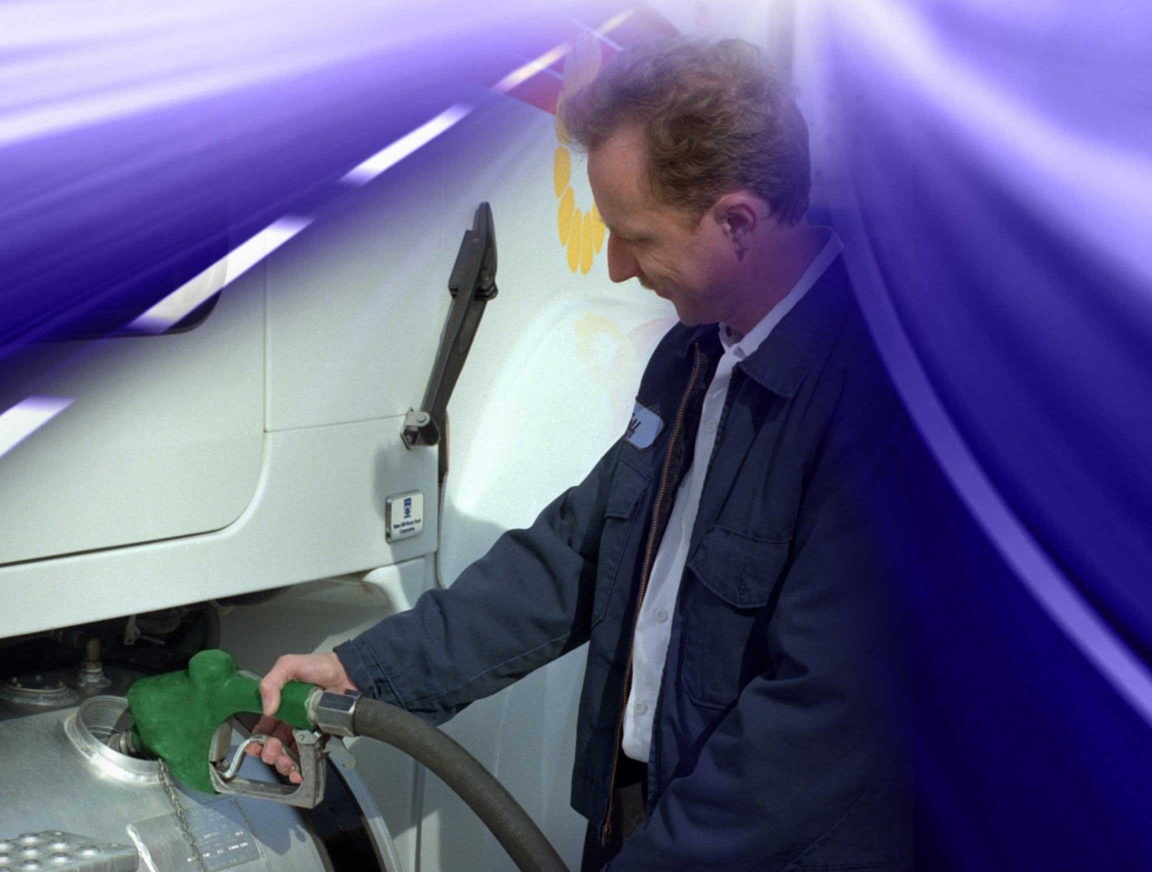
IEA-Advanced Motor Fuels

ANNUAL REPORT 2015

iea Energy Technology Network

ADVANCED MOTOR FUELS IEA-AMF



IEA Technology Collaboration Programme for

Advanced Motor Fuels Annual Report 2015

Rainbow Spine: The colors used for the spines of Advanced Motor Fuels Annual Reports follow the colors of the rainbow. Using colors allows readers to easily distinguish between the different editions of the annual report. The spines of previous editions (2010, 2011, 2012, 2013, and 2014) were blue, dark green, light green, yellow, and red, respectively.

This year's edition has a violet spine, because in 2015, AMF has started a new working period, and violet is the first color in the rainbow. A preference for violet indicates a spirit of dedication. AMF is driven by the contributions that its member countries dedicate towards the collaborative work of AMF.

Cover: This truck's engine has been modified to run on 95% ethanol, a biofuel made from corn. Refueling with ethanol is as quick and easy as refueling with diesel.
URL: https://images.nrel.gov/bp/#/folder/207415#6323894
Photo credit: Warrent Gretz, National Renewable Energy Laboratory.

Cover Design: Sana Sandler, Argonne National Laboratory, USA

International Energy Agency

Advanced Motor Fuels Annual Report 2015

This Annual Report was produced by Kevin A. Brown (project coordination/management), Pat Hollopeter (lead editor), Vicki Skonicki (document production), and Gary Weidner (printing) of Argonne National Laboratory. The cover was designed by Sana Sandler, also of Argonne National Laboratory.

Contributions were made by a team of authors from the Advanced Motor Fuels Technology Collaboration Programme, as listed below.

Country reports were delivered by the Contracting Parties:

Austria	Ministry of Transport, Innovation, and Technology (BMVIT)
Canada	CanmetENERGY
Chile	Ministry of Energy
China	China Automotive Technology and Research Center (CATARC)
Denmark	Technical University of Denmark (DTU)
Finland	The Technical Research Centre of Finland (VTT)
France	Institut Francais du Pétrole (IFP)
Germany	Fachagentur Nachwachsende Rohsoffe (FNR)
Israel	Ministry of National Infrastructure, Energy and Water Resources
Italy	ENI S.p.A.
Japan	• National Institute of Advanced Industrial Science and Technology (AIST) • Organization for the Promotion of Low Emission Vehicles (LEVO)
Republic of Korea	Korea Institute of Energy Technology Evaluation and Planning (KETEP)
Spain	Instituto para la Diversificación y Ahorro de la Energía (IDAE)
Sweden	Swedish Transport Administration (STA)
Switzerland	Swiss Federal Office of Energy (SFOE)
Thailand	PTT Research and Technology Institute
USA	U.S. Department of Energy (DOE)

Annex reports were delivered by the respective Operating Agents and Responsible Experts:

Annex 28	Information Service and AMF Website	Dina Bacovsky
Annex 43	Performance Evaluation of Passenger Car, Fuel, and Powerplant Options	Juhani Laurikko
Annex 44	Research on Unregulated Pollutants Emissions of Vehicles Fuelled with Alcohol Alternative Fuels	Fan Zhang
Annex 46	Alcohol Application in CI Engines	Jesper Schramm
Annex 47	Reconsideration of DME Fuel Specifications for Vehicles	Mitsuharu Oguma
Annex 48	Value Proposition Study on Natural Gas Pathways for Road Vehicles	Ralph McGill
Annex 49	COMVEC – Fuel and Technology Alternatives for Commercial Vehicles	Nils-Olof Nylund
Annex 50	Fuel and Technology Alternatives in Non-Road Engines	Magnus Lindgren
Annex 51	Methane Emission Control	Jesper Schramm
Annex 52	Fuels for Efficiency	Somnuek Jaroonijtsathian
Annex 53	Sustainable Bus Systems	Alfonso Cadiz
Annex 54	GDI Engines and Alcohol Fuels	Debbie Rosenblatt
Annex 55	Real Driving Emissions and Fuel Consumption*	Kevin Stork

Other sections of this report were delivered by the Chair and the Secretary:

Magnus Lindgren	Swedish Transport Administration (STA)	ExCo Chair
Dina Bacovsky	BIOENERGY 2020+	Secretary

* Annex 55 not submitted for 2015 Annual Report.

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1

The Advanced Motor Fuels Technology Collaboration Programme

1.a Chairperson's Message

An important event during 2015 was the 21st Session of the Conference of the Parties to the United Nations Framework on Climate Change (COP 21). When the meeting ended, the parties had agreed to reaffirm the goal of keeping the average global warming below 2°C. However, the ambition went even further when the parties were asked to "pursue efforts" to limit global warming to 1.5°C. To reach these ambitions, two long-term goals were set: (1) stop increasing emissions of greenhouse gases as soon as possible, and (2) find "a balance between anthropogenic emissions by sources and removals by sinks." All parties shall also develop "nationally determined contributions" (NDCs). These NDCs shall be reviewed every fifth year. The new NDC shall "represent a progression" compared with the previous one.

Another important event occurred on September, 1, 2015; Dr. Fatih Birol replaced Maria van der Hoeven and became the new Executive Director of the International Energy Agency (IEA). I would like to wish Maria all the best in her new projects and challenges. Dr. Birol has new ideas and new expectations for the Technology Collaboration Programmes (TCPs). The TCPs can be described as a "sleeping giant" — they work together, sharing knowledge, burdens, and resources, but they have not yet reached their full potential as energy technology ambassadors to countries in all parts of the world. At a workshop among the TCPs, it was stated that collaboration through a TCP provides mutual benefits. TCPs can enable countries to strengthen national technology capabilities, providing information on best practices and best available technologies, while at the same time facilitating the IEA's work with supporting partner countries and developing networks with governments currently beyond IEA membership.

This is all good news for a TCP working on advanced motor fuels. Unfortunately, not all news during 2015 was good. For example, the emission behavior of certain diesel passenger cars in normal driving conditions compared with the emission certification test resulted in a heavy debate, particularly in the United States and Europe. A discrepancy between the emission performance during certification conditions and in real life was nothing new — it was the magnitude of this discrepancy and the mechanism behind it that was astounding. Although diesel-fuelled vehicles were the focus in this case, the lesson learned covers a much broader scope of fuels and technologies. In the early stages of deployment of a new technology or concept for advanced motor fuels, similar emission behavior can overturn the whole process. It is a tough challenge for AMF TCP and other stakeholders in the area of advanced motor fuels to identify performance gaps and true potential.

For the last 1½ to 2 years, market prices of crude oil have decreased significantly, from $100 to $120 per barrel, to around $30 per barrel for Brent crude oil. A low crude oil price usually results in a reduction in the competitiveness of advanced motor fuels. A continued dependency on fossil fuels and a lower market uptake than expected in renewable power technologies, including vehicles, reinforce the role of governments, organizations, individuals, and other stakeholders such as TCPs to ensure that progress toward the IEA's 2°C Scenario (2DS) is maintained.

In theory, the reduced running cost due to a low energy price in the short term could be used for long-term strategic investments in clean and energy-efficient technology to promote sustainable transport. However, perhaps it is time to change the focus from sustainable transport to transport in a sustainable society. In a broader concept, there is no lack of energy in the world, just no economically, environmentally, socially, and ethically sustainable way of recovering this energy. A less energy-efficient process could be preferable compared to a more efficient process based on fossil materials. Whatever the process, it should be as efficient and sustainable as possible.

Current AMF Annexes cover the full range of applications from passenger cars, busses, heavy-duty trucks to non-road mobile machinery and the marine sector. On the fuel side, there are activities on alcohols, natural gas, and bio methane; liquefied gas in the form of dimethyl ether (DME) and liquefied petroleum gas (LPG); and diesel substitutes like fatty acid methyl ester (FAME) and hydrotreated vegetable oil (HVO). These activities represent different links in the chain — research, development, demonstration, and deployment.

It is with great pleasure that I can state that the AMF Annexes are of high quality and represent independent research on advanced motor fuels. This is something we must both maintain and continue to develop further. Last year, we started work to facilitate access to our results for a broader audience with short non-technical summaries. The next step is to address policy and other measures to strengthen development or market uptake of various advanced motor fuels, technologies, and concepts.

Additional good news during 2015 included welcoming a new member, Chile, to the AMF family; Annex 39 (Gaseous Fuelled Heavy-duty Engines) was selected by the IEA to prepare a report in conjunction with COP21; and we started a process to awaken the sleeping giant of the TCP of AMF. During 2016, I hope that we can both expand our cooperation with other stakeholders and develop our current network further. AMF's strength rests on collaboration and sharing of knowledge and research activities.

Magnus Lindgren
AMF Chairperson

1.b
Introduction to the International Energy Agency

The International Energy Agency (IEA) is an autonomous agency that was established in 1974. The IEA carries out a comprehensive program of energy cooperation among 28 advanced economies, each of which is obliged to hold oil stocks equivalent to 90 days of its net imports. The aims of the IEA are to:

- Secure the access of member countries to reliable and ample supplies of all forms of energy and, in particular, maintain effective emergency response capabilities in case of oil supply disruptions.
- Promote sustainable energy policies that spur economic growth and environmental protection in a global context, particularly in terms of reducing greenhouse gas (GHG) emissions that contribute to climate change.
- Improve the transparency of international markets through collection and analysis of energy data.
- Support global collaboration on energy technology to secure future energy supplies and mitigate their environmental impact, through improved energy efficiency and the development and deployment of low-carbon technologies.
- Find solutions to global energy challenges through engagement and dialogue with nonmember countries, industries, international organizations, and other stakeholders.

To attain these goals, increased cooperation among industries, businesses, and governments engaged in energy technology research is indispensable. The public and private sectors must work together and share burdens and resources while, at the same time, multiplying results and outcomes.

The multilateral technology initiatives (Technology Collaboration Programmes or TCPs) supported by the IEA are a flexible and effective framework for IEA member and nonmember countries, businesses, industries, international organizations, and nongovernment organizations to conduct research on breakthrough technologies, fill existing research gaps, build pilot plants, and carry out deployment or demonstration programs — in short, to encourage technology-related activities that support energy security, economic growth, and environmental protection.

More than 6,000 specialists carry out a vast body of research through these various initiatives. To date, more than 1,000 projects have been completed. There are now 41 TCPs that work in the following categories:

- Cross-cutting activities (information exchange, modeling, and technology transfer),
- End-use (buildings, electricity, industry, and transport),
- Fossil fuels (GHG mitigation, supply, and transformation),
- Fusion power (international experiments), and
- Renewable energies and hydrogen (technologies and deployment).

The Technology Collaboration Programme for Advanced Motor Fuels (AMF TCP) belongs to the category of "end-use."

The TCPs are at the core of a network of senior experts consisting of the Committee on Energy Research and Technology (CERT), four working parties, and three expert groups. One of CERT's key roles is to provide leadership by guiding the TCPs in shaping work programs that address current energy issues in a productive way, by regularly reviewing their accomplishments, and by suggesting reinforced efforts where needed. For further information on the IEA, CERT, and TCPs, please consult http://www.iea.org/techinitiatives/.

1.c Technology Collaboration Programme for Advanced Motor Fuels

Need for Advanced Motor Fuels
Because internal combustion engines will be the prime movers for the transport of goods and passengers for many years to come, there is a clear need for fuels that:

- Emit lower levels of GHGs,
- Cause less local pollution,
- Deliver enhanced efficiency, and
- Offer a wider supply base for transportation fuels.

It is also necessary that we understand the full impact of alternative energy solutions from a well-to-wheel perspective and we use solid data for decision making.

Our Approach
We have established a strong international network that fosters collaborative research and development (R&D) and deployment and provides unbiased information on clean, energy-efficient, and sustainable fuels and related vehicle technologies. We intend to:

- Build on this network and continue its fruitful contributions to R&D,
- Strengthen collaborations with other closely related (in terms of topics) Technology Collaboration Programmes (TCPs), and
- Do a better job of involving industry in our work.

By verifying and generating data, we are able to provide decision makers at all levels with a solid foundation for "turning mobility toward sustainability."

Benefits
We bring stakeholders from different continents together to pool and leverage their knowledge of and research capabilities in advanced and sustainable transportation fuels. Our cooperation enables the exchange of best practices. With our broad geographical representation, we are able to take regional and local conditions into consideration when facilitating the deployment of new fuel and vehicle technologies.

Competition
Internationally, there are several fuels-related organizations. However, without exception, these organizations are working for a specific fuel or group of fuels — for example, alcohols, natural gas, liquid petroleum gas, and synthetic fuels. In addition, there are organizations promoting electromobility. In the field of transportation fuels, we are the only internationally recognized, technology-neutral clearinghouse for fuel-related information.

Sustainable Transport Systems
- Reduce GHG emissions globally,
- Secure a stable supply of fuel for transport services, and
- Reduce emissions of toxic pollutants.

Vision

The vision of the members of the Advanced Motor Fuels Technology Collaboration Programme (AMF TCP) is a sustainable transportation system that uses advanced, alternative, and renewable fuels; has reduced emissions of greenhouse gases and air contaminants; and meets the needs for personal mobility and the movement of goods on both a local and global scale. The AMF TCP contributes to the achievement of this vision by providing a solid basis for decision making (information and recommendations) and by providing a forum for sharing best practices and pooling resources internationally.

Mission
The mission of the AMF TCP is to provide sound scientific information and technology assessments to citizens and policy makers to allow them to make informed and science-based decisions about options involving the use of advanced fuels for transportation systems. To provide such data to decision makers, the AMF TCP acts as a clearinghouse by:

- Pooling resources and information on an international level;
- Identifying and addressing technology gaps and barriers to deployment;
- Performing cooperative research on advanced motor fuels;
- Demonstrating advanced motor fuels and related vehicle and after-treatment technologies; and
- Aggregating data and deriving key recommendations for decision makers within governments, municipalities, and industry.

The AMF TCP fulfills its mission through the international cooperation of academia, industries, governmental institutions, and nongovernment organizations. The Annexes in the AMF TCP are started to enable members to cooperate in groups that share common interests and to learn and grow as they interact and share different perspectives.

1.d
How to Join the Advanced Motor Fuels Technology Collaboration Programme

Participation in the multilateral technology initiative AMF TCP is based on the mutual benefits it can bring to the TCP and the interested newcomer.

If you are interested in joining the AMF TCP, please contact the AMF Secretary, Dina Bacovsky at dina.bacovsky@bioenergy2020.eu.

The Secretary will give you details on the AMF TCP and invite you to attend an Executive Committee (ExCo) Meeting as an observer. By attending or even hosting an ExCo Meeting, you will become familiar with the TCP.

Contracting Parties to the AMF TCP are usually governments. Therefore, you need to seek support from your government to join the TCP. The government will later appoint a Delegate and an Alternate to represent the Contracting Party in the ExCo.

Financial obligations of membership include:

- An annual membership fee, currently €9,500 ($10,650 US);
- Funding for an ExCo Delegate to participate at two annual meetings; and
- Cost-sharing contributions to Annexes in which you wish to participate; cost shares range from €2,000 to €100,000 ($2,255 to $112,739 US).

Participation in Annexes can take place through cost sharing and/or task sharing. The institution participating in an Annex does not necessarily need to be the institution of the ExCo Delegate.

The AMF TCP Secretary and IEA Secretariat will guide you through the formalities of joining the AMF TCP.

The Global Situation for Advanced Motor Fuels

2.a
Overview of Advanced Motor Fuels – Statistical Information on Fuels

Globally, the transport sectors consume 28% of total energy consumption (Figure 1).

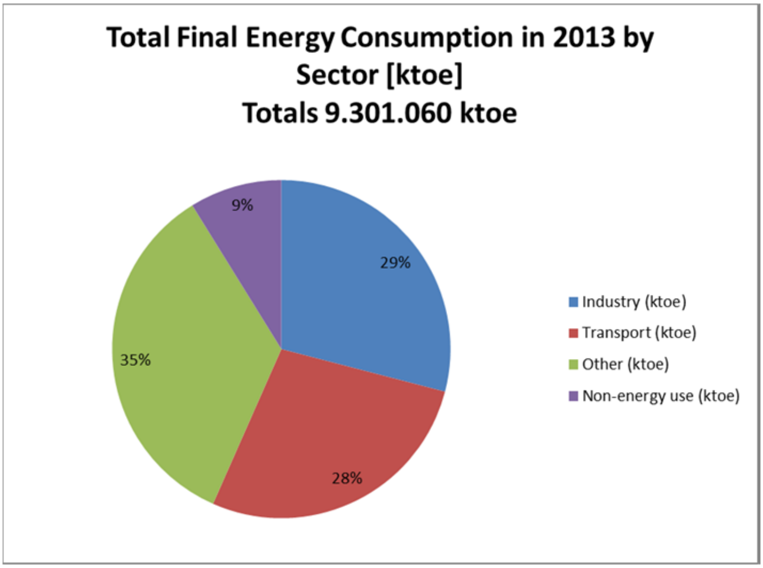


Fig. 1 Total Final Energy Consumption in 2013 by Sector
(Source: IEA Headline Energy Data 2015)

The transport sector is heavily dependent on oil products, which provide 92% of the energy consumed in the transport sector. The share of renewables and waste is 3%, electricity 1% (Figure 2).

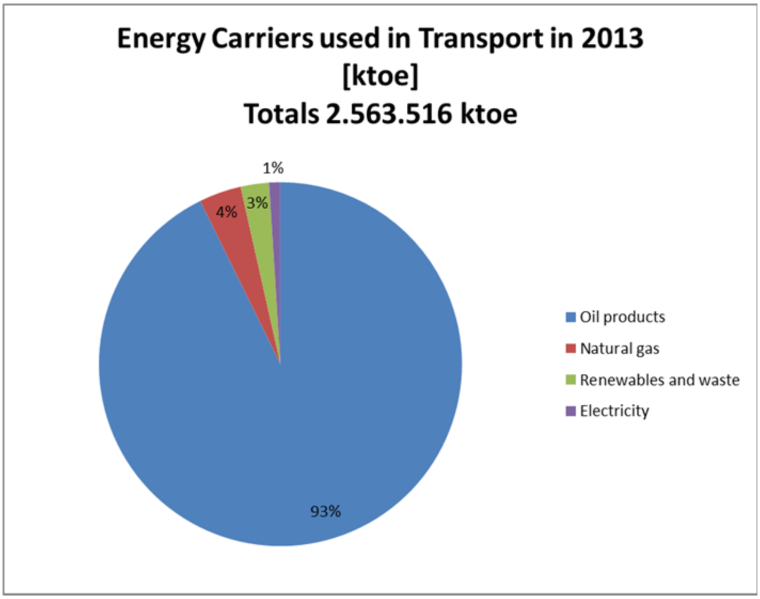


Fig. 2 Global Use of Energy Carriers in the Transport Sector in 2013
(Source: IEA Headline Energy Data 2015)

The global production of biofuels totalled 65.928 kilotonnes of oil equivalent (ktoe) in 2013. The largest producer is the United States, followed by Brazil and the European Union. In comparison, global oil production was 4.126.597 ktoe in 2013 (Figure 3).

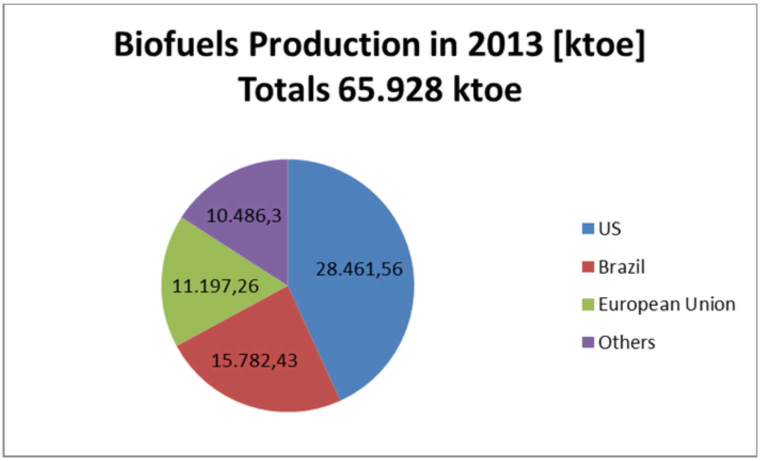


Fig. 3 Global Biofuels Production in 2013 (ktoe)
(Source: BP Statistical Review of World Energy 2015 Workbook)

Global ethanol production was estimated to be 39.687 ktoe in 2013, which represents 60% of total biofuels production. The largest producers are the United States, followed by Brazil and the European Union (Figure 4).

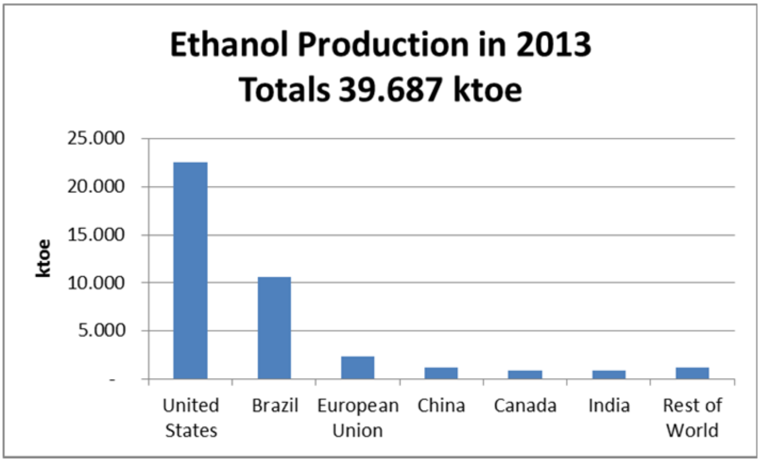


Fig. 4 Global Ethanol Production in 2013 (ktoe)
(Source: RFA analysis of public and private estimates)

The largest biodiesel producers are Europe, the United States, and Brazil (Figure 5). According to the European Biodiesel Board, the production of biodiesel in Europe was 9.189 ktoe in 2013. The National Biodiesel Board reported 6.383 ktoe for the United States, and the Brazilian Bioethanol Science and Technology Laboratory (CTBE) reported 5.850 ktoe for Brazil, both for 2013. Together, these three provided 21.422 ktoe of biodiesel. Other main producers are Argentina and Indonesia.

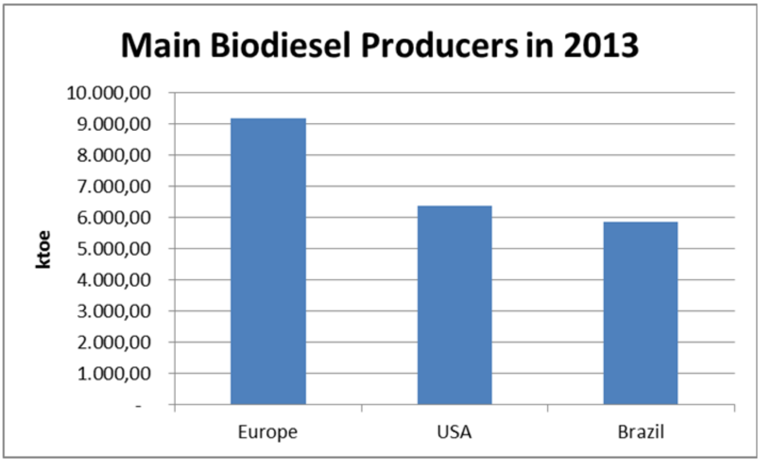


Fig. 5 Main Biodiesel Producers in 2013 (ktoe)
(Sources: European Biodiesel Board, National Biodiesel Board [USA], Ministry of Mines and Energy [Brazil])

Another biofuel that has recently come into the picture is hydrotreated vegetable oil (HVO). Production capacity in 2013 was estimated to be 3.116 ktoe (Figure 6). The two main technology providers for HVO production are Neste Oil (68% of capacity) and Honeywell's UOP/Eni (25% of capacity).

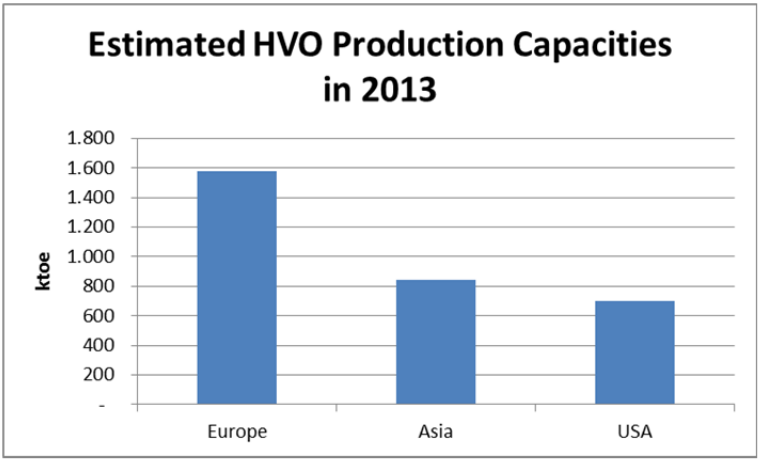


Fig. 6 Estimated HVO Production Capacities in 2013
(Source: Square Commodities)

Production of ethanol from lignocellulosic raw materials, such as straw or corn cobs, is estimated to be around 335 ktoe in 2014. Other advanced biofuels are produced in even lower quantities.

Dedicated alternative fuel vehicle numbers have increased over the past years. Figure 7 shows the development in the United States as an example.

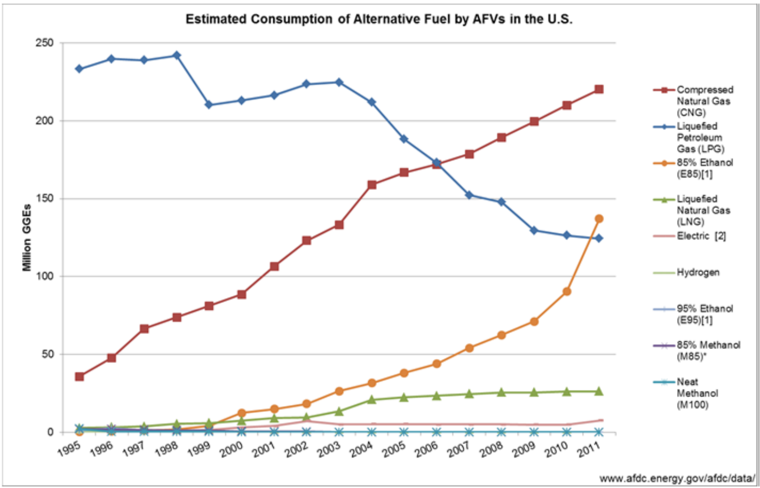


Fig. 7 Estimated Consumption of Alternative Fuel by Alternative Fuel Vehicles in the United States

(Source: EIA's Alternative Fuel Vehicle Data Alternatives to Traditional Transportation Fuels [http://www.eia.gov/renewable/afv/users.cfm#tabs_charts-2])

2.b
Country Reports of AMF TCP Member Countries

Most of the countries participating in the AMF TCP have prepared reports to highlight the production and use of advanced motor fuels in their respective countries, as well as the existing policies associated with those fuels.

Austria

Introduction

Austria is a small, Central European country with a territory of 84,000 km² (8.4 million ha) and a population of 8.6 million, which accounts for 1.7% of the European Union (EU) 28 population (EUROSTAT 2015[1]).

The gross domestic product (GDP) in Austria was worth €337.16 billion[2] in 2015 (0.50% of the world economy). The automobile industry is one of the most important industrial sectors in the country, with a GDP of €35 billion. In particular, it features a strong component supplier industry with global competence in the fields of engine development, lightweight construction, and clean mobility. International companies rely on Austria as a research and development (R&D) location. More than 450,000 employees work in the production and development of drivetrains. Thus, every ninth job is connected to the automotive industry. The development of advanced propulsion systems and their energy carriers has become a key factor in the country's competitive capability in recent years.

In 2014, the final quantity of energy consumed in Austria was about 1,063 petajoules (PJ), which is a decrease from that in 2013 (1.122 PJ).[3] The transport sector with 34% (367 PJ) has the highest share of final energy consumption, followed by the production sector with 30% (315 PJ). This distribution did not change much within the last two decades.

Contrary to general expectations, global growth did not take off in 2014. With 3.4%,[4] the global economy growth remained at about the same level as the two years before. In Austria, the economy grew by just 0.8% in 2015 (0.3% in 2014), according to the Austrian Institute of Economic Research (WIFO). Thus, the last spurt of economic growth was recorded in 2011, which was followed by three sluggish years. Austria had difficulty in joining the successively brighter trend. This was primarily due to low investment on the part of businesses consequent to uncertainties regarding the development of domestic and foreign sales markets, diminished consumption by private households as a result of a moderate increase in real incomes, and a lack of

1 http://ec.europa.eu/eurostat/data/database.
2 http://www.statistik.at/web_de/statistiken/wirtschaft/volkswirtschaftliche_gesamtrechnungen/index.html.
3 http://www.statistik.at/web_de/statistiken/energie_und_umwelt/energie/energiebilanzen/.
4 http://www.statista.com/statistics/273951/growth-of-the-global-gross-domestic-product-gdp/.

any strong foreign trade impetus. Plunging fuel prices slowed down inflation. Inflation (consumer price index) in Austria was 0.9 % in 2015. Housing, catering services, and food were the foremost contributors to inflation, according to the WIFO.

Fuel consumption declined by 2.5% in 2014 for petrol and by 1.5% for diesel over the year. The sale of petrol has been decreasing for years due mostly to a gradual increase in the efficiency of cars, while diesel consumption reflects economic growth to a greater extent (Figure 1).

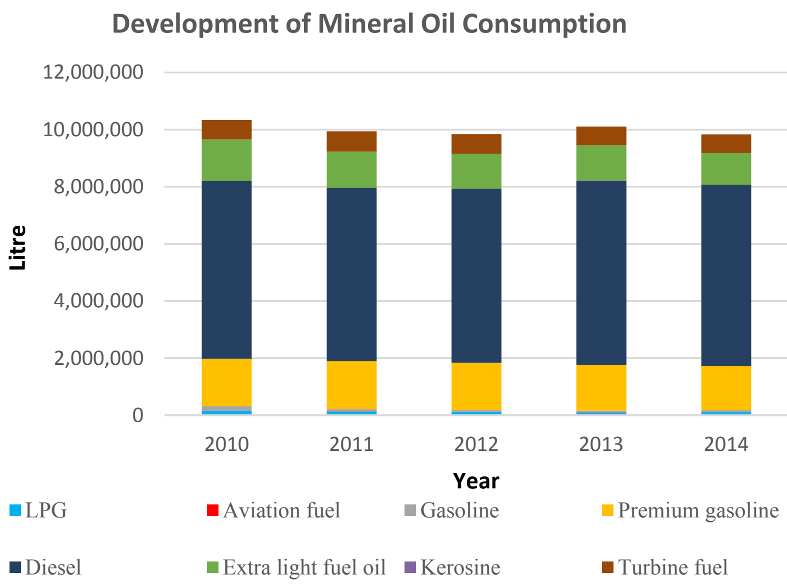


Fig. 1 Consumption of Mineral Oil by Type of Fuel in Austria, 2010–2014
(Source: Mineralölbericht 2015)

In 2014, the overall petroleum consumption, excluding the petrochemical industry, amounted to 10.6 million tons (down 2.75% from 2013). Domestic demand for natural gas shrank by 8% to 7.4 billion cubic meters (m³), the result of a major reduction in electricity generation by gas-fuelled power plants. In Austria, the companies OMV and RAG are prospecting for and extracting crude oil and natural gas in economically relevant quantities at the Vienna Basin, and in the molasses zone of Upper Austria and Salzburg.

