Good health and well-being	High	All regions	Forests offer products for both Western and traditional medicines, prevent infectious diseases such as malaria, reduce air pollution as a cause of death, including that caused by use of wood and charcoal for fuel, and improve well-being, including mental well-being.
SDG 6 – Clean water and sanitation	High	All regions	Forests have the capability to improve quality of water, control water cycles and rainfall, reduce cost of water treatment, prevent floods, and diminish the risk of drought.
SDG 7 – Affordable and clean energy	High	All regions especially Southern Africa and West Africa	Wood is an essential fuel, contributing 6% of global energy supply and 33% in developing countries. Two billion people globally depend on wood for heating and cooking.[579] Forests store water used in hydropower generation.
SDG 8 – Decent work and economic growth	Moderate	All regions	Forests create well-paying jobs, e.g. on plantations, and are sources of livelihoods at all stages of forest value chains. At least 54 million people globally are employed in the sector, 28% of income of communities in or near forests comes from forestry

[579] FAO. (2018.) Forests Pathways to Sustainable Development. http://www.fao.org/policy-support/tools-and-publications/resources-details/en/c/1144279/

SDG	Impact	Most relevant region	Rationale
			sectors, and 1.5 billion people depend on forests for some aspects of their livelihood.[580]
SDG 12 – Responsible consumption and production	Moderate	All regions	Better treatment of forests and recognition of the value of forest products and services can improve the sustainability of natural resources and food.
SDG 13- Climate action	High	All regions	Forest services to water quality, soil quality, climate stability, flood prevention, and drought management, as well as livelihood provision, make societies' economies more resilient.
SDG 15 – Life on land	High	All regions	75% of the world's land-based biodiversity lives in forests. Degradation of forests results in loss of biodiversity and adverse effects on the micro- as well as macro-climate. Restoration of forest habitats can have positive impacts.
Negative Impacts			
SDG 1 – No Poverty	Low	All regions, especially Indonesia, Southern Africa, West Africa	Forest mitigation could limit agricultural land, reduce food supplies, and raise food prices, especially with growing global populations, and result in loss of livelihoods, especially amongst women and those that depend on forests for livelihoods. This raises the need for a just rural transition.
SDG 2 – Zero hunger	Moderate	All regions, especially Indonesia, Southern Africa, West Africa	Forest mitigation could limit agricultural land, reduce food supplies, and raise food prices, especially with growing global populations, and result in loss of livelihoods, especially amongst women and those that depend on forests for livelihoods. This raises the need for a just rural transition.
SDG 6 – Clean water and sanitation	Low	All regions	Re/afforestation using trees with high water needs and absorption capacity can have detrimental effects on water supply.
SDG 8 – Decent work and economic growth	Moderate	All regions	Forest mitigation could result in loss of livelihoods, especially amongst women and those that depend on forests for livelihoods. This raises the need for a just rural transition.
SDG 15 – Life on land	Low	All regions	Re/afforestation can, in cases of monoculture plantations, have detrimental effects on biodiversity.

Source: Vivid Economics, ASI and Factor

Demand in target regions

The five regions show generally low to moderate commitment to forests evidenced by NDCs and national level policies. Globally 55 countries mention REDD+ in their NDCs and 50 countries have initiated national REDD+ programmes. All countries have forest strategies, policies, and laws, often developed in partnership with multilateral and bilateral donors. Despite the strength of forest policy across target countries, the extent of political commitment and the translation of policy into practice are significant dampeners on demand, and the long track record of forestry development assistance with mixed records of success further

[580] FAO. (2014.) State of the World's Forests: Enhancing the Socioeconomic Benefits from Forests. http://www.fao.org/3/a-i3710e.pdf

subdue demand for assistance. In some countries, Brazil above all, political will significantly diminishes policy commitments.

Table 39 Demand in target regions

Region	Demand	Rationale
Brazil	Low – Moderate	Robust policies and commitments are in place but, despite ambition at the sub-national level, there is declining political will under the present government.
Indonesia	Moderate – High	Ambitious policies and targets and some progress in meeting them.
Southern Africa	Moderate	Early states of implementation of national plans and policies.
South America	Moderate	Ambitious policies and targets in place and progress towards meeting them.
West Africa	Low – Moderate	Policies and plans in place and progress in meeting them.

Source: Vivid Economics, ASI and Factor

Brazil demonstrates robust NDC and policy commitments but political will is low. 89% of Brazil's NDC emission reductions are expected to derive from reduced deforestation and degradation via an 80% and 40% reduction in deforestation in the Amazon and Cerrado respectively.[581] As per its NDC, Brazil aims to restore and reforest 12 million hectares of forests by 2030.[582] The National Policy on Climate Change and the Forest Code of 2012 set the policy framework, whilst a National REDD+ Strategy, ENREDD+, was instituted in 2015.[583] Brazil has committed to zero illegal deforestation in Amazonia by 2030. However, deforestation in Brazil's Amazon in the first three months of 2020 rose 51% from a year earlier and deforestation on indigenous land increased by 74% from 2018 to 2019.[584] Recent political decisions are indicative of declining interest in climate action. Under the government of President Jair Bolsonaro the political cimate has tilted in favour of deforestation for agriculture, agribusiness, and mining. The influence of the Ministry of Environment and other forestry bodies such as the National Space Research Institute has diminished, regulatory and budgetary measures have loosened Brazil's environmental laws, and funding to Brazil's National Policy on Climate Change has fallen by 40%.[585] [586] Civil society and indigenous groups also have less purchase and influence under the present government. However, running counter to national trends are decisions and actions at the state level. States such as Acre, Amazonas, Mato Grosso, and Para have committed to maintain plans for reducing deforestation and degradation, implementing re/afforestation and SFM, forged international agreements under the Governors Climate and Forests Taskforce and international business, and established jurisdictional REDD+ programmes in partnership with multilateral donors.[587] [588]

Indonesia has ambitious policies and targets and is making progress in meeting them. There is coverage of, and reliance on, reduced deforestation in the NDC, in which Indonesia has committed to reforest 12 million hectares of degraded land. In 2011 the country introduced a forest moratorium policy, made permanent in 2019, that banned clearing primary forests and peatlands. A second moratorium bans palm oil licences for

[581] Gallo, Patrícia, Brites, Alice and Micheletti, Tatiane, (2020). REDD+ achievements and challenges in Brazil: Perceptions over time 2015-19. CIFOR. https://www.cifor.org/publications/pdf_files/infobrief/7628-infobrief.pdf
[582] UNFCCC. (2015). Federal Republic of Brazil Intended Nationally Determined Contribution. https://www4.unfccc.int/sites/ndcstaging/PublishedDocuments/Brazil%20First/BRAZIL%20iNDC%20english%20FINAL.pdf
[583] May, Peter, et al. (2016). The Context of REDD+ in Brazil: Drivers, Actors and Institutions – 3rd Edition. CIFOR and CGIAR. http://www.cifor.org/knowledge/publication/6338/
[584] DW. (2020). 5 deadly countries for environmental defenders. https://www.dw.com/en/5-deadly-countries-for-environmental-defenders/a-54298499
[585] Gonzales, Jenny. (2020). Mongabay. https://news.mongabay.com/2020/08/brazil-end-runs-environmental-laws-via-huge-surge-in-executive-acts-study/
[586] Angelo, Mauricio. (2020). Reuters. https://www.reuters.com/article/us-brazil-deforestation-climate-change-a/brazil-slashes-budget-to-fight-climate-change-as-deforestation-spikes-idUSKBN2392LC
[587] Gallo, Patrícia, Brites, Alice and Micheletti, Tatiane, (2020). REDD+ achievements and challenges in Brazil: Perceptions over time 2015-19. CIFOR. https://www.cifor.org/publications/pdf_files/infobrief/7628-infobrief.pdf
[588] Insight from expert interview. (2020).

three years from 2018. In 2018 there was a 40% decrease in deforestation in Indonesia's primary forests compared to the average annual rate of loss from 2002 to 2016.[589] Over the past two decades Indonesia has decentralised the forests sector to provinces, giving them greater powers of governance and management.[590] Provinces such as East and North Kalimantan, Maluku, and West Papua have enacted measures to protect primary forests and slow deforestation and are affiliated with the Governors Climate and Forests Taskforce.[591] [592] In 2014, the government pledged to hand over 12.7 million hectares of state forests to rural communities as part of measures to reform land rights and reduce deforestation. Nonetheless, the country's 2020 Omnibus Law raises concern that forests will play less of a priority than other economic sectors and President Joko Widodo has announced plans to delay and dilute Indonesia's forest commitment as part of its Covid-19 stimulus.[593] [594] Indonesia's total area of primary cover decreased by 0.36% in 2018 and by 0.35% in 2019.[595]

Southern African countries are beginning to implement national plans and policies to protect forests. In Southern Africa, eight of ten countries identify broader land use change and forests as a mitigation pathway in their NDCs. Forestry policy and strategy is included in a majority of national climate change plans. Malawi's National Climate Change Management Policy aims at reducing emissions from deforestation and forest degradation and fostering carbon sinks, Zambia has a National Investment Plan to reduce Deforestation and Forest, while Mozambique has a National Strategy and Action Plan of Biological Diversity (2015-2035), which encourages sustainable management of forests. Angola's National Biodiversity and Strategy Action Plan (2019 – 2025) aims to restore one million hectares of degraded forest by 2025. Similarly, Madagascar has adopted a National Biodiversity Strategy and Action Plan (2015 – 2025). From 2013 to 2019, the total area of primary forest in Malawi decreased by 3.5%, in Mozambique by 6.4%, in Zambia by 5.2%, in Angola by 3.1%, and in Madagascar by 11%.[596]

South American nations generally have ambitious national level policies in place and are showing progress and political will in meeting them. In South America, 83% of countries mention land use change and forests in their NDCs. Bolivia and Colombia set specific forest-related targets in their NDCs. Chile has doubled its commitments and made its forest management and reforestation targets unconditional. Colombia plans net zero deforestation by 2020 and to increase forested land area more than 2.5 million hectares.[597] Bolivia aims to achieve zero illegal deforestation by 2020 and to increase the surface of forested and reforested areas to 4.5 million hectares by 2030.[598] There are several national level plans and policies, including Argentina's National Action Plan on Forests and Climate Change, Chile's National Forest Policy, Colombia's National Strategy for REDD+, and Peru's National Environmental Action Plan.[599] [600] From 2013 to 2019, the total area of primary forest in Argentina decreased by 3.1%, in Bolivia by 3.1%, in Colombia by 1.4%, in Ecuador by 0.81%, in Paraguay by 9.1%, and in Peru by 1.5%.

West African nations have national level policies in place and are showing progress in meeting them. In West Africa, 14 out of 17 countries identify land use change and forests as a mitigation pathway in their NDCs though specific forest-related targets are absent. An exception is Ghana, which intends to increase

---

589 Global Forest Watch. (2018). Map. https://www.globalforestwatch.org/
590 Thung, Paul Hasan. (2019). Decentralisation of government and forestry in Indonesia. CIFOR and CGIAR. https://www.cifor.org/publications/pdf_files/Books/BBarr0601.pdf
591 Insight from expert interview. (2020).
592 Wijaya, Arief, et al. (2019). Indonesia Is Reducing Deforestation, but Problem Areas Remain. *WRI.* https://www.wri.org/blog/2019/07/indonesia-reducing-deforestation-problem-areas-remain
593 Jacques, Harry. (2020). Indonesia inches forward on community forest goal, hobbled by pandemic. *Reuters.* https://www.reuters.com/article/us-indonesia-forests-communities-trfn/indonesia-inches-forward-on-community-forest-goal-hobbled-by-pandemic-idUSKCN252194
594 Insight from expert interview. (2020).
595 Ibid.
596 Ibid.
597 UNFCCC. (2015). Government of Colombia Intended Nationally Determined Contribution. https://www4.unfccc.int/sites/ndcstaging/PublishedDocuments/Colombia%20First/Colombia%20iNDC%20Unofficial%20translation%20Eng.pdf
598 UNFCCC. (2015). State of Bolivia Intended Nationally Determined Contribution. https://www4.unfccc.int/sites/ndcstaging/PublishedDocuments/Bolivia%20(Plurinational%20State%20of)%20First/INDC-Bolivia-english.pdf
599 Forest Legality Initiative. (2020). A tool to help companies buy legal forest products. https://forestlegality.org/risk-tool/
600 KfW and GIZ. (2015). Rewarding REDD+ Action and Supporting Low-deforestation Development in the Colombian Amazon. https://www.kfw-entwicklungsbank.de/PDF/Entwicklungsfinanzierung/Themen-NEU/REM-Colombia-agreement-resumen_english_final.pdf

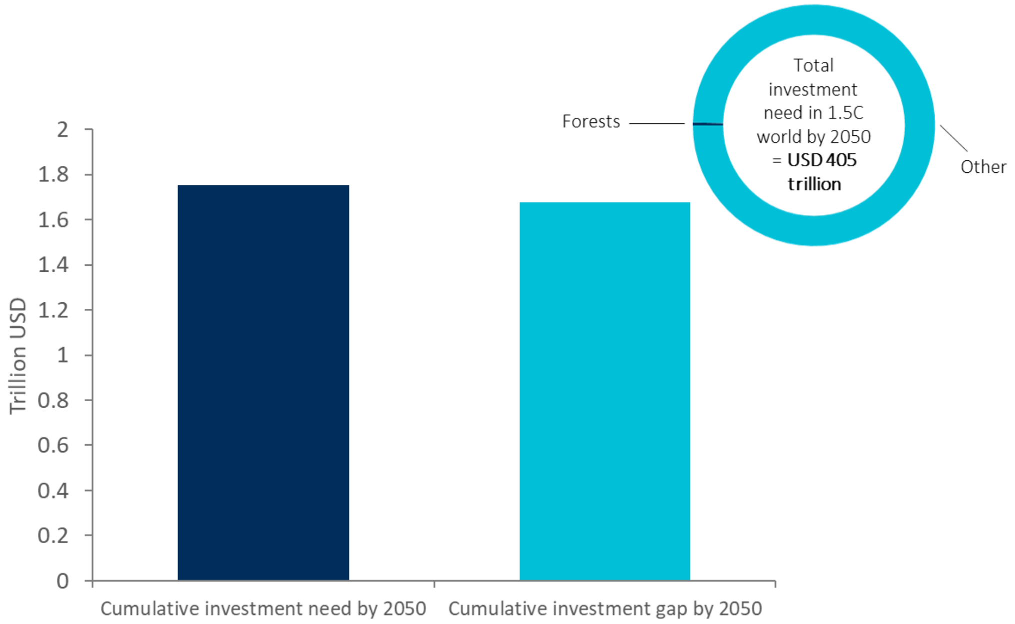
re/afforestation of degraded lands by 10,000 hectares annually and REDD+ on 20,000 hectares.[601] There is a high presence of forests in national policy and strategy. This includes the Central African Forest Code, the Democratic Republic of the Congo's (DRC)Forest Code, Gabon's Forest Code, Ghana's Forest and Wildlife Policy, Nigeria's National Forest Policy, and Sierra Leone's Conservation and Wildlife Policy.[602] Cameroon's Forest Code has been awaiting government approval for over 20 years.[603] West African countries except Mauritania have joined the Forestry Partnership Carbon Facility and UN-REDD+ programme. From 2013 to 2019, the total area of primary forest in Cameroon decreased by 2.3%, in the DRC by 2.9%, in the Gabon 0.61%, in Ghana by 5.1%, in Nigeria by 4.1%, and in the Republic of Congo by 0.96%.[604] Covid-19 has added impetus to deforestation in the DRC.[605]

[601] UNFCCC. (2015). Republic of Ghana Intended Nationally Determined Contribution. https://www4.unfccc.int/sites/ndcstaging/PublishedDocuments/Ghana%20First/GH_INDC_2392015.pdf
[602] Ibid.
[603] Insight from expert interview. (2020).
[604] Ibid.
[605] DW. (2020). WWF: Rainforest deforestation more than doubled under cover of coronavirus. https://www.dw.com/en/wwf-rainforest-deforestation-more-than-doubled-under-cover-of-coronavirus/a-53526064

Investment need

In the most ambitious of the 2-degree scenarios, global investment into forests in low- and middle-income countries will need to scale up to, on average, USD 37 bn per year between now and 2050, an order of magnitude higher than investment today. IMAGE does not produce investment need estimates for forestry and so investment cost estimates presented here are generated by combining IMAGE's forest cover results with per hectare cost estimates for avoided deforestation and re/afforestation from the literature.[606] This results in an estimated cumulative investment gap by 2050 of approximately USD 1.7 trillion or, equivalently, an average annual investment of USD 58 billion/year up to 2050. Although this number appears large, relative to other opportunities the scale of required investment is small. For example, annual investment requirements for on-grid renewables are multiple hundreds of billions, although generating only about two times the mitigation. This estimate is slightly larger than the range of cost estimates in the literature for achieving similarly ambitious forest targets. Kindermann et al. (2008) estimate that reducing deforestation by 50%, resulting in 1.5-2.7 Gt CO_2/year in mitigation, would cost USD 17.2-28.0 billion/year.[607] New York Declaration on Forests Assessment Partners (2017) estimates that achieving the New York Declaration on Forests, which aims to end deforestation and restore 350 Mha by 2030, delivering 4.5-8.8 Gt CO_2/year in mitigation, would cost USD 837-1,208 billion.[608] [609]

Figure 35 Investment need in forests is large, but low compared to other opportunities



Source: Vivid Economics, ASI and Factor. Calculation using PBL's IMAGE output and reforestation/avoided deforestation costs per hectare from the literature.

Notes: BAU investment assumes a continuation of current annual investment levels. The current investment level used is USD 2.2 billion/year from the European Commission (2018) report on REDD+ financing and

[606] More specifically, investment need is calculated by multiplying the avoided deforestation and re/afforestation potential presented in Figure 34, by per hectare cost estimates that vary by region and between avoided deforestation and re/afforestation. The cost of avoided deforestation is taken from the national costs of foregone land uses from Grieg-Gran (2008), inflated to USD 2019. Where data is not provided for a country of interest, we take the cost from the closest country for which there is data. Due to a lack of data on reforestation costs by region, we use an average global cost of tropical reforestation per hectare of USD 4,100/ha, from TEEB (2009) inflated to USD 2019.

[607] Kindermann et al. (2008). Global cost estimates of reducing carbon emissions through avoided deforestation. https://www.pnas.org/content/105/30/10302.short.

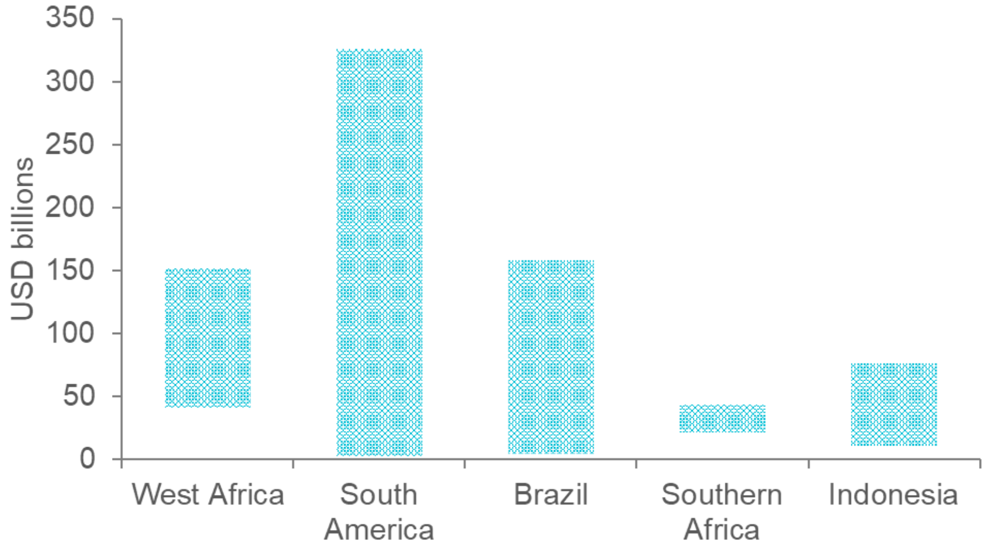
[608] NYDF Assessment Partners. (2019). Protecting and Restoring Forests: A Story of Large Commitments yet Limited Progress. New York Declaration on Forests Five-Year Assessment Report. https://forestdeclaration.org/images/uploads/resource/2019NYDFReport.pdf.

[609] UNDP. (2017). Global platform for New York Declaration on Forests launched. https://www.undp.org/content/undp/en/home/news-centre/news/2017/new-york-declaration-on-forests-global-platform-launched.html.

so does not include re/afforestation.[610] The Climate Policy Initiative (2019) calculates that total climate finance going to forestry and agriculture is approximately USD 11 billion.[611] Even if this number is used as the baseline annual investment there is a large investment gap.

Across focus regions, the cumulative investment gap between now and 2050 ranges between USD 43 billion and USD 326 billion in the 2-degrees lifestyle scenario. The calculated investment gap is greatest in South America at USD 326 billion in the 2-degrees lifestyle scenario,[612] largely due to the regions high potential for re/afforestation. However, in other scenarios, where no re/afforestation occurs, the investment gap in this region is very low at only USD 2 billion. This low estimate is likely largely driven by the ambitious assumptions on avoided deforestation in the baseline scenario, as discussed above. In contrast, the investment need in West Africa is relatively high across all scenarios. This is because the opportunity in avoided deforestation is large across all scenarios in this region. In addition to the magnitude of avoided deforestation and re/afforestation mitigation potential, variation in investment need across regions is also driven by the differing opportunity cost of avoided deforestation across regions. The opportunity costs of avoided deforestation in West Africa, Southern Africa, and Brazil, are about half the opportunity cost in Indonesia, while the opportunity cost in South America is in between.[613] The large opportunity cost of deforestation in Indonesia is due to the high profitability of palm oil plantations.[614]

Figure 36 Range of cumulative investment need estimates across focus regions.



Notes: Investment need estimates account for regional variation in the opportunity cost of avoided deforestation and in the difference in cost of avoided deforestation and re/afforestation.

Source: Vivid Economics, ASI and Factor using IMAGE outputs and literature.

[610] European Commission (2018). Study on EU financing of REDD+ related activities, and results-based payments pre- and post-2020. https://op.europa.eu/en/publication-detail/-/publication/6f8dea1e-b6fe-11e8-99ee-01aa75ed71a1.

[611] Climate Policy Initiative. (2019). Global Landscape of Climate Finance 2019. https://climatepolicyinitiative.org/wp-content/uploads/2019/11/2019-Global-Landscape-of-Climate-Finance.pdf

[612] IMAGE results suggest the cumulative investment need in China is over USD 400 billion in the 2-degrees lifestyle scenario. However, China was not selected as a focus region, in part because this large investment need is driven by large re/afforestation efforts that are do not arise in other scenarios.

[613] The opportunity cost numbers used in the calculations are adapted from Grieg-Gran (2008).

[614] Ibid.

Cost-effectiveness

Forests are one of the most cost-effective mitigation opportunities, and re/afforestation provides a cheap source of potential negative emissions. The first 500 Mt CO_2e/year of abatement from avoided deforestation in tropical regions costs on average USD 3/t CO_2. The first 500 Mt CO_2e/year of re/afforestation in tropical regions costs about USD 33/t CO_2, on average.[615] However, within this first 500 Mt CO_2/year of abatement there is large variation in the cost of re/afforestation projects with a range between close to USD 0/t CO_2 and about USD 70/t CO_2. Even though the cost of re/afforestation is, on average, notably higher than avoided deforestation, it is significantly cheaper than the present-day cost of BECCS, the only other negative emissions technology with a currently clear potential pathway to at-scale deployment.[616]

Cost-effectiveness varies across regions due to four principal characteristics:

Potential for mitigation through avoiding deforestation vs. re/afforestation. Regions with large forests currently under threat from expanding agriculture and logging intuitively have higher potential for abatement through avoided deforestation. Given the higher cost-effectiveness of avoided deforestation, forests mitigation investments in these regions will be more cost-effective. Hence, IMAGE results suggest that forest mitigation in West Africa will be particularly cost-effective.

Competition from other land uses. Growth in global demand for bioenergy and food will increase the value of forested land, increasing the cost of interventions in regions where forested land could be used for bioenergy and food production. Overmars et al. (2014) estimate the differences in opportunity cost of avoided deforestation in Sub-Saharan Africa, Central and South America, and Southeast Asia. [617] They find that the cost of mitigation through avoided deforestation in Southeast Asia is substantially higher than in the other two regions, while the cost in Sub-Saharan Africa is lowest amongst the three regions. Phan et al. (2014) similarly find that the cost-effectiveness of avoided deforestation interventions is significantly higher in Africa than in Latin America and Southeast Asia. [618]

Strength of government institutions to monitor and enforce protected areas. Regions where technology, technical know-how, and enforcement ability are stronger will allow for more cost-effective forestry interventions. The strength of government institutions, as measured by the World Development Indicators' Government Effectiveness score, is highest in Indonesia and South America, and lowest in West Africa, Southern Africa, and Brazil[619].

Climatic conditions. The climate of certain regions supports higher carbon density forests, resulting in cheaper per tonne abatement. This is usually true of tropical forests relative to temperate forests. The vast forested peatlands in Indonesia mean that the forest carbon density here is particularly high. Therefore, all else equal, protecting one hectare of forested land in Indonesia is more cost effective per t CO_2 than in most other regions.[620] However, the practical implementation of varying the per tonne cost of abatement with climatic conditions requires having MRV and pricing systems in place to accurately assess these conditions in each potential intervention area. See section 0 for discussion on how the difficulty of implementing MRV and pricing systems varies across the focus regions.

---

[615] Busch et al. (2019). Potential for low-cost carbon dioxide removal through tropical reforestation. https://www.nature.com/articles/s41558-019-0485-x.

[616] Fuss et al. (2018). Negative emissions – Part 2: Costs, potentials and side effects. https://iopscience.iop.org/article/10.1088/1748-9326/aabf9f/pdf

[617] Overmars et al. (2014). Estimating the opportunity costs of reducing carbon dioxide emissions via avoided deforestation, using integrated assessment modelling. https://www.sciencedirect.com/science/article/abs/pii/S0264837714000799.

[618] Phan et al. (2014). The economic costs of avoided deforestation in the developing world: a meta-analysis. https://www.sciencedirect.com/science/article/abs/pii/S1104689913000263.

[619] World Bank (2020). Worldwide Governance Indicators. https://databank.worldbank.org/source/worldwide-governance-indicators

[620] Overmars et al. (2014) and Phan et al. (2014) assess regional cost-effectiveness in terms of dollars per t CO_2 abated. Hence, their results account for regional differences in the carbon density of forests.

Table 40 Summary of cost-effectiveness by region and influencing factor.

Region	Ratio of avoided deforestation vs re/afforestation potential	Competition from other land uses	Strength of government institutions	Climatic conditions
Brazil	Moderate	Moderate	Moderate	Moderate
Indonesia	Moderate	Low	High	High
Southern Africa	Low	High	Moderate	Moderate
South America	Moderate	Moderate	High	Moderate
West Africa	High	High	Low	High

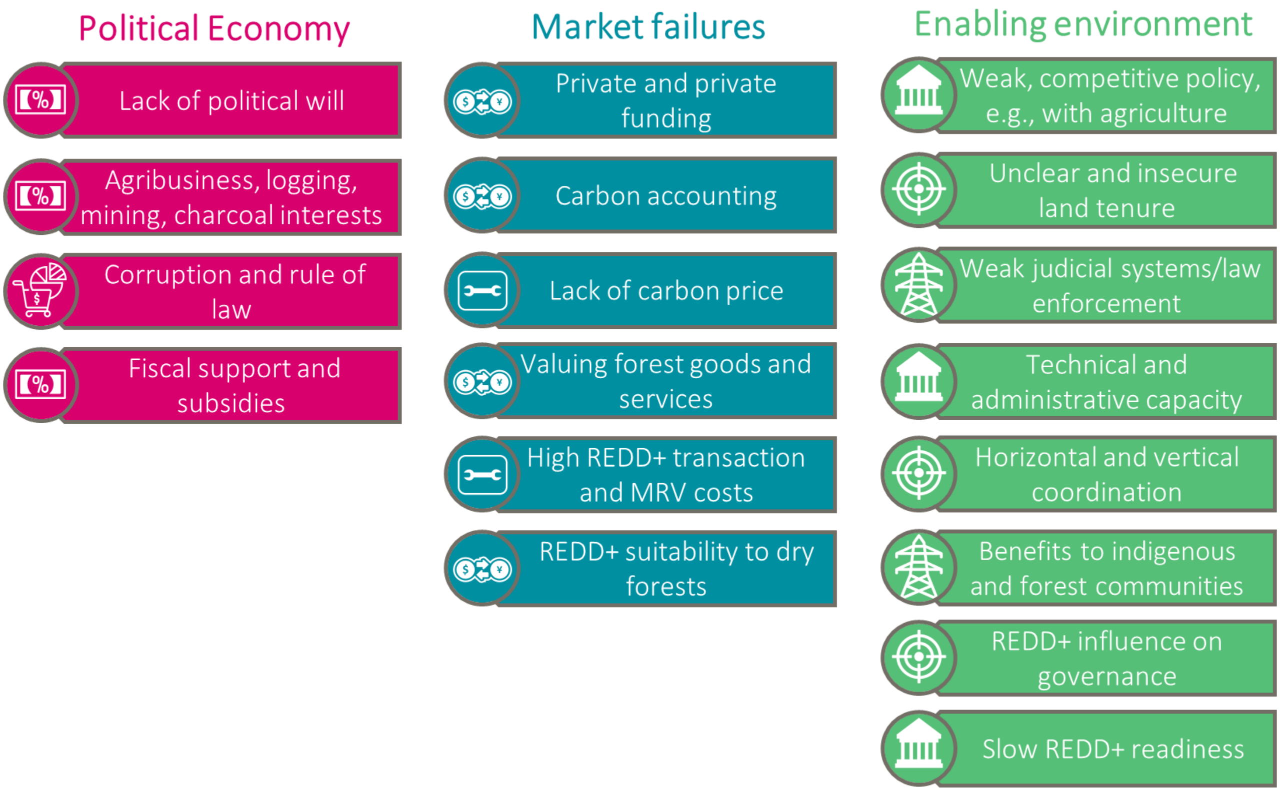
Note: This table summarises which regions have the highest forest intervention cost-effectiveness when evaluated along four influencing factors. High indicates high cost-effectiveness as assessed along the influencing factor given in the corresponding column, while low indicates low cost-effectiveness.

Source: Vivid Economics, ASI and Factor

Barriers to adoption

The largest barriers to governance for low-carbon transitions faced are those related to i) political economy challenges, ii) market failures, and iii) enabling environment (Figure 37). Each of these barriers are then mapped to regions and potential solutions below. The greatest drivers of greenhouses gases (GHG) emissions from forests may lie in agricultural production and commodity supply chains (in beef, soy beans, cocoa, palm oil, logging, paper and pulp), transport and urban infrastructure expansion, mining, and food consumption patterns, and lack of access to affordable energy – and in the policies and market forces that drive them. Between 2001 and 2015 large-scale agriculture was responsible for about 25% of global deforestation, smallholder agriculture for about 21%, extraction of forest products, timber primarily, for about 31%, and urban growth for about 1%.[621] Commercial agriculture was the largest driver in Latin America and smallholder agriculture the highest driver in Africa and Asia. This section equally identifies the barriers that exist within the forests sector itself.

Figure 37 Barriers to an opportunity



Source: Vivid Economics, ASI and Factor

In Brazil, Indonesia, Southern Africa, the South America, and West Africa high political economy barriers to investment or adoption are likely to include the following:

In all regions there is, at best, fragile political commitment for forest action, and often governmental priorities lie with other sectors, resulting in weak, competing, and contradictory enforcement and policy implementation. Enforcement of the Brazilian Forest Code has varied in recent decades alongside the strength of promotion of agriculture and livestock expansion, and since 2018 the government's *de facto* relaxation of laws and its public messaging have led to a surge in

[621] Chaturvedi, Rohini, et al. (2019). Public-Sector Measures to Conserve and Restore Forests: Overcoming Economic and Political Economy Barriers. *WRI.* https://www.wri.org/publication/folu-overcoming-economic-and-political-barriers

deforestation.[622] [623] Indonesia's Ministry of Agriculture, which covers the palm oil sector, and Ministry of Energy and Mineral Resources have plans that contradict the country's forest objectives.[624]

In all regions, powerful lobbies exist in logging, charcoal, agriculture, livestock, and mining, all of which are interests leading to high rates of deforestation and degradation.[625] Indonesia's economy relies heavily on palm oil for its rural economy and exports and politically influential companies and individuals have been shown to gain hold of forest concessions for profitable purposes.[626] In Colombia, Guyana, and Peru illegal logging and mining are pervasive.[627] Countries in Southern Africa have an entrenched fuelwood and charcoal industry.[628] In West Africa, agriculture and timber concessions are dispensed to private actors without oversight and transparency.[629]

In all regions, weakness of government institutions is common, leading to unclear and insecure land tenure, corruption, and poor law enforcement with regards to forestry, and therefore resulting in *de facto* immunity for those in breach of the law.[630] [631] [632] There is a correlation between deforestation and countries with high levels of corruption.

Fiscal policies such as agricultural or commodity subsidies, often offered under popular pressure and under the influence of powerful interests, exist at either the producer or consumer end in all regions and encourage deforestation and degradation and discourage re/afforestation.[633]

Moderate to high market failures to investment or adoption exist in all regions. Failures relating to all forest mitigation pathways are as follows:

In all regions, funding for forest mitigation falls short of required levels and neither donor countries nor the private sector have yet demonstrated the willingness and ability to provide funds at the level envisaged by the Paris Agreement.[634] [635] The lack of confidence in the availability of compensation has not yet incentivised the necessary scale of change.[636] Globally, annual agriculture sector investments have totalled USD 55 billion compared to USD 2.2 billion for REDD+.[637] Brazil, for example, received USD 1 billion for REDD+ credits between 2009 and 2013, which was less than one tenth of the value of the REDD+ credits it had earnt – the remainder emerging from federal and state budgets.[638] The USD 5 price for a tonne of CO_2e determined by REDD+ is likely too low.[639] Due to barriers such as land tenure and the absence of both a project pipeline and MRV, the private sector

---

622 May, Peter, et al. (2016). The Context of REDD+ in Brazil: Drivers, Actors and Institutions – 3rd Edition. CIFOR and CGIAR. http://www.cifor.org/knowledge/publication/6338/
623 Chaturvedi, Rohini, et al. (2019). Public-Sector Measures to Conserve and Restore Forests: Overcoming Economic and Political Economy Barriers. *WRI.* https://www.wri.org/publication/folu-overcoming-economic-and-political-barriers
624 Insight from expert interview. (2020).
625 May, Peter, et al. (2016). The Context of REDD+ in Brazil: Drivers, Actors and Institutions – 3rd Edition. CIFOR and CGIAR. http://www.cifor.org/knowledge/publication/6338/
626 Chaturvedi, Rohini, et al. (2019). Public-Sector Measures to Conserve and Restore Forests: Overcoming Economic and Political Economy Barriers. *WRI.* https://www.wri.org/publication/folu-overcoming-economic-and-political-barriers
627 Ibid.
628 Insight from expert interviews. (2020).
629 Insight from expert interview. (2020).
630 Chaturvedi, Rohini, et al. (2019). Public-Sector Measures to Conserve and Restore Forests: Overcoming Economic and Political Economy Barriers. *WRI.* https://www.wri.org/publication/folu-overcoming-economic-and-political-barriers
631 May, Peter, et al. (2016). The Context of REDD+ in Brazil: Drivers, Actors and Institutions – 3rd Edition. CIFOR and CGIAR. http://www.cifor.org/knowledge/publication/6338/
632 Mpoyi, Augustin, et al. (2013). The context of REDD+ in the Democratic Republic of Congo: Drivers, agents and institutions. *CIFOR*. https://www.cifor.org/knowledge/publication/4267/
633 Insight from expert interviews. (2020).
634 Angelsen, Prof Arild, et al. (2018). Transforming REDD+: Lessons and new directions. CIFOR. https://www.cifor.org/knowledge/publication/7045
635 Forest Carbon Partnership Facility. (2019). Forest Carbon Partnership Facility Annual Report 2019. https://forestcarbonpartnership.org/system/files/documents/FCPF_Annual%20Report_2019.pdf
636 Insight from expert interview. (2020).
637 Angelsen, Prof Arild, et al. (2018). Transforming REDD+: Lessons and new directions. CIFOR. https://www.cifor.org/knowledge/publication/7045
638 Angelson, Prof A. (2017). REDD+ as Result-based Aid: General Lessons and Bilateral Agreement of Norway. https://onlinelibrary.wiley.com/doi/full/10.1111/rode.12271
639 Insight from expert interview. (2020).

has not yet contributed sizeable volumes either via carbon market mechanisms (REDD+ or earlier mechanisms such as the Clean Development Mechanism) or supply chain initiatives.[640] Reliance on limited and unpredictable results-based payments and the absence of a global forest carbon market – nascent and voluntary market initiatives such as the Carbon Offsetting and Reduction Scheme for International Aviation (CORSIA), Architecture for REDD+ Transactions – The REDD+ Environmental Excellency Standard (ART-TREES), and the California Tropical Forest Standard notwithstanding – means the potential supply of emissions credits exceeds demand.[641]

In all regions, carbon accounting is a significant barrier to effective and affordable MRV and to the establishment of result-based finance mechanisms and carbon markets for deforestation and forest degradation, as well as for reforestation and afforestation. Problems lie in ensuring the permanence of carbon sequestered and stored in forests and internalising the uncertainty of permanence over a number of decades; in proving the additionality of forest mitigation; in the risk that forest mitigation can lead to leakage of carbon in other regions or sectors; and in measurement systems that are sufficiently accurate over time. The increase in Brazilian deforestation between 2012 and 2016 after eight years of progress reveals, at a national level, the difficulty of accounting for the permanence of forest carbon sequestration.[642] Brazil has also experienced leakage issues.[643]

In all regions, the lack of recognition and value given to forest carbon and other goods and services puts the economic feasibility of reducing deforestation and degradation, as well as re/afforestation and SFM, into question.[644] Competitive factors driving alternative land uses are the value of agricultural commodities, land values, access to markets, and capital availability.[645] If the non-forests benefit to land is high and the return on forests is low the incentive is against the preservation and/or expansion of forests.[646]

In all regions, difficulties in valuing forest goods and services such as biodiversity, rainfall, climatic protection, water quality, and flood prevention often mean that the non-market and intangible benefits from forests are ignored or undervalued.[647] Costa Rica's longstanding PES programme shows how to consider a wider array of forest goods and services, but its case is an exception and there have been no examples of scalable PES initiatives to date.[648]

In all regions, and especially with regards to re/afforestation, there is a disparity between the length of time required to overcome barriers in forests and to see results in carbon sequestration and other forest goods and services and the shorter timelines associated with government planning and investment cycles. Related to this is the fact that discount rates tend to penalise forest interventions that require longer time periods for benefits to accrue compared to alternatives.

Moderate market failures relating to REDD+ are as follows:

In all regions, for example Brazil, the DRC, Indonesia, and the Republic of Congo, REDD+ has proven it can make a difference to forest carbon mitigation. But to date it has not yet led to a rapid, cheap, and lasting reduction in GHG emissions from deforestation and degradation.[649] This is due, in part, to high transaction costs resulting from MRV, weaker than intended financial incentives, low ambition of

[640] Chaturvedi, Rohini, et al. (2019). Public-Sector Measures to Conserve and Restore Forests: Overcoming Economic and Political Economy Barriers. *WRI.* https://www.wri.org/publication/folu-overcoming-economic-and-political-barriers
[641] Ibid
[642] Ibid.
[643] Ibid.
[644] FAO. (2016). Forests for a low-carbon future. http://www.fao.org/3/a-i5857e.pdf
[645] Ibid.
[646]Chaturvedi, Rohini, et al. (2019). Public-Sector Measures to Conserve and Restore Forests: Overcoming Economic and Political Economy Barriers. *WRI.* https://www.wri.org/publication/folu-overcoming-economic-and-political-barriers
[647] FAO. (2018.) Forests Pathways to Sustainable Development. http://www.fao.org/policy-support/tools-and-publications/resources-details/en/c/1144279/
[648] IIED. (2012). Payments for environmental services in Costa Rica: from Rio to Rio and beyond. https://pubs.iied.org/17126IIED/
[649] Chaturvedi, Rohini, et al. (2019). Public-Sector Measures to Conserve and Restore Forests: Overcoming Economic and Political Economy Barriers. *WRI.* https://www.wri.org/publication/folu-overcoming-economic-and-political-barriers

some countries' baselines and projections, and issues of permanence and leakage – as well as enabling environment issues laid out below.[650] [651] [652] But, as described in Section 0, domestic financial contributions have risen, sizeable bilateral and multilateral REDD+ results-based payments have been awarded to the likes of Brazil, Guyana, and Indonesia, and several other countries have agreed to results-based finance initiatives with multilateral donors.[653]

REDD+, as currently designed, is better suited to closed, moist forests in the tropics than to regions home to dry forest savanna and dry deciduous forests, such as Angola, Bolivia, Mozambique, and Zambia.[654] This is due to the denser forest canopy cover in the former, their more clearly defined boundary, their high carbon content, and the resulting (relatively) greater simplicity and cost-effectiveness of MRV.[655] Dry forest types tend to have more fluid boundaries, lower carbon content, and are often more fragmented. REDD+ readiness is, nonetheless, proceeding in a number of dry forested countries in Southern and West Africa and South America, from which the results are yet to be determined.[656]

High enabling environment / absorptive capacity barriers to investment or adoption are common across five regions and are as follows:

The absence, insecurity, and lack of transparency of land tenure is a powerful driver of deforestation and degradation and a deterrent of re/afforestation in all regions.[657] Land tenure concerns enable deforestation by contesting land use demarcations and permissions, by permitting widespread illegal occupation of public and community land and protected areas, by limiting the dependability of contracts for REDD+ or SFM, by diminishing individual, community and indigenous rights, by incentivising untitled smallholders to search for more reliable tenure and continue deforestation, and by making it difficult to identify individuals responsible for deforestation.[658] Challenges to effective land tenure include incomplete or unreliable land registries, lack of integrated databases, and institutional, policy and regulatory complexity.[659] Brazil and other South American countries have, in the past, retroactively given rights to those who have illegally occupied land.[660]

In all regions, weak judicial systems and sparsely applied law enforcement mechanisms at national, state, and municipal levels of government, serve to prevent illegal land use changes, facilitate the issuance of licences and permits in protected and indigenous areas, and remove an important impediment to deforestation and degradation.[661] [662] [663]

Technical and administrative capacity for preparing strategy and policy, for running land registration and forest information systems, for complex MRV of carbon emissions and sequestration, and for the

---

[650] Angelsen, Prof Arild, et al. (2018). Transforming REDD+: Lessons and new directions. CIFOR. https://www.cifor.org/knowledge/publication/7045
[651] Ibid.
[652] World Rainforest Movement. (2020). The GCF Board must refrain from approving more REDD+ funding requests. https://wrm.org.uy/actions-and-campaigns/support-this-open-letter-the-gcf-board-must-refrain-from-approving-more-redd-funding-requests/
[653] Angelsen, Prof Arild, et al. (2018). Transforming REDD+: Lessons and new directions. CIFOR. https://www.cifor.org/knowledge/publication/7045
[654] Insight from expert interviews. (2020).
[655] Insight from expert interview. (2020).
[656] Forest Carbon Partnership Facility. (2019). Forest Carbon Partnership Facility Annual Report 2019. https://forestcarbonpartnership.org/system/files/documents/FCPF_Annual%20Report_2019.pdf
[657] Insight from expert interviews. (2020).
[658] May, Peter, et al. (2016). The Context of REDD+ in Brazil: Drivers, Actors and Institutions – 3rd Edition. CIFOR and CGIAR. http://www.cifor.org/knowledge/publication/6338/
[659] Gallo, Patrícia, Brites, Alice and Micheletti, Tatiane, (2020). REDD+ achievements and challenges in Brazil: Perceptions over time 2015-19. CIFOR. https://www.cifor.org/publications/pdf_files/infobrief/7628-infobrief.pdf
[660] Chaturvedi, Rohini, et al. (2019). Public-Sector Measures to Conserve and Restore Forests: Overcoming Economic and Political Economy Barriers. *WRI.* https://www.wri.org/publication/folu-overcoming-economic-and-political-barriers
[661] Duchelle, Amy, et al. (2019). Forest-based Climate Mitigation: Lessons from REDD+ Implementation. WRI. https://www.wri.org/publication/forest-based-climate-mitigation
[662] Mpoyi, Augustin, et al. (2013). The context of REDD+ in the Democratic Republic of Congo: Drivers, agents and institutions. CIFOR. https://www.cifor.org/knowledge/publication/4267/
[663] Insight from expert interview. (2020).

implementation of forest policies and programmes is highly uneven between priority regions.[664] Brazil has a reliable and transparent technology-based forest monitoring system in the form of PRODES but implementation skills fall short.[665] In Southern and West Africa, in countries from the DRC and Liberia to Madagascar and Malawi, ministries of forestry and associated government departments generally contain few people with scientific and technical knowledge who are responsible for a high number of functions and vast areas of public and community land.[666] [667] Capacity constraints are particularly acute at the level of states and municipalities affecting the effectiveness of their mandates. With a small human resources pool, the loss of people through emigration or to donor programmes has a substantial effect.

The involvement of multiple institutions of government – amongst them ministries of forests, environment, agriculture, and transport – at national and sub-national levels leads to horizontal and vertical coordination failures, duplications, and competition in the design and delivery of policy and regulation.[668] Effective coordination between government, private sector stakeholders, civil society, and indigenous groups is also lacking. Such failures are particularly apparent in countries such as Brazil and Indonesia with federal, devolved, or decentralised systems of government. Equally, vertical coordination in unitary or centralised systems, as in much of Southern and West Africa, can impede jurisdictional or state level forest efforts.[669]

Forest and indigenous communities are often the greatest victims of deforestation and degradation, for example through lack of land tenure, weak law enforcement, or lack of valuation of forest goods and services. Indigenous and forest communities have recognised tenure for just 10% of the forest land that they occupy.[670] For these reasons, forest and indigenous communities have risked exclusion and damage to livelihoods from the benefits that REDD+ as well as re/afforestation and SFM initiatives may bring.[671] [672] Their participation is, nonetheless, essential for conserving forests and for MRV and their opposition can be an impediment to success.[673] Successful forest initiatives have adequately involved indigenous communities in consultation and planning, offered greater right and security of tenure, apportioned a role in forest monitoring and reporting, and provided economic benefits to those that depend on forests for livelihoods. Others have struggled to design participatory processes and give greater security and social and economic returns.[674] [675] Inclusion can be equally a concern with jurisdictional and national approaches, which may be further removed from communities, as with project approaches, which are likely to be closely related to communities.

Moderate enabling environment / absorptive capacity barriers relating to REDD+ are as follows:

REDD+ has a mixed but improving record in addressing governance barriers and drivers of deforestation and degradation.[676] On the one hand, REDD+ has been a valuable driver of progress in forest policy, horizontal coordination, land tenure and rights, technical capacity and skills, forest and indigenous

[664] Sills, Erin, et al. (2014). CIFOR. REDD+ On the ground: A case book of sub-national initiatives across the globe. http://www.cifor.org/knowledge/publication/5202/
[665] May, Peter, et al. (2016). The Context of REDD+ in Brazil: Drivers, Actors and Institutions – 3rd Edition. CIFOR and CGIAR. http://www.cifor.org/knowledge/publication/6338/
[666] Insight from expert interview. (2020).
[667] Mpoyi, Augustin, et al. (2013). The context of REDD+ in the Democratic Republic of Congo: Drivers, agents and institutions. CIFOR. https://www.cifor.org/knowledge/publication/4267/
[668] Duchelle, Amy, et al. (2019). Forest-based Climate Mitigation: Lessons from REDD+ Implementation. WRI. https://www.wri.org/publication/forest-based-climate-mitigation
[669] Ibid.
[670] Ibid.
[671] Gallo, Patrícia, Brites, Alice and Micheletti, Tatiane, (2020). REDD+ achievements and challenges in Brazil: Perceptions over time 2015-19. CIFOR. https://www.cifor.org/publications/pdf_files/infobrief/7628-infobrief.pdf
[672] Insight from expert interviews. (2020).
[673] Duchelle, Amy, et al. (2019). Forest-based Climate Mitigation: Lessons from REDD+ Implementation. WRI. https://www.wri.org/publication/forest-based-climate-mitigation
[674] Sills, Erin, et al. (2014). CIFOR. REDD+ On the ground: A case book of sub-national initiatives across the globe. http://www.cifor.org/knowledge/publication/5202/
[675] Angelsen, Prof Arild, et al. (2018). Transforming REDD+: Lessons and new directions. CIFOR. https://www.cifor.org/knowledge/publication/7045
[676] Ibid.

and community rights and livelihoods, civil society mobilisation, and international collaboration.[677] [678] However, the persistence of issues in land tenure, vertical coordination, law enforcement, and stakeholder engagement point to the limitations of REDD+ influence at the national level of government.[679] [680]

Becoming ready for REDD+, which carries greatest potential for success, has absorbed more time than anticipated, particularly at jurisdictional and national levels, and in all regions there remain gaps in regulation, funding, participation, and transparency.[681] [682] REDD+ readiness consists of planning and policy, stakeholder engagement, monitoring systems, and safeguarding and just transition actions against social and environmental consequences. Readiness has advanced in a majority of countries in priority regions, though only in the last two years have a handful of countries officially turned to implementation and results-based payments.[683] The demands of REDD+ readiness have proven taxing in some countries and in the likes of Angola, the Central African Republic, Malawi, and the Republic of the Congo policy, institutional and technical capacity barriers and smaller domestic funding sources have inhibited effective participation in REDD+ to date.[684] [685] [686] In others, for example Cameroon, the DRC, Guyana, and Peru, readiness exists in certain pockets of government, for example in the ministry of forests, but relevant government departments lack focal points and organisation and capacity has not spread to wider government bodies or cascaded to state or municipal levels.[687]

Table 41 Barriers per region

Region	Political economy barriers	Market failures	Enabling environment barriers
Brazil	**High** Political commitment, entrenched interests (in logging, charcoal, agriculture, livestock, and mining), corruption, fiscal support.	**Moderate to high** Funding shortfalls, carbon accounting, lack of carbon price and recognition of forest goods and services, REDD+ MRV and transaction costs.	**High** Weak and competitive policy, unclear and insecure land tenure, judicial systems / law enforcement, technical capacity, horizontal / vertical coordination, benefits to indigenous / forest communities, REDD+ influence on governance.
Indonesia	**High** Political commitment, entrenched interests (in logging, charcoal, agriculture, livestock, and mining), corruption, fiscal support.	**Moderate to high** Funding shortfalls, carbon accounting, lack of carbon price and recognition of forest goods and services, REDD+ MRV and transaction costs.	**Moderate to high** Weak and competitive policy, unclear and insecure land tenure, judicial systems / law enforcement, technical capacity, horizontal / vertical coordination, benefits to indigenous / forest communities, REDD+ influence on governance.

677 Gallo, Patrícia, Brites, Alice and Micheletti, Tatiane, (2020). REDD+ achievements and challenges in Brazil: Perceptions over time 2015-19. CIFOR. https://www.cifor.org/publications/pdf_files/infobrief/7628-infobrief.pdf
678 Forest Carbon Partnership Facility. (2019). Forest Carbon Partnership Facility Annual Report 2019. https://forestcarbonpartnership.org/system/files/documents/FCPF_Annual%20Report_2019.pdf
679 Angelsen, Prof Arild, et al. (2018). Transforming REDD+: Lessons and new directions. CIFOR. https://www.cifor.org/knowledge/publication/7045
680 Mpoyi, Augustin, et al. (2013). The context of REDD+ in the Democratic Republic of Congo: Drivers, agents and institutions. CIFOR. https://www.cifor.org/knowledge/publication/4267/
681 Duchelle, Amy, et al. (2019). Forest-based Climate Mitigation: Lessons from REDD+ Implementation. WRI. https://www.wri.org/publication/forest-based-climate-mitigation
682 Insight from expert interview. (2020).
683 Duchelle, Amy, et al. (2019). Forest-based Climate Mitigation: Lessons from REDD+ Implementation. WRI. https://www.wri.org/publication/forest-based-climate-mitigation
684 Insight from expert interview. (2020).
685 BEIS. (2019). Forest Carbon Partnership Facility Carbon Fund Annual Review 2019. https://science-and-innovation-network.s3.eu-west-2.amazonaws.com/BEIS+ICF/FCPF/FCPF+Annual+Review+2019.pdf
686 Angelsen, Prof Arild, et al. (2018). Transforming REDD+: Lessons and new directions. CIFOR. https://www.cifor.org/knowledge/publication/7045
687 Insight from expert interviews. (2020).

Region	Political economy barriers	Market failures	Enabling environment barriers
Southern Africa	High Political commitment, entrenched interests (in logging, charcoal, agriculture, livestock, and mining), corruption, fiscal support.	Moderate to high Funding shortfalls, carbon accounting, lack of carbon price and recognition of forest goods and services, REDD+ MRV and transaction costs, REDD+ suitability to dry forests.	High Weak and competitive policy, unclear and insecure land tenure, judicial systems / law enforcement, technical capacity, horizontal / vertical coordination, benefits to indigenous / forest communities, REDD+ influence on governance, slow REDD+ readiness.
South America	High Political commitment, entrenched interests (in logging, charcoal, agriculture, livestock, and mining), corruption, fiscal support.	Moderate to high Funding shortfalls, carbon accounting, lack of carbon price and recognition of forest goods and services, REDD+ MRV and transaction costs.	Moderate to high Weak and competitive policy, unclear and insecure land tenure, judicial systems / law enforcement, technical capacity, horizontal / vertical coordination, benefits to indigenous / forest communities, REDD+ influence on governance.
West Africa	High Political commitment, entrenched interests (in logging, charcoal, agriculture, livestock, and mining), corruption, fiscal support.	Moderate to high Funding shortfalls, carbon accounting, lack of carbon price and recognition of forest goods and services, REDD+ MRV and transaction costs, REDD+ suitability to dry forests.	High Weak and competitive policy, unclear and insecure land tenure, judicial systems / law enforcement, technical capacity, horizontal / vertical coordination, benefits to indigenous / forest communities, REDD+ influence on governance, slow REDD+ readiness.

Source: Vivid Economics, ASI and Factor

UK additionality

Historical donor activity in this opportunity has been driven by a handful of countries in Europe and the USA.

In the past 15 years global support for forests has largely been driven through REDD+ initiatives and the Forest Law Enforcement, Governance and Trade (FLEGT) approach to forest governance, anti-corruption, and markets. By comparsison, relatively little bilateral or multilateral assistance is channelled to re/afforestation and SFM, where Germany is, nonetheless, a major funder.

Norway, the UK, Germany, and the USA (in this order) have been the major funders of forest mitigation, REDD+ especially.[688] Norway channels most of its funding bilaterally into results-based payments, whereas the UK, Germany, and the USA contribute more to broader multilateral initiatives. The UK, Germany, and Norway have a Germany, Norway, UK (GNU) Partnership to offer GBP 5 billion in forests funding.

Global multilateral REDD+ programmes deploy a combination of technical assistance and finance in forested countries with most funding devoted to REDD+ preparedness and results-based payments at jurisdictional and project levels. They include the World Bank's Forest Carbon Partnership Facility (FCPF), the Bio-Carbon Fund ISFL, the REDD+ Readiness Programme, the Green Climate Fund, the Forest Investment Programme of the Climate Investment Funds, and the UN REDD Programme. The Bio-Carbon Fund ISFL further links REDD+ to commodity supply chains in jurisdictions. Regional funds include the Amazon Fund, the Congo Basin Forest Fund, and the Central Africa Forest Initiative.

Notwithstanding the barriers mentioned in Section 0, recent developments may indicate an acceleration of REDD+ progress and payments.[689] There are at least 350 REDD+ projects in 53 tropical countries and analyses of jurisdictional approaches in 39 states in 12 tropical countries point to a reasonable degree of commitment and sustainability.[690] The FCPF has 47 countries in its Readiness Fund, 19 in its Carbon Fund, and in the past two years has signed four emission reduction payments agreements (ERPAs) in Chile, the DRC, Ghana, and Mozambique, whilst in Cote d'Ivoire, Indonesia, Madagascar, Peru, and the Republic of Congo ERPA preparations are proceeding.[691] The REDD Early Movers Programme has recently completed a suite of results-based payments in Colombia.

In the past decade Brazil has received about half of the total multilateral REDD+ finance and Latin America 56%, of which the Amazon Fund is the major funder. Just under a quarter of multilateral funding goes to Sub-Saharan Africa, primarily the DRC. Indonesia, which receives relatively little multilateral finance, receives a large volume of bilataral finance from Norway and Australia.[692]

In priority regions, the UK has typically had good ties in Indonesia and Southern and West Africa and moderate ties in Brazil and South America with most recent programmes of support focusing on REDD+.

The UK is politically committed to supporting forests mitigation and REDD+ globally in recognition of the high mitigation potential, the nexus between mitigation and SFM, accompanying social and sustainability benefits, and the potential for building country capacity. The UK has been an important promoter of REDD+ in international climate negotiations, in particular in ensuring that it was incorporated into the Paris Agreement and promoted by the UNFCCC.

[688] ODI. (2016). Climate Finance Thematic Briefing: REDD+ Finance. https://www.odi.org/publications/10610-climate-finance-thematic-briefing-redd-finance
[689] BEIS. (2019). Forest Carbon Partnership Facility Carbon Fund Annual Review 2019. https://science-and-innovation-network.s3.eu-west-2.amazonaws.com/BEIS+ICF/FCPF/FCPF+Annual+Review+2019.pdf
[690] Angelsen, Prof Arild, et al. (2018). Transforming REDD+: Lessons and new directions. CIFOR. https://www.cifor.org/knowledge/publication/7045
[691] Forest Carbon Partnership Facility. (2019). Forest Carbon Partnership Facility Annual Report 2019. https://forestcarbonpartnership.org/system/files/documents/FCPF_Annual%20Report_2019.pdf
[692] ODI. (2016). Climate Finance Thematic Briefing: REDD+ Finance. https://www.odi.org/publications/10610-climate-finance-thematic-briefing-redd-finance

The UK has decades of bilateral ODA experience in forested countries and continued Department for International Development (DFID), now the Foreign, Commonwealth and Development Office (FCDO), and/or BEIS presence in all priority regions via historic support to forest governance, law enforcement, markets, and indigenous and forest communities. Current major programmes are the Forests, Governance, Markets and Climate Programme, which supports the FLEGT approach; Investments in Forests and Sustainable Land Use, which concerns public-private partnerships and supply chains; and Partnership for Forests, which encourages private investment into forests and demand for sustainable forest products. Strong FCDO partnerships exist in Indonesia, Southern Africa, and West Africa where the former DFID placed its efforts on forest governance and land rights. BEIS has a high-level partnership with Colombia and relationships with Brazil, Indonesia, and Peru. BEIS and DEFRA have, in the most recent ICF, offered £330 million to forestry programmes, namely the FCPF, the Bio-Carbon Fund ISFL, and the REDD Readiness Programme.

The UK's additional value is moderate to high resulting from COP26 and good technical expertise. There is moderate to high potential for UK additionality in forested countries given domestic technical expertise in forests, particularly in re/afforestation, SFM, but also in the UK's advice on, and support to, forest governance, markets, and private sector engagement, and multilateral and bilateral REDD+ initiatives. The UK's expertise in climate finance and fiscal measures is also an asset.

The UK's hosting of COP26 and the breadth of its diplomatic networks in all regions will give it leverage to enhance political ambition, address political economy constraints, and channel assistance to address policy and market barriers.

There is substantial domestic expertise in re/afforestation and SFM to draw on, despite variations in UK domestic ambition and performance since the 1970s, and the UK has set a target to plant 30,000 hectares of new forest every year.

UK experience in advising and funding SFM, REDD+, forest governance, and forest market initiatives in forested countries, including tropical forest countries, has built up a body of expertise within BEIS, DEFRA, and FCDO as well as within the consultancy sector.

The UK's experience in developing strong standardised domestic forestry carbon offset markets and its broader financial sector strength can lend itself to the development of international carbon markets that have the confidence of financial institutions.

Despite limitations in uptake due to similar market failures, enabling environment barriers, and financial hurdles as in prioritised regions, the Woodland Carbon Code sets a high policy standard in afforestation and reforesation and can be valuable as countries develop forest carbon policies.

The Commonwealth Forestry Association, an international forum for foresters, the Forestry Commissions in England, Wales, Scotland, and Northern Ireland, the department responsible for the sustainable management of UK forests, and UK Forestry Standards, which sets sustainable forests standards, can be a model for UK support to the promotion and expansion of SFM and re/afforestation in all regions.

Intervention opportunities

Global intervention opportunities

There is substantial opportunity for the UK to support forests in all prioritised regions while noting the high complexity of delivering support successfully. Due to high levels of need and mitigation potential and the ability to focus on specific countries and intervention there is high potential to provide additional support despite a number of other actors in the space. The barriers, however, are substantial – particularly those related to political commitment, corruption, and capacity – and the current level of funding and type of international mechanisms deployed for reducing deforestation and degradation, re/afforestation, SFM, and PES are yet to reach the scale and design required.

- Forest mitigation pathways depend to a large extent on ambitions in other sectors, notably livestock and agriculture; logging, pulp and paper; food consumption; and energy and transport infrastructure – these are explored in related reports on Agriculture and Food Productivity Enhancement, Mass Transit, Passenger Vehicles, Variable Renewables, Non-Variable Renewables, Demand-side Management, and Energy Storage. There will need to be transformational shifts in national development planning, policy, and coordination with regards to these sectors.
- Influential non-forest interventions could include joint agriculture and forests programmes with emphasis on productivity, agroforestry, and climate-smart agriculture; reforming agricultural subsidies and fiscal incentives; tightening agricultural credit systems, including penalising financial institutions involved in deforestation; and conducting behavioural change campaigns in Europe, Brazil, China, and North America to reduce meat and dairy consumption.

Within the forests sector the most critical barriers to deployment are:

- The lack of political will to address deforestation and degradation, particularly currently in Brazil, alongside powerful interests in agriculture, mining and commodities, and conflicting government plans in forests, agriculture, and infrastructure.
- Insufficient and unreliable funding for reduced deforestation and degradation, re/afforestation and SFM, across all regions, from public sources and private carbon markets.
- The absence of a comprehensive and scalable PES model for both carbon and other goods and services.
- The absence, insecurity, and lack of transparency of land tenure, weak judicial capacity, and poor law enforcement.
- Slow progress in REDD+ in some countries, due to design complexities, and lack of REDD+ suitability in others.
- Low technical and administrative capacity, particularly in Southern and West Africa.

Interventions to address these barriers will consist of a combination of technical assistance and exchange of expertise and of results-based payments for forests mitigation. The UK should be prepared to make long-term commitments of 20 years or more, respecting the long timeframe for forest interventions to generate impact. Interventions should balance improvements at policy and institutional levels with more tangible programmes in the conservation and restoration of forests. Programmes should also be aware of technical and financial absorptive capacity issues in forest countries, especially in Southern and West Africa. The funding channels for interventions will vary – a combination of bilateral and multilateral channels will be necessary based on UK additionality and the strengths of existing multilateral mechanisms. Coordination between all donors and programmes needs to improve.

Re/afforestation and SFM interventions could include the following.

In regions with sizeable amounts of secondary forest and degraded land, such as Brazil, Ghana, Indonesia, Malawi, and Uganda, support large-scale re/afforestation via a results-based grant funding model, appropriate MRV, and drawing on the lessons of REDD+ preparedness and implementation. In recognition of the multiple benefits of forests, re/afforestation support should have several purposes, both commercial, for timber and agroforestry for example, as well as for non-monetised benefits like carbon sequestration and biodiversity. These benefits will appear in varying proportions depending on the project, some primary and some secondary. The type of deforestation would vary according to country and forest, tree, and soil type. Bilateral public funds could be used over the long term to design and pilot interventions, forge durable commitments with countries, generate best practices and lessons learned, and incentivise private sector participation and sustainable forest practices. Gender and social inclusion, indigenous and other community and business participation, and livelihoods generation will be vital.

Support SFM and associated socio-economic benefits in all regions via the deployment of bilateral public finances to incentivise private investment. In addition to carbon sequestration and biodiversity, this could include a variety of measures including mixed plantations, controlled use of fast-growing and exotic species, agroforestry, harvesting, and reduced-impact logging, increased tree rotation lengths, enhancing soil carbon, watercourse management, management of pests and diseases, and fire management.

To support reduced deforestation and degradation, interventions could include the following:

Enact improvements to REDD+ in all regions and in partnership with Germany, Norway and multilateral donors such as the World Bank and UN to make it more impactful and effective and to align it with other types of forests interventions. This would include:

Adjusting the readiness process for low-capacity environments in countries in which political economy, market failures, and enabling environment barriers continue to inhibit REDD+, including offering further capacity development on policy, property rights, inclusion, livelihoods, and conflict sensitivity, and consider how the MRV system can be adapted to the country context.

Advancing the system of MRV to reduce transaction costs, for example via scientific and technology developments, in countries in which capacity is improving and that are launching and/or receiving results-based payments.

Devising methods of MRV in dry forested countries like much of Southern Africa, identified based on forest canopy cover or proxies for carbon content, that are less suited to REDD+ due to forest types.

Support the enhancement of forests policy, strategy, and ambition with a focus on preventing policies for the conversion of forests to agricultural or other land uses, placing moratoria on forest conversion as Indonesia has done, and establishing protected areas.

Recognising that the presence and participation of indigenous and forest communities is one of the most effective barriers to deforestation and degradation, strengthen decentralised and participatory forest management through programmes to reduce deforestation and degradation and manage forests that involve them. They can be involved in MRV, monitoring land use concessions, and combatting commercial and illegal drivers of deforestation whilst supporting small and medium-sized enterprises and entrepreneurship and raising the benefits that these communities receive.

Support countries, states, and municipalities to form sustainable partnerships with international business interests to strengthen deforestation-free commodity supply chains and alter consumer demand.

This can leverage UK diplomatic influence around COP26 and build on initiatives such as the FCDO's and BEIS's Partnership for Forests, FLEGT and Bio-Carbon IFSL Programme as well as, weaknesses notwithstanding, the Consumer Goods Forum, the New York Declaration on Forests, the Tropical Forests Alliance, and the Cocoa and Forests Initiative. There need to be more companies and financial institutions making deforestation-free supply chain commitments, greater implementation of commitments already made, and efforts to avoid leakage.

To address enabling environment barriers and market failures, interventions could include the following:

Use BEIS and broader UK leverage and expertise, including via COP26, to ensure complementarity rather than competitiveness between forests and other land use and infrastructure policies and plans and transform the political narrative. Emphasis should be on national development plans and strategies, involvement of ministries of finance and planning, coordination between ministries of forests, environment, agriculture, energy, and transport, removal of competing agricultural and other subsidies, increasing agricultural productivity, land use planning, and transport and urban planning. Coordination and planning should also involve the state and local levels of government, as well as agriculture, logging, and mining businesses and associations, financial institutions, and forest and indigenous communities.

Enforce the law and strengthen judicial oversight at national, state, and local levels of government by bolstering judicial capacity via funding and training, putting remote sensing tools in place to detect and prosecute deforestation in protected areas, increasing transparency about land use changes, penalising individuals and businesses that are responsible for land use changes as well as financial institutions that fund them, seizing illegally converted land, and appointing forest law enforcement champions. Law enforcement should be fair in pursuing those responsible and avoid penalising marginalised communities, and efforts should be internationally coordinated with FLEGT.

Secure and clarify land tenure and land rights between government, business, smallholders, and communities, with particular attention to the rights of indigenous and forest communities and those that depend on forests for their livelihoods and live near forests. Important measures include the resolution of disputes between owners, effective and transparent land registries, and mapping of land boundaries for different types of community land, in partnership with FLEGT.

Where high political economy and commitment issues are apparent, as in all regions but particularly in Brazil, channel support on policy and institutional coordination, enforcement, and land tenure to state and municipal government, international businesses, national business associations, civil society, and indigenous groups and forest communities to strengthen coordination, implement jurisdictional and project approaches, and exert leverage on national governments. International partnerships of sub-national actors, such as the Governors' Climate and Forests Taskforce and Cities4Forests, can also be influential.

Offer long-term training and capacity development within national, state, and local governments, especially in Southern and West Africa, on issues of REDD+, re/afforestation, SFM, and PES, policy implementation, MRV, GHG emissions inventories, remote sensing technologies, law enforcement, partnership with indigenous and forest communities, and stakeholder engagement. Partnerships with national universities and forest and agriculture colleges will raise effectiveness and sustainability.

To increase funding to forests, interventions could include the following:

In all regions, establish comprehensive PES models and initiatives including all forest goods and services, encompassing biodiversity, flood prevention, water quality, and others in order to raise their value to economic actors dependent on forests or land conversion and increase the economic incentive to avoid deforestation and return land to forest. This will involve, firstly, understanding the full value of goods and services and the opportunity cost of forested land vis-à-vis other land uses in all regions, secondly, incorporating these values into public accounts, and thirdly committing sufficient public funds. Placing a value on a greater number of forest goods and services will need to be sensitive to affordability and access in the context of the needs, income, and livelihoods of local populations.

In Brazil, Indonesia, and South America, develop and improve domestic forest carbon policies and standards to establish standardised offset markets and increase private investment into forests, building on nascent and voluntary market initiatives such as CORSIA, ART/TREES, and California Tropical Forest Standard and the work of organisations such as Plan Vivo. Effective and transparent forest carbon policies, incentives, standards, and codes in alignment with financial market and credit risk regulation will strengthen offset markets and improve local capacity to adjust policies in the future, for example integrating into regional or global carbon markets or PES.

Intervention case studies

Box 24 Uganda Sawlog Production Grant Scheme (SPGS)[693]

By 1998, following a long period of internal instability, exacerbated by refugees from neighbouring countries, Uganda's forests were severely over-exploited with a concurrent severe shortage of sawn timber. Plantation resources had been inefficiently liquidated and seed stands destroyed, while field technical competence had been seriously eroded. The tree seed centre was unable to produce high quality seed that was true to type. The climate and soils are generally conducive to productive wood plantations: large grassland areas of degraded and, in forest reserves, were available for plantations.

The objectives of SPGS were to:

- Establish a rapidly maturing resource of utility timber to reduce pressure on natural forests;
- Engage a wider range of actors in growing timber to provide employment and income;
- Demonstrate good practices in plantation silviculture and inculcate required skills.

In pursuit of those objectives, the activities of SPGS were to:

- Define operating standards and register approved nurseries and contractors;
- Provide guidance on species choice, simple plan development, and training opportunities for field tasks – initially, only robust species were planted until skills levels rose;
- Visit all scheme participants to provide advice and check standards prior to payments, supported by an informative newsletter and simple technical publications.

As a consequence, the results of SPGS were:

- More than 45,000 hectares of high-quality plantations established within 15 years;
- Substantial forestry benefits accruing from well-manged planted trees, opportunities for diversification;

In the course of the programme, important clients and stakeholders were: Self-formed groups, larger farmers, contractors, tree nursery owners, Tree Growers' Association, commercial forestry companies; National Forestry Authority (NFA), Ministry of Finance, and donors.

Key risks managed during SPGS included:

- Elite capture, undermining of core strategy, and subsumption by government agency;
- Pests and disease risks, which were minimised by good nursery hygiene and correct species choice;
- Limited strategic level planning by NFA, which the project could not fully remedy;
- Exposure to tenure disputes amongst leaseholders in forest reserves;
- Lack of attention to road planning for extraction and group marketing opportunities.

SPGS provided multiple lessons and practical experiences which are:

- Results-based grant payments can deliver high quality plantations, i.e. there is no need for cash up-front;
- Most field tasks are within the capacity of average farmers if practical skills training is given;
- Regular contact with forest extension advisers is crucial for strong motivation and success;
- Commercial-scale companies can provide useful demonstrations of good practice, but grant levels must be reduced compared with those for small-scale planters;
- Low-growing intercrops can be grown by the tree owners, without conflict from differing owners, to increase early benefits.

Box 25 Bolsa Floresta Programme, 2007-2018

The Bolsa Floresta Programme (BFP) was launched in 2007 by the State of Amazonas, Brazil, in order to implement incentive-based forest conservation. It was one of the first initiatives in Brazil to rely on direct, conservation-conditional incentives to protect forests at large scale.[694] It is operated by a non-governmental organization, the Sustainable Amazonas Foundation (Fundação Amazonas Sustentável, FAS), which is co-financed by Amazonas State and the Amazon Fund, and has also been supported by multiple domestic and foreign private donors over the years.[695]

The objectives of Bolsa Floresta are to reduce deforestation and conserve biodiversity by improving livelihoods and increasing income of local residents with forestry and biodiversity products and by empowering residents of communities living in supported Conservation Units (CUs). It is important to note that the programme was aimed at meeting livelihoods with a consequence of reducing pressure on forest resources and achieving forest protection. It is also intended to promote involvement of communities in reducing deforestation and enhancing local appreciation of the standing forest.[696]

FAS established four modalities within the Bolsa Floresta Programme: (i) Family Bolsa Floresta, with a monthly payment of R$50 for the women of families living in CUs contingent on signing a zero-deforestation commitment (and not tied to complex conditions); (ii) Bolsa Floresta Association, earmarked for residents associations of the CUs to strengthen capacity and social organisation and increase community involvement; (iii) Bolsa Floresta Income, destined for the support of sustainable production to add value to and increase revenue of forest and biodiversity products; and (iv) Bolsa Floresta Social for collective actions aimed at improving education, health, communication and transportation.[697]

As a consequence, the results of BFP were:

- There are 35,000 participants from 15 protected areas covering roughly 10 million hectares;
- Over 90% of the families that participated in the educational workshops signed the formal commitment to zero deforestation;[698]
- Deforestation at the aggregate regional scale between BFP-implementing and comparable non-BFP reserves suggests that deforestation in BFP reserves has been reduced by 12% compared to the comparison group.[699]

In the course of the programme, important clients and stakeholders were local communities and leaders, Amazonas State Secretariat of the Environment and Sustainable Development, State Centre for Protected Areas, State Centre on Climate Change and the State Secretariat of Planning and Economic Development. And private sector actors.

Key risks and challenges which the BFP faced and managed follow:

- There is debate as to the extent of, and limitations in, enforcement of the conditionalities of conservation compliance associated with the programme;

[694] Forest Compass. (2007). The Bolsa Floresta Programme: direct incentive payments for forest conservation. https://forestcompass.org/case-studies/bolsa-floresta-programme-direct-incentive-payments-forest-conservation.html

[695]World Bank. (2019). Impacts of conservation incentives in protected areas: The case of Bolsa Floresta, Brazil. http://documents1.worldbank.org/curated/en/963101576773519234/pdf/Impacts-of-Conservation-Incentives-in-Protected-Areas-The-Case-of-Bolsa-Floresta-Brazil.pdf

[696] Brazilian Development Bank. (2019) Effective Evaluation Report. Bolsa Floresta Project http://www.fundoamazonia.gov.br/export/sites/default/en/.galleries/documentos/monitoring-evaluation/impact-evaluations-ex-post/Bolsa-Floresta_Effectiveness_Evaluation_Report.pdf

[697]Ibid.

[698] Viana M. (2010). Sustainable Development in Practice: Lessons Learned from Amazonas. https://pubs.iied.org/pdfs/17508IIED.pdf

[699] Borner Jan et al. (2013). Promoting Forest Stewardship in the Bolsa Floresta Programme: Local Livelihood Strategies and Preliminary Impacts https://www.cifor.org/publications/pdf_files/Books/BBorner1301.pdf

- There were no mechanisms to manage outside pressures on reserves and communities;
- Buy-in from stakeholders and ensuring local participation and buy-in from local communities was a risk during design and implementation;

These are the primary lessons from the BPF programme for BEIS.

- Benefit-sharing mechanisms within REDD+ programmes can simultaneously benefit the poor and protect forests. Results were achieved at relatively low cost, with strong support and engagement of local communities, and in an open, transparent and democratic process.
- The programme provides an example of how money can be disbursed through a combination of in-kind and cash payments. The system is a simple one, especially if it involves financially weaker section of the community, and can be adapted for other regions of the developing world.
- BFP implied a change both in actor and institutional structures. Engaging with the community, empowering and training community associations, and expanding general participation among households at all levels was key for the project to achieve impact.[700]
- Engaging stakeholders and local groups and empowering them to make decisions that contribute to sustainability of the programme is important. BFP was established by engaging the public – leaders of social organisations, public officials and researchers – in identifying and developing solutions that most help them and the forests. In cases where there were conflicts between urban and forest stakeholders, the project tended to favour those coming from communities.

Though the programme lacked sanctions, local peer pressure and behavioural change served to help with the issue of compliance, but when deforestation pressures are higher peer pressure may not be a sufficient incentive.

[700] Salviati V et al. (2017). Management regimes for REDD+An analysis of the regime in the RDS Rio Negro REDD+ pilot. https://www.eldis.org/document/A102073

Glossary

Acronym / Term	Definition
ART-TREES	Architecture for REDD+ Transactions – The REDD+ Environmental Excellency Standard
Avoided deforestation	Forest loss which occurs in the baseline scenario but does not take place in the low-carbon scenarios.
BAU	Business-as-usual
BECCS	Biomass energy with carbon capture and storage
BEIS	UK Department of Business, Energy and Industrial Strategy
BFP	Bolsa Floresta Programme
COP26	The 26th UN Climate Change Conference
CORSIA	The Carbon Offsetting and Reduction Scheme for International Aviation
CU	Conservation Unit
DAC	Development Assistance Committee
DFID	Department for International Development
EJ	Exajoule
FAO	Food and Agricultural Organisation of the United Nations
FAS	Fundação Amazonas Sustentável
FCDO	The Foreign, Commonwealth & Development Office
FCPF	Forest Carbon Partnership Facility
FLEGT	Forest Law Enforcement, Governance and Trade
Forest	An ecosystem with greater than 30% tree cover.
GHG	Greenhouse gas
Gt CO2e/year	Gigatonne carbon dioxide equivalent per year
ha	Hectare
ICF	International Climate Finance
IPCC	Intergovernmental Panel on Climate Change
MRV	Measurement, Reporting and Verification
Natural Forest Management	Includes reduced impact logging for climate, extended harvest cycles, increased post-harvest sequestration rates, and set-asides from logging activity. Does not include avoidable illegal logging emissions.
NDC	Nationally Determined Contribution
NFA	National Forest Authority
NGO	Non-governmental organizations
ODA	Official Development Assistance

Acronym / Term	Definition
PES	Payments for Ecosystem Services
RD&D	Research, design and development
Re/afforestation	The shift of non-forest cover to forest cover at the 30% tree cover threshold (includes afforestation with native trees).
REDD+	Reducing emissions from deforestation and forest degradation in developing countries, and the role of conservation, sustainable management of forests, and enhancement of forest carbon stocks in developing countries.
SDG	Sustainable Development Goal
SFM	Sustainable Forest Management
SPGS	Uganda Sawlog Production Grant Scheme

Agricultural Productivity

Summary

The agricultural productivity opportunity – encompassing agriculture and food production productivity enhancements – considers all mitigation measures in agriculture which have a demonstrable impact on productivity. The mitigation potential of this opportunity is large, being highest in regions with low agricultural productivity and/or high current rates of deforestation. Investment need is large in absolute terms, but moderately sized relative to energy opportunities assessed in the other companion opportunity reports. The cost-effectiveness and positive development impacts of the productivity-enhancing interventions considered in this analysis are generally high, due to measures often being cost-saving or income-boosting, leading to increased income security and reduced hunger. Barriers to adoption are significant, largely due to difficulties disseminating information amongst many small landholders, agricultural lobbies wielding significant political influence in many of the focus regions, and inadequate infrastructure existing in most of the focus regions. UK additionality is moderate due to the UK having strong historical support of agricultural development, but the agriculture development space already being crowded.

Interventions to encourage adoption of agricultural productivity enhancements in focus regions include:

- Technical assistance and capacity building for the construction of new infrastructure, application of natural solutions, and use of climate-smart agriculture practices.
- Collection and distribution of data for improved farm management decisions.
- Developing effective dissemination strategies that resonate with target farmers.

Table 42 Agricultural productivity assessment summary

Criteria	Assessment	Notes
Climate impact	High	• The mitigation potential of agricultural productivity enhancements is large by 2050 at well over a few gigatonne carbon dioxide per year (Gt CO2/year). • Precise estimates of the mitigation potential of productivity enhancements are not prevalent in the literature as they are difficult to quantify and depend heavily on uncertain projections over how crop yields will evolve in a baseline scenario.
Development impact	High	• Significant potential to achieve immediate and lasting impacts on most Sustainable Development Goals (SDGs), and particularly in addressing hunger and malnutrition; reducing poverty and promoting sustainable and equitable livelihoods; as well as building climate resilience, and promoting the sustainable use of water resources, soils, and the environment.
Investment need	Medium	• The absolute magnitude of the cumulative investment need is substantial at over USD 4 trillion to 2050, however, this figure is only moderately sized relative to the investment need assessed in the companion energy opportunity reports.
Cost-effectiveness	High	• Many agriculture productivity enhancement measures are cost-saving, leading to negative or close-to-zero marginal abatement costs. Measures that are necessary to couple with productivity enhancement measures, such as forest protection, are also relatively cheap in the regions assessed, at under 10 USD/t CO2.

Criteria	Assessment	Notes
Barriers to adoption	High	• Significant market failure-related barriers exist, including poor information dissemination networks, key knowledge gaps, and unpriced greenhouse gases (GHG) emissions. • Key political economy barriers exist, including powerful agricultural lobbies; these can stymie progress, as can productivity enhancement interventions that are overly simplistic and focus on technocratic or managerial solutions. • Significant enabling environment barriers include inadequate (food storage and distribution) infrastructure and limited agricultural data collection systems.
UK additionality	Medium	• Strong ongoing ties and historical track record in supporting agriculture sector development, especially within various target regions. • Leadership roles and collaboration building within multilateral programmes; albeit that the agriculture sector is a very crowded development space. • Significant donor funding provider, and solid track record in both Research, Design and Development (RD&D) and leveraging private sector participation.

Source: Vivid Economics, ASI & Factor

Key lessons for supporting mitigation through improving agricultural productivity:

- The development impacts associated with agricultural productivity enhancements are likely the, or one of the, highest among the 15 mitigation opportunities assessed. This is because these interventions can directly lead to both positive outcomes for farmers, through larger and more secure incomes and food sources, as well as for the surrounding environment, through reduced fertiliser use and the expansion and protection of forests.

- The full benefits of agricultural productivity increases will only be realised if productivity enhancing interventions focus on promoting climate-smart agriculture over conventional agriculture, and if forest protection policies are implemented to prevent productivity enhancements from leading to increased deforestation.

- Agriculture is a crowded development space and so interventions must be carefully selected to ensure that they have value in addition to programmes already in place.

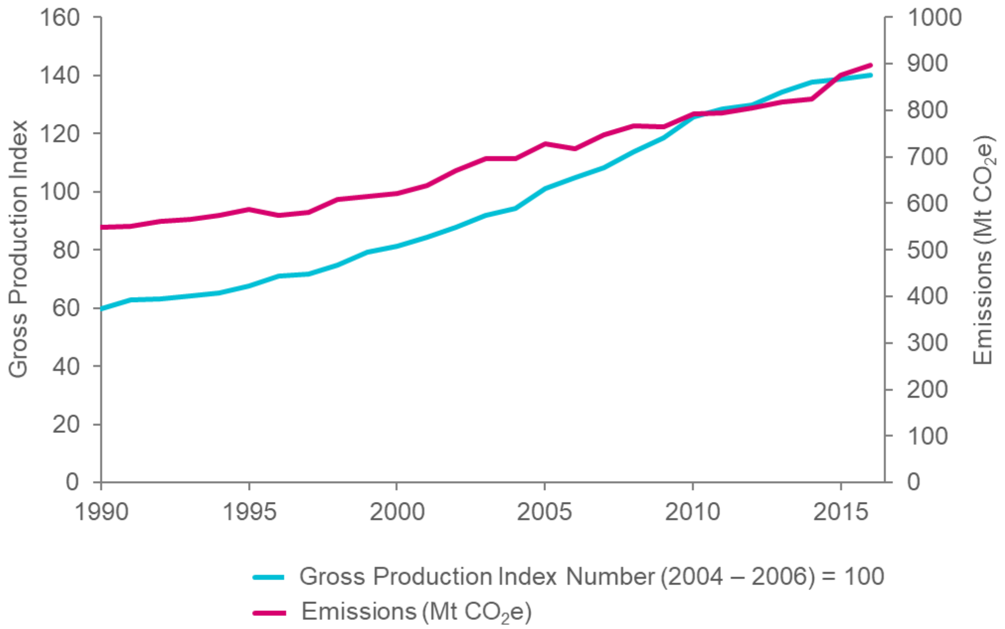
West and East Africa likely have the largest mitigation opportunities due to rapidly growing populations and low current productivity.

Introduction to the opportunity

Role of the opportunity in decarbonising developing countries

Agricultural emissions are large today and expected to increase further unless significant productivity gains are made across developing regions. According to the Intergovernmental Panel on Climate Change (IPCC), between 2007 and 2016, Agriculture, Forestry and Other Land Use (AFOLU) activities accounted for around 23% of total net anthropogenic GHG emissions.[701] Approximately half of these emissions came directly from agriculture, with the sector emitting over 5.4 Gt CO_2e/year in 2017, about 11% of global emissions.[702] As agriculture and food production activities are increasing internationally, emissions from agriculture are increasing further, especially in developing economies, as shown in Figure 38. While world agricultural emissions grew by 14% between 2000 and 2016, agricultural emissions in low income countries grew by 44%. This increase in agricultural emissions is driven by significant population growth as well as a growing demand for more emissions-intensive animal products in diets as countries get wealthier. A recent report from the World Resources Institute (WRI) estimates that, due to these drivers and without additional productivity gains, agricultural and associated land use emissions could increase from the 12 Gt CO_2e/year recorded in 2010 to over 37 Gt CO_2e/year in 2050. However, the report also concludes that almost all of this increase can be avoided through productivity enhancing investment.

Figure 38 Historical relationship between agricultural production and agricultural emissions in low income countries.



Source: Vivid Economics calculation from UN Food and Agriculture Organization (FAO) data.
Note: The data presented in this figure does not include emissions from agriculture-driven deforestation. Only data past 1990 is presented here as the FAO emissions calculation methodology changed in 1990, adding two new sources of GHG emissions.

The increasing carbon footprint of the agricultural sector in developing countries is due to both increasing direct agricultural emissions and indirect emissions through land use changes. Direct emissions from agriculture include emissions from livestock and their pastures, cropland management, and manure and fertiliser management. Mitigation of these emissions can be achieved through adopting climate-smart agriculture (CSA) or regenerative practices, many of which are productivity enhancing, as well as investments

[701] IPCC. (2019). Climate change and land: Summary for policymakers. https://www.ipcc.ch/site/assets/uploads/2019/08/4.-SPM_Approved_Microsite_FINAL.pdf
[702] Calculated from FAO (2019)., European Commission (2019) and Centre for Climate and Energy Solutions (2019).

to directly increase crop and livestock yields. Indirect land use emissions come from the conversion of land from its natural, often forested, state to make it agriculturally productive. Between 2001 and 2015, five mega hectare (Mha) of forest were lost each year globally, with over 50% of this deforestation being driven by commodities such as beef, soy, and palm oil as well as from shifting agriculture.[703] [704] Hence, emissions from deforestation can theoretically be reduced by increasing crop and livestock yields through RD&D, irrigation, and other infrastructure investments, to decrease the use of emissions-intensive inputs, such as land.[705]

Scope considered in this assessment

The agricultural productivity opportunity covers interventions that directly increase crop and livestock yields as well as CO_2 mitigation measures in agriculture which have a demonstrable impact on productivity. Therefore, the opportunity encompasses on-farm investments such as improved irrigation, improved product distribution infrastructure, research and development, and data-driven farm management practices as well as natural solutions, CSA, and regenerative measures which have a clear impact on productivity.

The assessment focuses on a subset of official development assistance (ODA)-eligible regions: West Africa, East Africa, Brazil, South America (excl. Brazil), henceforth 'South America', and India. These regions were chosen considering the total agricultural production, agricultural productivity, agricultural emissions, land use emissions, agricultural emissions intensity, land use emissions intensity, public agricultural RD&D spending, share of agricultural land that is irrigated, projected population growth, government effectiveness, and regulatory quality of each region. These indicators were selected as they are likely to represent the absolute and relative mitigation potential of investments in agricultural productivity enhancements and the likelihood of success of interventions in each region. This regional list was created in consultation with BEIS ICF stakeholders.

This assessment focuses on the benefit of supporting the opportunity as a whole and does not aim to comprehensively assess the effectiveness of specific investment opportunities or interventions. However, for context, potential specific investment opportunities to support productivity could include:

- Provision of support to agriculture productivity enhancement RD&D, especially in India and West Africa.
- Promotion and facilitation of private sector engagement (commercial sustainability) with initiatives to enhance agriculture productivity. This intervention is especially recommended for India and Eastern African countries.
- Provision of support and expertise for comprehensive rural infrastructure development planning and roll out. This could involve analysing the different options (and their respective merits and limitations) for scaling up food and agricultural product collection, processing, storage and distribution to market, and environmentally sustainable irrigation systems. It is recommended to focus on the regions of East Africa and West Africa.
- Support for the design and operation of data collection and dissemination systems for climate-smart and optimal farming and production decision-making, (including agriculture extension services, climate and weather data, service providers, and market demand and pricing data) and which could help optimise coordination and best practice dissemination. The Climate Intelligence and Data opportunity provides an in-depth assessment of data collection and dissemination interventions in all sectors, including agriculture. Prioritised regions for support include East Africa, West Africa, & India.

---

[703] Curtis et al. (2018). Classifying drivers of global forest loss. https://science.sciencemag.org/content/361/6407/1108
[704] Shifting agriculture is defined by Curtis et al. (2018) as small- to medium-scale forest and shrubland conversion for agriculture that is later abandoned and followed by subsequent forest regrowth.
[705] See Section 0 for discussion on why productivity enhancements on their own may not lead to reduced emissions from deforestation.

Case studies on some of the potential investment opportunities are detailed in Section 0.

Climate impact

Mitigation potential and urgency

The mitigation potential of agricultural productivity enhancements is large. A recent report by the WRI finds that investments into agricultural productivity enhancements are required to avoid growth of emissions from agriculture of around 25 Gt CO_2e/year by 2050.[706] The report suggests that continuing agricultural productivity increases at historical rates will result in approximately 90% of this mitigation. However, it should be noted that these historical gains were largely achieved through expanding industrial agriculture, which often have had detrimental environmental effects. In addition, historical productivity gains were largely funded by public investments into agricultural RD&D and, in developing regions, development assistance into productivity-enhancing infrastructure such as irrigation systems. Hence, without significant international public funding into both RD&D and expanding existing climate-smart management practices, it is unlikely that historical productivity gains will be continued in the future and deliver the large mitigation potential estimated by the WRI.

Investments in infrastructure, RD&D, and CSA measures and natural solutions will all likely contribute significantly to agricultural emissions reductions. Valin et al. (2013) investigate the differences in productivity enhancement mitigation potential delivered via improvements to infrastructure, RD&D, and climate-smart agriculture.[707] [708] They find that closing 50% of the world's yield gap via infrastructure improvements and conventional intensification can lead to about 450 Mt CO_2e/year of mitigation relative to a scenario where historical crop yield improvements continue. Delivering the same productivity gains through RD&D can lead to mitigation of about 300 Mt CO_2e/year. Productivity increases delivered via climate-smart agriculture measures are found to lead to the largest mitigation, of over 600 Mt CO_2e/year, while also avoiding many of the deleterious environmental side effects of conventional agriculture, such as agrochemical pollution and destruction of biodiversity. Unlike the WRI report, these estimates take into account feedbacks such as enhanced productivity leading to decreased prices, which stimulates demand, increasing production and emissions. Ignoring these feedbacks and accounting for the baseline used lead to estimates closer in magnitude to the WRI numbers.[709]

The mitigation opportunity is high and urgent across all focus regions, but how this mitigation is likely to be achieved varies across them. As illustrated in Figure 39, West and East Africa currently have very low agricultural productivity and high projected population growth rates over the next three decades. Without productivity enhancements, this suggests there will be large strains on local land systems and that emissions will increase to meet increases in local food demand.[710] Given the current low share of irrigated agricultural land in these regions, a large portion of the required mitigation from productivity enhancements will likely come from irrigation improvements. In Brazil and South America, the land use emissions intensity of agriculture is large due to high rates of commodity-driven deforestation, particularly from cattle ranching. Further, agricultural systems in Latin America are relatively emissions-intensive. This is in part due to the fact that the primary purpose of cattle ranching is often occupying land or storing value as a financial asset.[711] [712] Therefore, much of the mitigation potential in this region will likely be achieved through the adoption of livestock productivity enhancing measures, CSA, and regenerative measures, but also legislation and enforcement that address issues related to land tenure and access to financial services. India has one of the

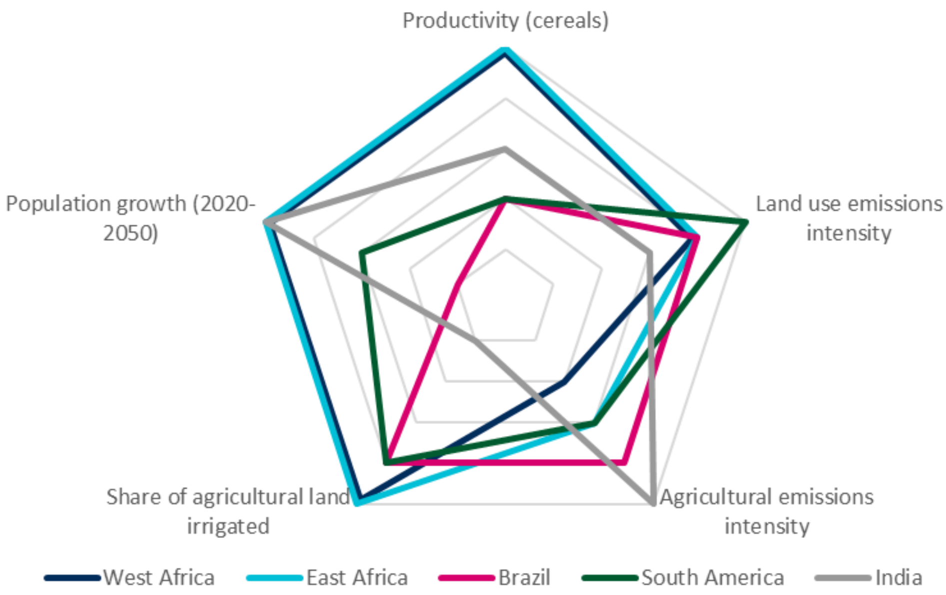
[706] World Resources Institute. (2019). Creating a sustainable food future. https://wrr-food.wri.org/sites/default/files/2019-07/creating-sustainable-food-future_2_5.pdf
[707] Valin et al. (2013). Agricultural productivity and greenhouse gas emissions: trade-offs or synergies between mitigation and food security? https://iopscience.iop.org/article/10.1088/1748-9326/8/3/035019/meta.
[708] Valin et al. (2013) label one of their pathways "sustainable intensification", which largely overlaps with the definition of climate-smart agriculture employed here as it includes productivity gains/abatement from optimised rotation, crop-livestock system integration, and precision farming.
[709] The World Resources Institute (2019) estimates that agricultural productivity enhancements can deliver about 2 Gt CO_2e/year of mitigation in 2050 relative to a baseline where yields increase at historical rates. When ignoring feedbacks, Valin et al. (2013) find that closing the world's yield gap by 50% via sustainable intensification will lead to about 1.6 Gt CO_2e/year by 2050, relative to a baseline where yields increase at historical rates.
[710] This is assuming imports cannot sustainably support this growth, given food security and poverty concerns.
[711] Monga Bay. (2019). Brazil fails to give adequate public access to Amazon land title data, study finds. https://news.mongabay.com/2019/03/brazil-fails-to-give-adequate-public-access-to-amazon-land-title-data-study-finds/
[712] Thornton, PK. (2010). Livestock production: recent trends, future prospects. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC2935116/

most emissions-intensive agricultural sectors of the developing world and so much of the country's mitigation potential is likely to come through adopting CSA and regenerative practices. Given the rapid growth in population, forest-risk commodity exports, and/or consequent rates of deforestation in these regions, early investments into productivity enhancements are important to avoid the continued rapid expansion of agricultural land and emissions-intensive practices.

Much of the mitigation potential in Brazil, South America, and West Africa comes via avoided commodity-driven deforestation, but to achieve this mitigation productivity enhancements must be coupled with strong forest conservation policies to prevent productivity increases leading to additional agricultural expansion. While agricultural productivity enhancements are likely essential in achieving goals to reduce deforestation,it is not guaranteed that improved productivity will automatically lead to reduced deforestation. The opposite effect could theoretically hold, due to higher productivity leading to an incentive to further expand agricultural land. However, recent research suggests that if zero-deforestation policies are coupled with productivity investments, both crop output growth and zero-deforestation goals can be achieved. Assuncao and Braganca (2019) find that investments in productivity coupled with forest-protection policies can lead to a 79-105% increase in crop output and a 27% increase in beef output without any additional deforestation. [713] In fact, Koch et al. (2019) find that forest conservation policies may actually induce productivity increases as they incentivise farmers to invest in on-farm capital rather than forest-clearing. [714] There is also some historic evidence to suggest that productivity enhancements on their own do not lead to increased deforestation. Assuncao et al. (2016) assess the deforestation impacts of five productivity shocks, through increased electrification, between 1970 and 2006 in Brazil. [715] The paper finds that increased productivity leads farmers to expand crop farming but shift away from cattle ranching. On balance, this leads to a net decrease in deforestation.

[713] Assuncao & Braganca. (2019). Pathways for sustainable agricultural production in Brazil: necessary investments and potential gains of increasing efficiency. https://climatepolicyinitiative.org/publication/pathways-for-sustainable-agricultural-production-in-brazil/
[714] Koch et al. (2019). Agricultural productivity and forest conservation: Evidence from the Brazilian Amazon. https://academic.oup.com/ajae/article/101/3/919/5376645
[715] Assuncao et al. (2016). Agricultural productivity and deforestation in Brazil. https://climatepolicyinitiative.org/wp-content/uploads/2017/06/Agricultural-Productivity-and-Deforestation-in-Brazil-CPI.pdf

Figure 39 The relative importance of selected indicators for each of the focus regions.



Source: Vivid Economics, ASI and Factor calculation from FAO, United Nations and World Bank data. Cereals productivity and emissions data from 2017 and 2018. Share of irrigated land data is from most recent year available.

Note: For each indicator above, all 15 ODA-eligible regions were divided into quintiles. This figure shows which quintile the five focus regions fall into for selected indicators. For all indicators, quintiles have been constructed so that a high quintile (illustrated as being farther from the centre of the diagram) signifies a high mitigation potential. For example, if productivity is low, the region will receive a high score as there is high potential to improve productivity leading to mitigation. Further, note that West Africa and East Africa fall into the same quintile for four out of the five indicators. For these indicators, though the quintile is the same, the line on the graph that represents West Africa is shown just below the East Africa line so that both are displayed on the graph.

Transformational change

Enhancing agricultural productivity offers enormous potential for transformational changes in the economy. Almost all of today's advanced countries industrialised by improving agricultural productivity, and the 'virtuous' development cycle that is unleashed by increasing agricultural productivity is the quintessential example of transformational change in economies. Within the agriculture sector, increasing productivity supports rising rural household income, which in turn increases local demand and capacity to invest, which stimulates further growth and activity. Agricultural productivity investments also spill over into the wider economy by improving labour productivity, which allows rural labour surpluses to move to higher wage jobs in industry, which increase incomes and therefore stimulates local economic activity. This economic transformation can unlock better outcomes especially for women and children, whose disproportionate share of on-farm and household labour can instead be put toward education or outside job opportunities.

Strategic investments in agricultural productivity now also have potential to create transformational change to benefit the environment. Strategic, catalytic investment now, especially in innovative approaches such as climate-smart or regenerative agriculture and its enabling environment, could help break the patterns of development that expand conventional agriculture. Conventional efforts to enhance agricultural productivity (e.g. through intensive fertiliser use) can result in large GHG emissions increases. It is critical that future agricultural productivity enhancements are designed to minimise GHG emissions. Hence, climate-smart and regenerative agriculture approaches should play a central role in efforts to enhance agricultural productivity in developing countries. Supporting actions targeting key sensitive intervention points – including improving local capacities and creating incentives for others to act (and invest) – could help catalyse a wholesale shift towards high production and climate-smart agriculture. Conventional agriculture has not only contributed to high emissions of greenhouse gases but is also one of the single greatest contributors to the destruction of biodiversity and other natural habitats. Supporting productivity enhancements can also amplify efforts to reduce the rate of deforestation and land conversion by offering viable livelihood alternatives.

All five of the focus regions offer substantial opportunities for agricultural productivity investments to create transformational change. Catalysing transformational change is difficult and identifying the 'tipping point' investment to create that change is even harder. Nevertheless, Table 43 below lays out enabling criteria for transformational change and identifies the most promising interventions in each focus region.

Table 43 Agriculture and food: productivity enhancements assessment summary

Transformational change criterion	Interventions to support change	Regional potential
Sensitive intervention points		
Improvement of local capacities and capabilities	Measures that support capacity building of local agricultural authorities (e.g. regional irrigation authorities) can, for example, directly improve governance, effective regulation design, and infrastructure management.	East Africa and West Africa
Local ownership and strong political will	Measures to bring farmers to the efficiency frontier (e.g. provision of technical assistance to farmers) can help to build up local ownership and buy-in to productivity enhancement objectives.	East Africa, India, and West Africa
Leverage / creation of incentives for others to act	Off-farm measures to improve the size and security of revenue streams (e.g. support for well-informed planning of rural infrastructure and physical networks), can create service provision and infrastructure investment opportunities that are likely to be taken up by the private sector. Measures that promote and facilitate private sector engagement with initiatives to enhance agricultural production can directly leverage further investment.	East Africa, India, and West Africa
Spillovers		
Broad scale and reach of impacts	Many off-farm measures to improve the size and security of revenue streams (e.g. support for coherent rural infrastructure development planning) can unlock wider economic opportunities and the enhanced connectivity of communities.	All regions
Sustainability (continuation beyond initial support)	Certain off-farm measures to improve the size and security of revenue streams (e.g. support for coherent rural infrastructure development planning, food processing and storage facilities, irrigation systems) have operating lifetimes well beyond the period of intervention.	All regions (especially in East Africa and West Africa)

Transformational change criterion	Interventions to support change	Regional potential
	Innovation	
Catalyst for innovation	Measures designed to bring farmers to the efficiency frontier (e.g. promoting the uptake of innovative climate-smart agriculture and regenerative approaches), as well as those to control unwanted side effects on the natural environment (e.g. rolling out agroforestry and other agroecological approaches) can involve the use of approaches and techniques that are highly innovative and novel in the target regions.	All regions
Evidence of effectiveness is shared publicly	Measures to bring farmers to the efficiency frontier (e.g. support in the design and operation of data collection and management systems) can support better farm management decisions by all farmers when systems are publicly accessible (e.g. information broadcasts via public radio). Efforts to support RD&D activities and centres, with emphasis on widespread results dissemination, can facilitate uptake of new practices amongst the RD&D community and farmers.	East Africa, India, and West Africa

Source: Vivid Economics, ASI and Factor

Two intervention types in particular lend themselves to creating transformational change:

- **Measures to bring farmers to the efficiency frontier** through the development of human capacities, skills, and knowledge networks. Agricultural extension networks, or programmes designed to improve the awareness and dissemination of production technology and best practices, are a key factor in enabling transformation. The current norm of farmer-to-farmer knowledge transfer in much of the developing world has dramatically slowed uptake of improved seed varieties and farm management practices throughout all five focus regions. Investment in the public agricultural research organisations and universities that help inform those best practices could complement extension efforts, especially in Brazil, and East and West Africa.

- **Off-farm measures to improve the size and security of revenue streams**, particularly access to markets, can support more reliable and efficient availability of inputs and delivery of products. This pairs well with improved knowledge networks, ensuring that farmers have easy access to the inputs they need. Efficient market access allows farmers more optionality of what to grow, and enable price premia for certified products, such as those enjoyed by organic foods. It also comes with reduced food waste; through being able to keep produce fresher for longer (via improved storage infrastructure) and deliver products to market in a timelier manner (via improved road networks). Certified products can also be easier to sell and allow access to additional markets. Moreover, by producing a wider range of foods, farmers can control production levels of each food type to obtain optimal quantities of each (with respect to market demand) whilst also ensuring that, across their activities, they obtain sufficient income. Therefore, reducing food waste simultaneously boosts farmer income and realised productivity.

Development impact

SDG impacts

Agriculture is central to the Sustainable Development Goal (SDGs) framework via its many positive development impacts. Its importance is particularly strong in rural areas, where it is often the principal source of employment and income, but it also supports good health and strong communities in urban settings, notably by supplying affordable and fresh food.[716] Table 44 illustrates impact by SDG.

Table 44 Impacts of the agriculture and food sector on the different SDGs

SDG	Strength of impact	Most relevant region	Rationale
Positive impacts			
SDG 1 – No poverty	High	All regions, esp. in certain East African nations (and esp. cattle farmers)	Higher production will facilitate increased revenues, lifting more farmers out of poverty and providing more financial stability. Agriculture productivity enhancements can allow farmers to diversify their income streams.
SDG 2 – No hunger	High	All regions	Increased quantities of food and crops will help meet overall (increasing) demand for food driven by a growing population, thereby contributing to increased food security.
SDG 3 – Good health and well-being	Medium	All regions	Adequate nutrition is central to good health. More efficient production techniques will provide farmers with more time for non-work activities.
SDG 4 – Quality education	Medium	All regions	Nutritional adequacy encourages school attendance and educational efficiency. Reduced labour and time input requirements can increase the available time for school attendance and studying.
SDG 5 – Gender equality	Medium	All regions	Women are a central part of the agriculture workforce, but often face higher risks (e.g. underrepresented in land and title rights).
SDG 6 – Clean water and sanitation	Medium	Especially in India, and some South American countries	Water use in agriculture can severely affect overall water demand. Water scarcity, poor water quality, and inadequate sanitation affect food security. Well-planned agriculture irrigation systems and climate-smart agriculture approaches can significantly reduce water use compared to conventional systems, thereby increasing access to clean water and sanitation.
SDG 7 – Affordable and clean energy	Low	All regions	Energy is a central input in agricultural processes, but a dirty one where no access to modern forms of energy is available.
SDG 8 – Decent work and economic growth	Medium	All regions	Development of modern agricultural sectors has huge job generation potential and can lower drudgery. Productivity enhancements can also help to increase and diversify revenue streams for rural farmers (especially cattle farmers).
SDG 9 – Industry, innovation and infrastructure	Medium	All regions, esp. East Africa and West Africa	The functioning of agricultural systems and their productivity are directly linked to the existence of infrastructure for transport and market access.

[716] FAO. (2018). Transforming Food and Agriculture to Achieve SDGs. http://www.fao.org/3/I9900EN/i9900en.pdf.

SDG	Strength of impact	Most relevant region	Rationale
SDG 10 – Reduced inequalities	High	All regions	Improving access to food, land, health, revenue streams, and education for farmers, who often live on the breadline, can help address inequality.
SDG 12 – Responsible consumption and production	Medium	All regions	Reduced land requirements per unit output eases pressure to create new farmland (deforestation); reduction in spoilage of produced food.
SDG 13 – Climate action	Medium	All regions	Significant opportunities for GHG mitigation and boosting resilience to climate change impacts.
SDG 15 – Life on Land	Medium	All regions	Financing sustainable agriculture contributes to life on land.
SDG 16 – Peace, justice and strong institutions	Medium	All regions, esp. East Africa	Food insecurity can multiply stresses and tensions that affect the peaceful functioning of societies and countries.
SDG 17 – Partnerships for the goals	Low	All regions	Partnerships are promoted which allow the global community to collaborate on key intervention areas (e.g. data collection; leverage of finance).
Negative impacts			
SDG 6 – Clean water and sanitation	Medium	Especially in India, and some South American countries[717]	Some irrigation systems can put huge pressure on water tables and may cause excessive salination of soils.

Source: Vivid Economics, ASI and Factor

[717] Some irrigation systems can result in significant salination of soils and water bodies and divert critical water resources from other needs especially when agriculture production is increased.

Demand in target regions

Interventions that enhance the productivity of agriculture and food production have differing levels of demand in target regions, as set out in Table 45.

Table 45 Demand in target regions

Region	Demand	Rationale
East Africa	Moderate-high	Nationally Determined Contributions (NDCs) focus on enhancing food production and boosting climate change resilience. Limited but growing RD&D capacities. 80% of livelihoods directly linked to agriculture.
West Africa	High	NDCs focus on enhancing food production and boosting climate change resilience. High deforestation pressure in selected countries. Early stage regional cooperation initiatives to enhance agricultural productivity.
Brazil	High	High interest around productivity enhancement; limited ambition on climate mitigation or resilience. Substantial agricultural research track record and capacities. Very significant deforestation pressures.
India	High	NDC has focus on agriculture productivity enhancements and climate-resilient agriculture. Government agriculture strategy aims to double farmers' incomes through productivity enhancements (including leveraging private sector participation, diversifying production, reforming policy, and improving agriculture marketing).
South America	Moderate-high	Major exporting region of agricultural commodities, NDCs set clear aims on productivity improvements. Inter-country variation on demand, state of rural infrastructure, and extent of competition with forested areas for land.

Source: Vivid Economics, ASI and Factor

Improving agriculture and food productivity is a longstanding key strategic goal in all five focus regions. The important role of agriculture in the economies of each region, combined with the fact that agriculture is a dominant source of livelihoods, means that agricultural productivity features prominently in national strategies (including strategies to support adaptation to the impacts of climate change; please refer to Box 26, below). Progress has been made across all five regions, but enormous potential remains to improve productivity further. Agricultural productivity is often the subject of entire national strategies in target regions, but considering the NDCs within each region offers an indicative view of demand:

- The NDCs of East African countries feature provisions for sustainable agriculture but using it to deliver climate mitigation is not generally a priority. They instead focus on increasing total food production while building climate resilience. Kenya, for example, established a climate change law in 2016, with the specific aims to develop, manage, implement, and regulate mechanisms to enhance climate change resilience and low-carbon development. Agriculture is central to the East African regional economy, and is the basis of livelihoods for around 80% of the region's population.[718] There is significant demand to consolidate agriculture RD&D capacities; improve regional level cooperation for agriculture productivity enhancement; and to facilitate the transfer of agricultural technology, information, and knowledge across national boundaries in East Africa.[719] A key initiative is the First

[718] East African Community. (2020). Investment in agriculture. https://www.eac.int/investment/why-east-africa/investment-opportunities/agriculture#:~:text=Agriculture%20is%20a%20sector%20that,80%25%20of%20the%20region's%20population.
[719] ASARECA. (2020). The East African Agricultural Productivity Programme (EAAPP). https://www.asareca.org/printpdf/4108

Agricultural Productivity Program Project for Eastern Africa being driven by Ethiopia, Kenya, Tanzania, and Uganda.[719]

West African countries typically also place considerable emphasis on the need to enhance agricultural productivity. The NDCs of West African countries typically feature provisions for implementing sustainable and environmentally low-impact agriculture, and delivering production gains, as well as building climate change resilience. There is severe agricultural commodity-driven deforestation, especially in Nigeria and the Ivory Coast. The West Africa Agricultural Productivity Program (WAAPP) is a regional cooperation programme that works to achieve agricultural sector growth and increased food production and availability in West Africa, by technological innovation, improving enabling environments, capacity building, creating employment, engaging women, and building resilience to climate change.[720]

Agricultural productivity growth remains a priority in Brazil, with historic improvements being driven by investments in agriculture innovation, facilitation of sector financing, and trade liberalisation. Brazil's NDC includes provisions for sustainable low-carbon agriculture. In recent years, Brazil's central government has shown significantly reduced levels of ambition for climate change mitigation, but improving productivity and farm incomes remains a priority. Climate change law and policies exist at both national and regional levels in Brazil, with regional level ambition often substantially higher compared to measures and targets mandated at the national level. Brazil is considered to be a world leader in the RD&D of certain agricultural techniques (e.g. replacement of nitrogen fertilisers with biological fixation).[721] Agriculture productivity improvement would help alleviate significant deforestation pressure on the Amazon rainforest.

India's NDC includes provisions for agriculture productivity enhancement, especially with regard to vulnerability and adaptation to climate change. The overarching priorities of the national government as regards the India's agriculture sector are contained within the Government's Union Budget,[722] National Development Agenda, and the 3-year Action Agenda.[723] The key objective is to double farmers' income, which will be achieved by enhancing production. The strategy for achieving this will involve increasing private sector participation, diversifying into high-value agricultural goods, reforming agricultural land leasing policy, and improving agriculture marketing at state levels.[723] Indian central government policy also aims to enhance production through climate-smart agriculture, integrated soil management, and the uptake of organic farming and sustainable (efficient) irrigation practices.

In South America, most countries' NDCs include provisions for enhancing agriculture production while also helping address other goals such as GHG mitigation, climate change adaptation, and reducing vulnerability. Food security is a motivating concern for productivity investments, as is environmental protection, improving smallholder farmers' access to markets, and increasing foreign exchange earnings.[724] Demand varies markedly throughout the region, with significant differences in the state of rural infrastructure and the degree to which agriculture competes with forested areas for land. South America has positioned itself as a leading exporter of agricultural commodities,[725] with major exports of soya beans, pork, maize, poultry, animal feed, sugar, coffee, and fruits and vegetables.

[720] The WAAPP was created by the Economic Community of West African States (ECOWAS) and is funded in part by the World Bank. Participating countries include Benin, Burkina Faso, Côte d'Ivoire, The Gambia, Ghana, Guinea, Liberia, Mali, Niger, Nigeria, Senegal, Sierra Leone, and Togo. Source: World Bank, 2016. WAAPP. https://www.worldbank.org/en/topic/agriculture/brief/the-west-africa-agricultural-productivity-program#:~:text=The%20program%20aims%20to%20achieve,disseminate%20and%20adopt%20improved%20technologies
[721] Agrilinks. (2018). Policy tools to transform agriculture: The Brazil experience. https://www.agrilinks.org/post/policy-tools-transform-agriculture-aspects-brazil-experience
[722] Indian Ministry of Finance.(2020). Union Budget. https://www.indiabudget.gov.in/
[723] FAO. (2018). Country programming framework for India. http://www.fao.org/3/I9066EN/i9066en.pdf
[724] OECD/FAO. (2019). OECD-FAO Agricultural Outlook 2019-2028: Chapter 2. Latin American Agriculture: Prospects and Challenges. http://www.fao.org/3/CA4076EN/CA4076EN_Chapter2_Latin_American_Agriculture.pdf
[725] FAO. (2019). Latin American agriculture: prospects and challenges. http://www.fao.org/3/CA4076EN/CA4076EN_Chapter2_Latin_American_Agriculture.pdf

Brazil is the largest agricultural and food exporter in South America, followed by Argentina, Mexico, Chile, Ecuador, and Peru.

Box 26 Adaptation to climate change in the agriculture sectors of the target regions

In each of the considered target regions it is important to ensure that agriculture and food production productivity enhancement efforts also serve to increase the sector's resilience to the impacts of climate change and support timely and cost-effective adaptation.

In 2017, a report (*10 best bet innovations for adaptation in agriculture: A supplement to the UNFCCC National Adaptation Plan technical guidelines*[726]) was published that summarised a vast body of research on agriculture in the global South and its performance in the context of climate change. It provides a distillation of the longstanding and extensive research conducted by the 15 international agricultural research centres that constitute CGIAR. Its findings are intended to inform countries' ongoing efforts to develop effective National Adaptation Plans (NAPs) and associated national adaptation strategies. The 10 best bet innovations recommended and elaborated within the report are agroforestry, aquaculture, stress tolerant seed varieties, improving smallholder dairy production, alternative wetting and drying in rice systems, solar irrigation, digital agriculture, climate-informed advisories, weather-indexed agricultural insurance, and scaling up finance for farming.

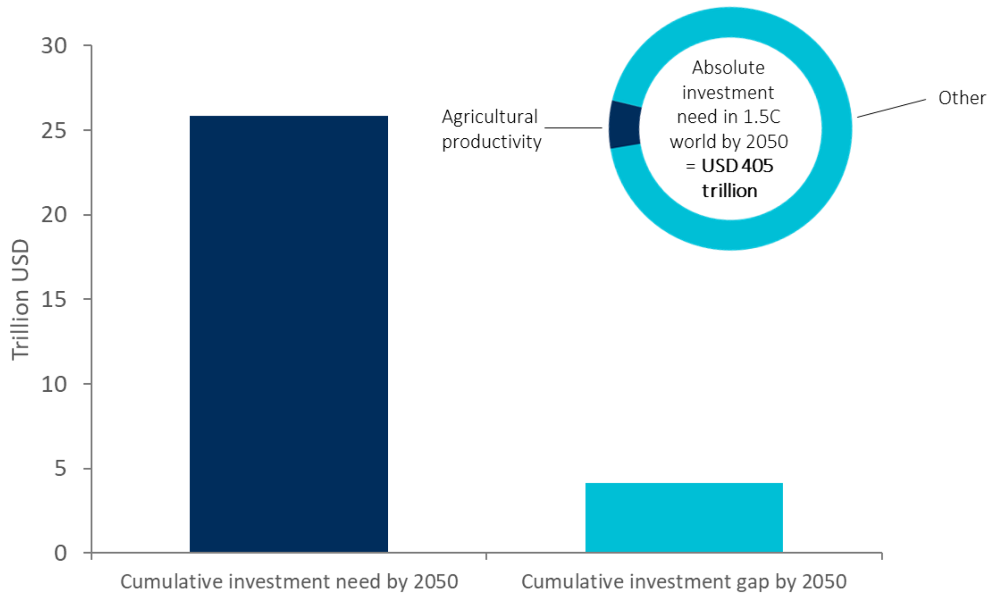
By considering both climate change mitigation and adaptation perspectives, a fuller picture will be obtained regarding the needs and opportunities these countries face in improving their agriculture and food systems. The lesson for the present analysis is that interventions should be designed to heed the concerns flagged by the NDC documents insofar as possible, while also seeking to ensure its recommendations and activities are aligned with the NAP documents of these countries.

[726] CGIAR. (2017). 10 best bet innovations for adaptation in agriculture: a supplement to the UNFCCC NAP Technical Guidelines. https://cgspace.cgiar.org/bitstream/handle/10568/89192/http://CCAFSWP215.pdf

Investment need

The projected annual investment gap in low- and middle-income regions under a 1.5-degree scenario is estimated to be large in the short term, at approximately USD 90 billion in 2030 and growing to over USD 300 billion by 2050. Investment need estimates are produced by the global land use model MAgPIE and cover the investment need in improved irrigation as well as general productivity enhancements through technological change.[727] As illustrated in Figure 40, the model results suggest that the cumulative investment gap in agricultural productivity enhancements between the present and 2050 in low- and middle-income countries is estimated to be over USD 4 trillion. Approximately USD 39 billion of the annual investment gap in 2050 are from irrigation improvements, while the remaining USD 262 billion is required for general technological change. These modelled investment figures do not include the cost of climate-smart agriculture measures. However, many of these measures are not capital intensive and so will likely have a comparatively small investment need.

Figure 40 Cumulative investment need in absolute terms and relative to business-as-usual (BAU).



Source: Vivid Economics, ASI and Factor calculation from forthcoming work for Orbitas.

Note: Data presented here is from the global land use model MAgPIE, whereas model output in the rest of this report is from the integrated assessment model IMAGE. MAgPIE results are used here since IMAGE does not generate investment need estimates for the agriculture sector. The bar on the left is the total cumulative investment need by 2050 in a 1.5-degree scenario and so includes both the additional investment need expected under this scenario as well as the investment expected to be met by the private sector in a business-as-usual scenario. The bar on the right is the "investment gap" between the investment needed in a 1.5-degree and a BAU scenario.

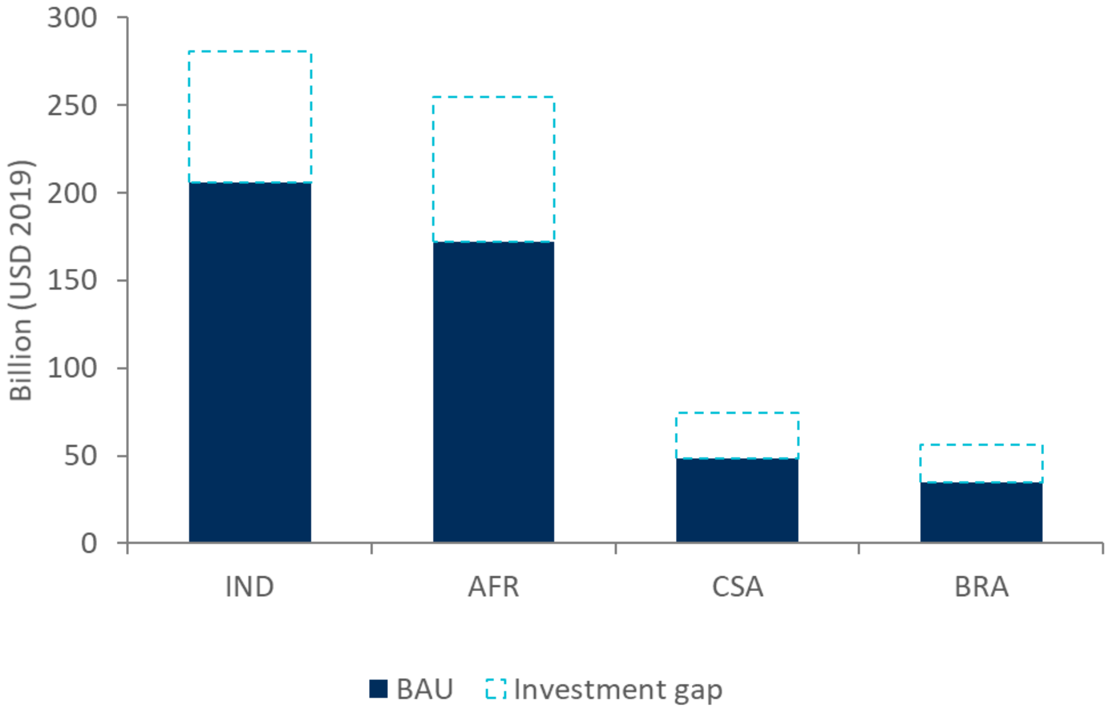
[727] General technological change investments include investment in RD&D and infrastructure for transport, energy distribution, telecommunications, and financial services (but MAgPIE does not allow disaggregation of investment need to these smaller groups). Hence, these investment need estimates do not directly capture the costs of all mitigation measures covered in this opportunity. For example, the RD&D expense of testing the efficiency of using perennial rice varieties is captured, however, the cost of incentivising uptake and acquiring the new varieties is not. For more information on how investments in productivity are captured in MAgPIE, see Dietrich et al. (2014). Forecasting technological change in agriculture—An endogenous implementation in a global land use model. https://www.sciencedirect.com/science/article/pii/S0040162513000279?via%3Dihub

The investment gap in 2050 is estimated to be largest in Africa and India, reaching close to USD 80 billion/year by 2050 in each.[728] Figure 41 displays the modelled annual investment in agricultural productivity enhancements under a business as usual scenario in 2050, as well as the required additional investment in a 1.5-degree scenario, labelled the "investment gap". The figure shows Africa and India as the regions with the largest investment gap in 2050, although the investment gap is still large in Brazil and Central and South America, at USD 21 billion/year and USD 26 billion/year, respectively. While these numbers do not allow for disaggregation by region in Africa, it is likely that investment need will be highest in East and West Africa due to low productivity, higher projected population growth, and greater agricultural output than Northern and Southern Africa. Irrigation improvements make up close to 50% of the total investment need in Africa. The large investment need in irrigation improvements and, more generally, agriculture infrastructure in Africa is corroborated by a recent report by McKinsey & Company, which finds that increasing agricultural production by approximately 150% in Sub-Saharan Africa will require cumulative investments of USD 65 billion in irrigation systems and USD 8 billion in storage facilities.[729] The required investment in irrigation improvements in Brazil similarly accounts for half of the country's total investment need, while the investment need into irrigation improvements for the rest of Central and South America makes up approximately one third of the region's total investment need into productivity enhancements. In India, however, less than 2% of the investment need is in irrigation improvements. These investments lead to large productivity gains in each region. Agricultural productivity increases by close to 130% in India, 80% in Africa, 76% in Central and South America, and 57% in Brazil.

[728] Investment data presented here are from the global land use model MAgPIE, whereas model output in the rest of this report is from the integrated assessment model IMAGE. MAgPIE results are used here since IMAGE does not generate investment need estimates for the agriculture sector. Regions in MAgPIE differ slightly from those in IMAGE, explaining why the regional breakdown above differs from the regional breakdown elsewhere in the report.

[729] McKinsey & Company. (2019). Winning in Africa's agricultural market. https://www.mckinsey.com/industries/agriculture/our-insights/winning-in-africas-agricultural-market#

Figure 41 Annual investment need in 2050 under BAU and investment gap in a 1.5-degree scenario by region.



Source: Vivid Economics, ASI and Factor calculation from forthcoming work for Orbitas.

Note: Data presented here are from the global land use model MAgPIE, whereas model output in the rest of this report is from the integrated assessment model IMAGE. MAgPIE results are used here since IMAGE does not generate investment need estimates for the agriculture sector. Regions in MAgPIE differ slightly from those in IMAGE, explaining why the regional breakdown above differs from the regional breakdown elsewhere in the report. IND = India; AFR = Africa; CSA = Central and South America; BRA = Brazil.

Cost-effectiveness

The cost-effectiveness of investments into agricultural productivity is on average very high, with some interventions achieving net cost savings. Interventions can be classified into four groups, within which the cost-effectiveness of interventions are relatively similar. Cost-effectiveness therefore varies by region according to the class of intervention required in the region; regional suitability of each intervention type is discussed in Section 0. The four classes are:

Measures to bring farmers to the efficiency frontier. This group covers interventions which increase RD&D and infrastructure investments. A recent review of 113 studies spanning 39 years and 25 African countries assessed the average Internal Rates of Return (IRR) of food and agricultural research (i.e. research-enabled growth in agricultural productivity) conducted in, or of direct consequence for, Sub-Saharan Africa[730]. The study found a mean IRR of 47.5% in West Africa, and 37% in East Africa. Zou et al. (2013) found that in China investments in channel lining irrigation have negative marginal abatement costs, and that the costs of other irrigation investments per unit of additional output were below average grain prices, indicating that it is profitable for farmers to invest in irrigation improvements.[731]

Measures to mitigate GHG emissions. This class captures interventions that stimulate the implementation of climate-smart agricultural practices that can impact productivity. Recent analysis by McKinsey & Company on GHG reduction options in the agriculture sector finds that of a total 25 proven technologies and measures, 15 have marginal abatement cost values of zero or less.[732] Note that there are a variety of promising technical mitigation interventions with unclear or negative productivity impacts covered in the first phase of research but not taken forwards for additional analysis within these opportunity reports.

Measures to control unwanted side effects on the natural environment, such as deforestation, soil degradation, and biodiversity loss. This group covers policy changes that aim to keep agricultural productivity enhancements from leading to negative environmental outcomes. A common policy to reduce agricultural expansion into natural areas is area protection, for which the primary cost is compensating landowners for lost revenues from their land, for example income that would have come from timber harvesting or converting to cropland. Overmars et al. (2014) estimate this cost by comparing the costs and mitigation benefits associated with forest protection[733]. They find that the cost of forest protection in Sub-Saharan Africa is less than 2 USD/t CO_2 while in Central and South America it is between 4 and 7 USD/t CO_2.

Off-farm measures to improve size and security of revenue streams. This class includes interventions that improve farmers' access to markets, credit, and general financial services. These interventions can both improve profitability as well as diversify income streams, improving farmers' financial resilience. Interventions in this group enable mitigation measures in other groups, so the cost-effectiveness per t CO_2 is difficult to quantify. However, given that many farmers, particularly in Sub-Saharan Africa, do not have easy access to markets and are credit-constrained, it is likely that interventions in this group are also highly cost-effective.

---

[730] Pardey et al. (2016). Returns to food and agricultural RD&D investments in Sub-Saharan Africa. https://www.sciencedirect.com/science/article/pii/S0306919216303761.

[731] Zou et al. (2013). Cost-effectiveness analysis of water-saving irrigation technologies based on climate change response: A case study of China. https://www.sciencedirect.com/science/article/pii/S0378377413001856.

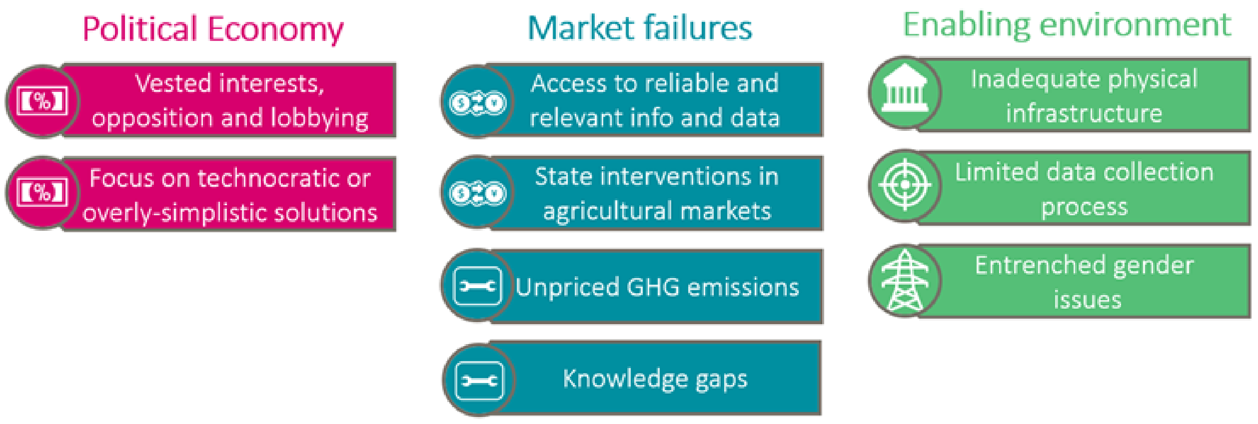
[732] McKinsey & Company. (2020). Agriculture and climate change. Reducing emissions through improved farming practices. https://www.mckinsey.com/~/media/McKinsey/Industries/Agriculture/Our%20Insights/Reducing%20agriculture%20emissions%20through%20improved%20farming%20practices/Agriculture-and-climate-change.ashx.

[733] Overmars et al. (2014). Estimating the opportunity costs of reducing carbon dioxide emissions via avoided deforestation, using integrated assessment modelling. https://www.sciencedirect.com/science/article/abs/pii/S0264837714000799.

Barriers to adoption

Barriers to agricultural productivity enhancements are substantial but varied across the focus regions. Market failure, political economy, and enabling environment barriers exist in all five focus regions and have presented substantial obstacles to past development efforts. It is critical that interventions account for and ameliorate these barriers. Prominent barriers in each category are summarised in Figure 42 and highlighted in the sub-sections below.

Figure 42 Barriers to Agricultural productivity



Source: Vivid Economics, ASI and Factor

<u>Political economy barriers</u>

Powerful agricultural lobbies can represent a force for maintaining current practices or an obstacle to progress. Large entities such as seed or agrochemical companies may have a vested interest in either opposing mitigation efforts or in advocating for particular input-intensive approaches, even when these may be environmentally damaging or threaten sustainable production and productivity growth. Such forces are often particularly powerful in large exporting states such as Brazil but are also significant in countries like Argentina and India. Such interests are also powerful in African countries. For instance, the Alliance for a Green Revolution in Africa (AGRA) is a high-profile initiative to enhance agricultural productivity in 13 food insecure countries in Sub-Saharan Africa using Green Revolution approaches, [734] with strong support from such agricultural lobbies in its target countries.

Interventions in areas like productivity enhancement or climate change often focus on technocratic and managerial solutions, while de-emphasising the complex interactions between politics and the economy. Yet neglecting such questions increases the risk that initiatives could prove ineffective, while explicitly considering them can maximise the chances of success. Politicians in the target countries could likewise have a vested interest in particular technologies and solutions, perhaps via their linkages to the aforementioned agricultural lobbies.

<u>Market failures</u>

Poor networks of information dissemination slow technology uptake, increase the likelihood that it is incorrectly applied, entrench inequities, and make market formation for agricultural products difficult. This is especially true in the rural areas and informal settings of both West Africa and East Africa,[735] as well as in India, where existing public extension services can be slow and ineffective. The

[734] The Green Revolution refers to a suite of technology transfer initiatives that led to major scale improvements in agriculture production globally, and particularly in rice and wheat. The Green Revolution took place mainly in Asia and Latin America (in particular during the 1950s and 1960s). The key initiatives taken up during the green revolution included the application of agricultural fertilisers, the use of scaled-up irrigation systems, tools for the mechanisation of agriculture practices, and the use of hybridised seed varieties.

[735] Evergreen Agriculture Partnership. 2020. Eastern Africa. https://evergreenagriculture.net/evergreen-nations/eastern-africa/

incorrect application, use, and maintenance of productivity-enhancing technologies, including irrigation systems, makes these technologies much less effective and more likely to contribute to environmental harms, such as unsustainable water withdrawal.

National governments can sometimes intervene in agricultural markets in ways that cement inefficiencies, for instance in response to pressure from special interests or based on particular national priorities. Export bans and state-purchasing agencies, such as those seen in Brazil[736] and India, are examples of blunt instruments that can reduce incentives to improve agricultural productivity. Widespread agricultural subsidies have entrenched unsustainable practices in many developing countries. These include, for example, over-irrigation and monoculture cropping. Substantial subsidy reform may be needed before, or as a part of, interventions, if they are to have the desired effect.

Unpriced GHG emissions could constrain the uptake of climate-smart food and agriculture practices, notably those that either reduce GHG emissions or sequester carbon. This issue applies across the focus regions, since the global community has not yet effectively incorporated land use into carbon markets. Where carbon markets do create opportunities for mitigation efforts within agriculture, such as the Kenya Agriculture Carbon Project, the financial rewards to farmers can be modest, limiting their incentive to engage. Such incentives could, however, greatly improve in the future, particularly if carbon prices rise significantly as called for by various authoritative voices including the IPCC.[737] This barrier is highest where smallholder farmers predominate, (particularly true in India[738] and West Africa), where subsistence farming is prevalent and hence farmers are unable to save for on-farm investments and investment in agricultural RD&D remains modest. [739] Such conditions are especially prevalent in India, East Africa, and West Africa.

Knowledge gaps can constrain farm production, particularly inhibiting progress towards securing productivity gains and building resilience to climate change impacts. Securing optimal farm production presumes a high level of knowledge on several levels and changing rural contexts can make it difficult for farmers to remain up to date. One key type of knowledge gap that may constrain farming is familiarity with relevant farming innovations, such as different types of improved seed varieties, agro-ecological practices like conservation tillage or agroforestry, or irrigation technologies like drip irrigation. Other types of knowledge gaps include optimal timing of key agricultural tasks in light of climate change, and changes in relevant markets, such as market demand and product pricing.

Enabling environment barriers

Inadequate infrastructure can restrict market access and discourage productivity improvements. A lack of adequately sized, well-located storage spaces for products can contribute to food waste and limit farmers' capacity to sell their products in more distant markets or at periods when prices are higher. Transportation networks are also needed to deliver products to market and access required inputs. Infrastructure constraints are particularly pronounced in East Africa[740] and West Africa.

Limited data collection constrains the timely use of information to improve both productivity and resilience, as well as the capacity of agriculture to help mitigate climate change. Limited collection of

---

[736] Anselmi et al. (2016). Factors related to adoption of precision agriculture technologies in Southern Brazil. http://afurlan.com.br/lap/cp/assets/layout/files/tc/pub_factors-related-to-adoption-of-precision-agriculture--technologies-in-southern-brazil--anselmi-a-a-c-bredemeier-federizzi-lc-molin-jp-icpa-2014-24-02-2016.pdf
[737] See, for example: Rogelj et al. (2018). Mitigation Pathways Compatible with 1.5°C in the Context of Sustainable Development. https://www.ipcc.ch/site/assets/uploads/sites/2/2019/02/SR15_Chapter2_Low_Res.pdf.
[738] IFPRI. (2016). Agricultural R&D factsheet. India. http://ebrary.ifpri.org/utils/getfile/collection/p15738coll2/id/130971/filename/131182.pdf
[739] While some on-farm investments may require farmers to save financially, it is also important to note that 'on-farm investments' need not involve spending money. They can also involve investing labour power in different practices, for instance.
[740] International Growth Centre. (2017). Growth brief. https://www.theigc.org/reader/seeding-success-increasing-agricultural-technology-adoption-information/information-barriers-can-prevent-uptake-agricultural-technologies/

relevant data is particularly a problem in East Africa[741] and West African[741] countries, where recent efforts to mainstream data collection have been slow to improve agricultural information provided to farmers. This is also an issue in India.

Gender issues are critical in farming communities in the global South, which typically adhere to rigid gender roles. Men often control farm revenues and decision making, as well as land titling and farm revenue, [742] although women and children may be responsible for much of the physical labour associated with agricultural work.[743] Agriculture productivity enhancements can involve new practices with potentially major implications for gender dynamics. For instance, some agriculture productivity enhancement practices (such as intercropping or manually incorporating trees into agricultural landscapes) may be seen as drudgery or may require working during the dry season and could particularly affect women and girls. They might also affect culturally important concepts like resting in the dry season and fulfilling family commitments. It should also be noted that some roles commonly played by women are particularly affected by threats from climate change, such as cultivating food crops or gathering fuelwood and water. By contrast, typically male tasks, like herding and non-farm labour, are less affected. One consequence is that men may be less aware of such threats and slower to recognise the significance of potential solutions. Such gender linkages could vary widely even within focus regions, highlighting the importance of careful, context-sensitive intervention design.

Table 46 Barriers to agricultural productivity: severity across target regions

Type of barrier	Brazil	East Africa	India	South America	West Africa
Political economy barriers	High Powerful agricultural lobbies which promote large-scale agri-business, and approaches that sometimes fail to optimise productivity.	Moderate Certain promotion of input-intensive approaches with support from agricultural lobbies (e.g. via AGRA).	Moderate Agriculture lobbies well-established.	Moderate Agriculture lobbies well-established in certain countries (e.g. Argentina).	Moderate Substantial agricultural lobbying.
Market failures	Moderate Chronic and significant levels of state intervention in agricultural markets.	Moderate Unpriced GHG emissions and poor information dissemination networks.	Moderate to high State intervention in market, and use of subsidies.	Low Information dissemination networks are established (albeit with potential for improvement).	Moderate to high Poor information dissemination networks, plus unpriced GHG emissions in the context of subsistence farming.

[741] World Bank. (2020). Harvesting prosperity. https://openknowledge.worldbank.org/bitstream/handle/10986/32350/9781464813931.pdf
[742] Considering women's rate of access to land (i.e. share of women agricultural landowners) as one indicator of gender inequality, of the target regions, this barrier is moderate-critical in India and Brazil, with both countries ranked significantly below the developing country average. Of the other considered regions (i.e. East Africa, South America, and West Africa), there is considerable variation at the country level, where the barrier (land titling rights) can be considered as ranging from low to critical. Source: UNCTAD, 2019. https://unctad.org/en/PublicationChapters/diaeia2019d3a4_en.pdf
[743] Prasad el al. (2013). An overview of gender issues in agriculture. file:///C:/Users/CJM/Downloads/An_Overview_of_Gender_Issues_in_Agriculture.pdf

Type of barrier	Brazil	East Africa	India	South America	West Africa
Enabling environment barriers	**Moderate** Data collection networks are in place but patchy.	**Moderate to high** Inadequate (food storage and distribution) infrastructure restrict access to market, poor data collection, and entrenched gender roles.	**Moderate** Data collection limitations hinders the ability of farmers to respond in a timely way.	**Moderate** Food storage and distribution networks lacking in some regions (esp. in mountainous and geographically isolated zones, e.g. the Andes range).	**Moderate to high** Patchy and often sub-optimal infrastructure restrict access to market, limited data collection, and entrenched gender roles.

Source: Vivid Economics, ASI and Factor

UK additionality

The UK's substantial existing track record and experience in providing agriculture-focused development assistance makes a compelling case for UK additionality in this opportunity. It is worth underlining that enhancing agriculture productivity in the global South is a 'crowded' development space, with many different development actors and many target countries. Notable donors to this sector include the World Bank, the FAO, and the 15 institutes that comprise the CGIAR.[744] Official development assistance for agriculture reached an all-time high of USD 10.4 billion in 2017, yet agriculture's share of total development assistance remains modest at just 6%. The donors who contribute most to agricultural development are the US, Germany, Japan, the UK, and France.[745]

The UK has several key strengths in relation to agriculture productivity enhancement support. Specifically, UK additionality in this sector is based on:

- **Understanding of, and experience in working with, private sector companies in the agriculture sector.** This has been developed both through the delivery of technical assistance programmes and bespoke support to investment, such as AgDevCo,[746] especially in parts of Africa. Private sector experience is important because commercial sustainability in the private sector is much more likely to deliver long-term benefits to smallholder farmers (if it can effectively be harnessed), compared to public sector institutional sustainability.

- **A strong track record as an early adopter and supporter of new research in agriculture.** The UK's support of climate-smart and resilient agriculture implementation, combined with its experience in funding and working with agricultural research organisations such as those in the CGIAR network, give it a relatively unique perspective in the international community. Based on the opinions of some key interviewed experts who have been working for several decades in the international agriculture development sphere, there is a prevailing (albeit subjective) view that the Department for International Development (DFID), now the Foreign, Commonwealth & Development Office (FCDO), has often seemed "ahead of its time".

- **Having an 'insider' perspective on numerous developing countries due to its strong historical links with them**. Notably, the UK has significant connections and longstanding ties with several of the target regions, including, for example, India and West African countries (e.g. Nigeria and Ghana). The UK also has growing ties with certain South American countries, such as Colombia. In terms of human capacities, many individuals working in key UK institutions either have family ties to the target countries or have been based in them for an extended period. Such linkages provide these individuals with nuanced socio-cultural knowledge of these countries and the wider region. These individuals may also have ongoing relationships with people in these countries that could afford them insight into local dynamics. If such individuals could be consulted, then these insights could inform discussions on the project's aims and design, thus ensuring it is firmly grounded and aligned with the target populations, thereby helping maximise the chances of delivering a project that achieves a profound and lasting impact.

The UK can draw on various strengths and substantial experience in supporting agricultural productivity enhancements in the international context. Significant experience has been gained through the following initiatives:

---

[744] Agriculture remains a critical sector for a large majority of countries in the global South, whether as a share of gross domestic product, a source of jobs, or a means to meet basic needs. Despite the achievements of agricultural development over recent decades, this remains a sector where need remains acute in many countries and communities due to challenges such as population pressure, environmental degradation, and climate change impacts.

[745] Donor Tracker. (2020). Agriculture. https://donortracker.org/sector/agriculture

[746] AgDevCo Limited is incorporated in the UK as a private limited company. Its shares are owned by AgDevCo Holdings Limited, a company limited by guarantee that exists to preserve AgDevCo's mission to invest in African agriculture for impact. Source: AgDevCo. (2020). About us. https://www.agdevco.com/about-us.html

The UK is a significant provider of ODA focused on agriculture. The UK spent around 5% of its total ODA on agriculture in 2016. When considering both bilateral funding and contributions to multilateral organisations working in agriculture, in 2016 the UK had the fourth-largest spend of OECD donor countries, at USD 952 million.[747] [748]

The UK provides significant financial support to key international agriculture improvement institutions, including donations to CGIAR, AGRA, and AgDevCo. In 2016, almost half (45%) of UK agriculture ODA was spent as contributions to multilateral organisations. The main recipient organisations included International Development Association (World Bank) and the EU institutions, which received 41% and 39%, respectively. In addition, the UK contributed to the general budgets of the African Development Fund, the International Fund for Agriculture Development, the Global Environment Facility, and the FAO. Through its ongoing participation and funding support for these multilateral development programmes, the UK can help shape the focus of ongoing and forthcoming agriculture development programmes. Moreover, the UK has significant capacities in promoting multilateral collaborations and cooperation across various countries and can draw on long-term experience in this regard.