Oil production rose slightly in 2014, while natural gas production declined over that in 2013. Specifically, overall annual crude and natural gas liquids (NGL) production increased by 27,678 tons to 944,826 tons (a change of +3% over 2013). Crude production, excluding NGL, accounted for 883,016 tons (a change of +4.1% over 2013). Crude oil imports into Austria — sourced from many countries, including Kazhakstan, Libya and Saudi Arabia — totaled 7.5 million tons in 2014. Altogether, crude for Austria was sourced from 17 countries. Processing is carried out at the OMV refinery in Schwechat, the only refinery in Austria. In 2014, natural gas extraction (including petroleum gas) ran to 1.23 billion m^3, of which 992 million m^3 was natural gas (80%) and 243 million m^3 was petroleum gas. Natural gas imports declined by 10% to 41.8 billion m^3; exports dropped by 15% to 34.4 billion m^3. After balancing imports and exports, 7.5 billion m^3 remained in Austria.

The OMV refinery processed 8.6 million tons of crude in 2014 (8.7 million tons was processed in 2013) at a capacity utilization rate of 90%.
Ten percent of the processed crude came from domestic production and about 90% from abroad. From this input, the refinery produced 39% diesel, 21% petrol, 14% fuel oil (extralight, light, and heavy), 11% petro-chemical basics, 8% jet A-1 fuel, 4% bitumen, and 3% other products. Diesel and petrol had biogenic fuel components admixed to them; altogether, about 234,000 tons of fatty acid ethyl ester (FAME) and 82,000 tons of ethyl alcohol. Total consumption of petroleum products in Austria from liquefied petroleum gas (LPG) to petrol, gas oil, fuel oils and bitumen, but excluding petrochemical basics, was 10.6 million tons in 2014 (down 2.75% from 2013).

Austrians consumed almost 8 million tons of petrol and diesel (down 1.7% from 2013), or about 9.65 billion L (including biogenic components), in 2014. Of these, 2.15 billion L was petrol and 7.5 billion L was diesel (Figure 2). Petrol consumption declined by 2.5% from that in 2013, while diesel recorded a slighter reduction of 1.5%. The amount of extralight fuel oil consumed was 1.1 million tons, or 10.7% less than in 2013 (1.3 billion L). Extralight fuel oil continued its downward trend: sales were down by 17% from those in 2013.

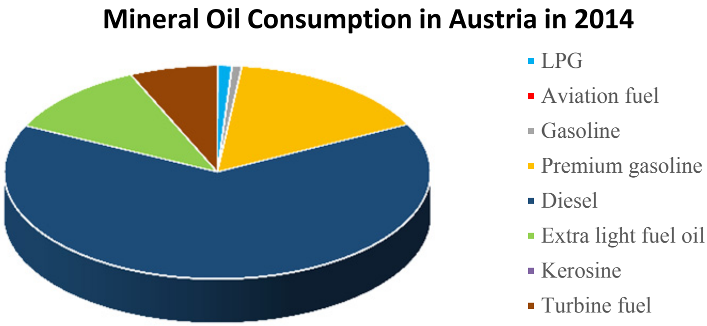


Fig. 2 Austria's Mineral Oil Consumption in 2014
(Source: Mineralölbericht 2015)

Greenhouse Gas Emissions in Austria from 1990 until 2020

In 2013, greenhouse gas (GHG) emissions in Austria amounted to 79.6 million tons of carbon dioxide equivalents (CO_2e). The GHG emissions were thus 0.2% (0.2 million ton) below the levels of 2012. The decreasing trend observed since 2005, the year with the highest emission levels, has thus continued. The decrease is mainly due to the decrease in emissions in the energy production sector. Total emissions in Austria in 2013 were 1.2% above those in 1990. Since 2013, there has been no overall national target for all GHG emissions, since a distinction is made between emissions falling under the emission trading system (for which there is only one European target) and those not included in the system. For Austria, the emission reduction to be achieved by 2020 (relative to 2005) is 16%.

Sector Emissions and Targets of the Austrian Climate Strategy

The main sources of GHG emissions in 2013 were in the following sectors: energy and industry (45.6%), transport (28.0%), buildings (10.5%), and agriculture (9.7%). GHG emissions in the transport sector in 2013 amounted to about 22.3 million tons of CO_2e, an increase of 1.0 million ton (+ 4.7%) compared with 2012. This can be attributed to a sharp increase in fuel sold (+ 4.4%) and a slight decrease in biofuel sold (in its pure form and blended) of 1.4%. Since 1990, a 61% increase in transport emissions has been observed, mainly due to an increase in vehicle kilometers travelled and a strong increase in the net amount of fuel exported in vehicle tanks.[5]

[5] http://www.umweltbundesamt.at/fileadmin/site/publikationen/REP0568.pdf.

Quantities of Biofuels in Austria

Since October 2005, biofuels have been placed on the market in Austria primarily by mixing biodiesel with diesel, and, since October 2007, by mixing bioethanol with fossil petrol grades. By October 1, 2009, the "substitution obligation" to substitute biofuels for other fuels in accordance with fuel regulations had increased to 5.75%. Since the introduction of the Austrian Fuel Regulation in 2012, the country has been obligated to substitute at least a share of 3.4% of fossil gasoline fuels and at least 6.3% of fossil diesel fuels by using biofuels. In addition to blending fuels, municipal and business vehicle fleets are obligated to migrate to pure biofuels or to increase their use of biofuels by more than 40%.

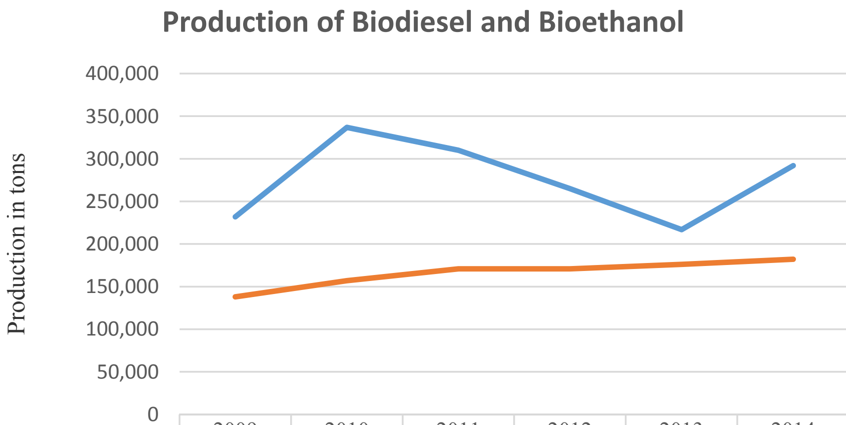
In 2014, a high percentage of fossil fuels had been substituted by the use of biofuels. Compared to 2013, the amount of biofuels used has risen, which can also be attributed to better detection of these fuels in comparison to 2013. Overall, the consumption of gasoline compared to 2013 declined slightly. For 2014, only those amounts of biofuels that were quantified by appropriate sustainability certificates were taken into account. Until mid-2014, there was no legal obligation for verifying the sustainable use of pure biofuels (e.g., 100% biodiesel [B100]) by means of certificates. Therefore, until mid-2014, the amounts of B100 without certificates of proofed sustainability were not taken into account for the calculation of the substitution target. Due to the significantly higher detection of biofuels in pure use, the substitution ratio strongly increased compared to 2013.

In total, about 576,533 tons of biodiesel, 87,872 tons of bioethanol, and 16,028 tons of vegetable oil were used in Austria in 2014.[6] Over the course of calendar year 2014, the required substitution target of 5.75% (measured by energy content) was significantly exceeded; the final was 7.7%. Thus, the substitution rate in comparison to 2013 (6.2%) clearly increased. Austria, together with Germany, France, and Sweden, is still located at the top of the EU 28.

Biodiesel and Bioethanol in Austria

In 2013, 6,107,678 tons of diesel was sold, of which 5,869,745 tons was blended with 7.0 vol% biodiesel (see Figure 3).

[6] https://www.bmlfuw.gv.at/umwelt/luft-laerm-verkehr/verkehr-laermschutz/alternatkraftstoffe/biokraftstoffbericht.html.



	2009	2010	2011	2012	2013	2014
biodiesel	232,000	337,000	310,000	265,000	216,866	292,009
bioethanol	138,000	157,000	171,000	171,000	176,200	182,306

Fig. 3 Trends in the Production of Biodiesel and Bioethanol in Austria, 2009–2014 *(Source: Biokraftstoffbericht 2015)*

In 2014, 292,009 tons of biodiesel were produced in Austria by nine producers. This amount covers about 56% of the domestic consumption of biodiesel, which represents about 12% more than in 2013. In 2013, a total of 1,623,904 tons of gasoline were sold. All gasoline fuels contained at least 4.60 vol% of bioethanol. Therefore, with the addition of the quantities marketed as “superethanol,” 87,872 tons of bioethanol were sold during 2014. The total demand of bioethanol for biofuel substitution can be covered by the production plant at Pischelsdorf (Lower Austria), which can annually process up to 191,000 tons of grain into fuel. In 2014, 182,306 tons of ethanol (about the same as in 2012 and 2013) was processed from using 56% maize and 44% grain.

Vegetable Oil and Biogas in Austria

Biogas produced from biomass is almost entirely used in Austria for the generation of electricity and heat. At the beginning of 2015, Austria contained 384 biogas plants with a maximum capacity of 113.9 MW in total. Currently, 7 biogas plants supply purified biogas directly into the natural gas grid. This enables the transport of the produced biogas over long distances. According to experts, the sum of biogas produced in Austria amounts to between 387,000 and 607,000 tons. In 2014, the total quantity of vegetable oil used for agricultural applications was 769 tons. Furthermore, the quantity of vegetable oil used for highway transport amounted to 15,259 tons.

In addition to blending bioethanol and biodiesel into fossil fuels, Austria tries to force the pure use of BD100, bioethanol (E85 – "superethanol"), and vegetable oil, and a significant increase in the use of biogas. According to the National Energy Strategy, the most effective measure was the introduction of E10 and B10 following the approval of the corresponding European Standard for these fuels. Using biofuels achieved savings of about 1.9 million ton CO_2e in 2014 (1.7 million ton CO_2e in 2013).

Fleet Distribution and Number of Vehicles in Austria

As of December 31, 2015, 8.6 million people were living in Austria, and 4.7 million passenger vehicles were on Austrian roads. According to Statistics Austria, a total of 6,545,878 vehicles (including 4,748,108 passenger cars) were registered in Austria as of December 31, 2015. Newly registered motor vehicles totaled 401,039 in 2015 (a decrease of 1.4% in comparison to 2014). Newly registered passenger cars accounted for 308,555 vehicles — a decrease of 1.7% from 2014.

A study[7] conducted by a Viennese insurance group about consumers' preferences for buying a new car, pointed out that 44% of all car owners plan to buy a new car within the next two years, but 80% of them would not pay more for eco-mobility. The preferences are diesel (50%) and gasoline (30%), followed by hybrid electric vehicles (HEVs) (15%) and battery electric vehicles (BEVs) (5%).

However, an ongoing trend toward advanced propulsion systems can be seen in the numbers of vehicles on Austrian roads in 2015 (Figure 4). The majority of these vehicles are flex-fuel vehicles (FFVs, powered by gasoline or ethanol [E85]) and HEVs (with a gasoline engine and an electric motor). Because of significant progress in the electrification of the drivetrain, it is foreseeable that the number of HEVs will strongly increase within the next years.

In addition to HEVs, BEVs are very popular in Austria. In numbers, these total 15,862 plug-in hybrid electric vehicles (PHEVs), which feature an eco-motor via an internal combustion engine (93% gasoline/7% diesel). The number of BEVs increased to 5,032 in 2015 (3,032 in 2014). The number of vehicles driven by compressed natural gas (CNG) and LPG, (including

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7 https://www.generali.at/fileadmin/media/pdf/Presse/user_upload/20150522_Grafiken_Autostudie_2015.pdf.

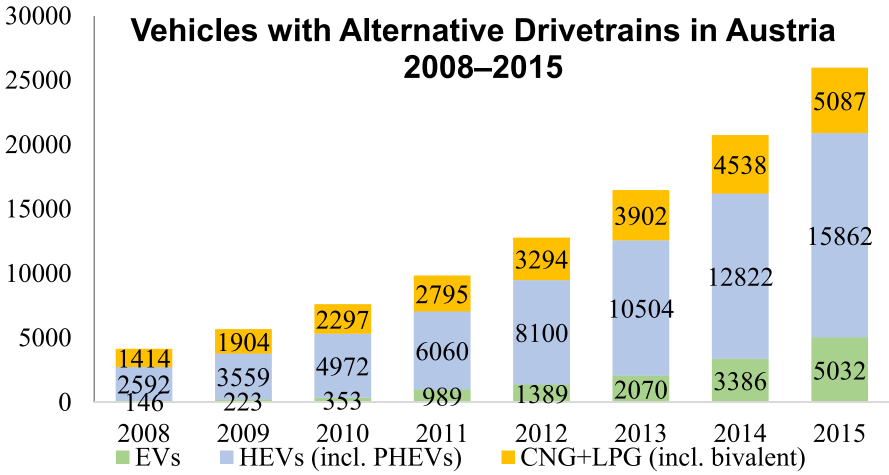

Fig. 4 Trends in Vehicles with Alternative Drivetrains in Austria, 2008–2015

bivalent ones) rose to 5,087. The number of vehicles driven by hydrogen rose to 6.[8]

Taking into account the absolute number of new registrations based on alternative drivetrains (5,901 vehicles), their proportion of total registrations counts for 1.9% of all new registered vehicles. Table 1 shows the development of the fleet distribution of passenger cars by drivetrains between 2013 and 2015.

Development of Filling Stations

Generally, established trends in the saturated domestic petrol market of petrol stations continued in 2015. By the end of 2015, Austria had a total of 2,622 publicly accessible petrol stations. Austria has the lowest prices for diesel and gas fuels in Europe. As an annual average, the price of Eurosuper at the petrol station is €1.35/L; for diesel, the price is €1.3/L. The EU average continued to be clearly above the Austrian average, by €.19/L for Eurosuper and by €.10/L for diesel.

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8 http://www.statistik.at/web_de/statistiken/energie_umwelt_innovation_mobilitaet/verkehr/strasse/kraftfahrzeuge_-_bestand/index.html.

Table 1 Fleet Distribution of Passenger Cars by Drivetrain in Austria, 2013–2015

Drivetrain	2013	2014	2015
Gasoline	1,997,302[a]	2,004,724	2,012,885
Diesel	2,621,133	2,663,063	2,702,922
Electric	2,070	3,386	5,032
LPG	1	1	1
CNG	2,219	2,397	2,475
H_2 (hydrogen)	0	3	6
Bivalent gasoline/ethanol (E85)	6,397	6,380	6,254
Bivalent gasoline/LPG	250	279	311
Bivalent gasoline/CNG	1,432	1,865	2,300
Hybrid gasoline/electric	10,049	12,232	14,785
Hybrid diesel/electric	455	591	1,077
Total	4,641,308	4,694,921	4,748,048

[a] Includes gasoline/ethanol (E85).

Source: Statistics Austria, KFZ Bestand as per end of 2012 through December 31, 2015.[9]

Table 2 shows the number of filling stations in Austria. The number of natural gas filling stations has increased in recent years. Today, there are approximately 171 public filling stations in Austria that have CNG dispensers. In Europe, Austria is currently the champion in terms of number of CNG filing stations per size of the country; it offers the best CNG coverage in Europe.

Policies and Legislation

Since 2011, an increase in the mineral oil tax for conventional vehicles has been in effect — €0.04/L for gasoline and €0.05/L for diesel. As compensation for drivers, the commuting allowance was increased by 10%. In Austria, pure biofuels are exempt from the tax.

Since December 2010, the tax rates have been as follows for 1,000 L of fuel:

- For gasoline containing a minimum of 46 L of biofuel and a maximum of 10 mg/kg of sulphur, the tax is €482 ($540 US); the tax is €515 ($577 US) for gasoline without this.

[9] http://www.statistik.at/web_de/statistiken/energie_umwelt_innovation_mobilitaet/verkehr/index.html.

Table 2 Filling Stations for Alternative Fuels and Conventional Gas Stations in Austria, 2012–2015

Filling Stations	2012	2013	2014	2015
CNG (public)	146	175	174	171
LPG	32	36	38	38
Biogas	1	3	3	3
E85	28	33	33	29
Electric vehicle (public charging station, Level 2 AC)	1,060	1,160	1,449	1,705
H_2 (public station)	1	1	1	3
Vegetable oil	19	20	20	20
Conventional (public)	2,575	2,515	2,640	2,622

Source: Fachverband der Mineralölindustrie, Mineralölbericht 2015[10]

- For diesel containing a minimum of 66 L of biofuel and a maximum of 10 mg/kg of sulphur, the tax is €397 ($444 US); the tax is €425 ($476 US) for diesel without this.

Starting in July 2008, the Normverbrauchsabgabe (NoVA) — a uniquely bonus/malus system for CO_2 emissions — was introduced for taxing the acquisition of new vehicles. As of March 2014, the calculation of the NoVA has been in accordance with the CO_2 emissions of the car. New cars that emit less than 90 g of CO_2/km do not have to pay the NoVA. The excess amount (i.e., amount over 90 g) is divided by 5 and gives the NoVA tax rate. For vehicles with CO_2 emissions above 250 g/km, the NoVA increased by 20€/g of CO_2.

Austria is pushing strongly for eco-mobility. States and communities offer many promotions such as purchase premiums. Many insurance companies provide a discount of 10% to 20% for electric vehicles. For companies, associations, and non-profit organizations, there is support for 30% of the environment-related investment costs for the acquisition and conversion.

Until the end of 2015, vehicles that run on alternative drivetrains (hybrids, those using fuels E85, CNG, LPG, or H_2), receive a tax reduction of €600 ($639 US). Since January 1, 2013, HEVs and range extender vehicles have been subject to the motor-dependent insurance tax, but only for the engine

[10] https://www.wko.at/Content.Node/branchen/w/Mineraloelindustrie/fachverband-mineraloelindustrie-mineraloelbericht-2014.pdf.

power of the combustion engine; BEVs are exempt from the motor-dependent insurance tax.

Federal Funds and Supporting Programs

Pushing advanced propulsion systems forward in Austria is done by exposure through promotions and funding programs, as well as increasing the attractiveness of eco-mobility by regulatory measures.

Each year, Austria is obligated to record all energy-related research, development, and first-of-its-kind demonstration projects and supporting programs financed by public funds. The results of this annual survey emphasize the importance of HEVs and EVs for Austria.
Since 2007, the Austrian government has more than tripled public funding in the energy research, development and demonstration (RD&D) sectors, adopted a new energy research strategy, and launched several priority programs. In 2014, Austria's public expenditures for energy-related R&D amounted to €143.1 million; an increase of 14.9% over expenditures in 2013 and representing an all-time high (Figure 5). The research areas of energy efficiency (43.1%), smart grids and storage (24.7%), and renewables (22.7%) define the priorities of publicly financed energy research within Austria.

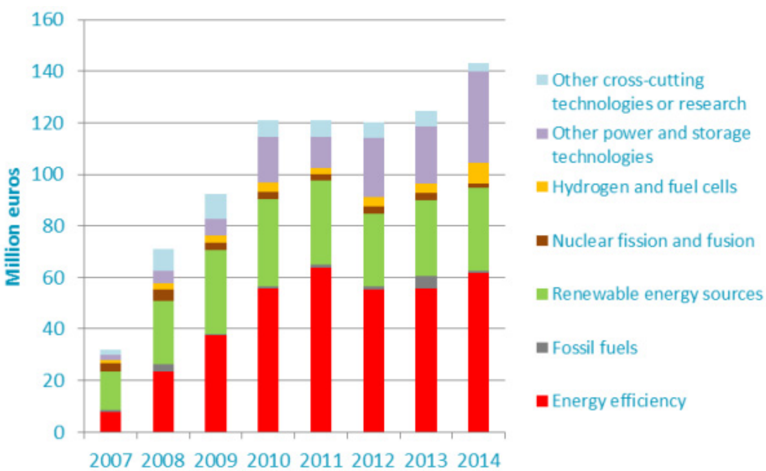

Fig. 5 Austria's Public Expenditure for Energy-related R&D in 2014
(Source: BMVIT 2015)[11]

[11] http://www.nachhaltigwirtschaften.at/iea_pdf/201512_energieforschungserhebung_2014_praesentation_en.pdf.

The subcategories with the highest expenditures in 2014 (shown in millions of euros) were electricity transmission and distribution (€21.5), efficient residential and commercial buildings (€17.8), communities and smart cities (€13.4), photovoltaics (€11.5), energy storage (€11.5), biofuels (€9.4), hybrid and electric vehicles (€8.5), energy efficiency in industry (€8.1), solar heating and cooling (€5.1), and fuel cells (€5.1).

About 80% of these expenditures were provided by governmental authorities; the remaining part came from publicly funded research institutions and universities provided in equity capital. Seventy-one percent of the funds were used for applied research, and 17% for experimental development. Expenditures for first-of-its-kind demonstration amounted to 7% in 2014. Basic research represented a small, yet very important, portion of 5%. A strong decrease in expenditures to a moderate level can be seen in terms of fossil fuels, where €616,533 were used for this area in 2014 (−87.7% in comparison to 2013).

With €9.4 million in 2014, biofuels funding volume increased by €1 million in comparison to 2013. The high share of "unallocated," which can be seen in Figure 6, came basically due to many integrated projects and financing of a competence center Bioenergy 2020+.

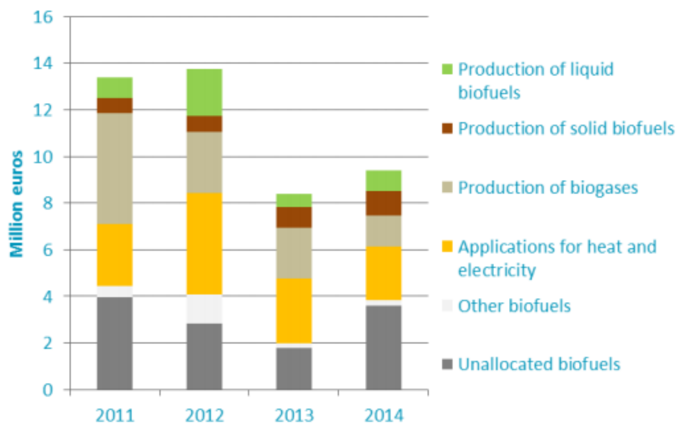

Fig. 6 Development of Energy Research Public Expenditure – Bioenergy, 2011–2014
(Source: BMVIT 2015)[12]

[12] ibid.

Austria has some programs that fund and support the implementation of advanced fuels. One launched in 2004, called “klima:aktiv Mobil,” is Austria’s action program for mobility management to reduce CO_2 emissions and to promote environmentally friendly and energy-efficient mobility. The program provides free advice and financial support to help businesses, fleet operators, and property developers, as well as cities, municipalities, regions, and tourism operators to develop and implement sustainable mobility projects and transport initiatives.

In order to develop a sustainable energy system, the “e!MISSION.at” program was funded in 2012 by the Climate and Energy Fund. It supports innovations that make a significant contribution toward protecting the climate and increasing efficiency. The focus of funding is on energy efficiency, renewable sources of energy, smart energy systems, and eco-mobility.

In 2006, the Federal Ministry for Transport Innovation and Technology (abbreviated BMVIT) established the Austrian Association for Advanced Propulsion Systems (A3PS) as a strategic public-private partnership for close cooperation among industry, research institutions, and the Ministry, with the goal of developing and launching alternative propulsion systems and fuels.

“Mobility of the Future,”[13] Austria’s national transportation research funding program (2012–2020), was developed and adopted by BMVIT. It is a mission-oriented R&D program to help Austria create a transport system designed to meet future mobility and social challenges by identifying and refining middle-to long-term technological improvements. It includes four complementary areas in which different research themes are addressed: passenger transport; transport infrastructure; vehicle technologies, and freight transport.

A great deal of R&D took place in Austria in 2015. The following are excerpts from ongoing R&D:

- *Fuel4Me*.[14] This project aims at developing and demonstrating an integrated and sustainable process for continuous biofuel production from microalgae, thereby making the second generation of biofuels competitive alternatives to fossil fuels. One of the largest nonuniversity research institutions in Austria — JOANNEUM RESEARCH Forschungsgesellschaft mbH — is performing the sustainability

[13] http://www.bmvit.gv.at/en/service/publications/downloads/mobility_of_the_future.pdf.
[14] http://www.fuel4me.eu/.

assessment of the Fuel4Me project, as well as participating in the communication and dissemination of project results.

- *Flex fuel reformer for fuel cell systems*.[15,16] This Technical University of Graz project examines the decentralized production of high purity hydrogen from locally available hydrocarbons by using methane and biogas. Output of this project is a decentralized small-scale production unit for pressurized pure hydrogen based on different renewable hydrocarbons.
- *CO_2 use.* Carbon dioxide, which is purified from flue gas, is used for the cultivation of phototrophic microorganisms (e.g., microalgae). From the produced biomass, the product (e.g., an alternative for fossil plastics) will be isolated and the residual biomass will enter a biogas process. Via anaerobic digestion, energy (biogas) is produced and the nutrients will be made available. These nutrients are recirculated for algae cultivation. This national project is led by EVN AG (an Austrian-based producer of electricity).
- *Winddiesel.* Funded by the Austrian Climate and Energy Fund, this project is the first leap to convert wind power to diesel. For this purpose, wind power is converted by electrolysis to hydrogen; the hydrogen is then added to synthesis gas from a biomass gasifier. The primary goal of the project is to develop a slurry reactor that is suitable to be operated between 30% and 100% load. Via change of the syngas composition of an attached gasification plant, hydrogen generated from excess wind power plants can be injected and more Fischer-Tropsch (FT) diesel can be produced. Additional R&D is under way in parallel to this design in order to minimize the development risk essential.
- *GreenFly.* This project is funded by BMVIT under the Austrian aviation program TAKE-OFF. In the long term, the aviation industry will need liquid hydrocarbons as fuel. One technology to produce renewable kerosene is the FT technology in which the waxes are converted over hydroprocessing into kerosene and diesel. The goal of this project is to develop a CO2-neutral engine for small airplanes and unmanned aerial vehicles (UAVs) based on an existing rotary engine and to supply this engine with synthetic kerosene from biomass.
- *Barrel/day.* Funded by the Austrian COMET program within Bioenergy 2020+, Technical University Vienna and Bioenergy2020+ have been working since 2004 on the FT synthesis, using syngas from dual fluidized bed steam gasification. In this project, the FT slurry reactor is scaled up from lab scale to 1 bbl/day, and long-term tests using syngas

[15] http://www.h2fc-fair.com/hm14/images/tech-forum-presentations/2014-04-10-1030.pdf.

[16] http://www.tugraz.at/en/institute/ceet/forschung/fuel-cell-research/.

from wood are performed. The main goal is to get enough data so that at the next step, a demonstration plant can be realized.

- *Hydrogen from biomass.* This project is funded by the Austrian COMET program within Bioenergy 2020+. Renewable hydrogen can be produced by several pathways, but biomass gasification is at the moment one of the most economic ones. Bioenergy 2020+, together with Technical University Vienna, is investigating two different approaches for hydrogen production from wood. One is based on polygeneration, where only a slip stream of syngas is converted to hydrogen and the rest of the syngas is used for heat and power production. The polygeneration concept is an excellent option for producing decentralized hydrogen on demand. The second approach is the maximization of hydrogen for large-scale applications (e.g., refineries). Both pathways are being investigated experimentally and by simulation approaches.

Austria is quite involved in the development and implementation of advanced biofuels. Austrian companies working in that field include:

- Bio Energy International AG (BDI) has again received several orders for biodiesel plants.
- Vogelbusch delivers distillation technology for ethanol plants (Inbicon).
- Lenzing AG is a leader in fiber technologies.
- Repotec provides plants for gasification (GoBiGas).
- Agrana Group, a food company, produces ethanol fuel.
- Andritz supplies treatment plants for the digestion of cellulose (POET, Biochemtex).
- Ecoduna offers a technology for algae cultivation.

Implementation: Use of Advanced Motor Fuels

Two of the main aims of Austrian energy policy have been to reduce the country’s dependence on energy imports and to strengthen the security of its supply. The share of renewable energy production increased from about 69% in 2000 to about 78% in 2014, of which primary energy production from renewables other than biomass and from biomass and biogenic waste are distributed nearly equally. Bioenergy and waste now provide about 20% of the total prime energy supply, an exceptionally high share by international comparison.

In 2014, alternative fuels used in the transportation sector represented approximately 9.02% (8.35% in 2013) of the fuel used, as shown in Figure 7. The predominant fuel consumed was diesel blended with 7.0 vol% biodiesel, followed by gasoline with 4.60 vol% bioethanol. The number of

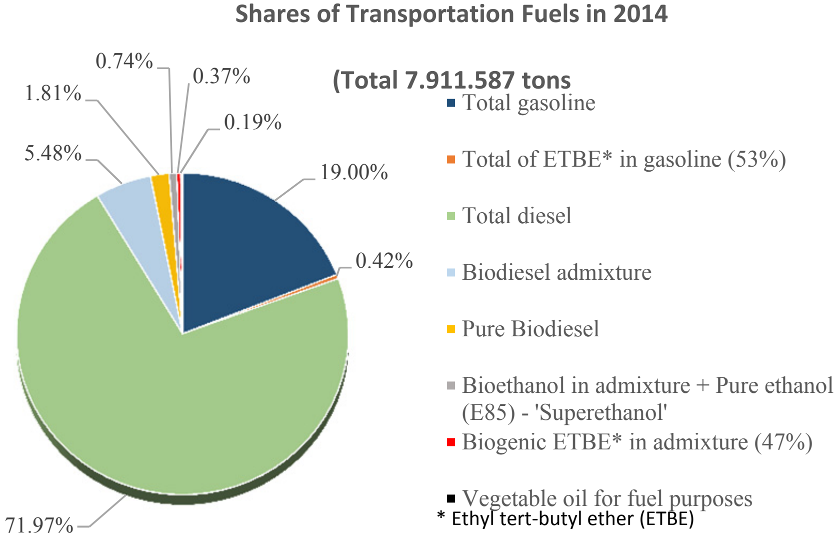

Fig. 7 Shares of Transportation Fuels in Austria in 2014
(Source: Lebensministerium 2015)[17]

registered vehicles with alternative drivetrains increased in 2014. As shown in Table 2, the number of alternative fuel stations is still increasing, with CNG and electrical charging stations being notable.

Outlook

Austria has more than tripled public funding for energy RD&D since 2007, and the government continues to try to increase energy RD&D funding. The country aims to enhance its domestic energy security; the International Energy Agency (IEA) says that it should increase its energy efficiency and produce more natural gas domestically. In a report *Energy Policies of IEA Countries: Austria 2014 Review*,[18] the IEA encourages Austria to start shale gas exploration activities to increase its energy security and reduce its dependence on Russian imports. The introduction of a law in Austria obliges companies to have a detailed environmental inspection before each planned project, but this raises costs. The Austrian energy group OMV has abandoned plans to produce shale gas in Austria because addressing all

[17] https://www.bmlfuw.gv.at/umwelt/luft-laerm-verkehr/verkehr-laermschutz/alternatkraftstoffe/biokraftstoffbericht.html.
[18] http://www.iea.org/Textbase/npsum/austria2014sum.pdf.

environmental concerns related to fracking makes it not viable economically.

Additional References

Relevant institutions and programs:

- Austrian Ministry for Transport, Innovation and Technology, http://www.bmvit.gv.at/
- Statistic Austria, www.statistik.at
- The Austrian Federal Ministry of Agriculture, Forestry, Environment and Water Management, https://www.bmlfuw.gv.at/en.html

Benefits of Participation in the AMF TCP

Austria benefits in a number of ways by participating in the AMF TCP. Membership offers great opportunities with regard to international contacts and the exchange of knowledge, information, and results that can support domestic authorities. Participating in this TCP gives Austria wider and easier access to information and analyses. Thus, it helps to raise awareness of advanced motor fuel issues and areas that need further development.

Canada

Introduction

Canada is a vast northern nation with a relatively small population, a developed economy, and a large natural resource base. Combined, these factors have helped to shape Canada's energy production and consumption patterns. Climate and geography play a key role in Canada's relatively high energy intensity. A cold and variable northern climate means more energy is consumed heating homes and businesses. Similarly, goods and people often travel farther to reach their destinations due to Canada's large land mass. This requires more energy use compared to geographically smaller nations.[19]

There are more than 1.3 million lane-kilometers (two-lane equivalent) of public road in Canada. Approximately 34% of the road network is paved, while 66% is unpaved. In 2013, the National Highway System included more than 38,000 lane-kilometers. In 2013, more than 23 million road motor vehicles were registered in Canada, up 2.9% from 2012. A majority (92.4%) were vehicles weighing less than 4,500 kilograms (kg) (mainly passenger automobiles, pickups, sport utility vehicles, and minivans), while 4.3% were medium- and heavy-duty trucks weighing 4,500 kg or more, and 3.3% were other vehicles such as buses, motorcycles, and mopeds.[20]

In 2014, oil sands production was 2.2 million barrels/day compared to 1.6 million barrels/day of conventional oil. Canada has the third largest oil reserve in the world behind Venezuela and Saudi Arabia. Oil sands represent 97% of Canada's proven reserves.[21]

Canada produced an average of 14.7 billion cubic feet/day of marketable natural gas in 2014.[22] Remaining marketable Canadian natural gas resources as of December 2014 were 1,087 trillion cubic feet.[23]

Table 1 shows the Canadian supply of and demand for ethanol and biodiesel in 2014.

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19 https://www.neb-one.gc.ca/nrg/ntgrtd/ftr/2016/index-eng.html.
20 https://www.tc.gc.ca/media/documents/policy/2014_TC_Annual_Report_Overview-EN.pdf.
21 http://www.nrcan.gc.ca/publications/key-facts/16013.
22 https://www.neb-one.gc.ca/nrg/sttstc/ntrlgs/rprt/ntrlgsdlvrblty20152017/ntrlgsdlvrblty20152017-eng.html.
23 http://www.neb-one.gc.ca/nrg/ntgrtd/ftr/2016/index-eng.html.

Table 1 Canadian Supply of and Demand for Biofuels (in millions of liters)[24]

Parameter	Ethanol (2014)	Biodiesel (2014)
Canadian production	1,731	Not available
Imports	1,138	506
Exports	Not available	123
Domestic use	2,869	Not available

Policies and Legislation

Renewable Fuels Regulations

The *Renewable Fuels Regulations* (SOR/2010-189), published on September 1, 2010, in the *Canada Gazette,* Part II, require fuel producers and importers to have an average renewable content of at least 5% based on the volume of gasoline that they produce or import commencing December 15, 2010. These regulations include provisions that govern the creation of compliance units, allow trading of these units among participants, and also require recordkeeping and reporting to ensure compliance.

The regulations also require fuel producers and importers of diesel fuel and heating distillate oil to have an average annual renewable fuel content equal to at least 2% of the volume of diesel fuel and heating distillate oil that they produce and import commencing July 1, 2011. The *2013 Regulations Amending the Renewable Fuels Regulations (SOR/2013-187)* introduced a national exclusion of heating distillate oil volumes for space heating purposes as of January 1, 2013.[25]

Table 2 provides an overview of federal and provincial biofuels regulations.

24 http://www.nrcan.gc.ca/sites/www.nrcan.gc.ca/files/energy/files/pdf/EnergyFactBook2015-Eng_Web.pdf
25 http://www.ec.gc.ca/energie-energy/default.asp?lang=En&n=0AA71ED2-1.

Table 2 Federal and Provincial Regulations on Biofuels[26]

Location	Percentage of Renewable Fuels Content	
	Gasoline	Diesel
Canada	5	2
British Columbia	5	4
Alberta	5	2
Saskatchewan	7.5	2
Manitoba	8.5	2
Ontario	5	2
Quebec	5 (target only)	0

Renewable-Fuels-Related Standards

The Canadian General Standards Board (CGSB) is the responsible authority for developing fuel quality standards, including standards for renewable fuel quality through a consensus process with the public and private sectors. Table 3 shows the biofuel-related standards for transportation.[27]

Table 3 CGSB Renewable Fuel Quality Related Standards[27]

Fuel Standard	Number
Oxygenated Automotive Gasoline Containing Ethanol (E1–E10)	CAN/CGSB 3.511
Automotive Ethanol Fuel (E50–E85)	CAN/CGSB 3.512
Denatured Fuel Ethanol for Use in Automotive Spark Ignition Fuels	CAN/CGSB 3.516
Automotive Diesel Fuel Containing Low Levels of Biodiesel (B1–B5)	CAN/CGSB 3.520
Diesel Fuel Containing Biodiesel (B6–B20)	CAN/CGSB 3.522
Biodiesel (B100) for Blending in Middle Distillate Fuels	CAN/CGSB 3.524

Passenger Automobile and Light Truck Greenhouse Gas Emission Regulations

In October 2010, the Government of Canada released the final *Passenger Automobile and Light Truck Greenhouse Gas Emission Regulations*, which prescribe progressively more stringent annual emission standards for new vehicles of model years 2011 to 2016. The Government also published

26 http://www.nrcan.gc.ca/sites/www.nrcan.gc.ca/files/energy/files/pdf/EnergyFactBook2015-Eng_Web.pdf.
27 http://www.tpsgc-pwgsc.gc.ca/ongc-cgsb/index-eng.html.

regulations in 2014 for the second phase of action on light-duty vehicles (LDVs), which contain increasingly stringent greenhouse gas (GHG) emissions standards for LDVs of model years 2017 to 2025.

Under both phases of LDV regulations, spanning model years 2011 to 2025, the fuel efficiency of new cars will increase by 41% as compared with model year 2010 (and 50% compared with the 2008 model year), and the fuel efficiency of new passenger light trucks will increase by 37%. The sales-weighted fuel efficiency of new cars is projected to improve from 8.6 liters per kilometer (L/100 km) in 2010 to 6.4 L/100 km in 2020 and to 5.1 L/100 km by 2025. The sales-weighted fuel efficiency of new passenger light trucks is projected to improve from 12.0 L/100 km in 2010 to 9.1 L/100 km in 2020 and to 7.6 L/100 km by 2025.[28]

Heavy-duty Vehicle and Engine Greenhouse Gas Emission Regulations

The objective of the *Heavy-duty Vehicle and Engine Greenhouse Gas Emission Regulations* is to reduce GHG emissions by establishing mandatory GHG emission standards for new on-road heavy-duty vehicles and engines that are aligned with U.S. national standards. The development of common North American standards will provide a level playing field that will lead North American manufacturers to produce more advanced vehicles, which enhances their competitiveness. The regulations will apply to companies manufacturing and importing new on-road heavy-duty vehicles and engines of the 2014 and later model years for the purpose of sale in Canada. These include the whole range of on-road heavy-duty full-size pickup trucks, vans, tractors, and buses, as well as a wide variety of vocational vehicles such as freight, delivery, service, cement, and dump trucks. The regulations will also include provisions that establish compliance flexibilities, which include a system for generating, banking, and trading emission credits. The regulations will include additional credits for hybrid vehicles and electric vehicles, as well as for innovative technologies to reduce GHG emissions. The regulations will include further flexibilities for companies to use a phased-in approach for model year 2014 through 2016 tractors and vocational vehicles. Companies will also be required to submit annual reports and maintain records relating to the GHG emission performance of their vehicles and fleets.[29] The regulations for heavy-duty vehicles will improve the average fuel efficiency of trucks from 2.3 L/100 tonne-km in 2012 to 2.2 L/100 tonne-km by 2020.[30]

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[28] https://ec.gc.ca/ges-ghg/default.asp?lang=En&n=E0533893-1.
[29] http://www.ec.gc.ca/lcpe-cepa/eng/regulations/detailReg.cfm?intReg=214.
[30] https://ec.gc.ca/ges-ghg/default.asp?lang=En&n=E0533893-1.

Sulphur in Gasoline Regulations

The *Sulphur in Gasoline Regulations*, published on June 23, 1999, limit sulphur in gasoline to an annual average level of 30 milligrams per kilogram (mg/kg), or 30 parts per million (ppm), with a never-to-be-exceeded limit of 80 mg/kg, beginning in 2005. The regulations also include a simpler default option of a 40-mg/kg per batch limit, with minimal administrative requirements. These regulations have reduced the sulphur content of gasoline by more than 90% from 1999 levels. On July 29, 2015, the *Regulations Amending the Sulphur in Gasoline Regulations* were published. These amendments limit the allowable sulphur content of gasoline to an annual average level of 10 mg/kg, with a never-to-be-exceeded limit of 80 mg/kg, beginning in 2017. The default per batch limit remains at the current sulphur level of 40 mg/kg until the end of 2016, and will be reduced to 14 mg/kg during the 2017–2019 period. For 2020 and beyond, the default per batch limit will be 12 mg/kg.[31]

Implementation: Use of Advanced Motor Fuels

The Government of Canada has committed to developing increasingly stringent GHG emissions regulations for passenger cars and trucks, in alignment with the United States. In order to meet these standards, manufacturers will introduce a wide range of technology innovations to improve vehicle efficiency over the next several years.

ecoTECHNOLOGY for Vehicles Program

Transport Canada's ecoTECHNOLOGY for Vehicles Program (eTV) conducts in-depth safety, environmental, and performance testing on a range of new and emerging advanced vehicle technologies for passenger cars and heavy-duty trucks. The eTV Program will help ensure that Canada is ready for new and emerging advanced vehicle technologies, and that Canadians can benefit from these new innovations. To achieve this, eTV is proactively testing and evaluating a range of new advanced vehicle technologies. Results are helping to inform the development of environmental and safety regulations to ensure that these technologies are introduced in Canada in a safe and timely manner. The eTV Program also supports the Canada–U.S. Regulatory Cooperation Council. Test results will help align vehicle regulations throughout North America, in order to reduce and prevent barriers to cross-border trade, lower costs for businesses and consumers, and support jobs and growth.[32]

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31 https://www.ec.gc.ca/energie-energy/default.asp?lang=En&n=BEA13229-1.

32 https://www.tc.gc.ca/eng/programs/environment-etv-menu-eng-118.htm.

Program of Energy Research and Development

The Program of Energy Research and Development (PERD) is a federal, interdepartmental program operated by Natural Resources Canada. PERD funds research and development (R&D) designed to ensure a sustainable energy future for Canada in the best interests of both the economy and environment. It directly supports energy R&D conducted in Canada by the federal government and is concerned with all aspects of energy supply and use. Part of PERD consists of coordinated research activities designed to extend key areas of knowledge and technology that will help reduce both the carbon footprint of fuels and vehicle emissions from transportation sources in Canada.[33]

Outlook

As depicted in Table 4, the transportation sector comprises several distinct subsectors: passenger, freight, air, and others (e.g., rail and marine). Each subsector exhibits different trends during the projected period. For example, emissions from passenger transportation are projected to decrease by 8 megatonnes (Mt) between 2005 and 2020, while those for ground freight, off-road, and other vehicles are projected to grow by 10 Mt over the same time period due to anticipated economic growth. As a result, net emissions remain essentially stable over the period. Although absolute emissions are expected to grow in the freight subsector due to expected economic growth, emissions are expected to decrease relative to business-as-usual levels as a result of various federal, provincial, and territorial programs.[34]

Table 4 Transportation: Emissions (Mt CO_2 equivalent)[34]

Transportation Subsector	2005	2012	2020	Change (2005 to 2020)
Passenger Transport	96	94	88	−8
Cars, trucks, and motorcycles	87	85	78	−9
Bus, rail, and domestic aviation	9	8	9	0
Freight Transport	57	61	67	10
Heavy-duty trucks, rail	49	54	59	10
Domestic aviation and marine	8	7	8	0
Other: Recreational, commercial, and residential	14	11	12	−2
Total	168	165	167	−1

33 http://www.nrcan.gc.ca/energy/science/programs-funding/1603.
34 https://ec.gc.ca/ges-ghg/default.asp?lang=En&n=E0533893-1.

Passenger energy demand declines over the projection period, largely due to increasing fuel economy associated with Canada's *Passenger Automobile and Light Truck Greenhouse Gas Emission Regulations*. Since passenger travel uses the majority of gasoline in the transportation sector, this leads to a decrease in the fuel share of gasoline demand, as shown in Figure 1.[35]

Freight demand is driven by growth in the goods-producing industries and increases at a slower rate than it did from 1990 to 2013. This is from fuel economy gains, associated with Canada's *Heavy Duty Vehicle and Engine Greenhouse Gas Emission Regulations*, and somewhat slower economic growth over the projection period. The increase in freight share leads to an increase in the fuel share of diesel.[35]

Natural gas use in the transportation sector is another emerging trend. Natural gas vehicles (NGVs) use either compressed natural gas (CNG) or liquefied natural gas (LNG). In the longer term, the projections include a moderate penetration of NGVs in both forms. The outlook also accounts for the recent adoption of LNG use by ferries, and assumes moderate levels of LNG adoption by marine tankers and rail locomotives. In the reference case, freight natural gas use reaches 151 petajoules (PJ) in 2040, representing 10% of total freight demand.[35]

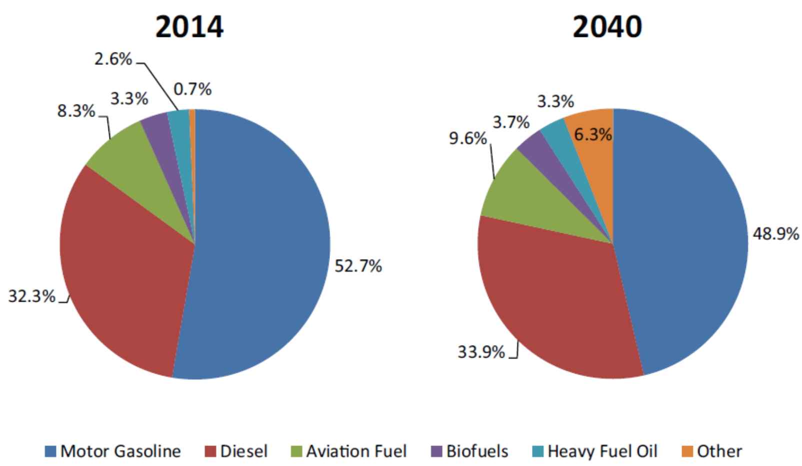

Fig. 1 Transportation Energy Fuel Share of Demand, Reference Case (Other includes natural gas, electricity, lubricants, and propane)[35]

[35] http://www.neb-one.gc.ca/nrg/ntgrtd/ftr/2016/index-eng.html.

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- National Research Council Canada, Industrial Research Assistance Program, http://www.nrc-cnrc.gc.ca/eng/irap/index.html
- Natural Resources Canada, the ecoENERGY Innovation Initiative, http://www.nrcan.gc.ca/energy/funding/current-funding-programs/eii/4985
- Natural Sciences and Engineering Research Council of Canada, http://www.nserc-crsng.gc.ca/index_eng.asp
- Sustainable Development Canada, SD Natural Gas Fund, https://www.sdtc.ca/en/apply/sd-natural-gas-fund

Chile

Introduction

Chile has considerable potential for implementing energy efficiency measures that would improve the safety of the country's energy supply and achieve significant economic, social, and environmental impacts.

The transport sector represents almost one-third of Chile's final energy consumption, of which 82.6% is due to land transport. Of this energy, 99% is derived from oil, resulting in a high dependence on this energy source, which is mostly imported. Chile produces only 2% of the oil it consumes.

Currently, the Ministry of Energy is working with the Ministry of Transport and Telecommunications to improve energy efficiency gradually in the transport sector. Evidence of this can be seen at the beginning of 2015, when a collaboration agreement between the Ministry of Energy and the Ministry of Transport and Telecommunications was established. The main objective of the work involving the two ministries is to advance legislation, policies, and programs to improve the energy efficiency of the country's vehicle fleet. Together, they will address labelling to show fuel consumption and carbon dioxide (CO_2) values in light-duty and medium-duty vehicles, and buses. They will establish energy consumption standards for light-duty and medium-duty vehicles as a key action to reach the national target of 20% energy savings by 2025.

During 2015, the Secretary of Energy of Chile joined the IEA-AMF, which will allow Chile to work on projects for energy efficiency in the transport sector with international support.

Policies and Legislation: Progress in Transport Regulation

Advances in the development of new energy efficiency regulations during 2015 focused on the followings areas:

- Extension for other vehicle categories of the labeling of vehicular energy efficiency.

The current regulation of energy consumption (Supreme Decree No. 61 of June 2012) includes only light-duty, diesel, and gasoline vehicles up to 2,700 kilograms (kg) to be used for passenger transport. For this reason, during 2015, a regulation for the expansion of vehicular labeling was established, in agreement with the industry. This new regulation will include all light-duty and medium-duty vehicles carrying cargo and passengers using diesel fuel, gasoline, or hybrid or electric, weighing less than 3,860 kg. This regulation is undergoing revisions and is expected to be issued and published during 2016.

- Advances in obtaining better energy efficiency in Trans-Santiago buses.

Currently undergoing public consultation are regulations updating the plan to reduce pollution gas emissions in the metropolitan area, which will require public transportation buses operating in Santiago to have technology to meet Euro 6 standards in early September 2017.

In order to validate a specific drive cycle for measuring fuel consumption of the new buses that will be in the passenger transport system in Santiago, "Trans-Santiago Buses," the Ministry of Energy and the Ministry of Transport and Telecommunications, and the Mario Molina Center of Chile have been working on obtaining parameters to develop a drive cycle dynamometer chassis to measure these buses, now with the support of the VTT Technical Research Centre of Finland and AMF programs through Annex 53, Sustainable Bus Systems. The main objective is to develop a methodology for setting requirements for clean and energy-efficient buses for use in the tendering process (a process by which the government invites bids for large projects that must be submitted within a finite deadline) for public transport operators in Santiago.

- Draft Energy Efficiency Act

This is currently under development. It is expected that the Act will be delivered to Congress to initiate official proceedings for approval in the second half of 2016. The main target in the transport sector is to improve the energy efficiency of Chile's vehicle fleet in a gradual way.

- Emission and fuel consumption tax for the vehicle market in Chile.

The "green tax" law has been in effect since January 1, 2015, for new purchases of light-duty and medium-duty vehicles. The tax is calculated based on a vehicle's efficiency and emissions of nitrogen oxides (NOx), and it complements the labelling system. Exemptions from this tax include purchases of light-duty trucks and vans for commercial and working purposes. The tax for fuel economy is relatively small for vehicles with a fuel economy of more than approximately 15 kilometers per liter (15 km/L); however, it becomes more significant as fuel economy goes below 15 km/L.

The tax is showing impacts on diesel vehicles sales, with a 45% drop in January of 2015 in comparison with the same month in 2014.

Implementation: Use of Advanced Motor Fuels

Electric Taxis in Santiago
Chile is making a great effort to introduce electric mobility to Santiago. In 2014, the Ministry of Transport and Telecommunications started a new tendering process for taxis in the metropolitan area. To encourage the purchase, the government subsidizes one-fifth of the electric car's value. Since December 2015, the first electric taxis (3) are being driven through the streets of Santiago. These cars are from green tech company BYD's factory. They can accommodate five people, have a range of 250 km, and are 100% electric. Total charge takes around 4 hours. It is expected that there will be 68 electric taxis in Santiago in the next 3 to 4 years.

Government-Provided Incentives for Taxis That Comply with Energy Efficiency Requirements
In June 2015, the Ministry of Transport and Telecommunications established a special program to subsidize collective taxis. Collective taxis, or group taxis, are shared by four persons. Owners of collective taxis can apply for this program if their vehicle is at least 4 years old. In addition, the vehicle must have technology improvements in fuel economy, safety, and emissions.

Research

Study of Health and Environmental Impacts of Exhaust from Biofuels
During 2014 and 2015, the Ministry of Transport and Telecommunications, through the Center for Vehicle Control and Certification (3CV Center), together with Centro Mario Molina Chile and the Harvard School of Public Health, developed a study to advance the current understanding of the health and environmental impacts of biofuels compared with traditional petroleum fuels. The study was funded with a grant from Interamerican Developing Bank as part of the development of its new Climate Change Strategy. The Bank has identified sustainable biofuels as a priority area.

The study examined the health effects of exposure to ambient vehicular exhaust and systematically investigates the biological outcomes of exposure to exhaust fumes from vehicles burning different fuels. An objective of the study was to determine the toxicity on the pulmonary and cardiovascular system resulting from exposure to primary and secondary particles formed from vehicular combustion of various formulations of biofuels.

Main activities were as follows:

- *Testing of each of the specific hypotheses by generating fresh and photochemically aged vehicle exhaust from a variety of different fuels.* Using the chassis dynamometer and emissions testing equipment, 3CV Center generated fresh exhaust from vehicles fuelled with different blends of gasoline and biofuels. Exhaust emission was irradiated in a photochemical chamber to simulate atmospheric aging of vehicle emissions and the formation of secondary organic aerosol (Figure 1).
- *Characterization of the physicochemical properties of primary and secondary particles.* Particle exposures were characterized using integrated measurement of particulate matter (PM), trace elements, elemental carbon/organic carbon (EC/OC), water soluble OC, and some specific organic species (polycyclic aromatic hydrocarbons [PAHs], hopanes, and stearanes).
- *Exposure of an animal model to well-characterized PM.* A toxicity test was performed in Boston. Particulates of the various formulations collected on filters in Chile were extracted, dispersed, and insufflated in rats.
- *Assessment of biological effects.* In vivo chemiluminescence was performed on the rats. The lung and the heart were analyzed in order to assess the response of PM exposure.

Fig. 1 Chamber for Photochemical Aging of Vehicle Primary Emission

The most important findings of the Health and Environmental Impacts of Gasoline/Biofuels blends are the following:

- All gasoline-ethanol formulations generate particles that are harmful to health.
- Toxicity for primary and secondary particles is similar. This is an important finding, because until now the focus of regulation has been on primary emissions.
- Brazilian BR22 blend generates more ozone and secondary particles, in number and mass.
- U.S. E85 and E10 blends generate secondary particles with higher toxicity.
- E10 and BR22 blends generate primary particles with higher toxicity.

China

Introduction

From January to December in 2015, 276 million tons of petroleum products (including diesel and gasoline fuels) were consumed in China — an increase of 1.2% year-on-year. Of this, the consumption of gasoline fuels increased by 7.0% and diesel fuels decreased by 3.7%. Fuel consumption by road transportation vehicles is the main source of total Chinese gasoline and diesel consumption.

Natural gas is another main energy source for vehicles in China. From January to December 2015, natural gas consumption reached 193.2 billion cubic meters (m^3) — an increase of 5.7% from 2014.

In 2015, China's auto production and sales were 24.5 million vehicles and 24.6 million vehicles, respectively, with a year-on-year growth of 3.3% for production and 4.7% for sales.

Compressed natural gas (CNG) stations have spread over more than 200 cities across the country's 31 provinces. In 2014, there were 1.176 million new CNG vehicles, while total ownership reached 4.411 million cars — an increase of 36.6% over 2014. In 2014, there were 723 new CNG stations, and the total number of stations was 4,455 — an increase of 19.4% over 2013. In 2014, more than 54,000 new liquefied gas (LNG) vehicles were produced, while total ownership reached 1.84 million cars — an increase of 33.5% over the previous year.

By the end of 2013, cumulative sales of M15 methanol gasoline in Shanxi Province amounted to 2.8 million tons. Also, about 300,000 tons of gasoline with a high proportion of methanol (M85–M100) had been consumed. The number of fill-ups was more than 100 million. The number of vehicles refitted for the use of high-methanol blends in Shanxi Province was more than 130,000; of these, the one with the "highest mileage" (i.e., the longest driving distance) had gone more than 400,000 kilometers (km). The number of filling stations with gasoline with a low proportion of methanol in Shanxi Province was more than 1,200. There were approximately 39 stations with gasoline with a high proportion of methanol (M85 and M100).

Policies and Legislation

Development Plan for an Energy-Saving and Alternative-Energy Automotive Industry (2012–2020)

The automotive industry is a main industry in the Chinese economy and plays an important role in the country's economic and social development. Along with China's sustained, rapid economic development and accelerating urbanization, automotive demands continue to increase, and the energy shortage and environmental pollution problems that are resulting will become more prominent. Speeding up the cultivation and development of energy-saving and alternative-energy vehicles is urgently needed to effectively alleviate energy and environmental pressures and promote the sustainable development of the automobile industry. It is also needed as a strategic initiative to accelerate the transformation and upgrading of the automobile industry and to cultivate new economic growth and give China a competitive advantage internationally. China's plan was especially formulated to implement the decisions of the State Council to develop a strategic emerging industry and to strengthen energy savings and emission reductions, as well as to accelerate the cultivation and development of an energy-saving and alternative-energy automotive industry. The plan spans 2012–2020.

Technical Route

The goal is to make the pure electric drivetrain a main technology used in developing alternative vehicles and transforming the automotive industry. Currently, the focus is on promoting the industrialization of the pure electric and plug-in hybrid electric vehicle. As part of this focus, China will promote and popularize non-plug-in hybrid and energy-saving vehicles with internal combustion (IC) engines to improve the overall technological level of the country's automotive industry.

Main Objectives

- *Significantly advance industrialization.* By 2020, the production capacity for pure electric and plug-in hybrid vehicles must be up to 2 million, and cumulative production and sales must be more than 5 million cars. The development of fuel cell vehicles and the hydrogen vehicle industry in China must be done in cooperation with the international community.
- *Significantly improve fuel economy.* By 2020, the average fuel consumption of current passenger vehicles must be reduced to 5.0 L/100 km, and that of energy-saving passenger vehicles must be reduced to 4.5 L/100 km or less. The fuel consumption capacity of

commercial vehicles must be comparable to the advanced level around the world.

- *Substantially increase the level of technology.* Alternative energy vehicles, power batteries, and key components must achieve the technologically advanced level recognized around the world. Together, the energy savings associated with using gas hybrids, advanced IC engines, efficient transmissions, automotive electronics, lightweight materials, and other key core technologies are expected to be leveraged to form a group of energy-saving and alternative-energy vehicle enterprises that are more competitive.
- *Significantly enhance the ability to support technology.* Both the technology levels and production scales of key components must meet China's basic market demands. The construction of charging facilities must meet the requirements of alternative-energy vehicles and their operation in key regions and within cities.
- *Significantly optimize the management system.* China plans to (a) establish an effective management system associated with energy-saving and alternative-vehicle companies and products; (b) build a marketing, after-sales service and battery recycling system; and (c) improve support policies to form a relatively complete system of technical standards and management practices.

Main Tasks

- *Implement a technical innovation project to create energy-saving and alternative-energy vehicles.* Enhancing the capability for technical innovation is central to cultivating and developing the energy-saving and alternative-energy vehicle industry. To accomplish that objective, China will:
  - Strengthen the industry's position as it relates to technological innovation.
  - Concentrate innovative elements toward preponderant enterprises.
  - Improve the technological innovation system to define market orientation, in combination with production and research.
  - Through the national science and technology plan, special projects, and other channels, increase support for key, breakthrough core technologies and enhance industrial competitiveness.
- *Increase technical research and development (R&D) on energy-saving vehicles.* China plans to significantly improve vehicle fuel economy and actively promote the integration and innovation of vehicle energy-saving technology, as well as its introduction, absorption, and secondary innovation. In addition, China will:
  - Focus on the development of hybrid technology research, develop special hybrid engine and electromechanical coupling devices, and

support R&D on efficient IC technology and advanced electronic control technology, including diesel high-pressure common-rail, direct injection, homogeneous combustion, and turbo-charging engines.
  - Support the development of six-gear and more mechanical transmissions, dual-clutch automatic transmissions, and automatic control mechanical transmissions for commercial vehicles.
  - Create breakthrough low-resistance components, lightweight materials, and laser welding molding technology.
  - Substantially increase the technology level of small-displacement engines.
  - Effectively carry out technical research on polluting emissions, such as nitrogen oxides.
- *Accelerate the establishment of an R&D system for energy-saving and alternative-energy vehicles.* China will guide industry to increase its R&D investment in energy-saving and alternative-energy vehicles, encourage the establishment of cross-industry technology development of energy-saving and alternative-energy vehicles, and accelerate the construction of common technology platforms. In addition, China will:
  - Focus on the R&D of key core technology for pure electric passenger vehicles, plug-in hybrid passenger vehicles, hybrid commercial vehicles, and fuel cell vehicles.
  - Establish a (a) shared test platform of related industries, (b) product development database, and (c) patent database to enable resource sharing, and integrate existing science and technology resources.
  - Construct several national research and test bases for vehicles and components.
  - Build a sound foundation platform for technological innovation.
  - Construct several international advanced engineering platforms.
  - Develop a number of industrial technology innovation alliances led by industry, with active participation by research institutions and universities.
  - Encourage industry to implement trademark and brand strategies.
  - Strengthen intellectual property right creation, utilization, protection, and management.
  - Build the patent system for the whole industry chain and improve industrial competitiveness.

Existing National Standards on Alternative Motor Fuels

- GB/T 23510-2009, "Fuel methanol for motor vehicles" was released on April 8, 2009, and implemented on November 1, 2009.
- GB/T 23799-2009, "Methanol gasoline (M85) for motor vehicles" was released on May 18, 2009, and implemented on December 1, 2009.

- GB 18047-2000, “Compressed natural gas as vehicle fuel” was released on April 3, 2000, and implemented on July 1, 2000. This standard specified the technical requirements for CNG and the test method.
- GB 18350-2001, “Denatured fuel ethanol,” and GB 18351-2001, “Ethanol gasoline for motor vehicles,” were released on April 2, 2001, and implemented on April 15, 2001.
- GB 18351-2013, “Ethanol gasoline for motor vehicles (E10),” and GB/T 22030-2013, “Blendstocks of ethanol gasoline for motor vehicles,” were released on October 10, 2013, and implemented on January 1, 2014.
- GB/T 20828-2007, “Biodiesel blend stock (BD100) for diesel engine fuels,” was released in March 26, 2007, and implemented on May 1, 2014.
- GB/T 25199-2010, “Biodiesel fuel blend (B5),” was released on September 26, 2010, and implemented on February 1, 2011.
- GB/T 25199-2014, “Biodiesel fuel blend (B5),” and GB 20828-2014, “Biodiesel blend stock (BD100) for diesel engine fuels,” were released on February 19, 2014, and implemented on June 1, 2014.
- GB/T 25199-2015, “Biodiesel fuel blend (B5),” and GB 20828-2014, “Biodiesel blend stock (BD100) for diesel engine fuels,” were released on May 8, 2015, and implemented on May 8, 2015.

Implementation: Use of Advanced Motor Fuels

Promotion of Methanol Gasoline Vehicles Pilot Project

At the end of February 2012, the Ministry of Industry and Information Technology announced that three pilot projects involving methanol vehicles had been launched in Shanxi, Shanghai, and Shaanxi Provinces. This indicated that methanol gasoline had entered a new era of development. By the end of 2013, 26 provinces had entered the field, to different degrees, where five provincial governments had organized and implemented the pilot projects.

Shanghai is one of the cities that is carrying out the methanol vehicle pilot project required by the Ministry. As part of that project, a taxi test was conducted for 36 months. The cumulative quantity of methanol gasoline used for refuelling has risen to 1,551,200 L. The traveling distance covered by vehicles running on this fuel was 9,695,300 km during the 36-month test, without any related security incidents.

Shanxi Province was the first province to promote the use of methanol gasoline. The province now has 14 production bases. There are more than

900 filling stations operated by Sinopec, Petro China, and the Government that sell methanol gasoline. In 2012, sales reached 800,000 tons. In 2013, a total of 281 methanol vehicles (four models) ran in the pilot operation carried out in Shanxi Province. The pilot cities included Jinzhong, Changzhi, Xi'an, Baoji, Xianyang, Yulin, Hanzhong, and Shanghai.

In June 2015, 100 methanol taxis appeared on the streets of Guiyang, which officially marked the national pilot run of methanol vehicles in the city. It is expected that 300 methanol taxis will be on the streets of Guiyang in 2015.

Outlook

On June 28, 2012, the State Council officially issued the *Development Plan for Energy-Saving and Alternative Energy Vehicle Industry (2010–2020),* which defines the technical pathways and main goals of energy-saving and alternative-energy vehicle development. By 2050, the accumulative output of pure electric vehicles and plug-in hybrid vehicles will reach 500,000; by 2020, the capacity will reach 2 million, and the accumulative production and sales amount will reach more than 5 million. The plan clarified five tasks: (1) technical innovation project for energy-saving and alternative-energy vehicles, (2) scientific plan for industry structure, (3) accelerated promotion of demonstrations, (4) active promotion of charging equipment manufacturing, and (5) enhancement of step utilization and recycling of power batteries.

- In terms of industrial structure, China should focus on building the power battery industry to form two to three leading enterprises with an output of more than 10 billion watt-hours; establishing the research and production capability for key materials; and developing two to three key industries for components and materials, such as anodes and cathodes, diaphragms, and electrolytes.
- In terms of application and commercialization, China should enlarge the demonstration scope of alternative-energy vehicles in public areas of medium- and large-sized cities; carry out a pilot program for subsidizing the private purchase of alternative-energy vehicles; explore different business models for alternative-energy vehicles, battery leasing, and charging services; and greatly promote and popularize energy-saving vehicles.
- In terms of the construction of charging facilities, China should focus on (a) developing and implementing pilot programs for charging facilities within cities, (b) bringing charging facilities into the relevant industrial areas of city-wide transportation systems and construction, and (c) actively carrying out the spreading slow-charging mode at private and public parking stands.

According to the biomass energy section of *12th Five-Year Development Plan (2011–2015) for Renewable Energy,* the power-generation capacity of biomass will reach 13 million and 30 million kilowatts (kW) by the end of 2015 and 2020, respectively, thereby increasing the capacity 1.36 fold and 4.45 fold from 5.5 million kW at the end of 2010. By the end of the *12th Five-Year* period, agriculture and forestry biomass power generation will reach 800 million kW, methane power generation will reach 200 million kW, and waste-incineration power generation will reach 300 million kW. During the *12th Five-Year* period, the use of biomass molding fuel, biomass ethanol, biodiesel, and aviation biofuel will reach 10 million tons, 3.5 million to 4 million tons, 1 million tons, and 100,000 tons, respectively.

According to the study of the China Industrial Gases Industry Association, China will usher in the golden age of natural gas vehicle development over the next 10 years. According to the national plan, by 2020, China's natural gas vehicle (LNG and CNG vehicles) output could reach 1.2 million vehicles per year, including buses and trucks at 200,000 (LNG cars accounting for 50%), and passenger cars at 1 million (LNG cars accounting for about 20%). By 2020, the population of natural gas vehicles will reach 10.5 million, which means the position of natural gas as the number one alternative vehicle fuel will be unshakable.

Plans are that by 2020, the use of methanol gasoline will be up to 2.4 million tons, the number of refitted vehicles will reach 120,000, and new methanol load vehicles will reach 40,000.

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Denmark

Introduction

Energy Strategy 2050 represents a giant step toward realizing the Danish Government's vision of becoming independent of coal, oil, and gas. Figures 1 through 4 present data on transport energy consumption for various transportation applications in Denmark between 1990 and 2013. In 2010, the Danish Commission on Climate Change Policy concluded that transition to a fossil-fuel-independent society is a real possibility. Energy Strategy 2050 builds on this work. This strategy is the first of its kind in Denmark and in the rest of the world. The strategy outlines the energy policy instruments to transform Denmark into a green sustainable society with a stable energy supply. The strategy is also fully financed and takes full account of Danish competitiveness. In March 2012, a historic new Energy Agreement was reached in Denmark. The Agreement contains a wide range of ambitious initiatives, bringing Denmark a step closer to the target of 100% renewable energy in the energy and transportation sectors by 2050.

In many ways, Denmark has started the green transition well. The Agreement calls for achieving goals more rapidly, with large investments expected in energy efficiency, renewable energy, and the energy system by 2020. In 2020, we expect approximately 50% of electricity consumption to be supplied by wind power and more than 35% of final energy consumption to be supplied from renewable energy sources.

No energy agreement has ever been reached by a larger and broader majority in the Danish Parliament than this one, and no Danish energy agreement has previously covered such a long time horizon. In other words, a solid framework has been established to enable significant private and public investments in the years to come.

Policies and Legislation

Climate Policy

Denmark has committed to meeting an ambitious and binding target for reducing greenhouse gases (GHGs) by 2020. This target is the most ambitious in the European Union (EU). By 2020, Denmark must have reduced GHG emissions from Danish non-ETS (Emissions Trading System) sectors by 20% relative to 2005.