In terms of specific ongoing programmes, the UK government is currently operating several relevant initiatives, including, for example:

The Enhancing Digital and Innovations for Agri-food Systems and Livelihoods programme, running from 2019-2026. This GBP 32 million programme led by DFID works to increase productivity and incomes for farmers by harnessing digital technology and innovation, generating evidence on scalable approaches to deliver market access for smallholders at scale, and mainstreaming this evidence by improving open data policies in DFID focus countries[749].

The Agri-Tech Catalyst: Supporting Agricultural Innovation for International Development programme, running from 2014-2024.This GBP 20 million programme is led by DFID and aims to accelerate the development of new agricultural innovations and address food security challenges in developing countries. Key activities include supporting research and private sector partnerships.

The UK has links with the 5 target regions on several levels. In the case of India and parts of East Africa, West Africa, and South America, this includes them being former British colonies and also fellow members of the Commonwealth. As for Brazil and the remaining countries in East Africa, West Africa, and South America, their main links to the UK are as trade partners and aid recipients.

In West Africa, the UK is currently funding agriculture productivity enhancement programmes. Through the Rural and Agriculture Markets Development (PrOpCom Mai-karfi) programme (2013-2021; GBP 51 million),[750] for example, DFID is working to increase employment and improve productivity in selected rural and agricultural market systems in northern Nigeria. Through the Agriculture Transformation – Ghana programme (2020-2025; GBP 32 million),[751] DFID is supporting the development of markets for agriculture and trade, improving resilience to climate change, and creating additional jobs and increased incomes by focusing on the development of high potential value chains in pro-poor sectors, supporting them to become productive, competitive, and attractive for investment.

[747] Donor Tracker. 2020. Agriculture. Received from: https://donortracker.org/sector/agriculture
[748] In principal, this leadership role in terms of spend on aid to the agriculture sector positions the UK well to become one of the world's primary funders of climate-smart agriculture. However, it is important to underline that the ability to maintain this role (in terms of high spend) may be affected as a consequence of Brexit and some of the significant (negative) economic impacts of that transition, based on the government's forecasts.
[749] Development tracker. (2020). Enhancing digital and innovations for agri-food systems and livelihoods. https://devtracker.dfid.gov.uk/projects/GB-GOV-1-300644
[750] Development tracker. (2020). Rural and Agriculture Markets Development programme (PrOpCom Mai-karfi) – Nigeria. https://devtracker.dfid.gov.uk/projects/GB-1-202098
[751] Development tracker. (2020). Agriculture Transformation – Ghana. https://devtracker.dfid.gov.uk/projects/GB-GOV-1-300794

- In India, the UK is currently supporting a bilateral research partnership to deliver evidence-based solutions for global development challenges on health, food, and women, through the DFID-run Global Research Partnership Programme (2014-2021; GBP 6 million).[752]
- In Brazil, the UK Department of Environment, Food & Rural Affairs (DEFRA) is running the Low Carbon Agriculture for Avoided Deforestation and Poverty Reduction programme (2016-2024; GBP 37 million).[753] It has the core objective of restoring deforested and degraded land on small- and medium-sized farms and targeting the barriers to farmers' access to rural credit.
- In South America, the UK is supporting agriculture productivity enhancement. For example, the programme Increase Investment and Yield in the Agriculture Sector in Colombia (2018-2022; GBP 2 million),[754] run by the UK Foreign Commonwealth Office (FCO), now the FCDO, seeks to encourage innovative technology uptake in Colombia's agriculture sector and to stimulate demand for agricultural insurance among smallholder farmers and agri-businesses. The UK is not currently funding ongoing agriculture programmes in Brazil, and the country is not a target for UK aid to agriculture at the present time.

These strengths position the UK well to support technical capacity building, infrastructure development, and data and information dissemination systems in pursuit of improved agricultural productivity in the focus regions.

[752] Development tracker. (2020). Global research partnership programme. https://devtracker.dfid.gov.uk/projects/GB-1-202766
[753] Development tracker. (2020). Low carbon agriculture for avoided deforestation and poverty reduction. https://devtracker.dfid.gov.uk/projects/GB-GOV-7-ICF-PO014-LCP2
[754] Development tracker. (2020). Increase investment and yield in the agriculture sector in Colombia. https://devtracker.dfid.gov.uk/projects/GB-GOV-3-PF-COB-924001

Intervention opportunities

There are four main categories of intervention opportunities to address identified barriers. It is important to note that many of these intervention options are already being deployed by different development actors in a crowded development space. It will be important to consider specific options on a case-by-case basis, and to examine carefully the specific required time periods of interventions, so as to ensure the project complements existing efforts and delivers clear benefits.

Measures to bring farmers to the efficiency frontier

Provision of technical assistance to farmers: This intervention covers direct technical assistance to farmers, in coordination with relevant local agriculture extension partners. This can support farmers' adoption of climate-smart agriculture or regenerative approaches, [755] for example in identifying where agroforestry will be most beneficially applied and which species should be used. The possibility of providing financial assistance (e.g. through loans or grant finance) to cover any transition costs should also be explored, especially in light of the fact that new systems or practices could take time to deliver returns. Technical assistance to farmers is especially needed in East Africa and West Africa, given that low access to information on productivity-enhancing approaches is a critical barrier in those regions.

Investment in key RD&D institutions, their research, and dissemination efforts: This intervention would provide support to existing agricultural research and extension institutions. It would also work with local governments to establish such institutions where there are gaps. It would ensure that these institutions have the resources and support required to take optimal decisions on RD&D prioritisation, as well as supporting the dissemination of research results to target users, including both the RD&D community and farmers. It may also directly fund RD&D initiatives to improve crop and livestock yields across a range of contexts; with a strong focus on supporting high-potential and ongoing initiatives. Innovative approaches to dissemination may be required, such as local demonstration farms in smallholder areas. Support for RD&D is generally considered to be in greatest need in East Africa and West Africa (as compared to in Brazil and India, where there is demand but RD&D institutions tend to be more established and enjoy larger resources and funding. The need for RD&D support in South America varies markedly between countries).

Support the design and implementation of data collection and management systems: These systems can support better farm management decisions and will require capacity building of system administrators and the development of locally appropriate tools to ensure a wide dissemination of information. Intervention support of this kind is especially needed in East Africa, India, and West Africa.

Measures to control unwanted side effects of agricultural expansion on the natural environment

Support the roll-out of regenerative or agroecological approaches such as agroforestry: The applicability of these approaches varies with local context, but they should be promoted wherever possible. Farms located in drylands, on degraded lands, or in areas with erratic rainfall are examples of places that could benefit substantially from such approaches. Given the significant unwanted side effects of conventional agriculture on the natural environments of all target regions, and the large scope for applying agroforestry, regenerative, and agroecological approaches, support in this topic area is needed in all considered regions.

Support forest restoration in conjunction with agriculture as part of a mosaic landscape approach: Restoring forests can be inexpensive if done via assisted natural regeneration. Further it offers a way

[755] Please refer to Box 27 for an example of a programme (Vuna – CASP) which successfully supported climate-smart agriculture uptake in Southern Africa.

to transform unproductive degraded lands into ones that deliver valuable ecosystem services and useful products.[756]

Off-farm measures to improve the size and security of revenue streams

Support for well-informed infrastructure development planning: This intervention would help local governments invest in productivity-enhancing infrastructure, including sustainable irrigation systems, product storage and processing facilities, and coherent and well-connected transportation networks to get products to market. Road networks, for instance, often have multiple development objectives and benefits, and it is important to plan across these in a coordinated way. Infrastructure development planning is especially needed in East Africa, and certain parts of South America, especially in mountainous isolated regions with high levels of agricultural activity.

Design and operation of concessional agricultural loan and insurance systems: A wide variety of financial products could better support agricultural producers of varying sizes. This ranges from ensuring access to credit and basic crop insurance for small holders, to more sophisticated financial instruments that can incentivise investment and mitigation activity uptake by larger commercial players. Intervention support could come in the form of offering lines of credit to be offered on concessional terms, or in technical assistance to local financial institutions. One key benefit of this type of intervention is that it could introduce a variety of financial services to rural farmers, which could increase working capital and/or increase farmers' ability to save. A further benefit is that it could enable farmers to diversify their income sources through investing in new crops/assets, making them more resilient to economic shocks. Support in the design and operation of concessional agricultural loan and insurance systems are particularly needed in East Africa, certain parts of South America, and West Africa.

Capacity building support for local agricultural authorities: Many of the providers and administrators of agriculture infrastructure, such as irrigation cooperatives or regional irrigation authorities, would benefit from technical assistance and capacity building to promote good governance and effective regulation or infrastructure management. Support for capacity building for local agricultural authorities is required across all considered regions, but especially so in East Africa and West Africa where enabling environment and critical infrastructure barriers are critical.

Design of systems to compensate farmers for adopting productivity-enhancing farming practices that are explicitly linked to GHG emissions mitigation: Technical assistance could be provided to establish modalities for payments (made within voluntary carbon markets) for the delivery of ecosystem services. Such payments can come either from donors (e.g. the World Bank) or the private sector via carbon markets. The latter offers scope for higher unit payments to farmers, particularly via the voluntary carbon market, where considerations like the various social or environmental benefits delivered by projects can help secure higher prices for those providing the carbon credits. Support for the design of systems to compensate farmers for adopting productivity-enhancing farming practices that are explicitly linked to GHG emissions mitigation is needed in all considered regions.

Measures for the mitigation of GHG emissions

Carbon pricing that incorporates the land sector into compliance markets: Pricing signals could strongly incentivise changes in both *what* is produced, and *how* it is produced, encouraging the uptake of sustainable practices and encouraging shifts throughout agriculture value chains. Substantial support is needed, particularly through technical assistance, to help ensure that carbon markets are well designed and implemented since there are few good examples of markets that incorporate land use sectors around the world. Support for measures on carbon pricing that incorporate the land sector into compliance markets are in demand in all target regions. However, support is especially needed

[756] The issue of forest restoration is considered in detail in the Forests opportunity report.

in East Africa, India, and West Africa, given that the strength of this barrier is highest where there are many smallholders, there is insufficient investment in agricultural RD&D, subsistence farming is most prevalent, and farmers are unable to save for on-farm investments.

- Support governments to better incorporate their GHG mitigation commitments into their Nationally Appropriate Mitigation Actions (NAMAs), notably those that touch on agriculture and food production: This can involve supporting governments to screen and prioritise potential GHG mitigation actions within the agriculture and food production sectors of their countries. Given the characteristics (including the strengths, challenges, and sources of resistance to change) of national agriculture and food production sectors, NAMAs need to be tailor-made at the individual country level. Support under this intervention area is needed in all considered regions.

- Support the financial sector to better anticipate risks to agriculture due to climate change: This could involve developing tools that allow the financial sector to identify, characterise, and objectively compare climate change-related risks across different agriculture and food production investment opportunities. Those risks could then be adequately reflected in the lending conditions that institutions subsequently offer. Investments in climate-smart and low-carbon agriculture would then be encouraged, through having lower risk profiles and hence better lending conditions. This intervention area is recommended for all considered regions.

Taking into account the key barriers to agriculture and food production enhancement (as identified in Section 0) and based on analysis of the core UK strengths and areas of additionality, strong intervention opportunities for the UK include:

- Providing support and expertise for comprehensive rural infrastructure development planning and roll out: This could involve analysing the different options for scaling up food and agricultural product collection, processing, storage and distribution to market, and environmentally sustainable irrigation systems. The UK could fund infrastructure planning programmes, as well as providing capacity building to key stakeholders for planning and roll out of those programmes. The UK could also fund certain demonstration projects, such as food storage networks or irrigation systems. This intervention area would help overcome the enabling environment barrier of inadequate physical infrastructure. East Africa and West Africa are recommended regions of focus.

- Supporting the design and operation of data collection and dissemination systems for climate smart agriculture and optimal farming and production decision-making: This should include working with agriculture extension services, climate and weather data, service providers, and market demand and pricing data, the effective dissemination of which could help improve uptake of best practices. This intervention area would help overcome the enabling environment barrier of limited data collection, and the market failure of poor networks of information dissemination. Whilst East African and West African countries and India are increasing their efforts to mainstream data collection, such processes are advancing very slowly in rural contexts. Consequently, it is recommended that support for data collection and dissemination system improvements be targeted towards initiatives within these three regions.

- Promoting and facilitating private sector engagement with initiatives to enhance agriculture productivity: This is likely to be of greatest necessity in regions where farmers tend to live hand-to-mouth and struggle to save for certain on-farm investments, a situation that is compounded by relative economic poverty and market failures such as unpriced GHG emissions. Private sector engagement is a vital part of addressing key enabling environment barriers such as inadequate physical (storage and distribution) infrastructure. This is because (some) private entities have the experience, technical knowledge, and finances required to develop such infrastructure, whereas many local communities and individual farmers do not have the required resources or capacities. Hence, this intervention area is especially recommended for India and Eastern African countries.

Supporting agriculture productivity enhancement RD&D: Support could be given to existing and established hubs, or to support struggling RD&D centres in regions with significant need. Assistance would, amongst other things, aid the timely dissemination of research results and new products. The UK can draw on its experience in stimulating RD&D generally, providing support to create country- and regional-level networks for RD&D activities, with an overall high participation and engagement with key stakeholders (researchers, farmers, private sector, investors, etc.). This intervention area would help overcome the market failures of knowledge gaps on productivity enhancing systems and practices and poor networks of information dissemination. This intervention appears to be in greatest demand in India and West Africa, whose governments are currently committing relatively limited funds to agricultural RD&D activities.

Intervention case studies

These case studies provide real-world insights into intervention design and challenges. Each case study provides an overview of the context, the aim of interventions, and the challenges faced.

Box 27 Vuna – the Climate Smart Agriculture Programme (CSAP) for Southern Africa, UK DFID Africa Region and ICF – 2015 -2018, GBP 17 million

Southern Africa is one of the world's regions which will be most impacted, and most quickly affected, by climate change. The large numbers of smallholder farmers make increasing their "climate resilience" an urgent challenge. As part of the wider CSAP, the Vuna programme was established to find transformative approaches to increasing the use of "climate-smart agriculture" technologies. Having worked across Malawi, Mozambique, Tanzania, Zambia, and Zimbabwe, Vuna provides an innovative model from which multiple valuable lessons can be taken and which is readily transferable to other parts of Africa, especially, and potentially to other regions of the world.

The objectives of Vuna were to:

- Increase, and improve the use of, research evidence and data about a holistic, "farmer-centric" form of CSA.
- Improve (selected parts of) the enabling environment for the use of CSA.
- Pilot and, where appropriate, scale up innovative and effective approaches to the delivery of support for CSA uptake.

In pursuit of those objectives, Vuna also deliberately sought to:

- Raise the profile of CSA approaches in the sector.
- Support increased coordination about CSA-uptake, within each country and across the region.
- Work with private sector companies to find different business models and different approaches which would produce benefits for them, as a result of them helping their smallholder customers and suppliers to get the benefits of adopting CSA practices.

The focus on finding commercially sustainable methods of increasing the use of CSA was a deliberate and innovative response to the constraints of other approaches, in particular the general weakness of governmental extension services and dependence on fragmented non-governmental organization led extension support. The programme demonstrated the importance of working in a coordinated way with: the farmers targeted themselves; the private sector companies selling to, and buying from those farmers; the research community targeting the challenges of those farmers; and the governmental policy, strategy, and delivery agencies.

After only three years, the Vuna programme had resulted in:

- 13 innovative agricultural business models being tested.
- 15 formal policy recommendations developed and made to the five governments.
- Eight high level research evidence reports produced and disseminated, on topics relevant to the farmers of the region.
- More than 210,000 smallholder farmers adopting various CSA practices.

- Some 704,000 people being assessed as being "more climate resilient".

The programme also supported production of training manuals, a raised profile, and coordination groups that have continued the momentum started and this has been built on in subsequent donor and government programmes.

In the course of reaching some 71,000 female farmers and testing five "gender transformative" business models, Vuna produced valuable lessons on how to optimise the empowerment of women and girls in smallholder farming, including that:

- Maximising female empowerment requires the deliberate targeting of gendered crops and subsectors, as well as mainstreaming gender in other activities.
- Closing the gender productivity gap requires a detailed understanding of constraints at sector, farm, and intra-household level, which in turn requires the development of trust to allow greater exploration of, and attention to, socio-cultural matters.
- Overall, gender is not just an issue of social justice but also a business imperative for optimised adoption of CSA and it requires investment of dedicated time and resources.

In the course of the three-year programme, Vuna worked with:

- 18 main partner organisations testing innovative models for delivery of CSA support, from whom over GBP 1.6m in co-contributions was made.
- Over 650 other participants in the value chains it was covering, mostly small-scale "agro-dealers", who all received training on the impacts of climate change and CSA and were equipped to extend that understanding to their smallholder customers.

Key risks managed during the Vuna programme included:

- Work with small-scale companies is necessary to reach smallholders farmers in many districts, but requires intense support and oversight to ensure effectiveness and financial accountability.
- Political economy factors and political complexity can cause delays and lead to unforeseen constraints;.
- Developing momentum for increased adoption of CSA requires inclusive and wide-ranging consultation, consensus building, trust-building, and coordination. To be optimally effective and to maximise return on investment, donor timeframes and resources need to allow for this.

The Vuna programme provided multiple lessons and practical experiences which are likely to be readily applicable:

- Across Southern and Eastern Africa.
- With adaptation, in Western and Central Africa.
- Potentially across other regions where climate change is already adversely affecting the ability of smallholder farmers to maintain their livelihoods and to develop their commercial viability.

Box 28 CRIDF – the Climate Resilient Infrastructure Development Facility for Southern Africa, UK DFID Africa Region – 2013 -2017, GBP 25 million

In the face of a rapidly changing climate, the provision of adequate water infrastructure becomes more urgent due to adaptation pressures, especially in rural communities. Many of the countries in Southern Africa have a large backlog of water infrastructure projects which are required for effective management of water resources, water supply infrastructure, irrigation schemes, and hydropower opportunities. Further, watersheds do not neatly follow national borders making transboundary projects particularly complex.

The capacity to identify, develop, test the feasibility of, arrange financing for, and oversee water infrastructure projects is not yet adequate in the region. As part of a wider Transboundary Water Management Programme, CRIDF was an innovative and effective response to this lack of capacity. The programme was successful in its own objectives, led on to a larger second phase (now in operation), and offers a model suitable for application to many types of infrastructure, including in other regions.

The two main objectives of CRIDF were to:

- Facilitate the design and implementation of transboundary water infrastructure projects in Southern Africa.
- Directly design, fund, and implement selected, climate-resilient, transboundary water infrastructure projects.

In addition, CRIDF also deliberately sought to:

- Improve coordination of transboundary projects.
- Support capacity building amongst the relevant agencies.
- Reduce tension amongst South African Development Community member countries linked to lack of agreement on management of water resources.
- Facilitate the development of multi-country Integrated Water Resource Management Plans, which contain an agreed programme for a particular, border-straddling water catchment.

In the course of the 4-year period, key results achieved by CRIDF included:

- 120 project proposals screened for suitability.
- 70 of these projects were selected and developed further through work including: consultation, pre- and full-feasibility analysis, testing of "bankability", arrangement of funding, and preparation for procurement.
- 21 of the selected projects progressed to (at least) the "bankability" stage
- 13 of the 21 projects reached financial closure, indicating funds were available.
- 7 projects, serving some 0.5m people, were completed by July 2017.

In addition, regional cooperation was improved and an agreement was brokered with a large, private sector land user to integrate their own flood prevention and irrigation schemes with the wider plans. Moreover, some 28 knowledge products were developed, prepared, and disseminated, improving the availability of research and technical information to the region's water authorities.

CRIDF developed a practical methodology for increasing and improving the consideration of gender aspects of water infrastructure development and planning. The approach led to broader thinking about social issues by water engineers, changes to boundaries of irrigations schemes to allow inclusion of larger numbers of female farmers, and more equitable compensation to women farmers in negotiations about land redistribution.

Part of CRIDF's remit was to facilitate the mobilisation of funds for water infrastructure projects. By the fourth year:

- GBP 13.5 million was legally committed from public sector organisations.
- GBP 113.4 million was formally committed – but not yet legally committed - from public sector organisations.
- GBP 2.58 million was mobilised from private sector companies.

The effects of the funding activities continued after the end of CRIDF Phase 1 and are continued and increased during Phase 2.

Key issues and risks managed during the CRIDF programme included:

- The planning, prioritising, and implementation of water infrastructure is a continuing, long-term activity. The time horizon needed is lengthened in situations where cross-border coordination will optimise return on investment. A donor project cycle which can recognise and respond to those longer-than-average durations needed is more likely to be successful and more likely to achieve a higher economic and financial return on investment.
- Political economy factors and political complexity can cause delays and lead to unforeseen constraints – and flexibility and time are required to counter those.

Challenges of not-yet-adequate infrastructure adversely affect the climate resilience of people in rural areas, especially, in many regions of the world. They include water infrastructure, as in CRIDF, but also rural roads, crop aggregation / storage facilities, and cell phone / internet access and speed, all of which can be important for helping people to become better adapted to climate change. The success of the CRIDF programme offers a model which can be applicable to all of those types of infrastructure, to both national and cross-border projects, and to multiple regions.

Box 29 Rajasthan Agricultural Competitiveness Project, implemented by the World Bank, predominately financed by the International Development Association (IDA) (USD 79.57 million of total project cost of USD 166.50 million), 2012-2020 [757, 758, 759]

Being an essential factor of agricultural and industrial production, water has become subject to fierce competition in India, and especially in the state of Rajasthan. Restrictions on water availability critically limit agriculture productivity in surface and groundwater irrigated agriculture processes. This calls for efforts to promote water-efficient agriculture as a means of enhancing farming output and value.

[757] World Bank. (2012). USD 109 million for Rajasthan agricultural competitiveness project in India to directly benefit 155,000 smallholder farmers. https://www.worldbank.org/en/news/press-release/2012/03/27/us109-million-for-rajasthan-agricultural-competitiveness-project-in-india-to-directly-benefit-155000-smallholder-farmers
[758] World Bank. (2020). Rajasthan agricultural competitiveness project. https://projects.worldbank.org/en/projects-operations/project-detail/P124614
[759] World Bank. (2012). Rajasthan agricultural competitiveness project. Social Assessment and Managament Framework. http://documents1.worldbank.org/curated/fr/963831468040752151/pdf/RP12280v20RP0P07856B0SAR0RI0P124614.pdf

The World Bank launched the Rajasthan Agriculture Competitiveness Project (RACP) to enhance agricultural productivity and farmer incomes in the region. The project is a multi-pronged agricultural development scheme aimed at mainstreaming sustainable water management, as well as improving market organisation and access, and supporting capacity building in the sector.

There are three core objectives to the RACP:

- To improve the efficiency and resilience of the agricultural sector, specifically with respect to water usage, technology-transfer, and livestock management.
- To promote the participation of private sector entities, and the establishment and strengthening of value chains in the processing and marketing of agricultural produce.
- To build the capacities of private and public institutions to support the development of sustainable agriculture sectors.

The RACP includes three main intervention components, which correspond to the objectives described above:

- Efficient and Climate Resilient Agriculture: The intervention aims at increasing long-term productivity and farm incomes by (a) reducing water-intensity of irrigated and rain-fed farming processes via the deployment / improvement of efficient irrigation infrastructure, (b) through extension services aimed at demonstrating location-specific soil and water conservation practices and the benefit of improved crop varieties, as well as (c) by establishing small ruminant livestock pastures and livestock production / processing and marketing structures in the region.
- Markets and Value Chains: Via the establishment of (a) an Agri-Business Promotion Facility the competitiveness of agricultural businesses is to be promoted, while (b) technical assistance to agricultural stakeholders on commercialisation options and viable business models aims to provide focused support for existing and emerging agricultural businesses. These market development activities are further supported by (c) infrastructure investments.
- Farmer Organisations and Capacity Building: (a) Farmer groups are mobilised and capacity building activities are implemented, aimed at promoting participatory planning and joint sector development, while simultaneously (b) public and private institutions and human resources associated with the project implementation are strengthened.

The RACP set out to achieve productivity gains from the adoption of sustainable farming (seed management and cultivation processes) and water usage practices for 155,000 farmers, or a respective land cover of 200,000 ha. The intervention's impact on the region's agricultural sector is channelled via the efficiency enhancement in (smallholder) farming processes, and the resulting economic gains:

- For almost 30,000 households working in the region's agricultural sector, significant economic benefits in terms of direct incremental wage gains are expected.
- Positive multiplier effects and externalities will produce secondary benefits and efficiency enhancement for those not directly affected by the market integration interventions and sector investments, for example, via the provision of secured access to water through improved groundwater recharge or better water distribution.
- Total gross area under agricultural cultivation is expected to increase as a result of the project's efforts to reduce water scarcity in the region.

The relevance of the gender-specific impact of interventions focused on agricultural efficiency enhancement is immense and fully reflected by the RACP:

- The RACP applies a comprehensive gender strategy, which not only reflects women's role as farmers, but also actively promotes women's participation and inclusion in planning, implementation, and monitoring of the project's interventions, and in the sector's development approach as a whole.
- The burden of drudgery, disproportionately carried by women in agricultural processes, is actively countered via focus on the deployment of productive use appliances that seek to automate processing and as such enhance production efficiency.

Opportunities to leverage national and international flows of public and private finance are expected to be the result of newly formalised markets and value chains:

- A key component of the programme is to promote the establishment of sustainable functioning markets and value chains in the region, as well as the support of the formalisation of farmer groups and community initiatives.
- These processes are expected to leverage national investors' interest and drive the formation of commercial partnerships, predominately facilitated through the Agri-Business Promotion Facility established as part of the RACP.

Key risks of the RACP are those inherent in the establishment and promotion of market-driven efficiency enhancement approaches, i.e., the fairness of allocation and the risk of exclusion:

- The distribution of water resources, although improved, may be perceived as unfair and spark conflict among users of this scarce resource. The facilitation of a farmers' organisation is meant to mitigate this risk.
- The promotion of cash crops or other value-oriented cropping patterns subjects farmers to the risk of high stake loss, for example in the context of flooding. Extension services need to effectively communicate these risks.
- Formalisation of markets may shift power away from (female) household heads or disempower marginalised or informal stakeholders. This risk may be partly mitigated by promoting female-only farmer groups, or farmer groups representing minority groups.

Glossary

Acronym / Term	Definition
AGRA	Alliance for a Green Revolution
BAU	Business-as-usual
BECCS	Biomass energy with carbon capture and storage
BEIS	UK Department of Business, Energy and Industrial Strategy
CRIDF	The Climate Resilient Infrastructure Development Facility for Southern Africa
CSA	Climate-Smart Agriculture
DAC	Development Assistance Committee
DFID	Department for International Development
FAO	Food and Agricultural Organisation of the United Nations
FCDO	The Foreign, Commonwealth & Development Office
GHG	Greenhouse gas
Gt CO2/year	Gigatonne carbon dioxide per year
ICF	International Climate Finance
IPCC	Intergovernmental Panel on Climate Change
IRR	Internal Rate of Return
Mha	Mega hectare
NAMA	Nationally Appropriate Mitigation Action
NAP	National Adaptation Plan
NDC	Nationally Determined Contribution
NGO	Non-governmental organizations
ODA	Official Development Assistance
RCAP	Rajasthan Agriculture Competitiveness Project
RD&D	Research, design and development
SDG	Sustainable Development Goal
WAAPP	The West Africa Agricultural Productivity Program
WRI	World Resources Institute

Solid Waste and Wastewater

Summary

The solid waste and wastewater opportunity considers the construction and enhancement of waste management and wastewater treatment facilities. Importantly, this includes the use of waste and biomass residues for energy**.** The mitigation potential from solid waste and wastewater is moderate relative to other opportunities at around 1 – 2 gigatonnes carbon dioxide equivalent per year (Gt CO_2e/year) by 2050. Despite the opportunity's medium-sized mitigation potential, the investment need is large and urgent at USD 140 billion/year by 2030. This is because investments in waste management improvements generally have very high non-carbon benefits, in particular, public health impacts. Similarly, measured in dollars per tonne CO_2e abated, the cost-effectiveness of investments into the solid waste and wastewater sector is not high, but considering the many co-benefits associated with landfill and wastewater improvements, mitigation investments into this sector become more attractive in terms of total impact per dollar. In all regions assessed there are relatively high political and enabling environment/absorptive capacity barriers to action, often linked to corruption in many countries' waste sectors. The UK's additional value in this sector is moderate, resulting from moderate to high domestic expertise and relatively low levels of donor investment in the regions assessed.

The interventions considered here in order to increase solid waste and wastewater mitigation activity in focus regions include:

<u>Institutional capacity building for national, state, and municipal governments</u> on policy, consistency of implementation, and technologies.

<u>Capacity building to help government to improve the regulatory environment</u> for the private sector and increase participation.

<u>Formal and complementary informal platforms and mechanisms for dialogue</u> between national and sub-national governments, private sector, non-governmental organisations (NGOs), and universities.

<u>Public awareness initiatives</u> to better communicate with and engage citizens about the benefits of solid waste and wastewater management.

<u>Research, design and development (RD&D) support</u> in partnership with stakeholders for low-carbon technologies.

<u>Concessional financing and associated advice</u>, for example assisting public-private partnerships and offering debt and guarantees, and demonstrating pilot projects in in more advanced technologies.

Table 47 Solid waste and wastewater assessment summary

Criteria	Assessment	Notes
Climate impact	Moderate	• Mitigation potential by 2050 is 2.2 Gt CO2e/year in the 1.5-degree scenario. • 80% of this mitigation potential comes from the use of agriculture and forest residues used in bioenergy carbon capture and storage (BECCS).

Criteria	Assessment	Notes
Development impact	High	• Impacts on Sustainable Development Goals (SDGs) are high, focused on SDGs 3, 6, 7, 13, 14, and 15 and impact on public health, clean water and sanitation, air pollution, clean and affordable energy generation, and improving conditions for life on land and in water. • If interventions are implemented insensitively, there will be negative SDG impacts, particularly amongst low-income populations that rely on work in the informal waste sector.
Investment gap	Moderate	• In the 1.5-degree scenario, the cumulative investment gap for the solid waste and wastewater sector across all Official Development Assistance (ODA)-eligible regions is large at about USD 3.4 trillion • This is double the investment gap of forests, but less than half the investment gap of variable renewables.
Cost-effectiveness	Low	• The cost-effectiveness of landfill mitigation is above USD 50/ t CO2 and the cost-effectiveness for wastewater treatment abatement is in the hundreds of dollars per tonne abated. • Interventions that increase the use of BECCS residues are likely cost-effective; however, assessments that quantify their abatement cost are not yet available in the literature.
Barriers to adoption	Moderate	• In all regions, moderate to high political economy barriers, moderate market failures, and moderate to high enabling environment barriers exist, which have prevented the deployment of proven infrastructure and technologies. • Barriers include lack of political will, entrenched interests, high informal employment, corruption, lack of trust between government and stakeholders, financing shortfalls, lack of carbon price, low land availability, RD&D shortfalls, data shortages, government clarity and consistency, policy implementation, private sector participation, institutional coordination, use of technical capacity, government HR and budgets, and public awareness.
UK additionality	Moderate	• The UK's additional value is moderate, resulting from moderate to high domestic expertise and low levels of donor investment and attention. • In priority regions the UK has typically had low to moderate ODA ties in waste management with most assistance focusing on sustainable urban growth.

Source: Vivid Economics, ASI & Factor

Key lessons for supporting mitigation through investment in solid waste and wastewater treatment include:

The investment case for many waste and wastewater treatment interventions hinges mainly on development impacts other than mitigation, such as reductions in air and water pollution and improvements in health that accompany better sanitation. This may imply interventions are best managed by UK government bodies, such as the Foreign, Commonwealth and Development Office (FCDO), with experience outside the context of ICF.

Waste and wastewater treatment opportunities remain firmly in the realm of public investment in most localities, particular in lower and middle-income urban settings and rural areas. The variety of existing barriers to action mean that countries generally cannot rely on the private sector to fill the existing substantial funding gaps resulting from historic underinvestment in waste and wastewater facilities, networks, and infrastructure.

There is currently low donor presence and interest in the solid waste and wastewater sector, particularly in the bilateral arena, which raises the potential to address immediate barriers. In all regions, the imperative in the next five to ten years should be to lay the foundations of decent basic solid waste and wastewater infrastructure and technology while the enabling environment improves, including factors such as institutional capacity development, private sector participation, awareness raising, and cost recovery. Thereafter, investment might turn to more advanced mitigation technologies such as engineered landfills, waste incineration, methane capture and use, and waste-to-energy. China, and to an extent Brazil, may be readier for new technologies sooner than other regions.

Bioenergy generation from agricultural waste streams, representing a large portion of this opportunity's mitigation potential, is currently still in early pilot stage and limited to industrialised country contexts. Early investments in this area could help support scale-up and development over time. Interventions, however, should take care to ensure the sustainability of agricultural residue streams, which, depending on location and land management practices, can have larger carbon mitigation potential if put toward building soil carbon.

Introduction to the opportunity

Role of the opportunity in decarbonisation of developing countries

Developing countries must invest significantly in solid waste and wastewater improvements to avoid global emissions from the sector rising by approximately 50% by 2050. The waste sector currently accounts for about 5% of global emissions, with a higher proportion of emissions from non-Annex I countries coming from waste relative to Annex I countries.[760 761 762] This is largely due to the fact that in most developing regions over half of produced waste is disposed of in open dumps and most citizens in developing regions are not connected to wastewater treatment systems. As populations grow and incomes rise, waste from low-income countries is expected to increase by more than three times by 2050.[763] If action is not taken, this will lead to emissions from solid waste alone rising to 2.38 Gt CO_2e/year. Further, IMAGE results suggest that in a 1.5-degree scenario, developing regions could supply the world with close to 40 exajoules (EJ)/year of bioenergy from forestry and agriculture residues. Therefore, developing countries are likely to also have a significant role to play in generating negative emissions from sustainable sources of biomass.

While investing in mitigation in the solid waste and wastewater sector does not generate high carbon abatement per dollar spent, it has important development impacts. Investments in the treatment of wastewater, in particular, have large public health and environmental benefits as wastewater treatment plants both reduce methane production and the concentration of pathogenic bacteria from sewage. Further, supporting the development of biomass residue supply chains will help to avoid some of the expansion and associated negative impacts of first- and second-generation energy crop cultivation.

Scope considered in this assessment

The solid waste and wastewater opportunity includes the construction and enhancement of waste management and wastewater treatment facilities. The opportunity covers three main categories of intervention:

- **Solid waste management –** the collection, treatment, and disposal of industrial and municipal discarded solids. Interventions include the construction or upgrade of facilities such as sanitary landfills, anaerobic digesters, and waste incinerators.
- **Wastewater management –** the collection and treatment of wastewater. Interventions include the construction or upgrade of centralised wastewater treatment plants, and natural solutions in landfills and wastewater treatment plants, such as constructed treatment wetlands.
- **Bioenergy generation from waste –** the use of waste streams, including agricultural residues, for energy production. This includes upgrades to landfills to introduce methane collection for flaring, electricity generation, and direct use as well as the uptake and deployment of technologies that convert energy stored in biomass waste and residues to usable forms of energy other than through combustion. Note that this opportunity does not include any interventions that impact the use of non-waste bioenergy streams and associated technologies, such as first- and second-generation bioenergy crops and the BECCS plants that use them.

---

[760] Annex I countries refer to industrialised countries that were members of the Organisation for Economic Co-operation and Development in 1992, plus countries with economies in transition. For a full definition, see the full United Nations Framework Convention on Climate Change definition.
[761] The World Bank. (2018). Trends in solid waste management. https://datatopics.worldbank.org/what-a-waste/trends_in_solid_waste_management.html
[762] Bogner et al. (2007). Waste Management, In Climate Change 2007: Mitigation. Contribution of Working Group III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. https://www.ipcc.ch/site/assets/uploads/2018/02/ar4-wg3-chapter10-1.pdf.
[763] The World Bank. (2018). Trends in solid waste management. https://datatopics.worldbank.org/what-a-waste/trends_in_solid_waste_management.html

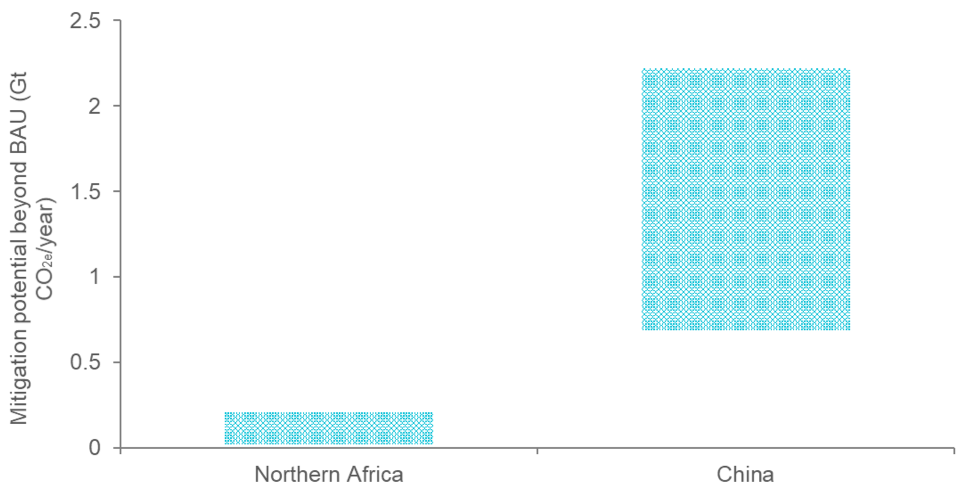
The assessment focuses on a subset of ODA-eligible regions: West Africa, China, South Asia (excl. India), Brazil, and South Africa. These regions were selected using IMAGE modelling results as well as World Bank data on municipal solid waste. Regions with the largest mitigation potential from landfills, wastewater treatment, and that produce the most biomass residues for bioenergy, and which have the greatest potential for growth in using waste for energy were chosen. This list was created in consultation with BEIS ICF stakeholders. Mitigation potential estimates from IMAGE include mitigation of carbon dioxide, methane, and nitrous oxide emissions.

Climate impact

Mitigation potential and urgency

Across all ODA-eligible regions, the mitigation potential of the solid waste and wastewater sector is between 20 – 210 Mt CO_2e/year in 2030 and 690 – 2,220 Mt CO_2e/year in 2050. The significant growth in mitigation potential in this sector between 2030 and 2050 is driven by a very large increase in the amount of agricultural and forest residues produced in these regions and used in BECCS. In the 1.5-degrees pathway, only 3 Mt CO_2e/year, or 1% of ODA-eligible region mitigation, comes from BECCS with residues in 2030. However, this grows to 1,800 Mt CO_2e/year, or 80% of the sector's mitigation potential, by 2050. While the 2050 mitigation potential estimates for the solid waste and wastewater sector are large, there is greater uncertainty in these estimates relative to other mitigation opportunities such as forests, due to uncertainty in the feasibility and true mitigation potential of large-scale BECCS. Mitigation from landfills and wastewater also increases between 2030 and 2050 in the 1.5-degree pathway, albeit less significantly, approximately doubling for each. Landfill mitigation increases from 169 Mt CO_2e/year in 2030 to 386 Mt CO_2e/year, while wastewater mitigation increases from 35 Mt CO_2e/year to 65 Mt CO_2e/year. These results suggest that there is greater urgency in mitigation investments in landfills and wastewater treatment relative to forestry and agricultural residues.

Figure 43 Range of solid waste and wastewater sector mitigation compared to BAU in 2030 and 2050



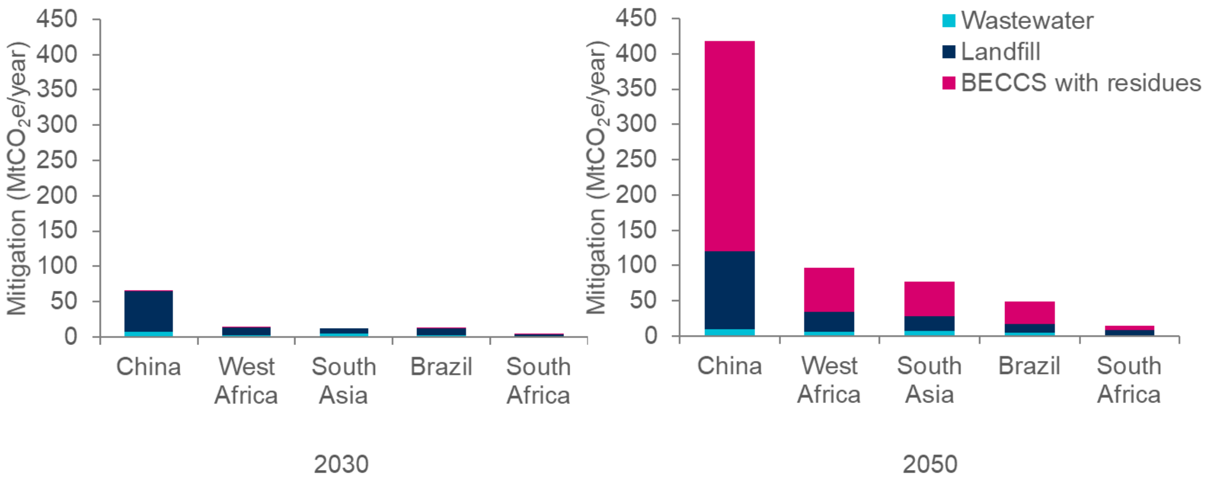
Source: Vivid Economics, ASI and Factor based on PBL's IMAGE model results.

Note: The bars indicate the range of modelled solid waste and wastewater sector mitigation potentials from IMAGE across six scenarios. The national policies scenario is used as the business-as-usual (BAU) scenario, and so mitigation estimates are calculated relative to this scenario.

The mitigation potential from the solid waste and wastewater sector in China is much larger than in other focus regions. Figure 44 illustrates the dominance of China over other regions in its solid waste and wastewater mitigation potential. In 2030, the country accounts for approximately one third of all ODA-eligible region mitigation in the solid waste and wastewater sector, at 70 Mt CO_2e/year whereas in 2050 China makes up about one fifth of total mitigation in the sector, at 420 Mt CO_2e/year. Similar to the aggregate results for ODA-eligible countries, this large growth in mitigation potential between 2030 and 2050 is driven by high production of residues used in BECCS. In 2030 about 90% of China's solid waste and wastewater mitigation potential comes from landfills, whereas by 2050 over 70% comes from residues used in BECCS. Under the 1.5-degree pathway, China produces over 8 EJ/year worth of agriculture and forest residues by 2050, equivalent to about 20% of the world's bioenergy from residues. Figure 44 also shows that landfill mitigation is higher in China than in any other focus region in 2030 and 2050. United States Environmental Protection Agency (US EPA) (2013), however, finds that China has a landfill mitigation potential of about 37 Mt CO_2e/year, half of what is suggested by IMAGE results.

While small in magnitude, other focus regions see significant mitigation potential in the solid waste and wastewater sector relative to today's emissions. While China's 2050 wastewater mitigation potential accounts for only 6% of today's emissions, the 2050 wastewater mitigation potential in Rest of South Asia is 17% of today's emissions, at 8 Mt CO_2e/year. Further, relative to today's emissions, the potential of landfill mitigation is highest in West Africa, Rest of South Asia, and South Africa, with mitigation potentials in 2050 being 197% of today's emissions in West Africa, 147% in Rest of South Asia and 108% in South Africa. Wastewater mitigation potential in West Africa grows by the largest amount between 2030 and 2050 across all focus regions, increasing from 2 Mt CO_2e/year to 6 Mt CO_2e/year.

Figure 44 Mitigation potential in focus regions broken down by contribution from wastewater, landfill and BECCS with residues mitigation in 2030 and 2050.



Source: Vivid Economics, ASI and Factor based on PBL's IMAGE model results.

Notes: Results are from the 1.5-degree pathway. Mitigation potential from residues is calculated by multiplying the residues produced in each region by the average negative emissions generated per EJ of biomass used in BECCS per region.

Transformational change

Transformational change involves actions that themselves catalyse further change, leading to broader, faster, or more ambitious climate action. Interventions may deliver transformational change in a number of ways:

They may target *sensitive interventions points* to encourage further changes in socioeconomic/ technological/ political systems to advance climate change mitigation by improving the enabling environment.

They may create *spillovers* that increasing efficiency of the overall system, either nationally or globally, and so increase the speed or depth of mitigation action.

They may support *innovation* in new or improved ideas/methods/products that reduce costs or increase mitigation impact within opportunity areas.

Table 48 Assessment of transformational change

Transformational change criterion	Interventions to support change	Regional potential
	Sensitive intervention points	
Improvement of local capacities and capabilities	Improving government institutional capacity can a) raise the effectiveness of solid waste and wastewater management and b) create an enabling environment and trust for the participation of the private sector.	All regions
Local ownership and strong political will	Improved government accountability, less widespread corruption, and greater financial transparency will raise solid waste and wastewater management effectiveness and incentivise private sector investment.	All regions
Leverage / creation of incentives for others to act	Leveraging the services of large and small actors in the private sector would substantially improve effectiveness of solid waste and wastewater management.	All regions
	Spillovers	
Broad scale and reach of impacts	Reforming the solid waste and wastewater sector to take advantage of all the actors – government, business, NGOs, and universities – can transform sector effectiveness.	All regions
	Innovation	
Catalyst for innovation	The private sector has proven itself willing to take on solid waste and wastewater management on a commercial basis if the enabling environment is conducive to it.	All regions
Evidence of effectiveness is shared publicly	Greater government and public awareness of the need for, and benefits of, solid waste and wastewater management can be a catalyst for change.	All regions

Source: Vivid Economics, ASI and Factor

Development impact

SDG impacts

Impacts on the SDGs are likely to be high, focused on improving public health (SDG 3), increasing access to clean water and sanitation (SDG 6), expanding access to affordable and clean energy (SDG 7), reducing water pollution (SDG 14), and reducing land pollution (SDG 15). However, if interventions are implemented in a way that is not sensitive to local contexts, there are potential negative SDG impacts as well. If local low-income populations rely on work from the informal waste sector, formalising waste management, collection, and landfills can take away jobs and income from these already vulnerable communities (SDGs 1 and 10). The informal sector must be recognised and represented during planning improvements in waste management infrastructure and practices.

Table 49 SDG impacts

SDG	Strength of impact	Most relevant region	Rationale
Positive Impact			
SDG 3 – Good health and well-being	Moderate	All regions, especially South Africa, South Asia, West Africa	Waste management would reduce pollution via avoidance of burning, and reduce accidents or dumping waste and toxins entering the water supply.
SDG 6 – Clean water and sanitation	High	All regions especially South Asia, West Africa	Avoidance of dumped waste in water source, particularly the discharging of hazardous chemicals and materials, can improve water quality.
SDG 7 – Affordable and clean energy	Moderate	All regions especially Brazil, South Africa, South Asia	Biomass waste, other organic waste residues, and methane from landfills can act as energy sources.
SDG 8 – Decent work and economic growth	Moderate	All regions	Advances in solid waste and wastewater management can create new jobs and skills in new sectors.
SDG 13 – Climate action	Moderate	All regions	Improved infrastructure and practices in the solid waste and wastewater sector have the potential to reduce greenhouses gas (GHG) emissions as well as resilience.
SDG 14 – Life below water	High	All regions	Waste management can reduce marine pollution caused from land-based activities including reduced disposal of waste in stormwater drains.
SDG 15 – Life on land	High	All regions especially Brazil, South Asia, West Africa	Improved waste management practices and infrastructure can reduce pollution in land-based ecosystems through control and treatment of leachate and reduction in the uncontrolled burning of waste.
Negative Impact			
SDG 1 – No Poverty	Moderate	All regions	Poorly planned formalisation of waste management has the potential to take away jobs from the poorest and impact livelihood – particularly within the informal sector.
SDG 10 – Reduced Inequalities	Moderate	All regions	Rapid improvement without planning has the potential to take away jobs from local enterprises.

Source: Vivid Economics, ASI and Factor

Demand in target regions

All regions show a degree of commitment to solid waste and wastewater treatment, while the extent of this commitment is greater in China and South Africa than in West Africa and South Asia.

Table 50 Summary of demand in target regions

Region	Demand	Rationale
China	Moderate – High	Robust policies, plans, and targets including in its Nationally Determined Contributions (NDCs), laws, and strategies.
Brazil	Moderate	Strong policy and regulatory demand but weaknesses in NDC and gaps between policy and implementation.
South Africa	Moderate	Strong policy and regulatory demand but substantial gaps between policy and implementation.
West Africa	Low - Moderate	Some commitment via policies and plans but substantial implementation gaps.
South Asia	Low Moderate	Some commitment via policies and plans but substantial implementation gaps.

Source: Vivid Economics, ASI and Factor

Brazil shows strong policy and regulatory demand but gaps between policy and implementation are high. Brazil does not include GHG reduction targets for the waste sector in its NDC but has adequate domestic policies to manage solid waste and wastewater treatment. Brazil's National Solid Waste Policy establishes guidelines for National, State, Regional, and Municipal Solid Waste Plans. The government's National Sanitation Plan sets goals and strategies for the universalisation of water supply in urban areas by 2023, the collection of solid waste by 2033, and the elimination of 100% of landfills by 2031. However, despite these plans and policies, in 2017 approximately seven million tonnes of waste generated had an unidentified destination. Lack of political will and systems can be evidenced by the fact that 3,352 municipalities still direct their waste to inappropriate places (landfills or controlled landfills) and 29 million tonnes of waste is being directed to environmentally unsuitable locations.[764]

China demonstrates robust policies, plans, and targets. China identifies waste as a mitigation sector in its NDC and in September 2020 made a commitment to net-zero GHG emissions by 2060. The National Plan for Tackling Climate Change (2014-2020) promotes urban waste incineration and landfill gas power generation.[765] In April 2020, the Standing Committee of the National People's Congress China amended its Solid Waste Law, which strengthens the supervision and management responsibilities of the government and its relevant departments.[766] It also furthers efforts to achieve zero solid waste imports, and integrates solid waste management into current environmental programmes. As per China's 13th Five Year Plan, the country aims to spend 0.75% of its gross domestic product on wastewater treatment. China's National Development Strategy prioritises environmental protection over economic growth, which has driven a rapid development of China's wastewater sector. In particular, the treatment capacity of municipal wastewater treatment plants has been substantially strengthened and stricter effluent quality control enforced.[767]

Demand is high, as shown in South Africa's policy and planning but substantial gaps between policy and implementation exist. South Africa includes waste as a mitigation pathway in its NDC. There is a National

[764] Costa, I.M., and Ferrera Dia, M. (2020). Evolution on the solid urban waste management in Brazil: A portrait of the Northeast Region. *Energy Reports.* https://www.sciencedirect.com/science/article/pii/S2352484719312429
[765] Climate Change Laws of the World. (2020). Climate targets: Energy. https://climate-laws.org/cclow/geographies/china/climate_targets/Energy
[766] Goldberg, Aaron, and Luo, Weiwei. (2020). *National Law Review.* https://www.natlawreview.com/article/china-promulgates-amendment-to-its-solid-waste-law
[767] Lu, Jia-Yuan, et al. (2019). Optimizing operation of municipal wastewater treatment plants in China: The remaining barriers and future implications. *Environment International.* https://www.sciencedirect.com/science/article/pii/S0160412019308669

Waste Management Strategy in place[768] and in 2019 the country imposed a ban on all forms of liquid waste from being dumped at landfill sites.[769] In 2001 South Africa issued the Polokwane Declaration, which set a target of 50% reduction in waste to landfill by 2012 and a full zero waste plan to be in place by 2022. In 2018, South Africa published its National Water and Sanitation Master Plan to curb poor alignment of existing policies in wastewater sector, reduce grey areas in responsibility and accountability, and to improve institutional arrangements. However, despite these measures and strategies, national level policies are often not implemented at the municipal level. Only 10% of waste is recycled and an estimated 98 million tonnes waste is deposited into landfills each year.[770]

South Asian countries show some commitment via policies and plans but are yet to fully initiate ambitions. All South Asian countries identify waste as a mitigation sector in their NDCs. The Pakistani government has recently reviewed the National Environmental Policy to establish new landfill sites and the 11th Five Year Plan specified that 50% of industries by 2018 and 100% by 2022 will treat industrial effluents along with municipal wastewater treatment as per guidelines.[771] As per its NDC, Sri Lanka is developing a Solid Waste Management Plan.[772] Afghanistan recently revised its Waste Management policy, Bangladesh has a number of waste-related policies. Bhutan has a National Waste Management Strategy and Nepal has a Solid Waste Management Act. However, Bangladesh's political will is low and its frameworks for solid waste management and wastewater do not give targets for achieving waste disposal, composting, and energy recovery.[773] In Pakistan, less than 8% urban wastewater was treated in the first quarter of 2017.[774]

West African countries show some commitment via policies and plans but are yet to fully initiate ambitions. In their NDCs, 70% of West African countries identify waste in their NDCs whilst 30% do not, including the Democratic Republic of the Congo, Equatorial Guinea, Guinea, Mali, Mauritania, Niger, and Togo. Ghana, Sierra Leone, and Nigeria have National Solid Waste Management Action Plans in place and Gambia has a Solid Waste Management Strategy while Senegal recognises waste management in its National Development Plan. Despite these policies and plans, waste management remains a challenge in the region. Lack of enforcement of these measures demonstrates a lack of political will and little is being done to overcome other barriers. The state of wastewater treatment is poor in most West African countries despite National Water and Sanitation Plans. For example, in the case of Nigeria, while the government has a decentralisation policy in water treatment, little actual decentralisation has happened to date.[775]

---

768 Republic of South Africa. (2011). National Waste Management Strategy. https://www.environment.gov.za/sites/default/files/docs/nationalwaste_management_strategy.pdf

769 Pandey, Kiran. (2019). Down to Earth. https://www.downtoearth.org.in/news/waste/south-africa-bans-dumping-of-liquid-waste-in-landfills-66390

770 Tomita, Andrew, et al. (2020). Exposure to waste sites and their impact on health: a panel and geospatial analysis of nationally representative data from South Africa, 2008–2015. *The Lancet*. https://www.thelancet.com/journals/lanplh/article/PIIS2542-5196(20)30101-7/fulltext

771 Korai, Muhammad Safar, et al. (2019). Comparison of Municipal Solid Waste management practices in Pakistan and China. https://www.springerprofessional.de/en/comparison-of-msw-management-practices-in-pakistan-and-china/17479596

772 UN Climate Change Secretariat. (2017). Catalysing the Implementation of Nationally Determined Contributions in the Context of the 2030 Agenda through South-South Cooperation. http://sdg.iisd.org/news/un-report-highlights-south-south-cooperation-in-achievement-of-climate-development-goals/

773 Yoshino, Naoyuki, Araral, Eduardo, and Seetha Ram, K.E. (2019). Water Insecurity and Sanitation in Asia. *Asian Development Bank Institute.* https://www.adb.org/sites/default/files/publication/544131/adbi-water-insecurity-and-sanitation-asia.pdf

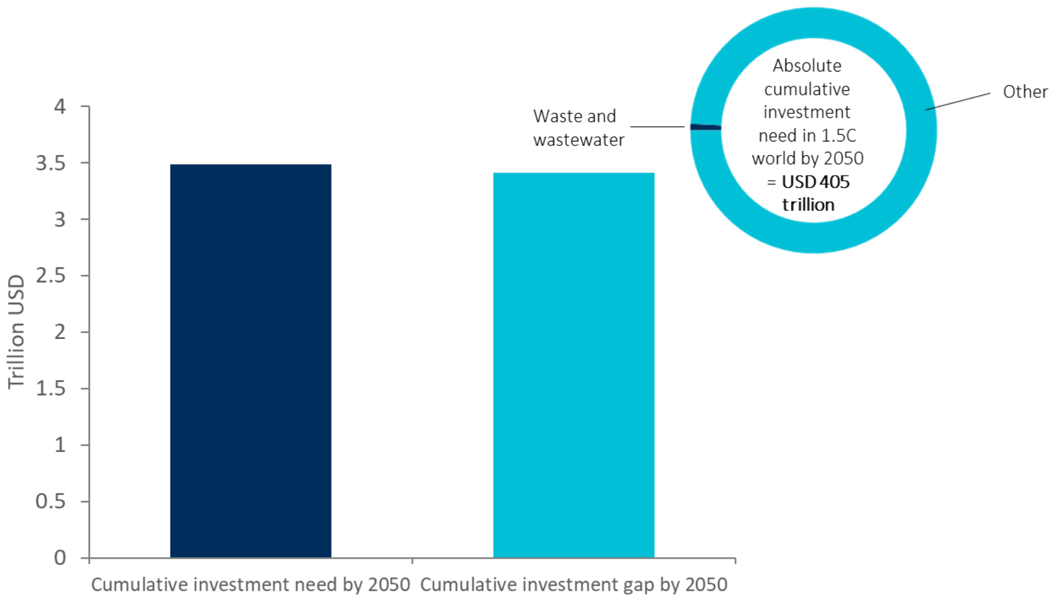
774 Wasif, S. (2017). *The Express Tribune*. https://tribune.com.pk/story/1362083/world-water-day-less-8-urban-waste-water-treated-pakistan-says-report t

775 USAID. (2018). USAID Water and Development Country Plan for Nigeria. https://www.globalwaters.org/sites/default/files/Nigeria%20Country%20Plan%20final.pdf

Investment need

In the 1.5-degree scenario, the cumulative investment gap for the solid waste and wastewater sector across all ODA-eligible regions is large at about USD 3.4 trillion and frontloaded with an annual investment gap of USD 140 billion/year in 2030, but which falls to USD 50 billion/year in 2050. This cumulative investment gap (Figure 45) is large not only in absolute terms but also relative to other land use opportunities assessed in this report. The gap is about double the assessed gap for forests and just slightly smaller than the gap for agricultural productivity. Approximately USD 1.9 trillion of the cumulative investment gap is in wastewater treatment, USD 1.3 trillion in BECCS plants using residues as feedstock, and USD 0.19 trillion in landfill improvements. The reason that the cumulative investment need and cumulative investment gap are so similar in Figure 45 is that the BAU investment need is assumed to be a continuation of current levels of climate finance into the solid waste and wastewater sector. This number is taken from Climate Policy Initiative (2019) and is USD 2 billion/year.[776] The projected annual investment gap in 2030 is significantly higher than in 2050 is due to decreases in the investment need in BECCS with residues. In 2030, the annual investment gap in BECCS with residues is about USD 80 billion/year, whereas in 2050 it is only USD 4 billion/year. This reflects the fact that IMAGE deploys BECCS technology very quickly in the 1.5-degrees scenario.

Figure 45 The investment gap in solid waste and wastewater is large.



Source: Vivid Economics, ASI and Factor calculation using IMAGE output and capital costs for landfills and wastewater treatment plants from US EPA (2013).

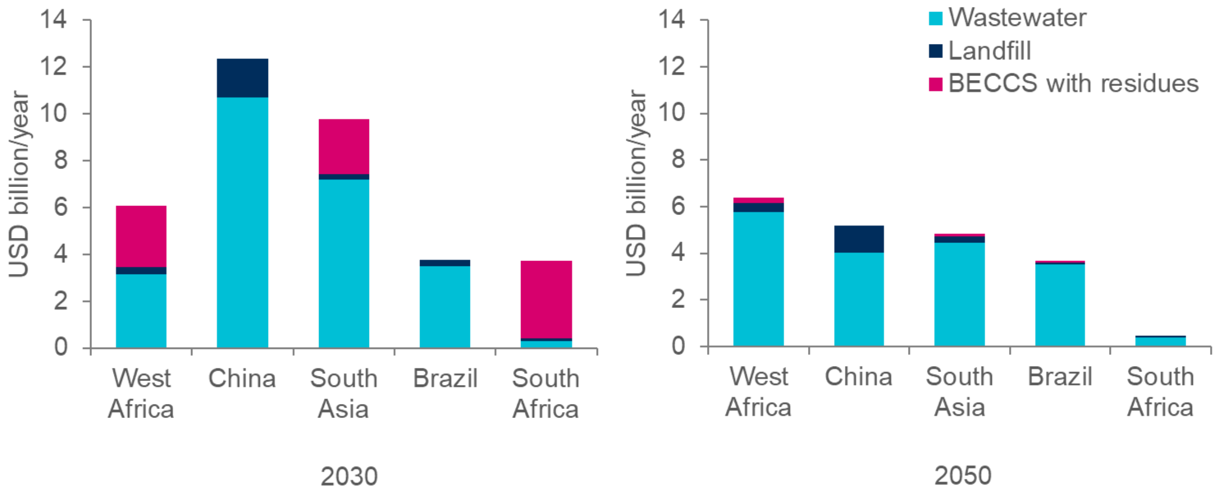
Notes: The absolute waste-wastewater investment need is calculated by summing the investment gap in the 1.5-degree scenario with the BAU investment need. BAU investment need is assumed to be a continuation of current levels of climate mitigation finance into the solid waste and wastewater sector.

Across focus regions, the investment gap ranges from USD 3.7 – 12.4 billion/year in 2030, but reduces to between USD 0.5 – 6.4 billion/year in 2050, suggesting urgent need for investments in certain regions. Figure 46 shows the investment gap split out by region and mitigation opportunity. As illustrated in the figure, China, South Asia, and South Africa see large decreases in the predicted investment gap between 2030 and

[776] Climate Policy Initiative. (2019). Global Landscape of Climate Finance 2019. https://climatepolicyinitiative.org/wp-content/uploads/2019/11/2019-Global-Landscape-of-Climate-Finance.pdf

2050. In China and South Asia, the investment gap in wastewater treatment is particularly high in 2030, suggesting a relatively urgent need for investment into wastewater treatment plants in these regions. In South Africa, West Africa and South Asia the investment gap in BECCS with residues as the feedstock is notably higher in 2030 than in 2050. In West Africa, the total investment gap for the sector remains constant due to a large increase in the wastewater treatment investment gap. In all regions, landfill improvements make up a small share of the total investment need. The investment gap in landfills is concentrated in China, accounting for about 60% of the total landfill investment need across focus regions.

Figure 46 Investment gap estimates across focus regions in 2030 and 2050 for 1.5-degree scenario, by mitigation opportunity.



Source: Vivid Economics, ASI and Factor using PBL's IMAGE outputs and literature.
Notes: This figure presents the investment gap for each region. Hence, the total investment need is higher.

Cost-effectiveness

Investments in solid waste and wastewater treatment are not highly cost-effective when measured in terms of mitigation impact. In landfills, the cost of methane capture and utilisation is between about USD 60-90/t CO_2e for open dumps.[777] While the cost is significantly cheaper for basic and engineered landfills, these more advanced landfill systems make up a small minority of the landfills in operation in the regions assessed here, with the exception of Brazil. The abatement cost of wastewater treatment systems is significantly more, at over USD 500/t CO_2e. However, the primary purpose of wastewater treatment is for public health, not climate mitigation, and so assessing its cost per tonne of CO_2 abated does not accurately portray the cost-effectiveness of this opportunity with regards to its wider benefits. The interventions considered in this report for increasing mitigation from residues for bioenergy focus on developing the supply chain and supporting RD&D and piloting of new bioenergy conversion technologies. While literature does not yet exist on the cost-effectiveness of these interventions, investments in developing supply chains are likely to be relatively cost-effective where transport infrastructure already exists, as required interventions will likely be in technical assistance and capacity building. Investments in RD&D are risky for any given technology, but generally have high returns to society on average.

Cost-effectiveness varies across regions due to three principal characteristics:

Landfill types currently in operation. Landfill mitigation measures are more costly to implement for open dumps versus basic landfills and engineered landfills.[778] Approximately 50% of waste in South Asia and 20% in West Africa is disposed of in open landfills,[779] and so landfill mitigation will likely be more costly in these regions. 75% of waste in Brazil and 72% of waste in South Africa goes to basic or sanitary landfills, suggesting that landfill mitigation will be less costly in these countries. The World Bank's Waste Database does not have good data on what type of landfill most waste is destined for in China.

Concentration of population in urban areas. Wastewater treatment plants are much more costly in rural areas due to the high cost of connecting households. The majority of the population in South Asia and West Africa are in rural areas, indicating that wastewater treatment plant interventions are likely more costly in these regions than in areas where there is a higher concentration of people in urban areas, such as in Brazil, South Africa, and China.

Prevalence of existing infrastructure for transporting agricultural and forestry residues to BECCS plants. To be used for bioenergy, biomass residues need to be collected from fields and forests and then transported to power plants. Setting up biomass residue supply chains will be significantly cheaper if good quality transportation infrastructure in active agriculture and forestry areas is already in place. West Africa has a very low road density at around 5 km/100 km^2, whereas other focus regions have road densities of between 20 to 43 km/100 km^2. Therefore, the cost-effectiveness of investments in establishing biomass residue supply chains is likely lowest in West Africa.

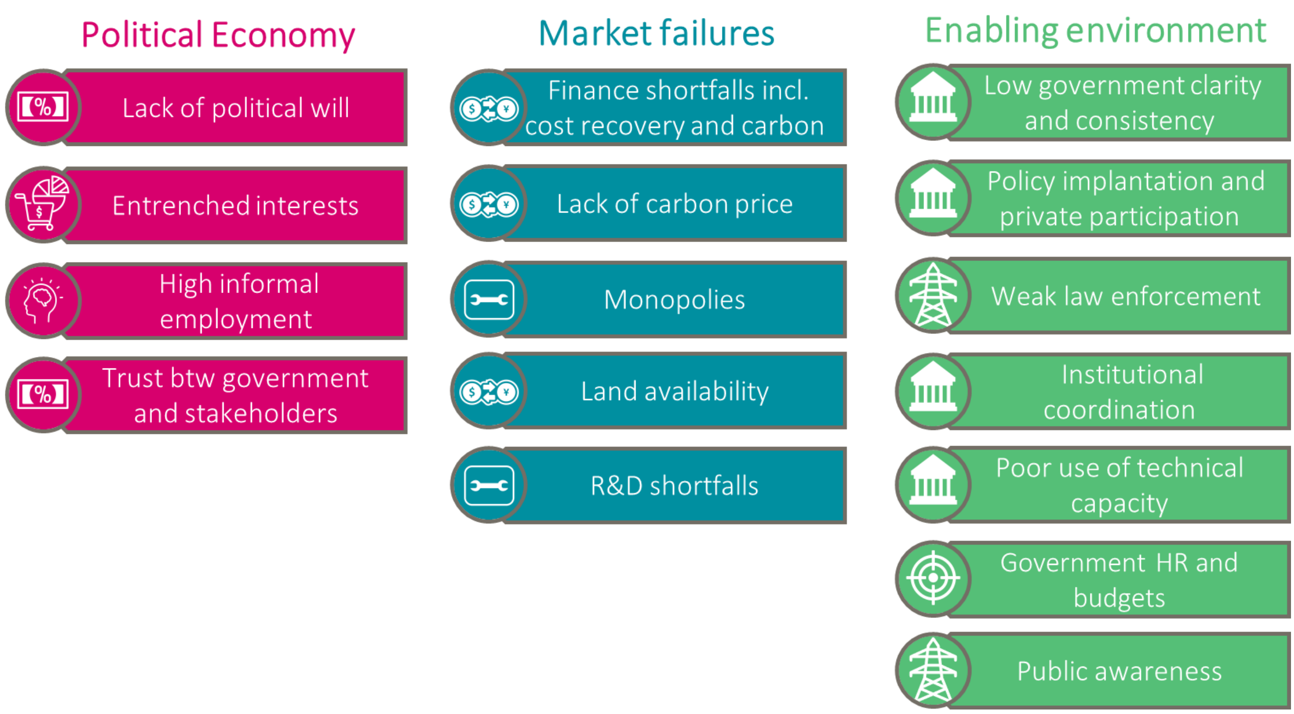
[777] US EPA. (2013). Global mitigation of non-CO_2 greenhouse gases: 2010-2030. https://www.epa.gov/sites/production/files/2016-06/documents/mac_report_2013.pdf.
[778] Ibid.
[779] 37% of waste in South Asia and 30% in West Africa goes to unspecified landfills, so the amount going to open dumps could be notably higher. This data is from The World Bank's Waste Database.

Barriers to adoption

The largest barriers to the solid waste and wastewater opportunity are those related to i) political economy challenges, ii) market failures, and iii) enabling environment (Figure 37). Each of these barriers, applying to varying degrees to all three categories of solid waste management (SWM), wastewater, and biomass conversion, are mapped to regions and potential solutions below. Because the application of mitigation pathways and technologies in the solid waste and wastewater sector is new and largely untested at scale in all priority regions, many of the barriers to GHG mitigation from solid waste and wastewater apply to the sector more broadly, whether in its political economy, institutional arrangements, financing shortfalls, or understanding of the technologies and benefits amongst government and citizens.[780]

Due to barriers in all regions there are high levels of solid waste dumping in fields, rivers, streets, or drains and of wastewater leakage directly into water systems.[781] Some of the dumped waste is subsequently burnt. In South Asia, South Africa and West Africa, for example, two-thirds of solid waste is dumped informally.[782] In Brazil just under half of solid waste goes to dumpsites. For most of the population in South Asia, South Africa, and West Africa there is no formal solid waste and wastewater collection, which applies only to middle- and upper-income districts of towns and cities. Similarly, the rate of reuse and recycling is low, accounting for under 10% of solid waste in South Asia and South Africa and West Africa, and there is little composting of the almost 50% of waste that is compostable in these regions.[783]

Figure 47 Barriers to an opportunity.



Source: Vivid Economics, ASI and Factor

The strength of the barriers has prevented the widespread and successful deployment of proven infrastructure and technologies. Engineered sanitary landfill accounts for 50% of solid waste in Brazil.[784] In many South African and South Asian, and most West African, cities there are only one or two landfill sites,

[780] Insight from expert interviews. (2020).
[781] World Bank. (2018). What a Waste 2.0. https://openknowledge.worldbank.org/handle/10986/30317
[782] Ibid.
[783] Insight from expert interviews. (2020).
[784] De Souza Marotta Alfaia, Raquel Greice, et al. (2018). Municipal solid waste in Brazil: A review. https://journals.sagepub.com/doi/full/10.1177/0734242X17735375

generally under-budgeted, substantially overused, and damaging to air and water sources. In these regions, wastewater treatment facilities are both insufficient in number and in a poor state of repair. Proven technologies, such as waste-to-energy plants, waste incinerators, anaerobic digesters, methane capture and use, small-scale biogas generation, composting, and advanced wastewater treatment plants, are peripheral or absent.[785] Where they do exist they have generally been provided through the intervention of bilateral donors and multilateral development banks. Other technologies, including biomass conversion, natural solutions in landfills and wastewater treatment, biomass briquettes, and bio-toilets, are unproven and only at the pilot stage and remain far from dissemination in the selected regions.

Though falling within the scope of the Sustainable Consumption opportunity report in this assessment, the most effective way of reducing emissions from the solid waste and wastewater sector in the selected regions is to reduce the amount of waste that is produced and to increase rates of reuse and recycling, including composting, thereby cutting the amount of waste in landfills and informal dumpsites.[786] The amount of solid waste and wastewater is also strongly influenced by wider processes of urbanisation and population growth, and in particular by the rapid and generally unplanned nature of urbanisation in most priority regions.

In Brazil, China, South Africa, South Asia, and West Africa moderate to high political economy barriers to investment or adoption are as follows:

Despite international and national commitments, solid waste and wastewater management – and especially waste sector mitigation – do not form a priority for governments when compared with other developmental needs.[787] China is to some extent an exception to this trend. The dearth of commitment has been brought to the fore in the context of Covid-19 when budgets for solid waste and wastewater management are amongst the first to be cut.

In South Africa, South Asia, and West Africa informal employment in solid waste management is high, both in the collection of waste in lower-income urban districts and in sorting waste from the point of collection, transfer, and final treatment for new purposes or reuse or recycling. As a result, there may be local opposition to the introduction of reforms and investments, for example stronger sector regulation or waste incineration.

The relationship between government and formal solid waste management, particularly around landfills, can be subject to entrenched interests and state capture whereby influential businesses with ties to government hold powerful positions. This is observed in South Africa, South Asia, and West Africa and hinders investment and new entrants.[788] [789] In China, on the other hand, solid waste and wastewater management are dominated by government, which poses challenges for private involvement.

Corruption in solid waste and wastewater management is a concern at all levels of government in all regions, limiting the effectiveness of collection and treatment.[790] Political corruption and the high incidence of kickbacks at both the local and national levels often influences the selection of inappropriate, capital-intensive waste management solutions.[791]

Problems of trust between national and sub-national government, the private sector, and citizens exist in all regions, in Brazil, South Africa, and West Africa especially, as a consequence of corruption,

---

785 Insight from expert interviews. (2020).
786 van Niekerk, Sandra and Weghmann, Vera. (2019). Municipal Solid Waste Management Services in Africa. https://www.world-psi.org/sites/default/files/documents/research/waste_management_in_africa_2018_final_dc_without_highlights_2019.pdf
787 World Bank. (2018). What a Waste 2.0. https://openknowledge.worldbank.org/handle/10986/30317
788 van Niekerk, Sandra and Weghmann, Vera. (2019). Municipal Solid Waste Management Services in Africa. https://www.world-psi.org/sites/default/files/documents/research/waste_management_in_africa_2018_final_dc_without_highlights_2019.pdf
789 Ferronato, Navarro and Torretta, Vincenzo. (2019). Waste Mismanagement in Developing Countries: A Review of Global Issues. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC6466021/
790 World Bank. (2018). What a Waste 2.0. https://openknowledge.worldbank.org/handle/10986/30317
791 Insight from expert interviews. (2020).

entrenched interests, and successive failed policies and initiatives.[792] This inevitably leads to low levels of compliance and payment of waste collection fees as services are of poor quality and citizens do not trust the government to manage the sector effectively.

Moderate market failures to investment or adoption are likely to be:

In all regions, especially India, South Africa, South Asia and West Africa, financing and capital issues covering low public budgets, low collection fees that fail to cover costs, unenforced tariffs, poor data on the cost of services, and the absence of a carbon price have a significant inhibiting effect on public services, deter private participation, and prevent the deployment of solid waste and wastewater infrastructure and technologies.[793] [794] Shortfalls apply to ongoing operational costs as much as, if not more than, capital investments. In general, in middle-income countries 40%- 50% of solid waste management equipment is out of use. In lower-income countries this figure rises to 80%-90%, often due to an inability to source and purchase spare parts.[795]

In all regions, especially South Africa, South Asia, and West Africa, influential and monopolistic actors in solid waste management emerging from a close relationship to government or state capture raise barriers to entry and limit private and NGO innovation and investment.[796]

In all regions, suitable land for landfills and treatment is becoming scarcer and its procurement more complicated as a result of rising waste volumes, population pressure on land, and land prices. Land selection is complicated by mistrust between government and citizens and is exacerbated by a lack of attention to public education and engagement.[797]

Due to a combination of political economy, market failure, and enabling environment barriers, research and development activities in solid waste and wastewater are a low priority in all regions. This leads to the persistence of outdated and inappropriate infrastructure, technology, and methods, and preventing deployment of new technologies. The lack of RD&D has particular salience to biomass conversion, as an unproven technology largely absent from priority regions.

The non-availability of quality data prevents government planning and decision-making and deters private investment.[798] In all regions, especially South Africa, South Asia, and West Africa, data are either lacking, partial, variable in quality, or inconsistent.

Moderate to high enabling environment / absorptive capacity barriers to investment or adoption are as follows:

The clarity of government purpose, defined by comprehensive treatment of the sector and all actors within it and consistency in decision-making is a barrier in all regions. This deters the private sector and NGOs from taking responsibility for parts of solid waste and wastewater management including collection, transportation, reuse and recycling, landfills, composting, and the variety of mitigation technologies.[799] Government treats the sector in individual project terms rather than a national endeavour, is short-termist, shows failings in stakeholder engagement, and concentrates resources in some regions more than others.

In all regions, solid waste and wastewater strategies and policies set objectives and targets for waste collection, transportation, segregation, landfills, treatment of hazardous materials, composting,

[792] Insight from expert interviews. (2020).
[793] World Bank. (2018). What a Waste 2.0. https://openknowledge.worldbank.org/handle/10986/30317
[794] Insight from expert interviews. (2020).
[795] Insight from expert interviews. (2020).
[796] World Bank. (2018). What a Waste 2.0. https://openknowledge.worldbank.org/handle/10986/30317
[797] Ibid.
[798] van Niekerk, Sandra and Weghmann, Vera. (2019). Municipal Solid Waste Management Services in Africa. https://www.world-psi.org/sites/default/files/documents/research/waste_management_in_africa_2018_final_dc_without_highlights_2019.pdf
[799] Insight from expert interviews. (2020).

anaerobic digestion, methane collection, waste-to-energy, and sanitary landfills. They nonetheless fall short in creating an accountable, transparent, and reliable environment for public-private partnerships as well as in defining the rules, regulations, and processes for implementation, which leads to slow and ineffective delivery of policy and insufficient private sector involvement.[800] Few policies in priority regions contain objectives or provisions for GHG mitigation.[801]

Weak enforcement mechanisms and corruption undermine policy implementation, leading to infrastructure deterioration, and discourage public-private partnerships and investment. For example, tariffs for solid waste and wastewater collection and treatment are generally insufficient and are not enforced.[802] Almost all cities in Brazil, South Africa, South Asia and West Africa practise open dumping due to an absence of formal collection services and inadequate monitoring and compliance by government and despite the existence of rules and regulations to the contrary.[803]

In all regions, horizontal and vertical coordination within government undermine policy implementation. Direct responsibility for solid waste and wastewater usually sits with state or municipal governments under the supervision of national government. Municipalities and states may have varying priorities and capacities and, nationally, several ministries may be involved, for example ministries of environment, health, water resources, local government, and planning. This results in competition, overlap of mandates, and confusion. Municipal authorities frequently fail to collaborate with each other, as in South Asia and West Africa. South Africa has experienced competition between ministries and levels of government in wastewater treatment.

Particularly in South Africa, South Asia, and West Africa, national technical and institutional capacity is not effectively utilised in solid waste or wastewater management and in mitigation opportunities and technologies therein.[804] [805] This affects the application of scientific and technological knowledge, the adoption of new technologies, operational management of facilities, and policy implementation capacity. Skills gaps are apparent, particularly in state and municipal government as well as in regulators, and training is absent or inadequate. Trust issues, for example in Bangladesh, inhibit collaboration between government, the private sector, NGOs, and universities where greater expertise may lie.[806]

In all regions, shortages of government staff and resources assigned to waste management preclude effective management. The solid waste and wastewater sector is generally not seen as an attractive career path, exacerbating HR and budget concerns.[807]

In all regions, public and citizen awareness about the mechanisms and benefits of effective solid waste and wastewater management and of mitigation opportunities is low, which leads to poor practice amongst producers of solid waste and wastewater, inhibits government initiatives, and disincentivises public-private partnerships and private investment.[808] Enhanced public awareness would help to build trust amongst stakeholders.

[800] World Bank. (2018). What a Waste 2.0. https://openknowledge.worldbank.org/handle/10986/30317
[801] Insight from expert interviews. (2020).
[802] Insight from expert interviews. (2020).
[803] World Bank. (2018). What a Waste 2.0. https://openknowledge.worldbank.org/handle/10986/30317
[804] van Niekerk, Sandra and Weghmann, Vera. (2019). Municipal Solid Waste Management Services in Africa. https://www.world-psi.org/sites/default/files/documents/research/waste_management_in_africa_2018_final_dc_without_highlights_2019.pdf
[805]. Ferronato, Navarro and Torretta, Vincenzo. (2019). Waste Mismanagement in Developing Countries: A Review of Global Issues. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC6466021/
[806] Insight from expert interviews. (2020).
[807] Insight from expert interviews. (2020).
[808] World Bank. (2018). What a Waste 2.0. https://openknowledge.worldbank.org/handle/10986/30317

Table 51 Summary of barriers per region

Region	Political economy barriers	Market failures	Enabling environment barriers
Brazil	Moderate to high Lack of political will, corruption and weak rule of law, eroded trust between government and stakeholders.	Moderate Financing shortfalls, lack of carbon price, low land availability, RD&D shortfalls.	Moderate to high Low government clarity and consistency, inadequate policy implementation, low private sector participation, weak law enforcement, institutional coordination, public awareness.
China	Moderate State capture, corruption and weak rule of law, eroded trust between government and stakeholders.	Moderate Lack of carbon price, monopolies, low land availability, RD&D shortfalls.	Moderate Low government clarity and consistency, inadequate policy implementation, low private sector participation, weak law enforcement, public awareness.
South Africa	Moderate to high Lack of political will, entrenched interests, high informal employment, corruption and weak rule of law, eroded trust between government and stakeholders.	Moderate Financing shortfalls, lack of carbon price, monopolies, low land availability, RD&D shortfalls, data shortages.	Moderate to high Low government clarity and consistency, inadequate policy implementation, low private sector participation, weak law enforcement, institutional coordination, poor use of technical capacity, government HR and budgets, public awareness.
South Asia	Moderate to high Lack of political will, entrenched interests, high informal employment, corruption and weak rule of law, eroded trust between government and stakeholders.	Moderate Financing shortfalls, lack of carbon price, monopolies, low land availability, RD&D shortfalls, data shortages.	Moderate to high Low government clarity and consistency, inadequate policy implementation, low private sector participation, weak law enforcement, institutional coordination, poor use of technical capacity, government HR and budgets, public awareness.
West Africa	Moderate to high Lack of political will, entrenched interests, high informal employment, corruption and weak rule of law, eroded trust between government and stakeholders.	Moderate Financing shortfalls, lack of carbon price, monopolies, low land availability, RD&D shortfalls, data shortages.	Moderate to high Low government clarity and consistency, inadequate policy implementation, low private sector participation, weak law enforcement, institutional coordination, poor use of technical capacity, government HR and budgets, public awareness.

Source: Vivid Economics, ASI and Factor

UK additionality

Historical donor activity in this opportunity has been driven by the World Bank, Global Environment Facility (GEF), Asian Development Bank (ADB), and African Development Bank (AfDB). Traditionally, donor funding has focused upon infrastructure works and equipment and has paid insufficient attention to factors such as institutional capacity development, private sector participation, awareness raising, and cost recovery. The rationale for this was to concentrate on project-based assistance and avoid institutional complexities and politics. Amongst large capital investments and application of new technologies, notably engineered landfills, waste incineration, methane capture and use, and waste-to-energy, there has been a high failure rate. Governments and multilateral development banks, mostly the World Bank and regional development banks, have nevertheless favoured these projects despite their poor track record.

Most initiatives treat solid waste and wastewater management as part of urban development, air quality, healthcare, and water and sanitation initiatives, rather than concentrating on GHG mitigation and low-carbon investments.

According to data from the Organisation for Economic Co-operation and Development's Development Assistance Committee (DAC), in between 2015 and 2018 in the waste management disposal sector, DAC members spent USD 6m in Brazil, USD 0.5m in China, USD 1.9m in South Asia, and approximately USD 62m in West Africa.

The World Bank has committed over USD 4.7 billion to solid waste and is implementing key programmes in Brazil, South Asia, and West Africa.[809] In China and South Asia, the Asian Development Bank is implementing programmes in solid waste management. The Sustainable Energy Fund for Africa of the AfDB has invested in waste-to-energy plants across Africa. The GEF is running sustainable waste management programmes in West Africa.

Bilateral donors have made smaller contributions in the sector but include the United States Agency for International Development (USAID) and the German Agency for International Cooperation (GIZ), which have minor presence in Brazil, South Asia, South Africa, and West Africa.

Certain foundations and trusts have paid particular attention to wastewater, most notably the Bill and Melinda Gates Foundation, with a focus on decentralised wastewater improvements and treatment.

In regions with the largest mitigation potential, the UK has typically had low to moderate ties and with most programmes of support focusing on sustainable urban growth rather than solid waste and wastewater specifically.

The UK has long-standing and strong ODA relationships with South Africa and countries in South Asia and West Africa, predominantly centred on the DFID, now FCDO. BEIS and the UK Prosperity Fund have growing relationships with Brazil, China, South Africa, and West African countries like Nigeria. DFID made particular progress in insisting on long-term programming, additionality, and evidence-informed policy.

The UK has not provided large volumes of direct assistance in solid waste and wastewater, including for GHG emission reduction purposes. However, the FCDO's sustainable urban growth programmes, such as Cities for Economic Growth, cover countries in South Asia and West Africa and its Prosperity Fund Future Cities Programmes are active in Nigeria and South Africa. DFID has provided substantial assistance in water and sanitation in South Africa, South Asia, and West Africa.

[809] World Bank. (2018). What a Waste 2.0. https://openknowledge.worldbank.org/handle/10986/30317

The UK's additional value is moderate, resulting from moderate to high domestic expertise and the relatively low levels of donor investment and attention in selected regions.

- After Germany and Sweden, the UK occupies a market and technology leadership position in SWM and wastewater treatment, including in public-private partnerships and low-carbon technologies.
- The UK's institutional expertise, for example Loughborough University and the Chartered Institute in Wastes Management (CIWM), can be valuable. The CIWM offers advice and knowledge on scientific, technical, and practical aspects of solid waste and wastewater management. Loughborough University's Water Engineering and Development Centre teaches courses on SWM and wastewater and holds large annual events for sector learning.
- The UK's policies and regulations can act as a resource for international assistance, for example the UK Sewage Treatment Legislation, Resource and Waste Strategy, Landfill Tax, and Plastics Pact.
- The UK's RD&D into new technologies is an asset, for example via the partnership between the Department for Environment, Food & Rural Affairs and UK Research and Innovation.

Intervention opportunities

There are moderate but tangible opportunities across all regions for the UK to address the identified barriers.

- There is currently low donor presence and interest in solid waste and wastewater, particularly in the bilateral arena, which raises the potential to address immediate barriers and achieve impact and removes complications of donor coordination and duplication.
- Brazil and China have higher capacity and have made greater progress in solid waste and wastewater than other regions and thus may show impact sooner. South Africa and most countries in South Asia and West Africa have relatively high barriers and low capacity and may thus display greater need, though impact would fall in the medium term.

For solid waste and wastewater the most critical barriers to deployment are as follows:

- Lack of political commitment to solid waste and wastewater management, especially post-Covid-19, and entrenched interests intertwined with weak enforcement mechanisms and corruption in all regions.
- Lack of clarity of government purpose and comprehensive treatment of solid waste and wastewater, combined with the absence of policy and institutions that offer an accountable, transparent, and reliable environment for public-private partnerships, leading to low private sector involvement.
- Particularly in South Africa, South Asia, and West Africa, the lack of productive stakeholder engagement and ineffective utilisation of technical and institutional expertise between national and sub-national government, the private sector, and universities.
- Lack of attention paid to public education and awareness raising resulting in low understanding of benefits and mitigation potential and a lack of compliance with service requirements and payment of collection fees.
- Challenges in funding solid waste and wastewater management coupled with cost recovery, especially in South Africa, South Asia, and West Africa, inhibiting services and deterring private participation.
- Minimal RD&D development in all regions, leading to the persistence of outdated and inappropriate infrastructure, technology, and methods, and preventing deployment of new technologies.

UK interventions could simultaneously address barriers in the solid waste and wastewater sector more broadly as well as barriers to mitigation. They could rely on a combination of technical assistance, exchanges of expertise between UK and priority country institutions, e.g. of chartered waste managers and environmental engineers, and concessional funding, and should adopt five- to ten-year time horizons rather than one- to three-year ones. Particularly in Brazil, South Africa, South Asia, and West Africa, the imperative in the next five to ten years should be to lay the foundations of decent basic infrastructure and technology while the enabling environment improves. Thereafter, investment might turn to more advanced mitigation technologies. China, and to an extent Brazil, may be readier for new technologies sooner than other regions.

Interventions to improve the broader solid waste and wastewater enabling environment include the following:

- Institutional capacity-building support to national, state, and municipal governments to improve policy implementation and consistency, strengthen vertical and horizontal coordination, give clarity to government approaches, and establish comprehensive treatment of solid waste and wastewater across all stakeholders.

Capacity-building support to government to improve the regulatory environment for the private sector and increase participation, including accountability and transparency, procurement processes, contract preparation, monitoring, and enforcement.

Capacity-building support and training to municipal government in managing engineered sanitary landfills, waste incinerators, and waste-to-energy facilities.

Formal and complementary informal platforms and mechanisms for dialogue between national and sub-national government, the private sector, NGOs, and universities to discuss barriers and responses, build confidence and trust, and plan reforms and public-private partnerships.

Public awareness initiatives to better communicate with and engage citizens about the benefits of solid waste and wastewater management in order to achieve enhanced participation, acceptance, compliance, and payment of collection fees.

RD&D support in partnership with stakeholders for low-carbon technologies, for example those that convert biomass waste and residues into usable energy.

Where high political economy and commitment issues are apparent, as in all regions, channel support to state and municipal governments, national associations, and civil society to leverage influence, improve coordination, and raise government and public awareness and understanding.

Interventions to incentivise investment into solid waste and wastewater infrastructure and technology include the following:

Concessional financing and associated advice, for example assisting public-private partnerships and offering debt and guarantees, to raise finance for accessible and deployable solid waste and wastewater management infrastructure that is consistent with low-carbon development, such engineered landfills and sanitary landfills.

Financing of pilot demonstration projects in partnership with government and the private sector in more advanced technologies such as biomass conversion, waste-to-energy, waste incineration, anaerobic digestion, and wastewater treatment plants.

Box 30 Johannesburg Waste-to-Energy Project, South Africa, 2012 – ongoing

Landfill gases are responsible for 4% of South Africa's greenhouse emissions. The Johannesburg Waste-to-Energy project started in 2007 and was registered under the United Nations Framework Convention on Climate Change Clean Development Mechanism (CDM) in 2012 via which it receives a stream of revenue from carbon credits. It is still ongoing and is a successful example of commercial waste-to-energy generation. It consists of a partnership between the local authority in Johannesburg and EnerG Systems Joburg, a private energy company that constructed and is operating the landfill sites covered.

The objectives of the project are to reduce GHGs, particularly methane, from landfills; to produce electricity from renewable sources; and to reduce adverse environmental effects of landfill gas and contribute to South Africa's sustainable development.[810] As such, activities undertaken include the capture of landfill gas from five landfill sites through a network of pipes and pumps, conversion of a proportion of this gas into electricity, and sale of the electricity produced to ESKOM, South African electricity utility, through the Renewable Energy Independent Power Producers Procurement Programme (REIPPP). Remaining gases are safely burnt, with the possibility of future conversion. As a consequence, the results of the project are:

- Renewable energy generation capacity of 13 MW, contributing to the national renewable energy target and a specific landfill gas target of 25 MW, offering a policy incentive to the project;[811]
- GHG emission reductions of approximately 459,034 tCO2e per year, equal to removing more than 153,000 cars from the roads;[812]
- Regulatory measures under REIPPPP to link landfill gas to the power sector, including sale of electricity and establishment of realistic tariffs;
- Development of public and private sector capacity to undertake, implement and monitor low-carbon projects, via training staff and new and green employment opportunities.

The project has provided important lessons, which include:

- Donor funding, in this case in the form of CDM, is useful to kick-start these types of public-private partnerships and enable businesses to enable accept certain downstream risks, especially with new technologies, and to give confidence to local government counterparts.
- New technologies such as those involved in landfill gas conversion to electricity require effective operation, maintenance and access to spare parts;
- Regulatory factors such as setting up and revision of tariffs, as well legal rights and restrictions, can deter the private sector and/or delay project planning and implementation.

Challenges and causes of uncertainty faced by the project have included changes in regulation and tariffs due to evolving political dynamics and legislation; legal issues, namely EnerG Systems's access rights to waste streams; and management of the numerous relationships within the project, notably between EnerG Systems, the local authority and ESKOM, particularly on matters of contract and risk-sharing.

[810] Republic of South Africa Designated National Authority. (2012). Project Design Document: Landfill Gas Utilisation Programme of South Africa http://www.energy.gov.za/files/esources/kyoto/2012/PDD_AppForm_LandfillGasUtilisationProgramme_120330.pdf
[811] Urban Energy Support. (2015). Municipal Landfill Gas to Energy Project. http://www.cityenergy.org.za/uploads/resource_359.pdf
[812] Climate Neutral Group. (2020). Joburg Waste to Energy Offset Project. http://climateneutralgroup.co.za/wpcontent/uploads/2020/02/Joburg-Waste-to-Energy-Offset-Project-v1.pdf

Box 31 Support to the implementation of the National Policy for Solid Waste considering climate-protection (ProteGEEr), 2017 - 2021

Despite Brazil's National Solid Waste Policy, GHG emissions from solid waste are increasing. This project aims to improve the solid waste enabling environment, mitigate emissions and improve efficiency by advising ministries on integrating climate mitigation into sector rules and regulations. It also supports study into climate-friendly waste management measures and the establishment of a German-Brazilian research and advisory network. The programme is supported by the International Climate Initiative and GIZ. In pursuit of its objectives, the activities of ProteGEEr are:

- Review and amendment of methods of calculating GHG emissions from municipal solid in the National Basic Sanitation Plan and other national guidelines;
- Promotion of technologies to minimise GHG emissions and encourage recycling;
- Training of local government and private sector officials in planning and implementing effective and climate-neutral waste management;
- Development of postgraduate studies on sustainable waste management and mitigation in collaboration with six national universities and one research centre;
- Support for research projects and dialogue between German and Brazilian research institutions.

As a consequence, the results of ProteGEEr as of August 2020 are:[813]

- Training and advice of 16 pilot municipalities in Ceará, Minas Gerais and Mato Grosso on regional waste management plans, waste tariffs and waste management financing;
- Advice to ministries and municipalities on strengthening national level strategies and coordination;
- Integration of recycling management into a €7 million tender by the Ministry of the Environment for investment subsidies in the waste sector;
- Eleven university-level waste management research projects in institutions in Brazil and Germany as well as research proposals on climate-friendly waste management instruments;
- Awareness raising at the Associação Brasileira de Engenharia Sanitária e Ambiental, the Foreign Trade Chamber, and the Congress on climate financing for urban waste management.

Important clients and stakeholders were Brazil's Ministry of Regional Development, Ministry of Cities, Ministry of Environment , municipal governments, and Universität Braunschweig. The coordination of stakeholders in the solid waste sector was a key challenge during ProteGEEr. ProteGEEr provided multiple lessons and practical experiences:

- Given the complex nature of policy reform and the stakeholders involved, the project required time to propose changes or understand concerned policies and plans;
- Coupling long-term objectives with short-term actions draws commitment from stakeholders at all levels and has the potential to yield higher impact and build sustainability.
- Capacity building at different levels enabled the project to gain traction and progress more swiftly, particularly at municipal level where capacity gaps were prevalent;
- To strengthen vertical coordination, it was practical to promote a dialogue between national and local levels on solid waste management.[814]

[813] IKI. (2020). Climate friendly technologies and capacity development for the implementation of the Brazilian National Waste Policy. https://www.international-climate-initiative.com/en/details/project/climate-friendly-technologies-and-capacity-development-for-the-implementation-of-the-brazilian-national-waste-policy-17_I_264-544

[814] GIZ. (2020). Support to the implementation of the National Policy for Solid Waste considering climate protection. ProteGEEr: Cooperation for climate protection with urban solid waste management. https://www.giz.de/en/worldwide/66147.html

Glossary

Acronym / Term	Definition
ADB	Asian Development Bank
AfDB	African Development Bank
BAU	Business-as-usual
BECCS	Biomass energy with carbon capture and storage
BEIS	UK Department of Business, Energy and Industrial Strategy
CCC	UK's Committee on Climate Change
CDM	Clean Development Mechanism
CIWM	Chartered Institute in Wastes Management
DAC	Development Assistance Committee
DFID	Department for International Development
EJ	Exajoule
FCDO	The Foreign, Commonwealth & Development Office
GEF	Global Environment Facility
GHG	Greenhouse gas
GIZ	German Agency for International Cooperation
Gt CO2e/year	Gigatonne carbon dioxide equivalent per year
ICF	International Climate Finance
MW	Megawatt
NDC	Nationally Determined Contribution
NGO	Non-governmental organizations
ODA	Official Development Assistance
RD&D	Research, design and development
REIPPPP	Renewable Energy Independent Power Producers Procurement Programme
SDG	Sustainable Development Goal
SWM	Solid Waste Management
US EPA	United States Environmental Protection Agency
USAID	The United States Agency for International Development

Sustainable Consumption

Summary

The sustainable consumption opportunity considers interventions to reduce the consumption of carbon-intensive goods and decrease emissions from avoidable landfilling of solid waste. This assessment includes interventions to reduce food waste through behavioural change among consumers and preventing losses along the supply chain, increasing household rates of recycling and reuse by changing consumer habits and improving institutions and/or facilities for the disposal and treatment of waste, and reducing consumption of fast-moving consumer goods (FMCGs) and plastics.

Interventions to support sustainable consumption include:

Financing, technical assistance, and capacity building to reduce the consumption of FMCGs, to support consumers broadly with recycling, to promote behavioural change, and to prevent food loss throughout the cold chain.

Combined technical assistance and financing to promote business-to-business partnerships, to encourage public-private partnerships, and to support the development of Bioeconomy Strategies and the design and implementation of regulation and fiscal policy.

Direct investment in the improvement of general infrastructure, the improvement and expansion of cold chains, improved storage and transport of agricultural food commodities, and replacement of old equipment.

Table 52 Sustainable consumption assessment summary

Criteria	Assessment	Notes
Climate impact	High	• High aggregate mitigation potential, particularly in regions with large gaps between waste production and current recycling rates and high producers of food waste – notably China and Brazil. • High potential across a range of interventions, including technical recycling investments but especially among behavioural interventions to reduce food waste and material consumption.
Development impact	High	• Significant potential to achieve immediate and lasting impacts on most Sustainable Development Goals (SDGs), and particularly in addressing hunger, promoting good health and well-being, contributing to sustainable cities and communities, and advancing responsible consumption and production.
Investment gap	High	• Investment need is high to meet sustainable consumption aspirations, though investment spend is considerably less for interventions to change consumer behaviour than for capital spending or infrastructure investments. • New facilities for the treatment and recycling of waste likely to require high levels of additional investment.
Cost-effectiveness	High	• Infrastructure investments and technological investments to support increased recycling, reduced food waste, and improved cold chains are frequently cost-effective, but may require high upfront costs that inhibit investment. • Regulatory and behavioural interventions offer greater cost-effectiveness, though the associated emissions reductions may also be lower than with technical interventions unless large-scale behavioural change is created
Barriers to adoption	Medium	• Moderate political economy barriers, such as unsuitable regulations on food safety and packaging, moderate market failures, such as information asymmetries, and high enabling environment barriers, such as social impact of emissions not reflected in prices in all the focus regions.

Criteria	Assessment	Notes
UK additionality	Low	• The UK has relevant experience in the design and roll out of awareness raising campaigns collaborations; RD&D in systems and solutions that reduce food loss and waste; and design and roll out of key waste management infrastructure. Therefore, the UK can build on previous experience in the focus areas.

Source: Vivid Economics, ASI & Factor

Key lessons for supporting mitigation through sustainable consumption:

Brazil and China are likely to provide particularly large mitigation opportunities within this opportunity. There is likely to be significant development impact potential across all regions though demand may be highest in China and Indonesia given considering policy factors.

The range of interventions within the opportunity offer good cost-effectiveness, especially for behavioural and regulatory interventions.

The UK can build on its significant strengths and experience in the focus areas to overcome moderate to high barriers. Design and roll out technical assistance, capacity building, and financing interventions. To be successful, interventions should engage with companies and non-governmental institutions, as the private sector is often better positioned to generate innovative solutions to prevent food loss and waste.

Introduction to the opportunity

Role of the opportunity in decarbonisation of developing countries

Two-thirds of global waste – 1,300 megatonnes (Mt) - is generated in lower- and middle-income countries, 50% of which is food and green waste. The effect of food waste on climate is substantial. Estimates suggest that a quarter to one-third of all calories produced—associated with 6-8% of global emissions—are never eaten.[815] Another 200 Mt (16%) of waste in low- and middle-income countries consists of recyclable materials such as plastic, metals, paper, and cardboard.[816] While post-consumer waste emissions are modest (approximately 1.6 gigatonnes (Gt) of emissions in 2005 came from waste, with methane emissions from landfilling being the largest component),[817] the circulation of key inputs, such as plastic, steel, and aluminium, could have a dramatic effect on the resource efficiency of carbon-intensive industry and reduce global emissions by as much as 40% in 2050.[818] In 2016, the world generated 242 Mt of plastic waste, 12% of all municipal solid waste;[819] by 2050 plastics production could represent 20% of oil consumption and 15% of global emissions.[820]

Low- and middle-income countries typically suffer from poor infrastructure for the transport and storage of perishable food products as well as inadequate waste disposal and treatment. In low-income countries, the large majority (approximately two-thirds) of wasted food is lost up-stream from the household due to insufficiently developed cold chains and poor harvesting and/or handling techniques.[821] Moreover, post-consumer waste is typically disposed of unsustainably. Controlled landfills and recycling facilities are typically uncommon in low-income countries, with 93% of waste being openly dumped in lower-income countries, compared to 2% in high-income ones. This is consistent with a poor regulatory environment for waste, with only 15% of developing countries having systems, national laws, and enforcement for waste disposal.[822] With waste created in lower- and middle-income countries projected to increase by 200-300% over the next 30 years, due to population growth and urbanisation, there is a pressing need for intervention and international support.[823] To the extent that these waste generation trends are avoidable, interventions are needed to change consumer behaviours and support more efficient consumption practices. To the extent that they are not avoidable, there must be adequate systems in place to prevent unnecessary landfilling or illicit disposal of recyclable materials in order to support the circular economy.

Scope considered in this assessment

This assessment of the sustainable consumption opportunity includes interventions to reduce the consumption of carbon-intensive goods and decrease emissions from avoidable open dumping, open incineration, and landfilling of solid waste. The scope of activities included in the analysis includes:

- **Reducing food waste**, through behavioural change among consumers and preventing losses along the supply chain.
- **Increasing household rates of recycling and reuse** by changing consumer habits and improving institutions and/or facilities for the disposal and treatment of waste.

---

815 Poore & Nemecek. (2018). Reducing food's environmental impacts through producers and consumers. ; Blakeney, Michael. (2019). Food loss and food waste: Causes and solutions.
816 Kaza et al. (2018). What a Waste 2.0.
817 Bogner et al. (2007). Waste Management. In Climate Change 2007: Mitigation. Contribution of Working Group III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change.
818 Ellen Macarthur Foundation. (2019). Completing the picture – How the circular economy tackles climate change.
819 Kaza et al. (2018). What a Waste 2.0.
820 Barroso Fernández. (2020). Mitos y Verdades. Revista Nuevo Comienzo (Vol. 17).
821 Poore & Nemecek. (2018). Reducing food's environmental impacts through producers and consumers. ; Blakeney, Michael. (2019). Food loss and food waste: Causes and solutions.
822 Kaza et al. (2018). What a Waste 2.0.
823 Ibid.

- **Reducing consumption of FMCGs and plastics,** through fiscal policies, social impact and climate disclosures, and awareness raising and information campaigns.

This opportunity does not consider dietary change, in particular a move towards plant-based diets, demand-side measures for energy consumption, or the construction and enhancement of solid waste management facilities, wastewater treatment facilities, or bioenergy generation from waste. Waste and wastewater mitigation opportunities are considered in a separate opportunity report.

This assessment prioritises regions that exhibit unsustainable consumption behaviours, produce a relatively high amount of total waste, and have an existing system for waste management that can be utilised for enhanced waste treatment and recycling. The sustainability of consumption is gauged through per capita measures of food and non-food waste creation as well as the composition of waste at the national/regional level. Additionally, the quality of existing waste management is assessed by whether countries/regions have the systems, laws, and enforcement mechanisms associated with waste management in place. Macro-environmental factors, such as aggregate emissions and population growth, as well as institutional indicators including government effectiveness and regulatory quality, are also taken into consideration, with fast-growing, high-emitting countries taking priority. This exercise led to the prioritisation of the following regions:

- Brazil
- China
- Eastern Europe and Central Asia
- Indonesia
- Mexico

Climate impact

Mitigation potential and urgency

Across developing countries as a whole, sustainable consumption activities have the potential to deliver substantial mitigation benefits as indicated below:

In particular, increasing household and industrial recycling to a feasible benchmark (65% globally) by 2050 could lead to 5.8 Gt CO2e of cumulative mitigation by 2050[824] – approximately 5 Gt taking place in non-OECD countries given current population and waste projections.[825]

In addition, for paper specifically, increasing recycling rates to 75% globally would reduce emissions in the industry by 7% annually or 1.1-1.95 Gt cumulatively between 2020 and 2050.[826] Encouraging paper recycling is particularly important for developing economies as paper consumption increases the fastest with rising incomes.[827]

Most importantly, reductions in avoidable food loss could lead to 0.6-6 Gt of mitigation in 2050, depending on the size of the reduction.[828] A 50% reduction in global food waste, for example, could result in 4.5 Gt of mitigation in 2050.[829] Separate estimates from the Food and Agriculture Organisation of the United Nations (FAO) show that a 38% reduction in food waste would generate 1.4 Gt of emission reductions per year.[830] From 2020 to 2050, a 50-75% reduction in global food waste could result in very high cumulative emissions reductions, amounting to 87.5-94.6 Gt of mitigation potential.[831] With approximately 80% of food waste occurring outside of Europe and North America in 2013 (and per capita food waste projected to increase in low-and middle-income countries over the next three decades), it is likely that the majority of mitigation would occur in low income countries.

Within the target regions considered in this assessment, Brazil and China are likely to provide particularly large mitigation opportunities and hence climate impact. Regional mitigation potential is assessed based on underlying trends across food waste, recycling, and materials consumption. Each region's relative mitigation potential is assessed as a high, moderate, or low priority within the set of top five prioritised regions – noting that all five regions have been identified as having particularly high mitigation potential in absolute terms. Brazil and China both offer high mitigation potential within the set of regions, based on substantial potential within each of three critical sustainable consumption themes. Eastern Europe and Central Asia and Mexico both offer moderate mitigation potential, based on consistent moderate mitigation potential across themes in the former region, and a mix of potential (cold chain improvements and behavioural change) in Mexico. Indonesia offers the lowest relative abatement due to low potential for behavioural interventions and modest potential for cold chain improvements.

[824] Project Drawdown. (2020). The Drawdown Review.
[825] Vivid Economics calculation using Project Drawdown (2020) estimates, World Bank waste composition data, World Bank per capita waste projections to 2050, and UN population projections to 2050.
[826] Project Drawdown. (2020). The Drawdown Review.
[827] Kaza et al. (2018). What a Waste 2.0.
[828] Smith et al. (2014). AR5 Climate Change Mitigation 2014: Mitigation of Climate Change
[829] Bajzelj et al. (2014). Importance of food-demand management for climate mitigation
[830] FAO. (2015.). Food wastage footprint & Climate Change.
[831] Project Drawdown. (2020). The Drawdown Review.

Table 53 Relative mitigation potential by region

Region	Mitigation potential	Cold chains and reducing household food waste	Increasing recycling rates and reuse	Reducing consumption of FMCGs and plastics
Brazil	High	- Second-highest producer of aggregate food waste and food waste per capita. - High mitigation potential for improved cold chains and for behavioural change.	- Generally high levels of total and per capita waste but very low recycling rate. - Moderate mitigation potential for waste management, high potential for changing consumer behaviour.	- Upper middle-income country with a large population. - High mitigation potential for product standards, labelling, and other measures to decrease the consumption of FMCGs and plastics.
China	High	- Highest producer of food waste on aggregate, but very low food waste per capita. - Low mitigation potential for behavioural change but very high mitigation potential for improved cold chains.	- Largest producer of recyclable waste, moderate governance and institutions for solid waste management but a low recycling rate. - High mitigation potential for waste management as well as behavioural change.	- Fast-growing middle-income country with a very large population and high demand for FMCGs and plastics. - Despite low waste per capita, high mitigation potential for product standards, labelling, and other measures due to size of the economy.
Eastern Europe and Central Asia	Moderate	- Moderate levels of food waste at the regional level and high per capita levels of food waste. - Moderate mitigation potential for improved cold chains and high potential for behavioural change.	- Moderate levels of aggregate, and high per capita, waste with countries typically having existing environments for waste collection and management. - Higher mitigation potential for behavioural change than for investment into waste management.	- Mostly composed of middle-income countries that represent a large population on aggregate. - Moderate mitigation potential for product standards, labelling, and other measures to decrease the consumption of FMCGs and plastics.
Indonesia	Low	- High levels of food waste on aggregate but low to moderate levels of food waste per capita. - Mitigation potential higher for cold chains than for behavioural change.	- Moderate producer of waste but among the lowest per capita waste producers. - Mitigation potential primarily from improving waste management.	- Lower consumption of FMCGs and plastics per capita than other regions. - Low to moderate mitigation potential for product standards, labelling, and other measures to decrease the consumption of FMCGs and plastics.

Region	Mitigation potential	Cold chains and reducing household food waste	Increasing recycling rates and reuse	Reducing consumption of FMCGs and plastics
Mexico	Moderate	- Produces the least amount of waste in aggregate of the shortlisted regions, but produces the most food waste per capita. - High mitigation potential for behavioural change and moderate mitigation potential for improved cold chains.	- Moderate producer of recyclable waste on aggregate but highest producer of waste per capita. - Moderate mitigation potential from improving waste management, high mitigation potential from behavioural change.	- Upper middle-income country with a smaller population relative to other regions. - Low to moderate mitigation potential for product standards, labelling, and other measures to decrease the consumption of FMCGs and plastics.

Source: Vivid Economics, ASI and Factor

Transformational change

Table 54 below assesses the potential for this opportunity to support transformational change.[832] Sustainable consumption opportunities may target *sensitive interventions* by improving local capacities and capabilities, by promoting business-to-business partnerships, and by creating incentives for others to act through information campaigns, fiscal policies, and direct investments. Support for improving fiscal policies, direct investments to improve cold chain infrastructure and creating dedicated credit lines may generate *spillovers.* Finally, *innovation* may be supported by acting as catalyst for innovation in food loss and waste prevention initiatives, and by publicly sharing evidence of the effectiveness of the opportunity through social impact and climate disclosures.

Table 54 Assessment of transformational change

Transformational change criterion	Interventions to support change	Regional potential
Sensitive intervention points		
Improvement of local capacities and capabilities	Initiatives to improve institutions and/or facilities for the disposal and treatment of waste.	China
Local ownership and strong political will	Promoting business-to-business partnerships.	Eastern Europe and Central Asia
Leverage / creation of incentives for others to act	Support for improving fiscal policies. Creating credit or product lines (dedicated to reducing food loss and waste). Support for information campaigns and awareness raising. Direct investment to improve cold chain infrastructure. Support to measure food loss across borders.	All regions

[832] Climate Change Compass. (2018). Extent to which ICF intervention is likely to lead to Transformational Change.

Transformational change criterion	Interventions to support change	Regional potential
Spillovers		
Broad scale and reach of impacts	Support for improving fiscal policies. Support for information campaigns and awareness raising. Support to measure food loss across borders.	Brazil, Eastern Europe and Central Asia, and Mexico
Sustainability (continuation beyond initial support)	Support for improving fiscal policies. Direct investment to improve cold chain infrastructure.	All regions
Replicability by other organisations or actors	Creating credit or product lines (dedicated to reducing food loss and waste).	All regions
Innovation		
Catalyst for innovation	Measures to prevent losses along the supply chain. Initiatives to improve facilities for the disposal and treatment of waste.	All regions
Evidence of effectiveness is shared publicly	Social impact and climate disclosures.	All regions

Source: Vivid Economics, ASI and Factor

Development impact

SDG impacts

The promotion of sustainable consumption patterns has positive impacts on achieving SDGs in all the analysed regions. There may also be some negative SDG impacts in some regions, but these are expected to be of substantially lower strength, relative to the strength of positive impacts on SDG outcomes.

Table 55 SDG impacts

SDG	Strength of impact	Most relevant region	Rationale
Positive impacts			
SDG 2 – Zero hunger	High	All regions have challenges with this SDG[833] (and especially in some Eastern European or Central Asian countries, Indonesia, and Mexico).	Reducing food losses can help reduce hunger.
SDG 3 – Good health and well-being	High	All regions have challenges with this SDG (and especially in Brazil and some Eastern European or Central Asian countries).	The opportunity helps reduce the amount of landfilled and incinerated waste, reducing Nitrogen Oxide (NO_x) and sulphur oxide (SO_x) emissions.
SDG 4 – Quality education	Low	Brazil, some Eastern European and Central Asian countries, and Mexico have challenges.	Reducing food waste could reduce unnecessary household spending and free up money for education.[834]
SDG 5 – Gender equality	Low	All regions have challenges with this SDG (and especially in some Eastern European and Central Asian countries).	Reducing food waste could reduce unnecessary household spending and free up money for education, improving access to education rates for women.
SDG 6 – Clean Water and Sanitation	High	All regions have challenges with this SDG (and especially in some Eastern European and Central Asian countries, Indonesia, and Mexico).	The opportunity could help reduce the amount of landfilled waste and polluted water.
SDG 8 – Decent work and economic growth	Medium	Brazil, some Eastern European and Central Asian countries, and Mexico have challenges with this SDG. These challenges are especially acute in Indonesia and other Eastern European and Central Asian countries.	Reducing food loss and waste and increasing household recycling rates could play a modest role in job creation across the supply chain.
SDG 11 – Sustainable cities and communities	High	All regions except Brazil and some Eastern European and Central Asian countries have challenges with this SDG.	Reducing landfilled waste and the consumption of FMCGs can reduce management fees for households.
SDG 12 - Responsible Consumption and Production	High	Brazil, some Eastern European and Central Asian countries, and Mexico have challenges with this SDG.	The opportunity directly affects SDG 12.

[833] Bertelsmann Stiftung and Sustainable Development Solutions Network. (2020). Sustainable Development Report 2020.
[834] World Resources Institute. (2019). Reducing Food Loss & Waste.

SDG	Strength of impact	Most relevant region	Rationale
SDG 14 – Life below water	Medium	China and some Eastern European and Central Asian countries have challenges with this SDG. These challenges are especially acute in Brazil and Indonesia.	The opportunity could help reduce the amount of waste (food, plastic, and non-recycled materials) that could otherwise end up underwater).
SDG 15 – Life on land	Medium	All regions have challenges with this SDG (and especially in some Eastern European and Central Asian countries and in Indonesia).	The opportunity could help reduce land pollution.
Negative impacts			
SDG 1 – No poverty	Low	Brazil, some Eastern European and Central Asian countries, Indonesia, and Mexico have challenges with this SDG.	The opportunity could leave informal waste-pickers without a job and thereby increase the number of people unemployed and with no income stream.
SDG 9 – Industry, innovation, and infrastructure	Low	All regions have challenges with this SDG (and especially in some Eastern European or Central Asian countries, Indonesia, and in Mexico).	Some of the existing industries could be negatively affected by the opportunity.

Source: Vivid Economics, ASI and Factor

Demand in target regions

The promotion of sustainable consumption patterns through reducing food waste, FMCGs consumption, and increasing household recycling rates has the following demand in target regions.

Table 56 Demand in target regions

Region	Demand	Rationale
Brazil	Low	Lack of national policies and nationally determined contributions (NDCs) support.
China	High	Policies in place, NDC support ("low-carbon way of life").
Eastern Europe and Central Asia	Moderate	Lack of comprehensive policy frameworks, limited NDC support.
Indonesia	Moderate – high	Policies in place, NDC support (increase water recycling and avoid waste).
Mexico	Low - moderate	Sustainable consumption and production (SCP) policies (labelling, education), but no NDC support.

Source: Vivid Economics, ASI and Factor

In Brazil, the idea that the emerging middle class can leapfrog into sustainable consumption patterns seems to be unrealistic, and instead significant intervention is required to compensate for the tendencies of consumer groups to adopt resource-intensive lifestyles. This is found to be mirrored by companies' marketing behaviour, which is not reflective of environmental or social concerns.[835] Efforts to promote sustainable consumption in the country are channelled via the Action Plan for Sustainable Production and Consumption (PPCS),[836] and, until recently, via the Sustainable Public Procurement and Environmental Labelling Project (SPPEL). The country has no direct reference to sustainable consumption pattern promotion in its NDC.

China is committed to promoting sustainable consumption and production patterns, having raised the issue to the level of a key national strategy. However, a lack of transparency and information mean that Chinese consumers only have a basic recognition of sustainable consumption opportunities, especially amongst older generations. Nonetheless, Chinese consumers express a willingness to pay more for sustainable products.[837] China has put forward multiple policies aimed at promoting sustainable consumption, such as the 'Guiding Opinions on Promoting Green Consumption' released by the National Development and Reform Commission (NDRC) in 2004 and 2016, respectively. China refers to the need to make sustained effort in further implementing enhanced policies in production modes and consumption patterns in its NDC. Explicitly, it seeks to promote the “low-carbon way of life”, aiming to enhance education on consumption.[838]

In several countries of Eastern Europe and Central Asia, the decoupling of material use from economic growth is already well advanced. Household consumption is limited by low purchasing power, which is, however, recovering and increasingly results in adverse environmental impacts. Increases in energy, home, and transport expenditure are likely to be the most significant environmental stressors stemming from household consumption patterns in the region. Policy aimed at promoting sustainable consumption patterns in the region must focus on increasing production and resource use efficiency. However, so far, the development of comprehensive policy frameworks is yet to be developed.[839] Only Kazakhstan makes reference to SDG12 in its NDC in relation to its production-side waste management.

Indonesia has set out a 2025 vision in its National Development Plan, which also calls for Indonesia to become “beautiful and sustainable”. Indonesia has proposed national and regional level policy action aimed at promoting sustainable consumption and production patterns via the National / Regional Long-term Development Plan (RPJP), the National / Regional Medium-Term Development Plan (RPMN), and the National / Regional Annual Government Work Plan (RKP), focused on sustainable development and sustainable innovation.[840] Indonesia features two areas in its NDC related to SDG12, which are to increase recycling to reduce water consumption, as well as a reduction in the release of waste and chemicals.[841]

In Mexico, research indicates that consumers are aware of the environmental externalities of unsustainable consumption.[842] Mexico’s Development Plan and SCP policies rely largely on the introduction of standards or labelling on products and services, and with respect to natural resource use.843 Mexico further focuses on consumer education,[844] such as through programmes developed by its Consumer Protection Federal Agency (Profeco).[845] Finally, Mexico does not feature any provisions for sustainable consumption behaviour or SDG12 in its NDC.

---

[835] do Amaral Junior et al. (2020). Sustainable Consumption: The Right to a healthy environment.
[836] Msuya, Joyce. (2019). UN Environment Brazil 2017-2018.
Ministério do Meio Ambiente. (2011). Plano de Ação para Produção e Consumo Sustentáveis – PPCS.
[837] China Sustainable Consumption Research Program. (n.d.). Report on Consumer Awareness and Behaviour Change in Sustainable Consumption.
[838] China Sustainable Consumption Research Program. (n.d.). Report on Consumer Awareness and Behaviour Change in Sustainable Consumption.
[839] European Environment Agency. (2007). Sustainable consumption and production in South East Europe and Eastern Europe, Caucasus and Central Asia.
[840] State Ministry of National Development Planning/National Development Planning Agency (BAPPENAS). (2007). Law of the Republic of Indonesia number 17 of 2007 on long-term national development plan of 2005-2025.
[841] German Development Institute. (n.d.). NDC-SDG Connections. Accessed via: https://klimalog.die-gdi.de/ndc-sdg/sdg/12/
[842] Deschamps et al. (2016). Public consciousness and willingness to embrace ethical consumption of textile products in Mexico.
[843] GMA Consult Group. (2019). Mexico Issues Standard on Energy Efficiency of Refrigerators and Freezers.
[844] United Nations. (2010). Trends in Sustainable Development: Towards Sustainable Consumption and Production.
[845] Institute for Global Environmental Strategies (IGES). (2009). Education for Sustainable Consumption in Northeast Asia: Strategies to promote and advance sustainable consumption.

Investment need

Global investment need to meet sustainable consumption aspirations is high - though investment spend is considerably less for interventions to change consumer behaviour or gain a better understanding of how unsustainable habits can be changed than for capital spending or infrastructure investments. Regulatory and behavioural-focused interventions, such as product labelling, packaging standards, or bans of certain plastics, research into and application of behavioural insights, and pilot studies in developing countries are likely to be substantially lower cost than hard infrastructure investments. At the same time, fiscal policies such as plastic bag fees and carbon pricing for protein-based products may have potential to raise revenues.

Increasing recycling rates will require a scaling up in waste treatment and recycling facilities to accommodate for this change.[846] Investment may also be required to build or expand institutions to incorporate well-functioning waste collection services that extend to both informal and formal settlements.[847] At the same time, increasing recycling rates will also require a large and permanent change in human behaviour.[848] This will need to be brought about either through targeted information campaigns, various forms of liberal paternalism, i.e. consumer nudges, financial incentives including punishments for illicit waste disposal, and/or direct regulation. Investment in these activities could reduce aggregate investment needs due to reductions in the need for capital investments in waste infrastructure.

Investment need for the reduction of food waste is similarly high. On the supply-side, harvesting, processing, and storage technologies will need to be improved to reduce losses before food reaches consumers. Reducing losses upstream in the supply chain is more pertinent in the developing world, where food waste at the consumer level is considerably less. At the retail and consumer level, investment will be required to pursue similar measures for recycling. This includes financial incentives, targeted information campaigns, and other awareness raising efforts.[849] More broadly, investment could also support public institutions to set targets and monitor progress towards reductions of food waste across the supply chain. As with recycling infrastructure, investment in these activities could reduce aggregate investment needs due to reductions in the need for capital investments in infrastructure.

Improving cold chains and cold chain logistics typically requires high capital spend, contributing to high investment need. The cold chain encompasses a low-temperature environment for perishable foods throughout harvest, collection, packing, processing, storage, transport, and marketing before the product reaches the end consumer.[850] Most developing countries lack the required infrastructure, equipment, facilities, and management for cold storage and refrigeration of temperature-sensitive food products in each stage between harvest and consumption, and it is estimated that only 10% of temperature-sensitive food products have access to cold chains worldwide.[851] Improving cold chain logistics requires significant investment spend in the developing world, where the overwhelming majority of food losses occur before reaching the consumer.[852] Furthermore, additional investment is needed to address the climate impacts of improving cold chain logistics, particularly the emissions from hydrofluorocarbons found in refrigerants as well as emissions from increased energy use for cooling and transport.[853] There are several low cost measures available to producers to mitigate the climate impacts of cold chains, such as harvesting at cooler times in the day, use of shade immediately after harvest, and sourcing to local buyers. However, additional investment is needed for zero- or low-global warming potential refrigerants and energy efficiency improvements to prevent further emissions.

The targeted regions typically have some forms of systems, laws, and enforcement for solid waste collection which represent a large share of costs for municipal solid waste management, but new facilities for the

---

[846] Project Drawdown. (2020). The Drawdown Review.
[847] Hoornweg et al. (2012). What a Waste : A Global Review of Solid Waste Management
[848] Smith et al. (2014). AR5 Climate Change Mitigation 2014: Mitigation of Climate Change.
[849] Ibid.
[850] The Postharvest Education Foundation (PEF). (2013). Use of cold chains for reducing food losses in developing countries.
[851] UN Environment Programme (UNEP). (2019). Sustainable Cold Chain and Food Loss Reduction.
[852] FAO. (2011). Global Food Losses and Food Waste.
[853] UNEP. (2019). Sustainable Cold Chain and Food Loss Reduction.

treatment and recycling of waste may also require high levels of investment. Recycling facilities can operate at lower costs than controlled landfills but require significant upfront capital expenditures. Costs can vary depending on the sophistication of the facility and its capacity and on local costs, for example waste management costs in US dollars (USD) per tonne can range from USD 5/tonne to USD 50/tonne across lower- and upper middle-income countries.[854]

Within the target regions considered in this assessment, Brazil and China are both likely to face a particularly high investment gap. Regional investment gaps are assessed based on anticipated investment needs and the likely availability of existing domestic and international support to meet those identified needs. Each region's relative investment gap is assessed as a high, moderate, or low priority within the set of top five prioritised regions. Brazil faces high investment need for cold chain interventions and moderate investment need for recycling activities. The average consumer in China wastes considerably less than most Official Development Assistance (ODA) regions, but the country faces very high investment needs cold chain expansion and recycling facilities, though it is likely to be have greater access to capital for hard infrastructure investments. Eastern Europe and Central Asia and Indonesia both face moderate investment gaps based on underlying investment needs. Mexico likely faces the lowest relative investment gaps based on lower investment need across all themes.

Table 57 Investment need by region

Region	Investment gap	Cold chains and reducing household food waste	Increasing recycling rates and reuse	Reducing consumption of FMCGs and plastics
Brazil	High	- High investment need for improved cold chains and low need for behavioural changes among consumers.	- Moderate investment need for recycling facilities but lower investment needed for changing consumer behaviour.	- Interventions require little capital spend. - Low investment need.
China	High	- Low investment need for targeted interventions for consumer behaviour interventions but very high investment need for improved cold chains.	- High investment need for recycling facilities and low need for behavioural change at the household level.	- Interventions require little capital spend. - Low investment need.
Eastern Europe and Central Asia	Moderate	- Moderate investment need for cold chain logistics, but high need for consumer behaviour interventions.	- Moderate investment need for recycling capacity, but low investment need for consumer behaviour interventions.	- Interventions require little capital spend. - Low investment need.

[854] Kaza et al. (2018). What a Waste 2.0: A Global Snapshot of Solid Waste Management to 2050.

Region	Investment gap	Cold chains and reducing household food waste	Increasing recycling rates and reuse	Reducing consumption of FMCGs and plastics
Indonesia	Moderate	- High levels of food waste on aggregate but low to moderate levels of food waste per capita. - Mitigation potential higher for cold chains than for behavioural change.	- High investment need for recycling facilities and low need for behavioural change at the household level.	- Interventions require little capital spend. - Low investment need.
Mexico	Low	- Produces the least amount of waste on aggregate out of the shortlisted regions, but produces the most food waste per capita. - High mitigation potential for behavioural change but low mitigation potential for improved cold chains.	- Moderate investment need for recycling facilities but lower investment needed for changing consumer behaviour.	- Interventions require little capital spend. - Low investment need.

Source: Vivid Economics, ASI and Factor

Cost-effectiveness

The cost effectiveness of interventions to promote sustainable consumption vary both across different themes and within categories of interventions, due to the potential for a range of investments including hard infrastructure, regulatory support, and behavioural change activities. Within intervention, cost-effectiveness of certain investments – particularly infrastructure – is likely to also vary by region due to differing investment costs.

Infrastructure investments and technological investments to support increased recycling, reduced food waste, and improved cold chains are frequently cost-effective, but may require high upfront costs that inhibit investment.

Recent estimates suggest that replacing sanitary landfills with improved waste recovery facilities would require a net marginal first cost upwards of USD 10 billion globally. However, given the revenues from industrial sourcing of recovered materials, such as metals and plastics, these new facilities could create operational savings of USD 230 billion throughout their lifetimes when compared to the operational costs of maintaining landfills.[855] These estimates do not consider the additional capital investment and operational costs of implementing and maintaining comprehensive waste collection programmes in developing countries, which are likely to run high. As such, the cost-effectiveness of new recycling facilities and infrastructure is likely to fall within the low-to-moderate range.

However, technical investments in reducing food waste and improving the cold chain typically provide the greatest private and social returns, which typically outweigh costs by a wide margin. However, despite overall positive cost-effectiveness, the specific mitigation cost-effectiveness may be lower from a strict marginal abatement cost perspective, and individual investment costs vary depending on the type of investment, including the added cost to reduce the global warming potential of new capital – for example human capital-related investments are substantially lower cost than investments in refrigeration or refrigerated transport.[856] An analysis of 1,200 sites of 700 food companies in 17 countries found that 99% of sites had a positive return on their investment in food loss and waste reduction efforts, and half of the sites yielded at least a USD 14 return for every USD 1 invested.[857] Moreover, analyses indicate some financial returns from investing in technologies and practices to reduce food losses near the farm. For instance, one study in Kenya found that farmers who used metal silos to prevent grain losses saved an average of 150–200 kg of grain, worth approximately USD 130.[858]

Regulatory and behavioural interventions to support reduced food waste and greater recycling are likely to offer greater cost-effectiveness, though the associated immediate or direct emissions reductions may also be lower than with technical interventions unless large-scale behaviour change can be instigated.

The cost-effectiveness of interventions supporting regulatory and behavioural changes are likely to be moderate-to-high, based on the low cost of such interventions (relative to capital-intensive infrastructure projects) and moderate emissions reduction impacts. For example, behavioural insights initiatives or programmes to reduce household food waste typically require little capital spend as costs are restricted to programming and administration, meaning that even programmes with relatively low mitigation potential can be cost-effective interventions. At the same time, interventions to promote recycling among households or the reuse of consumer goods such as plastic bags, though likely to lead to low levels abatement, are relatively cheap. That said, the efficacy of interventions are known to widely vary. Empirical evidence on interventions to promote

[855] Project Drawdown. (2020). The Drawdown Review.
[856] World Resources Institute. (2019). Reducing Food Loss & Waste.
[857] Hanson & Mitchell. (2017). The Business Case for Reducing Food Loss and Waste.
[858] World Resources Institute. (2019). Reducing Food Loss & Waste

pro-environmental behaviour has shown that providing more information is typically ineffective[859] [860] in isolation and may actually enforce existing habits.[861] Other behavioural interventions, such as changing social norms and comparisons, feedbacks i.e. repeated information on individual performance, goal setting, direct regulations, or a combination of multiple strategies, have been proven to more effective,[862] though evidence specifically pertaining to the reduction of food waste is thus far lacking.[863] Systematic trials of different behavioural interventions aimed at reducing consumer food waste in a developing country context may be a worthwhile investment given the lack of research in this area and especially the rising trends in consumer food waste.[864]

[859] van Geffen et al. (2020). Household Food Waste—How to Avoid It? An Integrative Review.
[860] Stockli et al. (2018). Call for testing interventions to prevent consumer food waste.
[861] Somson et al. (2017). The Behavioural Economics Guide 2017.
[862] Osbaldiston & Schlott. (2011). Environmental Sustainability and Behavioral Science: Meta-Analysis of Pro-environmental Behavior Experiments.
[863] van Geffen et al. (2020). Household Food Waste—How to Avoid It? An Integrative Review.
[864] Stockli et al. (2018). Call for testing interventions to prevent consumer food waste.

Barriers to adoption

Sustainable consumption faces moderate political economy barriers, moderate market failures, and high enabling environment barriers in the focus regions. Prevalent political economy barriers refer to weak and unsuitable policies and regulations on food safety and packaging, limited trust in institutions, and subsidies to unsustainable fishing and farming. Market failures include information asymmetries hampering informed choices by consumers, an insufficient provision of RD&D and networks to prevent food losses in the food chain, and capital market imperfections that constrain improving recycling services and infrastructure. Finally, enabling environment barriers refer to regulations failing to reflect the social cost of carbon of perishable consumer goods, lack of the requisite knowledge by consumers to make informed choices, and the absence of regulations for the redistribution of food.

Figure 48 Barriers to Sustainable Consumption

Source: Vivid Economics, ASI and Factor

Political economy barriers

Weak and unsuitable policies. There are still policies that encourage unsustainable consumption lifestyles and they hamper the adoption of sustainable consumption patterns. Additionally, the lack of trust in institutions also hinders the changes needed towards sustainable consumption patterns. Policies and regulations related to food safety, food quality, labelling, packaging, trade and customs, tax incentives, agricultural extension services, and use of unsold food for animal feed or energy, may be barriers, be poorly coordinated, or be absent, resulting in food leaving the food supply chain.[865] These barriers are particularly important in countries such as Brazil and Mexico, due to the current policies in place in those countries.

Wrong incentives from governments. Apart from the lack and unsuitableness of regulations, governments often put the wrong incentives in place, encouraging unsustainable consumption. There are countries that that have subsidies that encourage electricity and fossil fuel consumption and unsustainable fishing, water irrigation, and agriculture.[866] As per those incentives, and similar to the case of unsuitable policies, Brazil and Mexico are the countries that have the longest way to go to overcome these barriers.

Market failures

Information asymmetries: The type and amount of product-specific environmental-impact-related information provided to the consumer has evolved during recent years, and now many consumers have ready access to information on both the environmental and social aspects of many products.

[865] World Resources Institute. (2019). Reducing Food Loss & Waste.
[866] See footnote 52.

At the same time, there is some relevant information that is either unavailable or not considered to be credible. Likewise, poor design of labelling can have the effect of confusing consumers with excessive information. All of the analysed regions would need to address these barriers as there is still a need for labelling standardisation.

Capital market imperfections. Improving recycling services and infrastructure may also be constrained by capital market imperfections given high upfront investments and lower rates of return. Capital market imperfections are an important barrier for China, the country that showed highest investment needs / costs for recycling facilities.

RD&D. There is a huge potential for food waste reduction if RD&D helps to find solutions to food losses along the food chain through technologies to preserve food quality and extend shelf life and further research into post-harvest food losses. Additionally, plastic packaging is made without taking into account its later recyclability or environmental impacts; if investments in RD&D were made, different material options could be used to make plastic packaging more recyclable and less resource-intensive (i.e. development of mono-material solutions that deliver similar performance, development of multi-material packaging or separation technologies that enable the separation of those different materials after use).[867] Eastern Europe and Central Asia, Mexico, and Indonesia are the countries and regions that have the lowest current expenditures in RD&D of the analysed regions and hence the RD&D barrier is understood to be highest.

Networks are needed to reduce food waste. In a circular economy approach, what is considered as waste in an earlier stage of the value chain could be a useful input to another stage of the same chain or another one. In this context, the prevailing understandings of what is waste can effectively act as persistent barriers. The status of cluster development in Eastern Europe and Central Asia is the lowest among the five countries and regions analysed; networks are a critical barrier for that region.

Enabling environment / absorptive capacity barriers

The social impact of emissions is not reflected in the prices of perishable consumer goods. Consumers often make their purchasing decisions only considering the price of the product to be purchased, failing to take into account the fact that some products may be more costly if the whole lifecycle is considered. Thus, the perceptions of price, performance, and credibility play a very important role in driving sustainable consumption.[868] All of the analysed regions need to overcome this type of barrier as the social impact of emissions is still not reflected in the prices of consumer goods.

Consumers often lack the requisite knowledge to make informed choices. An increasing share of the population is concerned about the impact of their consumption, but it is often difficult for them to precisely know what the specific impacts of the consumption of different goods are and to what extent they should consume (or not consume) these goods to meet their personal environmental concerns. Consumers are often unaware, or not well-informed, regarding the multiple effects that the products they consume have on the environment. Knowing all the numerous features of the products requires time, and some impacts are complex and difficult for consumers to understand.[869] As studies show,[870] as countries obtain higher overall levels of education (averaged, across the population), they typically obtain a greater the depth of understanding on issues related to sustainability. This barrier is considered to be high in countries from Eastern Europe and Central Asia, Indonesia, Mexico, and Brazil.

[867] Ellen Macarthur Foundation. (2019). Completing the picture – How the circular economy tackles climate change. Accessed via: https://www.ellenmacarthurfoundation.org/publications/completing-the-picture-climate-change
[868] Ibid.
[869] Ibid.
[870] Grunert, Klaus G.. (2013). Sustainability labels on food products: Consumer motivation, understanding and use.

The lack of adequate regulation for the redistribution of food hinders the reduction of food loss. Redistribution of surplus food offers a way to feed people and use food that would otherwise be landfilled while addressing food security issues.[871][872] Therefore, the inexistence of regulations for the redistribution of food contributes to the wastage of food. Even though some countries do have food banks, this barrier is high in all regions and countries, as regulation for the redistribution of food and food security needs to be improved and developed.

Table 58 Barriers per region

Region	Political economy barriers	Market failures	Enabling environment barriers
Brazil	Moderate Lack of national policies and NDC support.	Moderate Information asymmetries, low current expenditures in R&D.	Moderate Social cost of carbon not reflected in prices, lack of consumer knowledge, lack of regulation.
China	Low Multiple policies in place (i.e. 'Guiding Opinions on Promoting Green Consumption').	Moderate Information asymmetries, capital market imperfections.	Low Social cost of carbon not reflected in prices, lack of regulation.
Eastern Europe and Central Asia	Moderate Decoupling of material use from economic growth, but limited comprehensive policy frameworks.	High Information asymmetries, low current expenditures in R&D, low cluster development.	Moderate Social cost of carbon not reflected in prices, lack of consumer knowledge, lack of regulation.
Indonesia	Low National and regional level policies in place to promote SCP.	Moderate Information asymmetries, low current expenditures in R&D.	Moderate Social cost of carbon not reflected in prices, lack of consumer knowledge, lack of regulation.
Mexico	Moderate SCP policies limited to standards, labelling, and education, no reference in NDC.	Moderate Information asymmetries, low current expenditures in R&D.	Moderate Social cost of carbon not reflected in prices, lack of consumer knowledge, lack of regulation.

Source: Vivid Economics, ASI and Factor

[871] Ellen Macarthur Foundation. (2018). Cities and circular economy for food: Technical Appendix.
[872] World Resources Institute. (2019). Reducing food loss and waste.

UK additionality

There is large scope for UK additionality in promoting sustainable consumption patterns, with focus on capacity building and technical and financial support and the UK can use its expertise to help developing countries to achieve a more sustainable society. The UK is currently measuring food loss across its borders, and based on this experience, could help other countries do so too. Measuring food loss and waste can facilitate decision-makers to better understand how much, where, and why food is being lost or wasted. By doing this, companies and entities can prioritise interventions to reduce food loss and waste, enabling monitoring of progress over time, and helping entities stay on track to achieving their targets.[873] Further areas representing strengths and possible UK additionality include:

- The development of sustainable consumption patterns awareness raising campaigns, based on collaborations across the public, private. and voluntary sectors.
- RD&D in systems and solutions that facilitate sustainable consumption and reduced wastage in the food cycle.
- Design and roll out of key infrastructure that facilitates more sustainable consumption patterns, including recycling and reuse processing infrastructure.

Within the five priority regions considered in this assessment, the UK can build on previous areas of support. These areas include:

- In March 2019, the Sustainable Consumption Institute held a series of activities to explore the contribution of sustainable consumption and production within and between cities, countries, and global regions, building bridges with Brazil. Nevertheless, existing projects in Brazil are mostly focused on agriculture, land use, sustainable economic growth, and reducing poverty, leaving room for projects on sustainable consumption patterns.
- In China, most of the investments are related to the decarbonisation of the energy system and governance, showing that further opportunities can be found in sustainable consumption projects. In 2017, the UK and China launched the Green is GREAT campaign, which was focused on working together to achieve more sustainable growth.[874]
- In Indonesia, most of the active projects found are focused on forest, land use, poverty, and renewable energy but the United Kingdom Climate Change Unit (UKCCU) is helping Indonesia to promote responsible consumption.[875]
- In August 2019, the UK and Mexico signed the Partnership for Sustainable and Inclusive Growth. In March 2020 they agreed a Declaration on Climate Change and Sustainable Development to strengthen the development of the urban-environmental agenda, including through support to local governments to increase climate ambition, and through support to scale up successful initiatives at the subnational level in line with enhanced NDC targets and Mexico's intentions to deliver the SDGs/ Agenda 2030.

Additionally, there are a number of (moderate) synergies between this opportunity area and the UK's planned decarbonisation pathway:

- Reducing food waste is part of the UK's Net Zero strategy to decarbonise the Agriculture, Forestry and Other Land Use (AFOLU) sector. Moreover, the UK performs well among its European counterparts in terms of energy recovery of waste and percentage of waste landfilled. However, by most indicators the UK is not currently a leader in sustainable consumption. Whether the UK is primed

[873] World Resources Institute. (2019). Reducing Food Loss & Waste
[874] Department for International Trade. (2019). GOV.UK: Campaign launch targets increased UK-China partnership.
[875] Department for International Development (DFID). (2018). DFID UK Climate Change Unit Indonesia Country Profile.

to provide expertise and international development assistance for these mitigation activities will partly depend on whether its domestic plans come to fruition.

The improvement of sustainable consumption is one of the concerns of the UK Government, which led a campaign called Every Action Counts (EAC) to improve sustainability. EAC trained 800 to 1,000 people and it helped to embed good practices in sustainability for diverse areas such as events, finance, governance, and human resources. The UK could help developing countries to move towards a more sustainable society based on this collaborative and consultative experience.

Love Food Hate Waste (LFHW). The government-funded organisation WRAP (the Waste and Resources Action Programme) established a campaign focusing on carrying out relevant research, building new partnerships, making consumers more aware of the issue of food waste, and introducing consumers to ways of addressing the issue. This campaign aligned with local initiatives from retailers and encouraged the involvement of retailers, fostering collaboration. The UK could use its expertise from this campaign and help other countries develop similar programmes.

Intervention opportunities

There are a number of promising intervention opportunities that can address the main identified barriers. The most promising intervention opportunities can be grouped within three key categories:

1. Financing, technical assistance, and capacity building.

Financing and technical assistance.

Direct investments.

Financing, technical assistance, and capacity building:

Providing technical assistance for awareness raising to reduce food waste and the consumption of FMCGs, thereby reducing information asymmetries. In order to overcome the aforementioned barriers (Section 0), the UK could use its expertise related to successful awareness raising campaigns to provide technical assistance in countries and regions where the success of these campaigns appears to be more likely (either due to the higher mitigation potential or the lower investment needs). In this sense, countries and regions such as Brazil, China, Eastern Europe and Central Asia, and Mexico show low investment needs for changing consumer behaviour and the mitigation potential of this intervention is also high except for China. Therefore, this intervention would most likely be successful in Brazil, Eastern Europe and Central Asia, and Mexico.

Capacity building for consumers on recycling, label definitions and meal planning, food storage, food handling, food preparation, and the use of leftovers to reduce food waste, as well as the impacts of plastics and their relation to the consumption of FMCGs. Additionally, capacity building programmes could target companies, to help them understand the importance of reducing food losses throughout the supply chain and the improvement of recycling rates. This intervention directly addresses two barriers: information asymmetries and consumers' lack of knowledge to make informed choices. In terms of the degree of positive impact of the intervention (understood as higher greenhouse gases (GHG) mitigation potential or lower investment needs), Brazil, Eastern Europe and Central Asia, and Mexico would be the regions that would benefit most from this type of intervention.

Financing for behavioural change to promote responsible purchases, sustainable lifestyles, buying only what is needed, consuming local products, thereby generating knowledge among consumers and an enabling environment for the opportunity. These interventions are low-cost and can be drawn from the UK's domestic experience with public health campaigns as well as its behavioural insights team. Brazil, Eastern Europe and Central Asia, and Mexico would be the regions most in need of this type of intervention.

Financing and/or technical assistance:

Creating credit or product lines (e.g. funds, bonds, and loans) to promote sustainable consumption through the reduction of food loss and waste as well as the improvement of the cold chain. This includes the creation of funds (and associated project preparation facilities) dedicated to reducing food loss and waste and improving infrastructure and the cold chain, the introduction of financial product lines in commercial and development banks focused on food loss and waste reduction technologies and programmes. The UK has the knowledge to design and roll out key infrastructure that facilitates more sustainable consumption patterns. This expertise could be drawn upon to help other countries which face capital market imperfection barriers, such as China, a country that shows the highest cost-effectiveness score in improving waste disposal and building new recycling facilities.

Technical assistance and financing to promote business-to-business partnerships. This includes partnerships to improve the information flow between all actors in the supply chain and collaboration platforms to share information about plastics and waste. The UK is well aware of the importance of engaging the private sector in the interventions to be carried out. Therefore, it could help other countries that do not have a sufficient provision of public goods, such as collaboration networks, like Eastern Europe and Central Asia.

Technical assistance and financing to encourage public-private partnerships. If public-private partnerships emerged in the following additional countries, then 20 of the world's largest agriculture exporters would be covered, representing 45 % of the world's population: Argentina, Belgium, Brazil, China, France, India, Italy, Malaysia, Mexico, New Zealand, Poland, Thailand, and Turkey,876 therefore helping to overcome certain market failure barriers, such as the lack of networks.

Technical assistance and financing for the development of bioeconomy strategies. Incentives for innovation for bioeconomy (e.g. bio-based materials adoption and scale) and products-services business models (e.g. regulating the commercialisation and new technologies) have high potential for climate change mitigation via more sustainable products as well as impacting on consumer behaviour change. The UK already has a bioeconomy strategy and could use its expertise to help other countries create their own. This intervention could help overcome political economy barriers in Brazil and Mexico, countries where those barriers are higher.

Financing and technical assistance for the design and implementation of regulation and fiscal policy. This extends to product labelling, recycling programmes, food redistribution, food date labelling, and financial incentives for reduced consumption of carbon-intensive products and landfilling of recyclable materials. This intervention could be especially effective in countries where political economy barriers are higher, such as Brazil and Mexico. Nevertheless, all of the target regions could benefit from this intervention.

Direct investment:

Investing directly in the improvement of general infrastructure (e.g. waste segregation infrastructure, electricity access, and roads,) and in the improvement and expansion of cold chains.