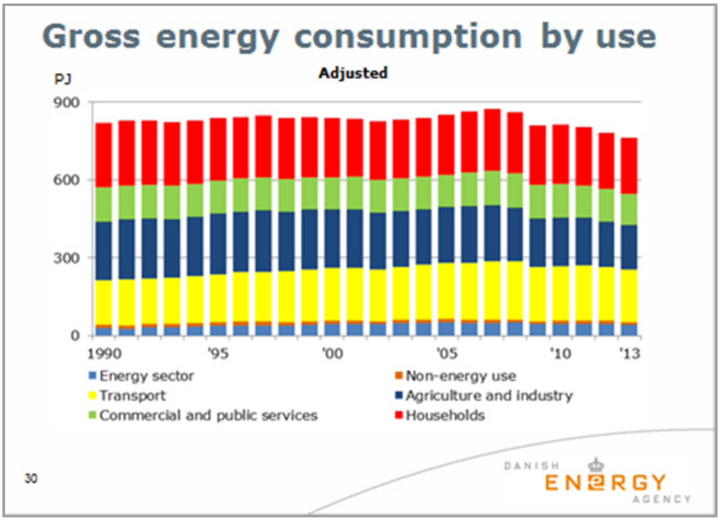

Fig. 1 Gross Energy Consumption by Use in the Period 1990–2013

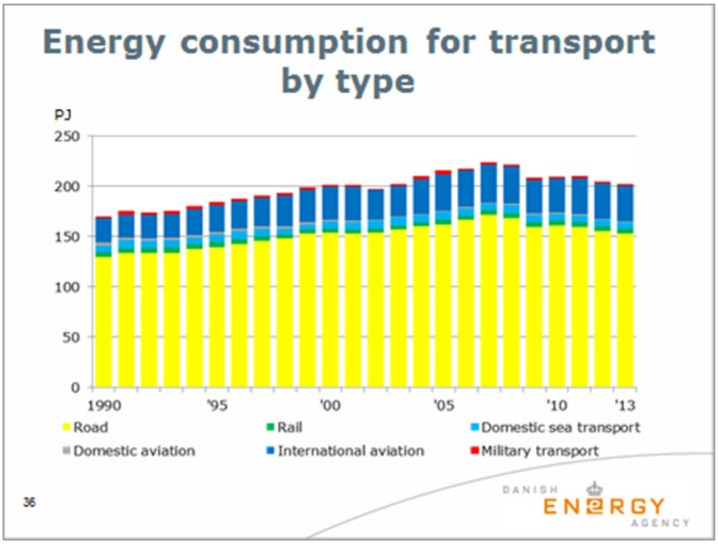

Fig. 2 Energy Consumption for Transportation by Transportation Type in the Period 1990–2013

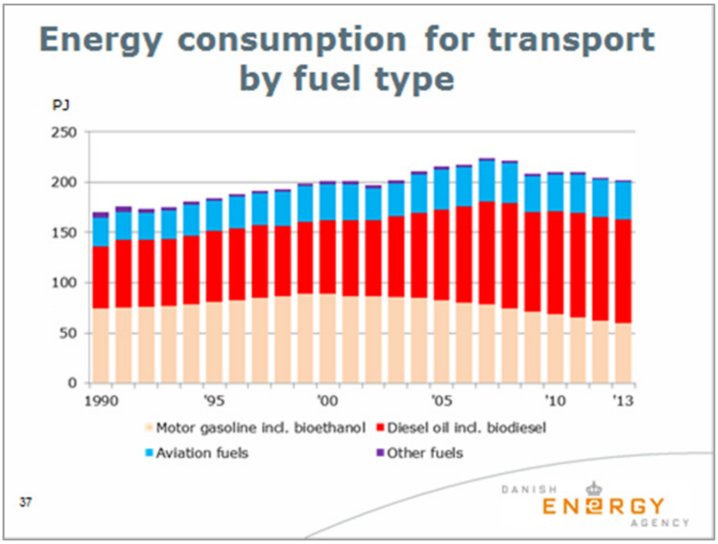

Fig. 3 Energy Consumption for Transportation by Fuel Type in the Period 1990–2013

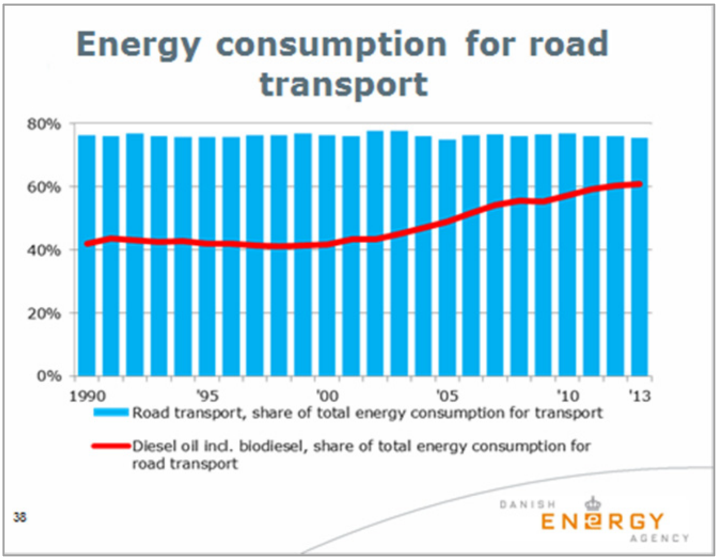

Fig. 4 Energy Consumption for Road Transportation in the Period 1990–2013

Denmark's international commitment to a significant reduction in GHG emissions not covered by the ETS in 2013–2020 poses a special challenge. The Government's climate target is to cut GHG emissions by 40% by 2020 relative to those in 1990. To reach both the total target for 2013–2020 and the target of 40%, the Government presented a climate plan in 2012. The Danish Government's ambitious goals underscore the need for a Danish policy that will give Denmark the highest return on climate and energy investments. A good example of such a climate and energy policy is investing in wind turbines.

Another good example is the electric car. Expanding the current infrastructure to accommodate electric cars is a relatively inexpensive way to reduce carbon dioxide (CO_2) emissions from the transportation sector. The electric car would contribute to the solution of three problems in one, since it would provide energy savings and opportunities for increasing the share of renewable energy in our energy system.

Energy Savings – The Road Forward

Energy savings and energy efficiency are important components of Danish energy policy and contribute to limiting energy consumption. We need significant and cost-effective energy savings within all areas. We need to use less energy in our homes, enterprises need to be made more energy efficient, and we need to focus special efforts on conserving energy in public institutions.

The initiatives agreed on in the Energy Agreement will result in a reduction of energy costs by almost 7.6% in 2020 relative to 2010.

Renewable Energy in Denmark

Along with security of supply, energy savings, and green growth, expanding the use of renewable energy in Denmark is at the core of Danish energy policy.

As a result of the Energy Agreement, renewable energy in Denmark is expected to represent more than 35% of final energy consumption in 2020. This is a major step toward achieving the long-term goal of establishing a green-growth economy with 100% renewable energy in the energy and transportation sectors.

The binding target in the EU is that by 2020, at least 30% of final energy consumption will be renewable energy in Denmark. This target is stated in the EU climate and energy package from 2008. In addition, there is a binding target that 10% of total energy consumption in the transportation sector be represented by renewable energy by 2020.

Security of Supply

The best strategy to ensure the long-term security of the Danish energy supply is to reduce energy consumption through energy savings, increased use of renewables, and closer collaboration among countries in Europe.

Implementation: Use of Advanced Motor Fuels

In Denmark, the transportation sector is still almost entirely dependent on oil. The Government has a goal that by 2050 all Danish energy supply will be met by renewable energy, including that required by the transportation sector. In February 2012, the Danish Energy Agency finalized a report on alternative fuels for the transportation sector, including socioeconomic aspects, energy efficiency, and environmental impact. The analysis indicates that by 2020 and beyond, electricity, biogas, and natural gas could become especially attractive as alternatives to petrol and diesel in the transportation sector. Electricity is the most energy-efficient alternative because of high efficiency in the engine and an increase in the share of wind-generated electricity supply.

Reference

Energistyrelsen, http://www.ens.dk/

Finland

Introduction

In 2014, the total consumption of energy in Finland amounted to 1,350 petajoules (PJ) (about 32 million metric tons or megatonnes of oil equivalent [Mtoe]; about 374 terawatt hours [TWh]), which was approximately 2% less than that in 2013. The energy mix in Finland is well balanced, including contributions from wood fuels, oil, natural gas, coal, nuclear energy, and hydropower (Figure 1).[36] Greenhouse gas (GHG) emissions from the whole energy sector were 44.4 million tonnes of carbon dioxide equivalents (CO_2e) in 2014 (−8% when compared to 2013), when the total GHG emissions in Finland were 59.1 million tonnes of CO_2e.[37]

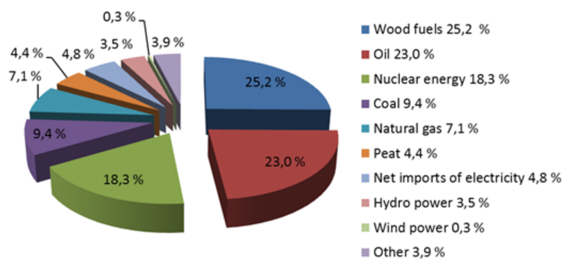

Fig. 1 Total Energy Mix in Finland in 2014[36]

The share of renewable energy of total energy consumption increased in 2014 and stood at 33%. European Union (EU) targets for renewable energy are calculated relative to total final energy consumption; calculated in this manner, the share of renewable energy was 39%. Wood fuels represented the majority of the renewable energy, about 25% of total energy used. In Finland, wood-based fuels are used for heat and power production for industry, and for municipalities in general. In addition, peat is used for energy purposes (+5% from 2013), and wood is used to heat small houses.[36]

Finland is a sparsely populated country with long (transportation) distances. Energy use for transportation work per capita, for both people and goods, is among the highest in the world. Transportation consumed about 174 PJ of Finland's primary energy in 2014, which was about 13% of the country's

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[36] http://www.stat.fi/til/index_en.html → Energy supply and consumption.

[37] http://www.stat.fi/til/index_en.html → Environment and natural resources → Greenhouse gases.

total energy consumption (Figure 2) for that year.[38] The GHG emissions from the domestic transportation sector were 11.1 million tonnes CO_2e in 2014. About 94% of the GHG emissions in the transportation sector were caused by road traffic (56% from passenger cars, 38% from vans and trucks, and the rest from busses/coaches, motorcycles, etc.).[38]

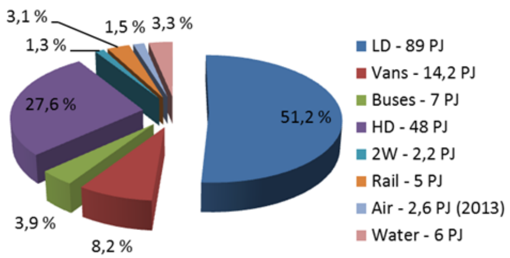

Fig. 2 Energy Consumption in Finnish Transportation Sectors in 2014[38] (The values have changed from previous years due to the renewal of LIPASTO; the data are now reported according to the international reporting system.)
(Sources: Figure by Roslund; data by LIPASTO, Mäkelä)

Table 1 presents the main types and numbers of vehicles in Finland as of December 2014, according to Trafi, the Finnish Transport Safety Agency. The size of the vehicle fleet that was registered totaled about 4.9 million vehicles (including nonroad vehicles and excluding all registered trailers), and the number in use amounted to about 4.0 million (including nonroad and excluding all registered trailers).

Table 1 Types and Numbers of Vehicles Registered (in Use) in Finland, December 2014, according to Trafi[a]

Passenger Cars	Vans	Trucks	Buses	Two-Wheelers	Other Vehicles	Nonroad
3,173,000 (2,596,000)	400,000 (304,000)	137,000 (95,000)	16,000 (12,000)	565,000 (434,000)	45,000 (26,000)	601,000 (537,000)

[a] There were about 474 passenger cars per 1,000 inhabitants in use (about 580 were registered). A share of about 25% of the passenger cars in use were diesel passenger cars.

[38] http://lipasto.vtt.fi/en/index.htm.

The number of vehicles using alternative fuels in Finland in 2014 was still quite small. There were about 3,400 flex-fuel vehicles (FFVs) capable of using high-concentration ethanol fuel (E85), and about 1,900 methane gas vehicles that used only methane (natural gas or biomethane), or that were bi-fuel gasoline/methane vehicles. The number of electric vehicles (EVs) was 1,600.

Policies and Legislation

The new Finnish Government started its 4-year term in May 2015. Under its Government Programme, it announced that Finland's target will be to increase its share of sustainable, emission-free, renewable energy so that in the 2020s its share will be more than 50%, and the energy self-sufficiency will be more than 55%. In addition, the use of fossil oil should be cut in half; the target is to have a 40% share of renewable energy in transport by 2030. The Government also published five strategic priorities in the Government Programme. One of which is "Bioeconomy and Clean Solutions," consisting of five key projects, of which, one, in particular, "Towards carbon-free, clean and renewable energy cost-efficiently," is related to bioenergy.

In Finland, a national law requires that fuel distributors provide biofuels to the market. The target is 6% for 2011–2014, then it increases incrementally to 20% (share of energy) in 2020 (Figure 3).

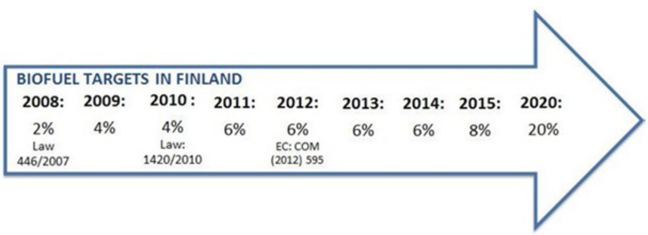

Fig. 3 Biofuel Laws and Target Energy Shares in Finland

The actual share of biofuels in 2014 was 12.3 % (energy share). Taking into account double-counting according to Directive 2009/28/EC, the share of biofuels was as high as 23.5 %. Thus the target for 2020 was met already in 2014.

According to the current national energy and climate strategy, in 2020, GHG emissions from the transport sector in Finland would be approximately

11 million tonnes CO_2e (−15% compared to 2005). If the proposed EU's 2030 climate and energy packet is realized, GHG emissions from the transport sector in Finland in 2030 could at the most be 8 million to 9 million tonnes CO_2e (−35% to −40% compared to 2005).[39]

The directive 2014/94/EU on the deployment of alternative fuels infrastructure came into effect in the EU in October 2014.

In May 2015, the Finnish Ministry of Transport and Communications published a report *Alternative Fuels Infrastructure − A Proposal for a National Framework until 2020/2030*.[40] According to the report, the primary concern of the state in Finland should be to ensure that new technologies using alternative propulsion systems will be increasingly used in vehicles. In addition, attention must also be paid to the development of the so-called drop-in biofuel markets in Finland and the entire EU.

In June 2015, a study — "How to Reach 40% Reduction in Carbon Dioxide Emission from Road Transport by 2030: Propulsion Options and their Impacts on the Economy" — of the impacts of biofuels and other alternative energy sources in transport on climate gas emissions and on the economy was published.[41] Different options and their costs were compared when the target was to reduce CO_2 emissions in the transport sector by 30% to 40% by 2030 compared to the reference year 2005. In short, it was concluded that the most cost-efficient way to reduce emissions in Finland is to invest in the production and uptake of domestic, advanced drop-in biofuels as they do not require changes to the vehicle fleet or fuel distribution system. Biogas would also be a relatively cost-efficient option in Finland, but it would require a significant increase in the number of gas-fuelled vehicles.

Taxes

Table 2 summarizes all the taxes related to the transportation sector and fuels in Finland. The CO_2-based purchase tax has been an effective instrument in reducing CO_2 emissions from new passenger cars. From 1993 to 2014, the average CO_2 value dropped by 34% for gasoline passenger cars (approximately 127 g/km in 2014) and by 35% for diesel passenger cars (approximately 130 g/km in 2014). In 2015, the new Finnish Government decided to further gradually reduce the level of purchase taxes for new low-emission vehicles.

[39] https://www.tem.fi/files/42670/TEMjul_25_2015-web_01042015.pdf.
[40] http://www.lvm.fi/-/vaihtoehtoisten-kayttovoimien-jakeluverkko-ehdotus-kansalliseksi-suunnitelmaksi-vuoteen-2020-2030-860050.
[41] VTT-R-00752-15.

Table 2 Taxes in Finland Related to the Transportation Sector and Fuels

Tax	Based On	Comments
Fuel taxes	• Volumetric heat value • CO_2 emissions • Local emissions such as nitrogen oxides (NO_X) and particulate matter (PM)	• Low volumetric heating value of biofuels is compensated for. • Biofuels are exempt from carbon component tax depending on wheel-to-wheel GHG emissions. • Bonus is given for paraffinic diesel and methane. • Biomethane is exempt from taxes.
Vehicle purchase tax	• Tailpipe CO_2 emissions	• Revised in 2015 • Minimum: 0 g/km CO_2 tax = 4.4% in 2016, 3.8% in 2017, 3.3% in 2018, and 2.7% from 2019 onward. • Maximum: 360 g/km CO_2 = 50% tax.
Annual vehicle tax	• Tailpipe CO_2 emissions or • A base tax and a “fuel-fee” tax depending on the energy source	• Minimum: 0 g/km CO_2 = €70 per year. • Maximum: 400 g/km CO_2 = €618 per year. • The annual “fuel-fee” tax for a 1,500-kg car is, for example, €301 for diesel, €82 for electricity, €170 for methane.

Research Programs

Special funds have been made available to stimulate research in and the demonstration of next-generation biofuels in Finland.

Smart Mobility Integrated with Low-carbon Energy, aka “TransSmart,” is a research program that the VTT Technical Research Centre of Finland Ltd. started in 2013. TransSmart is a multidimensional framework for transportation-related research that enables the cooperation of private and public sectors for common goals. TransSmart focuses on four core areas: low-carbon energy, advanced vehicles, smart transportation services, and transportation systems.[42]

42 http://www.transsmart.fi/transsmart/in_english.

Tekes (the Finnish Funding Agency for Technology and Innovation) had a research program dedicated to EVs. The program, called EVE, ran from 2011 to 2015. The total volume involved in the EVE program was €100 million, with a contribution of €35 million from Tekes. The main target of the program was to create an electric mobility ecosystem that could generate new knowledge and competence in EV-related technologies and services.[43,44]

A 5-year project called LignoCat (lignocellulosic fuels by catalytic pyrolysis) funded by Tekes started in October 2013. In this project, the companies Fortum, UPM, and Valmet have joined forces to develop a new technology to produce advanced high-value, lignocellulosic fuels, such as transportation fuels or higher-value bioliquids. The idea is to develop catalytic pyrolysis technology for upgrading bio-oil and to commercialize the solution.

The energy company St1 Biofuels Ltd. and VTT signed a 2-year €1.2-million contract in autumn 2014 to start a development project to optimize the production process for wood-based bioethanol. The research project is part of Tekes' BioEthanol2020 (Green Growth) project, which aims to secure the competitiveness of the Finnish bio-economy.[45]

Implementation: Use of Advanced Motor Fuels

In 2014, the dominant fuels used in Finland were gasoline and diesel. The total consumption of gasoline and diesel was approximately 3.93 Mt, of which 38% was gasoline and 62% diesel. In 2014, the national biofuels obligation required 6% of biofuels (energy share) (Figure 3). In total, the contribution from alternative liquid fuels, including fossil fuel options, was around 556 kilotonnes of oil equivalent (ktoe). In 2014, the actual biofuel portion in the transportation sector was 12.3%. It is estimated that using different biofuels reduced GHG emissions by 1.5 million tonnes CO_2e in 2014.[46]

Ethanol is used on its own and as fuel ethers ETBE (ethyl tertiary-butyl ether) and TAEE (tertiary amyl ethyl ether). With regard to diesel, the bio portion mainly consists of hydrotreated vegetable oil (HVO)–type,

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[43] http://www.tekes.fi/tekes/julkaisut1/eve--electric-vehicle-systems-2011-20152/.
[44] http://sahkoinenliikenne.fi.
[45] http://www.tekes.fi/en/programmes-and-services/tekes-programmes/green-growth/.
[46] http://www.stat.fi/til/index_en.html → Environment and natural resources → Greenhouse gases.

paraffinic renewable diesel fuel. In 2014, the contribution to liquid fuels from biofuels fulfilling the EU's sustainability criteria amounted to about 495 ktoe. Table 3 shows the use of different road transportation fuels in Finland.

Table 3 Road Transportation Fuels Used in Finland in 2014

Gasoline (Mt)	Diesel[b] (Mt)	Ethanol and Ethers[c] (Total/Bio Portion[d]) (Mtoe)	Renewable Diesel[b] (Total/Bio Portion[d]) (Mtoe)	Natural Gas (Mtoe)	Biomethane (Mtoe)
1.5[a]	2.4	0.129/0.068	0.421/0.421	0.003	0.0009

[a] E10 = 0.91 Mt, E5 = 0.60 Mt, and E85 = 0.0072 Mt.
[b] Diesel contains mainly HVO as a renewable component in Finland.
[c] Ethanol is used partly as fuel ethers in Finland.
[d] Fulfills the EU's sustainability criteria according to Renewable Energy Sources Directive 2009/28/EC.

Source: Finnish Petroleum and Biofuels Association and Finnish Customs

Hydrotreated Vegetable Oils (and Fats)

HVO is currently the main renewable component in Finnish diesel fuel. NEXBTL, produced by Neste Corporation (formerly Neste Oil), is a renewable paraffinic diesel fuel. The EN590 specification for diesel fuel can be met with blends containing up to about 30% NEXBTL. Neste's worldwide NEXBTL production capacity was about 2 Mt/year in 2014. Production of NEXBTL is based on crude palm oil and different wastes and residues (e.g., waste animal fats, waste fish fats, and vegetable oil fatty acid distillates). In 2014, the percentage of waste and residues in NEXBTL production was 62% (52% in 2013). In Finland, Neste is marketing a premium diesel fuel, "Neste Pro Diesel," containing at least 15% NEXBTL.

The Finnish pulp and paper company UPM has built a biorefinery in Lappeenranta. The plant uses hydrotreatment to produce renewable biofuels from crude tall oil. UPM's biorefinery will produce approximately 120 million liters (L) (approximately 100 ktoe) of hydrotreated renewable diesel, UPM BioVerno. The commercial production of UPM BioVerno started in January 2015, and 10 vol% of the renewable diesel UPM BioVerno is currently blended with fossil diesel fuel. The blend is sold at St1 (Diesel Plus) and ABC (Smart Diesel) refuelling stations in Finland.

Fatty Acid Methyl Esters (FAME)

A minor amount, about 12 ktoe, of conventional esterified biodiesel (fatty acid methyl esters, i.e., FAME), was used in Finland in 2014. Rapeseed methyl ester (RME) has been produced on a small scale, mainly on farms.

Bio-ethers

Neste has processed ETBE since 2004. Also, methyl tertiary-butyl ether (MTBE) and tertiary amyl methyl ether (TAME) are currently produced at the Porvoo refinery. In 2014, about 64 ktoe of different bioethers, mainly MTBE, ETBE, and TAME, were blended in gasoline in Finland.

Bio-alcohols

In 2011, gasoline containing 10 vol% ethanol (E10) was launched in Finland. E10 sales in 2014 were around 60% of all the gasoline sold. Forty percent of all the gasoline sold was still E5 (5 vol% ethanol), even though the majority of gasoline cars are E10 compatible in Finland. High-concentration ethanol, E85, was sold at 110 refuelling stations, and about 3,400 FFVs were registered in Finland in 2014.[47]

Since 2011, RED95 ethanol-diesel has been tested in the Helsinki region in Finland, using Scania's ethanol-diesel engines in three trucks and two buses.

St1 Biofuels is focusing on the decentralized production of fuel bioethanol in Finland using side streams from the food industry, via a process called Etanolix®*,* and from domestic waste, via a process called Bionolix™. In these processes, the waste is converted into an ethanol (85%)-water *(*15%) mixture at food industry sites, and then the ethanol is concentrated/dried to a purity of 99.8% in a dehydration facility. St1 Biofuels has a centralized dehydration facility in Hamina that has a capacity of 70 kt/year (approximately 44 ktoe). Five decentralized ethanol units (four Etanolix® and one Bionolix™) are currently running with a production capacity of about 800 to 5,500 metric tons (t)/year (0.5–3.5 ktoe/year) bioethanol per unit. The Bionolix™ unit in Hämeenlinna is also combined with a biogas production plant to convert side products of ethanol into green energy; it uses biowaste from households.

However, the majority of transportation fuel bioethanol consumed in Finland is still imported.

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47 FFV classification was not systematically registered for the Euro 4 car models, which may lead to underestimation of the FFV car population.

Natural Gas and Biomethane

A total of about 1,900 natural gas vehicles, consisting mostly of passenger cars and vans running on either solely methane or bi-fuel using methane and gasoline/diesel, were running in Finland in 2014.[48]

Electric and Hybrid Electric Vehicles

Hybrid electric vehicles (HEVs) have not made a major breakthrough in Finland, and approximately 1,600 EVs (battery electric vehicles and plug-in hybrids together) were in use in 2014. The Finnish CO_2-based purchase tax has increased the competitiveness of hybrids and EVs.

The first Finnish demonstration of fully electric buses started in the City of Espoo in 2012. In February 2015, the Helsinki Regional Transport Authority (HSL) announced it will purchase 12 electric buses from the Finnish start-up company Linkker. The first electric buses started operation in Espoo in 2015, and in Helsinki, the electric buses will start to operate in 2016. The aim is to have 400 electric buses operating in the Helsinki region by 2025.

Hydrogen

The demonstration of fuel-cell-powered working machinery began in the harbor of Helsinki in 2013. The first commercial and hydrogen fuelling station opened in March 2014 for private cars and buses at the Port of Helsinki. At Voikoski, one hydrogen fuelling station opened in January 2014 for Finland's first, and so far only, hydrogen car taken into service by national gas manufacturer Woikoski Oy.

Outlook

Bioethanol and renewable diesels will be used as biofuels more and more over time in Finland.

The use of ethanol produced by St1 Biofuels in Finland is increasing as the company broadens its feedstock sources to include straw and waste fibers. St1 Biofuels is constructing a bioethanol plant in Kajaani that will use sawdust and chips as feedstock. In 2016, the plant will produce around 5 ktoe/year of Cellunolix™ bioethanol.

Suomen Bioetanoli Oy received €30 million in support from the Ministry of Employment and the Economy in December 2014 to invest in a new

[48] http://epublications.uef.fi/pub/urn_isbn_978-952-61-1875-8/urn_isbn_978-952-61-1875-8.pdf.

bioethanol plant at Myllykoski (Kouvola). The Myllykoski plant will produce about 72 000 t/year (about 45 ktoe/year) of bioethanol from straw.

In November 2015, the Finnish company Neste (the world's leading supplier of renewable diesel) and Boeing (the world's largest aerospace company) announced that they will work together to promote and accelerate the commercialization of renewable aviation fuel.[49]

With regard to a potentially new alternative feedstock source for NEXBTL production, Neste and Renewable Algal Energy (RAE, a U.S.-based algae biomass producer) signed a contingent commercial algae oil off-take agreement.[50] In December 2014, Neste was also granted €3.3 million in support from the Finnish Ministry of Employment and the Economy to develop the continuous refining of biofuels (biodiesel, biogasoline, and other renewable fractions), involving a total of about 40 000 t/year from tall oil pitch at its Naantali refinery.

In the long-term, cellulosic BTL (biomass-to-liquid) fuels are expected to cover a significant share of the diesel pool in Finland. UPM was awarded €170 million for a solid-wood-based biorefinery project in Strasbourg, France. However, it has now announced that it will currently concentrate on its biorefinery in Lappeenranta.

Interest in the use of biomethane for transportation has been increasing. Gasum, together with Helen, a Helsinki-based utility, and Metsä Group, has biomethane-related plans, including plans for a large-scale wood-based bio-SNG (synthetic natural gas) plant in Joutseno. Total production of biogas could be around 1,600 GWh/year (about 138 ktoe/year), and the biogas would be transferred via Gasum's natural gas transmission network to end users (power plants, transportation). A final investment decision on construction has not yet been made.

In Finland, the liquefied natural gas (LNG) infrastructure is currently being built up for marine transportation as a result of sulphur regulations. The Ministry of Employment and the Economy granted energy investment support for four LNG terminal projects in 2014. In addition, Finland and Estonia have announced a plan to construct a gas pipe, Balticconnector, between the two countries, but only if sufficient (i.e., 75%) EU support for

49 https://www.neste.com/en/neste-and-boeing-lead-industry-commercialization-renewable-aviation-fuels.

50 https://www.neste.com/en/neste-oil-strengthens-its-algae-oil-procurement-program-new-take-agreement.

the project is granted. All these plans offer an opportunity to consider LNG options for transportation other than marine transportation (e.g., long-haul and heavy-duty transportation).

The first integration of wood-based pyrolysis oil production in a power boiler was done by Metso for Fortum in Finland in 2013. The bio-oil plant produced bio-oil amounting to approximately 50,000 t in 2014. Currently, bio-oil substitutes for heavy and light fuel oils in heating applications. However, in the future, bio-oil could also be feedstock for producing transport fuels and various chemicals.

Major Changes

The new Finnish Government started its 4-year term in May 2015. Under its Government Programme, it announced that Finland's target will be to increase its share of sustainable, emission-free, renewable energy so that in the 2020s its share will be more than 50%, and the energy self-sufficiency will be more than 55%. In addition, the use of fossil oil should be cut in half; the target is to have a 40% share of renewable energy in transport by 2030. The Government also published five strategic priorities in the Government Programme. One of which is "Bioeconomy and Clean Solutions" consisting of five key projects, of which one, in particular, "Towards carbon-free, clean and renewable energy cost-efficiently," is related to bioenergy.

The national target of 20% (calculatory share) biofuels in transport by 2020 was reached already in 2014.

In 2015, the new Finnish Government decided to gradually reduce the level of purchase taxes for new low-emission vehicles.

France

Introduction

French fuel consumption for use in road transportation increased continuously up to the very beginning of the past decade as a result of the increasing number of vehicles and road traffic (Figure 1). After a period of stabilization, a slight decline could be observed starting in 2011. This decline can be attributed to the economic situation, the improvement in engine efficiency and the consequent reduction in unitary consumption, and the dieselization of the fleet. In 2015, fuel consumption in road transportation registered a 0.9% increase (excluding biofuels). Oil products (gasoline, diesel, and liquefied petroleum gas [LPG] fuel) are still predominant, while biofuels reached 6% of the mix in 2014. The share of diesel in fuel consumption increased continuously between 1970 and 2014, rising from 28% to 83% (81.2% in 2015 according to Union Française des Industries Pétrolières [UFIP]). The SP95-E10, marketed since 2009 and which could contain up to 10% ethanol, represented more than 30% of the sales of premium fuels (unleaded 95 and 98, and SP95-E10) in 2014.

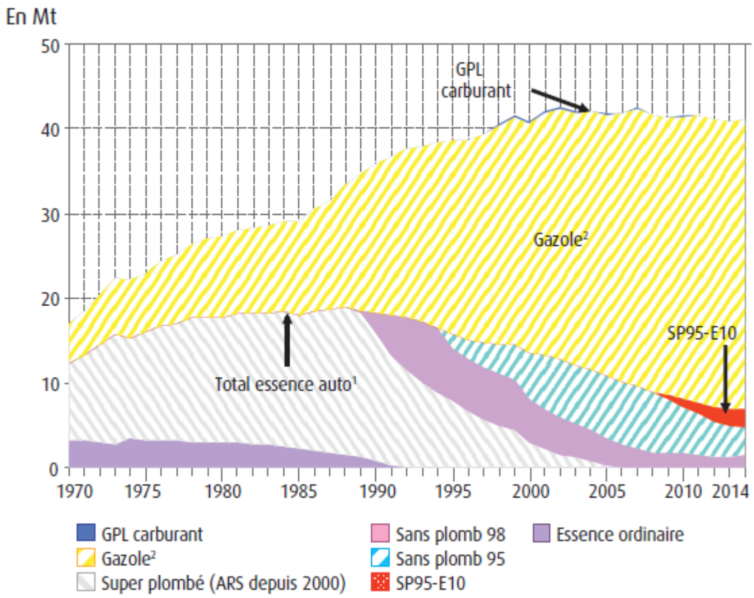

Fig. 1 Evolution of Fuels Sales for Road Transportation (including biofuels) (1 = gasoline, unleaded, unleaded 98, unleaded 95, SP95-E10, including biofuels; 2 = including biofuels)

(Source: Chiffres clés de l'énergie, 2016, 2015 Edition, Commissariat Général au Développement Durable, February)

In 2014, biofuels consumption for use in road transportation amounted to 2,955 kilotonnes of oil equivalent (Ktoe) (Figure 2). Biodiesel represents about 86% of this volume, compared to 14% for bioethanol. Between 2013 and 2014, biofuels consumption increased by about 268 Ktoe, that is, +10% (biodiesel consumption rose 10.8%, compared to 5.2% for bioethanol).

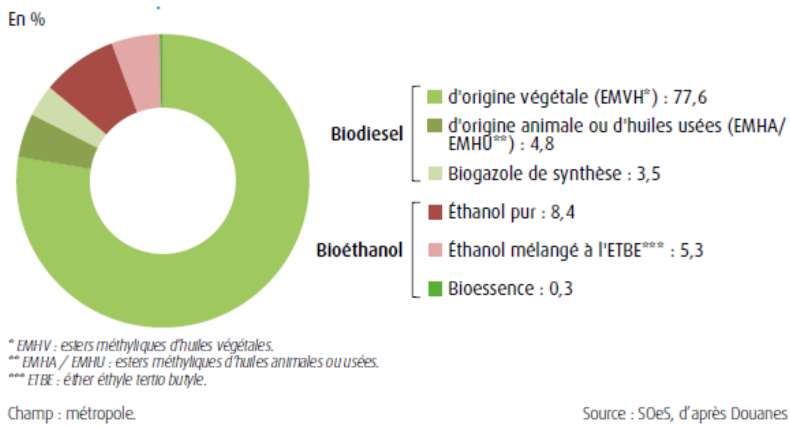

Fig. 2 Biofuels Consumption in France in 2014 — 2,955 Ktoe
(Source: Chiffres clés des énergies renouvelables, 2015, Commissariat Général au Développement Durable, December)

The economic crisis has been affecting new vehicle registrations continuously since 2009. Almost all kinds of vehicles are impacted, and more particularly the heavy and light commercial vehicles. Registrations of small gasoline vehicles are progressing, while those of diesel cars are declining. The share of electric and hybrid cars has increased significantly since 2012 as a result of the environmental bonus. It was around 3% in 2014, while less than 1% in 2011.

Policies and Legislation

Incentives To Promote the Use of Renewable Energy in Transport

Under the National Action Plan for Renewable Energy,[51] following the

[51] Directive 2009/28/EC of April 23, 2009, requires Member States to have a "National Action Plan for Renewable Energy" that sets out objectives in terms of a "renewable energy mix" in 2020 and annual trajectories by energy type (i.e., biomass, hydro, wind, and solar).

Grenelle de l'Environnement, a number of incentives were introduced to promote the use of energy from renewable resources in the transport sector.

Incentives To Use Biofuel Blends

- On April 1, 2009, the launch of new SP95-E10 in the gasoline sector corresponded to an incorporation rate of 10% ethanol in gasoline (between 7% and 8% ethanol composition, effectively). This product has been approved for sale in petrol stations since 2009. It aims to replace the SP95 (5% bioethanol), in accordance with European directives. In 2015, the SP95-10 accounted for a 45% share of the gasoline volume sold — a 13% increase compared to 2014 (32%). Since 2012, sales of SP95-E10 have exceeded those of SP98.

  France is the European country that has the largest number of petrol stations distributing SP95-E10 (available in around 57% of the total distributing network). In 2015, more than 90% of the French fleet was compatible with SP95-E10, as well as almost all petrol vehicles registered since 2000.