Direct capital investment, primarily targeted towards improved storage and transport of agricultural food commodities, improving and expanding the cold chain infrastructure,[877] as well as to cover the high upfront costs of municipal solid waste programmes.

Financing or direct capital investment and technical assistance for the update of old equipment (waste collection equipment, food collection, and distribution and transport equipment) in order to increase efficiency and effectiveness and for the implementation of best practices.

All of the interventions that include direct investment will help overcome capital market imperfection barriers, as they contribute to the high upfront investment levels needed for the improvement of different infrastructures. While all the target regions would benefit from these interventions, the success of the intervention would be highest in those countries where the cost-effectiveness of the measure is higher, such as China in terms of improving waste infrastructure. All of the considered regions are strong candidates for receipt of support to improve cold chain infrastructure.

[876] World Resources Institute, 2019. A 10-step plan for the world to cut food loss and waste by half by 2030. Accessed via: Accessed via: https://www.wri.org/blog/2019/08/10-step-plan-world-cut-food-loss-and-waste-half-2030

[877] It is should be noted that improvements of the cold chain must be made carefully, as there are some environmental impacts linked to the technologies used (refrigerants), and not all food needs to be continuously refrigerated.

Intervention case studies

These case studies provide real-world insights into intervention design and challenges. Each case study provides an overview of the context, the aim of the interventions, and the challenges faced, and jointly provide a number of lessons to inform future intervention design.

Box 32 Practices for the improvement of waste collection and separation in Sao Paulo, Brazil, Climate Clean Aire Coalition

Developing context: improper waste management is an environmental and social challenge that affects millions of people worldwide and continues to grow in scale with rising urban populations and incomes. Taking action on solid waste management is an opportunity for cities to improve the local and the global community – waste management can protect their local community's environment and public health and contribute to global climate change mitigation efforts. Sao Paulo is a member of the Coalition's Municipal Solid Waste network, and as a member it has undertaken multiple initiatives to improve waste collection and separation practices.

Programme objectives: the Waste Initiative is working with participating cities to help them develop robust waste management systems to achieve real and immediate short-lived climate pollutant reductions and other benefits. The aim is to improve cities' waste management practices through actions that are sustainable in the long term, that are compatible with the local context, and that are replicable through city-to-city collaboration.

The objectives of the coalition programme include the following:[878]

- Defining a strategy for bio-waste diversion and developing a pilot bio-waste treatment plant.
- Enhancing organic waste management in schools and raising awareness among teachers and schoolchildren.
- Using public gardens and parks for green waste and organic waste from street markets for recycling and public education.
- Managing source separation of the organic fraction from household waste.
- Diverting organic waste from the commercial sector.
- Enhancing citizen awareness of recycling and separate waste collection.
- Capacity building and knowledge transfer on organic waste management.

Programme activities: in order to achieve the objectives above, the city of Sao Paulo has undertaken the following initiatives so far:[879]

- **Strategy for Organic Waste Diversion - Collection, Treatment, Recycling.** With the help of the International Solid Waste Association (ISWA), and the aim of reaching the goals in the City's Municipal Solid Waste Master Plan 2014, Sao Paulo created a strategy for organic waste separation and collection. The strategy includes technical guidance, prepared together with a local management expert, on the operation of organic waste treatment plants.
- **Enhance Organic Waste Management in Schools and Awareness of Teachers and Children.** ISWA organised a meeting with school representatives and city officials to find ways to boost organic waste management in schools as well as the awareness of teachers and children.

[878] Climate and Clean Air Coalition. (2015). Sao Paulo waste actions.
[879] Ibid.

During this meeting, it was decided that the best way to meet the objective was to establish a feedback and communication platform via online social networks. The platform, to facilitate dialogues among schools, would also serve as a tool to collect information for a handbook on the management of organic waste, including the other fractions (dry and residual waste), for school education.

- Implementation Plan for a Trial for Separate Collection of the Organic Fraction of Household Waste in the Lapa District in Sao Paulo. A trial for separate collection of household organic waste was designed. This trial was focused on a selected area (maximum 5,000 inhabitants) in the Lapa District (City of Sao Paulo) and developed a roll-out/implementation plan.

- **Training Workshops for Capacity Building and Knowledge Transfer on Organic Waste Management.** Two workshops were organised for capacity building and knowledge transfer on organic waste management. The first training session, for city officials and waste service providers, was focused on communication techniques, instruments, and case studies from around the world and the second aimed was focused on organic waste treatment plant operations.

- **Environmental Communication Strategy for MSW Management in Sao Paulo.** A communication strategy with key stakeholders was developed. This strategy identifies the goals, target groups, and communication measures for the different target groups.

Additionally, the city of Sao Paulo works with the city of Copenhagen to share first-hand information and experiences related to the solid waste management system in Sao Paulo.

Programme's expected outcomes and risks: the programme's expected outcomes include:

- Improvement of the strategy for the collection and separation of organic waste.

- Optimisation of treatment plants.

- Increase awareness of the importance of recycling and knowledge of organic waste management.

- The high potential for replicability of this project reinforces the importance of capacity building initiatives as well as collaboration schemes.

The risks related to the programme include:

- The technical guide of the Strategy for Organic Waste Diversion may not to meet the specific needs of certain treatment plants.

- Awareness actions may be successful initially, but not lead to long-term positive and tangible impacts.

Lessons learned: The UK may draw the following lessons from the programme:

- Piloting new infrastructure demands strong capacity building and awareness raising components.

- Household waste is not the only stream of organic waste, with public gardens, parks, and markets also requiring attention.

Box 33 #SinDesperdicio (#NoFoodWaste) initiative in Latin America

Context: Latin America generates large amounts of food loss and waste. This occurs at every stage of the food chain, from the production process, where 28% is wasted, to handling and storage (21%), processing (6%), distribution and marketing (17%), and by food consumers (28%).[880]

In order to reduce these losses, the Inter-American Development Bank (IDB) is working with companies such as IBM, Nestlé, Coca-Cola, Dow Chemical, Bimbo, FEMSA, and Oxxo, as well as organisations such as the Global Food Banking Network, the Food and Agriculture Organisation (FAO), the World Resources Institute (WRI) and the Consumer Goods Forum, through #SinDesperdicio (#NoFoodWaste), a three-year initiative that launched on World Food Day on October 16th 2018.[880]

Programme objectives: the programme has the following two main objectives:

- To reduce food loss and waste in Latin America and the Caribbean.
- To support progress towards achieving SDG 12.3, which seeks to cut per capita food waste and reduce production and supply chain losses by half by 2030.

Programme activities: the programme envisages four types of activities:[881]

- Innovation: activities that apply technology to reduce food loss and waste throughout the supply chain, from production to consumption.
- Public policy: activities that help to advance legislation and public policy to create an enabling environment that tackles food loss and waste.
- Knowledge: development of studies and market analyses to measure and identify the causes behind food loss and waste.
- Behaviour: activities that promote responsible and sustainable behaviour throughout the supply chain.

As a result, this initiative included contests that aimed to find innovative solutions to reduce food loss and waste. One of these contests was carried out in Mexico, and two innovative solutions were awarded:

- SaveFruit. The start-up offers post-harvest technologies that can be used to extend the shelf life of the fruits after they are harvested, providing extra protection against fungal and bacterial diseases that may appear on the fruit. The product acts in a natural and specific way, so it is not toxic to humans or the environment and allows all participants within the fruit production chain to benefit; including storage, transportation, distribution, commercialisation, and domestic consumption.[882]

  Mi Fruta, Mi Pueblo. The proposal consists of a network of community learning circles to transform seasonal fruits into innovative by-products, visualising the possibility of commercialisation and the formation of producer cooperatives. They currently work in Zapotec communities in the state of Oaxaca with excess citrus, preventing the surplus from being wasted and thus promoting the prevention of food loss and waste in populations with food shortages and extreme poverty.[883]

Programme's expected outcomes and risks: the expected outcomes of the programme are:

- Increase awareness of the large amount of food that is lost and wasted.

- Reduce food loss and waste throughout the supply chain, from production to consumption, in Latin America and the Caribbean.

The risks related to the programme include:

- Awareness initiatives may seem successful at first, but not generate long-term and tangible positive impacts, for instance if the initiative outputs are discontinued.
- Changes in government could overturn public policies that promote the reduction of food losses and waste.

Lessons learned: The UK may draw the following lessons from the programme:

- Governments should engage with companies and non-governmental institutions to design successful interventions.
- The private sector is often better positioned to generate innovative solutions to prevent food loss and waste.

Box 34 Advancing and Measuring SC for a Low-Carbon Economy in middle-income and newly industrialised countries

Context: the non-existence of recognised labels and standards has been identified as a key barrier to enabling consumers and public administrations to make informed decisions when choosing one product or service over another in many countries. Reasons for this often include the lack of Sustainable Consumption Patterns (SCP and Sustainable Public Procurement (GPP) supporting policies, inadequate legal framework and requirements, lack of public awareness, and the non-availability of eco-labelling systems with defined criteria.[884]

Programme objectives: the project contributes to the 10-Year Framework of Programmes on Sustainable Consumption and Production (10YFP), more specifically to the 10YFP Consumer Information Programme for Sustainable Consumption and Production (CI-SCP).[885]

This project has been developed in the following countries: Morocco, Chile, Ethiopia, Peru, Indonesia, Malaysia, Philippines, and Thailand.

The main objectives of the programme are:

- To integrate climate friendly criteria into eco-labels.
- To improve mutual recognition of the eco-labels in the Southeast Asian region.

Programme activities: the activities carried out in this initiative included:[886]

---

[880] Inter-American Development Bank. (2018). Business leaders and the IDB issue call to reduce food waste in Latin America and the Caribbean.
[881] Sin desperdicio. (n.d.) Accessed via: http://sindesperdicio.net/en/
[882] Sin desperdicio. (n.d.) Accessed via: http://www.sindesperdicio.net/concursos/en/
[883] Ibid.
[884] Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety. (n.d.) Advancing sustainable consumption and production.
[885] UNEP. (2016). Advance SCP: Advancing and Measuring Sustainable Consumption and Production (SCP) for a Low-Carbon Economy in Middle-Income and Newly Industrialized Countries.
[886] Hofmann, Kai. (2015). Advancing and Measuring Sustainable Consumption and Production (SCP) for a Low-Carbon Economy in Middle-Income and Newly Industrialized Countries (Advance SCP).

- Development of systems that inform consumers (government organisations, companies, and private consumers) about sustainable goods and services with the help of eco-labels.
- Development of a handbook on nationally appropriate mitigation action (NAMA) to offer decision-makers guidance on exploring opportunities for NAMAs that can be realised within the 10YFP.
- Identify industries with significant potential for carbon dioxide savings in order to create consumer 'sustainability information systems' for products manufactured primarily in these industries.
- Capacity building for decision-makers to provide them with the knowledge they need to prioritise environmentally friendly products with eco-labels and to use the 'sustainability information system' to find out more about the environmental sustainability of products.

Programme outcomes: in Indonesia, after the implementation of this project, GPP regulation was ratified, which is a major milestone for the country. These GPP procedures included the tender preparation and evaluation, life cycle costing (LCC), and life cycle Assessment (LCA) for which training has been provided to procurement teams within the Indonesian government.

Lessons learned: the UK may draw the following lessons from the programme:

- Learning and collaboration platforms allow the exchange of information among developing countries.

Glossary

Acronym / Term	Definition
10YFP	10-Year Framework of Programmes on Sustainable Consumption and Production
AFOLU	Agriculture, Forestry and Other Land Use
BEIS	UK Department of Business, Energy and Industrial Strategy
BMU	Federal Ministry for the Environment, Nature Conservation and Nuclear Safety
CI-SCP	Consumer Information Programme for Sustainable Consumption and Production
EAC	Every Action Counts
FAO	Food and Agriculture Organisation of the United Nations
FMCGs	Fast-moving consumer goods
GBP	Great British Pound
GDP	Gross Domestic Product
GHG	Greenhouse Gas
GIZ	Deutsche Gesellschaft für Internationale Zusammenarbeit
Gt	Gigatonne
ICF	International Climate Finance
IDB	Inter-American Development Bank
IKI	International Climate Initiative
ISWA	International Solid Waste Association
LCA	Life cycle assessment
LCC	Life cycle costing
LFHW	Love Food Hate Waste
Mt	Megatonne
NAMA	Nationally appropriate mitigation action
NDC	Nationally determined contributions
NRDC	National Development and Reform Commission
OECD	Organisation for Economic Co-operation and Development
PPCS	Action Plan for Sustainable Production and Consumption
RKP	Indoenesia National / Regional Annual Government Work Plan
RPJP	Indonesia National / Regional Long-term Development Plan
RPMN	Indonesia National / Regional Medium-Term Development Plan
RPMN	Indonesia National / Regional Medium-Term Development Plan
SCP	Sustainable consumption and production
SCP	Sustainable consumption and production
SDGs	Sustainable Development Goals
SDGs	Sustainable Development Goals

Acronym / Term	Definition
SPP	Sustainable Procurement Policy
SPPEL	Sustainable Public Procurement and Environmental Labelling Project
SPPEL	Sustainable Public Procurement and Environmental Labelling Project
UKCCU	United Kingdom Climate Change Unit
UNEP	United Nations Environment Programme
USD	United States Dollar
WRI	World Resources Institute

Fiscal Policy and Just Transition Support

Summary

The Fiscal policy and just transition support opportunity considers the reformation of fiscal policies to reflect Paris Agreement targets and incentivise sustainable development, and just transition initiatives that aim to facilitate fiscal policy changes. This assessment of fiscal policy actions includes fossil fuel subsidy reform (FFSR), carbon pricing, clean energy support schemes, and revenue recycling for green investment. These measures are most effective when combined with *just transition support*, which encompasses participatory approaches to provide representation of vulnerable groups' interests within decision-making both during and after transitions, and policies that address the potentially negative impacts of policy changes and economic transitions for these groups, to ensure that they benefit from new economic opportunities. Taken together, the objective of fiscal policy and just transition support is to create a sustainable economy that provides decent work (SDG 8) and contributes to the eradication of poverty (SDG 1).[887]

Interventions to support mitigation fiscal policies and just transition include:

- Providing technical assistance and capacity building in FFSR to support uptake.
- Providing technical assistance and capacity building through key carbon pricing initiatives to similarly support the uptake of, and ambition within, policy reforms and measures.
- Providing technical assistance to support the just transition, by supporting domestic policy making in target regions, potentially supported by programmatic spending to support social or industrial just transition investments.

Table 59 Fiscal policy & just transition assessment summary

Criteria	Assessment	Notes
Climate impact	Medium	• Fiscal policy support offers potentially large levels of abatement that can be ratcheted up with increased ambition over time, while just transition efforts can support and enable fiscal policy reform. • A price on carbon at socially optimal levels could offer substantial mitigation throughout lower- and middle-income countries, on the order of 1 gigatonne (Gt) carbon dioxide equivalent (CO2e) per year in the developing world.
Development impact	High	• Potential to achieve immediate and lasting impacts on some Sustainable Development Goals (SDGs). The opportunity will reduce local pollution and promote good health and well-being, generate green jobs, and contribute to sustainable cities and communities.
Investment gap	Medium	• Investment need for fiscal policy and just transition support are low to moderate in aggregate terms relative to other mitigation interventions as it involves regulatory and policy-based measures, and may deliver new revenues or cost savings. • Just transition support likely to be particularly costly in countries with high carbon-intensity sectors and high exposure to transition risk.
Cost-effectiveness	High	• High cost-effectiveness given moderate costs for policy development and implementation and potentially substantial cost savings from reduced government expenditures on subsidies, potentially leading to negative cost emissions reductions. • Cost-effectiveness of just transition support and green diversification depend on the extent of transition risk, and the likelihood that the region can compete in the green economy.

[887] International Labour Organisation (ILO). (2015). Guidelines for a just transition towards environmentally sustainable economies and societies for all.

Criteria	Assessment	Notes
Barriers to adoption	High	• Strong political economy barriers and inertia towards fossil fuels in all the regions covered; less relevant market failures; varying enabling environment barriers depending on institutional and bureaucratic capacity.
UK additionality	Medium	• The UK has experience in diversifying away from coal through a combination of policy instruments including carbon markets, is already one of the largest funders of fiscal policy interventions, and has supported interventions in the focus regions.

Source: Vivid Economics, ASI & Factor

Key lessons for supporting mitigation through fiscal policy action and just transition support:

China and India are likely to provide particularly high levels of abatement

Medium development impact potential, with highest relative demand in South Africa and China.

The opportunity faces strong political economy barriers, with focus regions betting heavily on coal-based power to satisfy their energy needs.

The UK can build on its successful experience in diversifying away from coal through a combination of policies and can provide the required technical assistance and capacity building, though may face questions from partners based on the UK's domestic just transition experiences.

To be successful, FFSR and carbon pricing interventions need to be coherent with the wider policy context, be built on strong analytical content, address distributional issues through revenue recycling and just transition considerations, and be based on effective communication strategies.

Introduction to the opportunity

Role of the opportunity in decarbonisation of developing countries

There is an urgent need for carbon pricing in lower- and middle-income countries, which represent a large share of global emissions. A growing number of Paris signatories – including low- and middle-income countries - are considering or planning carbon pricing to meet their Nationally Determined Contributions (NDCs), but only a small fraction of total emissions are covered by carbon pricing.[888] Furthermore, existing pricing systems have failed to achieve deep mitigation due to inadequate price levels, typically at or below USD 10/tCO_2e. Only 28% of emissions are covered by a carbon price globally and only 10% are covered in ODA countries, the majority of which have set prices significantly lower than levels consistent with meeting Paris targets.[889]

Global fossil fuel subsidies were USD 500 bn--USD 700 bn in 2015[890] and are projected to increase by approximately USD 0.7 -USD 1.2 trillion by 2030.[891][892] Consumption-based subsidies for fossil fuels are pervasive in lower- and middle-income countries. In 2015, 87% of global fossil-fuel subsidies were accounted for in low- and middle- income countries and two-thirds in the Middle East, North Africa, Mexico, and South America. When including other unpriced environmental and social externalities, such as global warming, air pollution, traffic congestion, and road accidents, subsidies in the developing world are even larger. By this definition, developing Asia is responsible for 40% of global fossil fuel subsidies and China (USD 1.2 trillion) and India (USD 209 billion) were the first and fifth largest subsidisers of fossil fuels globally in 2015, respectively.[893]

However, potentially negative developmental consequences of fiscal policy reform, misperceptions about climate policy, and other political economy constraints are major barriers to this opportunity, underscoring the importance of addressing distributional concerns with just transition support. New fiscal policies to incentivise sustainable development are not without cost. Addressing market failures through carbon pricing or energy subsidy reform could exacerbate poverty and threaten the livelihoods of vulnerable workers. The just transition elements within this opportunity provide assurance that the costs, not just from fiscal policy but climate policy more broadly, do not fall disproportionately onto the most vulnerable and least capable, but rather that interventions achieve mitigation and development simultaneously. Without providing new economic opportunities and addressing adverse distributional outcomes, fiscal policy and just transition support may be held back by various factors including the aforementioned threats to occupations and livelihoods, as well as lack of awareness, communication, and understanding on the scale and scope of potential benefits of mitigation activities. Beyond the perceived trade-off between emissions reductions and economic growth, vested interests, limited resources, deficient institutions and/or insufficient bureaucratic capacity for the design, implementation and enforcement of climate policy are also inhibiting factors.

---

[888] World Bank. (2020). State and Trends of Carbon Pricing 2020.
[889] Ibid.
[890] Monasterolo & Rabetro. (2018). The impact of phasing out fossil fuel subsidies on the low-carbon transition
[891] These values pertain to consumption-based subsidies, also known as the price-gap approach, defined as: subsidy = supply cost – end-user price x units consumed. This approach only captures interventions that change the final price paid by consumers, specifically those that lower the end-user price below what would otherwise be witness in a competitive market. By this definition, other forms of subsidies, such as for fossil fuel research, deployment and development (RD&D) and exploration or fossil fuel production, are not captured. Furthermore, the price-gap approach does not factor in the social and environmental externalities of fossil fuel consumption, including climate change, air pollution, and other combustion engine motor-vehicle related externalities. While the price-gap approach has the advantage of being easily identifiable and does capture most fossil fuel subsidies, it is a controversial measure given its incompleteness.
[892] Jewell et al. (2018). Limited emission reductions from fuel subsidy removal except in energy-exporting regions.
[893] International Monetary Fund (IMF). (2019). Global Fossil Fuel Subsidies Remain Large: An Update Based on Country-Level Estimates.

Scope considered in this assessment

This assessment of the fiscal policy and just transition support opportunity includes interventions to introduce taxes and subsidy reform, and to direct investment towards overarching green growth strategies and targeted workers protections. The scope of activities included in the analysis includes:

- **Fossil Fuel Subsidy Reform (FFSR),** entailing the complete phase-out of fossil fuel subsidies and targeted cash programmes to support socially vulnerable groups.
- **Carbon pricing,** for example through the introduction of a carbon tax or emissions trading scheme (ETS), and potentially linking existing carbon pricing systems.
- **Revenue recycling,** entailing the reallocation of FFSR savings (subsidy swaps) or proceeds from carbon pricing instruments and FFSR into green investment.
- **Just transition support,** including social dialogue and support policies to promote the interests of workers, and other affected groups within decision-making, during and after the transition; social protections to ensure that structural changes distribute benefits in a manner that is equitable for those most affected by economic and technological change; and green diversification strategies which support workers protections by a) prioritising the creation of decent, well-paid, and secure green jobs and b) increasing competitiveness in the production and trade of green goods and services through new investment.

This assessment is focused on five regions that were selected based on key factors relevant to fiscal policy and just transition support. Regions that exhibit a high economic dependency on fossil fuels or transition-risk-exposed[894] industries, signal a higher need for carbon pricing or subsidy reform, and that are primed to implement green fiscal policy measures are considered to be the highest priority. Likewise, we consider macroeconomic and environmental factors that are pertinent to long-term mitigation such as population growth, emissions intensity, aggregate emissions, government effectiveness, and regulatory quality. In consideration of all these factors, the countries/regions chosen for this opportunity are:

- China
- India
- Indonesia
- North Africa
- South Africa

[894] Transition risk corresponds to the risks associated with policy change, reputation and public perception, and shifting market preferences, etc. that are linked to economic decarbonisation and that could threaten the profitability of public or private enterprises that maintain carbon-intensive activities.

Climate impact

Mitigation potential and urgency

Fiscal policy support offers potentially large levels of abatement that can be ratcheted up with increased ambition over time. Mitigation activities such as carbon pricing and subsidy reform have the potential to be highly cost-effective in helping to achieve the targets of the Paris Accord and to address the fundamental market failures behind global warming. At the global level, the International Monetary Fund (IMF) estimates that 2015 emissions would have been 28% lower had fuel prices reflected the social and environmental costs of greenhouse gases (GHG) emissions.[895] This does not include the potential for carbon revenues and avoided subsidy expenditures to be put towards other mitigation activities, which could be large even at lower levels of ambition. Moreover, just transition measures can similarly enable further reductions by changing perceptions and attitudes towards climate action, but also by providing a strategy to diversify the economy away from fossil fuels.

A price on carbon at socially optimal levels could offer substantial mitigation throughout lower- and middle-income countries. Experience from developed nations are informative in lieu of evidence from the developing world where carbon pricing is mostly absent. It is estimated that the European Union ETS resulted in a 2.5-5% (150-300 megatonnes (Mt)) decrease in emissions during Phase I and a 6.3% (260 Mt) decrease in Phase II,[896][897] though a large share of abatement is likely attributable to external factors.[898][899] The Regional Greenhouse Gas Initiative in the northeastern United States coincided with a 57% decline in emissions between 2005 and 2016, and estimates suggest emissions would have increased by 24% without the Initiative.[900] In British Columbia, Canada, the economy-wide carbon tax is estimated to have reduced emissions by 5-15% [901] and per capita emissions by 12.9%.[902] Overall, the 43 countries which had a national carbon price in the last two decades saw annual emissions grow at rates 2% lower than countries without a carbon price.[903] As indicated by the varied and generally modest depth of mitigation seen in the developed world,[904] actual abatement is contingent on the ambition and details of new carbon pricing schemes. Recent evidence suggests every one euro increase in the price of carbon results in a decrease in the annual growth of emissions by 0.3 percentage points[905], implying that that a sufficiently high carbon price is needed to achieve rapid emissions reductions by 2050. However, a modest carbon price may be preferable to no price at all, especially as introducing a system for carbon pricing is an important milestone with the scope for a scale-up of ambition over time.

The exact mitigation potential of FFSR is uncertain but likely to be on the order of 1 Gt CO_2e per year in the developing world. Previous work has predicted that removal of fossil fuel subsidies in 2020 would reduce emissions by 5-6 %[906][907] and 6-8%[908][909] in 2035 and 2050, respectively. However, more recent estimates, which have explored sensitivities in oil and gas prices, suggest that the removal of fossil fuel subsidies would be more modest, on the order of 0.5-2 Gt CO2e of annual abatement by 2030, the majority occurring outside of Europe, North America, and the Pacific Organisation for Economic Co-operation and Development (OECD) countries.[910] The International Institute for Sustainable Development (IISD) similarly explores the

---

895 IMF. (2019). Global Fossil Fuel Subsidies Remain Large: An Update Based on Country-Level Estimates.
896 Brown et al. (2012). The EU Emissions Trading System: Results and Lessons Learned.
897 Hu et al. (2015). Ex-ante evaluation of EU ETS during 2013–2030: EU-internal abatement.
898 Bel & Joseph. (2015). Emission abatement: Untangling the impacts of the EU ETS and the economic crisis.
899 Narassimhan et al. (2017). Carbon Pricing in Practice: A Review of the Evidence.
900 Murray & Maniloff. (2015). Why have greenhouse emissions in RGGI states declined? An econometric attribution to economic, energy market, and policy factors.
901 Murray & Rivers. (2015). British Columbia's Revenue-Neutral Carbon Tax: A Review of the Latest 'Grand Experiment' in Environmental Policy.
902 Metcalf, Gilbert E. (2015). A conceptual framework for measuring the effectiveness of green fiscal reforms.
903 Best et al. (2020). Carbon Pricing Efficacy: Cross-Country Evidence.
904 Tvinnereim & Mehling. (2018). Carbon pricing and deep decarbonisation.
905 Best et al. (2020). Carbon Pricing Efficacy: Cross-Country Evidence.
906 Schwanitz et al. (2014). Long-term climate policy implications of phasing out fossil fuel subsidies.
907 IEA. (2011). World Energy Outlook.
908 Schwanitz et al. (2014). Long-term climate policy implications of phasing out fossil fuel subsidies.
909 Burniaux & Chateau. (2011). Mitigation Potential of Removing Fossil Fuel Subsidies.
910 Jewell et al. (2018). Limited emission reductions from fuel subsidy removal except in energy-exporting regions.

mitigation potential in different price scenarios and finds that FSSR could abate 1.1 Gt CO2e annually but that fixing fossil fuel prices at USD 50 per barrel of oil could increase this figure to 5.3 Gt CO2e per year over 2017 to 2050.[911]

Within the target regions considered in this assessment, China[912] and India are likely to provide particularly large mitigation opportunities. Regional mitigation potential is assessed based on underlying emissions intensity and reliance on fossil fuels, levels of existing subsidies for fossil fuels, and degree of exposure to transition risk and relative dependence on fossil fuel exports. Each region's relative mitigation potential is assessed as a high, moderate, or low priority within the set of top five prioritised regions – noting that all five regions have been identified as having particularly high mitigation potential in absolute terms. China and India both offer high mitigation potential within the set of regions, based, in particular, on substantial emissions and high emissions intensity of energy production and industry, and substantial volumes of fossil fuel subsidies. Indonesia and North Africa both offer moderate relative mitigation potential, based on lower, but still substantial, emissions and reliance on fossil fuels within energy generation and high fossil fuel subsidies, with moderate to high reliance on fossil fuel exports. South Africa[913] offers the lowest relative mitigation potential, based on lower presence of fossil fuel subsidies or reliance on fossil fuel exports, though it has a high share of fossil fuel within energy generation.

Fiscal policy and just transition support may be able to provide over 1 Gt CO2e of mitigation by 2030 in China, India, Indonesia, North Africa, and South Africa combined. These estimates are based on work by the IISD, which reviews the impact of green fiscal policy measures in 26 different countries.[914] Their analysis assumes that fossil fuel subsidies are completely phased out by 2025, a modest carbon price on fuels and electricity set at 10% of the price of energy (which will therefore vary by country), and that 10% and 20% of savings are reinvested in renewable energy and energy efficiency upgrades, respectively. The remaining savings are put towards other just transition measures. Overall, these select fiscal policy and just transition measures would lead to a 10% reduction in emissions by 2030 relative to 2017 levels. Intuitively, the largest emissions reductions are seen in China and India, which are the two largest emitters within our regional analysis and are both characterised by high emissions intensities and a large reliance on fossil fuels in the domestic energy supply. However, the largest reductions as a share of emissions would be seen in Indonesia and North Africa, where the carbon price and FFSR would lead to a 12 and 11% decrease in emissions relative to 2017 levels, respectively. Overall, the analysis shows that a modest price would lead to 0.4 Gt CO2e of abatement by 2030. A carbon price set at levels consistent with the Paris Accord, i.e. USD 40/tCO_2e - USD 80/CO_2e now and USD 50/tCO_2e - USD 100/CO_2e by 2030, would likely contribute to far greater abatement in all regions.[915] FFSR in these counties leads to an annual reduction of approximately 0.3 Gt by 2030, which is broadly in line with expected emissions reductions globally in 2030. Cumulative mitigation would be approximately 2 Gt between 2020 and 2030.

911 IISD. (2017). Zombie Energy: Climate benefits of ending subsidies to fossil fuel production.
912 Future abatement opportunities from carbon pricing may be slightly lower than suggested by historic figures given China's plans for an ETS with a low price floor of USD 1.40, but still important opportunities to scale up ambition.
913 The South African carbon price is similarly under USD 10 per tonne and unlikely to create rapid mitigation at this level. Once again, there is an opportunity for larger reductions in the country by ramping up ambitions and using revenues for green diversification and other just transition support measures.
914 IISD. (2019). Raising ambition through FFSR: Greenhouse gas emissions modelling results from 26 countries.
915 Best et al. (2020). Carbon Pricing Efficacy: Cross-Country Evidence.

Table 60 Mitigation potential by region

Region	Mitigation potential	Carbon pricing	FFSR	Just transition support, inc. green diversification
China	High	- Largest emitter globally with 73% of domestic energy from coal and a high emissions intensity of production. National ETS planned and regional ETS currently in place. - Very high mitigation potential.	- Largest subsidiser of fossil fuels in ODA regions. - High mitigation potential.	- Very high economic dependence on fossil fuel exports and poised to become more competitive through green exports. - High mitigation potential for revenue recycling and green diversification.
India	High	- Third-largest emitter globally with 75% of domestic energy supply from coal and a moderate emissions intensity of production. - Very high mitigation potential.	- Third-biggest subsidiser of fossil fuels in ODA regions. - Moderate mitigation potential.	- Low to moderate dependence on fossil fuel exports and poised to become significantly more competitive through green exports despite some vulnerability to transition risk. - High mitigation potential for revenue recycling and green diversification.
Indonesia	Medium	- Moderate regional emitter with a moderate domestic reliance on coal and fossil fuels in the energy supply. - Moderate mitigation potential.	- Fifth-biggest subsidiser of fossil fuels in ODA regions. - Moderate mitigation potential.	- Moderate dependence on fossil fuel exports and poised to become more competitive through green exports. - Moderate mitigation potential for revenue recycling and green diversification.
North Africa	Medium	- Relatively large regional emitter with a high emissions intensity and moderate reliance on fossil fuels in the domestic energy supply. - High mitigation potential.	- Second-highest subsidiser of fossil fuels in ODA regions. - Moderate mitigation potential.	- Very high economic dependence on fossil fuel exports and high vulnerability to transition risk. - High mitigation potential for revenue recycling and green diversification.

Region	Mitigation potential	Carbon pricing	FFSR	Just transition support, inc. green diversification
South Africa	Low	- The largest emitter on African continent, principally due to the highest dependence on coal out of any ODA region (93% of the domestic energy supply). Action should be taken to raise ambition since a carbon price is already in place. - High mitigation potential.	- Not a major subsidiser of fossil fuels relative to other regions. - Low mitigation potential.	- Low to moderate dependence on fossil fuel exports and poised to become more competitive through green exports despite a higher vulnerability to transition risk. - Low to moderate mitigation potential for revenue recycling and green diversification.

Source: Vivid Economics, ASI and Factor

Just transition interventions play a critical role in enabling and supporting the implementation of carbon pricing and subsidy reform activities, but there is limited evidence on the direct emissions reduction potential of just transition activities. Key just transition interventions mainly deliver policy or social protection outcomes, but support emissions reductions insofar as they enable mitigation action that would not have happened without the inclusion of these measures. Real-world case studies suggest that, in some cases, just transition initiatives and social protection schemes have been successful at securing buy-in for broad fiscal policy action. Examples include Iran's FFSR scheme which re-allocated subsidies from fossil fuels to social programmes leading to reduced income inequality, Indonesia's allocation of proceeds from subsidy reform to provide healthcare to poor households,[916] and Germany's Coal Commission. The latter is composed of various interests groups, including climate scientists, non-governmental organisations (NGOs), industry, and trade unions and has explicitly adopted principles of the just transition within its recommendations for the phase-out of coal.[917] In other cases, for example in Nigeria in 2012 and France in 2018, the exclusion of measures to support adjustments has been associated with substantial social protest and backlash against mitigation action, and may have ultimately led to delayed or reduced action. Key actions include:

Mainstreaming equity in climate-related policy-making, taking into account skills needs, health and safety risks, social protection needs, promoting social dialogue to ensure that the needs of workers and vulnerable communities are addressed and represented within the decision-making processes of government, and therefore reduce potential opposition to mitigation action. This may include high-level macroeconomic and growth policy, industrial and sector-specific policy, enterprise policy, and climate policy.

Targeted re-skilling and upskilling programmes to mitigate negative distributional consequences and increase buy-in from workers, business, and industry that may be negatively impacts by changing fiscal policy schemes and changing prices as a result of climate action.

The creation of a green diversification strategy, ideally funded through recycled revenues from carbon pricing and FFSR, which prioritises green investment and the creation of decent, well-paid, and secure green jobs so as to support the reallocation of labour into a sustainable and just economy.

[916] Gupta et al. (2015). Financing Universal Health Coverage by Cutting Fossil Fuel Subsidies.
[917] Litz et al. (2019). The German Coal Commission: A Roadmap for a Just Transition from Coal to Renewables.

Social protection and social dialogue initiatives, to ensure that the interests of affected groups are reflected within decision making and have a seat at the table throughout the process of green diversification.

Transformational change

Table 61 below assesses the potential for this opportunity to support transformational change.[918] Fiscal policy and just transition opportunities may design *sensitive interventions* that address distributional impacts of the green economy transition by improving local capacities and livelihoods, and that create incentives for others to adopt green technologies. Secondly, support for FFSR and carbon pricing schemes enshrined in law or reflected in new, enduring market conditions that lead to green growth pathways will lead to broad, sustainable, and replicable interventions, thus leading to *spillovers.* Finally, *innovation* may be supported by acting as catalyst for innovation within the industry covered by carbon pricing schemes, and by publicly sharing evidence of the effectiveness of the opportunity through the disclosure of just transition and other revenue recycling programmes.

Table 61 Transformational change potential

Transformational change criterion	Interventions to support change	Regional potential
Sensitive intervention points		
Improvement of local capacities and capabilities	Support for reskilling and upskilling programmes, at-risk workers´ protections, and the design of other social support policies.	All regions
Local ownership and strong political will	Support to the design of just transition and social schemes that address social concerns likely to have strong local buy-in.	China, India, Indonesia, South Africa (coal-based power generation)
Leverage / creation of incentives for others to act	Support through revenue recycling for immature clean technologies (e.g. battery storage); support to enabling climate investment climate for mature technologies (e.g. solar photovoltaic and wind).	China, India, Indonesia (big market potential)
Spillovers		
Broad scale and reach of impacts	Support for FFSR, carbon pricing, and revenue recycling programmes.	All regions
Sustainability (continuation beyond initial support)	Support for carbon pricing schemes and goals enshrined in law or reflected in new, enduring market conditions. Support to policies that lead to green growth and competitiveness (e.g. through distributed clean energy).	All regions
Replicability by other organisations or actors	Support to fiscal policies that lead to green growth pathways. Support state-owned enterprises that diversify away from coal.	South Africa
Innovation		
Catalyst for innovation	Support for carbon pricing schemes likely to spur innovation in the industry.	China, India (energy-intensive industry)

[918] Climate Change Compass. (2018). Extent to which ICF intervention is likely to lead to Transformational Change.

Transformational change criterion	Interventions to support change	Regional potential
Evidence of effectiveness is shared publicly	Support the disclosure of all monitoring, reporting, and verification outputs of just transition and other revenue-recycling programmes.	All regions

Source: Vivid Economics, ASI and Factor

Development impact

SDG impacts

Fiscal policies that reduce fossil fuel subsidies, put a price on emitting carbon, and recycle revenues for a just transition have notable positive impacts on achieving SDGs in all regions with a particularly high impact in India. Table 62 sets out key SDG impacts in the target regions.

Table 62 SDG impacts

SDG	Strength of impact	Most relevant region	Rationale
Positive impacts			
SDG 3 – Good health and well-being	High	India, Indonesia (high age-standardised death rate attributable to household and ambient air pollution).	The opportunity will reduce air pollution.
SDG 7 – Affordable and clean energy	Moderate	India, Indonesia (low access to electricity, clean fuels, and technology for cooking).	The opportunity will contribute to the scaling up of clean energy systems.
SDG 8 – Decent work and economic growth	High	North Africa (high vulnerability to transition risk and job destruction; high unemployment rate).	The opportunity will enable a just transition and create green jobs.
SDG 9 – Industry, innovation and infrastructure	Low	China, South Africa (regions with a carbon price in place).	The end of fossil fuel production subsidies and carbon pricing will spur innovation within industry.
SDG 11 – Sustainable cities and communities	High	India, China, North Africa (high annual mean concentration of air pollutants (i.e. particulate matter) of less than 2.5 microns in diameter).	The opportunity will reduce local air pollution in cities.
Negative impacts			
SDG 8 – Decent work and economic growth	Moderate	North Africa (energy transition to impact a high unemployment rate).	The opportunity will disrupt employment linked to fossil fuel value chains.
SDG 15 – Life on land	Low	All regions.	Some clean energy investments require additional land use, with potential implications for biodiversity.

Source: Vivid Economics, ASI and Factor

Demand in target regions

Fiscal policies that reduce fossil fuel subsidies, put a price on emitting carbon, and recycle revenues for a just transition have different demands in target regions, as set out in Table 63.

Table 63 Demand in target regions

Region	Demand	Rationale
China	Moderate	FFSR & carbon pricing interest (national ETS), existing transition support programmes albeit with limited social dialogue.
India	Low	Initial FFSR changes, no carbon pricing.
Indonesia	Moderate	Experience of FFSR and interest in carbon pricing, coal-based power.
North Africa	Low-Moderate	Moderate interest in FFSR and carbon pricing.
South Africa	High	Coal-dependant, carbon pricing in place, NDC mentions just transition.

Source: Vivid Economics, ASI and Factor

China has already participated in a G20 peer review of inefficient fossil-fuel subsidies with the US and has plans to shut down coal in Eastern cities, with low local air quality acting as a policy driver. Its NDC establishes a peak in emissions "around 2030" as well as an emissions intensity target of its GDP of 60–65 per cent by 2030 from 2005. As part of its policy mix to achieve that target, China expects to launch its national ETS in 2021, building up on eight ETS pilots that already cover 0.35 Gt, with carbon prices ranging from USD 3 to USD 12 per tonne. China could also demand assistance in the design and roll-out of transition support programmes, since it has plans to reduce huge overcapacity in the coal mining and coal power sector. It has a national coal cap policy, as well as an industrial special fund for employment restructuring in the coal and steel sectors, which is partially funded from surcharges on coal-fired power.[919]

India has plans to peer review its fossil fuel subsidies with France as part of G20 efforts to end subsidies to fossil fuels, with low local air quality acting as a policy driver. It has embarked on reducing gasoline and diesel subsidies. Its NDC establishes an emissions intensity target of its GDP of 33–35 per cent by 2030 from 2005, and is betting aggressively on renewable energy development, with some of its SOE such as Coal India Limited betting on the clean energy transition. India has no carbon pricing instrument in place yet. [920]

Indonesia has some recent experience with FFSR, as it reduced subsidies to gasoline and diesel consumption in 2014. Its NDC plans to reduce GHG by 26% against a business-as-usual (BAU) scenario by 2020, and by 41% with international support. In addition, the country is considering a domestic ETS for power and industry, which would start with a voluntary phase for the power sector. No transition support policies have been identified.[921]

Some North African countries have implemented partial removals of electricity and fuel transport subsidies, but subsidies to butane remain. Most of the region's NDCs set unconditional targets against a BAU scenario by 2030, and more ambitious targets contingent on international support. In terms of carbon pricing, Egypt's NDC mentions a national ETS as a possibility, and several countries are considering carbon pricing instruments to reduce GHG emissions from electricity generation, cement production, and phosphate processing. No transition support policies have been identified.

South Africa provides consumption subsidies to transport (VAT-free gasoline) and electricity (free basic access) but has announced plans to unbundle its vertically integrated and financially troubled utility, Eskom. Its NDC mentions that GHG are set to "peak, plateau and decline", but poverty reduction and inequality are mentioned as a policy concern. Likewise, its NDC mentions the need for a "just transition" for workers (coal mining and coal power generation employ 1% and 0.6% of the workforce, respectively). Despite its coal dependency, South Africa was the first African country to introduce a carbon pricing instrument in 2019. Its

[919] Global Subsidies Initiative (GS). (2019e). Beyond Fossil Fuels: Fiscal transition in BRICS. Case Study: China.
[920] GSI. (2019f). Beyond Fossil Fuels: Fiscal transition in BRICS. Case Study: India.
[921] GSI (2019a). Beyond Fossil Fuels: Indonesia's fiscal transition.

carbon tax has a nominal value of USD 7 per tonne of CO_2, but an effective tax rate of USD 1 per tonne of CO_2 after allowances.[922]

[922] GSI. (2019). Beyond Fossil Fuels: Fiscal transition in BRICS. Case Study: South Africa.

Investment need

Investment needs for fiscal policy and just transition support are low to moderate in aggregate terms relative to other mitigation interventions. Fiscal policy support is a regulatory and policy-based measure and therefore requires relatively lower investment spend compared to capital investment. The administrative costs of designing, implementing, and monitoring these policies is low relative to the potential mitigation that could be achieved, contributing to high value for money. New revenue streams from carbon pricing or revenue saved from subsidy reform could be recycled to prevent higher energy prices from being passed on to consumers and assist in the reallocation of labour from carbon-intensive sectors and industries. Indeed, investment need for this opportunity is primarily driven by green diversification and other just transition support measures, for which the costs of new programmes to reallocate workers within the green economy may run high.

Within the target regions considered in this assessment, North Africa and South Africa are likely to face a particularly high investment gap. Regional investment gaps are assessed based on the anticipated investment needs for each mitigation intervention area and the likely availability of existing domestic and international support to meet those identified needs. Each region's overall relative investment gap is then assessed as a high, moderate, or low priority within the set of top five prioritised regions. North Africa and South Africa likely face overall smaller investment needs than some other regions, but may have fewer resources available to implement activities directly. China and India both face particularly substantial investment needs for just transition supports and green diversification, but investment gaps may be lower due to greater availability of domestic resources to support these investments. Indonesia is likely to require the lowest relative investment needs, and hence also a low investment gap.

Table 64 Investment need by region

Region	Investment gap	Carbon pricing	FFSR	Just transition support, inc. green diversification
China	Moderate	- Interventions are low cost, and region has very high government effectiveness but moderate regulatory quality. China has a national ETS planned but it has since been delayed. - Low investment need.	- Interventions are low cost and require minimal capital spend. - Low investment need.	- Low vulnerability to transition risk. - However, high investment need for green diversification and workers protection due to the size of the economy and country's emissions.
India	Moderate	- Interventions are low cost, and region is characterised by good levels of government effectiveness and regulatory quality. Carbon pricing, however, is not under consideration. - Low investment need.	- Interventions are low cost and require minimal capital spend. - Low investment need.	- Moderate vulnerability to transition risk. - High investment need for green diversification and workers protection due to the size of the economy and country's emissions.

Region	Investment gap	Carbon pricing	FFSR	Just transition support, inc. green diversification
Indonesia	Low	- Interventions are low cost, and region is characterised by good levels of government effectiveness and regulatory quality. Carbon pricing under consideration within the region. - Low investment need.	- Interventions are low cost and require minimal capital spend. - Low investment need.	- Moderate vulnerability to transition risk. - Moderate investment need for green diversification and workers protection.
North Africa	High	- Interventions are low cost, but region is characterised by moderate government effectiveness and poor regulatory quality. No countries considering carbon pricing. - Low to moderate investment need.	- Interventions are low cost and require minimal capital spend. - Low investment need.	- High vulnerability to transition risk. - High investment need for green diversification and workers protection.
South Africa	High	- Interventions are low cost, and region is characterised by the highest government effectiveness and regulatory quality. South Africa implemented a carbon price in 2019. - Low investment need.	- Interventions are low cost and require minimal capital spend. - Low investment need.	- High vulnerability to transition risk. - High investment need for green diversification and workers protection.

Source: Vivid Economics, ASI and Factor

Cost-effectiveness

Given moderate costs for policy development and implementation and potentially substantial cost savings from reduced subsidies (particularly for fossil fuels) the opportunity may offer negative cost emissions reductions. However, note that this value may be reduced if the proceeds from reduced subsidies are used to support just transition activities that specifically target the protection of at-risk workers and other vulnerable groups.

Carbon pricing instruments are cost-effective by definition, as they encourage GHG abatement below the carbon tax or the carbon price.

- Carbon taxes and emission trading schemes are cost-effective for three reasons. First, a carbon price equalises marginal abatement costs across emitters. Second, carbon prices decentralise abatement decisions, thus overcoming the asymmetry of information between the government and polluters. Third, they stimulate innovation and provide an ongoing incentive to cut emissions.[923]
- Compared to carbon markets, carbon taxes send clearer price signals, can collect more revenue, and are easier to administer.[924]
- A recent publication by Ian Parry and other IMF staff concluded that a tax on carbon emissions of USD 35 would suffice to meet the Paris Agreement pledges of China, India, Indonesia, and South Africa, and over 75% of the NDC targets of some North African countries, such as Morocco.[925]

Fossil fuel subsidies act as a negative carbon price and could also be considered along with carbon pricing discussions.

- GSI estimated that governments save an average of USD 93 by 2030 for every tonne of CO_2 removed through FFSR.[5] In 2017 alone, subsidies may have averaged more than USD 27, with coal, gas, oil, and electricity subsidies averaging USD 5, USD 38, USD 26, and USD 30 per tonne of CO_2 respectively. The amount of subsidies per tonne of CO_2 varies significantly per region, ranging from over USD 40 per tonne in North Africa (Algeria, Tunisia) to less than USD 5 per tonne in China and South Africa, including around USD 20 per tonne in India and around USD 30 per tonne in Indonesia.[926]
- Because GHG abatement through FFSR is carbon negative, developing countries should include FFSR as part of their country NDCs.[927]

The cost-effectiveness of just transition support and green diversification depend on the extent of transition risk, and the likelihood that the region can compete in the green economy. All five regions were selected on the basis that transition risk is high, signalling the need for economic diversification, workers protections, and other social support measures. However, the size of this risk, and the region's ability to cope with decarbonisation, can vary. China already performs quite well in the markets for green goods and services. It is likely that the country can mobilise capital at fast speeds and coordinate a rapid diversification away from fossil fuels, but—most importantly—it is also likely to benefit from these changes and become more competitive in the green economy. While India lacks the degree of coordination to organise such a swift response, it too can negate the risks of decarbonisation and become one of the most competitive countries in terms of trading green products and services. For these reasons, though a very real risk exists that industries and workers could be adversely impacted by climate policy, just transition measures would be more cost-effective given the economic returns on these green investments. The same can be said for Indonesia, albeit to a lesser degree since the country is less exposed to transition risks than the other four

[923] OECD. (2017). Investing in Climate, Investing in Growth.
[924] IMF. (2019). Putting a Price on Pollution.
[925] Ibid.
[5] GSI. (2019e). Beyond Fossil Fuels: Fiscal transition in BRICS. Case Study: China.
[926] GSI. (2020b). How do fossil fuel subsidies create an effective negative carbon price?
[927] GSI. (2019e). Beyond Fossil Fuels: Fiscal transition in BRICS. Case Study: China.

regions. In North Africa and South Africa, the potential gains from decarbonisation are muted and in the case of South Africa, the economy is predicted to become less competitive relative to other countries. While South Africa is characterised by a major reliance on coal within the domestic energy supply, its wider economic reliance on fossil fuels pales in comparison to that of North Africa, where the majority of merchandisable exports come from fuel. For these two regions, green diversification and just transition measures are crucial, but may be less cost-effective than the other two regions given the potential social and economic consequences faced by decarbonising.

Barriers to adoption

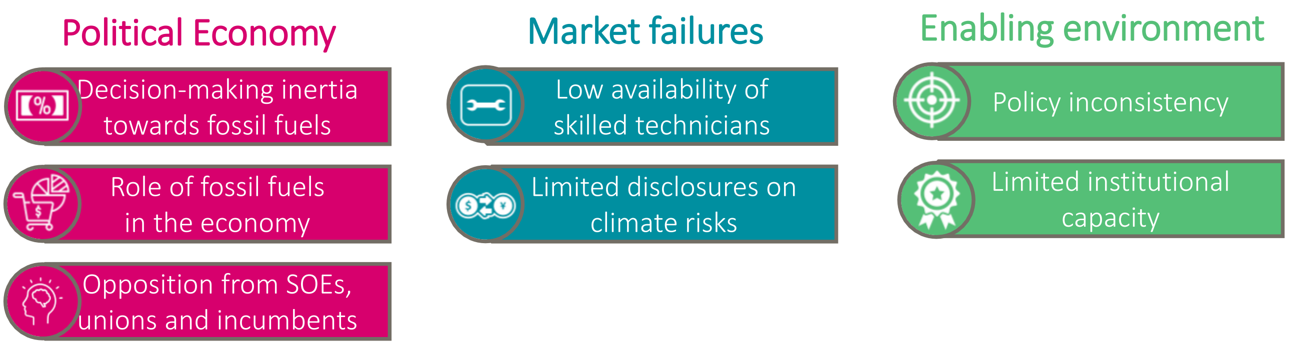
Fiscal policy reform faces strong political economy barriers in all the regions covered. Decision-making inertia towards fossil fuels threaten the perpetuation of fossil-fuel based energy systems and economies. The IEA suggests that fossil fuels are expected to supply 78% of the global energy used in 2040, with countries like China, India, or Indonesia betting heavily on coal-based power to satisfy their energy needs.[928] This is supported by the contribution of the fossil fuel industry to the economy, including trade balance, and government revenue. In addition, SOE and union support to the coal industry is still significant.[929] Finally, governments may face populist opposition against energy price increases.[930]

Market failures are much less relevant than political economy barriers in this opportunity. Market failures may include the shortage of suitably trained workforces to deliver the green transition, which requires new technical and soft skills at all levels of education, especially in developing countries.[931] Another market failure may relate to information gaps in financial markets, with investors, banks, regulators, and governments lacking sufficient information on the risks of stranded assets in the energy system.[932]

More broadly, lack of institutional and bureaucratic capacity also represents a barrier to implementing fiscal policy reform and just transition programmes. Policy inconsistencies regarding FFSR and carbon pricing instruments are present in all of the considered regions but may be a sign of political economy barriers rather than a lack of institutional capacity. In turn, the bureaucratic capacity differs between the covered regions, with North Africa lagging behind the others.

Political economy barriers are high in all regions, and result in changing fossil fuel subsidy policies, weak carbon price signals, and inconsistent policies. The relationship between the government and the fossil fuel industry is strong in all regions, with SOEs accounting for a large share of coal mining, oil and gas extraction, and fossil fuel-fired electricity generation. There is policy inconsistency between energy policies, FFSR, and carbon pricing instruments (China, India, and South Africa) and political difficulties in implementing FFSR (Indonesia and North Africa). North Africa presents some peculiarities: here, just transition topics will be related to winding down of the oil and gas sector, whereas the role of coal in power generation is important in all of the other focus regions. Figure 49 provides an overview of barriers to the opportunity, and barriers that are specific to each focus region are summarised in Table 7.

Figure 49 Barriers to Fiscal Policy and Just Transition Support



Source: Vivid Economics, ASI and Factor

[928] GSI. (2019g). Beyond Fossil Fuels: Fiscal transition in BRICS.
[929] GSI. (2019d). Beyond Fossil Fuels: Fiscal transition in BRICS. Case Study: South Africa.
[930] GSI. (2019c). Fossil Fuel to Clean Energy Subsidy Swaps: How to pay for an energy revolution.
[931] ILO. (2019). Skills for a Greener Future. A Global View.
[932] Carbon Tracker. (2020). Decline and Fall. The size and vulnerability of the fossil fuel system.

Political economy barriers

Decision-making inertia towards fossil fuels may dent FFSR and the uptake of carbon pricing instruments. China, for instance, is the world's largest coal producer and plans to expand its coal-based electricity generation in the west of the country. India's ambitious renewable energy targets coexist with coal power expansion plans, with coal-based power generation capacity likely to double in the period from 2017 to 2040, according to the 2017 National Energy Policy. And Indonesia relies on coal power to achieve universal electrification at subsidised prices.[933][934]

The role of fossil fuels is very significant in all economies. In North Africa, fossil fuel exports represented 54% of the region's merchandise exports between 2008 and 2018. In turn, Indonesia is the world's third-largest exporter of coal. In India, 17.2% of the government's revenue is dependent on taxation of fossil fuel production and consumption. South Africa is the world's fifth-largest exporter of coal, and fossil fuels represent 92% of its primary energy supply.[935]

Opposition from SOEs, unions, and incumbents are preventing FFSR and the establishment of more ambitious carbon pricing instruments in all focus regions. India has reduced gasoline and diesel subsidies, but still subsidises Liquified Petroleum Gas (LPG). Indonesia initiated a FFSR in 2014 and reduced subsidies to transportation fuels, but subsidies were reinstated in 2018 in the wake of rising international prices and upcoming elections. Some North African economies have initiated a partial removal of electricity and transportation subsidies, but butane subsidy elimination is outstanding, and other efforts to phase out energy subsidies have faced populist opposition. In South Africa, labour unions are blockading the clean energy transition, over legitimate concerns of job losses. And ESKOM, the vertically integrated SOE, has blockaded Power Purchase Agreements (PPAs) with Independent Power Producers (IPPs).[936]

As a result of high political economy barriers, climate and energy policies are inconsistent in all the focus areas. At home, China provides subsidies to coal through below-cost electricity and preferential transport freights. Abroad, China is financing other developing countries' coal mining and coal-fired power expansion, sending mixed signals on the topic of carbon pricing. South Africa was the first African country to introduce a carbon pricing instrument, a carbon tax with a face value of USD 7.[937] In the meantime, the South African government holds a 22% stake in Sasol, the world's biggest producer of liquid fuels from coal, and is betting on shale and offshore gas to diversify away from coal.[938]

Market failures

Labour markets in the focus areas may lack the number of suitably trained workers needed to deliver the green transition. This market failure is regarded as low in China, moderate in India, Indonesia, and North Africa, and high in South Africa. Based on China's success in the production of green products, it may be inferred that it has skilled technicians to deliver the green transition. The number of green jobs is already picking up in India, Indonesia, and North Africa, but not in South Africa.

Financial markets may not be able to price a looming transition risk. This market failure is moderate to high in India, where a combination of coal shortages, cost competitiveness of renewables, water shortages, and pollution regulations have rendered over 40 GW of coal-fired power capacity as non-performing assets, pointing to information gaps in financial markets. Another 25 GW of gas-fired power is largely stranded.

[933] GSI. (2019e). Beyond Fossil Fuels: Fiscal transition in BRICS. Case Study: China; GSI. (2019). Beyond Fossil Fuels: Indonesia's fiscal transition.
[934] GSI. (2019f) Beyond Fossil Fuels: Fiscal transition in BRICS. Case Study: India
[935] GSI. (2019g). Beyond Fossil Fuels: Fiscal transition in BRICS. Case Study: South Africa.
[936] GSI. (2020a). Rethinking Eskom: Lessons from electricity sector reform in India and Mexico.
[937] World Bank. (2020). State and Trends of Carbon Pricing 2020.
[938] GSI. (2019g). Beyond Fossil Fuels: Fiscal transition in BRICS. Case Study: South Africa.

Enabling environment / absorptive capacity barriers

The Global Competitiveness Report provides a good indicator of the enabling environment and absorptive capacity of each focus area. The overall ranking may indicate the ability of each region to leverage private investments, while the "institutions" section, which covers topics such as checks and balances, public sector performance, property rights, and future orientation of the government, may indicate the institutional capacity to implement fiscal policies. A lack of institutional capacity may hinder the implementation of carbon pricing instruments, or the ability to substitute one-size-fits-all consumption subsidies with targeted cash programmes to vulnerable groups.

Enabling / absorptive capacity barriers are low in China, moderate in Indonesia, South Africa, and India, and high in North Africa. China ranks 28th on the overall ranking of the Global Competitiveness Report but falls back to 58th on the "institutions" section; Indonesia ranks 50th and 51st respectively; South Africa 60th and 55th; and India, 68th and 59th. North African countries present high enabling environment and absorptive capacity barriers, with countries ranking between 75th and 93rd in the overall ranking, and between 45th and 111th in the "institutions".[939]

Table 65 Barriers per region

Region	Political economy barriers	Market failures	Enabling environment barriers
China	**High** Largest coal producer, plans to expand coal-based power generation in the East; financing coal mining and coal-fired power abroad.	**Low** Green jobs available to deliver the green transition.	**Low** 28th in the overall ranking of the Global Competitiveness Report, and 58th in the "institutions" section.
India	**High** Coal-based power generation to double by 2040.	**High** Information asymmetries in financial markets leading to stranded assets.	**Moderate** 68th in the overall ranking of the Global Competitiveness Report, and 59th in the "institutions" section.
Indonesia	**High** Significant role of fossil fuels in the economy, relies on coal-based power generation to achieve universal electrification, backtracked from FFSR.	**Moderate** Green jobs on the rise.	**Moderate** 50th in the overall ranking of the Global Competitiveness Report, and 51st in the "institutions" section.
North Africa	**High** Significant role of fossil fuels in the economy, populist opposition to FFSR.	**Moderate** Green jobs on the rise.	**High** Countries ranking between 75th and 93rd in the overall ranking, and between 45th and 111th in the "institutions" section.
South Africa	**High** Significant role of coal in the economy, opposition from unions and ESKOM to the green transition.	**High** Lack of green jobs.	**Moderate** 60th in the overall ranking of the Global Competitiveness Report, and 55th in the "institutions" section.

939 World Economic Forum. (2019). The Global Competitiveness Report. 2019.

Source: Vivid Economics, ASI and Factor

UK additionality

Since 2015, the UK's support for fiscal policy has focused predominantly on North Africa and India, but has also supported activities in other regions.[940] Key historic interventions include:

- In China, the UK's Foreign, Commonwealth and Development Office (FCDO) has provided small technical assistance funds to channel UK expertise in the power sector reform of certain provinces (Fujian, Jiangsu), supported China in developing subsidy policies for offshore wind, and supported the Energy and Low Carbon Economy strand of the China Prosperity Fund Portfolio Phase 1 Programme with GBP 4 million.
- In India, the UK Department for International Development (DFID) has supported power market reforms to scale up of renewables with GBP 14 million.
- In Indonesia, the UK - FCDO has provided small technical assistance grants as part of the Prosperity Fund Renewable Energy Programme, whereas DFID has supported the Economics of Low Carbon Development for Indonesia programme with GBP 4.9 million.
- In North Africa, CDC Group plc. is providing investment finance to 9 of the 13 solar power plants at the Benban Solar Park in Egypt, for a total capacity close to 0.4 GW. Budget estimates are not provided.
- No substantial interventions have been identified solely for South Africa, though in Sub-Saharan Africa (inc. South Africa) and India, BEIS is supporting the clean energy transition through the regional UK Climate Investments programmes: a GBP 200 million joint venture with Macquarie to support clean energy projects with late-stage minority equity stakes.

The UK is already one of the largest funders of fiscal policy interventions. According to OECD Development Assistance Committee (DAC) data, the UK was the third-largest donor to climate-related principal development finance in 2018, after Germany and European Union (EU) institutions, and ahead of donors such as Norway, the United States, Japan, or Canada.[941]

The UK can take advantage of moderate-to-high synergies with its UK decarbonisation strategy and planning. The UK has successfully navigated a near total phase-out of energy production from coal sources, due in part to fiscal policies such as fuel duties, price floors for carbon pricing, renewable energy obligations, and feed-in tariffs, and is primed to make further progress under its legally binding commitment to net zero by 2050. The UK piloted a carbon market that was the forerunner of the EU's Emission Trading System (EU ETS) and continues to deliver the financial services required by the EU ETS. The UK can also leverage the expertise of its world-leading institutions and experts to assist in the just transition of the focus regions, although past domestic errors may pose some questions about the UK's credibility on the topic. The UK could use Scotland's Just Transition Commission as a model to help the focus countries define just transition activities and form new policies or programmes based on similar principles and objectives.

[940] Development Tracker, 2020. Accessed via: https://devtracker.dfid.gov.uk/
[941] OECD, 2020. Climate Change: OECD DAC External Development Finance Statistics. Accessed via: http://www.oecd.org/dac/financing-sustainable-development/development-finance-topics/climate-change.htm

Intervention opportunities

Key potential UK interventions include providing technical assistance and capacity building in FFSR areas such as increasing transparency on fossil fuel subsidies, providing capacity building to implement tax reform with targeted instruments, supporting ongoing plans to establish a carbon price in the focus regions, and providing technical assistance and capital investment for the just transition.

Providing technical assistance and capacity building in FFSR

Increasing transparency on fossil fuel subsidies and providing information to inform policy dialogue and decision-making, thereby supporting developing countries in raising the ambition of their NDC through FFSR and reducing decision-making inertia towards fossil fuels. This could be achieved, for instance, by supporting recent efforts by United Nations Environment Programme (UNEP), OECD, and the IISD to develop SDG indicator 12.c.1[942] and link back the topic to sustainable development.[943]

Technical assistance and capacity building to equip existing institutions with the ability to develop a road map to the complete phase-out of fossil fuel subsidies and plans for other subsidy reform, including tax transfers and the replacement of energy consumption subsidies with cash transfers or clean energy swaps. Technical assistance should also be provided to prevent the reversal of progress through the use of legal and regulatory instruments.

This intervention is suitable for all target regions. More specifically, the UK can support more efficient price setting in Chinese power markets, and phase out subsidies to coal power production in China; it can support India in its ongoing effort to phase out consumption subsidies; it can support the reinstatement of FFSR in transport fuels in Indonesia, and the introduction of clean energy swaps or cash transfers instead of LPG subsidies; it can introduce clean swap energy schemes in North Africa to replace butane subsidies with off-grid solar PV or irrigation; or it can provide technical support in South Africa to phase out consumption subsidies to electricity and transport fuels and to introduce clean energy swap regulations to favour off-grid solar PV.

Providing technical assistance and capacity building through key carbon pricing initiatives

Support key Multilateral Development Bank (MDB) programmes, including additional support to World Bank's (WB) Partnership for Market Readiness (PMR), the WB's TCAF, or the WB's Partnership for Market Implementation (PMI). The UK already supports PMR with GBP 14 million (2010-2020), and TCAF with GBP 60 million (2020-2030) (see Section 0). Sustained support is deemed key to protecting carbon pricing instruments from economic and political shocks (i.e. dynamic political economy barriers), and to increase their ambition over time.

Create a dedicated platform to support carbon markets in focus countries, thereby increasing the amount of funds channelled bilaterally, which currently stand at around 20%.[944] This intervention could address political economy and enabling environment barriers.

This intervention is appropriate for all target regions except India, which is not considering a carbon price, and where the UK could support initial policy dialogue, either bilaterally or through the WB's PMI. More specifically, the UK can support the development of the Chinese national ETS, it can provide technical support to Indonesia to accelerate its plans for a domestic ETS for its power and industry sectors; it can provide technical assistance in North Africa to support the uptake of carbon pricing instruments, or it can support initial policy dialogue in countries that are lagging behind in this

[942] SDG Indicator 12c relates to the rationalisation of inefficient fossil-fuel subsidies that encourage wasteful consumption by removing market distortions, in accordance with national circumstances, including by restructuring taxation and phasing out those harmful subsidies, where they exist, to reflect their environmental impacts, taking fully into account the specific needs and conditions of developing countries and minimizing the possible adverse impacts on their development in a manner that protects the poor and the affected communities.
[943] GSI. (2019b). Raising Ambition Through FFSR: Greenhouse gas emissions modelling results from 26 countries.
[944] Independent Commission for Aid Impact (ICAI). (2019). International Climate Finance: UK aid for low-carbon development.

topic; and it can provide technical assistance to South Africa to gradually increase the ambition of its carbon tax.

Providing technical assistance for the just transition

Technical assistance in the identification of groups and industries vulnerable to transition risks; in the design, implementation, and monitoring of just transition programmes; and in the incorporation of just transition programmes and principles into broader industrial growth strategies at national and regional levels, so as to address limited institutional capacity.

Providing technical assistance and support to non-public stakeholders that operate in the energy markets, with initiatives such as supporting SOEs in diversifying away from fossil fuels and thus reducing their opposition to the energy transition, or building capacity in the financial sector of the focus regions to adequately value transition risk and reduce market failures (supporting the adoption of disclosure standards such as the Taskforce on Climate-related Financial Disclosures (TCFD), developing accounting and impairment rules, etc.), and to pilot the inclusion of the just transition in ongoing initiatives to reduce opposition from incumbents and increase institutional capacity.[945][946]

This intervention is relevant to China, South Africa (closure of coal mines and coal-fired power generation) and India (stranded assets). More specifically, the UK can support China in green diversification away from its coal mines and coal-fired power generation; it can provide technical support to Indian SOEs to diversify away from stranded assets in coal and natural gas generation into clean energies; it can support policy dialogue in Indonesia to initiate a long-term roadmap to phase out coal mining and coal-based power production; it can support initial policy dialogue in North Africa on the decommissioning of power plants that run on imported coal; and it can support South Africa in its power market reform.

In principle, BEIS could provide support for re-purposing sites/demonstrations/etc. This may support mitigation as place-based development requires support in certain locations; and providing technical assistance for reskilling or upskilling programmes, conditional on specified policy or climate outcomes. As in the previous case, this intervention may be appropriate for China and South Africa. For example, the UK could increase support to the World Bank's Energy Sector Management Assistance Programme (ESMAP)'s coal transitions, where it already contributes with GBP 8 million support. ESMAP's 2021-2024 business plan foresees the development of two just transition roadmaps in two coal regions with USD 50 million.

[945] Just Transition Centre. (2017). Just Transition. A Report for the OECD.
[946] Grantham Research Institute. (2018). Climate change and the just transition A guide for investor action.

Intervention case studies

These case studies provide real-world insights into intervention design and challenges. Each case study provides an overview of the context, the aim of interventions, and challenges faced, and jointly provide a number of lessons to inform future intervention design.

Box 35 World Bank's Energy Sector Management Assistance Programme (ESMAP)

Developing context: to meet the Paris Agreement, the world must quickly diversify away from coal electricity generation, and "leave it in the ground". The Powering Past Coal Alliance (PPCA) is urging OECD countries to phase out coal by 2030 (Germany has just approved coal phase-out by 2038) and developing countries by 2050. This urgency contrasts heavily with the 593GW of coal generation in the pipeline, which is concentrated in Asian middle-income countries such as China, India, and Indonesia.[947]

Programme objectives: ESMAP is a partnership between the World Bank and 18 donors to help low- and middle-income countries achieve universal access by 2030 and decarbonisation across the energy sector in support of international commitments on climate change. To achieve that goal, its business plan for 2021-2024 will focus on delivering clean cooking solutions, increasing access to electricity, supporting the take-off of mature renewable technologies, and accelerating decarbonisation with innovative technologies. The overall budget amounts to USD 1.3 billion.[948]

The UK's BEIS is supporting ESMAP "Energy Transitions" programme with GBP 19.1 million between 2018 and 2023. Four elements are being supported:

- **Maximising (i.e. filling funding gaps in) ESMAP "Asia Energy Transitions"** programme with (indicatively) GBP 9 million**,** which provides technical assistance to fast-growing economies on topics such as policy reform support (China), integration of clean energies into India's Smart Cities Programme, or advisory support for solar PV actions (Pakistan, Indonesia).
- **Expanding the "Energy Transitions" programme to additional countries** with (indicatively) GBP 8 million. Examples of developing countries that are relying on coal capacity expansions are Turkey, **South Africa,** and **Egypt**.
- **Expanding ESMAP's "Renewable Energy"** programme to other technologies with (indicatively) GBP 5 million. The focus will be on offshore wind, where the UK has significant experience, and where ESMAP has received technical assistance requests from countries like **India**. A UK expert will be recruited to ESMAP.
- **Supporting economic and social transitions from coal mining in South Africa** with around GBP 8 million. The programme will assist the government and the vertically integrated ESKOM in planning the closure of coal mines and the decommissioning of coal power stations. The activities include: (1) the design of phase-out social programmes (retrenchment, compensation) and transition programmes (training, incentives for workers recycling in the green economy); (2) rehabilitation of coal sites (including local economy revitalisation); and (3) policy reforms to factor in these social costs (energy transition fund, power sector deconstruction cost in tariff structure, etc.).

Programme expected outcomes and risks: according to the theory of change of the BEIS intervention, countries will reduce emissions by transitioning from unabated coal-fired power generation. The programme's expected outcomes are:

[947] BEIS. (2018). Energy Sector Management Assistance Programme (ESMAP) Business Case.
[948] World Bank. (2020). ESMAP Business Plan FY2021-2024 Affordable, Reliable, Sustainable and Modern Energy: Universal Access, Zero Carbon.

- **Amended market structures** that currently favour investment in unabated coal-fired power generation.
- **Institutions and frameworks strengthened:** Improved enabling environment and institutional/policy/regulatory frameworks for alternatives to coal, including offshore wind.
- **Increased capability** in countries to plan transition from unabated coal, including increased capacity to deploy offshore wind.
- **Countries move towards being able to sign up to the PPCA** (to date, just three sub-national governments have signed up in Asia: South Chungcheong Province, South Korea; Province of Ilocos Norte and Province of Negros Oriental, The Philippines; in Africa, three countries have endorsed the initiative: Angola, Ethiopia, and Senegal).

Despite ESMAP's strong track record, the risks of the intervention are:

- **Political economy barriers:** the energy policies of developing countries are at a crossroads between growing energy demand and decarbonisation. Because the energy transition is hindered by strong and complex political economy barriers, ESMAP may fail in diversifying away from coal.
- **ESMAP does not align its programme with other donors or UK programmes**, including the UK's Sustainable Infrastructure Programme in the Inter-American Development Bank or the Technical Assistance Programme, which is part of the ICF.
- **The performance of the management and governance of ESMAP deteriorates** if key individuals leave or established governance procedures change.

Lessons learned: The UK may draw the following lessons learnt by the EBRD's Green Transition Approach in Northern Africa (interview with Mr. Jan-Willem van de Ven, 16 July 2020):

- To deliver transformational change, systemic measures like carbon pricing must be linked with decarbonisation investments that abide with the tenets of the just transition. But the key is that demand must come from the country itself as part of its long-term strategies and climate goals.

Box 36 World Bank's Transformative Carbon Asset Facility (TCAF)

Developing context: economy-wide carbon pricing instruments reduce GHG emissions cost-effectively. For example, employing global emissions trading among Parties to the Paris Agreement could reduce the total mitigation cost by up to 79%.[949] However, only around 15% of emissions are covered by a carbon price globally[950].

Programme objectives: TCAF is an international finance facility hosted by the World Bank and supported by six donors (Canada, Germany, Norway, Sweden, Switzerland, and the UK) that aims to pilot innovative, results-based carbon market mechanisms under Article 6 of the Paris Agreement. The programme will run

[949] Environmental Defence Fund. (2019). The Power of Markets to Increase Ambition.
[950] World Bank. (2020). State and Trends of Carbon Pricing 2020.

until 2028. The UK is the second-largest donor with GBP 60 million, of which GBP 2 million have been spent.[951]

TCAF's purpose is to:

- Support mitigation ambitions in developing countries, by putting a price on carbon and by supporting developing countries in planning, implementing, and scaling up their NDCs. This will require the development of standardised baselines and robust MRV (monitoring, reporting and verification) which provides the building blocks for these countries to develop future carbon pricing policies.
- Help shape international carbon markets post-Kyoto and provide an additional source of flexibility for meeting domestic carbon budgets in donor countries.

To achieve its goals, TCAF provides three types of lending instruments: Investment Project Financing (IPF), Programs for Result (PfR), and Development Policy Financing (DPF).

According to the theory of change of the BEIS intervention business case,[952] innovative carbon pricing instruments will be used by developing countries to reduce GHG emissions and promote sustainable development. The programme's expected outcomes are:

- Participating jurisdictions can implement robust and sustainable mechanisms that lead to verified emission reductions.
- Non-participating jurisdictions are better able to consider and implement robust carbon pricing as a result from lessons learned from TCAF support.

According to the BEIS intervention business case, the risks of the intervention are:

- The failure rate of programmes undermines confidence in, and viability of, the TCAF.
- Long lead-in times for programmes mean that if a programme is developed but not then endorsed by the Facility Board there could be delays to TCAF implementation and results.
- TCAF over-subsidises a country's own effort if the baseline is incorrectly set.

Lessons learned:: The UK may draw the following lessons learnt by the WB's Carbon Markets and Innovation division which runs TCAF (interview with Mr. Venkata Ramana Putti, 22 July 2020):

- To be successful, carbon pricing interventions need to be coherent with the wider policy context, be built on strong analytical content, address distributional issues through revenue recycling and just transition considerations, and be based on effective communication strategies.

[951] Development Tracker, 2020. Transformational Carbon Asset Fund. Accessed via: https://devtracker.dfid.gov.uk/projects/GB-GOV-13-ICF-0027-TCAF
[952] BEIS. (2017). Transformational Carbon Asset Fund (TCAF) Business Case.

Glossary

Acronym / Term	Definition
BECCS	Bio-energy with Carbon Capture and Storage
BEIS	Department for Business, Energy & Industrial Strategy
Carbon leakage	Refers to the situation that may occur if, for reasons of costs related to climate policies, businesses were to transfer production to other countries with laxer emission constraints. This could lead to an increase in their total emissions. The risk of carbon leakage may be higher in certain energy-intensive industries.
CCUS	Carbon Capture, Utilisation, and Storage
CETP	Clean Energy Transitions Programme
Clean energy swap	In the context of the FFSR, a clean energy swap means reallocating some of the savings from subsidy reform to fund the clean energy transition—could magnify the contributions to long-term, permanent emission reductions, the economy, jobs, public health, and gender equality.
CPCL	Carbon Pricing Leadership Coalition
DECC	Department for Energy and Climate Change
DFID	Department for International Development
EBRD	European Bank for Reconstruction and Development
EDF	Environmental Defense Fund
EITI	Extractive Industries Transparency Initiative
ESMAP	Energy Sector Management Assistance Programme
ETS	Emission Trading Schemes
EU	European Union
EU ETS	European Union's Emission Trading System
FFFSR	Friends of FFSR
FFSR	FFSR
Fossil fuel subsidy types	Fossil fuel subsidies include production and consumption subsidies. A recent methodology to increase transparency under SDG 12 includes all fossil fuel subsidies and splits them into four categories: (1) Direct transfer of funds – payments made by governments to individual recipients; (2) Induced transfers – energy prices regulated by government; (3) Tax expenditure, other revenue foregone, and underpricing of goods and services – for example, tax reductions, allowances, rebates, or credits; and (4) Risk transfers – direct involvement of a government in the fossil fuel industry, by taking on risks on behalf of parts of the industry.[953]
GBP	Great British Pound
GDP	Gross Domestic Product
GHG	Greenhouse Gas
GSI	Global Subsidies Initiative
ICF	International Climate Finance
IEA	International Energy Agency
IISD	International Institute for Sustainable Development

[953] GSI. 2019d "Beyond Fossil Fuels: Fiscal transition in BRICS" https://www.iisd.org/sites/default/files/publications/beyond-fossil-fuels-brics.pdf

Acronym / Term	Definition
ILO	International Labour Organisation
IMF	International Monetary Fund
ITUC	International Trade Union Confederation
Just Transition	The ILO endorses a narrow definition provided by the International Trade Union Confederation which focuses on social dialogue. According to this definition, the just transition brings together workers, communities, employers, and government in social dialogue to drive the concrete plans, policies, and investments needed for a fast and fair transformation. It focuses on jobs, livelihoods, and ensuring that no one is left behind as we race to reduce emissions, protect the climate, and advance social and economic justice (International Trade Union Confederation in WB,2019). In turn, multilateral development banks such as the European Bank for Reconstruction and Development provide a wider, more programmatic, and action-oriented definition of the just transition. According to that broader view, the just transition aims at "sharing the benefits of a green economy transition and protecting vulnerable countries, regions and people from falling behind", and provides the framework to prioritise for three specific interventions: the green economy transition, support for workers, and regional economic development.[954]
LCOE	Levelised Cost of Energy
LPG	Liquified Petroleum Gas
MDB	Multilateral Development Bank
MWh	Megawatt hour
NDC	Nationally Determined Contribution
ODA	Official Development Assistance
OECD	Organisation for Economic Co-operation and Development
PMR	Partnership for Market Readiness
PPCA	Powering Past Coal Alliance
Pre-tax vs. post-tax subsidy	It is helpful to distinguish between two different notions of fossil fuel subsidies. One is a narrow measure, termed pre-tax subsidies, reflecting differences between the amount consumers pay for fuel use and the corresponding opportunity cost of supplying the fuel. In contrast, a broader measure, termed post-tax subsidies, reflects differences between actual consumer fuel prices and how much consumers would pay if prices fully reflected supply costs plus the taxes needed to reflect environmental costs and revenue requirements.[955]
PV	Photovoltaic
RD&D	Research, Development and Deployment
REEP	Renewable Energy Performance Platform
SDG	Sustainable Development Goals

[954] EBRD. 2020. "The EBRD just transition initiative. Sharing the benefits of a green economy transition and protecting vulnerable countries, regions and people from falling behind" https://www.ebrd.com/what-we-do/just-transition-initiative

[955] IMF. 2019a. "Global Fossil Fuel Subsidies Remain Large: An Update Based on Country-Level Estimates" https://www.imf.org/en/Publications/WP/Issues/2019/05/02/Global-Fossil-Fuel-Subsidies-Remain-Large-An-Update-Based-on-Country-Level-Estimates-46509

Acronym / Term	Definition
SOE	State Owned Enterprise. SOEs accounted for about 61% of total global electricity capacity installed in 2016 and for around 52% of capacity currently planned or under construction and have a key role in the energy transition. On a positive note, SOEs have an overall positive effect on renewables investments, either because SOEs gain competitive advantage with respect to capital-intensive renewables investments through preferential treatment (e.g. lower capital costs), or because governments use SOEs as vehicles to implement renewable policy goals. On a negative note, SOEs still account for roughly 56% of the ownership of coal power plants and of 52% of coal power plants planned. Evidence suggests that SOEs are, on average, continuing to invest in coal power at a higher rate than their private counterparts.[956]
Stranded assets	Stranded assets are those assets that at some time prior to the end of their economic life (as assumed at the investment decision point) are no longer able to earn an economic return as a result of changes associated with the transition to a low carbon economy. This definition covers both lower profits and totally stranded assets.[957]
Subsidies	Financial contributions from governments or other public bodies where there are direct transfers of funds, foregone or uncollected revenues, provision of goods or services, or any form of income or price support.[958]
TCAF	Transformative Carbon Asset Facility
TCFD	Taskforce on Climate-related Financial Disclosures
UK	United Kingdom
USD	US Dollar
WB	World Bank
WTO	World Trade Organisation

[956] OECD. 2018a. "State-Owned Enterprises and the Low-Carbon Transition". https://www.oecd-ilibrary.org/environment/state-owned-enterprises-and-the-low-carbon-transition_06ff826b-en
[957] Carbon Tracker. 2020. "Decline and Fall. The size and vulnerability of the fossil fuel system" https://carbontracker.org/reports/decline-and-fall/
[958] GSI. 2017 "FFSR and the Just Transition: Integrating approaches for complementary outcomes" https://www.iisd.org/sites/default/files/publications/fossil-fuel-subsidy-reform-just-transition.pdf

Greening the Financial Sector

Summary

The greening the financial *sector* opportunity considers interventions to embed the management of climate risks across the financial sector and to accelerate the pace of green investment in ICF-supported countries. This assessment of greening the financial sector includes interventions to support the deeper integration of low-carbon approaches in investment through reporting and management of climate risks, regulatory incentives for green investment among financial institutions, green asset and green investment promotion by establishing systems and processes to enable new investment classes, and financing incentives for green assets.

Interventions to support greening the financial sector include:

- Awareness raising and capacity building for central banks, financial regulators, and ministries of finance and supporting the establishment of climate risk reporting approaches in countries with more sophisticated financial sectors.

- Providing financing to promote and accelerate green investment and new green assets and savings tools in countries with weaker financial systems, including support for development and uptake of new tools, such as green bonds.

- Providing technical assistance, capacity building, and co-ordination support across the financial sector, including global advocacy and network formation, development of green financing strategies and taxonomies, pipeline development, financial institution awareness and uptake of green financing, advancing green banking approaches, and policy and regulatory improvements.

Table 66 Greening the financial sector assessment summary

Criteria	Assessment	Notes
Climate impact	Medium	• Moderate aggregate mitigation potential across developing countries, in particular in relatively more developed and larger financial markets, especially China and India. • High potential for actions to support and enable mitigation across many key sectors of the economy, but connections between financial sector greening initiatives and large-scale mitigation action are as of yet unproven due to relative novelty of action, even in mature financial markets.
Development impact	Moderate	• Impact on Sustainable Development Goals (SDGs) 1, 7, 8, 9, 11, 13, and 15 is moderate, with emphasis on clean energy, industry, infrastructure, and cities, recognising that greening finance will influence sectors with direct impact on SDGs in the future. All regions have more advanced financial sectors so SDG impact may be swifter. Negative impact could emerge from insufficient attention to a just transition.
Investment need	Low	• While overall flows of investment needed to achieve mitigation goals are high, levels of investment needed to support greening of the financial sector are lower given the focus on policy and regulatory action. • Regions with relatively less well developed financial markets are likely to face larger investment gaps, while some markets (e.g. China) with high mitigation potential face relatively lower gaps.
Cost-effectiveness	High	• Policy, regulatory, and capacity building measures will be lower cost than technical and capital investments in other opportunities, while still offering substantial transformative impact if well-targeted and designed to support uptake from financial institutions. • However, limited quantitative evidence exists on the cost-effectiveness of policy interventions to support the greening of financial sectors, even in mature financial systems.

Criteria	Assessment	Notes
Barriers to adoption	Medium	• In all regions, moderate to high political economy barriers, moderate market failures, and moderate enabling environment barriers exist ranging from lack of political commitment, state capture, poor recognition of climate risks, limited availability of capital, suitable financial instruments, lack of policy and regulation, and lack of capacity. A majority of barriers apply to all the countries under analysis.
UK additionality	High	• High additional value lies in the skills, resources and networks of UK based banks, non-bank financial institutions (NBFIs), and advisory bodies, UK leadership of initiatives such as the Green Investment Bank and Task Force on Climate-related Disclosures (TCFD), and COP26. The UK has moderate to strong ODA ties with all regions, focused on policy and regulatory reform and incentives for green investment.

Source: Vivid Economics, ASI & Factor

Key lessons for supporting mitigation through greening the financial sector:

The strategies and mechanisms for greening the financial sector sufficiently to meet the objectives of the Paris Agreement have not yet been found or deployed. This suggests a large potential arena for support and associated large mitigation benefits associated with action.

There is substantial need for development of financial sectors across developing country markets, and a wide range of graduated support approaches given the novelty of actions to support greening of financial sectors even in developed markets. BEIS will need to support the range of financial sector actors from commercial banks, corporates, and institutional investors to ministries of finance, central banks, and regulators.

BEIS support is likely to have most immediate effectiveness in more mature financial markets, but it should also not overlook the potential to support faster development and leapfrogging opportunities in earlier-stage markets. Assistance should be planned over a five- to ten-year period.

Cost-effectiveness of policy and regulatory measures is still not well understood, and targeted support could play an important role in developing knowledge about public goods here to help improve effectiveness of action on a broader scale.

Introduction to the opportunity

Role of the opportunity in decarbonisation of developing countries

Financial institutions in the developing world continue to grow in importance as a larger share of global growth, emissions, and green investment shift to emerging economies. The majority of renewable energy investment has taken place in the developing world since 2014. China and India have been leading the charge, with renewable energy investment in these two countries being comparable to the total investment in the entire developed world. Meanwhile other low income nations, such as Vietnam, South Africa, Mexico, and Brazil, also chartered record high investment levels of USD 47.5 billion in 2018.

At the same time, low- and middle-income countries require substantial further increases in levels of investment to meet national decarbonisation targets as set out in national climate plans and Nationally Determined Contributions (NDCs). In order to finance increasing volumes of mitigation investment, moving beyond easier green sectors such as renewable power, and avoiding continued or increased large-scale investment in high-carbon industries and sectors, it is important to support the reorientation of the financial sector in developing countries towards supporting greater flows of low-carbon investment.

Scope considered in this assessment

This assessment of greening the financial sector includes interventions to support the deeper integration of low-carbon approaches in investment and support for increased flows of investment into low-carbon sectors and assets. This assessment focuses on activities to 'green finance', and does not consider direct 'financing green' activities except inasmuch as targeted green investment can also help spur broader shifts in financial markets. The scope of activities included in the analysis of this opportunity includes:

- **Reporting and management of climate risks**, through regulatory action and supporting financial institutions.
- **Green asset and green investment promotion** by establishing systems and processes to enable new investment classes and processes.
- **Regulatory incentives for green investment among financial institutions** by establishing incentives for steering investment towards green assets and removing barriers to low-carbon investment.
- **Financing incentives for green assets to support broader market shift**, through direct co-investment or by supporting investment funds or initiatives, aimed at shifting domestic markets to promote maturation of green financial markets.

This assessment prioritises regions that have a sufficiently strong and developed financial system, previous commitments to sustainable financial sector reform, and signals of private and public sector facilitation of financing green. The strength and development of a financial system are gauged by using conventional measures of financial sector development including bank assets to gross domestic product (GDP) ratios, liquid liabilities to GDP ratios, and deposits to GDP ratios. We assume a mature financial system is more likely to initiate reforms than a shallow or less developed one. Previous commitment to sustainable financial sector reform is measured using the Sustainable Banking Network (SBN)'s methodology. We measure the extent of private and public action of financing green by looking at total levels of clean energy investment from 2014-18 and how fast investment levels are changing, overall availability of finance, and the level of development of climate change policy. We assess that higher levels of green energy investment and more action on climate change indicates that a region is more disposed to green financial sector reform than regions which have seen little movement on these issues by the private and public sectors. This exercise led to the prioritisation of the following regions:

Brazil

China

India

South Africa

Southeast Asia (excluding China), henceforth ‘Southeast Asia’

Climate impact

Mitigation potential and urgency

Across developing countries this opportunity is likely to offer moderate mitigation potential. It is an intervention that has the potential breadth to support mitigation across many key sectors of the economy. However, the depth of mitigation action linked to finance reforms is still unproven in many cases at this stage, even in mature financial markets. Key activities likely to deliver mitigation benefits include:

- **Reporting and management of climate risks:** Actions to support measuring and reporting of climate risk (including transition and climate policy risk) to improve transparency in the financial sector, enabling investors to make informed decisions. This includes mandating disclosure in financial filings to overcome inertia in integrating climate risks into decision making, and providing tools to help investors understand and report risk. Financial regulators can also promote financial stability by incorporating climate into their activities to safeguard against climate risks and promote mitigation action, by integrating climate into prudential regulation (e.g. climate stress tests and capital requirements) and by requiring investors or company directors to manage climate risks.
- **Green asset and green investment promotion:** Governments can develop supporting infrastructure and tools to enable the faster roll out of green investment and saving assets, including green bonds, green loans, and green mortgages, to enable investment into mitigation activities.
- **Regulatory and financing incentives for green investment among financial institutions:** Governments can support climate investments by establishing regulatory or fiscal incentives for steering investment towards green assets, for example through preferential tax treatment for income from green investments, lower capital requirements for financial institutions' green investments, or setting regulatory lending targets or limits.

Within the target regions considered in this assessment China and India are likely to provide particularly large mitigation opportunities. Regional mitigation potential is assessed based on underlying trends within the financial sector, the pace of green investment, and the ability to build on existing progress towards incentivising and regulating green investment to deliver mitigation outcomes. Each region's relative mitigation potential is assessed as a high, medium, or low priority within the set of top five prioritised regions – noting that all five regions have been identified as having particularly high mitigation potential in absolute terms. Brazil and China both offer high mitigation potential within the set of regions, based on substantial potential within each of three critical themes. China and India both have more developed financial sectors and are making good progress towards strong systems to encourage and promote green investment, suggesting good opportunities to scale up greening within the financial sector. Both provide opportunities to enhance the pace of green investment. Brazil and South Africa are likely to offer moderate relative mitigation potential – Brazil's policy environment may be somewhat less receptive to policy reform and the region currently sees lower than average green investment, while South Africa's financial sector is somewhat less developed than other regions. Southeast Asia offers the lowest relative mitigation potential, due to a mixed commitment to green financial policy reform and a mixed level of financial sector development.

Table 67 Mitigation potential by region

Region	Mitigation potential	Reporting and management of climate risks	Green asset and green investment promotion	Regulatory and financing incentives for green investment and green assets
Brazil	Medium	- Strong and developed financial sector, in the process of implementing environmental and climate risk disclosures. - Moderate mitigation potential.	- Slower growth rate of green investment relative to other ODA regions, but high levels of annual green investment and high availability of finance. - Moderate mitigation potential.	- Good progress towards commitments within the SBN. However, poor government effectiveness and regulatory quality. - Moderate mitigation potential.
China	High	- Strong and developed financial sector, developing nation closest to mainstreaming environmental and climate risk disclosures. - High mitigation potential.	- Moderate growth rate of green investment in recent years, but the highest levels of annual green investment by a substantial margin and high availability of finance. - However, very high levels of fossil fuel investment in COVID-19 stimulus responses. - High mitigation potential.	- Advanced progress towards commitments within the SBN and a relatively high score in terms of climate policy. However, poor regulatory quality. - High mitigation potential.
India	High	- Sufficiently developed financial sector, formulating commitments for environmental and climate risk disclosures but more progress needed. - High mitigation potential.	- Moderate growth rate of green investment among ODA regions in recent years, but the second-highest levels of annual green investment and high availability of finance. - High mitigation potential.	- Some progress towards commitments within the SBN and high regulatory quality. Moderately positive environment for climate policy. - High mitigation potential.
South Africa	Medium	- Sufficiently developed financial sector, in the process of implementing environmental and climate risk disclosures. - Moderate mitigation potential.	- High growth rate of green investment among ODA regions in recent years and high availability of finance, but moderate levels of annual green investment. - Moderate mitigation potential.	- Good progress towards commitments within the SBN and highest level of regulatory quality in all ODA regions. Good environment for climate policy. - High mitigation potential.

Region	Mitigation potential	Reporting and management of climate risks	Green asset and green investment promotion	Regulatory and financing incentives for green investment and green assets
Southeast Asia	Low	- Moderately developed financial sectors within the region, with a variety of levels of commitment to environmental and climate risk disclosures. - Moderate mitigation potential.	- Fastest growth rate of green annual investment in recent years out of any ODA region, but low overall levels of annual green investment and availability of finance. - Low mitigation potential.	- Some progress towards commitments within the SBN and high regulatory quality. However, poor progress on climate policy more generally. - Low to moderate mitigation potential.

Source: Vivid Economics, ASI and Factor

Transformational change

Greening the financial sector offers particularly large opportunities for transformational change because of the opportunity not only to enhance investment in green technologies and sectors but to divest from brown sectors and establish climate and environmental risk and regulation across the spectrum of the sector. The scale of change is likely to be highest in the near term, where the scope for raising green investment and reform and mitigation potential is greatest, i.e. in Brazil and China followed by India and South Africa and lastly Southeast Asia.

Table 68 Transformational change potential

Transformational change criterion	Interventions to support change	Regional potential
Sensitive intervention points		
Improvement of local capacities and capabilities	Greening the financial sector can improve green financial skills within government ministries, central banks, regulators, financial institutions, and project developers as investments are paired with technical assistance to improve capacity and the enabling environment.	All regions
Local ownership and strong political will	Greening the financial sector can, by demonstrating its own success, boost political will and incentivise the implementation and enforcement of laws and policies that are required for successful investments in green sectors.	All regions
Leverage / creation of incentives for others to act	The financial sector can prove influential in driving and shaping low-carbon transitions by stimulating local commercial banks and investors, by removing incentives and regulations against green investment, and by shaping government positions.	All regions
Spillovers		
Broad scale and reach of impacts	Better understanding of low-carbon opportunities, markets, and risks amongst government, project developers, and financial institutions can generate	All regions

Transformational change criterion	Interventions to support change	Regional potential
	spillovers for fiscal policy and carbon markets. Higher green investment flows into a country can, moreover, act as an incentive for governments to reform fiscal policy, e.g. subsidies or feed-in tariffs, and green policy and regulatory regimes to encourage further investment. The transition from a project-by-project to a more strategic, sector-led approach coordinated with all stakeholders can increase impact.	
Sustainability (continuation beyond initial support)	Systematic appreciation of climate change risks to businesses and financial institutions via instruments such as TCFD that are embedded – and mandated – in the financial system will not only promote green investment but aid divestment from brown sectors and improve low-carbon governance and climate intelligence.	All regions
Replicability by other organisations or actors	Advancements by one or a handful of banks and investors in a country or region can set a competitive incentive for others to act. Countries that serve as regional financial hubs can also drive progress in their less developed neighbours in both investment and capacity development.	All regions
Innovation		
Catalyst for innovation	Green asset and investment promotion via more mature markets, greater market information and understanding, and a greater array of green products with higher leverage potential can lead to substantial investment, scalability, and cost reductions in green sectors such as energy, industry, transport, agriculture, and land use.	All regions
Evidence of effectiveness is shared publicly	Publicity around green taxonomies, standards for green investments, lending and assets types, reporting and management of risks, and wider green investment trends can influence the behaviour of observer governments and financial actors.	All regions

Source: Vivid Economics, ASI and Factor

Development impact

SDG impacts

Impact on SDGs is likely to be moderate, recognising that greening the financial sector will influence the investments made in green sectors with more direct impact on SDGs in the future. Salient SDGs are no poverty (SDG1), affordable and clean energy (SDG7), supporting economic growth and decent work (SDG 8), increased industry, innovation, and infrastructure activity (SDG 9), sustainable cities and communities (SDG 11), climate action (SDG3), and land-based biodiversity (SDG15).

The five selected regions have more developed financial sectors and are likely to show SDG benefits more swiftly than developing and emerging countries with less advanced financial sectors. If broader economic and social considerations, e.g. for a just transition, and potential for negative trade-offs between sectors of green investment, such as agricultural productivity and forests, are not taken into account, there may be low to moderate negative impacts on no poverty (SDG1), affordable and clean energy (SDG7), reduced inequalities (SDG 10), and life on land (SDG 15).

Table 69 SDG impacts

SDG	Strength	Most relevant region	Rationale
Positive Impacts			
SDG 1 – No Poverty	Moderate	All regions especially India, South Africa, Southeast Asia	Green investment in energy, transport, agriculture, and other sectors will make basic necessities available and affordable.
SDG 7 – Affordable and Clean Energy	High	All regions especially India, South Africa, Southeast Asia	Financing clean energy will address insufficient grid connectivity and reliability and fulfil sustainable energy access.
SDG 8 – Decent Work and Economic Growth	Moderate	All regions	Green investment will create jobs in green sectors, reduce pollution, and improve working conditions, and proofing the financial sector from climate risks will support economic growth.
SDG 9 – Industry, Innovation and Infrastructure	High	All regions especially India and South Africa	Financing clean infrastructure and industrial decarbonisation can support industry competitiveness and innovation as well as resilience.
SDG 11 – Sustainable Cities and Communities	High	All regions	Financing clean transport and building infrastructure will improve urban sustainability, quality of life, and economic productivity.
SDG 13 – Climate Action	Moderate	All regions	Greater financial sector understanding of the risks of climate change will improve economic resilience.
SDG 15 – Land Based Biodiversity	Moderate	All regions especially Brazil and Southeast Asia	Financing sustainable forestry and agriculture, contributes to life on land.

SDG	Strength	Most relevant region	Rationale
Negative Impacts			
SDG 1 – No Poverty	Low	All regions especially India, South Africa, Southeast Asia	Green investment in energy, transport, agriculture, and other sectors could reduce access to basic needs if issues of access and affordability are not considered.
SDG 7 – Affordable and Clean Energy	Low	All regions especially India, South Africa, Southeast Asia	Green finance could reduce energy access amongst poorer rural and urban populations and lead to stranded assets and higher costs.
SDG 10 – Reduced Inequalities	Low	All regions	Green finance may contribute to income inequality if a just transition is ignored, i.e. if assets are stranded, jobs are lost, governments are indebted and cannot provide services, and the financial sector absorbs disproportionate profits.
SDG 15 – Land-Based Biodiversity	Low	All regions	Potential trade-offs exists if non-carbon forest goods and services are not considered in agriculture and transport planning and investment.

Source: Vivid Economics, ASI and Factor

Demand in target regions

Countries and regions show strong commitment to greening the financial sector, evidenced by NDC commitments, progress, and environmental and climate risk disclosures, and progress in green enabling environment reform. Increased green investment is a common NDC focus across all regions, notwithstanding ambitions generally incompatible with a 1.5-degrees °C pathway, and is usually achieved through policy, regulatory and broader enabling environment reforms, or financial incentives such as concessional finance, green bonds, grants to green funds or projects, or risk guarantees.

Table 70 Demand in target regions

Region	Demand	Rationale
Brazil	Moderate – High	Poor but improving regulatory environment, progress on SBN and TCFD, members of the Network for Greening the Financial System (NGFS), financial institution commitment, support from public institutions.
China	High	Comprehensive guidelines for green finance and good policy environment alongside poor regulation, strong progress on SBN and TCFD, members of NGFS, financial institution commitment.
India	Moderate – High	Good policy and regulatory environment though greater strategy and clarity required, moderate progress in SBN and TCFD, support from public institutions.
South Africa	Moderate – High	Strong policy and regulatory environment, moderate progress on SBN and TCFD, membership of NGFS, support from public institutions.

Region	Demand	Rationale
Southeast Asia	Low – High	Variable policy and regulatory environment across counties and progress against SBN and TCFD, some membership of NGFS, variable institutional support.

Source: Vivid Economics, ASI and Factor

Brazil has relatively poor government effectiveness and green regulatory quality but under the IFC SBN it has made progress and established regulations for understanding and reporting on green finance, green credit risk, and environment and social risk.[959] It has implemented measures under the TCFD. Sixteen Brazilian financial institutions are members of the United Nations Environment Programme Finance Initiative (UNEP-FI). The Central Bank of Brazil is a member of the NGFS. The Financial Innovation Laboratory has provided a platform for public and private sector dialogue.

China's policy environment is good but its green regulatory environment is poor. The country's Guidelines for Establishing the Green Financial System of 2016 give direction on green finance incentives, disclosure requirements, development plans for green financial products, and risk mitigation.[960] A small number of state-owned financial institutions play a dominant role in the sector. It is the largest sovereign issuer of green bonds in the world. Under the SBN, China has made significant advancements.[961] Progress on TCFD is high. Nine Chinese financial institutions are members of the UNEP-FI. The People's Bank of China is a member of NGFS. China plays an important role in providing green finance and building capacity to developing countries in Asia and Africa.

India's climate policy and green regulatory environment is good and there are several policies and plans in green sectors with emphasis on renewable energy expansion and energy efficiency. It nonetheless lacks a coherent green financing strategy and plan. India had made moderate progress under IFC SBN and some progress in TCFD.[962] One Indian bank is a member of the UNEP-FI. India has sponsored successful initiatives such as the India Innovation Lab for Green Finance.[963]

South Africa has a strong policy and regulatory environment though there is a need for more effective strategy and policy direction. It has made good progress under SBN and is in the process of implementing TCFD.[964] Nine South African financial institutions are members of the UNEP-FI. The South African Reserve Bank is a member of NGFS. The Renewable Energy Independent Power Production Procurement Programme has demonstrated a willingness to invest.[965]

In most Southeast Asian countries, there are policies and plans for green sectors but dedicated strategies or policies for green finance are lacking or are in early stages of development. Policy and regulatory quality is generally good, as is progress on the SBN. Progress on TCFD varies. Singapore is designing a Green Finance Action Plan while Cambodia and Vietnam have a National Strategic Plan on Green Growth and National Strategy Green Growth Plan. Three financial institutions in Malaysia, one in Myanmar, two in the Philippines and Singapore, and one in Thailand are members of the UNEP-FI. The central banks of Cambodia, Malaysia, Singapore, and Thailand are members of NGFS.

---

959 Sustainable Banking Network. (2019a). Brazil Country Progress Report: SBN Global Progress Report.
960 International Institute of Green Finance. (2017). Establishing China's Green Finance System: Progress Report 2017.
961 Sustainable Banking Network. (2018b). China Country Progress Report: SBN Global Progress Report.
962 Sustainable Banking Network. (2018c). India Country Progress Report: SBN Global Progress Report.
963 Global Green Growth Institute. (2019). Review of GGGI's Experience to Design and Operationalize National Financing Vehicles to Finance Climate and Green Growth Policy Implementation.
964 Sustainable Banking Network. (2018d). South Africa Country Progress Report: SBN Global Progress Report.
965 UNEP Finance Inquiry. (2016). Experience and Lessons from South Africa.

Investment need

While the overall flows of investment needed to achieve mitigation goals are high, levels of investment needed to support greening of the financial sector are lower given the focus on policy and regulatory action. Substantial investment is required for countries to achieve low-carbon growth trajectories, as well as substantial shifts in patterns of investment towards low-emissions sectors and activities. The Intergovernmental Panel on Climate Change (IPCC)'s Fifth Assessment Report (AR5) indicated that up to a trillion dollars may be needed annually to 2050 (compared to 2012 investment levels) just for low-emissions energy and energy efficiency investments needed for a 2-degree-scenario.[966] Shifts to a 1.5°C-scenario would require further direct investment and substantial investment in supporting substantial adjustments in the types and structures of financial institutions and in financing approaches – particularly as local financial sectors will need to provide the bulk of additional investment needed.

Within the target regions considered in this assessment, Southeast Asia is likely to face a particularly high investment gap. Regional investment gaps are assessed based on anticipated investment needs to support domestic green financial sector reforms, and likely availability of existing domestic and international support to meet these identified needs. Each region's relative investment gap is assessed as a high, medium, or low priority within the set of top five prioritised regions. Southeast Asia faces the largest gap, resulting from a need for significant strengthening of financial institutions, relatively low levels of current clean investment, and a relatively greater need for assistance in integrating climate mitigation into financial regulations and incentives. India and South Africa face moderate investment need, reflecting somewhat more advanced existing financial systems and green investment flows and capacity. Brazil and China present the lowest relative investment gap, given strong and developed financial sectors, high existing levels of green investment, and relatively greater experience with climate policy and environmental regulation.

Table 71 Investment need by region

Region	Investment need	Reporting and management of climate risks	Green asset and green investment promotion	Regulatory and financing incentives for green investment and green assets
Brazil	Low	- Strong and developed financial sector, may require minor strengthening of financial institutions and regulatory bodies. - Low investment need.	- Clean energy investment in Brazil is the third-highest among ODA regions despite a slower average investment growth rate of 15%. - Moderate investment need.	- Moderate experience in climate policy and environmental regulation. - Low investment need.
China	Low	- Strong and developed financial sector, may require minor strengthening of financial institutions and regulatory bodies. - Low investment need.	- Surpasses all developed and developing countries in terms of aggregate investment in clean energy – but may rebalance investment towards fossil fuels due to COVID-19 response. - Low to moderate investment need.	- Good experience in climate policy and environmental regulation. - Low investment need.

966 Blanco et al. (2014). ; International Energy Agency (IEA). (2014).

Region	Investment need	Reporting and management of climate risks	Green asset and green investment promotion	Regulatory and financing incentives for green investment and green assets
India	Medium	- May require moderate strengthening of financial institutions and regulatory bodies. - Moderate investment need.	- Second-highest level of clean energy investment, and a fast growth rate of investment at 25% annually. However, investment must increase faster given the size of the economy. - Moderate investment need.	- Capacity for environmental regulation and new climate policy but may require assistance. - Moderate investment need.
South Africa	Medium	- May require moderate strengthening of financial institutions and regulatory bodies. - Moderate investment need.	- Moderate levels of aggregate clean energy investment but a very high average growth rate of investment at 68%. However, more promotion is needed given very high reliance on fossil fuels. - Moderate investment need.	- Good experience in climate policy and environmental regulation. - Low investment need.
Southeast Asia	High	- Likely requires significant strengthening of financial institutions and regulatory bodies. - High investment need.	- Low levels of clean energy investment but the highest growth rate of investment by a wide margin (over 300% annually). - Moderate investment need.	- Lacks experience in climate policy and environmental regulation, will likely require high levels of assistance. - High investment need.

Source: Vivid Economics, ASI and Factor

Cost-effectiveness

It is theoretically challenging to assess the cost-effectiveness of interventions that do not deliver mitigation outcomes in themselves, but rather support an enabling environment that promotes and accelerates other mitigation activities. Indeed, within traditional 'marginal abatement cost curve' assessments, a conducive policy environment and access to finance for investments and within supply chains have been viewed as pre-requisites for effective least-cost mitigation investment approaches.[967] Measures to support a more efficient and effective financial sector that supports mitigation activities could therefore be considered as highly cost-effective, given that they enable least-cost mitigation investments within economies.

Limited quantitative evidence exists on the effectiveness of policy interventions to support the greening of financial sectors, even in mature financial systems. Evidence on the effectiveness of interventions to support greening within financial systems is limited. A 2016 evaluation of the UNEP-FI aims to support systemic change in finance to support sustainable investment, banking and insurance noted that the programme has overall been 'satisfactory', but that its effectiveness and efficiency were considered 'moderately satisfactory'.[968] This suggests that, while policy measures to support greening of the financial sector may be lower cost than capital investment or technical interventions, the effectiveness by which these programmes bring about change may be less strong than in direct mitigation activity investments – and cost-effectiveness is highly likely to depend on careful design of interventions and support.

There is greater evidence on the cost-effectiveness of specific green investment approaches: many of the financing instruments available to support the greening of the financial sector are likely to offer high cost-effectiveness. This is particularly true given the focus of activities on catalysing substantial volumes of private sector co-investment and driving broader changes in investment patterns – though different financing approaches are likely to offer better leverage and higher cost-effectiveness than others. While much climate finance investment has been provided in the form of project-level grants and concessional loans, reviews of finance suggest less used approaches aimed at unlocking private co-investment and mitigating risks holding back investment, such as equity investment and guarantee approaches – can leverage greater volumes of finance.[969] Effective approaches to market development will require a range of supporting tools to help support early stage technologies and businesses through highly concessional finance and the use of investment facilitating tools for more developed markets and sectors to support financial market development, while also reducing capital costs to enable critical climate investment. For example, the Seed Capital Assistance Facility (SCAF) provided USD 20 million in equity, loan, and grant co-financing for low-carbon projects, and directly funded 25 projects across the world, with private equity firms, venture capitalists, and project development companies. In its first phase, SCAF supported USD 503 million in co-investment based on donor capitalisation of USD 9.4 million, and supported 577 megawatts (MW) of renewable energy investment.[970] Similarly, the GuarantCo guarantee mechanism facility has enabled USD 5.6 billion worth of investments across a wide range of infrastructure categories, accounting for 55 projects in 22 countries, creating 14,000 short-term and 220,000 long-term jobs.[971] Other approaches, such as intermediated financing, have supported high levels of overall investment. For example IFC provided USD 75 million anchor investment in a USD 300 million green bond issuance by AC Energy in the Philippines to mobilise international investment,[972] and has also invested USD 260 million into a USD 1.4 billion green bond fund focused on emerging markets.[973] These examples do not evidence direct mitigation potential of investment opportunities, but suggest that the potential for leverage and co-investment supports very high cost-effectiveness from public investment in green investment tools and approaches.

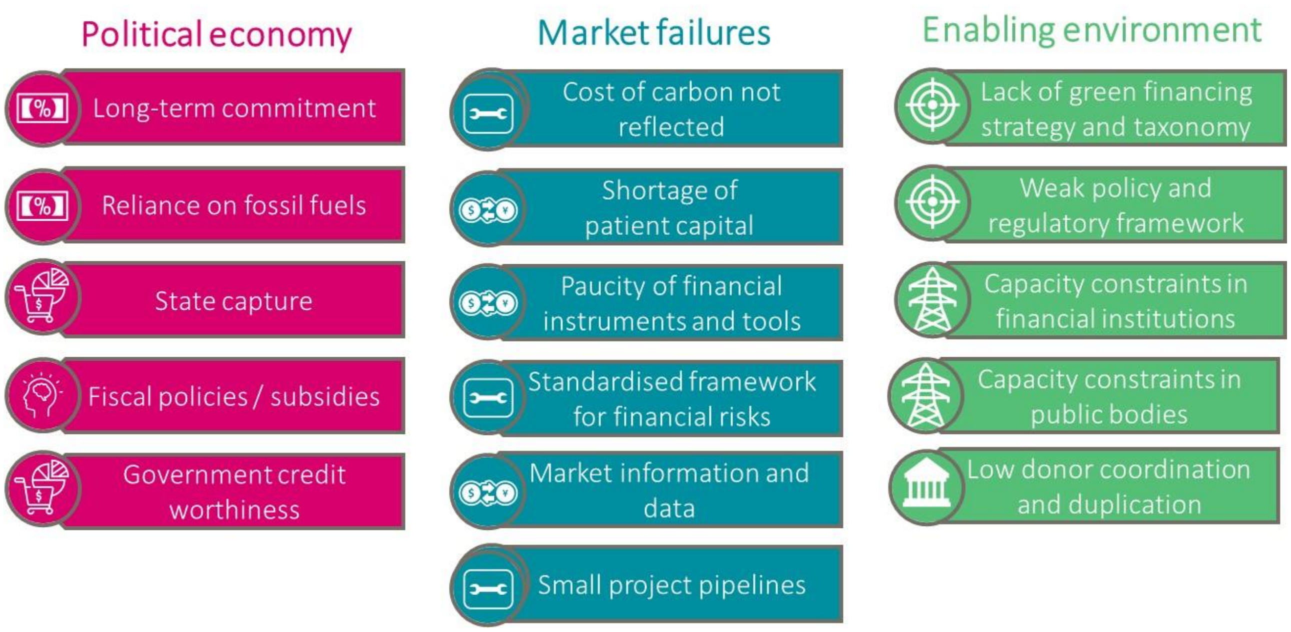
[967] For example, see IMF. (2011). Mobilizing Climate Finance: A Paper prepared at the request of G20 Finance Ministers.
[968] UNEP Evaluation Office. (2016). Evaluation of the UNEP Finance Initiative.
[969] Vivid Economics. (2020). Transformative Climate Finance.
[970] Woerlen, Zimmerman & Keppler. (2018). Terminal Evaluation: UN Environment/Global Environment Facility Project "Seed Capital Assistance Facility, Phase I (Renewable Energy Enterprise Development)".
[971] PIDG. (2020). 2019 Annual Review.
[972] AC Energy. (2019). ADB and IFC Invest in AC Energy Green Bonds.
[973] PRI. (2019). PRI Awards 2019 Case Study: Planet Emerging Green One Fund. https://www.unpri.org/pri-awards-2019-case-study-planet-emerging-green-one-fund/4826.article

Barriers to adoption

Barriers to greening the financial sector relate to i) political economy challenges, ii) market failures, and iii) enabling environment (see Figure 50). The five priority regions were selected for the relative development of their financial sectors, progress and commitment to sustainable finance reform, rising rates of green investment, and moderate to favourable green enabling environments. As a result they may be able to more quickly integrate reforms and improvements and show more rapid impact to UK interventions.

The barriers presented relate to both the greening of the financial sector as well as investment in green sectors. Most if not all barriers apply to all the countries under analysis, albeit to varying degrees, and most are well known, especially those related to green asset and investment promotion, regulatory reform, and financial incentives. In addition to the barriers themselves it is therefore important to examine the success of domestic and donor-supported attempts to overcome barriers and why they still persist. The list of barriers below draws on the Green Climate Fund, Organisation for Economic Co-operation and Development (OECD) Centre on Green Finance and Investment, UNEP Inquiry on a Sustainable Financial System, Network on Greening the Financial System, and the Climate Finance Leadership Initiative.

Figure 50 Barriers to the opportunity



Source: Vivid Economics, ASI and Factor

Political economy barriers

Moderate to high political economy barriers to greening finance and green investment are likely in all regions.

In all countries the lack of strong and tangible commitment by governments to support green sectors and markets is a major disincentive.[974][975] For example, the most significant barrier to greening the financial sector and green investment in Brazil is doubt over the Brazilian government's commitment to low-carbon growth with particular emphasis on energy, forests, transport, and industry.[976]

[974] Green Climate Fund. (2017). Analysis of barriers to crowding-in and maximizing the engagement of the private sector, including Private Sector Advisory Group recommendations.
[975] Climate Policy Initiative. (2020). Accelerating Green Finance in India: Definitions and Beyond.
[976] Climate Bonds Initiative. (2019b). Latin America & Caribbean: Green finance state of the market 2019.

- Countries that a) rely on fossil fuels revenues for public expenditure and b) have large existing investments in fossil fuel energy and industry, such as China, India, Indonesia, and South Africa, perceive trade-offs between a strong focus on economic growth and greening finance and green investment, particularly in the context of post-Covid-19 stimuli that predominantly favour brown sectors in all regions. This acts in opposition to the clear growth that the green financial system has seen in recent years.[977][978]
- State capture by powerful private sector interests with close ties to government, as in South Africa over Eskom, can dilute and delay financial sector reform and investment across green sectors.[979]
- Fiscal policies, such as subsidies to fossil fuel energy sources at either the producer or consumer end, exist in all regions and are a disincentive to reform and investment.
- Due to the low creditworthiness of government ministries and regulators, particularly in the energy sector, Brazil, India, South Africa, and Southeast Asia have high political and investment risk in international capital markets, which leads to either high cost of capital or non-investment.

<u>Market failures</u>

Moderate market failures to greening finance and green investment exist across most regions.

- The variety of fiscal, market, policy, and regulatory mechanisms deployed globally have so far failed to adequately understand and value the costs of climate change and thus to adjust the cost of capital and reform financial sector decision-making and investments in the timeframe required to reach the objectives set out in the Paris Agreement.
- In all regions, securing patient capital suited to green investment, given high upfront capital costs, five-year-plus lead-times for positive returns, and irregular payment cycles of some green investments, is difficult, particularly in the context of domestic commercial banks and NBFIs. Notwithstanding the steep reduction in renewable energy capital costs, this is an issue often associated with renewable energy, but it also affects energy efficiency, industry, transport, and agriculture, and it is experienced most frequently at the initiation and planning stages of the project cycle. Examples include India, South Africa, and Southeast Asian countries such as Thailand and Vietnam.[980][981]
- The absence of different types of investments and instruments beyond debt is a problem in all regions. Corporates, commercial banks, and development banks account for the majority of green investment with institutional investors, private equity, and venture capital accounting for much smaller volumes. In terms of instruments, balance sheet finance and market rate debt at project level form a majority whilst project equity, green bonds, grants, and concessional debt form the remainder.[982] Difficulties in securing early stage equity and the low capacity in project finance can deter projects from being bankable and limit innovation. Other than from multilateral development banks (MDBs), securing guarantees or insurance mechanisms at scale and beyond a project-by-project basis remains difficult. Limited availability of affordable local currency risk hedging instruments is a major constraint to investors.[983]
- In all regions, as in developed nations, there is no agreed and standardised framework between ministries of finance, central banks, financial regulators, financial institutions, and corporates for understanding a) the risks that climate change poses to financial institutions and carbon-intensive

---

[977] Green Climate Fund. (2017). Op. cit.
[978] UK Prosperity Fund. (2017). Financing South East Asia's energy transition.
[979] Climate Action Tracker. (2019). Climate Governance Assessment of the government's ability and readiness to transform South Africa into a zero emissions society.
[980] Global Green Growth Institute. (2019). Op. cit.
[981] UK Prosperity Fund. (2017). Op. cit.
[982] Climate Policy Initiative. (2019). Global Landscape of Climate Finance 2019.
[983] Green Climate Fund. (2017). Op. cit.

businesses and b) the risks these institutions and their assets pose to national economies. Risks may appear in policy, legal, market, technology, and physical domains and relate to climate proofing in the context of a changing climate as well as the less productive and stranded assets in low-carbon transitions.[984][985][986]

In all regions, though in China less than the rest, market information and data are hard to access, which has a limiting effect on pipelines of green projects.[987][988] Lack of clarity over national and international policy commitments, e.g. NDC or energy sector investment plans, and the paucity of information and data on pipelines, business performance, prices, and regulations have hampered businesses seeking to raise investment and expand and have deterred financial institutions and project developers from making investments.[989] In all countries, for example, China, India, and Vietnam, the issue of asymmetrical information in green sectors is a deterrent to foreign investors.[990]

Enabling environment / absorptive capacity barriers

Moderate enabling environment / absorptive capacity barriers to greening finance and green investment exist in all regions.

In all countries, the lack of a long-term, coherent, transparent, and straightforward strategic plan for greening finance and green investment, with supportive policy and regulatory frameworks and taxonomies defining and guiding investments, acts as a deterrent to progress and fails to offer necessary commitments and incentives[991][992]

In all countries, policy and regulatory barriers impede both greening the financial sector and green investment, reducing project pipelines and stemming innovation.[993] In China and South Africa, for example, there is a lack of clarity about banks' responsibilities in tracking environmental and social risks, and in India the lack of a common government position on green investment is a deterrent to investment.[994][995] Policy and regulatory barriers are:

Unclear financial sector regulation, particularly around credit risk and environmental and social reporting.

Poor investor rights and protections and inadequate foreign investment and repatriation laws, noting that the loosening of barriers to foreign investment and repatriation can cause domestic political tension.

Laws and benchmarks barring NBFIs such as pension funds and insurers from taking certain risks and investing in green sectors.

Fragmented and unclear policy and regulation in sectors such as renewable energy and agriculture.

The absence of sector-specific incentives, such as access to land rights, risk guarantees, power purchase agreements, auctions, and feed-in tariffs.

[984] Financial Stability Board's Task Force on Climate-Related Financial Disclosures. (2017). Recommendations of the Task Force on Climate Related Financial Disclosures.
[985] UNEP Finance Inquiry. (2016). Delivering a Sustainable Financial System in India.
[986] Network for Greening the Financial Sector. (2019). A call for action: Climate change as a source of financial risk.
[987] Ibid.
[988] UNEP Finance Inquiry. (2015). The Brazilian Financial System and the Green Economy.
[989] Global Green Growth Institute. (2019). Op. cit.
[990] International Institute of Green Finance. (2017). Op cit.
[991] UK Prosperity Fund. (2017). Op. cit.
[992] Climate Policy Initiative. (2020). Op. cit.
[993] Green Climate Fund. (2017). Op. cit.
[994] International Institute of Green Finance. (2017). Op cit.
[995] Climate Policy Initiative. (2020). Op. cit.

Public and private sector capacity constraints are key barriers in all countries, including:

The implementation capacity of Ministries of Finance and sector ministries in greening the financial sector and supporting investment in green sectors, including setting strategies and agenda, establishing public–private partnerships (PPPs), or launching blended finance mechanisms, for example in South Africa and Southeast Asia.

Project developers' corporate governance and accounting standards and skills in preparing investible projects, which diminishes the size of the investible pipeline, as, for example, in India.[996]

Amongst banks and NBFIs, including institutional investors, knowledge and skills around the potential and risks of investment in green sectors, of suitable financial products that can achieve scale, and of how to measure and report on environmental, social, and governance risks, for example in Brazil, South Africa, and Vietnam.

Central banks' and financial regulators' knowledge and capacity to address and oversee the green financial sector, including risks and resilience, and to introduce appropriate regulations and credit risk mechanisms, as in Brazil and South Africa.[997]

Table 72 Barriers per region

Region	Political economy barriers	Market failures	Enabling environment barriers
Brazil	Moderate to high Political commitment, reliance on fossil fuels, and subsidies.	Moderate Capital shortages, asset types, climate risks and disclosures, and pipelines.	Low to moderate Policy and regulatory issues.
China	Moderate to high Political commitment, reliance on fossil fuels, and subsidies.	Moderate Climate risks and disclosures and pipelines.	Low to moderate Policy and regulatory issues.
India	Moderate to high Political commitment, reliance on fossil fuels, and subsidies.	Moderate Capital shortages, asset types, climate risks and disclosures, and pipelines.	Low to moderate Policy and regulatory issues and capacity constraints.
South Africa	Moderate to high Political commitment, reliance on fossil fuels, and subsidies.	Moderate Capital shortages, asset types, climate risks and disclosures, and pipelines.	Low to moderate Policy and regulatory issues and capacity constraints.
Southeast Asia	Moderate to high Political commitment, reliance on fossil fuels, and subsidies.	Moderate Capital shortages, asset types, climate risks and disclosures, and pipelines.	Low to moderate Policy and regulatory issues and capacity constraints.

Source: Vivid Economics, ASI and Factor

[996] Ibid.

[997] Green Climate Fund. (2017). Op. cit.

UK additionality

Historical donor activity in this opportunity has been driven by a large number of countries including the UK.

A combination of investment funding in green sectors and technical assistance for green asset and investment promotion and green policy and regulatory reform comes from multilateral donors such as the World Bank, IFC, the Multilateral Investment Guarantee Agency (MIGA), Climate Investment Funds, Green Climate Fund, regional development banks, and bilateral donors in Europe, North America, and Japan.

The Global Green Growth Institute, the United Nations Development Programme (UNDP), and UNEP mainly offer technical assistance in improving enabling environments and building capacity within ministries, central banks, financial regulators, national commercial banks, NBFIs, and project developers.

The broader greening of the financial sector is less widespread but receives attention from countries through the IFC Sustainable Banking Network, initiatives on green bonds such as the Climate Bonds Initiative, the TCFD, the NGFS, and the International Platform for Sustainable Finance.

The effectiveness of donor assistance in greening the financial sector has suffered from project duplication and competition, poor appreciation of the policy economy, tendency towards short-term activities over long-term reforms, lack of country commitment, assistance given from overseas rather than in-country with counterparts, and crowding out private finance with public assistance. As a consequence, much donor assistance has limited durable impact.

The UK has had moderate to strong ties with priority regions with most programmes of support focusing on green policy and regulatory reform and incentives for green investment, including from the UK private sector.

Given the extent of UK relationships in focus regions it is likely that UK additionality is high. The UK has longstanding Foreign, Commonwealth and Development Officer (FCDO) relationships with India and South Africa. BEIS has emerging relationships in greening finance with Brazil, China, India, South Africa, and countries in Southeast Asia such as Malaysia and Vietnam via the Partnership for Accelerated Climate Transitions and Climate Finance Accelerator. The UK Prosperity Fund, run by the FCDO, has networks across many countries with green finance initiatives in Brazil and Southeast Asia, and the CDC Group has investments across all regions.

The UK's additional value is high resulting from its policy, regulatory and financial sector landscape and support for initiatives such as the Taskforce on Climate Related Financial Disclosures.

The UK has substantial expertise in greening private sector investment processes and integrating climate action and sustainability within financial sector regulation, which could offer models for other countries to follow. Despite the crowded donor environment there is high potential for UK additionality given:

Strong synergies with the UK's experience in central banking, financial sector regulation, green finance, and green investment promotion.

High levels of expertise, capital, and networks within UK-based banks, NBFIs, and advisory bodies to offer to selected countries and regions.

Experience in convening, forging alliances between, and advising stakeholders from government, the financial sector, expert institutions, and business, such as the Green Finance Institute.

- UK government experience in, for example the UK Clean Growth Strategy, the Green Finance Strategy, and the establishment of the Green Investment Bank (sold to Macquarie in 2017).
- Frameworks such as TCFD to drive greater levels of climate risk understanding.
- Very high investment needs and levels of demand in all countries and regions.

With its expertise in green finance and numerous sectors of the green economy the UK is well-positioned to address market failures and barriers in the enabling environment. In all countries, it can use its international leverage, including via COP26, to address political economy constraints. In countries with weaker financial systems, UK assistance will be well-placed to attract green investment and improve regulatory and financial incentives. In more sophisticated contexts, the UK can broaden the understanding of climate change opportunities and their risks and the role of central banks, regulators, and financial institutions in driving systemic change.

Intervention opportunities

There is substantial opportunity across all regions for the UK to address the identified barriers, drive green investment, and promote comprehensive financial sector reform driven by central banks, financial regulators, and other financial institutions. The intention should be to transform the financial sector and direct it towards green sectors and away from brown sectors to achieve 1.5 degree ambitions. The opportunity takes into account the context of the Covid-19 crisis and the imperative to ensure transitions channel finance into green sectors rather than locking in brown ones.

The type of intervention will vary according to country and regions. Countries with weaker financial policy and regulatory systems and higher market failures are likely to benefit from UK support for green asset and investment incentives. Countries with more sophisticated financial systems will demonstrate greater uptake of ministry of finance and central bank policy and regulatory reform and capacity development and of reporting on climate risks.

In greening the financial sector and raising green investment the most critical barriers to deployment are:

- In all countries – the existence of competing priorities and policies between the greening of the financial sector and support for brown sectors, particularly in the context of post-Covid-19 recoveries.
- In all countries – the absence of mechanisms to fully capture the cost of climate change as an externality, change the cost of capital, and reform the decision-making of financial institutions.
- In all countries – the lack of information and data, business performance, prices, and regulations that restricts the pipelines of investible projects.
- In countries with weaker and developing financial systems – constraints on the availability of patient capital and the absence of other financial instruments, such as risk guarantees, equity, currency hedging, and project finance mechanisms.
- In countries with more sophisticated financial systems – the lack of standardised framework and data for understanding a) the risks that climate change poses to financial institutions and carbon-intensive businesses and b) the risks these institutions and their assets pose to national economies.
- In countries with more sophisticated financial systems – the lack of an appropriate and straightforward strategic plan and regulatory framework for greening finance, particularly at the level of ministries of finance, central banks, and regulators, and the capacity to implement them.

UK interventions to address barriers rely on a combination of technical assistance, exchanges of expertise between UK and priority country institutions, and concessional funding. Interventions should seek to deploy national or regional expertise, where possible, for the sake of effectiveness and capacity building and should adopt five- to ten-year time horizons rather than one- to three-year ones. In countries with more sophisticated financial systems interventions should include the following:

- Awareness raising and capacity building for central banks and financial regulators to play a more substantive role in regulating and monitoring climate risks, building capacity within financial institutions, investing in green assets with their own resources, and using quotas and weightings to encourage investment in green sectors and away from brown sectors. This should be done whilst acknowledging that in selected countries central banks play a more interventionist role in the economy than in industrialised nations.
- The establishment of straightforward – and increasingly compulsory – measures for financial institutions and energy- and carbon-intensive businesses to gather data on emitting activities and to report on climate change risks and their relevance to governance, strategy, and risk management compatible with the TCFD.

In countries with weaker financial systems interventions should include the following:

The provision of funding to support a variety of concessional financing instruments including credit lines, green bonds, equity, risk guarantees, and currency hedging.

Support in the development of new green assets, mechanisms, and associated skills to expand the options open to financial institutions and project developers in green investment, including green bonds, guarantees, equity, and project finance models.

In all countries interventions should include the following:

UK leadership, in advance of COP26, in the establishment of an international platform for climate finance combining financial institutions – and their resources – in industrialised nations, as well as priority regions, to plan and direct the transformation of the financial sector, with the objective of setting obligations for financial institutions and holding them to account and also resolving political economy, market failure, and enabling environment barriers.

Improvements to green financing strategies and plans and development of frameworks and taxonomies in coordination with existing green sector plans and taxonomies, as well as international norms and standards to signal government commitment and give a systematic approach to green finance.

Awareness raising and capacity building for national commercial banks, NBFIs (including pension funds and insurers), and project developers on the financing needs of low-carbon projects, green financing models and assets, credit risk mitigation, environmental and social reporting, and investment readiness.

Advocacy on the part of influential green financial and business actors, such as financial institutions, project developers, chambers of commerce, and banking associations, to coordinate and run dialogues with ministries of finance, central banks, and regulators, in order to overcome knowledge and informational barriers, and to identify areas for regulatory reform and capacity development.

Enabling environment improvements covering, for example, financial regulations, credit risk, environmental, social, and governance reporting, removal of regulatory barriers to green investment, and green sector measures such as public-private partnership rules, power purchase agreement (PPAs), and feed-in tariffs for renewable energy.

Assistance to government ministries and commercial banks in generating investible project pipelines via channelling national policies and plans, improving market information and data availability, and raising the capacity of project developers.

The establishment of green finance innovation labs, redirection of existing development banks, or establishment of green investment banks to analyse and disseminate market information and data, stimulate partnerships between international and national financial institutions and corporates, and to identify new and effective green finance infrastructure, instruments, and regulation.

Fostering financial network expansion and participation between the UK and priority regions as a means of organisation and action via, for example, the aforementioned international platform for climate finance as well as networks such as NGFS, the UNEP-FI, the Institutional Investors Group on Climate Change, Climate Action 100+, and the Net Zero Asset Owner Alliance.

Effective bilateral, multilateral, and philanthropic donor coordination to ensure sustainability and effectiveness, hold viable country partnerships, avoid programme duplication and competitiveness, run five- to ten-year planning cycles, and promote long-term reform.

Preparation of a comprehensive taxonomy of readiness for greening the financial sector to act as a guide and standard in priority regions.

Intervention case studies

These case studies provide real-world insights into intervention design and challenges. Each case study provides an overview of the context, the aim of interventions, and the challenges faced.

Box 37 IFC support to the Bank of the Philippine Islands

The Bank of the Philippine Islands (BPI), the country's second-largest commercial bank, launched its Sustainable Energy Finance (SEF) programme in 2008 in partnership with the International Finance Corporation. From the IFC's perspective the programme's intention was to develop a self-sustaining project development and commercial financing market for renewable energy and energy efficiency projects in the Philippines.

BPI viewed the financing of clean energy projects as a significant growth opportunity and a new competitive advantage that can be served by introduction of new product lines to its clients and that at the same time enable the bank to diversify its existing lending portfolio.

BPI's engagement in financing clean energy developed organically and new market segments have been added throughout over the history of the programme until the present day. In partnership with the IFC, the programme originally targeted the financing of projects that would allow businesses to invest in technologies aimed at improving the efficiency of energy generation, energy distribution, and energy use. BPI has subsequently explored new sectors, such as clean energy in industry and agriculture, distributed energy – mainly rooftop solar and biomass, green buildings, and loans – to energy service companies.

The IFC played the roles of market enabler, provider of technical advisory services, provider of a risk-sharing facility for the BPI's renewable energy and energy efficiency portfolio, and convener in the adoption of the Philippines Green Building Regulation in 2015. With assistance of IFC grant funding and technical assistance, the objectives of SEF were to:

- Expand BPI's loan portfolio of renewable energy and energy efficiency projects by USD 50 million by the end of 2014, along with an annual greenhouse gas reduction expected of between 100,000-150,000 tonnes of CO_2.
- Create a new growth market aligned with current government laws and regulations on energy conservation and renewable energy.
- Offer new and innovative products, e.g. green loans and green bonds, gain first-mover advantage, and provide a new marketing channel through partnerships.
- Support financing for the emerging local energy service industry, i.e. energy service companies, technology providers, engineering firms, and project developers, bringing in new clients for the bank.
- Improve policy and regulation for renewable energy and energy efficiency and improve public-private platforms for dialogue and coordination.

In pursuit of those objectives, the activities of SEF were:

- Market research on selected industries where there were opportunities, like renewable energy and energy efficiency in the commercial sector, sugar mills, agriculture, and green buildings.
- Pipeline development in partnership between BPI, business, and service companies.

- Technical assistance to businesses to understand technology potential, assess the feasibility of energy efficiency or renewable energy projects, identify sources of energy savings, and structure the proper financing scheme to ensure project viability, profitability, and overall success.
- Product development, including new financing instruments and schemes for businesses and projects.
- Capacity building assistance to BPI's credit and account relationship officers in terms of understanding renewable technologies, assessing projects, developing eligibility criteria, and drafting evaluation tools for renewable energy and energy efficiency potential.
- Market development, including visits to clients to promote the programme, roadshows, and knowledge sharing events.
- Knowledge management, including the creation of promotional materials, success stories, and business cases.
- Overall programme management including strategy development.

As a consequence, the results of SEF were:

- Investments and products: Total SEF loans, as of the end of 2014, amounted to USD 503 million, and BPI launched into the green bond market.
- GHG emissions: Corresponding reduction in GHG emissions were approximately 852,000 tCO2e.
- Market expansion:
    - From early offerings of energy efficiency to clients, BPI expanded into the renewable energy market, service companies, and green buildings.
    - 1,198 small and medium-sized enterprises (SMEs) registered a growth in revenue of more than 20% as a result of SEF.
- Capacity development:
    - Improved and enhanced skills of bank officers in technical evaluation as well as in understanding the renewable energy and energy efficiency concept and promoting these to clients.
    - Understanding and application of environmental, social, and governance risks of projects by BPI's lending and credit officers.
- Governance: Environmental, social, and governance standards and risks were incorporated in BPI's general governance framework.
- Enabling environment: The Central Bank of the Philippines has recently released a circular on the country's sustainable financing framework requiring integration of environmental, social, and governance standards and risks into commercial banks' lending operations.
- Brand reputation – Enhanced the bank's reputation as a sustainable bank and leader in sustainable financing. Served as a model for other financial institutions to develop their own sustainable energy financing programmes.

The challenges that the IFC and BPI faced were:

- Limited awareness in the commercial banking sector about the real potential of renewable energy and energy efficiency and little understanding of how to penetrate the market.
- Lack of public awareness on the benefits of renewable energy and energy efficiency investments, drawing on views of new technologies as being high cost, and preference for more direct revenue-generating projects that would increase sales and market share rather than cost-savings and operational efficiency.
- Lack of BPI experience in evaluating renewable energy and energy efficiency projects, particularly amongst BPI staff who had no technical capacity to assess projects *(technical assistance of IFC provided technical capacity building with technical consultants assisting in the review of projects.)*
- Limited availability of financing beyond 5 years.
- Lack of financial capacity of businesses, especially SMEs, to invest in new technologies and their low access to knowledge and markets.
- The slow learning curve amongst businesses, which needed demonstration with real case studies to show that energy and cost savings can pay for investments.

For BEIS there are two primary lessons of the SEF programme in determining ICF investment:

- In designing and implementing initiatives to green the finance sector it is imperative to work in parallel with a spectrum of financial sector stakeholders including financial institutions, businesses, and service providers.

  Foster public-private discussions on mobilising finance, market awareness, regulation, capacity building, and market and fiscal incentives to determine needs and requirements, establish momentum and shared narratives, and strengthen financial sector leverage on ministries of finance, central banks, and financial regulators.

Glossary

Acronym / Term	Definition
BEIS	UK Department of Business, Energy and Industrial Strategy
BPI	Bank of the Philippine Islands
COP	Conference of the Parties
DFID	Department for International Development
FCDO	Foreign and Commonwealth Office
GBP	Great British Pound
GDP	Gross Domestic Product
GHG	Greenhouse Gas
Gt	Gigatonne
ICF	International Climate Finance
IFC	International Finance Corporation
MDBs	Multilateral Development Banks
MIGA	Multilateral Investment Guarantee Agency
Mt	Megatonne
MW	Mega Watt
NBFIs	Non-bank financial institutions
NDC	Nationally determined contributions
NGFS	Network of Central Banks and Supervisors for Greening the Financial System
OECD	Organisation for Economic Co-operation and Development
SBN	Sustainable Banking Network
SCAF	Seed Capital Assistance Facility
SDGs	Sustainable Development Goals
SEF	Sustainable Energy Finance
TCFD	Task Force on Climate-related Financial Disclosures
UNDP	United Nations Development Programme
UNEP	United Nations Environment Programme
UNEP-FI	United Nations Environment Programme Finance Initiative
USD	United States Dollar

Governance for Transitions

Summary

The governance for transitions opportunity considers the development of policies, institutions and systems to guide and enable low-carbon transitions. The assessment includes interventions to help develop co-ordinated sectoral and cross-sectoral policies (including developing overarching national climate legislation and specific policies for transitions within sectors), establishing climate change co-ordination and/or expert institutions to oversee, enable or advise on transitions, developing climate monitoring and evaluation systems to enable effective tracking of transitions, and mainstreaming climate change within policies, regulations and implementation.

Interventions to support governance for low-carbon transitions include:

Supporting institutional co-ordination and the establishment or strengthening of climate institutions, including the revision and strengthening of existing institutional frameworks, structures and mandates across national and sub-national government and establishing expert institutions to deliver technical, policy, regulatory and scientific expertise.

Supporting the development of strategies, policies and other frameworks to enable co-ordination and better governance, including establishing or strengthening climate finance strategies for channelling public finances to climate action and supporting development of coordinated climate change policies, strategies and laws, credible and long-term sector policies and regulations, and Nationally Determined Contributions (NDCs).

Supporting improved co-ordination and engagement in governance, including strengthening the platforms for engaging stakeholders in business, finance and civil society engagement nationally and at state and municipal level, advising and supporting sub-national actors to play greater roles in climate governance and action, and supporting the forging of shared political narratives and raising awareness of climate change within national and sub-national government and communicate climate planning and policy amongst stakeholders.

Table 73 Governance for low-carbon transitions assessment summary

Criteria	Assessment	Notes
Climate impact	Medium	• Moderate aggregate mitigation potential across developing countries, due to widespread support for and enabling of broad mitigation action. • However, potential impact from supporting governance for transitions will depend to a very substantial degree on the ambition and success of subsequent policy action, and as intermediate steps between governance interventions and resulting mitigation outcomes may include many intermediary steps, these could delay or dilute the impact of governance activities.
Development impact	Low	• Governance underpins the success of sectors that have direct development impact. As such impact on sustainable development goals (SDGs) is moderate with emphasis on affordable and clean energy, economic growth and work, industry, innovation and infrastructure, reduced inequalities, cities and communities, life on land, strong institutions, and partnerships for the goals.
Investment need	Low	• While aggregate demand for governance support is high, the total scale of investment needed for related activities is likely to be moderate in absolute terms, and low relative to other prioritised mitigation opportunities due to the focus on policy and technical assistance interventions.

Criteria	Assessment	Notes
Cost-effectiveness	High	• Policy support and capacity building measures will be lower cost than technical and capital investments in other opportunities, while still offering substantial transformative impact if well-targeted and designed. • However, there may be substantial lags and intermediate steps between governance interventions and emissions reductions, and previous experience with programmes aimed at building governance capacity suggests programmes often face barriers. • Nonetheless, relative benefits and costs suggests high cost-effectiveness relative to other mitigation opportunities considered.
Barriers to adoption	Moderate	• In all regions moderate to high political economy barriers, mild market failures, and moderate enabling environment barriers exist. • Common barriers are lack of political commitment to climate action – especially in Covid-19 response packages; entrenched interests; domestic and international policy coherence; institutional frameworks, structures and mandates; accountability mechanisms; vertical coordination; stakeholder coordination; public finances; climate information and data; and technical capacity shortages.
UK additionality	High	• The UK's additional value is high resulting from the effectiveness and ambition of its climate policy and institutional framework and its political influence. • In priority regions BEIS and FCDO, formerly DFID, maintain moderate ties via ODA-funding and support by the UK parliament.

Source: Vivid Economics, ASI & Factor

Key lessons for supporting mitigation through governance for low-carbon transitions:

There is broad demand and need for governance support to overcome political economy constraints, improve and mainstream climate change within policy and institutional frameworks, and strengthen coordination between national and sub-national government and between government, business and civil society. Salient barriers revolve around political leadership, absence of comprehensive climate laws and sector plans, lack of effective institutional frameworks, poor sub-national government coordination, and disjointed engagement with important stakeholders in finance, business associations, and civil society. This suggests a wide range of opportunities for BEIS to contribute to, and good opportunities to play to UK strengths and additionality.

The relatively lower cost of governance-supporting interventions compared to technical interventions, coupled with large benefits through support for system-wide mitigation suggests overall high relative cost-effectiveness – but this is contingent on the success of governance interventions, which can fail to achieve their aims.

Governance has notable development benefits insofar as it underpins the success of sectors with direct development impact and enhances mitigation and adaptation simultaneously. Negative impacts may arise where low-carbon governance has the potential to increase unemployment and inequality in some sectors. This requires interventions to encompass a just transition for workers and communities and participatory approaches to the representation of vulnerable groups.

There is a need for careful identification of demand and design of interventions, and attention to barriers, especially political economy and capacity, that could limit success. The UK should offer lasting support, over a five- to ten-year horizon, that a) will achieve durable reform rather than quick fixes, b) has the backing of government and stakeholders, c) enhances networks and communities of change, and d) transfers expertise to country institutions.

Effectiveness in supporting governance is linked to international recognition of the UK's domestic ambition and effective policy and institutional action, including climate legislation and the Committee on Climate Change (CCC). Continued ambition, for example net-zero policies and via COP26, may open up further opportunities to support mitigation through governance interventions.

Introduction to the opportunity

Role of the opportunity in decarbonisation of developing countries

Effective governance is, in many cases, a necessary pre-requisite for effective climate mitigation outcomes. Governance systems enable, inform, and shape a huge range of policy actions and government investments, and set the frameworks and create the enabling environments in which private sector and autonomous mitigation actions occur. Viewed through this lens, effective governance can therefore be seen as a crucial enabler of broad mitigation impact, and a necessary step to delivering effective policy and the resulting mitigation action.

However, at present the capacity for governance of low-carbon transitions is currently very varied, with large deficits in many countries and regions. Developing countries are starting from very different levels of general government capacity and institutional development, which transfers across to diverse levels of sophistication in climate policy design and ability to implement climate policies, enforce regulations, and co-ordinate the low-carbon transition within government and across the private sector.

Scope considered in this assessment

Governance for transitions includes development of policies, institutions, and systems to guide and enable low-carbon transitions. The scope of activities included in the analysis of this opportunity include:

- **Developing co-ordinated sectoral and cross-sectoral policies**, including developing overarching national climate legislation and developing specific policies for transitions within specific sectors.
- **Establishing climate change co-ordination and/or expert institutions** to oversee, enable, or advise on transitions, provide 'accountability mechanisms' to encourage robust climate action, or enable stakeholder engagement in decision making.
- **Developing of climate monitoring and evaluation systems** to enable effective tracking of transitions.
- **Mainstreaming climate change** within policies, regulations, operations, and policy implementation processes.

This assessment primarily considers national-level governance activities – while recognising that sub-national action may be critical in certain regions. The categories of governance activities are likely to be similar across both national and sub-national policy contexts, perhaps with more emphasis on collaborative action and sharing knowledge and experience at sub-national levels. However, in countries with strongly decentralised governance systems and/or facing high governance barriers at the national level, and so where sub-national support is needed to enable climate action, this may multiply the investments needed to support action compared with countries with strong centralised policy systems.