- Fuels with high levels of biofuel were authorized for use, including E85 in the gasoline sector and B30 in diesel fuel production. In the first quarter of 2015, superethanol E85, which contains 65%–85% bioethanol, registered a 7% growth in sales over those in the first quarter of 2014. As of October 2015, E85 has been sold in more than 700 petrol stations. To encourage the development of E85, it is subsidized and, accordingly benefits from reduced pump prices (€0.73/L in September 2015). The E85 price savings, compared to SP95, reached 20 to 40 cents/L (over-consumption effect is included).

  Since 2013, many manufacturers have suspended marketing flex-fuel vehicles. As a consequence of the tightening of European standards, few models are now available for sale. In 2015, Volkswagen added a flex-fuel motor on three models. In 2012, the number of sales of flex-fuel vehicles had reached 7,341. They accounted for no more than 129 vehicle registrations in 2015, or 0.01% of all new vehicle sales.

  With regard to B30 (gas oil that is not authorized for sale to the public), the Senate adopted two amendments in November 2014 that aim to apply a taxation scheme to B30 that is adapted to its low environmental impact, as is done for superethanol E85.

Fiscal Incentive Schemes

- A tax exemption is being granted to biofuels. It complies with European Directive 2003/96/EC on the taxation of energy, which allows Member States to have a special tax for biofuels to ensure their development and promotion.

- A general tax on polluting activities (Taxe Générale sur les Activités Polluantes, or TGAP) was levied to enable France to reach national objectives with regard to using biofuels. TGAP is an additional levy that must be paid by the operators and distributors (refiners, supermarkets, and independent dealers) that sell fuel containing a lower proportion of biofuels than the proportions represented by national goals. This rate increased from 1.75% in 2006 to 6.25% in 2009. The objective since 2010 of incorporating biofuels fixed at 7% was almost reached in 2013 (6.8%). The 2014 Finance Act established an incorporation target of 7.7% biodiesel in diesel. A decree in December 2014 authorized the incorporation of 8% fatty acid methyl ester (FAME) in diesel. For gasoline, the rate is maintained at 7%. To promote the second-generation biofuels industry, TGAP is double-counted. This incentive was designed to encourage the development of the production of biofuels that would not compete with farming for the production of food. Since 2014, the amount of biofuels that benefitted from this advantage was limited to 0.35% for incorporation in diesel and 0.25% for incorporation in gasoline. These limits were introduced to limit biofuel production from imported waste, which was observed in 2011.

- The domestic tax on consumption (Taxe Intérieure sur la Consommation, or TIC) aims to reduce the extra cost of manufacturing biofuels over the cost of manufacturing fossil fuels. This is a partial tax exemption for biodiesel and bioethanol and a total exemption for pure vegetable oil used as fuel for agriculture and fishing industries. After a gradual decrease, the tax exemption rates were stabilized from 2011 to 2013. The 2014 Finance Act ("Loi de Finances") proposes a further reduction of the tax exemption for 2014 and 2015 until its abolition in 2016. The biodiesel sector benefitted from a €3/hectoliter (hL) reduction in 2015, compared to €4.5/hL in 2014. The bioethanol sector tax exemption was €7/hL in 2015, compared to €8.25/hL in 2014. Taxation applied to superethanol E85 was maintained at a rate of €17.29/hL from 2011 to 2014. The energy product consumption tax (Taxe Intérieure de Consommation sur les Produits Énergétiques, or TICPE) was decreased to €12.62/hL in 2015. This device was stopped in December 2015.

The Climate Energy Contribution (CEC) came into force on April 1, 2014. It introduced a carbon component within the TICPE that was progressive and proportionate to carbon dioxide (CO_2) emissions from energy products under the TICPE, according to the value for a ton of CO_2 being fixed at €7 in 2014, €14.5 in 2015, and €22 in 2016.

Measures To Encourage Fleet Renewal

- The bonus-malus system that applied to the purchase of a new vehicle and which had been amended in November 2013, evolved again on January 1, 2015, for the bonus calculation scale, whereas the malus calculation scale established on January 1, 2014, remained unchanged for 2015. The bonus amount was revised downward, with the maximum CO_2 release being set at 60 grams/kilometer (g/km) (it had been set at 90 g/km previously). The maximum bonus of €6,300 introduced in 2013 has remained the same. The €150 bonus for the purchase of thermal vehicles (from 61 to 90 g CO_2/km) was removed.

  For a vehicle emitting more than 130 g CO_2/km, the ecological malus generates an increase in the purchase price of €150 up to €8,000. The objective of the bonus-malus system is to start the ecological transition by using measures that encourage individuals to acquire low-emission vehicles and consequently renew the old automotive fleet. The bonus-malus system from 2008 to 2015 (hybrid electric vehicles [HEVs] and electric vehicles [EVs] excluded) is shown in Figure 3. Figure 4 shows the bonus-malus for HEVs and EVs.

The bonus-malus system was revised downward again on January 1, 2016. The hybrid vehicles will be the most impacted category. The aid for the purchase of a hybrid vehicle will decrease from €2,000 in 2015 to €750 in 2016. As for the plug-in vehicles, the decrease is more important; the aid applied decreasing to €1,000 (€4,000 in 2015).

Environmental Bonus for Hybrid Vehicles

The aid applies only to hybrid vehicles with CO_2 emissions below 110 g/km. The hybrid vehicles segment was very much impacted by the new device in 2015. The amount of aid being allocated was only 5% (8.25% in 2014) of the vehicle price, with the minimum amount being €1,000 (€1,650 in 2014) and the maximum being €2,000 (€3,300 in 2014). The aid applied for the purchase of an HEV will decrease to €750 on January 1, 2016 (see Table 1).

Emissions de CO2 en g/km	2008 -2009	2010	2011	Du 1/1/2012 au 31/07/2012	Du 1/8/2012 au 31/12/12	Au 1/01/2013	Du 01/01/2014 Au 31/12/2014	Du 01/01/2015 Au 31/12/2015	Emissions de CO2 en g/km
0-20	-5000	-5000	-5000	-5000	-7000	-7000	-6300	-6300	0-20
20-50					-5000	-5000	-4000	-4000	20-50
51-60				-3500	-4500	-4500			51-60
61-90	-1000	-1000	-800	-400	-550	-550	-150	0	61-90
91-95			-400	-100	-200	-200	0		91-95
96-100		-500							96-100
101-105	-700								101-105
106-110				0		0			106-110
111-115									111-115
116-120									116-120
121-125	-200	-100	0						121-125
126-130									126-130
131-135	0	0					150	150	131-135
136-140						100	250	250	136-140
141-145				200	200	300	500	500	141-145
146-150						400	900	900	146-150
151-155			200	500	500	1000	1600	1600	151-155
156-160		200	750	750	750	1500	2200	2200	156-160
161-165	200	750							161-165
166-175	750								166-175
176-180						2000	3000	3000	176-180
181-185				1300	1300	2600	3600	3600	181-185
186-190						3000	4000	4000	186-190
191-195			1600	2300	2300	5000	6500	6500	191-195
196-200		1600							196-200
201-230	1600					6000	8000	8000	201-230
231-240			2600	3600	3600				231-240
241-245		2600							241-245
246-250									246-250
250-...	2600								250-...

Fig. 3 Bonus-Malus System from 2008 to 2015 (excluding HEVs and EVs)

With regard to plug-in HEVs (PHEVs), the bonus is capped at 20% of the purchase cost, plus the cost of the battery if it is rented. The aid applied is €4,000 as a maximum for a vehicle emitting less than 60g CO_2/km. The bonus applied on January 1, 2016, will decrease to €1,000.

Support for Electric Vehicles

Electric vehicles are eligible for the highest environmental bonus levels (Table 2). The bonus granted for purchasing an EV that emits less than 20g CO_2/km fell from €7,000 in 2013 to €6,300 in 2014 and 2015, and will be the same for 2016. The aid applied may not exceed 27% of the purchase price, including all taxes plus the cost of the battery if the vehicle is rented.

Emissions de CO2 en g/km	2008 -2009	2010	2011	Du 1/1/2012 au 31/07/2012	Du 1/8/2012 au 31/12/12	Au 01/01/2013	Au 01/01/2014	Au 01/01/2015	Emissions de CO2 en g/km
0-20				-5000	-7000	-7000	-6300	-6300	0-20
20-50	-5000	-5000	-5000		-5000	-5000	-4000	-4000	20-50
51-60				-3500					51-60
61-90		-1000							61-90
91-95	-1000				-4000	-4000	-3300	-2000	91-95
96-100			-2000	-2000					96-100
101-105									101-105
106-110		-500							106-110
111-115	-700								111-115
116-120									116-120
121-125		-100				0	0	0	121-125
126-130	-200			0	0				126-130°
131-135			0				150	150	126-135
136-140						100	250	250	136-140
141-145		0				300	500	500	141-145
146-150	0			200	200	400	900	900	146-150
151-155			200	500	500	1000	1600	1600	151-155
156-160		200							156-160
161-165	200			750	750	1500	2200	2200	161-165
166-175			750						166-175
176-180		750				2000	3000	3000	176-180
181-185						2600	3600	3600	181-185
186-190	750			1300	1300	3000	4000	4000	186-190
191-195									191-195
196-200				2300	2300	5000	6500	6500	196-200
201-230		1600	1600						201-230
231-240	1600						8000	8000	231-240
241-245						6000			241-245
246-250			2600	3600	3600				246-250
250-…	2600	2600							250-…

Fig. 4 Bonus-Malus System from 2008 to 2015 for HEVs and EVs

Table 1 Environmental Bonuses for HEVs

CO_2 Emissions (g/km)	Bonus in 2013	Bonus in 2014	Bonus in 2015	Comments	Examples of Vehicles
Less than 110	€2,000–4,000	€1,650–3,300	€1,000–2,000	Maximum financial aid of 5% of the acquisition cost plus the cost of the battery if it is rented.	Toyota Yaris HSD, Peugeot 3008 Hybrid4

Table 2 Environmental Bonuses for EVs

CO_2 Emissions (g/km)	Bonus in 2013	Bonus in 2014	Bonus in 2015	Comments	Examples of Vehicles
Less than 20	€7,000	€6,300	€6,300	Bonus is capped at 27% of the purchase price, plus the cost of the battery if it is rented.	Renault ZOE, Nissan LEAF

The Super Bonus

Initially introduced in October 2014 as part of the Law on "Transition Energétique," the super bonus was revised on April 1, 2015. This cumulative premium, together with the automotive bonus device, could add up to:

1. €500 for the purchase of a vehicle that meets the Euro 6,
2. €2,500 for a PHEV, and
3. €3,700 for EVs.

This super bonus will be set for the purchase of one out of those three types of vehicles and the scrapping of a diesel vehicle in service before January 1, 2001. For the purchase of an EV, the device will, under certain conditions, allow the amount to reach €10,000.

Bonus-Malus Budget

Since its introduction in 2008, the bonus-malus automotive device was originally designed to be in balance: revenues issued from the bonus-malus system were to balance expenses associated with the bonus system. However, this device showed a deficit from 2008 to 2013. It is subject to adjustment annually in order to account for technological developments and to ensure that the budget is balanced. In 2014, the bonus-malus device recorded a surplus of €141 million.

In 2015, the amount of aid for the purchase of a clean vehicle was €242.15 million, of which €214.5 million was in bonuses and €28 million in conversion premiums.

The share of vehicles with bonuses accordingly fell from 8.8% in 2014 to 3.2% in 2015. The share of cars subject to malus decreased from 17.4% in 2014 to 13.6% in 2015. The neutral zone gained 9.4 points to 83.2%.

In 2016, the French Government plans an increase in loans of approximately 10% or €236 million for the bonuses and €30 million for the conversion premiums.

Research and Development (R&D) in the Transportation Sector

Public support for innovation and R&D deployed within competing clusters (i.e., associations or partnerships) results in the following:

- Financial support via the single interdepartmental fund (Fond Unique Interministériel, or FUI). It involves the participation of various partners such as (1) the National Research Agency (NRA, or in French, Agence Nationale de la Recherche, or ANR) through a Carnot device[52]), (2) Oséo, which is now incorporated in La Banque Publique d'Investissement ou Bpifrance, or (3) Caisse des Dépôts in project financing; and
- Tax exemptions for companies with a cluster involved in an R&D project financed by the French Government.

NRA R&D Projects

The NRA, established in 2005, is responsible for implementing financing projects designed to boost the research sector, France's competitiveness, and the visibility of France's research abroad. The NRA is mobilized to focus its research efforts on economic and societal priorities at the highest level of the State and to consult with other stakeholders in the research results and develop European and international collaborations. Now the action of the NRA revolves around nine major societal challenges identified in the Strategic Research Agenda that are consistent with the European Strategic Agenda. Two of the challenges are related to transport issues: (1) clean, safe, and efficient energy and (2) sustainable mobility and urban systems. None of the NRA projects launched in 2015 relate to thematics on biofuels, transport, or energy.

Projects launched in 2014 on these thematics (see details in *IEA-Advanced Motor Fuels Annual Report 2014*) and which will be developed over the next 3 to 4 years, include the following:

- **CATAPILS.** This 3-year project deals with the catalytic conversion of lignin into biofuels and simple aromatic compounds by an innovative

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[52] The Association Institut Carnot is a network of 34 Carnot institutes. It is a research network dedicated to fostering enterprise innovation. A major national multidisciplinary research task is to build economic development through technologies and innovation. Founded in 2006, the Carnot label was designed to develop partnership-based research, meaning that research efforts are conducted by public laboratories in partnership with socioeconomic players, primarily enterprises (from subject matter experts to large corporations), to serve the partners' needs.

hybrid system composed of metallic nanoparticles stabilized by polymerized ionic liquids (PILs).
- **Cellutanol.** This 3-year project aims to build, within 4 years, an *Escheria coli* strain that will directly convert crystalline cellulose into butanol at a high yield and which will be able to be used to produce third-generation biofuel with a better octane rating than that of ethanol.
- **DIGAS.** This 4- and a half-year project aims to develop a heterogeneous catalytic process for the direct synthesis of dimethyl ether (DME) from sustainable sources to use in several energy applications. The DIGAS project focuses on the direct, one-step synthesis of DME from biomass-derived syngas in two reactions.
- **GreenAlgOhol.** The goals of this 4-year project are to develop efficient biomass production schemes and optimized enzymatic hydrolysis of seaweed glucans to produce algal glucose.
- **Four projects on Modeling, Forecasting, and Risk Evaluations.** (FOREWER, HYSTOR, APPIBio, and European Combustion Network [ECN] – France)

Under the NRA umbrella, the Instituts pour la Transition Energétique (ITE) previously les Instituts d'Excellence en Matière d'Énergies Décarbonées, or, in English, the Institutes of Excellence in Low-Carbon Energies, or IEED) implemented interdisciplinary platforms in the field of low-carbon energy that bring together the expertise of industry and public research. Among these are the PIVERT and VeDeCoM projects (see details in *IEA-Advanced Motor Fuels Annual Report 2014*).

The central role of competitiveness clusters (Pôles de Compétitivité) — such as Mov'eo (automotive cars) and Lyon Urban Trucks & Transport (LUTB) (heavy trucks) — in the field of transportation should also be emphasized, since they represent an important tool in supporting that sector.

In 2015, only one project in the field of alternative fuel for transport had been pre-selected, and it is waiting only for final budget and contract negotiations — DirectSynBioFuel (Design des nanocomposites métal-zéolithe hiérachisés pour la synthèse directe des carburants à partir de biosyngas).

ADEME R&D Programs

ADEME (Agence de l'Environnement et de la Maîtrise de l'Energie), the French energy public agency, also hosts R&D programs and is the operator of some investment (Investissements d'Avenir or PIA) for future plans such as these:

- **Bioresources, Industries, and Performance (BIP) Program.** Projects must be enrolled under at least one of the two topics detailed in the text of the "call for projects":
  1. Biorefineries: (1) plant chemistry, (2) bio-based products for chemicals and materials, and (3) biofuels
  2. Renewable and clean energy from biomass
- **Road Vehicle of the Future Program (inside PIA).** With €1.04 billion, the PIA's "Vehicle and Transport of the Future" program promotes the development of innovative technologies for mobility: EVs and charging infrastructure, thermal and hybrid engines, reduction of heavy vehicles, mobility and logistics, rail, and efficient ships. Projects cover (1) technology and (2) systems and mobility. Possible levers include alternative energy and auxiliary functions (including safety, comfort, and energy management).[53]

Some examples in the areas of advanced biofuels and the development of EVs and PHEVs are discussed below.

ADEME Advanced Biofuels Programs

In France, the challenges to developing biofuels industrial sectors are considerable and include (1) reducing greenhouse gas (GHG) emissions in the transport sector, (2) limiting the country's energy dependence, and (3) creating new economic activities.

Projects in France that aim to remove a number of scientific and technical bottlenecks in the advanced biofuels sector are summarized here (see details in *IEA-Advanced Motor Fuels Annual Report 2014*).

- **Futurol.** Launched in 2008, the Futurol project aims to develop and commercialize a complete solution for producing cellulosic ethanol, from the field to the finished product. Thanks to its pilot plant (180 cubic meters per year [180 m^3/yr]) and the involvement of its partners, the project has made breakthroughs in terms of the three key elements: pretreatment, enzymes, and yeasts. In 2015, the project passed a new key milestone in its development — the first R&D steps and the pilot plant validating the viability of the process under economic and environmental plans. A demonstration unit capable of producing 3,500 m^3/yr is under construction on the Tereos site in Bucy-Le-Long for production launch in 2016.
- **BioTfueL.** The 180-million BioTfueL project aims to develop and bring to the market a chain of processes for producing second-generation

[53] http://www.gouvernement.fr/sites/default/files/contenu/piecejointe/2015/03/aap_vhicule_routier_2015.pdf.

biodiesel and bio-kerosene by using a thermochemical process. It is led by a group of six partners: Avril, Axens, CEA, IFP Energies Nouvelles (IFPEN), Thyssenkrupp Industrial Solutions, and Total. The demonstration phase work has started, and two preindustrial units are currently being built: one to pre-process the raw biomass material on the Avril site in Venette (Picardy), and one to produce liquid biofuel on Total's refinery site in Dunkirk (Flanders establishment). Planned biomass processing capacity is 3 tons per hour. Tests are due to start in 2017.

- **Gaya.** This €57 million project involves BioSNG (synthetic natural gas made of renewable resources) production by a thermochemical process (bio-methane fuel produced by gasification followed by a methanation step). This project brings together 11 public research organizations and private partners. The R&D program amounts to €17 million, out of which a third is financed by ADEME. Engie (formerly GDF SUEZ Group) will coordinate the project. The R&D Gaya platform is due to start operation by the end of 2016.
- **Syndiese.** The aim of this project is to build a preindustrial demonstrator for producing second-generation biofuels that has a capacity of 10 metric tons per hour (t/h). As a result of their R&D programs, Air Liquide and CEA are working together to develop a concept for transforming biomass into synthesis gas (BtS technology).

ADEME and other EV and PHEV Programs

The electrification of vehicles has great potential for reducing fuel consumption, limiting the impact of vehicles on the environment, and diversifying energy sources. Many projects aim to eliminate existing technical barriers to this goal.

In order to promote electric mobility, the French Government is encouraging local authority projects to install electric charging terminals through the "Investments for the Future" (PIA) program:

- **BienVEnu Project.** This is an innovative Smart City project to encourage deployment of EVs in collective housing launched by the project coordinator, European Regional Development Fund (ERDF), and seven partners, including CentraleSupélec, G2Mobility, MOPeasy, Nexans, Park'N'Plug, Tetragora, and Trialog. Supported by ADEME under the PIA program and by the Ile de France Region, BienVEnu aims to meet these challenges through a simple "all-inclusive" offering, designed to meet the needs of collective housing managers and residents in the Smart City.

Based in the Ile de France region, the 3-year project has a €10 million budget (with €4 million supported by PIA). Charging facilities will be deployed in three "pilot" buildings during the first year, then seven more during the second year, both in private and socially owned collective housing. Initially, about 10 charging stations will be installed in each building.

The project is designed around "charging clusters." These provide an open-ended system that groups several charging stations together and can easily be expanded. This solution also limits the impact on both the local electricity distribution grid and the building's power load, thus providing a cost reduction opportunity for the community.

In order to increase the potential for developing the EV market in Europe, the "Mobilité Hydrogène France" consortium gathered 29 partners (including Air Liquide, Alphéa Hydrogène, AREVA H_2N, CEA, CETH2, EDF, ENGIE, GDF SUEZ, GRTgaz, IFPEN, INEVA-CNRT, Intelligent Energy, ITM Power, Linde, Michelin, McPhy Energy, PFA, Pôle Véhicule du Futur, PHyRENEES, Renault Trucks, Solvay, Symbio FCell, Tenerrdis, and WH2) to produce scenarios for the development of hydrogen-energy infrastructures across the nation. The HyWay project's filling stations represent the initial building blocks of a future national network.

- **HyWayProject.** This project aims to put a fleet of 50 electric cars on the road with a fuel cell range extender, and the construction of two hydrogen filling stations in Lyon and Grenoble. The HyWay project is backed by the French Government, through DREAL (Regional Department of the Environment, Planning and Housing) and ADEME, and by the Rhône-Alpes region (co-financing €1.4 million) with the help of the Tennerdis local cluster focused on energy transition. It also aligns with ERDF objectives. The partners of the project are Air Liquide, CNR, GEG, McPhy Energy, PUS (COFELY Services), STEF, and Symbio FCell.

Other Projects Continuing until 2016

- **HYDIVU.** This €90 million project will focus on an innovative solution for diesel hybrid powertrain, light utility vehicles (i.e., family vans and Trafic and Master ranges [ranges are van category]). Renault has partnered with Valeo and Continental, leading suppliers to the automotive industry, and with IFP Énergies Nouvelles and LMS to support this project.

- **ESSENCYELE.** The aim of this project is to combine a high-efficiency gasoline engine with a mild hybrid low-voltage powertrain. The goal is to reduce the consumption of fuel by 25%, while using affordable technologies based on:
  - A mild hybrid gasoline powertrain that takes advantage of all the synergies offered by the combined motorization;
  - A high-efficiency, downsized engine that implements affordable technologies;
  - Hybridization at low cost with an operating voltage of 48 V and with zero-emissions vehicle (ZEV) capability; and
  - A technological breakthrough in the electrical energy storage system due to the use of ultra capacitors.

The program, supported partly by ADEME (total budget is €79 million), involves the following partners: Valeo GKN, Hutchinson, PSA Peugeot Citroën, EFS, CORIA, IFP Énergies Nouvelles, Ecole Centrale de Lille, ENS Cachan, INP Toulouse, UTC Compiègne, and University of Valenciennes.

Air Transportation

In the field of air transportation, R&D (particularly research focusing on alternative powertrains, combustion, and low-carbon fuels) is conducted in cooperation with European partners. Examples of projects in the aviation sector include the undergoing CORAC and CORE Jet Fuel projects (see details in *IEA-Advanced Motor Fuels Annual Report 2014*).

The DGAC ("Direction Générale de l'Aviation Civile") is associated with the "Lab'line for the Future" initiative which was launched in 2014 by Air France. Since October 2014, a biofuel-powered Airbus A321 has been undertaking weekly flights between Toulouse and Paris-Orly. The biofuel used is farnesane. Produced by Total-Amyris, this biofuel comes from the fermentation of sugar cane. It does not compete with the food industry and meets the sustainability requirements recognized by the Commission. The DGAC-backed experiment should enable a study on the operational and socioeconomic impacts of the regular operation of flights using biofuels. First studies have shown that the use of farnesane could reduce GHG emissions by up to 80% compared to fossil-fuel-based kerosene.

After the end of the CAER (Alternative Fuels for Aeronautics) project, a new project, MOCASSIN, should begin in 2016. It will aim to develop modelling of the behaviour of conventional and alternative aviation fuel in order to have complementary models of experimental results.

Outlook

By adopting the Law on Energy Transition (LTE), France is strongly mobilized to act against climate change. It sets up the conditions for a gradual, balanced change, based on the development of a diversified energy mix responding to environmental constraints. Among the goals, the LTE is targeting 15% consumption of advanced biofuels in transportation by 2030: 15% PCI of renewable energies, –30% of fossil energies.

Various studies have tried to put into perspective the LTE's goal. Among these are the "Biofuels" working group from the NFI (Nouvelle France Industrielle) "New Resources" Solution which is composed of organizations and companies representing the biofuel industry, the refining sector, and car manufacturers, as well as representatives from the State (ministries and funding agency). Led by Mr. P. Barthélemy, Deputy General Director with IFP Energies Nouvelles, the working group has developed a scenario for the energy mix by 2030 supporting the development of advanced biofuels and meeting the objectives of the Law (15% of renewable energies, –30% of fossil energies). In addition to reaching these targets with 14.3% of biofuels and 0.7% of biogas and renewable electricity, the scenario foresees a 3.5 rebalancing diesel/gasoline ratio in France and the deployment of industrial units, including lignocellulosic biofuels production, necessary for its realization. The results of this scenario have been proposed for the elaboration of the Multi-Year Program of Energy, in particular for setting the objectives of the progressive incorporation of advanced biofuels.

The LTE also promotes several measures to lay the foundations for a sustainable mobility and levers of actions to develop the most environmentally friendly vehicles. These include:

- The obligation to purchase by the state and its public institutions, local authorities and their associations, national companies, car rental companies and taxi operators, environmentally friendly vehicles upon renewal of their fleet;
- The introduction of the possibility to define terms of "parking and traffic preferred" (including in areas with restricted circulation); and
- The introduction of a development strategy and infrastructure deployment of fuel alternative refuelling (e.g., natural gas, biogas).

The main objective of these measures is to reduce the local pollution generated by transport activities and GHG emissions via increasing low vehicle emissions.

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Germany

Introduction

The discussion, figures, and tables that follow show fuel consumption in Germany and the number of registered vehicles separated by fuel type. The assumptions about fuel consumption for 2015 are based on real data from 2014 and on trends-based assessments for January until November 2015.

Figure 1 shows Germany's 2014 consumption, with the following ranking from most to least consumed fuel: diesel (61%), gasoline (32%), and renewable fuels (5%).

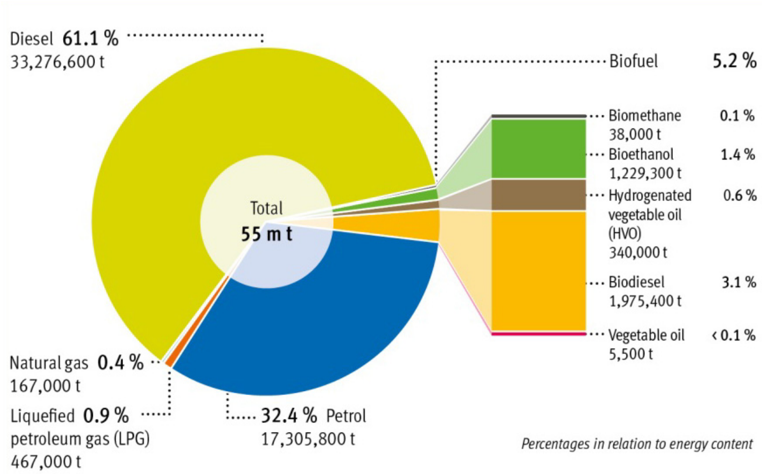

Fig. 1 Fuel Consumption in the Transport Sector in Germany in 2014
(Source: BAFA [Bundesamt für Wirtschaft und Ausfuhrkontrolle] et al. 2015a)
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In 2014, German fuel consumption for use in road transportation amounted to 55.0 million metric tonnes (Mt), including biofuels. Of this amount, 17.3 Mt of gasoline and 33.3 Mt of diesel were consumed. The consumption of biofuels amounted to 3.6 Mt, with the majority being low-level blends of biodiesel and hydrotreated vegetable oil (2.3 Mt) and bioethanol (1.2 Mt). Quantities of other biofuels consumed in 2014 were (a) pure biodiesel at 5 kilotons (kt); (b) ethanol with 1.1 Mt, (c) ethyl tertiary-butyl ether or ETBE, the additive for motor gasoline, at 139 kt; (d) pure vegetable oil at 5.5 kt; and (d) E85 at 8 kt. The consumption of biofuels in 2014 was a little bit higher than it was in 2013, at 3.4 Mt.

Tables 1 and 2 show the 2015 trends for biofuels and biofuel supplements, respectively. The decrease in all biofuel sales and its blends is expected to be the result of the new 2015 regulations on the greenhouse gas (GHG) quota system introduced in January 2015 (see Policies and Legislation).

Table 1 Trends in German Biodiesel Sales, 2009–2015

Sale (kt)	2009	2010	2011	2012	2013	2014	2015[a]
Blend	2,191	2,236	2,116	1,928	1,741	1,970	1,847
Pure biodiesel	241	293	97	131	30	5	4
Total	2,431	2,529	2,213	2,059	1,772	1,975	1,851

[a] Data available for Jan–Nov 2015; extrapolated for Dec 2015.

Source: FNR on basis of BAFA et al. (2015)

Table 2 Trends in German Bioethanol Sales, 2009–2015

Sale (kt)	2009	2010	2011	2012	2013	2014	2015[b]
E85[a] (ethanol share)	9(7)	18(15)	19(16)	21(17)	14(11)	10(8)	7(6)
Ethanol	687	1,028	1,054	1,090	1,041	1,082	1,047
ETBE[c]	198	122	162	142	154	139	116
Total	892	1,165	1,233	1,249	1,206	1,229	1,163

[a] Including only share of ethanol.

[b] Data available for Jan–Nov 2015; extrapolated for Dec 2015.

[c] Ethyl tertiary-butyl ether; percentage by volume share of bioethanol in ETBE = 47%.

Source: FNR on basis of BAFA et al. (2015)

Roughly 97% of the crude oil used in Germany in 2015 (for fuel, among other uses) had to be imported. German sources of imported crude oil are relatively well diversified. The Russian Federation accounts for 35% of imports; 14% comes from Norway; 11% comes from Great Britain; between 6% and 7% each comes from Nigeria, Kazakhstan, and Azerbaijan; and 20% comes from 25 other countries worldwide (BAFA 2015b).

Table 3 shows the number of passenger cars on the road in Germany by fuel type for 2006 through 2015.

Table 3 Number of Passenger Cars in Germany by Fuel Type on January 1 of Given Year[a]

Year	Gasoline	Diesel	LPG	NG	EV	Hybrid
2006	35,918,697	10,091,290	40,585	30,554	1,931	5,971
2007	35,594,333	10,819,760	98,370	42,759	1,790	11,275
2008	30,905,204	10,045,903	162,041	50,614	1,436	17,307
2009	30,639,015	10,290,288	306,402	60,744	1,452	22,330
2010	30,449,617	10,817,769	369,430	68,515	1,588	28,862
2011	30,487,578	11,266,644	418,659	71,519	2,307	37,256
2012	30,452,019	11,891,375	456,252	74,853	4,541	47,642
2013	30,206,472	12,578,950	494,777	76,284	7,114	64,995
2014	29,956,296	13,215,190	500,867	79,065	12,156	85,575
2015	29,837,614	13,861,404	494,148	81,423	18,948	107.754

[a] LPG = liquefied petroleum gas according to European fuel quality standard EN 589. NG = natural gas according to German fuel quality standard DIN 51624. EV = electric vehicles.

Source: Kraftfahrt-Bundesamt, the Federal Motor Transport Authority (KBA 2015a)

A total of 53.7 million vehicles were registered in Germany as of January 1, 2015, with 44.4 million of them (82.7%) being passenger cars. Of the registered vehicles, 4.1 million (7.7 %) were motorcycles and 2.7 million (5.0 %) were trucks. The rest were buses, tractors, and other vehicles. Of the passenger cars, 13.9 million (30.0%) were diesel-fuelled and 29.8 million (68.3%) were petrol-fuelled (see Table 1). Vehicles with alternative powertrains numbered 620,931 (1.5%). This total included 12,156 electric vehicles (EVs), 85,575 hybrid vehicles, 500,867 vehicles using liquefied petroleum gas (LPG), and 79,065 vehicles using natural gas (KBA 2015b).

Policies and Legislation

Since January 2015, the benchmark for biofuel quotas has been converted from energy content to a net GHG reduction. This net quota will increase in three steps: from 3.5% in 2015, to 4% in 2017, and to 6% in 2020. Biomethane of natural-gas-quality mixed with natural gas can also be used to fill the quota. This aspired-to quota will be 1% lower by 2020 than the quota previously proposed in 2013. Furthermore, the amendment to the German Emission Control Act (December 2014's Bundes-Immissionsschutzgesetz-BImSchG) bans all double-counting and excludes animal fats and bio-based oils that are co-refined with fossil-based oils from the quota eligibility. Biofuels are currently the only way to fulfill the target. It is expected that there will be provisions for electricity use in road transport in the law in the future.

The sustainability criteria for biofuels agreed to at the European level under the Renewable Energy Directive (RED, 2009/28/EC [European Commission]) and under the Fuel Quality Directive (FQD, 98/70/EC) became German law in 2009. The December 2014 amendment also reflects concerns about the sustainability and GHG-reduction benefits of some biofuels. The new law strives to consider the upcoming European Union (EU) legislation and aligns with the EU Energy Council's political agreement on a draft amendment to the RED and the FQD from June 2014.

In December 2014, the German Agency for Renewable Energy (Deutsche Energie-Agentur GmbH [DENA]), which is strongly aligned with the Federal Ministry of Economic Affairs and Energy, presented a policy paper for sustainable mobility in the EU to the EC. DENA considers the "use of renewable liquid and gaseous fuels of non-biological origin [as] essential for achieving the EU's climate protection objectives in the transport sector." It recommended:

- The minimum quota for advanced biofuels is 2.5% in 2020.
- Renewable liquid and gaseous fuels of non-biological origin shall be considered to be four times their energy content.
- Fuels produced from carbon-rich (carbon monoxide [CO] or carbon dioxide [CO_2]) gas streams from agricultural residues, waste, and residues of nonrenewable energy sources shall be considered to be four times their energy content.
- The use of renewable hydrogen in refineries is to be considered as a possible method of reducing the GHG emissions of fossil fuels (DENA 2014).

In addition to the promotion of an appropriate, consistent tax and regulatory business environment, the promotion of research and development (R&D) is also occurring across the various biofuel sectors to create conditions conducive to boosting biofuel use. In this context, the German Federal Government supports projects that will further develop existing biofuel technologies and develop new ones from scratch. This support encompasses the full value chain, including the provision of raw materials (e.g., growing of crops), biomass conversion, quality assurance, and the use of biofuels in vehicles (e.g., emissions, material compatibility).

Under the Renewable Resources Funding Scheme of the Federal Ministry of Food and Agriculture (BMEL), a reasonable decrease in funded projects related to biofuels can be seen. Forty R&D projects received funding in 2015 of €14 million ($15.6 million US) (in 2014, 70 projects received funding of €23 million/$25.7 million US). This support includes funding for projects related to bioethanol, biodiesel, vegetable oil, biomethane, and advanced biofuels, as well as to areas like biofuel sustainability. The aid is granted through the BMEL's project sponsor, the Agency of Renewable Resources (Fachagentur Nachwachsende Rohstoffe e.V., or FNR).