This assessment prioritises regions that have sufficiently developed existing governance systems to benefit from targeted BEIS support, coupled with high underlying emissions potential absent co-ordinated action. This assessment identifies regions that have moderately developed policy and planning frameworks for renewable energy and energy efficiency and moderate overall government effectiveness and regulatory quality, in order to identify areas that are likely to benefit most from support for ongoing governance activities. That is, the process identifies regions that are sufficiently developed that systems would benefit from support without the need to first provide substantial broad development in government capacity, but without systems that are so developed as to not benefit substantively from BEIS support. This is complemented by identifying areas of high emissions growth, based on current emissions or emissions per capita and on projected population growth, and confirming that the regions are areas of existing or potential

BEIS focus based on the average number of BEIS programmes per country in the region. This exercise led to the prioritisation of the following regions:

- South America (excluding Brazil), henceforth 'South America'
- Southeast Asia (excluding Indonesia), henceforth 'Southeast Asia'
- Indonesia
- Mexico
- South Africa

Climate impact

Mitigation potential and urgency

Across developing countries this opportunity is likely to offer moderate mitigation potential. Interventions within this opportunity do not deliver mitigation outcomes in themselves, but rather serve to motivate broader mitigation action across countries or within sectors. Given its role in enabling and motivating action, the contribution of individual interventions towards final mitigation outcomes is likely to vary substantially across different regions and across different types of interventions. In some regions better governance could be key to driving mitigation, depending partially on the strength of the role government plays in co-ordinating and supporting local, regional, or national-level mitigation action and on existing governance capacity.

Climate governance activities are critical enablers of mitigation outcomes. Key avenues by which governance activities can support enhanced mitigation outcomes include:

- **Policy design to develop co-ordinated sectoral and cross-sectoral policies.** Effective policies are a crucial underpinning of effective climate mitigation action within countries, for example national climate policy or legal frameworks to drive climate action.
- **Support for establishment of climate change co-ordination and/or expert institutions.** Key areas for action include developing robust institutions with the ability to convene relevant stakeholders and actors and co-ordinate action across government or the private sector and to enable input from civil society and marginalised groups in decision making. This may also include expert groups to provide input and guidance to support effective climate action.
- **Development of climate monitoring and evaluation systems.** The availability of independent private and public reporting and statistical institutions are integral to oversight, effective monitoring, reporting, and review. The creation and enhancement of these institutions can be an important contribution to an effective transition to a low-emission world. The Intergovernmental Panel on Climate Change (IPCC) notes that there is substantial need and opportunity to scale up local, national, and international monitoring and evaluation (M&E) approaches and capacity to support a transition to a world in which global warming is limited to 1.5 degrees Celsius.[998]
- **Climate change mainstreaming assistance.** Substantial support is needed to fully integrate climate change into governance and policy systems within developing country governments. Effective mainstreaming requires both technical support to develop policies and frameworks that incorporate climate change, as well as supporting the practical uptake and implementation of mainstreaming within institutions.

The potential impact from supporting governance for transitions will depend to a very substantial degree on the ambition and success of subsequent policy action. This, in turn, depends on domestic political factors in supported countries, such as the commitment of the government in question, the strength of existing policy environments, and on the multiple layers of actors in the intermediate steps between the establishment of governance processes and the realisation of mitigation outcomes. For example, sectoral interventions may involve fewer intermediary actors leading to more immediate emissions reductions, but at lower scale than overarching policy support, which may be slower moving but has the potential to drive mitigation action on a larger scale. Short-term impacts are likely to be higher in countries with stronger current commitments to climate action, and with supportive existing policy environments, and greater capacity; but the transformative impact would likely be higher in countries with less current capacity or less well-developed policies or institutions.

[998] IPCC. 2018. Global Warming of 1.5°C.

Within the target regions considered in this assessment, South America and South Africa are likely to provide particularly large mitigation opportunities. Regional mitigation potential is assessed for regions based on current and expected future emissions, existing government capacity (in both general terms and for specific low-carbon energy policy and regulation), and on the types of governance areas that countries identify as priorities for development or for international support in NDCs and national planning documents. Each region's relative mitigation potential is assessed as a high, medium, or low priority within the set of top five prioritised regions – noting that all five regions have been identified as having particularly high mitigation potential in absolute terms. South America and South Africa both offer high mitigation potential given their high per capita emissions. Of these two countries/regions, South American countries (on average) have lower existing government capacity but offer clear opportunities for governance support closer to mitigation activities through sector-level support By contrast, South Africa has greater current capacity but has identified governance support as a priority area for international support in its NDC. Southeast Asia offers moderate emissions reduction potential based on high emissions pathways, and is likely to require varying levels of support across different countries within the region based on variable levels of existing government capacity and variable amounts of nationally-identified needs for support, at both the economy-wide and sector-specific levels. Indonesia and Mexico offer lower relative emissions reduction potential, based on more moderate emissions pathways, and more targeted needs for governance support within specific areas or sectors. Indonesia has faced a range of challenges, including overlapping responsibilities in different ministries[999] and a need for stronger focus on climate mitigation and consistency of targets and policies; a lack of independent advice to government on decarbonisation measures and country specific analysis; room for improvement in processes for policy development, implementation, and review and ability to monitor NDC implementation;[1000] and financial management challenges at the local government level.[1001] Mexico needs to strengthen the institutionalisation of climate goals in environmental legislation and empower the enforcement of environmental regulations,[1002] and to develop and implement an effective collaboration scheme between key ministries and departments.[1003]

Table 74 Summary of mitigation potential in key regions

Region	Mitigation potential	Notes
Indonesia	Low	• Moderate emissions potential, although pronounced emissions reduction opportunities in land use areas. • Variable existing government capacity across different areas (good general capacity, some shortfalls in energy efficiency planning and renewable energy expansion) suggests fertile area for impact. Substantial capacity challenges at sub-national levels. • Key areas of support are likely in institutional design, suggesting longer lags between action and mitigation outcomes.

999 Resosudarmo et al. Lucentezza. (2013). The dynamics of climate change governance in Indonesia. https://www.researchgate.net/publication/284938268_The_dynamics_of_climate_change_governance_in_Indonesia
1000 Climate Action Tracker. (2019). Climate Governance Series: Indonesia. https://climateactiontracker.org/documents/651/2019-08-30_CAT_ClimateGovernance_Indonesia.pdf
1001 ADB. (2016). Indonesia's Summary Transport Assessment. https://www.adb.org/sites/default/files/publication/217196/ino-paper-15-2016.pdf
1002 MGM Innova Mexico. (2018). Spinning the Web. https://www.giz.de/en/downloads_els/Spinning%20The%20Web_Interactive-mexico.pdf
1003 WRI. (2016). Achieving Mexico's Climate Goals: An Eight-Point Action Plan. https://energyinnovation.org/wp-content/uploads/2016/11/WRI_OCN_Mexico_final.pdf

Region	Mitigation potential	Notes
Mexico	Low	• Moderate emissions per capita, but relatively high emissions overall for a single country. • Moderate-to-good existing government capacity suggest high capacity for uptake of supporting measures. • Potential limited priority for climate at national policy level may limit mitigation impact from governance support. • Priority areas for support are among higher-level general government co-ordination with longer lag and additional steps between support and mitigation outcomes, suggesting relatively lower potential contribution to mitigation outcomes.
South Africa	High	• High per capita emissions suggest good potential for impact (esp. within Africa). • High quality enabling environment suggests good potential for impact and uptake of support. • Governance identified as critical barrier and strong national commitment to capacity development suggests high potential impact from interventions.
South America	High	• High emissions potential based on high per capita emissions and high total emissions, with moderate population growth. • Moderate-to-low existing government capacity suggests high additionality from support for governance activities – but suggests good targeting and design may be needed to ensure impact. • Key areas of support in implementing NDCs are relatively closer to end mitigation investments & actions (around practical investment implementation and financing), suggesting good potential impact from support.
Southeast Asia	Medium	• High per capita and total emissions, and moderate projected population growth suggest high impact potential. • Diverse existing capacity ranging from medium-high to medium-low suggests good potential both for immediate impact and high additionality. • Key areas of action include both late-stage support (such as developing projects and pipelines) and earlier-stage support (for strategic frameworks and planning), suggesting mixed direct mitigation impact.

Note: Low / Medium / High assessments are relative within the five highest priority regions, and do not reflect absolute assessments of mitigation potential.

Source: Vivid Economics, ASI and Factor

Transformational change

Governance for low carbon transitions offers particularly large opportunities for transformational change as the opportunity is key in driving and scaling climate action in all other green sectors. Given the nature of the opportunity, all countries have high potential of transformational change.

Table 75 Transformational change potential

Transformational change criterion	Interventions to support change	Regional potential
Sensitive intervention points		
Improvement of local capacities and capabilities	Better institutional capacity to plan and implement policy; coordinate, enforce, and evaluate climate action across ministries and departments at national, state and municipal	All regions

Transformational change criterion	Interventions to support change	Regional potential
	levels leverages climate action across green sectors.	
Local ownership and strong political will	Governance systems open to input from progressive and coordinated business associations – especially in the finance sector, civil society, and citizens at large can durably influence governments to take stronger climate action.	All regions
Leverage / creation of incentives for others to act	Better collaborations between government and private sector via coherent, climate-aligned sector laws and plans and climate finance strategies can improve the enabling environment and leverage substantial climate investment.	All regions
Spillovers		
Broad scale and reach of impacts	Effective networking, coordination, and the generation of shared political narratives via formal and informal structures between government, business, civil society, financial institutions, and donor agencies will improve the enabling environment and the mandate for action in all green sectors over time.	All regions
Sustainability (continuation beyond initial support)	Passing climate laws that persist beyond government planning and budgeting cycles and, in part emanating from climate laws, establishing coordination and/or expert institutions with reliable funding can embed long-term climate action.	All regions
Replicability by other organisations or actors	Improved sub-national climate governance and vertical coordination between national and sub-national government can lead to state and municipalities replicating the actions of others over time.	All regions
Innovation		
Catalyst for innovation	Deliberative democracy, for example citizens' assemblies and participatory approaches to budgeting and decision-making, raise public understanding and consensus, sustain policy change, and drive greater ambition over time and across political cycles.	All regions
Evidence of effectiveness is shared publicly	Supporting thought leadership and communications, including in the media, and sharing success stories and best practices can stimulate behaviour change and enhance government, business, and finance sector ambition and transparency.	All regions

Source: Vivid Economics, ASI and Factor

Development impact

SDG impacts

Governance for low-carbon transitions has notable positive impacts on achieving SDGs in all selected regions. Inasmuch as governance for low-carbon transitions underpins the success of sectors and opportunities that have direct development impact it will have substantial development benefits. Equally, improved governance around emission reductions will often enhance climate resilience given that many government institutions, policies, and plans – whether climate change coordination and expert institutions, national climate change laws or sector strategies – are likely to have mandates for both mitigation and adaptation.

Impact on SDGs likely to be high, with direct impact on affordable and clean energy (SDG 7), supporting economic growth and decent work (SDG 8), increased industry, innovation, and infrastructure activity (SDG 9), reduced inequalities (SDG 10), sustainable cities and communities (SDG 11), life on land (SDG 15), peace, justice, and strong institutions (SDG 16), and partnerships for the goals (SDG 17).

However, negative impacts on development may arise. Whereas overall employment is expected to rise as a result of the transition to a low-carbon economy, the potential for increased unemployment and inequality in some sectors of the economy exists. It is therefore important that governance interventions encompass a just transition for workers and communities and participatory approaches to the representation of vulnerable groups, including considerations of gender, race, ethnicity, and disability.

Table 76 SDG impacts

SDG	Strength	Most relevant region	Rationale
Positive Impacts			
SDG 7 – Affordable and clean energy	High	All regions, especially Indonesia, South Africa, Southeast Asia	Improved governance can lead to greening the energy mix and increase financing for affordable and clean energy.
SDG 8 – Decent work and economic growth	Moderate	All regions	Low-carbon policy and investment can promote growth and employment in all low-carbon sectors, especially when combined with just transition and gender and social inclusion factors.
SDG 9 – Industry, innovation and infrastructure	Moderate	All regions, especially Indonesia, South America, Southeast Asia	Improved governance can promote low-carbon public and private infrastructure and manufacturing and encourage new technologies aligned with a low-carbon vision.
SDG 10 – Reduced inequalities	Moderate	All regions	Climate governance can generate equitable growth and employment and mitigate the concerns of a just transition.

SDG	Strength	Most relevant region	Rationale
SDG 11 – Sustainable cities and communities	High	All regions	Both national and sub-national legislations and institutions play a key role in shaping and building cities including sustainable urban planning, transport, and behaviours.
SDG 13 – Climate Action	High	All regions	Good governance and polices play a key role in adaptation and resilience.
SDG 15 – Life on land	High	All regions, especially Indonesia, South America, Southeast Asia	Protection of biodiversity and ecosystems requires strict legislations and cross-sectoral policies and institutions.
SDG 16 – Peace and justice institutions	High	All regions	Better governance relies on strong institutions that can present and deliver policies, are inclusive and transparent, and are resilient to shocks.
SDG 17 – Partnerships to achieve the goal	Moderate	Al regions	Successful governance requires partnerships between public, private, and civil society partners domestically and internationally.
Negative Impact			
SDG 8 – Decent work and economic growth	Moderate	All regions	Enhanced climate action can cause unemployment and inequality in some sub-sectors if there is insufficient concern for a just transition and inclusion.
SDG 10 – Reduced inequalities	Moderate	All regions	Enhanced climate action can cause unemployment and inequality in some sub-sectors if there is insufficient concern for a just transition and inclusion.

Source: Vivid Economics, ASI and Factor

Demand in target regions

We assess the extent of demand for low-carbon governance with the use of four criteria covering national and sub-national institutions and policy. The role of the private sector and civil society as influencers and sources of demand for better governance, particularly when demand from government is low, is acknowledged in section 0in interventions. The four assessment criteria are:

- The ambition of the NDC, as judged by the Climate Action Tracker, and the greenness of the post-Covid-19 economic stimulus package, if it exists, as proxies for political commitment.[1004, 1005]
- The existence of a comprehensive framework law for climate change harnessing and/or directing institutions and policies, or failing that presence of national climate change action plans.
- The number of laws and policies in sectors related to climate change, which, despite the possibility of multiple laws competing rather than cohering, indicates a degree of government attention.[1006]
- The number of states and cities that are signatories to the Under2 Coalition and members of C40 Cities, taking into account the extent of unitary or federal government in each country, which indicates the influence of sub-national vis-à-vis national government.[1007, 1008]

Table 77 National demand in target regions

Region	National demand	Rationale
Indonesia	Low - Moderate	NDC is highly insufficient. Existence of Low Carbon Development Initiative but no law. High number of climate-related laws. Low political commitment.
Mexico	Moderate - High	NDC is insufficient. Framework General Climate Change Law in place. High number of climate-related laws. Adverse political climate.
South Africa	Moderate – High	NDC insufficient but ambition rising. National Climate Change Response Strategy and National Climate Change Response White Paper in existence and framework climate change law under consideration in Parliament. High number of climate-related laws. Complex political economy but commitment rising.
South America	Moderate – High	NDCs generally insufficient. Colombia and Paraguay have climate laws and national level plans and Chile is preparing a framework climate law. Other countries have strategies and plans. General high number of climate-related laws.
Southeast Asia	Moderate – High	NDCs generally insufficient, excepting the Philippines which is compatible with the Paris Agreement. Vietnam is highly insufficient but ambition is rising. Cambodia, Myanmar, Malaysia, the Philippines, Thailand, and Vietnam either have climate change action plans or policies. Malaysia and Thailand are preparing framework climate laws. General high number of climate-related laws.

Source: Vivid Economics, ASI and Factor

Indonesia demonstrates low to moderate demand for low-carbon governance at national level and moderate to high demand at sub-national level. Its NDC commitments are highly insufficient for meeting the

[1004] Climate Action Tracker. (2020). https://climateactiontracker.org/countries/
[1005] Vivid Economics. (2020). Greenness of Stimulus Index. https://www.vivideconomics.com/casestudy/greenness-for-stimulus-index/
[1006] LSE Grantham Research Institute. (2020). Climate Change Laws of the World. https://climate-laws.org/cclow
[1007] Under2 Coalition. (2020). https://www.under2coalition.org/members
[1008] C40 Cities. (2020). https://www.c40.org/cities

Paris Agreement except in forestry.[1009] Institutional design is an area identified by the NDC as in need of support. Indonesia has included a 2025 renewable energy target in its updated NDC. In 2017 the country announced a Low Carbon Development Initiative which aims to maintain economic growth through low emissions development activities. Four laws and 18 policies exist addressing climate change, covering transportation, energy, waste, agriculture, industry, land use, land use change and forestry (LULUCF), reducing emissions from deforestation and degradation 'plus' (REDD+), and water.[1010] Nonetheless the government remains reluctant to raise the country's climate ambitions and its response efforts to Covid-19 are likely to reinforce negative environmental outcomes.[1011][1012] Indonesia has a devolved system of government, with its 31 provinces responsible for most government services. East Kalimantan, North Kalimantan, Papua, South Sumatra, and West Kalimantan are signatories of the Under2 Coalition and Jakarta is a member of C40 Cities.[1013][1014]

Mexico shows moderate to high demand for low-carbon governance at national level and high demand at sub-national level. Its NDC targets are insufficient in the context of a 1.5°C goal.[1015] National coordination is an area identified by the NDC as in need of support. The General Climate Change Law, the first such law in a developing country, was adopted in 2012 and updated in 2018 to include Mexico's NDC targets. Ten climate-related laws and 12 policies exist, including the 2015 Energy Transition Law, covering energy, transport, agriculture, waste, REDD+, and LULUCF.[1016] However, government statements since 2018 have cast doubt on Mexico's legal climate commitments and changed regulations to prevent the country from meeting its renewable energy targets.[1017] Mexico's Covid-19 response measures will have a negative impact on the environment.[1018] Mexico is a federal state with substantial powers devolved to its 32 states. Nineteen of these states are signatories of the Under2 Coalition and Guadalajara and Mexico City are members of C40 Cities.[1019][1020]

Demand for low-carbon governance at the national and sub-national level in South Africa is moderate to high. Though South Africa has put forward absolute emission targets, its NDC commitments are highly insufficient for Paris Agreement targets.[1021] Governance in general is an area identified by the NDC as in need of support. The National Climate Change Response Strategy appeared in 2004 and the National Climate Change Response White Paper in 2011. The Integrated Resource Plan, including green electricity production, was released in 2019 alongside the introduction of a carbon tax. The Draft Climate Change Bill of 2018 remains under evaluation.[1022] Seven climate-related laws and six policies exist covering industry, transportation, energy, LULUCF, agriculture, and water.[1023] Ongoing difficulties in reforming ESKOM, the monopoly state electricity supplier, which would allow greater green investment, indicates limits to South Africa's political commitment. Its Covid-19 stimulus is largely reinforcing trends in fossil fuel-intensive sectors.[1024] South Africa is a unitary state with some decentralisation to its nine provinces. KwaZulu-Natal

---

[1009] Climate Watch Data – Indonesia. (2020). https://www.climatewatchdata.org/countries/IDN
[1010] LSE Grantham Research Institute. (2020). Climate Change Laws of the World - Indonesia. https://climate-laws.org/cclow/geographies/indonesia
[1011] Carbon Brief. (2020). The Carbon Brief Profile: Indonesia. https://www.carbonbrief.org/the-carbon-brief-profile-indonesia
[1012] Jong, Hans. (2020). Indonesia won't 'sacrifice economy' for more ambitious emissions cuts. *Mongabay.* https://news.mongabay.com/2020/04/indonesia-emissions-reduction-climate-carbon-economy-growth/
[1013] Under2 Coalition. (2020).
[1014] C40 Cities. (2020).
[1015] Climate Watch Data – Mexico. (2020). https://www.climatewatchdata.org/countries/MEX
[1016] LSE Grantham Research Institute (2020). Climate Change Laws of the World – Mexico https://climate-laws.org/cclow/geographies/mexico
[1017] Martin, Jeremy. (2019). How AMLO Is Undermining Mexico's Clean Energy Goals. *World Politics Review*. https://www.worldpoliticsreview.com/articles/28370/how-amlo-is-undermining-mexico-climate-change-goals
[1018] Vivid Economics. (2020).
[1019] Under2 Coalition. (2020).
[1020] C40 Cities. (2020).
[1021] Climate Watch Data – South Africa. (2020). https://www.climatewatchdata.org/countries/ZAF
[1022] Climate Action Tracker. (2019). Climate Governance Series: South Africa. https://climateactiontracker.org/documents/545/2019-09-30_CAT_ClimateGovernance_SouthAfrica.pdf
[1023] LSE Grantham Research Institute (2020). Climate Change Laws of the World – South Africa https://climate-laws.org/cclow/regions/south-africa
[1024] Vivid Economics. (2020).

and Western Cape are signatories of the Under2 Coalition and Cape Town, Durban, and Johannesburg are members of C40 Cities.[1025][1026]

Demand at national level in South America is, on average, moderate to high and at sub-national level is high. All countries have NDCs in place and identified areas of support are commonly around practical investment implementation and financing. Chile, Peru, and Argentina's NDC commitments are not sufficient to become 1.5°C compatible.[1027] All countries have climate-related laws and policies.[1028] Colombia has a National Policy for Climate Change passed in 2017. Paraguay has a National law on Climate Change which seeks to establish National Committee on Climate Change and National Directorate on Climate Change. Chile is preparing a framework climate law and Chile and Colombia have climate change action plans. Ecuador, Guyana, Peru, and Suriname have climate change strategies. Bolivia has neither. Only Peru has a dedicated action plan specifically for gender and climate change. Argentina's climate change cabinet is developing a National Plan for Response to Climate Change. Chile and Colombia have the highest number of climate-related laws. Most South American countries are unitary with degrees of decentralisation, but Bolivia has a devolved system of government. Santiago City in Chile, Caqueta, Guainia, Guaviare, and Narino in Colombia, Azuay and Pastaza in Ecuador, and seven states (Amazonas, Huánuco, Loreto, Madre de Dios, Piura, San Martín, and Ucayali) in Peru are members of the Under2 Coalition whilst Bogota and Medellin in Colombia, Lima in Peru, Quito in Ecuador, and Santiago City in Chile are members of C40 Cities.[1029][1030]

Southeast Asia demonstrates moderate to high demand at national level and moderate demand at sub-national level. All countries except Brunei have NDCs in place and identified areas of support are commonly around strategic frameworks and planning and development of projects and pipelines. The Philippines is one of the few countries whose NDC targets are compatible with a 2°C target. Vietnam's NDC targets are critically insufficient though rising and the country has the highest number of specific climate targets in its NDC.[1031] Cambodia, Myanmar, Malaysia, the Philippines, Thailand, and Vietnam either have climate change action plans or policies while Brunei has none.[1032] Laos incorporates climate change actions in its Five Year National Socio-Economic Development Plan. All countries have climate-related laws and policies, with the Philippines and Vietnam having the highest number. Most Southeast Asian countries are unitary with degrees of decentralisation, but Malaysia has a federal system of government. No Southeast Asian states are signatories of the Under2 Coalition but Bangkok, Hanoi, Ho Chi Minh City, Kuala Lumpa, and Quezon City are members of C40 Cities.[1033][1034]

[1025] Under2 Coalition. (2020).
[1026] C40 Cities. (2020).
[1027] Climate Action Tracker. (2020).
[1028] LSE Grantham Research Institute. (2020). Climate Change Laws of the World.
[1029] Under2 Coalition. (2020).
[1030] C40 Cities. (2020).
[1031] Climate Action Tracker. (2020).
[1032] LSE Grantham Research Institute. (2020). Climate Change Laws of the World.
[1033] Under2 Coalition. (2020).
[1034] C40 Cities. (2020).

Investment need

While aggregate demand for governance support is high, the total scale of investment needed for governance support activities is likely to be moderate. Despite substantial demand and need for support, the cost of support for any individual governance activity, or for any individual country, is likely to be lower than capital investment interventions, given the focus on policy development and the types of capacity building and technical assistance activities to deliver these interventions. Within these generally lower costs, investment needs are likely to differ substantially across and within countries depending on levels of focus and specific needs. For example, UK government funding on governance programmes has varied from GBP 400,000 spent on the Ghana climate change and environmental governance programme to ensure government policies and responses on climate change and environmental governance are developed and implemented in sectoral development planning; to GBP 18 million spent in the Nepal Climate Change Support Programme, aimed at building capacity of the government to develop, cost, budget, and implement measures at the local level aimed at mainstreaming climate change in key development sectors. Larger multi-regional programmes may have much bigger budgets, such as the Climate Proofing Growth and Development in South Asia which cost around GBP 28 million to integrate climate change into development planning, budgeting, and delivery in national and sub-national governments in Afghanistan, India, Nepal, and Pakistan.

Within the target regions considered in this assessment, Southeast Asia is likely to face a particularly high investment gap. Regional investment gaps are assessed based on anticipated investment needs, and qualitative expert assessment of likely availability of existing domestic and international support to meet identified needs. Each region's relative investment gap is assessed as a high, medium, or low priority within the set of top five prioritised regions. As identified in more detail in Table 78 below, Southeast Asia faces the greatest investment need, resulting from diverse levels of existing governance capacity suggesting a need for broad institutional support, coupled with a need for a wide range of different types of governance support. Indonesia, South Africa, and South America face moderate investment need. For Indonesia this reflects a need for development of capacity in key mitigation areas and for support for long-running national and sub-national institutional development, in South Africa this reflects a self-identified need for climate governance capacity support despite good general government capacity, while in South America current capacity is varied but the type of support needed for implementation may be lower cost and more cost-effective than earlier stage governance interventions. Mexico presents the lowest level of relative investment need, based on good existing capacity and specific support needs being more targeted within developing and implementing co-ordination processes and activities.

Table 78 Investment need by region

Region	Investment need	Notes
Indonesia	Medium	• Shortfalls in capacity across a wide range of areas, including in energy efficiency planning and renewable energy expansion, as well as national co-ordination, independent institutional guidance, and general policy development processes, suggests need for broad and targeted investment. • Key areas of identified need for support in institutional design suggest need for long-term capacity building.
Mexico	Low	• Moderate-to-good existing government capacity suggests lower need for broad-based capacity development support. • A focus on supporting broad co-ordination (given identified priority demands) is likely to require relatively lower investment than other regions.

Region	Investment need	Notes
South Africa	Medium	• High quality enabling environment, suggested by relatively strong governance and regulatory systems, indicates lower need for broad-based technical/institutional capacity development support. • However, identification of governance as critical barrier and strong national commitment to capacity development and political economy challenges suggests high investment need in specific areas.
South America	Medium	• Moderate-to-low existing government capacity suggests high investment need for broad capacity development across the region. • Key needs identified are closer to end mitigation investments and actions, suggesting need for relatively targeted and more time-limited interventions.
Southeast Asia	High	• Diverse existing capacity across different countries in the region, ranging from medium-low to medium-high, suggests broad and substantial investment needs. • Wide range of support needed, including both late-stage support (such as developing projects and pipelines) and earlier-stage support (for strategic frameworks and planning), suggests a need for broad investment support.

Note: Qualitative assessments of investment need are based on qualitative evidence drawn (from national NDCs and other indicators of demand set out in Section 14.4.2, World Bank World Development Indicators government effectiveness and regulatory quality indicators, ESMAP Regulatory Indicators for Sustainable Energy national energy efficiency planning, legal framework for renewable energy & planning for renewable energy expansion indicators) and expert elicitation.

Source: Vivid Economics, ASI and Factor

Cost-effectiveness

Supporting governance for transitions is likely to offer moderate-to-high overall value for money. It is theoretically challenging to assess the cost-effectiveness of interventions that do not deliver mitigation outcomes in themselves, but rather support an enabling environment that promotes and accelerates other mitigation activities. Indeed, within traditional 'marginal abatement cost curve' assessments, a conducive policy environment, access to finance for investments and within supply chains has been viewed as a pre-requisite for effective least cost mitigation investment approaches.[1035] Governance measures to develop an effective enabling environment may therefore be considered highly cost-effective, given that they enable mitigation across a range of mitigation sectors. Additionally, individual interventions to support governance will be lower cost than capital investment interventions. As most technical mitigation investments are capital-intensive, even small changes in the 'hurdle rate' through investments in better governance and stronger enabling environments could lead to large impacts on the overall marginal abatement cost curve.

However, there are likely to be substantial lags and intermediate steps between interventions and ultimate emissions reductions. Early stage governance interventions may also require long-lasting support, such as establishing new institutions or systems within countries, or may require greater investment over the medium or long term. Longer-term support also raises the potential for inefficiencies due to lengthy delays or the need for multiple intermediate steps or actors between governance support and ultimate mitigation action, suggesting lower overall effectiveness of interventions compared to interventions supporting direct action.

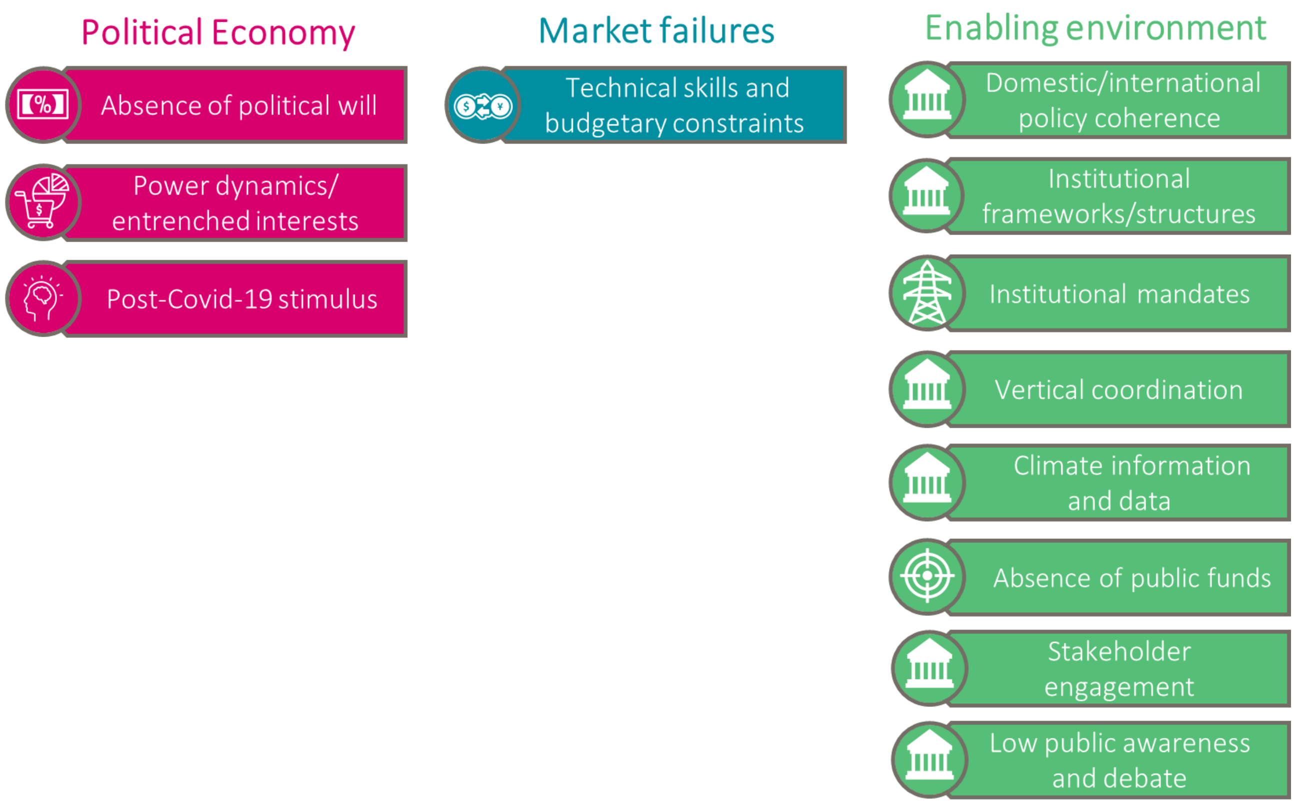
Cost-effectiveness is relatively difficult to assess as impacts from these types of interventions take a longer time to manifest themselves, governments and systems can change before impacts can be realised, and as interventions often have differing aims within (and beyond) governance. An Organisation for Economic Co-operation and Development (OECD) analysis found that for each example of successful intervention, there is usually an example of an unsuccessful one. The same report also finds that it is difficult to find the impact on improved service delivery. The challenge also arises from changes in government, where priorities or staff may change, and the work of the intervention is somewhat 'lost' and therefore impact is limited.[1036] It also difficult to compare different governance interventions to see which is more cost-effective because they have different end goals. This makes it challenging to set out benchmarks against which a certain intervention can be deemed cost-effective. These programmes are usually evaluated based on a project-specific baseline and against business-as-usual scenarios.

[1035] For example, see IMF. (2011). Mobilizing Climate Finance: A Paper prepared at the request of G20 Finance Ministers.
[1036] Betts & Wedgwood. (2011). Effective Institutions and Good Governance for Development. *OECD*. https://www.oecd.org/dac/evaluation/dcdndep/49247821.pdf

Barriers to adoption

Barriers to governance for low-carbon transitions faced relate to i) political economy challenges, ii) market failures, and iii) enabling environment. Each of these barriers are then mapped to regions and potential solutions below. The types of barriers are relatively common across all countries though they vary in their intensity. Barriers will be dependent on domestic political economy factors and levels of commitment, including the type of post-Covid-19 economic stimulus, the strength of the policy environment, effectiveness of institutional mandates and frameworks, horizontal and vertical coordination, stakeholder coordination, and public finances.

Figure 51 Barriers to an opportunity



Source: Vivid Economics, ASI and Factor

Political economy barriers

All selected regions face moderate to high political economy barriers to investment or adoption.

- The limits to political will for ambitious climate action are a concern in all regions and hamper efforts to create broad political consensus and inject clarity and commitment to climate change action amongst government institutions at all levels, as well as within business and finance. Lack of political will also acts as a counter to high demand for low-carbon capacity building and policy development in all regions.[1037] In country terms, Chile, Colombia, and Vietnam display relatively stronger political commitment at senior levels of government than Indonesia and South Africa, whose governments

[1037] Insight from expert interview. (2020).

are limiting ambitions and where influential parts of the government support fossil fuels, or Mexico, where ambitions are being watered down.[1038][1039]

- Power dynamics between government departments and entrenched business interests and influence, particularly from fossil fuel and energy industry, as well as government reliance on fossil fuels for revenues, raise barriers. Fossil fuel industries in Indonesia and Mexico have succeeded in delaying or watering down climate change targets and legislation, and in South Africa state capture, notably in the case of ESKOM's coal-powered electricity production, has in the past caused uncertainty over climate change direction.[1040][1041][1042][1043]

- A proxy for the extent of political will and extent of political economy challenges lies in the type of economic stimulus that countries offer. At present, few selected countries are offering stimulus packages that emphasise green growth and resilience. Malaysia and Myanmar are deploying solar energy as a vehicle of recovery, Indonesia is balancing green growth with investment in fossil fuels, whilst Mexico and South Africa are prioritising short-term growth in their existing brown economy over a green transition.[1044][1045]

Market failures

Across all regions, low-carbon governance efforts are likely to face some limited market failures.

- In all countries, technical skills and departmental budgetary constraints limit effective low-carbon governance in aspects of strategy, policy, enabling environment reform, climate mainstreaming, monitoring, reporting, and verification (MRV), financing, policy implementation, and stakeholder engagement.[1046][1047] They include shortages of expertise in science, industry, and finance, human resources shortages within departments, and limited budgets to prepare investments or arrange meetings.[1048] The increasing complexity of decarbonisation in selected countries exacerbates this barrier. Skills and budgetary resources are often particularly scarce at state and municipal level.[1049]

Enabling environment / absorptive capacity barriers

Moderate enabling environment barriers or limitations on their ability to absorb funding are common across the five regions.

- In all countries, there are varying degrees of policy coherence, as Section 14.4.2 indicates.[1050][1051][1052] Poor coherence increases the complexity of the policy and regulatory environment, slows implementation and investment, and causes countries to miss their mitigation goals – and also limits

---

[1038] Martin, Jeremy. (2019).
[1039] Coterill, Joseph. (2020). Ramaphosa vows to break Eskom's hold on South Africa energy. *Financial Times*. https://www.ft.com/content/fad17840-4ea9-11ea-95a0-43d18ec715f5
[1040] Averchenkova & Guzman. (2018). Mexico's General Law on Climate Change: Successes and challenges. *LSE.* https://www.lse.ac.uk/GranthamInstitute/wp-content/uploads/2018/11/Policy_brief_Mexico%E2%80%99s-General-Law-on-Climate-Change-Successes-and-challenges_8pp_AverchenkovaGuzman-2.pdf
[1041] Averchenkova et al. (2019). Governance of climate change policy: A case study of South Africa. *LSE.* https://www.lse.ac.uk/granthaminstitute/wp-content/uploads/2019/06/GRI_Governance-of-climate-change-policy_SA-case-study_policy-report_40pp.pdf
[1042] Climate Action Tracker. (2019).
[1043] Insight from expert interview. (2020).
[1044] Sambhi, Sonia. (2020). How green are Asia's post-Covid economic recovery plans. *Ecobusiness*.https://www.eco-business.com/news/how-green-are-asias-post-covid-economic-recovery-plans/?sw-signup=true
[1045] Vivid Economics. (2020).
[1046] NDC Support Cluster. (2018). Insights on Building and Strengthening Climate Governance Frameworks at All Levels to Support NDC Implementation. https://www.ndc-cluster.net/system/files?file=document/180918_Insights_NDC_Cluster_Workshop_Governance_final_0.pdf
[1047] Insight from expert interview. (2020).
[1048] IPCC. (2018). SR 1.5 Chapter 4 Strengthening and Implementing the Global Response. https://www.ipcc.ch/site/assets/uploads/sites/2/2019/02/SR15_Chapter4_Low_Res.pdf
[1049] NDC Support Cluster. (2018). Op. cit.
[1050] Averchenkova, & Guzman. (2018). Op. cit.
[1051] Averchenkova et al. (2019). Op cit.
[1052] Chaturvedi et al. (2019). Public-Sector Measures to Conserve and Restore Forests: Overcoming Economic and Political Economy Barriers. *WRI.* https://files.wri.org/s3fs-public/public-sector-measures-conserve-restore-forests.pdf

the ability of countries to develop and implement governance structures themselves. Coherence can be defined by the existence of a comprehensive framework law on climate change, alignment at a national level with national development plans, sector roadmaps and policies, and alignment with international commitments via NDCs:

Policy gaps and duplications exist between the objectives of climate change laws and of national development and energy plans, as in Mexico, and policy competition exists, e.g. between forestry and agriculture plans in Indonesia.[1053]

There is only partial alignment between ambitious NDCs, framework climate laws, and policies in energy, transport, agriculture and land use, for example in Indonesia's energy sector. A partial exception is Mexico, which aligned its General Law on Climate Change with its NDC in 2018 but hasn't followed through with alignment with sector laws.[1054]

In most countries where there is no comprehensive climate change law, as in Indonesia, the issue is often treated as just one of multiple environmental matters, impeding effective governance.[1055]

- Institutional frameworks and structures are weaknesses in all countries.[1056] Effective governance requires institutions close to the top of government that are entrusted with coordination and implementation of climate policy. A variety of ministries may have roles in implementation of mitigation and adaptation actions – energy, agriculture, livestock, fisheries, water, natural resources, or finance – and fragmentation, lack of clarity, and competition between ministries over turf impede climate action and have knock-on effects on signalling and commitments to sub-national government, the private sector, and other stakeholders. Cumulatively these issues lead to the sidelining of climate issues, slow implementation, disparate policy goals, and narrow government consensus. In Ecuador, Indonesia, and Vietnam, responsibility for climate change sits within ministries of environment, which are given the convening power over more influential ministries with varying, but often limited, effectiveness. In Chile climate change sits within the Permanent Presidential Advisory Committee on Climate Change with an influential mandate across government.
- Related to this, institutional mandates display varying degrees of fragmentation and clarity in all countries, holding back effective government collaboration and action.[1057] To enhance governance there should be designated institutions with a strong and clear mandate to enhance critical functions such as policy development, provision of public funding, institutional coordination, MRV, the provision of scientific and technical advice, and holding government to account:

In Colombia , the Philippines, and Vietnam, climate change coordinating and implementing institutions with defined mandates, processes, and resources exist but relationships are not well-established and important ministries lack climate change focal points and often operate in relative isolation.[1058][1059][1060]

In Indonesia, Mexico, and South Africa, climate change coordinating and implementing institutions exist but mandates, processes, and resources are poorly defined, relationships are not well-

[1053] Insights from expert interviews. (2020).
[1054] Insights from expert interviews. (2020).
[1055] Climate Action Tracker. (2019).
[1056] IPCC. (2018).
[1057] NDC Support Cluster. (2018).
[1058] Climate Action Tracker. (2019).
[1059] Climate Action Tracker. (2019). Climate Governance Series: Philippines. https://climateactiontracker.org/documents/663/2019-10-31_CAT_ClimateGovernance_Philippines.pdf
[1060] Insights from expert interviews. (2020).

established and important ministries lack climate change focal points and often operate in relative isolation.[1061][1062]

Climate change advisory bodies responsible for independent analysis and advice to government are absent in most countries, and where they do exist, for example in Mexico and the Philippines, they lack resources and authority and are unable to hold government to account.[1063]

- In all countries, poor vertical coordination of climate action between national and sub-national levels of government leaves the mandate, budget, and actions of sub-national government at state and municipal level unclear and impedes the flow of information and direction both ways.[1064] Sub-national government mandates and actions result from both nationally driven laws and plans, and local efforts at implementation. The extent and effectiveness of coordination will be influenced by the structure of the state, more unitary in the case of South Africa and more devolved or federal in the cases of Indonesia and Mexico, for example.[1065] In devolved or federal states sub-national governments will play greater parts in preparing and implementing laws and strategies, in alignment with national equivalents, in sectors such as energy and transport for which they are responsible. Sub-national government may also be better at targeting policy and implementation according to local characteristics, at creating opportunities for citizens and communities, and at participatory approaches.[1066] Poor vertical coordination is generally driven by institutional fragmentation at the centre and the strategies and the absence of mechanisms to deliver vertical coordination. As a result states and municipalities in all state systems often do not prioritise and plan for objectives of NDCs and framework and sector laws in their own planning and implementation.[1067] At the same time, there are often too few climate change champions at the sub-national level of government.

- Government recognition of the importance of stakeholders from business, business associations, finance, and civil society as generators of shared political narratives and engines for action varies. In all regions governance structures exist to consult stakeholders and incorporate their views though the mandate for engagement and the ways in which feedback is to be taken on board are often unclear. As a result, participation often happens only at certain stages and stakeholders are not offered influential roles in determining objectives or reforming the enabling environment. Indonesia displays relatively narrow stakeholder engagement beyond influential private sector actors.[1068] The Philippines has positive engagement of stakeholders but is hampered by management of their interests.[1069] Private sector fatigue at repeated rounds of abortive engagement is also common. This barrier is of particular concern in South Africa, where the level of engagement is high but where, due to recent history, there is mistrust between government and business.[1070]

- In all regions, public finances for the implementation of low-carbon transitions at both national and sub-national level are either absent or made only partially available. In addition, climate budgets are unpredictable and the mechanisms for apportioning and tracking budgets horizontally and vertically are inadequate.[1071] Dedicated climate finance institutions intended to overcome neglect of climate change in national budgets lack the level of funding to feasibly respond to low-carbon objectives, as Brazil's National Fund for Climate Change, Mexico's Climate Change Fund, and the Development

[1061] Climate Action Tracker. (2019). Climate Governance Series: South Africa. . https://climateactiontracker.org/documents/545/2019-09-30_CAT_ClimateGovernance_SouthAfrica.pdf
[1062] Insights from expert interviews. (2020).
[1063] Ibid.
[1064] Ibid.
[1065] IPCC. (2015). AR5 Climate Change 2014: Mitigation of Climate Change: Chapter 15: National and Sub-national Policies and Institutions. https://www.ipcc.ch/site/assets/uploads/2018/02/ipcc_wg3_ar5_chapter15.pdf
[1066] Ibid.
[1067] NDC Support Cluster. (2018).
[1068] Climate Action Tracker. (2019).
[1069] Ibid.
[1070] Averchenkova et al. (2019).
[1071] IPCC. (2018).

Bank of South Africa, which has a climate change mandate, show.[1072] Similar funding bodies are absent in many other countries. Issues related to this are the difficulties countries have in accessing international climate finance via, for example, the Green Climate Fund and Global Environment Facility.

- Shortages of climate information and data to aid decision-making are critical and the communication of data and information across government horizontally and vertically is haphazard.[1073] In all regions, this results in inadequate policymaking and implementation. Information gaps lie in scientific and technical expertise as well as policy, regulatory, and investment options.[1074] Often, information that is available is overly academic and unconducive to government processes or is confined to donor and international circles with limited absorption by government.

- In all regions, the extent of awareness amongst citizens of climate change and the benefits and risks of climate action is low but rising, the result of which is that there is limited common political narrative around climate change.[1075] The mechanisms for dialogue, debate, and information-sharing, via government communications, the media, or dedicated deliberative democratic and participatory approaches to budgeting and decision-making, are weak or absent in relation to climate change. There are, nonetheless, examples of participatory budgeting in countries in South America such as Colombia and Peru.[1076] The means of exchange between business, finance, workers, unions, and civil society exist, though they lack structure and commitment.

Table 79 Barriers per region

Region	Political economy barriers	Market failures	Enabling environment barriers
Indonesia	Moderate to high Political commitment, reliance on fossil fuels, state capture, Covid-19 response.	Low Technical skills and departmental budgets.	Moderate Domestic and international policy coherence, institutional frameworks and structures, institutional mandates, stakeholder engagement, vertical coordination, public finances.
Mexico	Moderate to high Political commitment, reliance on fossil fuels, Covid-19 response.	Low Technical skills and departmental budgets.	Moderate Institutional frameworks and structures, institutional mandates, stakeholder engagement, vertical coordination, public finances.
South Africa	Moderate to high Political commitment, reliance on fossil fuels, state capture, Covid-19 response.	Low Technical skills and departmental budgets.	Moderate Domestic and international policy coherence, institutional frameworks and structures, institutional mandates, vertical coordination, public finances.

1072 Insight from expert interviews. (2020).
1073 Insights from expert interviews. (2020).
1074 Averchenkova & Guzman. (2018).
1075 Insights from expert interviews. (2020).
1076 Schroedel, Jenna. (2020). The development of participatory budgeting in South America. *Citizen Lab*. https://www.citizenlab.co/blog/civic-engagement/participatory-budgeting/the-development-of-participatory-budgeting-in-south-america/

Region	Political economy barriers	Market failures	Enabling environment barriers
South America	**Moderate to high** Political commitment, reliance on fossil fuels, Covid-19 response.	**Low to moderate** Technical skills and departmental budgets.	**Moderate** Domestic and international policy coherence, institutional frameworks and structures, stakeholder engagement, vertical coordination, public finances.
Southeast Asia	**Moderate to high** Political commitment, reliance on fossil fuels, Covid-19 response	**Low to moderate** Technical skills and departmental budgets	**Moderate** Domestic and international policy coherence, institutional frameworks and structures, stakeholder engagement, vertical coordination, public finances

Source: Vivid Economics, ASI and Factor

UK additionality

Historical donor activity in this opportunity has been driven by a number of European and North American countries, particularly the UK and Germany, as well as multilateral donors.

A large number of donors have directed expertise, technical assistance, and knowledge platforms to improve low-carbon governance, including BEIS and DFID. Other major bilateral donors are USAID, GIZ, the Swedish International Development Cooperation Agency, and the European Union. Multilateral donors are UN Environment Programme, UN Development Programme, the World Bank, the Climate Investment Funds, the Global Green Growth Institute, and the regional development banks. Multi-donor programmes include the Climate, Development and Knowledge Network (CDKN), and the NDC Partnership. At the sub-national level, C40 Cities and the Under2 Coalition are the most prominent global programmes for cities and states respectively.

Most assistance to climate governance is channelled via programmes addressing broader reforms and investments in a particular sector and country. A minority, via the NDC Partnership or more concisely defined bilateral and multilateral programmes, is dedicated to climate governance alone. A majority of assistance is at the national level via support on NDCs, policy, legislation, institutions, capacity development, and climate information. Smaller volumes of assistance go to state and municipalities, though the amount is rising as recognition of their importance and influence rises. Technical assistance and short-term skill-shares and exchanges of expertise are the major types of assistance.

The effectiveness of donor assistance has suffered from project duplication and competition, poor appreciation of political economy, tendency towards short-term activities over long-term reforms, lack of country commitment, and assistance given from overseas rather than in-country with counterparts. As a consequence, much donor assistance has limited durable impact.

In regions with the largest mitigation potential, the UK has typically maintained moderate ties with most programmes of support focusing on ODA-funded technical assistance as well as support by the UK Parliament.

In recent years, the UK has offered varied channels of support to low-carbon governance in a majority of prioritised countries.

In terms of the ODA environment, the UK has relationships with Indonesia, Mexico, and countries in South America and Southeast Asia dating back to the 1960s. In the last two decades, Indonesia and South Africa have been the major recipients of UK ODA. BEIS has more recently undertaken Partnership for Accelerated Climate Transition initiatives in Colombia, Malaysia, and Mexico as well as South Africa, and BEIS has a Climate Partnership with Colombia. DFID has longstanding presence in Indonesia, in the forestry sector, and in Myanmar, more broadly. The UK as a whole has less ODA experience in other countries in South America and Southeast Asia. In addition to bilateral assistance the UK has financed partnerships, such as CDKN and the NDC Partnership, which have broad global coverage.

The UK Parliament has lent its expertise on climate law and policymaking to governments and parliaments globally. DFID support to organisations like Climate Parliament has similar ambitions.

The UK's additional value is high, resulting from the effectiveness and ambition of the UK's climate policy and institutional framework and its political influence.

- There is high potential for UK additionality given substantial UK experience in developing institutional, legal, and policy frameworks for climate change action, with the UK recognised as a world leader through, for example, the Climate Change Act including the establishment of the CCC , the subsequent legal commitment to net zero by 2050, and the (now-sold) Green Investment Bank.

The Climate Change Act passed in 2008 can act as a model for prioritised countries as a driver of political consensus and climate action. It has five key components: a long-term greenhouse gas (GHG) emissions target; five-year carbon budgets; continual adaptation planning; an independent advisory body (the CCC); and mandatory monitoring and accountability.1077

The CCC can be a model for an institution that helps to improve the technical basis for policy making and strengthen political buy-in and accountability for the implementation of climate change policies. It advises on policies and targets and monitors and reports on GHG emissions, with a mandate for mitigation and adaptation. Crucial qualities are its independence – including sufficient funding, the capacity to hold government to account, the ability to hold formal relationships with ministries and to engage stakeholders widely, data availability, and high quality of technical expertise.1078

The UK Green Investment Bank was the first of its kind in the world and demonstrated to other financial institutions, through the provision of expertise and investment, the potential for green investment at commercial rates, and raising commercial investment as a result.

The UK has political influence abroad via broad and proven diplomatic networks in all priority countries. The hosting of COP26 and leadership of the G7 in 2021 will prove useful channels of influence.

The UK Parliament has run deliberative democratic and participatory approaches in the form of Climate Change Citizens Assemblies, which generate understanding and consensus between varying groups as well as support for progressive and ambitious responses, including in the context of Covid-19.[1079][1080] They are a powerful means for creating a national political mandate for climate action by enabling all parts of society to contribute to climate action, encouraging debate and communication, and involving citizens in policy development, budgeting, and implementation.[1081]

[1077] Fankhauser et al. (2018a). 10 years of the UK Climate Change Act. *LSE*. https://www.lse.ac.uk/GranthamInstitute/wp-content/uploads/2018/03/10-Years-of-the-UK-Climate-Change-Act_Fankhauser-et-al.pdf
[1078] Fankhauser et al. (2018b). The role and influence of the UK's Committee on Climate Change. *LSE.* https://www.lse.ac.uk/GranthamInstitute/wp-content/uploads/2018/10/The-role-and-influence-of-the-UKs-Committee-on-Climate-Change_policy-brief.pdf
[1079] Willis, Rebecca. (2019). To tackle the climate crisis we need more democracy, not less. *The Conversation.* https://theconversation.com/to-tackle-the-climate-crisis-we-need-more-democracy-not-less-119265
[1080] Vaughan, Adam. (2020). UK's citizens' assembly shows big support for green covid-19 recovery. *New Scientist.*https://www.newscientist.com/article/2246693-uk-citizens-assembly-shows-big-support-for-green-covid-19-recovery/
[1081] Howarth, Candice. (2020). Society as a co-designer of climate action: Learning from COVID-19. *LSE*. https://www.lse.ac.uk/granthaminstitute/news/society-as-a-co-designer-of-climate-action-learning-from-covid-19/

Intervention opportunities

There is substantial opportunity across all regions for the UK to address identified barriers, overcome political economy constraints, improve and mainstream climate change within policy and institutional frameworks, and strengthen coordination between national and sub-national government and between government, business, and civil society. Interventions should be coordinated with those in the Greening of the Financial Sector, Fiscal Policy and Just Transition, and other sector opportunity reports.

Due to high levels of demand and the ability to focus on specific policy and institutional areas there is high potential to provide additional support despite a number of other actors in the space.

Most countries in the priority regions display moderate or above governance capacity and have moderate low-carbon governance policies and institutions in place, meaning that UK assistance is likely to result in swift impact. Some countries have less effective policies and institutions and less capacity, meaning that assistance will take longer to achieve substantial impact but the extent of reform and barriers overcome will be higher.

To be impactful, the UK should offer lasting support, for example over a five- to ten-year horizon, that a) will achieve durable reform rather than quick fixes, b) has the backing of government and stakeholders, c) enhances networks and communities of change, and d) transfers expertise to country institutions. In order to apply lessons from the UK's experience, a mapping of institutions, programmes, networks, and initiatives would aid other countries in understanding the UK's model.

In governance for low-carbon transitions the most critical barriers are:

Limited political leadership and will, driven by reliance on fossil fuels for revenue and by entrenched interests and state capture, manifested especially in post-Covid-19 economic stimulus packages.

The absence of comprehensive climate change laws or plans and of alignment between NDCs, framework laws, and sector laws and plans.

The lack of effective institutional frameworks, structures, and mandates for government collaboration and implementation of policies at national and sub-national levels.

In all regions, disjointed engagement with important stakeholders in finance, business associations, and civil society, e.g. NGOs and universities, that play vital roles nationally and sub-nationally in enhancing ambition, raising investment, improving the enabling environment, and generating knowledge and awareness.

UK interventions to address barriers rely on a combination of technical assistance and exchanges of expertise between the UK and priority country institutions. Building on the Paris Declaration on Aid Effectiveness, and the experience of other donors, effective technical assistance should be country-led, aim to support transformation, be flexible, provide opportunities for learning, and be sustainable.[1082] The experience of FCDO (formerly DFID) in delivering technical assistance, particularly in political complex or fragile environments, emphasises the importance of responding to government priorities and imperatives – both institutionally and personally, of understanding the political economy – notably around stakeholder interests and incentives, of reliable and trusting relationships, and of flexibility and iterative learning in delivering reforms.

In countries with comparatively stronger existing governance, such as Chile, Colombia, Mexico, the Philippines, and Vietnam, interventions could include the following:

[1082] Vivid Economics. (2017). Designing Technical Assistance Programmes: Guidelines for development practitioners. https://www.vivideconomics.com/wp-content/uploads/2019/08/171204-Principles-for-Technical-Assistance-1.pdf

Supporting the revision and strengthening of existing institutional frameworks, structures, and mandates across national and sub-national government, with a view to a) fulfilling governance practices of policy planning, implementation, and evaluation, b) clarifying processes and divisions of responsibilities between important ministries and with state and municipalities, including via the nomination of climate change focal points, c) ensuring effective information sharing, and d) resolving of gaps between intention and practice.

Establishing expert institutions to deliver technical, policy, regulatory, and scientific expertise in forms useful to policymakers and implementers nationally and sub-nationally, managing national emissions inventories, conducting MRV, and holding governments to account. Attention should be given to a) addressing adaptation as well as mitigation challenges and actions, b) managing political consensus and wider socio-economic consequences, i.e. ensuring a just transition, and c) building international communities of practice to spread knowledge and aid international ambition.

Establishing or strengthening climate finance strategies for channelling public finances to climate action by a) improving fiscal planning and predictability in the allocation of resources to low-carbon policies and programmes, b) boosting the budgets of national climate change funds, c) directing national development banks to focus on low-carbon investment, d) considering the establishment of dedicated green investment banks, and e) ensuring funds are available at sub-national as well as national levels.

In countries with comparatively weaker governance such as Indonesia, South Africa, and parts of South America and Southeast Asia, interventions could include the following.

Supporting comprehensive climate policy planning by a) the development of coordinated climate change strategies and laws, encompassing institutional mandates and frameworks, mitigation targets, emissions inventories, MRV, and links to SDGs, adaptation, and the just transition; b) long-term strategies in the form of stronger NDCs and commitments under the Paris Agreement aligned with national objectives; and c) clarity over the objectives and plans of states and municipalities.

In line with this, establishing national institutions, frameworks, and structures with consideration given to a) the fulfilment of key functions such as policy planning, implementation, and evaluation, b) their focus and influence within government, c) the direct involvement of ministries of finance and planning, d) systems of inter-ministerial coordination, including via ministerial climate change focal points, e) mandates of state and municipalities, and f) benefits of informal forums for dialogue and information exchange.

Establishing or strengthening climate finance strategies for channelling public finances to climate action by securing dedicated funding streams and budgetary codes for climate change action in the public financial system, requiring ministries to include climate-related activities and codes in their budgets, and potentially by forming national climate change funds.

In all countries, but particularly those, like Indonesia and South Africa, with complex political economies and lower political will, notably in the context of Covid-19, interventions could include the following.

Strengthening the platforms for engaging stakeholders in business, finance, and civil society engagement nationally and at state and municipal levels, and the access that stakeholders have to planning and decisions, thereby enabling effective participation and information sharing and building confidence and commitment beyond government. Existing platforms should be a starting point and new mechanisms deployed, e.g. informal dialogues to complement formal processes, neutral brokers between groups, and climate champions in and beyond government.

Advising and supporting states and municipalities to play greater roles in climate governance and action via a) promoting their participation in national policy, planning, implementation, and information sharing processes, b) increasing clarity over institutional mandates, budgets, and stakeholder engagement, particularly with the private sector, c) setting sub-national sector objectives and plans, and d) nominating climate champions.

In all countries, interventions could include the following.

Deploying UK diplomatic influence and COP26 planning networks to substantially raise the ambition of NDCs and international commitments and redirect post-Covid-19 stimuli from brown to green sectors.

Advising on preparing credible and long-term policies and regulations at the sector level – transport, energy, agriculture, forestry, and industry – to implement existing NDCs and national climate change policies by developing roadmaps, bringing together existing policies, addressing implementation gaps, and avoiding duplication, including at the sub-national level.

Supporting the forging of shared political narratives and raising awareness of climate change within national and sub-national government by offering continuous information, awareness-raising and training on climate change policy, institutional mandates, and budgets, the relationship with other sectors, and its impact on development, inclusion, and resilience.

Encouraging, and advising on, the launch and running of climate assemblies and other deliberative democratic and participatory approaches to offer opportunities for dialogue and debate, raise awareness of climate change and climate action, enable citizens to co-design climate policy, and establish a broad national consensus and narrative that all parts of society, including vulnerable groups classified by gender, race, ethnicity, and disability, can support. A representative portion of citizens should be encouraged to take part and approaches should seek the participation of government, business, finance, workers in different industries, unions, civil society, communities, and universities.

Communicating climate planning and policy and launch incentives for changing business and personal behaviours and social norms via raising understanding of climate change impacts and of the benefits of climate action, via government and business transparency, and via reputational measures.

Investing in a just transition encompassing participatory approaches, with a focus on representation of vulnerable groups' interests within decision-making during, and alongside, policies that address the potentially negative impacts of governance and economics changes and ensure that they benefit from new economic opportunities. It will be necessary to identify groups and sectors vulnerable to transition risks; to design and implement just transition programmes to empower workers and communities and give training and pathways to new careers; and to incorporate principals into broader low-carbon strategies at national and regional levels.

Box 38 Nigeria intended NDC (INDC) development and implementation, Nigeria, 2015-16

Nigeria's INDC was prepared for submission to the UN Framework Convention on Climate Change (UNFCCC) ahead of the 21st UN Climate Change Conference (COP21) in Paris in 2015 with support from the United Nations Development Programme (UNDP) and a small team of Nigerian and international advisers and members of the Nigerian Department of Climate Change in the Federal Ministry of Environment. The objective was to prepare a first INDC to meet UN requirements and to secure its implementation and attract investment from both government and the private sector. The draft INDC was submitted following endorsement by stakeholders and approved by the Federal Executive Council of Nigeria.

Subsequently, in order to support the INDC implementation, a DFID programme, the Nigeria Infrastructure Advisory Facility, was invited in 2015 by the Federal Ministry of Environment to provide advice to the Minister's office. UNDP also extended its support to the Department of Climate Change by funding the creation of a small NDC Support Programme Unit focused on NDC implementation and on engagement of the 36 states.

The Nigeria INDC was credited as an ambitious and transparent plan but the process had its weaknesses and challenges.

- It soon became clear that INDC implementation hinged on the sectoral ministries responsible for the five sectors that stood at the centre of the plan: agriculture, industry, oil and gas, power, and transport. Hence, UNDP decided to support five sectoral action plans to guide the implementation of the INDC.
- In the absence of comprehensive data, it had not been possible to prepare a costing of the INDC. Importantly, the government lacked the ability to track both domestic and international climate finance flows. It therefore proved difficult to mobilise NDC-aligned investment in a targeted manner. The advice to the government was to strengthen the monitoring system and collection of key data, to enable the 2020 NDC update to include such information.
- Following its decision to ratify the Paris Agreement, it became evident that Nigeria lacked the comprehensive legislation needed to guide the implementation of the INDC. Earlier efforts to introduce legislation had failed due to disagreements around the modalities for the creation of a national climate fund. The Inter-Ministerial Committee on Climate Change operated informally as it had no authority in law.

In response to these challenges the Nigeria Infrastructure Advisory Facility (NIAF)proceeded to provide support for the preparation of an NDC implementation and communications plan, built up the structures and processes of the Inter-Ministerial Climate Change Committee, advised the Minister of Environment's office and the chair of the House of Representatives Committee on Climate Change in drafting a new framework climate act, and provided a climate finance adviser to help attract climate finance. NIAF-supported draft legislation made its way through the National Assembly but was not fully adopted before the 2019 elections, which under Nigerian law means the legislation has failed and needs to be resubmitted.

Key lessons for BEIS include:

- Donors can make a significant difference in strengthening governance but there needs to be good communication and coordination among donors working in the same space, which in this example was not consistently the case.

- In the absence of political will and leadership by high-ranking officials, especially ministers, an inter-ministerial initiative such as NDC implementation will likely fail.
- Capacity building and longer-term technical assistance has proven to work, but it cannot make up for significant capacity weaknesses in national and sub-national government.
- Integration of government staff, local experts, and international consultants in task teams is effective and good value for money.
- Continuity sustainability needs to be built into technical assistance from the start, recognising that falling donor attention and funding around a policy priority diminishes domestic action.
- Donor support should cover the entire scope of an initiative from the start rather than expanding piecemeal over the course of project lifecycles.

Box 39 **Low Emissions Capacity Building (LECB) Project in the Philippines, 2012-2018**

The LECB Global programme emanated from the UNFCCC's call for developed national and international organisations to support developing countries in their programmes on climate change mitigation, in line with their national priorities. This global project is implemented by the EU and UNDP and is funded by the European Commission, Australian Government, and German Federal Ministry on Environment.

The Philippines is one of 15 Phase 1 countries participating in the LECB Global Programme. The Philippines programme ran for six years from 2012-2018 with a budget of USD 1,334,500. In 2011, the Philippines formulated its National Climate Change Action Plan to promote integration of climate adaptation and mitigation efforts. Systematic accounting and reporting of greenhouse gas emissions was recognised as a key strategy by the government towards achieving its sustainable development and mitigation goals. With increasing awareness and resolve to address climate change within the country's public and private sectors, the Philippines also sought to establish linkages for coordinated action.[1083]

The objectives of LECB were to:

- Implement ambitious low emission development strategies in the Philippines.
- Strengthen the Government of the Philippines' role in consolidating carbon emission data and acting as a coordinating body for low emission strategies across the economy.
- Strengthen the government's capacity to implement its national contributions within the Paris Agreement.[1084]

In pursuit of those objectives, the activities of the programme were as follows.

- To support the creation of necessary institutional arrangements for the national GHG inventory system and undertake a comprehensive capacity building programme, thereby ensuring that sectoral public agencies are well placed to lead the national GHG inventory process. Eighteen sectoral scoping meetings and engagement dialogues with key Ministries, two intensive training

[1084] UNDP. (2019). Low Emission Capacity Building Philippines Project. https://www.ndcs.undp.org/content/ndc-support-programme/en/home/impact-and-learning/library/lecb-programme-impact-and-results--philippines.html workshops on the national GHG inventory system engaging over 15 key staff members, and nine larger training sessions for national and sub-national Ministry representatives were conducted.[1085]

- To initiate business summits that became well-established platforms to engage business associations and private sector actors to help define the enabling environment to support low-emission goals.
- To develop the framework for the National Integrated Climate Change Database System (NICCDIES). This included extensive multi-sectoral stakeholder consultation while also ensuring compliance and harmonised data collection methods between the NICCDIES and REDD+ programme. Agreements were sought with data providers to promote long-term system sustainability.
- To coordinate the identification and prioritisation of mitigation actions in the agriculture, waste, transport, and energy sectors, with multi-party engagement. Multi-criteria decision analysis, developed by the project in cooperation with UNEP and its allied institutions such as the UNEP-Southeast Asia Network of Climate Change Offices (SEAN-CC) Partnership, was applied to evaluate and compare the socio-economic benefits of mitigation actions.

As a consequence, the results that the programme achieved were:

- One Presidential Executive Order was issued to institutionalise and streamline the national GHG inventory system. The project effectively leveraged synergies with on-going initiatives of other developmental partners such as USAID and GIZ, especially in training sessions conducted jointly to strengthen capacities of sectoral institutions on GHG inventory estimation, and use of the 2006 IPCC Guidelines, tools, and worksheets.
- The National Climate Change Database System, the NICCDIES, was developed and designed. It will underpin the government's MRV system for GHG inventory, mitigation actions, and climate finance.
- Development of the NDC Framework and Roadmap was completed.
- The national recognition awards programme and rating system was launched and implemented.
- The mitigation actions that were prioritised by the project were included in the Philippines' INDC.

The challenges that the project faced were:

- Climate adaptation was ranked higher on the Government's agenda as compared to mitigation, given the Philippines' vulnerability to climate change impacts, meaning the LECB Programme had to put in significant effort to fully engage ministries on climate mitigation.
- There was a concern that the elaboration of NAMAs would give further prioritisation to mitigation without attention to socio-economic benefits. The project design was thus adjusted to focus on the preparation of a mitigation strategy, which involved a holistic approach.[1086]

For BEIS the lessons from the programme in determining ICF investment are as follows.

- An integral part of MRV system design in the Philippines has been to agree upon business process design elements with other agencies. The process of agreeing upon this approach helped develop a more complete product, but also helps establish formal and informal networks and assists in gaining buy-in and support. The choice of MRV system design (e.g. decentralised, partially

[1085] UNDP. (2019).
[1086] Ibid.

centralised, centralised, etc.) should reflect national circumstances, but business process thinking is universally important.

- The development of enabling IT systems requires a significant investment in both time and resources. Careful consideration should be given prior to adopting this approach to ensure it matches the country's needs and capabilities.
- Although the project improved in terms of delays in the achievement of project outcomes, one future solution would be to set more realistic and practical timeframes to reduce the need for extensions, which have direct and indirect costs.
- Engagement with organisations, such as the Philippines Commission on Women or other agencies, institutions and/or individuals, to facilitate gender mainstreaming was lacking in the early stages of the programme. Gender and inclusion should be mainstreamed in each ICF intervention.

Glossary

Acronym / Term	Definition
BEIS	UK Department of Business, Energy and Industrial Strategy
CCC	UK's Committee on Climate Change
COP	Conference of the Parties
DFID	Department for International Development
ESKOM	South African electricity public utility
FCDO	Foreign, Commonwealth and Development Office
G7	Group of Seven major economies
GBP	Great British Pound
GHG	Greenhouse Gas
GIZ	German Agency for International Cooperation
HR	Human resources
ICF	International Climate Finance
INDC	Intended Nationally Determined Contribution
IPCC	Intergovernmental Panel on Climate Change
KPI	Key performance indicator
LECB Project	Philippines Low Emissions Capacity Building Project
MRV	Monitoring, reporting and verification
M&E	Monitoring and evaluation
NAMA	Nationally Appropriate Mitigation Action
NDC	Nationally Determined Contribution
NICCDIES	Philippines National Integrated Climate Change Database System
ODA	Official Development Assistance
OECD	Organisation for Economic Co-operation and Development
SDGs	Sustainable Development Goals
SEAN-CC	UNEP-Southeast Asia Network of Climate Change Offices Partnership
UN	United Nations
USAID	United States Agency for International Development

Climate Intelligence and Data

Summary

The climate intelligence and data opportunity considers interventions to provide the information and tools needed to inform and plan climate mitigation. Climate data and intelligence are crucial enablers of climate action – they are needed to inform public and private mitigation outcomes and can support transformative climate mitigation. This assessment of climate intelligence and data includes mitigation-supporting activities including actions to support the developing or improving of emissions inventories and models to identify priority areas, set targets, and create policy and technology pathways. It does so to help in identifying new opportunities and transition risks for targeted investment, through an economic and environmental profile that highlights risks and opportunities arising from a changing climate and the transition to a sustainable economy, and to disseminate new information regarding institutional and technological innovations and developments.

Interventions to support the uptake and use of climate intelligence and data include:

<u>Technical assistance to identify and address data gaps and assess current methodological approaches</u>, including the improvement and/or update of sectoral activity data and emission factors, development of, or guidance in, the selection of existing models and tools, and development of methodologies and user-friendly, dynamic tools to perform cost-benefit analyses of mitigation options.

<u>Capacity building support for the uptake and use of climate intelligence and data</u>, including promoting the implementation of climate services information systems, supporting the identification of required monitoring, reporting and verification (MRV) systems, and developing capacity building programmes to create permanent, autonomous, well-functioning, and articulated institutions.

Table 80 Climate intelligence & data assessment summary

Criteria	Assessment	Notes
Climate impact	Low	• Moderate mitigation potential in absolute terms, but lower relative to other opportunities considered in this assessment. • Support in this area is not sufficient to deliver mitigation on its own, but can enable it across a very wide range of regions and sectors, and is a crucial enabler of action for many other mitigation opportunities.
Development impact	Low	• Climate intelligence and data would be conducive to achieving numerous SDGs – including Decent work and economic growth, Industry, innovation and infrastructure, Sustainable Cities and Communities, 1Climate Action, and Partnership for the goals – through the provision of critical information for local actors to make informed, forward-looking decisions.
Investment need	Low	• Individual interventions can be relatively high cost for world-class intelligence and data, but aggregate investment needs across developing countries is low relative to other mitigation opportunities as limited infrastructure and capital spend is required. • Investment likely to vary substantially across regions due to high variability in current capacity, technical expertise, and needs.
Cost-effectiveness	Moderate	• Relatively lower mitigation outcomes but also relatively lower costs for individual interventions suggest overall moderate cost-effectiveness of intelligence and data interventions. • There are likely to be lags and intermediate steps between climate intelligence interventions and ultimate emissions reductions for some interventions, particularly for those informing government action, reducing the relative cost-effectiveness of these actions.

Criteria	Assessment	Notes
Barriers to adoption	Low	• Key political economy barriers include poor governance and limited commitment to climate intelligence generation. This is a widespread issue in target regions, which hinders the adoption of planning and assessment instruments. • Significant enabling environment barriers include insufficient public funds, lack of institutional capacities and data, infrequent monitoring, downstream infrastructure constraints, and lack of a climate change legal framework.
UK additionality	Moderate	• The UK has strengths and experience useful for certain areas of intelligence and data, especially developing robust and verified greenhouse gas (GHG) emissions inventories, and models for emissions projections and transition risk scenarios, using high-quality meteorological data and owned tools such as the UK 2050 Calculator and the UK carbon budgets MRV system. • Provision of support to, and strong partnerships with, world-leading institutions, economists, and climate scientists, such as the Met Office, the Network of Central Banks and Supervisors for Greening the Financial System (NGFS), the Nationally Determined Contribution (NDC) partnership, etc.; and through a number of high-profile climate intelligence and data programmes. The latter include the Sentinel Programme, Transition Pathways and Risk Analysis for Climate Change Mitigation and Adaptation Strategies (TRANSrisk), and INNOPATH, among others.

Source: Vivid Economics, ASI & Factor

Key lessons for supporting mitigation through climate intelligence and data:

Climate intelligence and data includes a wide range of potential interventions and can support activity across a variety of sectors, and indeed can be critical for effective action in many cases. A standalone assessment of mitigation impact therefore underestimates the wider and transformative impact from this opportunity area.