With regard to advanced biofuels, project support was focused on biomass-to-liquid (BTL) fuels, which have not been introduced to the market yet but are considered a promising option because of their broad raw material base and chemical composition. In addition, the production of hydrocarbons from biochemical pathways is playing an increasingly important role with regard to funding activities. Another funding focus is on developing ways to deploy energy from renewable resources, such as algae.

Since 2013, the project AUFWIND (with 12 partners) has been receiving financial support. The aim of the project is to produce kerosene made of algae. To identify the sustainable biomass potential of biofuel and to prevent some kind of impact related to indirect land use change (ILUC), the Federal Ministry for Environment, Nature Conservation, Building, and Nuclear Safety (BMUB) and BMEL funded four projects having a common priority — conducting "studies on aspects of the sustainability of biofuels." Results will be published in 2016.

The Federal Ministry of Transport and Digital Infrastructure (BMVI) launched the "Mobility and Fuel Strategy" in 2011 aimed at creating environment- and climate-friendly, socially responsible, and economically efficient modes of future transportation. It is based on a strategy launched in 2004 that was completed in 2013. The recent strategy does not favor a specific technology but includes all important transportation modes (road, aviation, railway, and waterborne) and all relevant drivetrains and energy sources (fossil-based fuels, biofuels, electric mobility, and fuel cells). In 2015, BMVI and other stakeholders announced the effort to push the implementation and usage of liquefied natural gas (LNG), especially for heavy-duty transport (HDT). The Mobility and Fuel Strategy is organized as a consistent and adaptive process, and stakeholders from government, industry, academia, society, and nongovernmental organizations (NGOs) participate. The main goals of its dialogue process are to find medium- and long-term prospects for the substitution of fossil fuels, to develop fuels based on renewable sources of energy, and to identify promising drivetrain technologies and the supply infrastructure required to support them. The process continued in 2014 and 2015; first recommendations can be reviewed in German on the BMVI website.

With respect to electrified transportation, the goal of the German Government is to have at least 1 million EVs on German roads by 2020. Electrification of transport is the main governmental strategy for reducing GHG emissions in this sector. In May 2010, the National Platform for Electro Mobility (Nationale Plattform Elektromobilität [NPE]) was founded. In the NPE, all relevant car manufacturers, suppliers, and research facilities are represented; they are organized into seven working groups who discuss specific issues and identify measures for dealing with them. Nevertheless, in 2014, only 24,000 EVs were sold instead of the planned 100,000. By the end of 2015, 31,311 EVs and 141,384 hybrids were registered. Thus, Germany is at risk of missing its climate targets for road transportation. Leading politicians from the German Government and the NPE are demanding stronger support of the sector, which would amount to €3 billion for the coming years (Focus Online 2014). Industry and politics are calling for strong incentives like tax exemptions for commercial vehicles, public programs to build 15,000 charging stations, publicly funded buyers' premiums in the range of €5,000 ($5,410 US),[54] and public campaigns to foster a shift in public behavior and buying decision. These recommendations were in discussion since the beginning of 2014, but no decision was taken until the end of 2015. The BMVI established grants for public procurement incentives for EV fleets in summer 2015. Experts claim that if not all measures are enacted soon, achieving the government's goal of 1 million EVs by 2020 and the targeted GHG savings will be at considerable risk. However, different propositions to approach this shortfall have been on several political agendas lately.

The program called the "Initiative for Natural Gas-Based Mobility – CNG and Biomethane as Fuels" supports the German Government's goal of encouraging greater use of natural gas vehicles (NGVs). Currently, natural gas is only 0.4% of the fuel mix. Compressed natural gas (CNG) and biomethane have the potential to reach 4% by 2020 in Germany, which would represent a greater-than tenfold increase. The members of the initiative are consumer organizations and well-known energy and transportation sector companies along the entire value chain. The initiative

[54] Main federal ministers (for economy, transport, and environment) decided in February 2016 to implement the buyers' premiums starting mid-2016. Private buyers should receive €5,000 and commercial buyers €3,000. Forty percent of the expected costs of €1.3 billon should be covered by the car manufactures. Further public investments should be spent for 15,000 charging stations, battery research, and for public procurement for the public fleet (Spiegel Online 2016).

is coordinated by DENA, the German Energy Agency. The NGV fleet in Germany in 2015 increased again by 2,500 vehicles, similar to 2014; however, the share of registered CNG vehicles is still rather low, with 0.18%. In 2014, the methane mixture achieved a higher share of biomethane (23%) than the year before, thus reducing GHG emissions and dependency on fossil-based natural gas (DENA 2015; KBA 2015a).

After the federal election in September 2013, the coalition agreement among the three parties forming the German Government — CDU (Christian Democratic Union), CSU (Christian Social Union), and SPD (Social Democratic Party) — was published in November 2013. The agreement supports the development of new powertrains and fuels. The German Government wants to develop a biofuels strategy oriented toward the potential of sustainable biomass. It was proposed to extend the tax relief for natural gas beyond 2018, but this was not decided in 2015.

At the end of January 2016, the international conference "Fuels of the Future 2016" took place in Berlin, with more than 500 visitors.

Implementation: Use of Advanced Motor Fuels

Incentives for using advanced motor fuels include a full tax exemption for specific biofuels (i.e., BTL, bioethanol from lignocellulose, biomethane, and E85 [E70–E90]), which expired the end of 2015, and a partial tax exemption for natural gas (CNG and LNG) and LPG as transport fuel until the end of 2018. The switch in the beginning of 2015 in the biofuels quota legislation from quantitative quotas (energy content) to GHG-reduction quotas (3.5% from 2015 on, 4% from 2017 on, and 6% from 2020 on) has provided a further impetus for using advanced biofuels. Biofuels performing better than the minimum GHG-reduction requirements of the RED and FQD (which are reductions of 35% until 2017, 50% from 2017 on, and 60% from 2018 on for new production facilities) should be rewarded by higher market prices.

German car manufacturers Audi and Mercedes-Benz are already testing advanced motor fuels. Under the leadership of Audi in Werlte, Lower Saxony, the world's first power-to-gas plant was built on an industrial scale to produce synthetic natural gas (Figure 2).

Fig. 2 Power-to-Gas Plant to Produce E-Gas
(Source: Audi AG)

The plant opened in June 2013. The Audi e-gas plant in Werlte produces hydrogen and synthetic methane from renewable energy surpluses, which will permit mobility that is almost CO_2-neutral. The Audi e-gas plant uses renewable electricity in the first stage for electrolysis — splitting water into oxygen and hydrogen (Audi e-hydrogen), which could power fuel cell vehicles someday. Because there is not a widespread hydrogen infrastructure, however, the hydrogen is then reacted with CO_2 in a methanation plant to produce renewable synthetic methane, or Audi e-gas.

Chemically speaking, this e-gas is identical to fossil-based natural gas. As such, it can be distributed to CNG stations via a natural gas network. The e-gas from Werlte (roughly 1,000 tons per year) can power 1,500 new Audi A3 Sportback g-tron vehicles for a distance of 15,000 km (9,320 mi) every year. To reach higher annual operating times, the plant contributed to the electricity balancing market in Germany in 2015, which benefitted the power grid and the amount of Audi e-gas that was produced.

Since July 2012, Clariant AG in Straubing near Munich has produced cellulosic ethanol on a large scale — 1,000 tons of bioethanol per year — by using its sunliquid20® process. This process converts wheat and barley straw, and corn stover (i.e., the leaves and stalks of maize, rice straw, and the leftovers of sugar cane) into cellulosic ethanol. This process, which extracts and then converts the sugars contained in the plant material almost entirely into ethanol, could make use of about 60% of the 240 million tonnes of residual cereal straw that could be collected from the fields in Europe after harvest every year.

Mercedes-Benz decided to run fleet tests for 1 year with sunliquid20 (Figure 3). German car manufacturers in general see significant benefits from using an E20 fuel, if engines are optimized for this fuel grade. Cellulosic ethanol is mixed with conventional fuel components to create the new fuel. As a benefit, cellulosic ethanol is virtually CO_2-neutral, and there is no competition with food production or for agricultural acreage. According to the tests, sunliquid20 improves engine efficiency so that its 4%-less energy content (compared with that of E10) is more than compensated for. Another notable finding was the 50% improvement in particle count emissions of sunliquid20 over those from using the European Union (EU) reference fuel, EU5. In addition, the fuel blend of cellulosic ethanol sunliquid20 demonstrates GHG emission savings of up to 95% across the entire value chain (well-to-wheel). Today, the latest Mercedes-Benz BlueDIRECT cars can run on sunliquid20 (Clariant AG 2014).

Fig. 3 Mercedes-Benz Cars in Front of the Sunliquid® Demonstration Plant
(Source: Daimler AG)

Outlook

At the end of 2015, it was difficult to provide a reliable outlook for the use of advanced motor fuels over both the short and long term. The EU target for 2020 is still to use 10% renewable energy sources in transportation. In September 2015, however, the EC brought to an end many months of debate about the revision of the RED and FQD. By 2017, these will have to be implemented into national legislation. The impact on advanced biofuels is uncertain. On a national level in Germany, the increasing GHG-reduction quota will guide market developments. Further R&D activities (e.g., reducing the GHG emissions of biofuels to make them compatible with the amended RED and FQD, upscaling advanced biofuel production processes to an industrial scale) are other important challenges.

Additional Sources

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- Bayerisches Staatsministerium für Ernährung, Landwirtschaft und Forsten, www.tfz.bayern.de
- Biofuels Portal, www.bio-kraftstoffe.info
- Biorefineries Roadmap as part of the German Federal Government action plans for the material and energetic utilization of renewable raw materials, www.bmbf.de/pub/BMBF_Roadmap-Bioraffinerien_en_bf.pdf
- Bundesverband der deutschen Bioethanolwirtschaft, www.bdbe.de
- Bundesverband Regenerative Kraft, www.brm-ev.de/de
- Federal Government's Mobility and Fuels Strategy under the lead responsibility of the BMVI, www.bmvi.de/SharedDocs/EN/Artikel/G/G-MKS/mfs-context.html?nn=86868
- Initiative for natural-gas-based mobility, www.erdgasmobilitaet.info/en/home.html
- Kraftfahrt-Bundesamt, www.kba.de
- National Policy Strategy on Bioeconomy, Renewable Resources, and Biotechnological Processes as a basis for food, industry, and energy, BMEL 2013 www.bmel.de/SharedDocs/Downloads/EN/Publications/NatPolicyStrategyBioeconomy.pdf?__blob=publicationFile
- ProcessNet initiative of Dechema and VDI-GVC: Sustainable Production, Energy and Resources (SuPER) Expert group on alternative fuels, http://www.processnet.org/en/
- Union zur Förderung von Oel–und Proteinpflanzen e.V., www.ufop.de

- Verband der Deutschen Biokraftstoffindustrie e.V., www.biokraftstoffverband.de
- Verband der Ölsaaten-verarbeitenden industrie in Deutschland, www.ovid-verband.de

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Major Changes

The move from an energy quota for biofuels to a GHG reduction quota by January 1, 2015, can be judged as the most important change in German legislation. With this change, all double-counting mechanisms have been stopped. The GHG quota is the key instrument as an incentive for biofuels and has led to significant progress with regard to the reduction of GHG emissions of biofuels.

The current market is strongly based on conventional biofuels. It is expected that they will dominate the market at least until 2020. In the field of advanced biofuels, a series of research, development, and demonstration (RD&D) projects on different technology readiness levels (TRLs) or fuel readiness levels (FRLs) are under way.

Israel

Introduction

Until recently, Israel was an energy-poor country that relied almost entirely on imports of primary energy commodities. Despite discoveries of natural gas from off-shore fields, the main challenge associated with decreasing dependency on oil imports remains how to implement alternative fuels in the transportation sector.

In 2015, the consumption of fuels for transportation in Israel had grown at 8% in comparison to 2014, with consumption reaching approximately 2.8 million tons of gasoline and a similar amount of diesel. Table 1 presents details on the vehicle fleet in Israel in 2015.

Table 1 Fuel and Vehicle Use in Israel in 2015

Parameter	Gasoline	Diesel					Jet Fuel
Type of Vehicle	Mainly Private Vehicles	Light-duty Trucks	Medium- and Heavy-duty Trucks	Buses	Private Vehicles, Minibuses, Taxis, and Other	Trains	Jet Planes
No. of vehicles	2,500,000	245,000	82,000	18,000	100,000	Not specified	Not specified
Current usage of fuel (%)	43	14.0	11	6.6	9.4	1	15

Policies and Legislation

The Fuel Choices Initiative, approved by the Cabinet of the Government of Israel in January 2013, is a 10-year Government program managed under the Prime Minister's Office. The program is dedicated to reducing the world's dependency on oil for transport and supporting alternative fuels in transportation. The Israeli Government's objective is to turn the country into a center of knowledge and industry of alternative fuel technologies by supporting the development and implementation of the next generation of alternative technologies. This program is being implemented with the cooperation of several vehicle manufacturers that support the increased use of alternative fuel technologies in the transportation sector in Israel.

The Fuel Choices Initiative encourages lowering dependence on crude oil for transportation for energy security, economic, and environmental reasons. It sets ambitious targets for Israel: cut the use of oil for transportation by 30% by 2020 and by 60% by 2025, as compared with currently projected "business as usual" oil consumption. The targets are based on a bottom-up analysis of the various Israeli transportation market sectors, under the assumption that any solution must be economically viable for the end user as well as the economy.

The alternative fuels being promoted are compressed natural gas (CNG, mainly for heavy-duty trucks and buses), methanol blends (for cars, starting with a 15% blend and advancing later to higher blends), and electric mobility (mainly for buses, mass transit solutions, and dedicated fleet solutions). The Fuel Choices Initiative also aims to implement projects, in the longer term, that use biofuels from second- and third-generation nonedible crops (developed in Israel), and a process of waste-to-energy conversion.

More information about this program can be found at http://www.fuelchoicesinitiative.com/.

Activities pursued by the Israeli Government for the local market include the following:

- Establish regulations for new type of fuels (E10, M15).
- Establish pilot projects for methanol (in cooperation with Fiat Chrysler Automobiles [FCA]), Pilot E-Bus, and Super-capacitor based Electric Urban Public Transportation.
- Implement Green Tax 3. (As a supportive policy to integrate alternative fuels, Israel has formulated a tax policy called "Green Tax 3" that taxes fuels according to their environmental externalities.)
- Switch major users to alternative fuels.
- Enact regulations to subsidize the purchase of transport vehicles using natural gas as a motor fuel.
- Establish grants and a safety net for the construction of CNG fuelling stations.
- Set up joint projects with municipalities.
- Conduct workshops and conferences.
- Support other types of transportation. (The Ministry of Transportation in Israel initiated a plan to reduce private transport by 20% by 2030 with respect to business as usual and trends as of 2015. As part of making public transport more efficient, currently in Israel, a transport information system is deployed that provides an efficient bus-customer relationship.

Implementation: Use of Advanced Motor Fuels

Main achievements thus far:

- Four research centers:
  - Solar Fuels I-Core. Challenge: Generate clean, efficient energy from renewable sources (http://www.i-core.org.il/Alternative-Energy-Sources).
  - Israel National Research Center for Electrochemical Propulsion (INREP). Challenge: Improve energy storage and integration into mobility platforms (http://www.inrep.co.il/).
  - Agro - Energy Research (Vulcani Center). Challenge: Generate clean, efficient energy from renewable sources.
  - Institute for Innovation in Transportation.
    - ✓ National center together with Tel Aviv University.
    - ✓ Multidisciplinary.
    - ✓ Research agreements with international institutes (Massachusetts Institute of Technology [MIT] Media lab and others).
    - ✓ Partnership with industry.
    - ✓ Accelerator for pre-seed ideas.
- Research grants (involving a total of 190 groups of researchers).
- $100 million Co-Invest Fund.
- 21 pilot projects — Ministry of Energy demonstration funds.
- Ecomotion Community. The Community is focused on innovative smart transportation technology and is made up of 2,000 entrepreneurs and more than 250 startups (a list of the startups can be found at http://www.fuelchoicesinitiative.com/files/PDF/Companies_Directory_Fuel_Choices_Initiative_A4.pdf).

Natural Gas and Synthetic Fuels for the Domestic Market

Recent findings on off-shore natural gas fields are turning Israel into a leading regional energy supplier. In order to fulfill the economic and energetic potential of its natural gas resources, the Israeli Government is building a long-term strategy and policies for increasing the use of gas in Israel.

One of the main targets of the Government is increasing the use of natural gas and natural-gas-based synthetic fuels in the Israeli transportation sector. This target, backed by Government policies and regulations, is expected to generate significant investments and vibrant business activity in the growing local market. Companies and investors that will enter this new and innovative alternative energy sector will also lead in the growing global natural gas sector.

The Ministry of Energy and Water Resources acts to implement fuels based on natural gas — namely, CNG, gas-to liquid (GTL, drop-in) fuels, and methanol. The Ministry conducts well-to-wheel (WTW) projects and is involved in all technical, regulatory, and economic aspects. The task is supported by a number of pilot and demonstration projects in this field and by a techno-economical study of these fuels and their relevance to the Israeli market. The extensive analysis has considered all relevant segments of the supply chain, including the production, transportation, and consumption of the fuels by end users, as well as the required infrastructure. An executive summary of the analysis can be found at http://energy.gov.il/Subjects/EGOil Replacement/Documents/ORcng.pdf.

CNG

The regulatory status of CNG is relatively established. The Israeli mandatory requirements (IMRs) for motor vehicles are compatible with the European requirements, regulations, and documentation as specified in the European Community Whole Vehicle Type Approval (ECWVTA) certificate. These requirements can be found at http://he.mot.gov.il/ index.php?option=com_content&view=category&id=183&Itemid=358.

Other mandatory requirements, laws, and standards for natural gas and CNG can be uploaded from the website of the Ministry of National Infrastructure, Energy and Water Resources at http://energy.gov.il/English/Subjects/ Natural%20Gas/Pages/GxmsMniNGLobby.aspx:

- The Gas (Safety and Licensing) Law, 5749-1989
- The Natural Gas Sector Law, 5762-2002
- Industrial Gas Installation Directive – Natural Gas Authority (NGA)
- Compressed Natural Gas Directive – NGA

The following standards can be purchased from the website of the Standards Institution of Israel (SII) at www.sii.org.il:

- Automotive natural gas: SI 6119
- CNG fuelling stations for vehicles: SI 6236

Methanol

Methanol, a fuel that could be produced from a variety of feedstocks, is already used in different percentages in China. Both the United States and Australia are currently looking into methanol as an automotive fuel, because it can be produced from low-cost natural gas.

Israel began looking into methanol as a strategic transportation fuel due to the fact that it can be produced from domestic natural gas and has significant economic viability. In addition, an economic study carried out under the

Ministry of Energy, Water and Resources shows high economic feasibility in high methanol percentages. Therefore, a part of Israel's strategic plan is to implement a fuel with high methanol percentages in dedicated flex fuel vehicles (FFVs) into the Israeli market.

During 2012–2015, the Government of Israel supported and closely monitored a field trial of M15 (15% methanol and 85% gasoline) in Israel. The field trial included an examination of the fuel and vehicle side (laboratory tests of the fuel stability, engine performance on test-bench, road tests, and vehicle-generated emissions), as well as examination of the infrastructure.

After collecting and analyzing the data from this pilot, it was concluded that although there are very few and small modifications needed, M15 could not be used as a drop-in fuel in all existing gasoline-operated vehicles with no changes or adaptations of the vehicle. As mentioned previously, since there is a clear economic advantage for the consumer at high methanol concentrations, high methanol percentages in FFVs are being targeted.

FCA car manufacturers showed interest in the results of the pilot. However, they stated that targeting FFVs directly is a high risk for them in terms of technological risk management, and indicated the necessity of M15 as an intermediate step.

Accordingly, the Ministry of National Infrastructure, Energy and Water Resources, is supporting another pilot project “Adaption of FCA Vehicles to Run on Methanol Blends.” The main product of the study will be a detailed report describing the changes that have to be made to the vehicles, if any, in order to authorize them for M15 according to FCA standards. This milestone is the first in a series of milestones that would lead FCA in the development of cars using a high percentage of methanol, in accordance with the vision outlined by the Fuel Choices Initiative under the Prime Minister’s office.

To realize this task, the Government initiated the creation of a national standard for M15 fuel — automotive gasoline: a methanol-gasoline (petrol) fuel blend composed of 85% unleaded gasoline (petrol) and 15% methanol (M15).

GTL Fuels

Since 2012, the Ministry has studied the potential benefits of developing GTL plants in Israel for producing liquid synthetic fuels (gasoline and diesel) from natural gas.

The main strengths of GTL are as follows:

- Energy security and diversity. GTL makes up the highest percentage of oil substitutes. The ability to rely on self-produced fuels greatly diminishes the risk and dependencies associated with relying on imported oil.
- Use of existing infrastructure. The fuel can be used without requiring any modifications to existing infrastructure, vehicles, or driving habits.
- Other uses. The GTL process allows the production of various distillates, such as kerosene and petrochemical products, that hedge demand risks.
- Export potential. An increasing demand in Europe and elsewhere may result in export markets for hedging local demand.
- Economics. The techno-economic analysis has shown that the economic viability of developing a GTL plant is highly attractive, especially if the plant is configured such that it can be integrated with existing refineries. Capital costs are estimated to range from $60,000 to $100,000 US per barrel of daily production, depending on plant configuration, with the higher estimated cost reflecting the expense of a stand-alone facility.

In June 2014, The Ministry of National Infrastructure, Energy and Water Resources of Israel published an invitation to submit standpoints, information, and expressions of interest regarding the possibility of building and operating a GTL (natural gas to liquid fuels) facility in Israel. Only a few technology owners and engineering companies responded to this Request for Information (RFI); the Israeli Government is currently considering its next steps, perhaps through a pre-feasibility study for specific technologies in specific locations.

Electric Vehicle and Energy Storage Cluster

The electric vehicle (EV) and Energy Storage Cluster emerged from decades of academic and applied research in the fields of electrochemistry and electric engineering; from the development and production of special energy applications for use in the defense and biomedical sectors; from world-class, innovative information and communication technology industries; and from a local business culture that supports entrepreneurship and innovation.

Israel has pioneering startup and technological companies that have entered the world of EVs and energy storage, offering innovative solutions and products for transforming electric transportation into an economically and technologically viable alternative. Companies in the cluster develop and produce improved batteries; new types of fuel cells, super-capacitors and metal-air batteries; grid and battery management systems; EV infrastructure solutions; and managed EV charging systems.

The Israeli Government has taken steps to incentivize a local market for implementing EV technologies and infrastructures and is offering large tax benefits and regulatory support. The Israeli business environment for EV technologies and infrastructures and the Government incentives are creating a local ecosystem that supports the expansion of companies into global markets.

Engines, Composite Materials, and Other Technologies
Thanks to advanced academic and applied research and defense-related developments in diverse technological fields and also to the local entrepreneurial spirit, many Israeli companies and startups are providing various solutions to help vehicles reduce oil consumption. Creative companies are developing new engines; efficient power train technologies; and new, composite light materials.

Biofuels and Energy Agriculture Cluster
The Biofuels and Energy Agriculture cluster emerged from decades of academic and applied research in the fields of biotech, agriculture, and chemistry; from world leading agro-tech and agro-industry; and from advanced biotech industries.

Israeli startups and technology companies are at the forefront of biofuel and agricultural research and development and are considered world leaders on multiple fronts. New types of fuel and biomass crops, as well as algae technologies, are being developed; better methods for breeding, cultivating, and irrigating energy crops are positioning energy production at the forefront of the next generation of agriculture; and innovative processes and catalysts for converting feedstock and waste into fuels are about to change the economics of biofuels.

Leading Israeli agricultural companies are starting to work on global agricultural projects, introducing their knowledge and experience and improving crop yields. Because of its small size, the local Israeli market is focusing on promoting second- and third-generation locally produced biofuels, and through that effort, giving its companies and investors a global competitive edge.

Outlook

Figure 1 shows where the market is expected to go.

The Fuel Choices Initiative sets ambitious targets for Israel — cut the use of oil for transportation by 30% by 2020 and by 60% by 2025, as compared to currently projected business as usual oil consumption. The targets are based on a bottom-up analysis of the various Israeli transportation market sectors, under the assumption that any solution must be economically viable for the end user as well as the economy.

The alternative fuels being promoted are CNG (mainly for heavy-duty trucks and buses), methanol blends (for cars, starting with 15% methanol and advancing to higher blends), and electric mobility (mainly for buses, mass transit solutions, and dedicated fleet solutions). The Fuel Choices Initiative also aims to implement projects, in the longer term, that use biofuels from second- and third-generation nonedible crops (developed in Israel), and a process of waste-to-energy conversion.

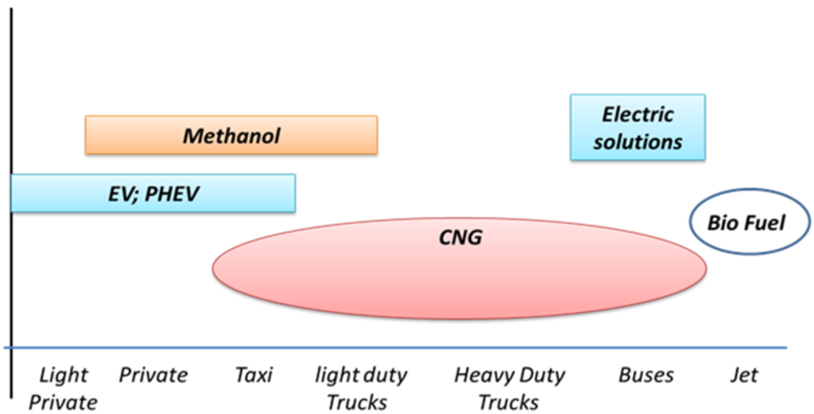

Fig. 1 Market Trends for Advanced Motor Fuels in Israel

AMF TCP Success Stories
Participation in the AMF TCP has given Israel greater access to the most relevant and up-to-date information and research on alternatives to traditional transport fuels. Leveraging this international expertise has helped Israel build its national research capabilities in support of its current and projected strategies.

Italy

Introduction

In 2014, the consumption of primary energy in Italy was around 166 million metrics tons or megatons of petroleum equivalent (Mtpe). As in previous years, oil remained the main energy source, representing 34.5% of consumption. Natural gas followed closely at 30.6%, and the percentage for renewable sources was 20.9% of consumption (Figure 1).

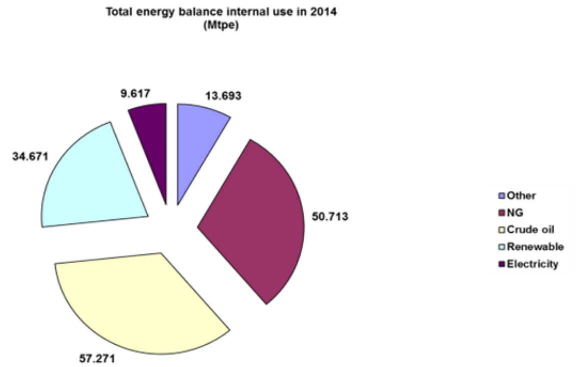

Fig. 1 Total Energy Balance by Type of Source in Italy in 2014
(Source: Ministry for Economic Development, 2014, National Energy Balance)

In 2014, Italy depended largely on imported oil; it imported 71.190 Mtpe (Figure 2).

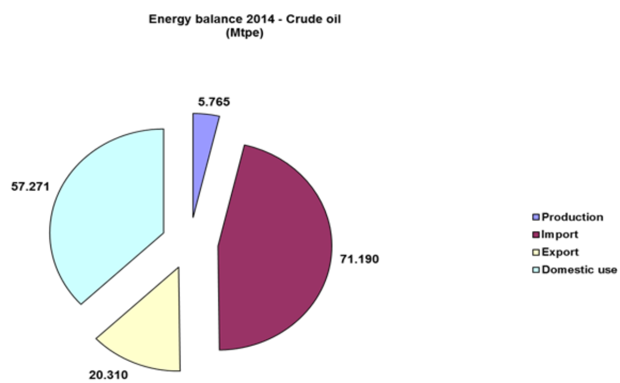

Fig. 2 Crude Oil Energy Balance in Italy in 2014
(Source: Ministry for Economic Development, 2014, National Energy Balance)

The major user (about 69%) of derived oil products in 2014 was the transportation sector (Figure 3).

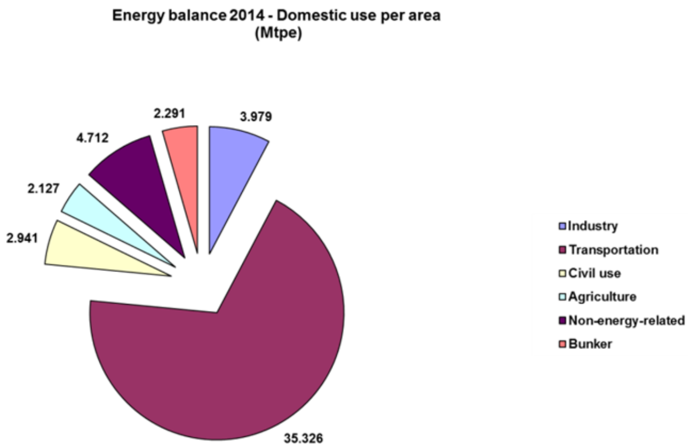

Fig. 3 Domestic Use of Oil per Sector in Italy in 2014
(Source: Ministry of Economic Development, 2014, National Energy Balance)

The main fuels used in road transportation were diesel fuel (66%), followed by gasoline (26%). Significant amounts of natural gas (3%) and liquefied petroleum gas (LPG, 5%) were also used in this sector (Figure 4).

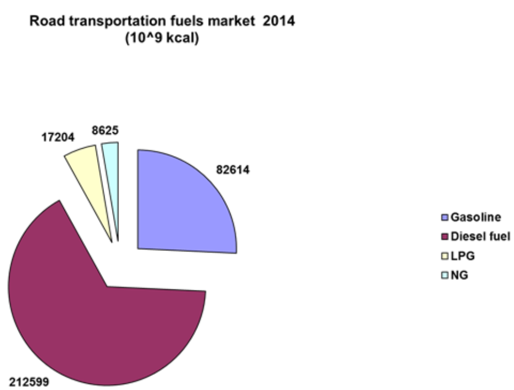

Fig. 4 Market for Different Types of Fuels in the Road Transportation Sector in Italy in 2014
(Source: Ministry for Economic Development, 2014, National Energy Balance)

With regard to the types of vehicles using the fuels, the top categories (in terms of number of vehicles) were passenger cars (76.13%), followed by motorcycles (13.49%), and lorries (8.05%) (Figure 5).

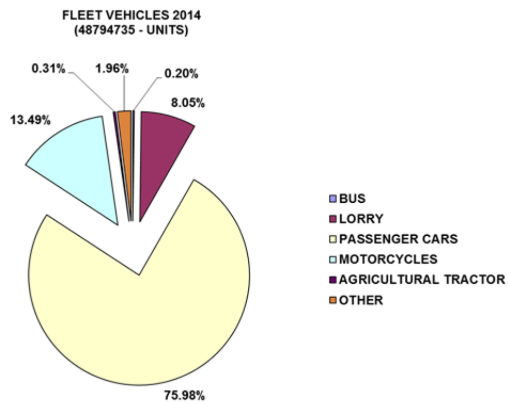

Fig. 5 Types of Fleet Vehicles Used in the Road Transportation Sector in Italy in 2014

(Source: ACI, 2014, Autoritratto)

In terms of passenger cars, the top categories were those that ran on gasoline (50.96%), followed by diesel fuel (41.10%). A significant percentage of vehicles also ran on natural gas (2.25%) and LPG (5.51%) (Figure 6).

In addition, diesel-fuelled vehicles could employ up to 7.0% of biodiesel, and gasoline-fuelled vehicles could employ gasoline containing oxygenated biofuels in which the oxygen content could amount to 3.7%.

Policies and Legislation

In both the long- and very-long term (until 2030–2050), Italy will subscribe to the spirit of the European Roadmap 2050 for a low-carbon economy. It aims to reduce emissions by up to 80%. In recent decades, however, it has been difficult to predict developments in technology and to predict vehicle and fuel markets, especially over the long term. Italy therefore intends to adopt a flexible and efficient long-term strategy for pursuing its key low-carbon policy. It will focus on and exploit (especially through research and technological developments) any pursuits that could result in significant positive changes. Examples would be more rapid cost reductions in renewable and storage technologies, use of biofuels, and the capture and storage of carbon dioxide (CO_2).

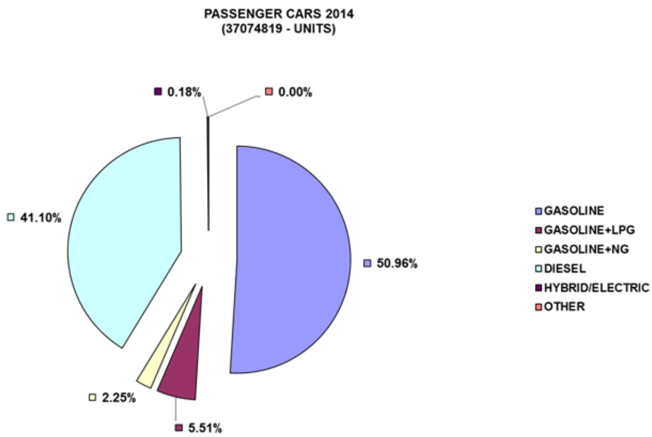

Fig. 6 Types of Fuels Used by Passenger Cars in Italy in 2014
(Source: ACI – Autoritratto 2014)

Italian Law has adopted two European directives: Renewable Energy Directive (RED, 2009/28/EC) and Fuel Quality Directive (FQD, 2009/30/EC). Under Italian Law 2009/99 (July 23, 2009) and in accordance with European Specification EN590:2009, the Italian Government has given permission for diesel fuel to contain biodiesel fuel (fatty acid methyl ester or FAME) in a percentage of up to 7%, as in other European Countries. Italian Decree 2011-28 acknowledges all European directives that promote the use of fuels or any other renewable sources. Italy grants energy incentives, like double-counting for using second-generation renewable sources (like those derived from wood cellulose or plant and animal residues). Italian Decree 2012-83 of June 22, 2012, established a limit of 20% for double-counting assigned to second-generation renewable sources.

Moreover, Italian municipalities have implemented important local measures that affect transportation. In order to improve air quality, reduce emissions of particulate matter with a mean diameter of 10 µm or less (PM_{10}), "smooth out" traffic on the road system, and lower noise in the cities, they have introduced measures to limit traffics in urban areas.

Implementation: Use of Advanced Motor Fuels

Biodiesel is the primary source for renewable advanced motor fuel in Italy. From 2009 until the present, biodiesel has been blended with up to 7 vol% diesel fuel. The renewable fuel currently used in gasoline is bio-ethyl tertiary-butyl ether (ETBE), derived from bioethanol. In 2014, the amount of bio-ETBE used in gasoline was 11 kilotons (kt), and the amount used in bio-ethanol was 1.5 kt.

At the end of 2013, there were 996 natural gas stations in the country, as well as a fleet of more than 700,000 passenger cars that use natural gas. The network was located mostly in northern Italy; central and southern Italy were not homogenously represented. In the region of Sardinia Island, there were no natural gas service stations at all. At the end of 2013, the LPG filling station network consisted of 3,250 stations, and there was a fleet of more than 1.9 million LPG-fuelled passenger cars. Figure 7 shows percentages of motor fuels used in 2014.

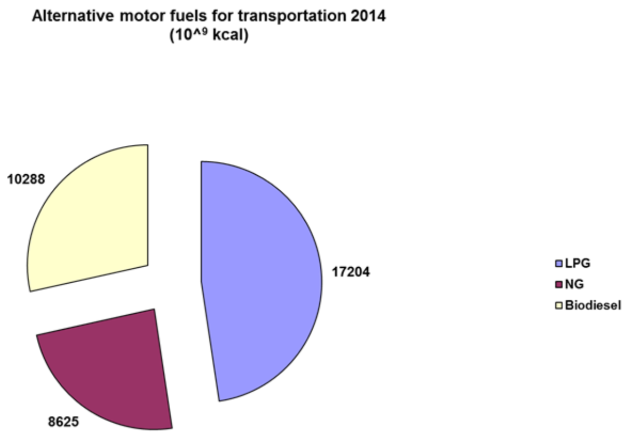

Fig. 7 Alternative Motor Fuels Used for Transportation in Italy in 2014
(Source: Ministry for Economic Development, 2014, National Energy Balance)

In 2012, the Italian oil and gas company Eni launched the Green Refinery project, which led to the conversion of the Venice Refinery into a biorefinery that produces innovative and high-quality biofuels. The project is the first in the world designed to convert a conventional refinery into a biorefinery by using the UOP/Eni Ecofining™ technology developed and patented by Eni in collaboration with UOP, a Honeywell company.

The Green Refinery project started with an initial conversion of the existing facilities of the Venice refinery that was started in the second quarter of 2013 and completed by the end of 2013. Biofuel production started in the second quarter of 2014 and has grown progressively as new facilities have begun operating.

At the new green plant site in Venice, industrial operations will be maintained in an economically sustainable manner over the long term, with a low environmental impact. Another activity associated with the Green Refinery project will be the construction of a new logistics center at the Venice plant site.

The Green Refinery project is based on distinctive environmental technologies that are highly compatible with Eni's continued commitment to research and innovation.

In 2006, Chemtex-M&G began research and development (R&D) activities designed to demonstrate the technological and environmental sustainability of second-generation bioethanol production from lignocellulosic feedstock (PROESA™ technology). Specifically, Chemtex-M&G conducted research on cellulosic crop optimization and agronomics; designed, engineered, developed, and tested (at both laboratory and pilot scales) proprietary technology and components for key aspects of the biomass-to-fuel conversion process; and partnered with leading technology providers to obtain the key biological process components. The world's largest cellulosic ethanol plant — in Crescentino, Vercelli Province, Italy — began production in 2012. The M&G PROESA™ process technology is extremely economical in converting nonfood biomass to sugars for the production of bioethanol. On October 9, 2013, the new technology was inaugurated at the plant in the presence of the Minister of Economic Development, and other local authorities

With regard to the optimization of the fossil fuel refining process, in 2013, Eni completed construction of the first plant for the total conversion of fossil fuel crudes at the Sannazzaro Refinery. The conversion process is based on its proprietary Eni Slurry Technology (EST). Startup was completed on October 14, 2013. This new hydroconversion process, which can completely convert unconventional oil, heavy crude, and tar sands into high-quality, high-performance fuels, is based on slurry technology that uses a special catalyst and self-starting hydrogen from natural gas. EST is the first invention in the history of scientific discoveries related to the oil sector that came out of Italy, and it came 40 years after the last oil manufacturing process was invented. Unlike traditional oil processes, EST can produce gasoline and gasoil without generating coke or fuel oil, for which the market is constantly declining.

Outlook

Italy has confirmed the 2020 target of 10% for biofuels. At the same time, the country intends to play an active part in reviewing the European Directive, with a view to promoting second- and third-generation biofuels. The review should leave open the possibility for a European assessment on whether to postpone the target in case more time is needed to adequately develop these technologies.

In the short term, the Italian Government has already adopted a number of "tactical" measures to steer the transport sector toward second-generation biofuel production (where Italy has reached levels of excellence). These measures are also designed to foster the development of the domestic and European Union (EU) system throughout the production sector.

In the transport sector, biofuel development is the subject of a wide-ranging international debate, in view of doubts regarding the real sustainability of "traditional" biofuels. The key decision will be whether to transition to second- and third-generation biofuels. For now, however, these biofuels are not able to completely replace traditional sources.

It will also be important to carefully evaluate the prospects for developing the domestic production of bio-methane for transport use.

Italian Decree, G.U. No. 250, October 27, 2014, defined the yearly minimum increases in the percentage of energy to be derived from biocomponents from 2015 to 2022 as follows:

- From January 1 to December 31, 2015: 5% biocomponents
- From January 1 to December 31, 2016: 5.5% biocomponents
- From January 1 to December 31, 2017: 6.5% biocomponents
- From January 1 to December 31, 2018: 7.5% of biofuels, of which at least 1.2% is advanced biofuels
- From January 1 to December 31, 2019: 9% of biofuels, of which at least 1.2% is advanced biofuels
- From January 1 to December 31, 2020: 10% of biofuels, of which at least 1.6% is advanced biofuels
- From January 1 to December 31, 2021: 10% of biofuels, of which at least 1.6% is advanced biofuels
- From January 1 to December 31, 2022: 10% of biofuels, of which at least 2% is advanced biofuels

In 2014, the minimum percentage of energy to be derived from bio-components was 5%.

Algae, straw, crude glycerine, bagasse, shells, and other cellulosic material were considered advanced biofuels.

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AMF TCP Success Stories
In Italy, information on AMF TCP activities is disseminated during regular meetings at the Ministry of Economic Development attended by the ExCo delegates of the IEA "end use" Technology Collaboration Programme.

Japan

Introduction

The transportation sector accounts for 23.1% of total energy consumption in Japan. Of this transportation sector energy consumption, passenger transport was responsible for 61.1%, and freight transport was responsible for the other 38.9% in 2013. Energy for transport in Japan depends mostly on imported oil (Figure 1).

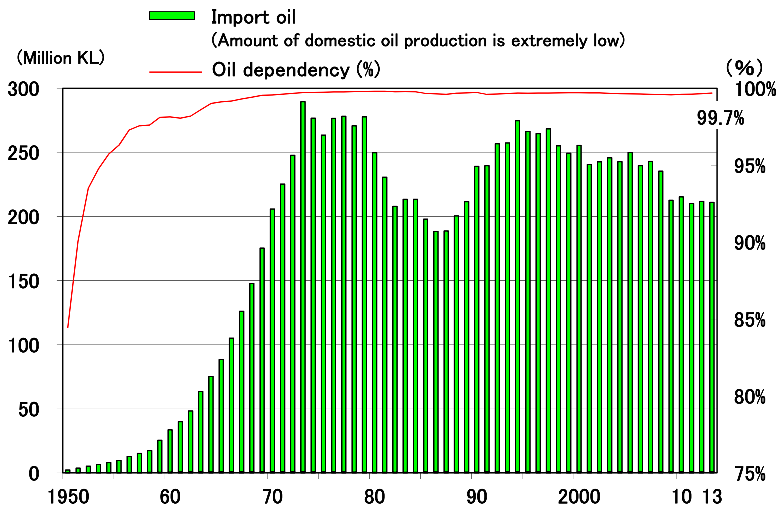

Fig. 1 Transition of Crude Oil Imports and Oil Dependency in Japan, 1950–2013 [1]

Figure 2 shows the energy sources used in the transportation sector [2]. Oil-related energy accounts for 97.9% of the total usage. The market for alternative fuels is very small in Japan, and the number of alternative fuel vehicles is small (Table 1). Methanol, compressed natural gas (CNG), hybrid, and electric vehicles currently constitute the low-emission vehicles. The number of hybrid vehicles is rather large, and the number of passenger hybrid vehicles contributes to this. CNG vehicles currently account for the largest number of vehicles in the low-emission truck category.

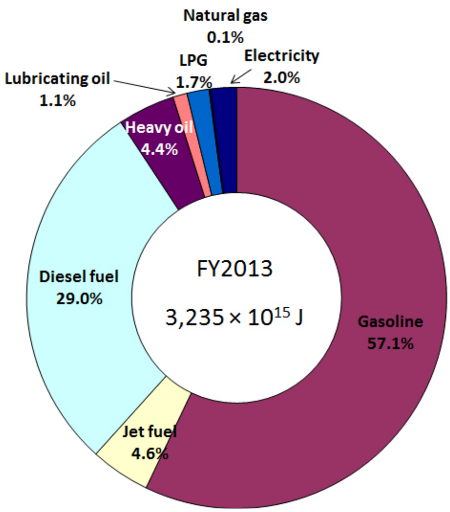

Fig. 2 Energy Sources Used in the Transportation Sector in Japan in 2013

Table 1 Current Penetration of Low-Emission Vehicles in Japan

Vehicle Type	Methanol [3]	CNG [4]	Hybrid [5])	EV [6]	Vehicle Registration [7]
Passenger vehicles	0	1,579	3,948,371	39,650	39,689,646
Light, mid, and heavy-duty trucks	576	5,784 19,367	13,470	24	5,877,354
Buses	0	1,575	978	34	226,944
Special vehicles	0	3,965	6,418	38	1,682,582
Small vehicles	0	12,406	435	15,974	Not available
Total	576	44,676	3,969,672	55,720	Not available

Policies and Legislation

In terms of primary energy, the new Strategic Energy Plan (the fourth plan) approved in April 2014 discusses the use of nuclear power and ensuring safety, improving the efficiency of electricity generation (such as through the application of an integrated gasification combined cycle for coal), expanding the use of liquefied natural gas (LNG) and liquefied petroleum gas (LPG), and places an emphasis on reducing the cost of renewable energy [8].

Regarding secondary energy, the plan cites the need to reform the structure of electricity generation. Consequently, on April 30, 2015, the Ministry of the Environment (MOE) and the Ministry of Economy, Trade and Industry (METI) presented a government proposal that targets reducing the level of greenhouse gases in 2030 by 26% compared to the level in 2013. The use of hydrogen as a fuel source was also widely discussed in the plan, which promoted the creation of a roadmap for the production, storage, transport, and use of hydrogen, as well as the strategic development of supply systems and infrastructure. As a result, the Strategic Roadmap for Hydrogen and Fuel Cells, which looks at the way that hydrogen fuel will be used in the future, was compiled in June 2014 [9].

Implementation: Use of Advanced Motor Fuels

Bioethanol

In Japan, the main activities promoting the use of biofuels are the three biofuel production site establishment projects between 2012 and 2016 managed by the Ministry of Agriculture, Forestry and Fisheries (MAFF). However, since it was determined that it would be too difficult to achieve the secondary objective of self-reliance and commercialization of these projects by Fiscal Year (FY) 2017, budgetary support as auxiliary projects of the MAFF was only provided up to FY 2014. The project to popularize the use of biofuels in Okinawa supplied roughly 70,000 kiloliters (kL) of E3 and E10 fuel in FY 2014. As of April 2015, it has established 57 service stations supplying E3 fuel and 29 service stations supplying E10 fuel [10]. In contrast, the number of service stations in Japan selling bio-gasoline blended with ethyl tertiary-butyl ether (ETBE) decreased by approximately 2% from April 2014 to 3,300, as of May 10, 2015 [11].

In Thailand, the New Energy and Industrial Technology Development Organization (NEDO) (outsourcing contractors: Sapporo Breweries Ltd. and Iwata Chemical Industry Co., Ltd.) has started demonstration operation of a plant to produce bioethanol from tapioca residue (production capacity of 80 kL/year) as a new bioethanol production technology). In addition, Iogen Corporation and Raizen, Inc. announced the start of continuous commercial production of ethanol from cellulose in Brazil beginning with the harvest in 2015.

Biodiesel

Over the past year, the main trend in Japan concerning biodiesel was the provision of subsidies by METI in cooperation with MAFF for regional biodiesel distribution system technology demonstration projects as a measure to help encourage the use and popularization of biomass-derived fuels. These subsidies will be used to support the main operators in each region in addressing technical issues surrounding an integrated and advanced distribution system for biodiesel. This is being done in an effort to promote and stabilize the supply, production, distribution, and production volume of biodiesel. The subsidies provided by METI will help the operators cover business expenses, giving METI and the operators the opportunity to identify and resolve issues blocking the wider use of biodiesel. This project and the subsidies began in FY 2013, and in FY 2014, 16 operators were adopted.

In terms of fuel properties, the JIS (Japan Industrial Standard) K 2390 standard has been aligned with the guidelines determined by EAS-ERIA (the Economic Research Institute for ASEAN (Association of Southeast Asian Nations) and East Asia at East Asia Summits), which is the unified standard for Southeast Asian countries. This was accomplished in four ways: (1) the provisions concerning kinematic viscosity, flash point, and iodine value were loosened to accommodate the diversity of oils derived from raw materials; (2) the provisions for monoglycerides related to vehicle cold startability were made stricter and the items in the test method (cloud point and cold filter plugging point) for cold startability were clearly specified; (3) the provisions concerning phosphorus related to catalyst poisoning in after-treatment devices were made stricter; and (4) a subcommittee of the Society of Automotive Engineers of Japan (JSAE) discussed how to clearly specify a standard value for oxidation stability. With regard to number 2, the European standard that concerns the low-temperature fluidity requirements for biodiesel fuels is EN14214:2012. It divides fuels into six classes through a complicated method that combines the cloud point, cold filter plugging point, and monoglyceride content. However, in Japan, the distribution of biodiesel fuel has not progressed very far, and Japanese manufacturers would likely be unable to adequately follow complicated standards. Therefore, the JSAE committee agreed to stop at the specification of two grades based on the monoglyceride content. However, this has not yet been reflected in the JIS standard.

Natural Gas

According to statistics published by the Japanese Ministry of Finance (MOF), Japan imports most of its LNG from Qatar, Australia, Malaysia, and Russia. In 2013, the import price into Japan was 16.2 U.S. dollars per

MMBtu. (MMBtu is an abbreviation for one million British thermal units and is roughly equivalent to 25 cubic meters [m^3] of natural gas.) This indicates that Japan was forced to pay a higher price in comparison to the import price into the United Kingdom (10.7 U.S. dollars/MMBtu) and the United States (3.7 U.S. dollars/MMBtu). Currently, light-duty and medium-duty CNG trucks have been disseminated in Japan. However the latest news is that Isuzu Motors Limited launched a CNG heavy-duty truck in December 2015.

Natural Energy and Hydrogen

In Japan, the most common use of natural energy (renewable energy) in the form of automotive fuel is hydrogen obtained via water electrolysis. In anticipation of the eventual realization of a hydrogen-fuel-based society, NEDO, a national research and development institute, has compiled a Hydrogen Energy White Paper that outlines the current state of research and development into hydrogen-based fuels. This white paper contains information concerning the use of hydrogen as an energy source, both inside and outside Japan, in a systematic manner. Starting with the characteristics of hydrogen itself, the white paper discusses the significance of using hydrogen as an energy source, the technology trends concerning hydrogen manufacturing, transportation, storage, and use, as well as the policy trends toward developing a hydrogen-fuel-based society, current issues, and future directions. The white paper also contains a section that provides the basics of hydrogen energy.

The Toyota Mirai hydrogen fuel cell vehicle (FCV) went on sale in December 2014. In conjunction with this event, Iwatani Corporation and JX Nippon Oil & Energy Corporation started selling hydrogen fuel at 1,100 yen/kilograms (kg) and 1,000 yen/kg, respectively. Therefore, it is now possible to compare the fuel costs of FCVs to existing gasoline engine and hybrid vehicles. Figure 3 compares the fuel cost in yen per kilometer (km) of driving distance at a gasoline price of 120 yen/liter. The fuel economy values for the gasoline engine vehicles and hybrid vehicles are the catalog values provided by each manufacturer. While the test cycle fuel economy of the Toyota FCV-ADV has been published, this information has yet to be published for the Mirai. Therefore, the values shown in Figure 3 were calculated based on the volume of the hydrogen fuel tank and travel distance.

Although it is difficult to make a direct comparison because the vehicle sizes are different, the Mirai has approximately the same fuel cost as a hybrid vehicle in the same vehicle class. Furthermore, according to the NEDO

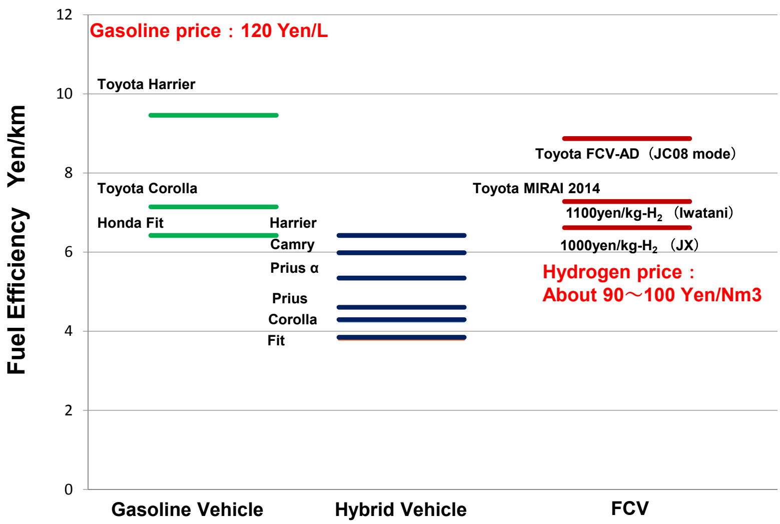

Fig. 3 Fuel Efficiency of FCVs Compared to Gasoline and Hybrid Vehicles [12]

project and other sources, the cost of supplying hydrogen around the year 2030 is predicted to be 20 to 40 yen/normal cubic meter (Nm^3) (approximately 230 to 450 yen/kg). Depending on the price of crude oil, there is a strong possibility that the market will accept this price range.

Dimethyl Ester (DME)

DME is attracting attention as an alternative fuel to diesel that can be produced easily from methanol. In North America, Oberon Co., Ltd. and Volvo Truck Corporation are planning to produce DME and run some vehicles on DME. Mitsubishi Gas Chemical Company Inc. and Mitsubishi Corporation have similar plans under way in Trinidad and Tobago, and Isuzu Motors, Ltd. is also producing low-pollution vehicles with DME engines.

Engines for Alternative Fuels

LPG Engines

The number of registered vehicles in Japan that run on LPG has been decreasing steadily after reaching a peak of 319,000 in 1991. There were 223,630 registered vehicles at the end of 2014 (including 4,619 bi-fuel vehicles and 5,093 mini-vehicles), a decrease of approximately

8,000 vehicles from 2013. The reasons for this decline are the long-term rise in LPG prices and the erosion of the relative cost merit of LPG vehicles as gasoline vehicles become more fuel efficient. A significant impact is also attributed to the policy of reducing the number of taxis, which represented 80% or more of registered vehicles. LPG stations can be found at approximately 1,600 locations in Japan.

Natural Gas Engines

Basic research on natural gas engines is focusing on dual fuel engines where a small amount of diesel is injected directly into the cylinder as an ignition source. Waseda University used a rapid compression machine to study combustion improvements in natural gas engines with diesel ignition and confirmed that under exhaust gas recirculation (EGR) conditions, the higher dispersion of the premixed gas resulting from the multi-injection of the diesel pilot stimulates flame propagation during the main injection and improves thermal efficiency [13]. Using a natural gas and diesel dual fuel (DDF) engine based on a 4-cylinder diesel engine, intake control indicators when supercharging and EGR were studied by the National Institute of Advanced Industrial Science and Technology and Denso Corporation for three load conditions ranging from light to heavy [14].

Hydrogen Engines

In Japan, a group consisting of Tokyo City University, the National Traffic Safety and Environment Laboratory, and Okayama University has issued reports on improving thermal efficiency through stratification in the axial direction in hydrogen engines with high-pressure direct injection in the cylinder [15] and measuring the local excess air ratio around the spark plug [16]. Nissan Motor Co., Ltd. demonstrated the possibility of ensuring stable combustion even at high EGR ratios by adding hydrogen obtained through gasoline reforming [17].

Dimethyl Ether (DME) Engines

Work on DME fuel standardization started at International Organization for Standardization (ISO) TC 28/SC 4 in 2007 and has led to the publication of the following standards:
ISO 16861:2015, Petroleum products — Fuels (class F) – Specifications of dimethyl ether (DME), 2015-05-15
ISO 17196:2014, Dimethyl ether (DME) for fuels – Determination of impurities – Gas chromatographic method, 2014-11-15
ISO 17197:2014, Dimethyl ether (DME) for fuels – Determination of water content – Karl Fischer titration method, 2014-11-15
ISO 17198:2014, Dimethyl ether (DME) for fuels – Determination of total sulfur, ultraviolet fluorescence method, 2014-11-15

ISO 17786:2015, Dimethyl ether (DME) for fuels – Determination of high temperature (105°C) evaporation residues, mass analysis method, 2015-05-01

Stirling Engines

Examples of units originally developed in Japan include 0.2-kilowatt (kW) to 10-kW-class engines for relatively low-temperature waste heat and biomass combustion power generation using waste heat from marine diesel engines and factories. These are either still under development or only available on a made-to-order basis. However, with the revision of the Electricity Business Act, Stirling engine generation facilities of 10 kW or less have been designated as electric facilities for general use, removing legal restrictions other than technical standards and facilitating the installation of such engines. The regional exchange center in the Omachi District of Minamisoma, which installed and operates a 10-kW-class Stirling engine power generation system that burns woody biomass produced by Suction Gas Engine Mfg. Co., Ltd., is an example.

Outlook

In April 2014, the Japanese government approved the new Strategic Energy Plan (the fourth plan) [18], which forms the basis for Japan's energy policies for the immediate future. The basic concepts behind this plan are ensuring stable energy supplies, economic efficiency, and environmental suitability. With the addition of safety to these concepts, the plan is now summed up as "3E+S."

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Republic of Korea

Introduction

South Korea has sought to increase the use of biodiesel (BD), specifically in public vehicles, since 2002. A pilot adoption project was implemented that lasted approximately 4 years, and which expanded the use of BD in all light oil automobiles in the country. The National Government and oil wholesalers reached a voluntary agreement in March 2006, under which BD producers were required to enter into annual supply contracts with oil wholesalers to blend automotive light oils with 0.5% BD content throughout the country, starting in July 2006. The blend percentage increased by 0.5% every year, so that starting in 2010, automotive diesel blended 2.0% BD. As a result, consumption of BD in South Korea in 2014 has reached approximately 400,000 kiloliters (kL).

South Korea has studied adoption proposals and detailed implementation plans through policy research, for the introduction of a Renewable Fuel Standard (RFS) program for renewable fuels (http://www.energy.or.kr/renew_eng/new/rfs.aspx). The Government issued a notice on quality standards for the RFS act on fuel oil and fuel oil alternative fuel businesses, which stipulates that automotive diesel fuels are to be blended with 2%–5% BD content. On the basis of its policy research, South Korea incorporated the RFS program into its implementing ordinances to promote the development, use, and spread of new renewable energy, which were passed into law and took effect in July 2015, and has begun the supply of BD2.5.

Korea has eight biomethane production plants for transport fuel in operation (Figure 1) by such companies as KOGAS and Potlatch. GS Caltex developed a lignocellulosic base biobutanol process and is constructing a biobutanol pilot plant (10 kilograms [kg]/day) (Figure 2); this pilot plant will be in operation in early 2017.

Almost all city buses in Korea (more than 38,000) use natural gas, and all taxis use liquefied petroleum gas (LPG). However, it is mandatory that all diesel fuel contain 2.5% BD fuel (i.e., BD2) by July 31, 2015, and this percentage will be reviewed and increased up to 3.0% by 2018. There is no policy on bioethanol (BE) use.

Fig. 1 Biomethane Charging Station

Fig. 2 Biobutanol Pilot Plant

The Korean Government discussed future scenarios on how to introduce BD and create a long-term road map. This discussion was finalized, and the conclusions were incorporated in the new Korean RFS in June 2013.

During the 21st Session of the Conference of the Parties to the United Nations Framework on Climate Change Conference (COP21) in 2015, Korea suggested a 37% carbon dioxide (CO_2) reduction by 2030. Discussions are now under way as to how to achieve this goal.

Policies and Legislation

The new RFS was enacted in South Korea's National Assembly in July 2013. This law requires that a renewable energy fuel be blended with any transportation fuel (Table 1). It also indicates that joint indemnity and fraternal insurance should be provided to business operators who work with manufactures and supply these renewable fuels.

Table 1 Blending of Biodiesel in Automotive Diesel Fuel in South Korea[a,b]

	2015	2016	2017	2018	2019	2020
Percentage (%) of new renewable energy fuel blended in transportation fuel	2.5	2.5	2.5	3.0	3.0	3.0

[a] Type of transportation fuel: automotive diesel.

[b] Type of new renewable energy fuel: BD.

Source: Ministry of Trade, Industry and Energy, South Korea, announced June 15, 2015

According to the revised RFS, oil refining agents and petroleum import and export agents are obligated to blend transportation fuel with a certain percentage or more of a renewable energy fuel. A system was established to impose a penalty on any violator. Also, an RFS task force of professionals was formed to manage the work related to carrying out this RFS.

However, the Korean Government, by allowing a 2-year grace period to implement the RFS system, enabled oil refinery companies and bioenergy-related enterprises to prepare the fuels. The Government believed that the RFS policy would be more acceptable if there was enough time to implement it.

According to legislation, it is expected that the mixing or blending of BD and BE will reach 3% in 2018, as a result of incremental increases in the mixing ratios associated with the new renewable energy sources each year. Also, the Ministry of Trade, Industry and Energy announced that quality standards exist to ensure that the renewable energy sources are of proper quality, and it is mandated that related companies register to obtain indemnity or fraternal insurance to cover a third party for any damage caused by defects in the renewable energy processes.

Implementation: Use of Advanced Motor Fuels

More than 38,000 natural gas vehicles (NGVs) and 164 compressed natural gas (CNG) or liquefied natural gas (LNG) stations are currently being operated in Korea. Since 2000, the Ministry of Environment has promoted NGVs — mainly city buses — by offering subsidies and low-priced natural gas to reduce air pollution in urban areas and cut greenhouse gas emissions. About 80% of NGVs are original equipment manufacturer (OEM) transit buses, and the other 20% are OEM trucks and dual-fuel retrofit passenger cars. Dedicated CNG buses and trucks are supplied by Korean automakers, such as Hyundai, Daewoo Bus, and Tata Daewoo. NGVs run mainly on CNG. However, dedicated buses recently developed by Hyundai (which also developed a CNG hybrid bus in 2010) and some LNG-diesel dual-fuel trucks with retrofit technology are in use. Hydrogen-CNG (HCNG) engine technology is currently being developed as part of a Government project.

Biodiesel has been used as an automotive fuel in Korea since 2002. After a few years of demonstration, the Ministry of Trade, Industry and Energy decided to introduce BD0.5 nationwide. After that, the blending ratio of BD in diesel oil has been increased gradually, and the blending ratio of BD2 has been fixed since 2010. Major feedstocks for BD are waste cooking oil and imported soybean oil and palm oil. Currently, there are 16 BD production companies, and production capacity is more than 1 million tons.

In 2014, consumption of BD was approximately 400,000 kL, of which 172,000 kL (approximately 43%) were from consumption of transportation BD through the collection of waste edible oil as a waste resource. South Korea is severely limited in its energy resources and is dependent on imports for 96% (in 2014) of its overall primary energy needs. This makes it highly desirable for South Korea to have projects that recycle domestic waste resources and convert them into energy resources. Also highly favorable for South Korea are proposals that use biogas (BG) for transportation fuels, a resource that can be obtained from organic waste without being solely dependent on imports. Some local governments in South Korea are at the center of projects to produce BG from raw garbage, livestock manure, and sewer sludge, thus improving their quality for use in regional taxis and buses. The goal is to further stimulate these projects. The City Gas Business Act has been revised to enable BG to be blended into city gas, and it is hoped that NGV buses will also be used in the country.

South Korea’s RFS policy sets mandates for transportation fuel businesses. But in terms of vehicles, the policy only affects approximately 38% of vehicles out of the approximately 20 million vehicles in the country. It is hoped that in the near future, BE will be used for gasoline vehicles, which account for approximately 48% of all vehicles in South Korea, and that biojet fuels will also be mirroring global trends. Currently, there is no stimulus for using biofuels in LPG vehicles, which account for approximately 14% of all vehicles in the country. However, biofuels, such as biopropane and biodimethyl ether (bioDME), which are currently in research and development, will need to be commercialized and adopted into the market.

Other alternative fuels, such as BE, DME, and synthetic liquid transportation fuels (collectively known as XTL), have been developed or demonstrated by Government institutes and some companies. However, it is not clear when these fuels will be introduced.

Outlook

According to the new Korean RFS, which takes into account the supply of and demand for raw materials, in the three-step, long-term plan for 2015 to 2023, BE3 and BD3 would be introduced in 2018. During the first step from 2015 to 2018, the introduction of BE and an increase in the BD percentage up to 2.5% would be reviewed. In the second step from 2018 to 2020, BE3 and BD3 would be introduced. The final step from 2020 to 2023 would be the introduction of BD5~7 and BE5~7. The introduction of BG beginning in 2017 is also being considered.

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- www.kpetro.or.kr/

Spain

Introduction

Spain has very little domestic oil and gas production and relies heavily on imports (Figure 1). In 2015, Nigeria remained the biggest oil supplier of crude oil (16.53%), followed by Mexico (14.03%), Russia (12.50%), and Saudi Arabia (10.56%). These four countries represented 53.62% of total Spanish imports in this period.

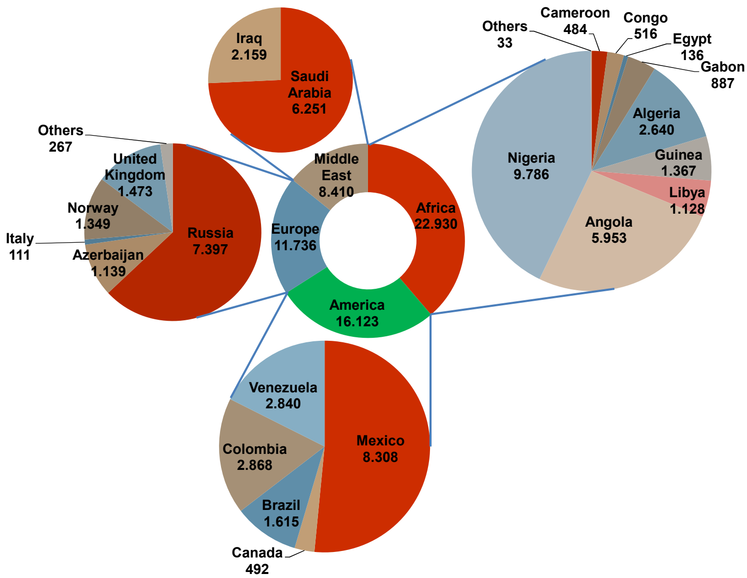

Fig. 1 Oil Imports to Spain from January through November 2015
(Source: CORES)

With regard to the external trade of oil products, by November 2015 (last consolidated available data), total imports amounted to 14,523 kilotons (kt), while exports reached 19,563 kt. Figure 2 shows imports and exports of oil products from January through November 2015.

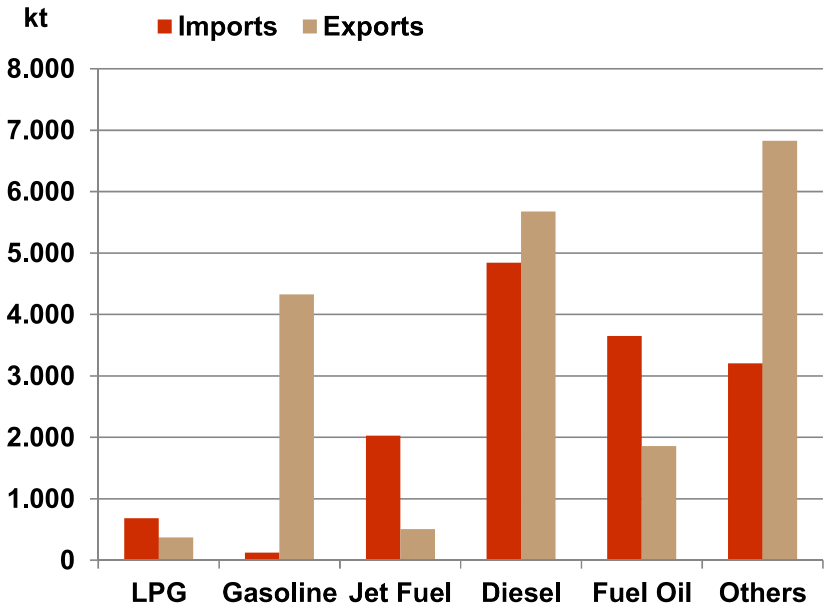

Fig. 2 Imports and Exports of Oil Products in Spain from January through November 2015
(Source: CORES)

Policies and Legislation

The only legal incentive for biofuel consumption in Spain is the blending mandate. Wholesale and retail operators of fuels, as well as consumers of fuels not supplied by wholesale or retail operators, are obligated to sell/consume a minimal quota of biofuels. Each obligated subject has to present a number of certificates to the national certification entity (the National Markets and Competition Commission) to prove compliance. Certificates have a value of 1 metric ton of oil equivalent (toe). In case of noncompliance with the targets, a penalty fee applies. In case of overcompliance (some parties selling or consuming more than they are obligated to), the amounts collected from the penalty fees are redistributed by the certification entity proportionally to the subjects that sold/consumed biofuels exceeding their set quota obligation.

Royal Decree 1085/2015, dated December 4, 2015, on the promotion of biofuels establishes mandatory goals for biofuels for the period 2016–2020. Former legislation on the biofuels obligation stated that, in addition to the general target, specific blending levels of biofuels in diesel and in gasoline had to be reached by obligated parties. Royal Decree 1085/2015 has repealed such specific mandatory goals.

Table 1 gives the mandatory blending targets (in energy content) for the period 2016–2020.

Table 1 Mandatory Biofuel Blending Targets in Spain for 2016–2020

2016	2017	2018	2019	2020
4.3%	5%	6%	7%	8.5%

Source: Royal Decree 1085/2015, dated December 4, 2015, on the promotion of biofuels

With regard to biofuels sustainability requirements, in 2013, Law 11/2013 established a sine die delay in sustainability implementation. A resolution dated April 29, 2015, by the Secretary of State for Energy, sets the expiration date for the suspension period (January 1, 2016). A transition period, to allow for the progressive adaptation of the verification system until the full scheme is in place, will be applied from now on. During the transition period, the economic agents in the supply chain can comply with sustainability by presenting a Responsible Declaration. Once the transition period is over and the sustainability verification system is fully implemented, a sustainability verification report prepared by a sustainability certification entity will be required.