The UK's comparative advantage is likely to be most clear in supporting generation of high-quality technical inputs, such as emissions data and inventories and developing models for GHG emissions projections and transition risks pathways.

Previous interventions suggest that to be successful, interventions should engage a consolidated team of local actors within relevant government ministries and involve national academic institutions, to ensure the transfer of information from the beginning of the process.

Introduction to the opportunity

Role of the opportunity in decarbonisation of developing countries

Climate intelligence and data provide the information and tools needed to inform and plan climate mitigation – and are crucial enablers of climate action. Climate information refers to key baseline and projected climate data and to information on climate mitigation technologies, for example including GHG emissions inventories, GHG emissions sources, databases of available abatement technologies across sectors, energy and emissions performance benchmarks, and technology development. Climate intelligence refers to models, tools, and frameworks that use climate data to inform mitigation planning and action. This includes tools forecasting the impact of mitigation policies on emissions and economic and financial implications such as marginal abatement cost curves, and comparisons of countries' NDC targets and their relative ambition, modelling analysis of long-term emissions pathways under different policy scenarios, and greenhouse gas accounting methodologies and MRV approaches, among others.

Climate data and intelligence are needed to inform public and private mitigation outcomes and can support transformative climate mitigation. Climate intelligence can support transformative mitigation action by enabling effective long-term policy responses to the need to reduce emissions, particularly through providing information on emissions sources, future emissions scenarios, and emissions limits in line with climate change goals or targets. Carbon emissions data can help governments understand the magnitude of domestic emissions, their spatial and sectoral distribution, and the relationships between climate policies and (positive and negative) economic outcomes. This information can help policymakers assess the costs and benefits of different policy options to meet climate ambitions. There is also substantial uncertainty over the environmental effectiveness of technologies; the rates of technology development, and hence future costs; and the political, social, and economic consequences of those costs on the electorate or customers. This can impede both private sector investment and public sector policies to incentivise that investment. Climate intelligence and data can help reduce uncertainty and help accelerate private mitigation action.

Developing countries are subject to several international obligations to generate climate data and intelligence – but often face challenges in developing the full suite of tools and data needed. National GHG emissions inventories are part of a country's reporting obligations to the United Nations Framework Convention on Climate Change (UNFCCC) through the country's National Communications,[1087] while Article 13 of the Paris Agreement requires countries to establish robust national MRV systems that in turn will improve and guide their NDCs. Developing countries have made significant improvements in preparing GHG inventories. However, the availability of updated official activity data, national emission factors, procedures to fill data gaps, lack of technical knowledge, and non-standardised methodologies or data collection practices, are some of the constraints to developing robust and reliable GHG emissions inventories,[1088] especially in the agriculture and land use, land use change and forest (LULUCF) sectors.[1089] Non-Annex I countries[1090] prepare National Communications irregularly and infrequently, which makes it difficult to assess the progress of mitigation strategies. Additionally, many developing countries still estimate their sectoral GHG emissions based on the 1996 Intergovernmental Panel on Climate Change (IPCC) Guidelines, especially in the waste, agriculture, and LULUCF sectors despite the latest 2019 Refinement to the 2006 IPCC Guidelines providing an updated and sound scientific basis to support good practices for the continuous improvement of GHG inventories.[1091] For developing countries, the lack of robust MRV systems represents a

[1087] National Communications are formal updates of climate change risk and action from parties that have ratified the UNFCCC.
[1088] LECB. (2014).
[1089] FAO. (2015). Estimating Greenhouse Gas Emissions in Agriculture.
[1090] The UNFCCC divides countries into three main groups, according to differing national level climate change commitments. "Non-Annex 1 countries" are mostly developing countries, that are recognized by the Convention as being especially vulnerable to the adverse impacts of climate change. The group of Non-Annex 1 countries includes those with low-lying coastal areas and those prone to desertification and drought. Others (such as countries that rely heavily on incomes from fossil fuel production and commerce) are considered more vulnerable to the potential economic impacts of climate change response measures. The Convention emphasizes activities that seek to address the special needs and concerns of these vulnerable countries, such as investment, insurance and technology transfer.
[1091] IPCC. (2019).

technical, technological, and financial challenge, as countries make quantitative commitments to reduce their GHG emissions.

Scope considered in this assessment

This assessment of climate intelligence and data includes developing and sharing key climate information to inform public and private mitigation actions and to guide green investment. The scope of activities included in the analysis of this opportunity includes:

- **Developing or improving emissions inventories and models** to identify priority areas, set targets, and create policy and technology pathways.
- **Identifying new opportunities and transition risks for targeted investment**, through an economic and environmental profile that highlights risks and opportunities arising from climate change and the transition to a sustainable economy.
- **Disseminating new information regarding institutional and technological innovations and developments.**

This assessment prioritises regions that have already identified a need for support in developing climate intelligence and data or in broader capacity building and MRV, and where countries have mitigation potential and sufficient baseline government capacity to support rapid uptake of support. The level of commitment to developing or using climate intelligence is judged primarily by countries' NDCs inclusion of need to access information to deliver NDC commitments, measured through a categorical scoring from the DIE Climate Explorer database.[1092] This is supplemented by similar categorical scorings of NDC assessments of the need for capacity building to implement the NDC, and whether countries identify a plan or need to develop a monitoring and review system. The general policy environment is assessed using government effectiveness indicators, as a proxy for government likelihood of autonomous development of information. This exercise led to the prioritisation of the following regions:

- South America (excluding Brazil), henceforth 'South America'
- Central America and the Caribbean
- Mexico
- Southeast Asia (excluding Indonesia), henceforth 'Southeast Asia'
- Southern Africa (excluding South Africa), henceforth 'Southern Africa'

[1092] Climate Explorer database: Accessed via: https://climexp.knmi.nl/start.cgi

Climate impact

Mitigation potential and urgency

Across developing countries this opportunity is likely to offer moderate mitigation potential. Interventions within this opportunity do not deliver mitigation outcomes in themselves, but rather serve to motivate broader mitigation actions across countries or within sectors. Given its role in enabling and motivating action, the contribution of individual interventions towards final mitigation outcomes is likely to vary substantially across different regions and across different types of interventions. The impact of the same type of intervention may vary substantially across countries, in some places being key to driving mitigation and in others having less impact, depending partially on the level of readiness and capacity to use climate intelligence and data across countries.

Climate intelligence and data alone is not sufficient to deliver mitigation, but can support it across a very wide range of regions and sectors. The climate impact of this opportunity is indirect insofar as it relies on institutions and actors to use this intelligence to create new regulations and policies or undertake private action. Interventions can support mitigation activity across the whole economy and all climate mitigation sectors. On their own, climate intelligence and data are critical starting points but unlikely to deliver deep mitigation outcomes themselves within sectors – they, rather, allow informed decision-making as to where and how to deliver these deep mitigation outcomes. As such, these interventions are likely to be highly effective at delivering crucial intermediate outputs, as the data can be provided directly by interventions with limited time lags or intermediate steps. Climate intelligence and data tools can support mitigation action in a number of key ways:

- **Data collection tools that ensure a robust baseline.** GHG inventories collect quantifiable data from measurements and reports as well as for verification of reports and trends. Inventories' results can serve as baseline information to identify mitigation potentials in a specific region and sector, track progress towards mitigation goals, and create new regulations and policies. These types of tools therefore have indirect low to moderate mitigation potential. The development of country-specific emission factors, as well as updating processes to reflect the latest IPCC guidelines, helps to set and achieve realistic mitigation targets, focusing on emission sources with greater mitigation potential. Open source climate data and analytical platforms can provide regions with the capacity to directly measure the impacts of their policy and planning decisions and to develop a semi-autonomous system for building, maintaining, and reporting their annual GHG emissions.[1093]

Planning tools to support public sector transition planning. More information can support better allocation of resources for the most effective and efficient reductions in emissions. It can enable countries to follow measures that are adapted to their circumstances rather than following world trends. Information can also help proactively answer issues arising from climate change before they become larger ones that are harder to treat. For example, providing a government with tools to monitor deforestation in real-time can potentially enable them to act more quickly before deforestation of a large area has occurred and people have settled on the land. Tools to measure and evaluate policies enable governments to make better informed decisions and learn what works and what doesn't for future policies. Key areas for action include developing climate intelligence tools to inform long-term emissions strategies and required economy-wide climate action, and to allow policy makers to develop policy and technology pathways. Models that project GHG emissions under a Business-as-Usual (BAU) scenario and different mitigation ones are essential tools as they provide insight of emissions trends, help to identify and prioritise emission measures, and set the basis for sectoral decarbonisation roadmaps.

[1093] Global Climate Change Alliance Plus Initiative, 2014. LECB Programme factsheet: measuring, reporting and verification(MRV). Accessed via: https://www.gcca.eu/sites/default/files/2020-01/2014%2C%20LECB_Fact%20Sheet_MRV.pdf

Policy and regulatory risk information to support private sector transition actions. Key areas for action include developing and sharing intelligence on the mitigation-related risks and opportunities that arise from climate transitions, developing intelligence on low-carbon technological development and deployment needs and opportunities, providing climate transition risk assessment intelligence, and generating and sharing intelligence on mitigation investment pipelines and investment benchmarking to support green investments. In this sense, the European Green Deal[1094] can be highlighted as a climate financing tool that consists of different milestones focused on fair transition mechanisms, climate neutrality in the EU, an action plan for the circular economy, and a biodiversity strategy, etc.

Within the target regions considered in this assessment South America is likely to provide particularly large mitigation opportunities. Regional mitigation potential is assessed for regions, based on overall emissions trajectories, to indicate the potential for climate intelligence and data to support action to reduce emissions; on needs for development of informational systems and information gaps as identified in key national planning documents (NDCs and other plans or strategies); and on the presence of sufficiently high quality enabling environments to support the uptake of intelligence and data outputs. Each region's relative mitigation potential is assessed as a high, medium, or low priority within the set of top five prioritised regions – noting that all five regions have been identified as having particularly high mitigation potential in absolute terms. South America has high emissions reduction potential based on high assessed need for additional information to realise NDCs, sufficient government capacity but limited previous investment in informational systems and capacity to use climate data, and high expected business-as-usual emissions. Southern Africa, Southeast Asia, and Central America and the Caribbean all offer moderate emissions reduction potential – due to high need and good potential to improve government capacity – but reveal certain limitations. These are: relatively lower baseline emissions in Southern Africa; high informational needs, but higher existing capacity in Southeast Asia; and variable needs and high emissions reduction potential in Central America and the Caribbean. Mexico offers lower relative emissions reduction potential, based on high self-assessed informational needs, but a relatively lower support requirement and more moderate emission reduction potential compared to other priority regions.

Table 81 Summary of mitigation potential in key regions

Region	Mitigation potential	Notes
Central America and the Caribbean	Medium	Consistent but variable need for information access, capacity building, monitoring and evaluation (M&E) support. Moderate existing general government effectiveness and regulatory quality. High emissions suggest potentially high impact.
Mexico	Low	High self-assessed information access needs. Moderate government effectiveness but high regulatory quality suggests good potential to advance activities through targeted support. Moderate projected total emissions suggests potentially moderate impact of activities.
South America	High	High assessed need for additional information to implement NDCs. Sufficient government effectiveness and regulatory quality, but limited focus thus far on capacity building and M&E suggests good potential for additionality of impact. High total and per capita emissions suggest high impact of activities.
Southeast Asia	Medium	High projected information assessment and monitoring need. Good existing general government effectiveness and regulatory quality. High projected emissions suggest high impact of activities.

[1094] European Green Deal, 2019. Accessed via: https://ec.europa.eu/info/sites/info/files/european-green-deal-communication_en.pdf

Region	Mitigation potential	Notes
Southern Africa	Medium	Highest need for information to deliver NDCs. Poor-to-moderate government effectiveness and regulatory quality suggest good potential for additionality if assistance is well targeted. Relatively lower total and per capita emissions but high projected population growth.

Source: Vivid Economics, ASI and Factor

Transformational change

Transformational change involves actions that themselves catalyse further change, leading to broader, faster, or more ambitious climate action. Interventions may deliver transformational change in several ways:

They may target sensitive interventions points to encourage further changes in socioeconomic/ technological/ political systems to advance climate change mitigation by improving the enabling environment.

They may create spillovers that increasing efficiency of the overall system, either nationally or globally, and so increase the speed or depth of mitigation action.

They may support innovation in new or improved ideas/methods/products that reduce costs or increase mitigation impact within opportunity areas.

In this sense, GHG inventories and modelling of emission trends, mitigation, and transition risk scenarios based on socioeconomic and political pathways are supporting tools to target green investments and enable decarbonisation of the main emitting sectors, generating medium- and long-term wins. Additionally, adequate institutional arrangements and the consolidation of a specialised local team of consultants within the ministries facilitates inter-institutional collaboration for data management and centralisation and ensure long-term information transfer. Thus, national capacity building shows a strong potential to overcome poor coordination between public institutions and avoid work being duplicated.

Table 82 below assesses the potential for interventions within the Climate intelligence and data opportunity to support transformational change, within these themes.

Table 82 Assessment of transformational change

Transformational change criterion	Interventions to support change	Regional potential
Sensitive intervention points		
Improvement of local capacities and capabilities	Access to intelligence and data can enhance understanding of strengths, weaknesses, and capacity requirements at all political levels.	All regions
Local ownership and strong political will	Embedded use of intelligence and data can provide crucial support in the elaboration of long-term national economic development plans, NDC development and target setting, supporting greater ownership.	All regions
Leverage / creation of incentives for others to act	Data can support the decision-making process to green the economy and implement sectoral mitigation and adaptation actions, creating new incentives for others.	All regions

Transformational change criterion	Interventions to support change	Regional potential
Spillovers		
Broad scale and reach of impacts	No potential to support this criterion identified.	No potential to support this criterion identified.
Sustainability (continuation beyond initial support)	The development of local technical capacities and data management systems supports the continuity of implemented actions.	All regions
Replicability by other organisations or actors	Sharing intelligence on successful intervention opportunities can support their replication in sub-sectors and regions.	All regions
Innovation		
Catalyst for innovation	Supports innovation directly in the development of models, methodologies, open source platforms and data management systems, and also provides a foundation for future innovation.	All regions
Evidence of effectiveness is shared publicly	No potential to support this criterion identified.	No potential to support this criterion identified.

Source: Vivid Economics, ASI and Factor

Development impact

SDG impacts

Sharing of new intelligence could provide critical information for local actors and their ability to make informed, forward-looking decisions, creating moderate to high development impacts. Robust GHG inventories and models that project emission trends directly or indirectly help achieve the SDGs under Agenda 2030, depending on the prioritised emitting sectors in a specific region. In general terms, the Climate intelligence and data opportunity is linked to the following SDGs.

Table 83 SDG impacts

SDG	Strength	Most relevant region	Rationale
Positive Impacts			
SDG 8 - Decent Work and Economic Growth	Medium	All regions	It is an important component part of being able to evaluate strategic options to decouple GHG emissions from economic growth and to make informed investments in industries and infrastructure, by the identification and quantification of transition risks associated with different mitigation and adaptation options, thus ensuring cost-efficient informed decision-making, benefiting long-term development prospects.
SDG 9 - Industry, innovation, and infrastructure	Medium	All regions	Promote industrial diversification and guide investments to encourage innovation and technology development that help achieve mitigation targets. Climate services information systems provide exceptional knowledge for risk assessment to guide investment in the country's infrastructure and industries that are less vulnerable to transition risks.
SDG 11 - Sustainable cities and communities	Medium	All regions, especially Mexico, Southern Africa and Southeast Asia (high annual mean concentration of air pollutants)	Better information and data would enable spatial urban planning and smart city design, improving citizens' quality of life. Reducing cities' GHG emissions has a direct impact on air pollution and therefore human health.
SDG 13 - Climate Action	High	All regions	More accurate GHG inventories, emissions trends, and climate risks analysis guide decision making towards climate change national strategies. Climate change adaptation is a major co-benefit within this opportunity – climate services information systems combining satellite data with meteorological information and other climate data may constitute the basis to design early warning systems, perform risk assessments, and anticipate the effects of climate change, and guide climate-resilience investment in key economic infrastructure (roads, bridges, dams, etc.)

SDG	Strength	Most relevant region	Rationale
SDG 17 - Partnership for the goals	Medium	All regions	Cooperation agreements aiming to improve climate intelligence and data enable access to science, technology, and innovation.
Negative Impact			
No negative impacts on SDGs were identified.			

Source: Vivid Economics, ASI and Factor

Demand in target regions

Although Non-Annex I countries report their GHG emissions and trends to the UNFCCC in their NCs and Biennial Update Reports (BURs), a significant level of demand for climate intelligence and data remains. This is due to the substantial need to improve emissions estimations in the reference and future scenarios in order to identify transition risk scenarios and evaluate their impact on business and discern potential responses. Since decision-making should be built upon a complexity of heterogeneous data sources, like meteorological data, satellite images, and land cover or usage information, all kinds of different data sources and appropriate archives need to be inter-operable for information generation to underpin decisions. In general terms, several countries need an appropriate climate change legal framework and better access to climate data to deliver their NDC commitments.[1095]

In addition, there is a widespread need to refine GHG emission projections that provide a better sense of where countries are heading and track the efforts of their current administrations. This could be particularly important and timely given that the economic upheaval associated with the COVID-19 pandemic is likely to alter worldwide socio-economic activity and patterns (and could change countries' priorities vis-à-vis climate change mitigation and adaptation actions). Moreover, reduced economic activity will likely lead to GHG emission reductions in the short term. The demand for climate intelligence and data in target regions is set out in Table 84 below.

[1095] Samaniego et al. 2019. "Panorama de las contribuciones determinadas a nivel nacional en América Latina y el Caribe, 2019: avances para el cumplimiento del Acuerdo de París", Santiago, Comisión Económica para América Latina y el Caribe (CEPAL).

Table 84 Demand in target regions

Region	Demand	Rationale
Central America and the Caribbean	Moderate	Several countries show strong commitment through their NDCs and legal frameworks. However, there is a widespread lack of updated GHG inventories and MRV systems.
Mexico	Low	Mexico has historically been a leading country in the region regarding action and legal measures on climate change, but it faces issues around government effectiveness and therefore there is a lack of access to information. Demand may be further suppressed by current national political priorities.
South America	Moderate	Several countries show strong commitment through their NDCs and legal framework. However, there is a lack of updated GHG inventories and MRV systems.
Southeast Asia	High	A strong demand for information evaluation and monitoring.
Southern Africa	Moderate	Demand for improved information to deliver on NDC commitments, but poor government effectiveness. Climate change legal frameworks are mainly focused on adaptation, potentially limiting demand for mitigation intelligence and data.

Source: Vivid Economics, ASI and Factor

Across the two priority regions of South America and Central America and the Caribbean, thirty-two countries have submitted their NDCs and are in the process of revising them in advance of the 26th Conference of the Parties (COP26), and sixteen countries committed to reduce GHG emissions in relation to a BAU projected path.[1095] Additionally, twenty-five countries have an institutional climate change framework, including laws, draft legislation, national policies, and strategies. Guatemala, Honduras, and Peru have included institutional arrangements in their legal frameworks to address NDC compliance. Argentina has also developed climate change policies at a regional level.

Chile takes the lead in the region regarding its climate change commitments and actions. The country has developed a framework that guarantees the use of common MRV approaches for appropriate mitigation actions at the national level and, through its National Climate Change Action Plan 2017-2022, it has defined measures to strengthen institutional capacities, and established a monitoring and reporting system for its NDC and to analyse GHG emission projections.

Uruguay, Paraguay, Colombia, and Peru have also demonstrated strong levels of commitment through their institutional arrangements and NDC commitments. In this context, it should be noted that Colombia has developed the Colombian Low Carbon Development Strategy (CLCDS) whose main objectives include the proper implementation of the country's NDC and the strengthening of the capacity of government officials and the private sector. Almost all countries in the region have estimated their latest GHG inventories (or are in the process of updating them) based on 2006 IPCC Guidelines, except for Bolivia,[1096] Peru,[1097] and Ecuador, which according to their latest National Communications still use the 1996 IPCC Guidelines.

Mexico was one of the world's first countries to set a National Climate Change Law (and the first in a developing country), and aims to turn its international commitments into national obligations.[1098] GHG inventorying and reporting is addressed in Article 4 of the General Law on climate change (originally passed in 2012; later updated in 2018 to include NDC targets). However, its outstanding climate data collection and

[1096] Bolivia's first and only National Communication was submitted to the UNFCCC in 2009.
[1097] For the waste, agriculture, and LULUCF sectors.
[1098] Climate Scorecard. 2019. "Mexico Has an Outstanding Climate Data Collection and Reporting System, but It is Not Being Used Effectively by Policy-Makers" Accessed via: https://www.climatescorecard.org/2019/06/mexico-has-an-outstanding-climate-data-collection-and-reporting-system-but-it-is-not-being-used-effectively-by-policy-makers/

reporting system, is not being effectively used by policy makers. Mexico's current administration has not yet developed, nor announced the development of, a third Special Program on Climate Change (PECC), required in the national strategy, meaning that the country has currently no short-term action plan for climate change mitigation.[1099] In addition, Mexico's intended nationally determined contribution (INDC) stresses the importance of consolidating platforms for the exchange of knowledge and information related to adaptation but makes no mention of mitigation. The country committed to reduce GHG emissions in relation to a projected BAU development path. For its latest GHG inventory, Mexico used the 2006 IPCC Guidelines, thus exceeding, as other countries in the region, the reporting requirements for Non-Annex I countries.

In Southeast Asia, all countries have submitted their NDCs, except for the Philippines and Brunei.[1100] In addition, all countries, except Brunei, have Climate Change related laws and policies in place. The depth of these frameworks ranges significantly at the country level. However, according to the Sustainable Development report 2020, government strategies and policy actions in Vietnam are critically insufficient to hold global warming below 2°C.

The Philippines is one the six countries worldwide that have made sufficient commitments and efforts to hold global warming well below 2°C[1101] and is the only country in the region that has institutionalised its GHG Inventory Management and Reporting System.[1102]

In Vietnam, emissions from industrial processes have not been included in the country's NDC target, even though they represent 13% of its 2014 emissions (excluding LULUCF). However, the country shows a strong commitment to improving its emissions estimation in the energy sector and is in the process of estimating the costs and benefits of mitigation actions.[1103]

Myanmar's NDC identifies financial support in the development and implementation of other sectoral, and eventually national, MRV systems for monitoring of actions, producing GHG emissions inventories, quantifying development co-benefits, and accounting for funds received.

Thailand has used previously existing structures as a basis for the operationalisation of an MRV system. In this sense, Thailand is in the process of establishing an MRV system for national climate reporting. The Office of Natural Resources and Environmental Policy and Planning (ONEP), under the Ministry of Natural Resources and Environment (MNRE), is leading this task, together with key sectoral ministries and agencies, with support from the German Agency for International Cooperation (GIZ). For more information on this practice, please refer to Section 0 of this report. In the same vein, Vietnam is currently receiving support to establish an MRV portal which serves as a systematic tool for knowledge management and data sharing.[1104]

In Southern Africa all countries, except Angola, have climate change-related policies, strategies, and action plans. However, African countries have attached far-reaching policy importance to adaptation, and the common position on mitigation includes reducing emissions from deforestation and forest degradation and implementing approaches to enhance the cost-effectiveness of, and to promote, mitigation actions. All countries have submitted their NDCs, with the exception of Angola, which submitted its INDC in 2015. In addition, Angola only submitted its first National Communication in 2010, reporting GHG emissions for the

---

1099 Climate Action Tracker, 2019. Mexico. Accessed via: https://climateactiontracker.org/countries/mexico/2019-12-02/

1100 UNFCCC. 2020. "Communication by Parties relating to their NDC". Accessed via: https://unfccc.int/process/the-paris-agreement/nationally-determined-contributions/party-declarations-on-ndcs

1101 Sachs et al. 2020. The Sustainable Development Goals and COVID-19. Sustainable Development Report 2020. Cambridge: Cambridge University Press. Accessed via: https://s3.amazonaws.com/sustainabledevelopment.report/2020/2020_sustainable_development_report.pdf

1102 The Climate Change legal framework by country in target regions was consulted in the *Climate Change Laws of the World* website: Accessed via: https://climate-laws.org/

1103 Vietnam has requested technical assistance to the Climate Technology Center and network to "Develop guidelines for audit and calculation of the emission factors (EF) of fossil fuel thermal power plants to enhance the quality of GHG inventory activities in the energy sector" and for the "Development of an interactive and dynamic tool to calculate cost and benefits of mitigation actions in rice sector".

1104 GIZ. 2017. "Analysis of MRV and accounting systems of Annex I and Non-Annex I countries: Good practices and lessons learned". Accessed via: https://www.gcca.eu/sites/default/files/2019-12/Good%20Practices%20transparency%20partnership.pdf years 2000 and 2005, and has not submitted its first BUR.[1105] Its National Communication reflects a clear need to improve climate data in all emission sectors and the methodological approach used to estimate the country's GHG emissions is unclear. The currently used methodological approach to estimating GHG emissions is based on 2006 IPCC Guidelines in Botswana, Malawi, and Namibia; on 1996 IPCC Guidelines in Angola, Lesotho, and Mozambique; and depending on the emission source, Swaziland, Zambia, and Zimbabwe use a combination of both Guidelines. Even if Non-Annex I countries are not obliged to calculate emissions based on 2006 IPCC Guidelines, these provide an updated and sound scientific basis to support good practices for the continuous improvement of GHG inventories.

[1105] Non-Annex I Parties, consistent with their capabilities and the level of support provided for reporting, should submit their first BUR by December 2014, and every two years thereafter. The least developed country Parties and small island developing States may submit BURs at their own discretion.

Investment need

While demand for climate intelligence and data is high, the total scale of investment needed is likely to be moderate. Despite substantial demand and need for support, the cost of support for any individual climate intelligence and data activity, or for any individual country, is likely to be substantially lower than technical or capital investment interventions, given the focus on technical outputs and capacity building and technical assistance activities to use climate intelligence and data. The scale of investment required to develop climate intelligence and data systems is likely to be moderate and includes the costs of mobilising specialised external consultants, building internal support teams, programme design and implementation, inventorying and modelling software, staff training and capacity building, server design and set-up, public engagement activities, and verification from third parties.[1106] One example of recent UK Government spending on programmes focused on Climate Intelligence and Data interventions is the GBP 2 million allocated for 2050 Energy Calculators and to help the NDC partnership both to create an online database that allows countries to navigate existing initiatives and to signpost users towards its support programmes. Another is the GBP 10 million for the Climate Development for Africa Programme, an innovative climate information service. More generally, investments to produce national GHG inventories in developed countries are similarly on the order of millions of pounds sterling. Nonetheless, investment costs are likely to differ substantially across activities and countries depending on levels of focus and specific needs:

- The development or improvement of GHG inventories and models is relatively resource-intensive and the cost will vary depending on the level (junior, senior, etc.) of the staff involved, and the software and models used, among other factors. For example, creating spaces to disseminate and exchange knowledge, as well as data identification, gathering, organisation, and systematisation, are both time-consuming and low cost, whereas the development of country-specific emission factors, sectoral projection models, and decarbonisation pathways are likely to require more resources as more technical and scientific knowledge is essential.

- The prioritisation of policies and programmes to foster climate action is also a time-consuming process which requires the consideration of the political, social, and cultural context, as well as the cost-effectiveness of measures, co-benefits, technical feasibility, funding sources, and institutional barriers. The investment in this case is related to working meetings, workshops, travel, and communication material.

- Funding amounts to implement big data information systems vary depending on technological availability and specific knowledge in the recipient country. Whereas server rent and acquisition of computers and low resolution satellite images require minimum investments, qualified manpower and acquisition of high resolution satellite data require higher resources.

Within the target regions considered in this assessment, Southeast Asia and Southern Africa are likely to face relatively higher investment gaps. Regional investment gaps are assessed based on anticipated investment needs, set against a qualitative expert assessment of likely availability of existing domestic and international support to meet identified needs through the data reported by individual countries. Each region's relative investment gap is assessed as a high, medium, or low priority within the set of top five prioritised regions. Southeast Asia and Southern Africa have the greatest investment needs. This results from the projected significant need for information assessment and monitoring systems, and a substantial need to increase the degree of sophistication in key national planning documents across a number of countries in Southeast Asia. The substantial level of investment required in Southern Africa results from the high need for information to deliver NDCs, to improve the current methodologies used, to improve the information assessment and monitoring systems used, and the substantial need to increase the degree of sophistication in key national planning documents in Southern African countries. In this sense, these investments are needed to meet the need for information for the delivery of NDCs and to improve the quality of existing approaches. South

---

[1106] Strategic Energy Innovations. 2009. "Conducting a Municipal Greenhouse gas emission inventory: a practical guide". Accessed via: https://www.ca-ilg.org/sites/main/files/file-attachments/Municipal_GHG_Inventory_Guidebook.pdf

America faces moderate investment need, based on a high assessed need for the development of information, coupled with a good general capacity but a need to develop specific investments in informational tools and the systems to use them. Mexico and Central America and the Caribbean present the lowest levels of relative investment need. Mexico identifies needs for investments in supporting data and intelligence but already benefits from relatively well developed national systems and international support, while Central America and the Caribbean faces varied investment needs that are likely to be lower overall than other priority regions.

Table 85 Summary of investment need in key regions

Region	Investment need	Notes
Central America and the Caribbean	Low	Consistent but variable need for information access, capacity building, M&E support, including moderate demand based on national commitments and legal frameworks. Moderate existing general government effectiveness and regulatory quality and some existing good commitments to, and investments in, information systems.
Mexico	Low	High self-assessed information access needs and strong potential investment need to fulfil legal requirements, but currently limited national demand due to political constraints. However, relatively more developed informational systems and support – despite low update within policy-making processes.
South America	Medium	High assessed need for additional information to implement NDCs, and good demonstrations of commitment within NDCs and national plans. Enough general government effectiveness and regulatory quality, but limited focus thus far on capacity building and M&E.
Southeast Asia	High	High projected information assessment and monitoring need, and high demand across countries, in particular for monitoring and evaluation support. Substantial need to increase sophistication in key national planning documents across a number of countries.
Southern Africa	High	High demand among need for information to deliver NDCs. Lower quality of existing approaches suggests substantial need for investment and support activities – though a focus on climate change adaptation may limit immediate uptake.

Source: Vivid Economics, ASI and Factor

Cost-effectiveness

Supporting climate intelligence and data is likely to offer moderate overall cost-effectiveness. Climate policies, green investments, and other mitigation activities are not possible without sufficient intelligence and data. It is theoretically challenging to assess the cost-effectiveness of interventions that do not deliver mitigation outcomes in themselves, but rather support an enabling environment that promotes and accelerates other mitigation activities. Within traditional 'marginal abatement cost curve' assessments, enabling environment factors have been viewed as a pre-requisite for effective least-cost mitigation investment approaches.[1107] Climate intelligence and data that support broad action and help inform the development of an effective enabling environment may therefore be considered highly cost-effective, given that they can enable mitigation across a range of mitigation sectors. Additionally, individual interventions to develop climate intelligence and data are likely to be lower cost than capital investment interventions.

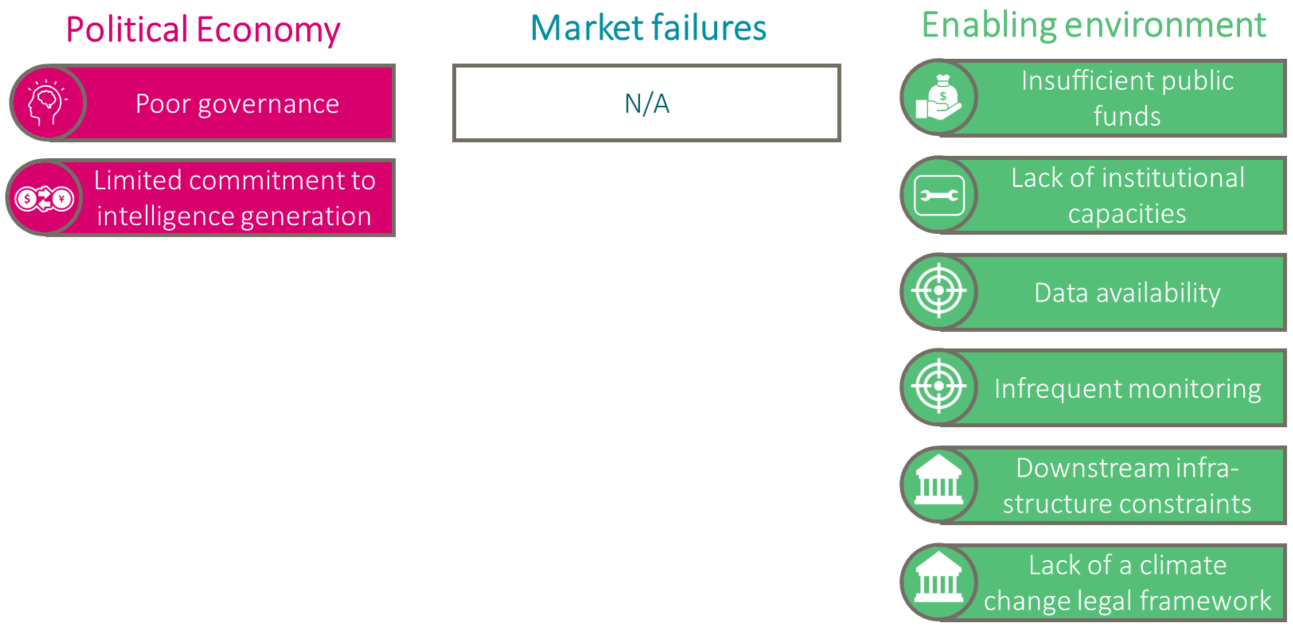
However, there are likely to be substantial lags and intermediate steps between climate intelligence interventions and ultimate emissions reductions, particularly for interventions informing government action. Climate intelligence and data interventions that inform subsequent governance interventions or public sector actions are likely to have long time lags or multiple intermediate steps or actors between governance support and ultimate mitigation action, suggesting lower overall effectiveness of interventions compared to interventions supporting direct action.

[1107] For example, see IMF. (2011). Mobilizing Climate Finance: A Paper prepared at the request of G20 Finance Ministers

Barriers to adoption

Barriers to the provision of climate intelligence and data relate to i) political economy challenges and ii) the enabling environment. These barriers, even if considered critical, are not expected to inhibit investment, as regional prioritisation for climate intelligence and data is judged primarily by a country's inclusion in their NDC of the need to access information to deliver the commitments it contains'. No market failures barriers were identified.

Figure 52 Barriers to adoption



Source: Vivid Economics, ASI and Factor

Political economy

Poor governance. Due to its multiple interactions and its cross-cutting nature, climate change requires the modernisation of governance and the adaptation of regulatory and institutional frameworks to generate changes, opportunities and solutions.[1095] In general terms, excessive bureaucracy in the operation of public administrations, lack of institutional arrangements, lack of transparency, corruption, and weak coordination among public institutions reduce incentives for integration and cooperation between government bodies across many countries, which in turn leads to data decentralisation and poor management and promotion of actions related to climate data and monitoring systems. Based on government effectiveness index rankings,[1108] and worldwide governance indicators (including political stability, regulatory quality, and control of corruption),[1109] poor governance is likely to be a critical barrier in many countries within the priority regions.

Limited commitment to climate intelligence generation. In many countries, key climate data such as national GHG inventories and models are perceived as a component of the obligations to the UNFCCC, and are not considered as a decision making tool that helps to track progress of the emissions reduction targets and to formulate realistic mitigation actions in order to identify new opportunities and transition risks for targeted investment. In the UNFCCC framework, Non-Annex I parties are not obliged to estimate and report GHG emissions following the latest IPCC Guidelines

[1108] Southern Africa ranked 2 and Mexico and Central America and the Caribbean ranked 3 in the government effectiveness index, 1 meaning highest priority and 5 meaning lowest priority for the indicator.
[1109] Worldwide Governance Indicators. 2020. Accessed via: https://info.worldbank.org/governance/wgi/Home/Reports

and may be reluctant to do so since it requires technical or scientific capabilities and additional financial resources. This is a moderate barrier that hinders both the adoption of a climate change legal framework (including planning and assessment instruments) and the allocation of internal financial resources to generate or improve climate data.

<u>Enabling environment</u>

Insufficient public funds. This limits governments' capacities to implement sufficient and sustainable data management systems for national GHG inventories and impedes the continuity of climate action based on real country needs. Budgetary constraints are critical in low-income countries, such as Honduras, Myanmar, Lesotho, Malawi, Mozambique, Zambia, and Zimbabwe, and are also particularly important in the Philippines and Vietnam,[1110] where funding for data collection activities or GHG emissions research in the agricultural sector is considered a practical difficulty. In Colombia, sustainability of funding for inventorying agencies (and related to the inventorying of certain GHG emitting sectors) is also a great challenge.[1111]

Lack of institutional capacities. The insufficient allocation of human resources to carry out climate intelligence gathering and data generation, and the associated lack of technical capabilities, are relevant barriers that obstruct governments' ability to produce the intelligence and data needed to guide mitigation decisions.

Several countries in the targeted regions do not have independent environmental councils or government advisory bodies like the UK's Committee on Climate Change (CCC), to conduct independent analysis on climate change science and data, and to monitor progress of reduction targets (except for Mexico, Costa Rica, and Guatemala).[1112] Additionally, structural and political changes lead to unstable national institutions, where teams in charge of GHG inventories and models are temporary and rely on external consultants who provide specialised assistance only during limited time periods. In this regard, most developing countries face major challenges to retain internal capacities and the expertise developed during the preparation of previous GHG inventories and models.

This is a critical barrier in Southern Africa,[1113] and a moderate barrier in some countries of South America and Southeast Asia. Technical and financial assistance is needed to improve the quality (availability, accuracy, and reliability) of sectoral data by establishing systematic data collection mechanisms, conducting field studies, the validation of emission factors, and conducting more surveys in order to reduce uncertainty in activity data.[1114]

Availability of sectoral data. Lack of sector-level data and default emission factors at a national level, particularly in the agricultural sector, is a widespread critical barrier to generation of climate data and tools across all priority regions. In addition, the collection, systematisation, and monitoring of emissions data from official sources is a complex and time-consuming process, which requires long-term inter-institutional coordination. Special attention should be given to countries whose NDCs identify a clear need for support for information access to deliver their commitments, especially countries in Southern Africa and Southeast Asia. This barrier also includes information gaps and lack of data in financial institutions and other private stakeholders, which are required in order to support

[1110] Wilkes et al. 2017. "Medición, reporte y verificación de las emisiones de GEI de la ganadería de países en desarrollo de la UNFCCC: prácticas actuales y oportunidades de mejora". Accessed via: https://globalresearchalliance.org/wp-content/uploads/2018/06/Medicio%CC%81n-reporte-y-verificacio%CC%81n-de-las-emisiones-de-GEI-de-la-ganaderi%CC%81a-de-pai%CC%81ses-en-desarrollo-de-la-UNFCCC-pra%CC%81cticas-actuales-y-oportunidades-de-mejora-2018.pdf
[1111] See note 1110.
[1112] Weaver et al. 2019. "The Finnish Climate Change Panel Report: Overview of National Climate Change Advisory Councils". Accessed via: https://www.ilmastopaneeli.fi/wp-content/uploads/2019/05/Overview-of-national-CCCs.pdf
[1113] For example, in Angola, the state of conflict lived until 2002 caused deficiencies in the structural organisation of most institutions, making it hard to obtain concrete data and information necessary for the preparation of the first National Communication which includes GHG emissions and trends. This difficulty was combined with lack of human resources capable of dealing with the issue of climate change.
[1114] See note 1110.

the assessment of climate risks and transition pathways that support green investments. Investors and business are often faced with the dilemma of a lack of scientific knowledge, programming skills, local computational power and storage space, or simply insufficient time to base their decision on a set of state-of-the-art datasets.

Infrequent monitoring. Limited monitoring of GHG emissions and infrequent practices to update national emission inventories using methodologies not based on those approved by National Communications to the UNFCCC precludes the generation of usable climate intelligence in this area. Within the land use sector, most countries have forest inventories with variable separation periods (in some countries, this occurs every ten years; in others, this occurs annually). This is a moderate and widespread barrier to assessing the annual speed of NDC compliance and to make necessary adjustments to public policies in order to ensure compliance with mitigation targets.[1115] The recent availability of satellite images in the Copernicus Programme of the European Union, for example, offers a great opportunity to overcome this barrier, by generating data on demand to fill current gaps. However, some African countries may face downstream infrastructure constraints to run appropriate servers, such as low internet connectivity and unreliable electricity supply. Data can be stored, but there may be problems running algorithms and downloading data.

Lack of an appropriate climate change legal framework. Although many countries have environmental policies related to natural resources management and climate change, only some of them have committed to formulating a climate change law or policy for the implementation and monitoring of NDCs and the standardisation of climate data collection, management, verification, and reporting. In Southern Africa and Southeast Asia, this could be a critical issue, because climate change regulations are mainly focused on adaptation. However, this is a moderate barrier in South America and Central America and the Caribbean, as several countries need better enabling frameworks. These include in particular Argentina, Bolivia, Brazil, Colombia, Ecuador, Guyana, Paraguay, Suriname, Venezuela in South America; Belize, Guatemala, Mexico, Nicaragua and Panama in Central America; and Antigua and Barbuda, The Bahamas, Barbados, Cuba, Dominica, Dominican Republic, Grenada, Haiti, Jamaica, St Kitts and Nevis, St Lucia in the Caribbean.

[1115] IPCC, 2019. 2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories. Accessed via: https://www.ipcc.ch/report/2019-refinement-to-the-2006-ipcc-guidelines-for-national-greenhouse-gas-inventories/

Table 86 Summary of barriers to climate intelligence and data: severity across target regions

Type of barrier	South America	Central America and the Caribbean	Mexico	Southern Africa	Southeast Asia
Political economy[1116]	Moderate – Low government effectiveness, except Argentina, Chile, and Uruguay and low political stability, especially in Colombia and Venezuela.	Moderate – Low government effectiveness and low political stability, except Costa Rica and Panama.	Moderate – Mild government effectiveness, poor control of corruption.	High – Poor government effectiveness and regulatory quality, corruption, and low political stability, except Botswana and Namibia.	Moderate – Low government effectiveness in Cambodia, Lao and Myanmar and low political stability in Thailand, Myanmar, and the Philippines.
Enabling environment	Moderate – Challenges to retain internal capacities and expertise due to changes in political structures.	Moderate – Consistent but variable need for information access.	Moderate – Outstanding legal framework and climate data collection and reporting system, but not used effectively by policy makers.	High – Need for additional information to implement NDC, lack of a mitigation legal framework, insufficient public funds.	High – Information assessment and monitoring need, insufficient funding for data collection, lack of a mitigation legal framework.

Source: Vivid Economics, ASI and Factor

1116 Specific governance indicators (control of corruption, regulatory quality, government effectiveness, and political stability) by country. Accessed via: https://info.worldbank.org/governance/wgi/Home/Reports

UK additionality

The UK has considerable experience in defining informed and ambitious climate targets by using comprehensive climate intelligence and data, collated by world-leading institutions, economists, and climate scientists. Under the UNFCCC framework, the UK is obliged to produce annual GHG inventories, in accordance with the 2006 IPCC Guidelines and using the latest available data. In April 2020 the UK submitted its national inventory report (NIR), containing GHG emissions estimates for the period 1990-2018. It provides data to assess progress towards the UK Government's own carbon budgets and to meet commitments as a party to the UNFCCC.[1117] The UK's National System for GHG emissions estimation was established for the collection, processing, and systematisation of data from wide emission sources; the selection of appropriate emission factors and methodologies;[1118] and the management of quality assurance and quality control (QA/QC) aspects. In addition, the UK has a rigorous monitoring and reporting framework to track progress against its domestic and international targets. Each year the UK Government publishes not only its GHG inventory but also energy and emissions projections[1119] in the period out to 2035 (including scenarios with existing and additional measures). This level of expertise is highly relevant in several areas that are critically important for providing developing countries with climate intelligence and data.

Synergies with UK decarbonisation are high.

The UK is a global leader of science and innovation and within its innovation network, funded by the Foreign and Commonwealth Office (FCO) with support from BEIS, it supports a number of interdisciplinary programmes including agriculture and future cities in Africa and countries in Southeast Asia, such as Singapore and Malaysia. The International Research and Innovation Strategy of the UK seeks to build research and innovation alliances to address climate change, which may help to develop methodologies and to fill information gaps in developing countries.[1120]

- The UK Green Finance Taskforce is an independent body consisting of senior leaders from across the financial sector and academia, which provides recommendations on how the government and the private sector can work together to accelerate the growth of green finance and deliver the investment required to meet the UK's carbon reduction targets.
- The UK has been leading NGFS. The purpose of the NGFS is to promote best practices to meet the goals of the Paris Agreement by improving the ability of the financial system to manage climate and environmental-related risks and to mobilise capital for green and low-carbon investments. The NGFS Climate Scenarios provide a range of data on transition risks, physical risks, and economic impacts that may be used by central banks, academic institutions, and the private sector.

In addition, the Transition Pathway Initiative (TPI),[1121] launched in 2017 as a joint initiative between the Chruch of England National Investing Bodies and the Environment Agency Pension Fund, provides robust and independent research and data[1122] to assess the quality of companies' management of their GHG emissions, their carbon perfomance compared to international targets, and the risks and opportunities related to the low-carbon transition. The initiative is aimed at investors to enable better informed investment processes and decisions, and aligns with the Task Force on Climate-

[1117] Brown et al. 2020. "UK Greenhouse Gas Inventory 1990 to 2018: Annual Report for submission under the Framework Convention on Climate Change". Accessed via: https://uk-air.defra.gov.uk/assets/documents/reports/cat09/2004231028_ukghgi-90-18_Main_v02-00.pdf
[1118] The UK inventory mainly uses higher tier methodological approaches for key categories and makes extensive use of country specific emissions factors.
[1119] The UK's projections of GHG emissions is derived from the BEIS Energy and Emissions Projections (EEP) model suite, using prospects for fossil fuel prices, carbon prices, economic growth and demographics.
[1120] HM Government. (2019). International Research and Innovation Strategy. Accessed via: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/801513/International-research-innovation-strategy-single-page.pdf
[1121] Transition Pathway Initiative. 2020. Accessed via: https://transitionpathwayinitiative.org/
[1122] FTSE Russell, a TPI partner, provides the climate change and corporate governance related data (financial cost of climate change risks, energy reduction targets, short and long-term emissions reduction targets, etc.) used in the TPI Tool.

related Financial Disclosures (TCFD). About 20% of the support that the TFCD receives comes from organisations in the UK, including the UK Government, that have formally endorsed the TFCD's recommendations and can use the knowledge gained to replicate good practices in other countries. The Centre for Ecology and Hydrology (UKCEH) in Edinburgh, with the support of Forest Research, provide the UK with LULUCF estimates for the national inventories, while Rothamsted Research provide the estimates of agricultural emissions.

UK researchers have worked together with European partners on several Horizon 2020-funded programmes. One example is the *TRANSrisk project*,[1123] which assesses low-emission transition pathways that are technically and economically feasible and acceptable from a social and environmental viewpoint, bringing together quantitative models and qualitative approaches. A second example is the *INNOPATHS project*, which assesses the anatomy of existing scenario and pathway studies for the low-carbon transition from technical, economic, and social perspectives.[1124]

The UK is involved in the Sentinel programme, which has included the provision of the satellite platform for the Sentinel-5 Precursor mission, providing relevant climate data measurements of greenhouse gas concentration in the atmosphere. In addition, the UK is working with European partners on the development of MicroCarb, a satellite monitoring system for CO_2 sources and sinks across the globe.[1125]

The UK funded the Global Network of Climate Innovation Centre's programme, which provides funding to the World Bank's Climate Technology Programme (CTP) to support the design, implementation, and international coordination of Climate Innovation Centres (CICs) in developing countries.

The UK carbon budgets MRV system,[1126] introduced in the Climate Change Act 2008 (CCA 2008), and led by the UK CCC and BEIS, is designed based on annual GHG reporting to monitor progress towards meeting the five-year budget targets, and covers GHG MRV and accounting scopes. The UK tracks progress towards its carbon budgets using its national GHG inventory and gives advice on the contribution that different sectors should make to the carbon budgets and the extent to which offsetting should be used. It is considered a "good practice case study" by the International Partnership on Mitigation and MRV because of its use of pre-existing and high-quality emissions data from the national inventory to track progress. Moreover, it uses a wide range of data from different sources to construct a credible picture of the drivers of GHG emissions trends, including information on contextual factors such as population, GDP, and climatic patterns, etc. The UK Government recognises the importance of sharing data and to integrate the net-zero challenge across all levels of government, business, and society, and to strengthen policy making and achieve emissions reduction.[1127]

BEIS, DEFRA, and the Devolved Administrations also fund research contracts to provide improved emissions estimates for certain sources, such as fluorinated gases, landfill methane, enteric fermentation, and shipping.[1128]

[1123] TRANSrisk, 2020. Accessed via: http://transrisk-project.eu/
[1124] Weaver et al. 2019. "The Finnish Climate Change Panel Report: Overview of National Climate Change Advisory Councils". Accessed via: https://www.ilmastopaneeli.fi/wp-content/uploads/2019/05/Overview-of-national-CCCs.pdf
[1125] Ibid
[1126] International Partnership on Mitigation and MRV. 2017. Accessed via: https://www.transparency-partnership.net/system/files/document/Good%20Practice-UK-Carbon%20Budgets%20MRV%20System.pdf
[1127] Committee on Climate Change. 2019. "Net Zero. The UK's contribution to stopping global warming." Accessed via: https://www.theccc.org.uk/wp-content/uploads/2019/05/Net-Zero-The-UKs-contribution-to-stopping-global-warming.pdf
[1128] Weaver et al. 2019. "The Finnish Climate Change Panel Report: Overview of National Climate Change Advisory Councils". Accessed via: https://www.ilmastopaneeli.fi/wp-content/uploads/2019/05/Overview-of-national-CCCs.pdf

The UK has several strong existing partnerships and can draw on past experience through a number of high-profile domestic and international climate intelligence and data programmes.

The UK 2050 calculator.[1129] This tool, developed and released by BEIS, enables users to experiment with various pathways to meet the UK's target to cut national GHG emissions by at least 80% by 2050, below the 1990 baseline emissions. It calculates GHG trajectories and costs for all activities related to GHG emissions, based on real scientific data. The tool has been replicated in some countries of the prioritised regions, such as Thailand. Therefore, there is high potential for the UK to provide technical assistance to replicate and adapt the tool to the local context of the priority regions for the assessment of different mitigation pathways and the review of their NDCs based on reliable models. Since its Sixth National Communication, the UK has continued to develop the 2050s Global calculator, as well as supporting 10 countries in developing their own versions, four of which used these in the development of their NDCs. All 10 calculators have now been launched, along with the Global calculator.[1130]

- UK climate projections provide a scientific basis to assess transition risk scenarios and track mitigation actions and climate impacts over time. Projections are based on modelling conducted by the Met Office Hadley Centre Climate Programme, funded by the UK government. The programme provides world-leading climate science that supports the UK's contribution to international initiatives and country capacity building projects funded through the UK Government's Newton Fund. The UK Met Office is the lead agency for making and collecting meteorological and atmospheric observations and is committed to the principles of free and unrestricted exchange of essential data. Its science is integrated into European and international science initiatives, such as the European Commission Horizon 2020 projects and the Grand Challenges of the World Climate Research Programme, and through the expanding agenda of climate services being supported by the Copernicus Programme and the World Meteorological Organisation's Global Framework for Climate Services.[1131]

- Since 1987, BEIS has been running a programme of atmospheric observations to estimate UK GHG emissions using the UK Deriving Emissions related to Climate Change (DECC) network. These observations derive background atmospheric concentrations and emissions estimates for the UK, which help to compare, verify, and improve their national GHG inventory. The UK is one of only three countries worldwide that currently routinely verify their reported inventory emissions as part of their annual UNFCCC submission of emissions.[1132]

- UK PACT is a 3-year (2018-2022) technical-assistance, capacity building programe under the ICF Portfolio, funded by BEIS. The programme supports ODA-eligible countries, aiming to raise their levels of carbon mitigation ambition, improve the technical capabilities of key institutions, and address implementation barriers. The key types of outputs of technical assistance include the exchange of tools, practices, and recommendations, the development of new skills, and the creation/dissemination of knowledge products. Through an open and competitive call for proposals the programme has allocated up to GBP 4 million for technical assistance activities in Colombia and Mexico.

- The NDC partnership, to which the UK contributes, encourages countries to strategically use their NDCs as a tool for achieving zero-carbon and climate-resilient development, by the implementation

[1129] Department of Business, Energy and Industrial Strategy. 2013. "2050 Pathways". https://www.gov.uk/guidance/2050-pathways-analysis and "2050 Calculator Wiki". Accessed via: http://2050-calculator-tool-wiki.decc.gov.uk/pages/1
[1130] Weaver et al. 2019. "The Finnish Climate Change Panel Report: Overview of National Climate Change Advisory Councils". Accessed via: https://www.ilmastopaneeli.fi/wp-content/uploads/2019/05/Overview-of-national-CCCs.pdf
[1131] Ibid
[1132] Met Office Hadley Centre and University of Bristol. (2019). Long-term Atmospheric Measurement Interpretation of Radiatively Active Trace Gases. Accessed via: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/890579/verification-uk-greenhouse-gas-emissions-atmospheric-observations-annual-report-2018.pdf

of MRV systems, and the enhancement of GHG inventories, among other things. The partnership provides support to Zambia in Southern Africa; the Philippines, Thailand, and Vietnam in Southeast Asia; Brazil, Chile, Colombia, Peru, Ecuador, and Paraguay in South America; and Costa Rica, Guatemala, and Trinidad and Tobago in Central America and the Caribbean. Chile developed a National MRV framework for Nationally Appropriate Mitigation Actions (NAMAs) in collaboration with the British Embassy's Prosperity Fund project, and Peru developed a long-term scenario model supported by DECC.

- The UK also supports CIC in Ethiopia and Vietnam through bilateral support programmes, while there are additional non-DFID supported CICs in South Africa, the Caribbean, Ghana, and Morocco.
- The UK Government was a major contributor to the Climate and Development Knowledge Network (CDKN), from 2010 to 2018. CDKN's knowledge services focus on making information and learning on climate-compatible development easier to access and use, in support of ambitious climate action, by combining knowledge, research, and technical advisory services.[1133] The Network has ongoing projects in Colombia, Ecuador, Chile, and Bolivia.
- It is worth noting that UK-provided support might be stronger than other international interventions in this area, such as the Capacity Building Initiative for Transparency (CBIT), reflecting the UK's strengths shown in this section. The CBIT supports a number of climate intelligence and data projects, including 35 GHG inventory projects, 28 information systems and technologies projects, 22 emission factor projects, and 23 NDC-tracking projects. However, building on its comprehensive experience in providing domestic and international support, the UK is likely to be well positioned to provide more comprehensive climate intelligence and data support, and to be additional to this initiative.

Given the UK's strengths and previous experience across both domestic and international programmes, the opportunities for UK additionality are likely to be particularly high around improving the quality of GHG inventories, emission projections, and transition risk scenarios due to the available tools for both calculation and information collection. Other areas of particular strength are around supporting the identification of new opportunities and investing in the generation of intelligence on institutional and technological innovations and developments.

[1133] Climate and Development Knowledge Network. 2020. Accessed via: https://cdkn.org/about/?loclang=en_gb

Intervention opportunities

There is substantial opportunity across all regions for the UK to scale up support for climate intelligence and data and thereby support increased mitigation ambition and action. While needs will vary across specific regions and countries – and even institutions within countries - based on local context and needs, there are several key potential intervention areas that are best aligned with the UK's experience and strengths.

Measures to improve climate data:

- **Supporting the development and verification of GHG inventories.** The UK can share its expertise to support the development of regular, complete, accurate, consistent, comparable, and transparent GHG inventories in compliance with the UNFCCC principles, following the most up-to-date IPCC approaches. National GHG inventories may be verified by contrasting them with real-time scientific data such as atmospheric observations of GHG emissions.

- **Assistance to identify data gaps and assess current methodological approaches.** This support, following established guidance and protocols (IPCC Guidelines, Tier approach, bottom-up vs top-down), can help countries to generate robust, high-quality GHG inventories, and emission projections. Assistance can also be provided to the private sector to generate relevant data for the assessment of transition pathways (under different climate-related scenarios) and track companies' GHG emissions management and carbon performance to guide green investments. Such data includes the financial costs of climate change risks, short- and long-term emissions reduction targets, and climate change policies, etc.

- **Assistance in improving and/or updating sectoral activity data and emission factors.** This area of support can be provided by direct measurement (using satellite images, for example[1134]) or by estimation using simple standard methods or complex models. This requires scientific knowledge and advanced tools or technologies but reduces uncertainty in the estimations.

- **Promote the implementation of climate services information systems.** These systems can generate climate information on demand to fill data gaps, with server-side technology to ensure accessibility even from low bandwidth regions. To enable the exchange of information with other systems, like land cover monitoring, the data structures should be built in line with the Open Geospatial Consortium (OGC) standards that define server architecture, interoperability, and other requirements. Big data servers that store geospatial and climate-related data are essential management mechanisms for accounting based on reliable and realistic information in the national context, enabling informed decision making and improving the articulation and data exchange between different international institutions.

- **The possibility of providing technical assistance to improve climate and inventory data is especially needed in Southern Africa and Southeast Asia, given the lack of updated data, the infrequent monitoring, and the downstream infrastructure constraints.** Therefore, the above-mentioned interventions could go some way towards addressing the enabling environment barriers.

Measures to develop models on emissions projections and transition risks scenarios:

- **Supporting the development of pathways and macro-emissions models.** The UK can provide expertise to strengthen the technical skills needed in developing countries to assess transition pathways using Integrated Assessment models, which combine economic drivers, energy, land-use, climate, and GHG emissions data, as well as policy, technology, and investment assumptions to provide coherent and

[1134] At the European level, as part of the implementation of the Copernicus Climate Change Service (C3S), the European Centre for Medium-Range Weather Forecasts aims to develop Sectoral Information Systems (SIS), which will provide sector-specific shop windows for the C3S Climate Data Store.

realistic scenarios.[1135] Macro-emissions models and transition pathways using high-quality input data can be used to track NDC compliance over time and to develop, guide, and appraise climate policies or general investment from private or public entities considering different transition risk scenarios.

Guidance in the selection of models and software. This support may vary considerably, based on the available and most suitable methodologies for the country and the frequency of recurring data generation exercises. For example, if the idea is to build a model once and to let it work alone driven by a single agency or governmental office, *ready-made* models appear to be the best choice. On the other hand, *ad-hoc models* could be very useful to develop a periodic work, starting from sectoral information, adapting it to expected relevant parameters, and expressed results as CO_2 emissions in a disaggregated output. If the goal is to evaluate GHG Projections in the UNFCCC context, *ad-hoc models* take the lead as they offer a more accurate output to the country needs and the input requirements can be adapted to fit the available data, enabling monitoring and the transparency principle.

Development of methodologies and user-friendly, dynamic tools to perform cost-benefit analyses of mitigation options to supplement the socio-economic dimension of mitigation actions. This would complement the physical component of GHG calculations to support decision making at the local level, track NDC progress and other climate change commitments, prioritise suitable technologies, and define investment portfolios focused on industries and infrastructures that are less vulnerable to transition risks.

Given that transition risk pathways and emissions projections can be used extensively to inform investors and policy and decision makers. The interventions providing technical assistance to improve models would help address political economy barriers and would have a greater impact in Mexico, South America, and Central America and the Caribbean. A good example of such an approach is described in Case Study A, Component 1, where the development of mitigation scenarios and abatement cost curves are the first step towards defining sectoral action plans and updating the climate targets.

Capacity building within governmental institutions to generate and manage national climate intelligence and data.

The development of capacity building programmes is essential to create permanent, autonomous, well-functioning, and articulated institutions which are responsible for generating the types of intelligence and data described in the direct interventions above. The consolidation of a team of local consultants within relevant government ministries is a key initial step to implementing a capacity building programme, engaging national academic institutions at all stages. UK support in this area is therefore likely to lead to longer-term, but potentially longer-lasting and more durable, emissions reductions following from the capacity of national bodies to drive forward national action on climate intelligence and data.

Support in the identification of required MRV systems. Capacity building programmes can include support in the development of different MRV systems considering specific needs, and spur action towards more ambitious and traceable climate commitments. An MRV of emissions is conducted to understand GHG emissions profiles and includes quantification of emissions, main emitting sectors, gases estimated, and trends. An MRV of mitigation actions is set up to assess the effects (changes in GHG emissions, sustainable development) of mitigation policies, monitor their implementation, and evaluate their effectiveness in attaining NDC commitments. An MRV of support aims to track provision and receipt of climate support (climate finance, technology transfer, and capacity building) and monitor the results achieved and the impact of the support received. This requires a clear identification of legal setups (national legislation), institutional setups (allocation of sectoral roles and responsibilities in all institutional structures), and procedural setups (methodologies, data sources,

[1135] Network for Greening the financial system. (2020). NGFS Climate Scenarios for Central Banks and Supervisors. Accessed via: https://www.ngfs.net/sites/default/files/medias/documents/820184_ngfs_scenarios_final_version_v6.pdf assumptions, and quality assurance procedures). This intervention includes the design and implementation of open source platforms to host a centralised and accessible system, addressing the infrequent monitoring and information asymmetries barriers. A good example of such an approach is described in the case study on MRV Practice in Thailand (below).

Capacity building for the financial sector. Support central banks and other financial institutions to identify and quantify transition risk, providing tools to help investors to understand integrated climate risk, enabling informed decision-making, encouraging investment in low-carbon sectors, and promoting mitigation action. Assistance would also promote the adoption of disclosure standards such as the TCFD.

Capacity building within the private sector. Awareness raising for non-public stakeholders, especially for carbon-intensive business, to promote the calculation of the carbon footprint and disclosure of climate-related risks. Capacity building would consist of providing methodologies and tools to establish a baseline for reducing GHG emissions based on quantifiable targets and facilitate the monitoring of GHG emissions and the impact of mitigation actions. Scenario analysis would be essential to help assess risks and understand the potential implications of climate change. A good example of the development of a corporate voluntary reporting platform is described in the case study on the Colombian Low Carbon development strategy (below).

Capacity building interventions are likely to help address a range of enabling environment barriers identified in this analysis, especially those related to information asymmetries, data availability, lack of institutional capacities, and infrequent monitoring, especially in Mexico and South America.

Box 40 Strategising to decouple economic growth from GHG emissions: The Colombian Low Carbon development strategy (CLDCS)

The CLDCS is a short-, medium- and long-term planning initiative. Its objective is to identify the GHG mitigation potential without affecting the growth of the country's economy. It does so via the implementation of low-carbon development policies and other political and financial tools, the design and construction of an MRV system in accordance with national strategies for information management and international standards, the regionalisation of mitigation actions, the implementation of the country's NDC, and capacity building for government officials and the private sector. The programme received technical and financial support from different institutions, including World Resources Institute (WRI), Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ), Centre for Clean Air Policy (CCAP), Climate and Development Knowledge Network (CDKN), Resources to Advance LEDS Implementation (RALI (USAID)), WB, and the embassy of the UK, among others.

Activities and achievements: The programme was divided into the following 5 components:

- **Component 1 – Scenarios and options:** focused on "climate intelligence and data", this component included activities such as the development of long-term inertial and mitigation scenarios at sectoral level, identification of mitigation measures and GHG reduction potentials, abatement cost curves, a 2050 carbon calculator, scenarios to determine the NDC, and analysis of co-benefits. High-level meetings were held from the start during the development of emission growth projections and mitigation measures.
- **Component 2 – Planning:** 8 Sectoral Action Plans (transportation, energy, hydrocarbons, mining, industry, agriculture, housing, and waste) were designed and approved including policies, programmes, and measures to reduce GHG emissions (quantitative mitigation goals), the formulation of a portfolio with 14 NAMAs, and the design and definition of the Colombian NDC.
- **Component 3 – Implementation and follow-up:** implementation of Publicly Available Standard (PAS) and NAMAs; alignment of emissions from the GHG inventory and the prioritised mitigation measures of the NDC under IPCC categories to strengthen monitoring at a sectoral level; territorial deployment and development of a MRV system for measures related to climate change, including 3 approaches: quantification of emissions, reduction of emissions, and financing for mitigation and adaptation.
- **Component 4 – Capacity building:** design and development of corporate voluntary reporting platform, creation of a professionals' network, and building capacities in the ministries. The technical capacity was increased in terms of MRV capacity management, sector support, and participation of the territories and the private sector.
- **Component 5 – Communication and cooperation:** development of guidelines for prioritisation of international cooperation within the NDC and publication of documents and brochures. The "carbon calculator 2050" was an essential tool to communicate and socialise the impacts of implementing mitigation measures.

The CLCDS is considered a good practice because of the intersectoral cooperation, the technical feasibility, the political buy-in, the alignment with the national framework, and its science-based approach.

Some of the lessons learned and key elements identified to replicate this practice in other countries include:

- Prioritise cooperation support to strengthen internal national capacities at all levels: central government, sectors, and regions.
- Consolidate a technical team of local consultants within the ministries and ensure transfer of information (economic modelling, emissions calculation, etc.) from the beginning. The development of technical capacities during the whole process guarantees the continuity of measures already implemented, instead of depending on external consulting firms.
- Develop binding mechanisms in existing policy instruments.
- Make use of existing mechanism for inter-institutional coordination.
- Select a single coordinator for the strategy who is also the manager of international cooperation funds, in order to avoid work duplication and guarantee an efficient use of resources.
- Involve all relevant stakeholders from the beginning.
- Deploy assertive communication to ensure empowerment of citizens and promote civic monitoring of climate change strategies.
- Systematise tools, approaches, instruments, and methodologies that could be useful for future knowledge exchange, such as development of mitigation action curves and elaboration of baseline scenarios.[1136]

Box 41 MRV Practice in Thailand

Thailand is one of 195 parties that adopted the UNFCCC 2 degrees Celsius target. In its NDC, Thailand committed to reduce 20-25% emission reduction against BAU by 2030. Mitigation is economy-wide, while adaptation focuses on the coastal zone, disaster risk management (DRM), and the sectors of agriculture, environment, health, water, LULUCF/forestry, and tourism. To monitor progress of the implemented policies for mitigation and adaptation, a strong institutional MRV system is essential.

In line with the NDC, there are also group of national strategies and policies in the place to promote MRV and an Emission Trading System (ETS). The “12th National Economic and Social Development Plan (2017-2021)” of Thailand calls for several mitigation measures, including the development of a domestic carbon market. The “National Climate Change Master Plan (2015-2050)” also refers to carbon markets as a potential mechanism to reduce GHG emissions in the private sector. According to the ‘National Reform Plan (2018),’ the Thai government must set up an economic instrument, such as a cap-and-trade programme, to incentivise the private sector to reduce emissions. The specific instrument will be outlined in the ‘Climate Change Act,’ which is expected to be proposed for cabinet consideration in 2021.

Thailand is in the process of establishing an MRV system for national climate reporting. ONEP under the MNRE is leading this task, together with key sectoral ministries and agencies, with GIZ support.

- Since 2013, a public organisation, the Thailand Greenhouse Gas Management Organization (TGO), has developed an MRV system for the ‘Thailand Voluntary Emissions Trading Scheme.’
- The first 3-year pilot phase (2015-2017) aimed at testing the MRV system for 4 industrial sectors, cement, pulp and paper, iron and steel, and petrochemical, setting a cap for facilities’ Scope 1 and 2 emissions, and allocating allowances for covered facilities.

[1136] Global Good Practice Analysis (GIZ UNDP). Accessed via: https://ndcpartnership.org/case-study/strategising-decouple-economic-growth-ghg-emissions-colombian-low-carbon-development

- The 2nd pilot phase (2018-2020) has tested the MRV, the registry, and trading platform for an additional five industrial sectors: petroleum refinery, glass, plastic, food and feed, and ceramics.
- In 2020, an MRV for another three industrial sectors will be developed, and many seminars and meetings will be held to introduce the ETS concept to various stakeholders.

The Thai-German Climate Programme (TGCP) brings in expertise to set up a solid MRV. The focus of the programme is on:

- Getting higher quality of data.
- Defining clear roles and channels for reporting.
- Using credible methods for monitoring.

These transparency approaches increase comparability between domestic and international levels. Looking at the way forward, there are several challenges in strengthening the existing MRV system in Thailand. The MRV system needs to articulate the requirement of monitoring plans, expand the limitations of information technology, and harmonise the reporting guidelines consistently. To prepare for Thai-ETS readiness, the MRV system for ETS and Registry system were developed by using national budget funds. Market players, being one of the most important components to drive the mechanism, will need to explore opportunities for close engagement with private sector actors and promote such engagement. Given that, the availability of capacity building programmes is the key to unlocking the situation.[1137]

[1137] Thai-German Cooperation Partnership on Sustainable Development (Climate Programme)
Accessed via: https://www.thai-german-cooperation.info/en_US/thailand-on-course-for-an-improved-mrv-system/

Glossary

Acronym / Term	Definition
BEIS	UK Department for Business, Energy and Industrial Strategy
BURs	Biennial Update Reports
CBIT	Capacity Building Initiative for Transparency
CCA 2008	Climate Change Act 2008
CCAP	Centre for Clean Air Policy
CCC	UK's Committee on Climate Change
CDKN	Climate and Development Knowledge Network
CICs	Climate Innovation Centres
CLCDS	the Colombian Low Carbon Development Strategy
COP	Conference of the Parties
CTP	World Bank's Climate Technology Programme
DECC	Department for Energy and Climate Change
DEFRA	Department for Environment, Food and Rural Affairs
DFID	Department for International Development
DRM	Disaster risk management
ETS	Emission Trading Schemes
EU	European Union
FAO	Food and Agriculture Organisation of the United Nations
FCPF	Forest Carbon Partnership Facility
GBP	Great British Pound
GCPF	Global Climate Partnership Fund
GDP	Gross Domestic Product
GHG	Greenhouse Gas
GIZ	German Agency for International Cooperation
ICF	International Climate Finance
INDC	Intended nationally determined contribution
IPCC	Intergovernmental Panel on Climate Change
LULUCF	agriculture and land use, land use change and forest
M&E	Monitoring and evaluation
MNRE	Thailand Ministry of Natural Resources and Environment
MRV	Monitoring, reporting and verification
NAMA	Nationally Appropriate Mitigation Action
NDC	Nationally Determined Contribution
NGFS	Network of Central Banks and Supervisors for Greening the Financial System
NIR	National Inventory Report
ODA	Official Development Assistance

Acronym / Term	Definition
OECD	Organisation for Economic Co-operation and Development
OGC	Open Geospatial Consortium
ONEP	Thailand Office of Natural Resources and Environmental Policy and Planning
PAS	Publicly Available Standard
PECC	Mexico Special Program on Climate Change
QA/QC	Quality assurance/quality control
RALI (USAID)	Resources to Advance LEDS Implementation
REDD+	Reducing emissions from deforestation and forest degradation in developing countries, and the role of conservation, sustainable management of forests, and enhancement of forest carbon stocks in developing countries
SDGs	Sustainable Development Goals
TCFD	Task Force on Climate-related Financial Disclosures (TCFD)
TGCP	The Thai-German Climate Programme
TGO	Thailand Greenhouse Gas Management Organization
Thailand V-ETS	Thailand Voluntary Emissions Trading Scheme
TPI	Transition Pathway Initiative (TPI)
TRANSrisk	Transition Pathways and Risk Analysis for Climate Change Mitigation and Adaptation Strategies
UK	United Kingdom
UK PACT	UK Partnering for Accelerated Climate Transitions
UKCEH	Centre for Ecology and Hydrology
UNFCCC	United Nations Framework Convention on Climate Change
USD	US Dollar
WB	World Bank
WRI	World Resources Institute

Company profile

Vivid Economics is a leading strategic economics consultancy with global reach. We strive to create lasting value for our clients, both in government and the private sector, and for society at large.

We are a premier consultant in the policy-commerce interface and resource- and environment-intensive sectors, where we advise on the most critical and complex policy and commercial questions facing clients around the world. The success we bring to our clients reflects a strong partnership culture, solid foundation of skills and analytical assets, and close cooperation with a large network of contacts across key organisations.

Contact us

Vivid Economics Limited
163 Eversholt Street
London NW1 1BU
United Kingdom

T: +44 (0)844 8000 254
enquiries@vivideconomics.com