Incentives for alternative energy sources other than biofuels were approved by means of Royal Decree 1078/2015, dated November 27, 2015. This Royal Decree regulates the direct granting of aid for the purchase of alternative energy vehicles and for the implementation of electric vehicle charging infrastructure (MOVEA).

The Alternative Energy Vehicle Mobility Incentive Plan (MOVEA) is a measure that forms part of Spain's 2014–2020 Alternative Energy Vehicle Incentive Strategy (VEA), designed and implemented by the Ministry of Industry, Energy and Tourism, in collaboration with other entities and Ministries. The goal is to unify various programs and plans intended to support the purchase of the most efficient vehicles developed to date. The Council of Ministers approved the agreement through which it was informed of the plan on June 26, 2015.

The purpose of this Royal Decree is to regulate the guidelines for the direct granting of aid for the purchase of electric, liquefied petroleum gas (LPG), compressed natural gas (CNG), and liquefied natural gas (LNG) vehicles, and electric motorcycles and bicycles with pedal assistance. Such regulation will foster sustainability in the transport sector, pollutant emissions reduction and air quality improvement, as well as diversification of energy sources in transport and a consequent decrease in energy dependency on oil.

Implementation: Use of Advanced Motor Fuels

Biofuels represent the largest share of alternative transportation fuels in Spain. At the time of preparing this report, the national biofuel certification entity (the National Markets and Competition Commission) had published data for the period January through August 2015. Figures 3, 4, and 5 show the balances for biofuels production, consumption, imports, and exports.

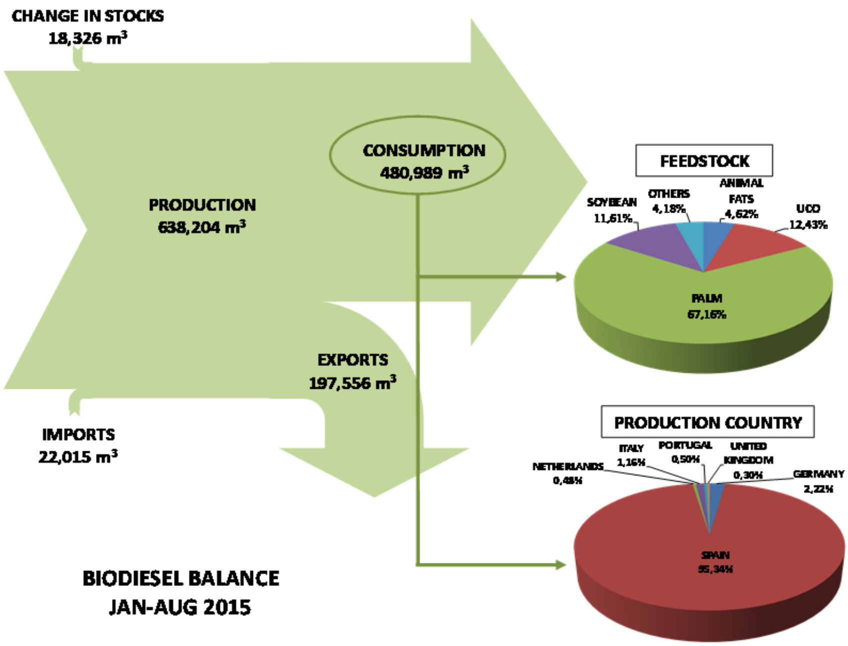

Fig. 3 Biodiesel Balance in Spain in January through August 2015
(Source: CNMC)

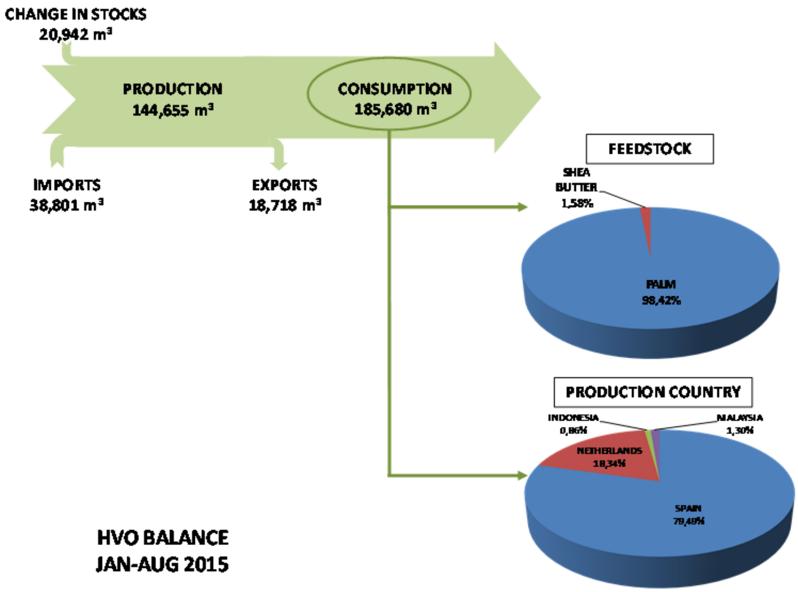

Fig. 4 Hydrotreated Vegetable Oil (HVO) Balance in Spain in January through August 2015
(Source: CNMC)

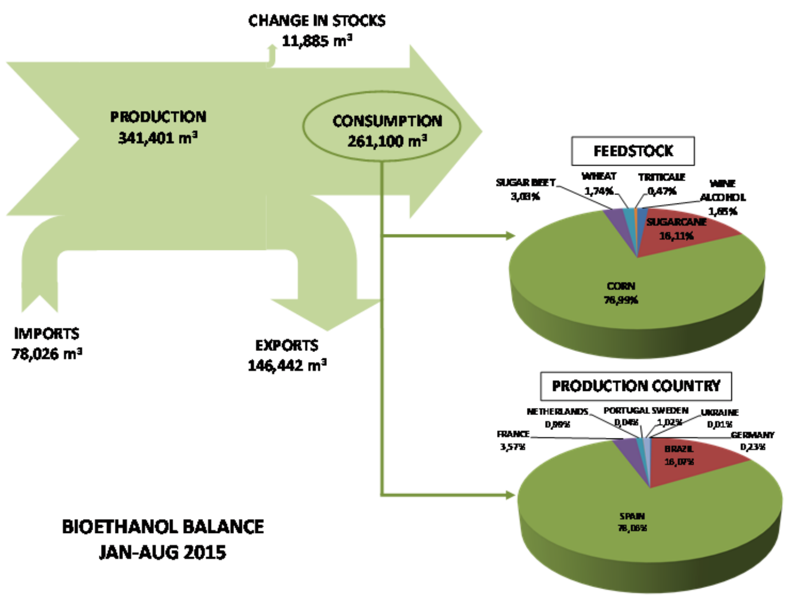

Fig. 5 Bioethanol Balance in Spain in January through August 2015
(Source: CNMC)

LPG and natural gas constitute a small part of the total market. Figure 6 shows the current number of vehicles capable of using these fuels.

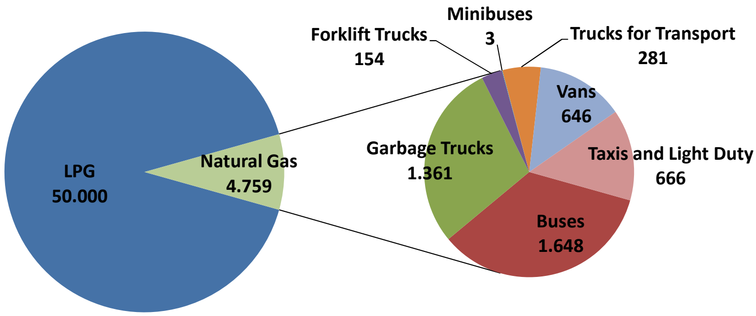

Fig. 6 Number of Vehicles in Spain That Could Use LPG and Natural Gas
(Source: IDAE elaboration on data from AOGLP and GASNAM)

With regard to hydrogen vehicles, only a few pilot projects (not commercialized today) have been developed (cars, micro-cars, and scooters). However, wide research activity is carried out in Spain in relation to hydrogen technologies.

Table 2 shows the number of public filling stations with alternative fuels.

Table 2 Filling Stations for Alternative Fuels in Spain

Alternative Fuels		No. of Filling Stations
Biodiesel blends	B7 or lower	18
	B10	10
	B12	37
	B15	7
	B20	26
	B30	21
	B40	1
Bioethanol blends	E10	1
	E15	3
	E85	9
LPG		495
Natural gas		41
Hydrogen		4

Source: MINETUR (Geoportal), AOGLP, GASNAM, AEH2

Outlook

According to the National Renewable Energy Action Plan, in order to fulfill the committed targets, consumption of biofuels is expected to reach 2,713 kilotonnes of oil equivalent (ktoe) in 2020. Of this, 400 ktoe corresponds to biofuels in gasoline (bioethanol and bio-ETBE [ethyl tertiary-butyl ether]), and 2,313 ktoe corresponds to biofuels in diesel (mainly fatty acid methyl ester [FAME] and hydrotreated vegetable oil [HVO]; HVO achieved a significant market penetration in 2013 and 2014).

Additional References

- AEH2: Spanish Hydrogen Association, www.aeh2.org
- AOGLP: Spanish Association of LPG Operators, www.aoglp.com
- CNMC: National Markets and Competition Commission, www.cnmc.es
- CORES: Corporación de Reservas Estratégicas, www.cores.es
- GASNAM: Spanish Association of Natural Gas for Mobility, www.gasnam.es
- Geoportal (MINETUR): Filling Stations, www.geoportalgasolineras.es
- IDAE: Instituto para la Diversificación y Ahorro de la Energía, www.idae.es
- MINETUR: Ministry of Industry, Energy and Tourism, www.minetur.gob.es

Major Changes

Royal Decree 1085/2015, dated December 4, 2015, on the promotion of biofuels establishes mandatory goals for biofuels for the period 2016–2020.

A resolution dated April 29, 2015, by the Secretary of State for Energy, sets the expiration date for the suspension period for biofuels sustainability requirements (January 1, 2016).

Royal Decree 1078/2015, dated November 27, 2015, regulating the direct granting of aid for the purchase of alternative energy vehicles and for the implementation of electric vehicle charging infrastructure (MOVEA), establishes guidelines for the direct granting of aid for the purchase of LPG, CNG, and LNG vehicles.

Sweden

Introduction

Total energy use in the transport sector, including foreign transport, amounted to 113 terawatt-hours (TWh) in 2013. The shares of energy use for the different transport modes are shown in Figure 1. Bunkering for foreign maritime traffic amounted to 19 TWh, and fuel for nondomestic aviation accounted for slightly less than 9 TWh. Swedish domestic transport used 85 TWh, representing almost one quarter of the country's total energy use in 2013. Petrol and diesel oil, including low blending, met 83% of the country's energy requirements for domestic transport.

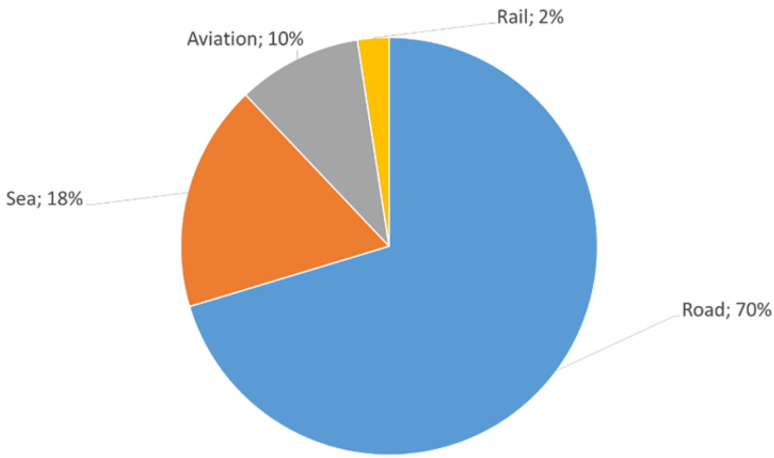

Fig. 1 Share of Energy Use among Different Transport Modes in 2013, both Domestic and Foreign

Sweden imported just less than 20 million tonnes (equivalent to about 200 TWh) of crude oil in 2014 and net-exported 32 TWh of refinery products. Around 50% of Sweden's total crude oil imports came from the North Sea, mainly from Denmark and Norway. Imports from Russia have increased significantly in the last 3 years and now amount to 42% of total imports.

Between 2004 and 2014, the use of diesel fuel increased by about 40%, while the use of petrol fell by 40% over the same period. One reason for this was the change in the mix of different types of vehicles on the road. In 1995, less than 5% of newly registered passenger cars were diesel fuelled. Twenty years later, that figure has changed to almost 60%.

The proportion of renewable motor fuels used by road vehicles continues to rise and accounts for almost 13% of energy use today. The main biofuels currently used by vehicles are ethanol, biogas, fatty acid methyl ester (FAME), and hydrotreated vegetable oil (HVO), both as admixtures and in pure form. Figure 2 shows the percentages for various alternative fuels.

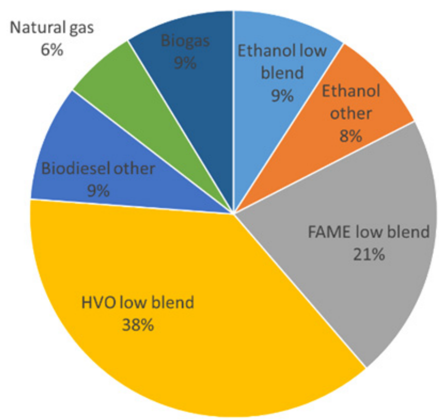

Fig. 2 Share of Alternative Motor Fuels in Road Transport in 2014

Ethanol is blended with gasoline, and it is also the main constituent in fuels such as E85 and the ethanol-diesel mix, ED95, used in public transport. FAME is blended with regular diesel fuel and is also used (to a limited extent) as 100% FAME. HVO was introduced on the domestic market, in measurable amounts, a few years ago and has fast become the main alternative fuel in Sweden. The use of biogas has also increased rapidly during the last couple of years. Currently, the content of almost all petrol is 5% ethanol, while about 85% of diesel fuel contains a 5% blend of FAME. For road use, almost all diesel fuel contains a 5% blend of FAME, and a high share of the diesel fuel also contains a varying degree of HVO.

There are about 300,000 passenger cars running on alternative fuels, and around 200,000 of these are flex-fuel vehicles (E85). There are more than 3,000 buses running on renewable fuels, of which more than 600 are ED95 buses, and there are around 9,700 trucks running on renewable fuels.

Policies and Legislation

The Swedish Government has a long-term priority that by 2030, the country shall have a vehicle fleet that is independent of fossil fuel. It also has a vision that by 2050, the country will have a sustainable and resource-efficient energy supply, with no net emissions of greenhouse gases (GHGs) in the atmosphere.

Sweden is using a relatively high proportion of biofuels in relation to most other countries in the European Union (EU). The main driver behind biofuel policy is to decrease the amount of carbon dioxide (CO_2) emissions from the transport sector. Another policy aim, not directly related to biofuels, is to increase overall energy efficiency in the transport system.

The fuel tax consists of two parts: an energy tax and a CO_2 tax. Bio-based motor fuels are fully exempted from CO_2 tax both for low blending (i.e., up to 7% biodiesel and 10% ethanol) and high blending (i.e., more than 85%). The reduction in energy tax is related to both the type of bio-based motor fuel and the blending ratio. Only bio-based motor fuels that fulfill the EU sustainability criteria are eligible for tax reduction.

Since 2004, all fuel stations of a certain size, in terms of volume of fuel sold, are required by law to also offer at least one renewable fuel. Most fuel stations have fulfilled this requirement by offering E85.

In October 2006, the motor vehicle tax was changed to be based on a vehicle's CO_2 emissions instead of its weight. The purpose of this change was to encourage the sale of more low-carbon vehicles. Some other tax relief is provided for vehicles that are capable of running on bio-based motor fuels. Starting in 2011, the vehicle tax for newly registered light goods vehicles, buses, and motor caravans was also subject to the CO_2 tax charge. The vehicle tax for heavy goods vehicles does not include a CO_2 element but depends on the vehicle's weight and level of regulated emissions.

Starting on July 1, 2009, new "clean vehicles" have been exempted from the vehicle tax for 5 years. The definition of a clean vehicle was revised in 2013 as follows:

- A vehicle with a mass in running order[55] of 1,372 kilograms (kg) is allowed to emit 95 grams (g) of CO_2 per kilometer (km) if it runs on petrol or diesel fuel. Vehicles capable of running on alternative fuels

[55] Mass in running order is the term to be used according to CO_2 legislation on passenger cars in the EU.

(i.e., all other fuels than diesel and gasoline/petrol) are allowed to emit 150 g CO_2/km.

- Heavier vehicles can emit more, while lighter vehicles must emit less (the slope corresponds to 4.57 g CO_2/100 kg).
- The electricity consumption of electric vehicles, including plug-in hybrid vehicles, must be less than 37 kilowatt-hours (kWh)/100 km.

Implementation: Use of Advanced Motor Fuels

The sustainability criteria for biofuels and bioliquids aim to reduce GHG emissions and ensure that no areas with "high biological values," according to the definition in Directive 2009/28/EC, have been damaged as a consequence of the production of renewable fuels. Starting in the spring of 2012, those operators in the Swedish economy that must report on their biofuel and bioliquid use have had to submit annual reports. The reports describe the quantities of sustainable biofuels and bioliquids used in Sweden in the previous year.

Emission Reduction of More Than 2 Million Tonnes of CO_2

Biofuels used in 2014 included ethanol, FAME, biogas, HVO, ethyl tertiary-butyl ether (ETBE), and dimethyl ether (DME) (Table 1). The total amount of sustainable biofuels was equivalent to more than 11.5 TWh. Of the biofuels used, HVO showed the highest increase, from 1.3 to 4.6 TWh. Most of the feedstock for the biofuel used in Sweden originated from Europe. For ethanol, some of the feedstock came from Russia or Ukraine, while the non-European feedstock for HVO came from Indonesia and Malaysia.

Table 1 Biofuel Use 2012 to 2014 in GWh

Fuel Category	2012	2013	2014
HVO	1 300	3 729	4 607
FAME	2 780	3 009	4 156
Ethanol	2 255	2 060	1 902
Gaseous biogas	903	834	972
Liquid biogas	12	36	39
ETBE	43	10	3
DME	3	2	2

Feedstocks and Emission Reductions

The current emission reduction requirement is set at 35% for biofuels (compared to fossil fuels); however, the majority of the biofuels in Sweden that have been reported on already fulfill the 50% reduction requirement that will not come into effect until 2017. On average, the emission reduction was 57% for all biofuels. Only HVO produced from palm oil had a reduction of less than 50%.

The emissions from the cultivation of biomass often constitute a large proportion of the total emissions from biofuels from a life-cycle perspective. Depending on the feedstock, the average emission reduction that results from using ethanol varies between 50% and 85%. HVO is associated with the largest reduction in GHG emissions at 85%, while the use of FAME, based mostly on rapeseed, has achieved a 40% reduction.

The use of alternative fuels has resulted in avoided emissions of CO_2, compared with if fossil fuels had been used, with 2.3 million tonnes CO_2 equivalent. This was an improvement of 19% compared with 2013. As shown in Figure 3, HVO and FAME accounted for almost three-fourths of the total emission reduction.

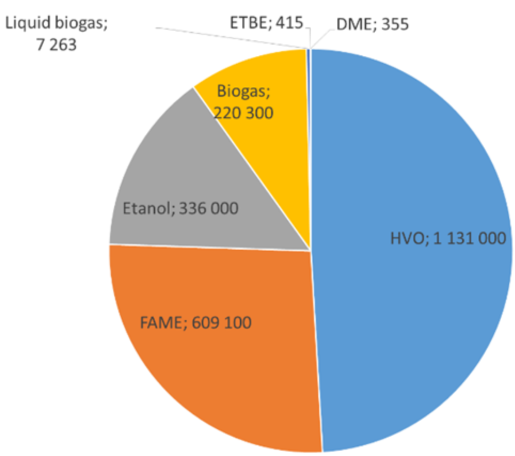

Fig. 3 Avoided Emissions of CO_2 in Tonne CO_2 Equivalent in 2014

The ethanol delivered in 2014 was derived from a high number of different types of feedstock, mostly wheat and corn. About one-fifth of the ethanol was produced from domestic feedstock, a significant reduction compared with 2012.

HVO is based mainly on slaughterhouse wastes, waste oil (of both vegetable and animal origins), and tall oil, which is a residue from the forest industry (Figure 4). The use of different waste oils has increased compared with other feedstocks.

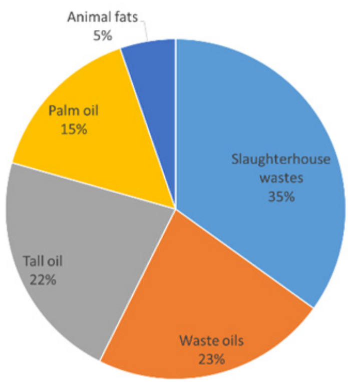

Fig. 4 Feedstock for HVO in 2014

Biogas intended for transport is subject to the sustainability criteria. Swedish feedstock contributed to 94% of the biogas used for transport in 2014. The biogas was produced from various feedstocks, which, in most cases, were waste or residues. The biogas produced from manure yields the best reduction in emissions — more than 80%. Cultivated biomass, such as barley, rye, corn, and ley crops, result in the lowest emission reduction — 40%–60%.

Approximately 34% of the biofuel quantities also meet certain requirements for social and economic sustainability that go beyond the sustainability criteria set by the EU Commission by having been certified under one of the EU Commission's 19 approved voluntary certification schemes.

Outlook

In December 2013, the Swedish Commission on Fossil-Free Road Transport presented possible courses of action and identified measures to reduce the emissions from and dependence on fossil fuels within the transport sector. The suggestions are in line with Sweden's 2050 vision and priority of having a fossil-independent vehicle fleet in 2030. Four different groups of actions were identified:

- Planning and developing attractive, accessible towns and cities with a reduced demand for transport and greater transport efficiency;
- Instituting infrastructure-related measures and changes in modes of transport;
- Using more efficient vehicles and more energy-efficient driving strategies; and
- Using biofuels, including electric-powered road vehicles.

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Switzerland

Introduction

Final total energy consumption in Switzerland in 2014[56] amounted to 825,770 terajoules (TJ), of which 36% was transport fuels [1]. Compared to 2013, transport fuel consumption lightly decreased by 0.4%. There were some changes in specific applications: diesel +2.5%, gasoline −4.0%, and aviation fuels +0.7%. All fossil fuels were imported. Figure 1 shows shares of energy sources in energy consumption for all kinds of transportation. With regard to aviation fuel, 10% is used for domestic flights [2]. Electricity is used for railroad transportation only.

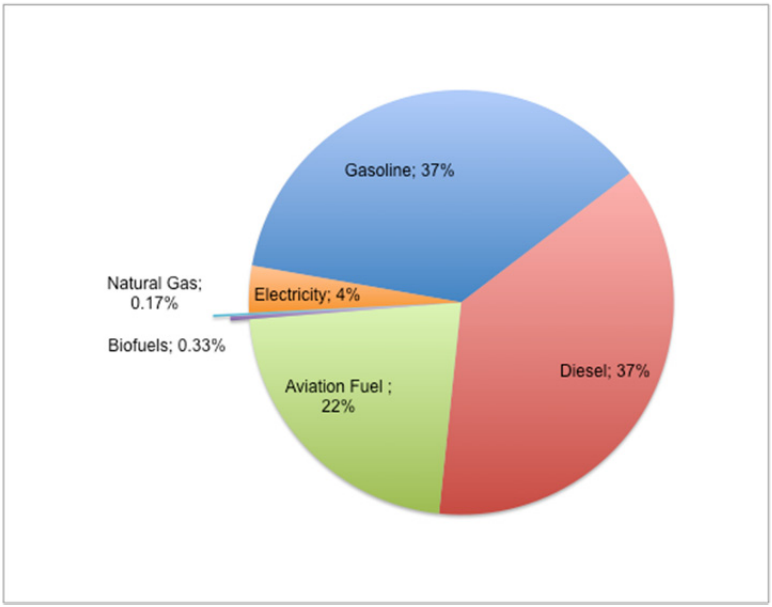

Fig. 1 Shares of Energy Sources in Energy Consumption for the Transportation Sector in Switzerland in 2014 [1]

Despite a large increase in biofuels used for transportation, from 640 TJ in 2013 to 1,017 TJ in 2014 (+59%), the share of total transport fuels remains very small (0.33%). The increase was mainly due to higher sales of biodiesel and bioethanol.

[56] At the time this report was prepared, only data from 2014 were available for Switzerland.

A total of 396,588 motor vehicles were newly registered in 2014 [3]. This represented a drop of −1.4% in the total amount of 5,784,084. Of passenger cars, 304,083 are newly registered, and with 4,384,490 units in total, these cars represent the most important share (75%). Of all passenger cars, 73% had gasoline engines, and 26% had diesel engines, of which 67% had a diesel particulate filter. The percentage represented by other propulsion systems was 1.4% (41,158 hybrid, 4,439 electric, and 13,507 other) [3].

Within the last 10 years (through 2014), the consumption of transport fuels (minus aviation fuel) increased by only 1.1%. In the same period, the number of cars (all types) increased by 15%. The average fuel consumption per car dropped significantly, and there was an important change in the kind of motor fuel used. The use of gasoline decreased by 25%, and the use of diesel increased by 56%. The consumption of biofuels rose by 335% in this 10-year time frame, but it represents a very low percentage of the overall motor fuel demand, increasing from 0.12% to 0.33%. Figure 2 shows the development in gasoline and diesel consumption by motor vehicles in 2005–2014.

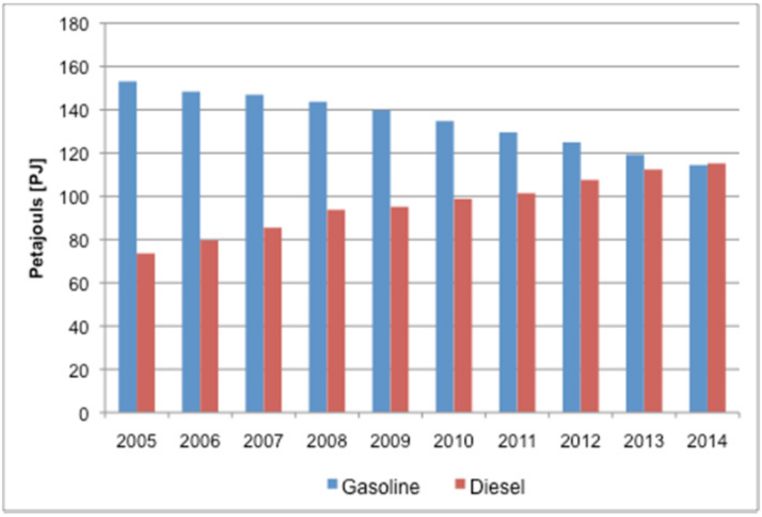

Fig. 2 Development in Gasoline and Diesel Consumption by Motor Vehicles in Switzerland, 2005–2014 [1]

Unlike other countries, in Switzerland, firms marketing motor fuels are not under any obligation for blending. This could be a reason for the rather low share of biofuels in the total amount of motor fuels.

Different cantons (Swiss member states) give vehicle tax reductions or even exemptions for purchasing environmentally friendly and energy-efficient vehicles, but there is still scepticism about alternative propulsion systems because of their higher capital costs and reduced ranges.

Policies and Legislation

Energy Strategy 2050

In 2011, the Federal Council decided that Switzerland would withdraw from the use of nuclear energy on a step-by-step basis without increasing carbon dioxide (CO_2) emissions [4]. The five existing nuclear power plants, which provide 40% of the electricity in Switzerland, will be decommissioned when they reach the end of their safe service life and will not be replaced by new ones. The first nuclear power plant will be switched off in 2019, and the last probably in 2034.

To ensure a secure supply of energy, the Federal Council is emphasizing increased energy savings (energy efficiency); the expansion of hydropower and new renewable energy sources; and, if necessary, fossil-fuel-based electricity production (cogeneration facilities, gas-fired combined-cycle power plants) and imports. To achieve these targets, the Swiss energy system will need to be successively restructured during the time period up to 2050. In view of this, the Federal Council developed a long-term energy policy — Energy Strategy 2050. In September 2013, the Council launched an initial package of measures aimed at securing the country’s energy supply over the long term [5]. This package will be supported by a fundamental revision of the 1998 Energy Act. In 2014, the Parliament started the debate. The final decision is expected in 2016. Important measures related to motor fuels are to (1) reduce CO_2 emissions, (2) increase energy efficiency, (3) increase the use of renewable energy sources including biomass, and (4) strengthen energy research.

CO_2 Emission Regulations for Cars

Like the European Union (EU), Switzerland has introduced CO_2 emission regulations for new cars. Swiss importers are required to reduce the level of CO_2 emissions from passenger cars registered for the first time in Switzerland to an average of 130 grams (g) of CO_2 per kilometer (km) by 2015 [6]. In 2014, 80% of the newly registered passenger cars had to fulfil this target. Car importers missed that target and had to pay a penalty of 1.7 million CHF. The average CO_2 emission of passenger cars was 142 g CO_2/km, and the average fuel consumption was 6.11 liters (L)/100 km [7].

Along with introducing the new Energy Act, the Federal Council aims to align with the EU Commission's legislative proposal to tighten CO_2 regulations on cars. By the end of 2020, the average CO_2 emissions from passenger cars have to be reduced to 95 g CO_2/km. A law for light commercial vehicles (vans up to 3.5 metric tons [t]) similar to the one for new passenger cars is awaiting formal adoption. For new vans sold in Switzerland, the targets are a fleet average of 175 g CO_2/km by 2017 and 147 g CO_2/km by 2020 [5]. In 2012, the average was 180.2 g CO_2/km.

CO_2 Emissions Compensation: Motor Fuels

All importers of fossil motor fuels are required to use domestic measures to compensate for 10% of the CO_2 emissions caused by the entire transportation sector by 2020 [8]. The compensation rate started in 2014 at 2% and will be raised in three subsequent steps to the level of 10% in 2020. Importers of fossil motor fuels may carry out their own projects or acquire attestations (i.e., certificates). They may group together to form compensation pools. In response to this, the Swiss Petroleum Association established the Foundation for Climate Protection and Carbon Offset (KliK), a nonprofit organization. It operates as a carbon offset group and launches and subsidizes projects and measures to reduce CO_2 emission in different fields such as transportation, industry, buildings, and agriculture.

Another measure to reduce CO_2 emission is to blend fossil fuels with biofuels. This is the reason for the steep upswing in the amounts of biodiesel and ethanol in 2014.

Energy Label for Motor Vehicles and Tiers

The energy label for motor vehicles is intended to support efforts aimed at reducing the average fuel consumption of motor cars. It provides information about the kind of motor fuel, fuel consumption (L/100 km), and CO_2 emissions (g/km) in relation to the curb weight of the vehicle. It increases transparency and helps individuals considering purchasing a new car decide which model to buy. In 2014, Switzerland introduced a label for tiers. It classifies, among other qualities, the rolling resistance of the tier and, with this, its energy efficiency [9].

Mineral Oil Tax (Petroleum Tax)

The mineral oil tax is an excise tax that varies heavily depending on the product and its use (engine fuel, heating fuel, and technical purposes). For instance, the tax per liter is:

- 0.73 CHF for unleaded petrol,
- 0.76 CHF for diesel oil, and
- 0.003 CHF for extra light heating oil.

Tax reductions are provided for engine fuels used in agriculture, forestry, professional fishing, licensed transport companies, and other industries.

Mineral Oil Tax Reduction for Natural Gas

To support Switzerland's target for CO_2 emissions, a reduction or even an exemption for environmentally friendly motor fuels came into effect on July 1, 2008, with the amendment to the Mineral Oil Tax Act. The tax for natural gas used as a motor fuel was reduced to 0.22 CHF/kg [10].

Mineral Oil Tax Exemption for Biofuels

Switzerland is the first country in the world to introduce sustainability criteria, such as minimum ecological and social requirements for the production of biofuels, into its legal framework. To promote the use of biofuels (e.g., biogas, bioethanol, biodiesel, and vegetable and animal oils) that satisfy minimum environmental and social standards, those biofuels are completely or partially relieved from the mineral oil tax. As a result, the tax reduction for biofuels is up to 0.72 CHF/L, in comparison with fossil fuels.

To obtain a tax exemption, the following criteria, which apply to both the cultivation and utilization of fuels, have to be fulfilled:

- Emissions of greenhouse gases from the biofuels must be at least 40% lower than emissions from fossil fuels.
- The environmental impact may not be greater than that from fossil fuels.
- The protection of rain forests and biodiversity must not be endangered.
- The biofuels must be obtained from raw materials that were produced in accordance with local social standards.

Implementation: Use of Advanced Motor Fuels

Use of Biofuels as Motor Fuels

The share of biofuels within total transport fuels remains very small (0.33%). The most important biofuel is biodiesel, and in 2014, the amount almost doubled compared to previous years, and the use of bioethanol increased more than twice. The use of upgraded biogas remains at a low level, and the use of pure vegetable oil (PVO) as fuel has almost ceased. Figure 3 shows the development of biofuel consumption in motor vehicles over the last 10 years.

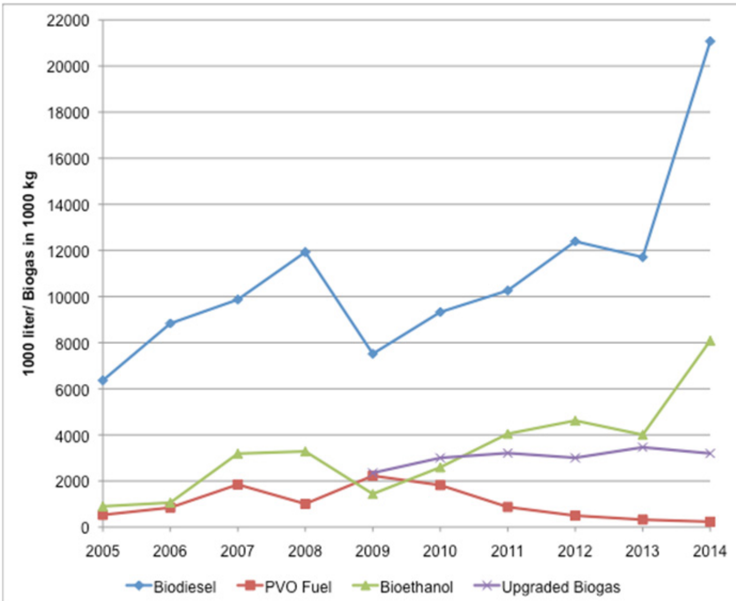

Fig. 3 Trends in Biofuel Consumption by Motor Vehicles in Switzerland, 2005–2014

Biodiesel and PVO Fuel

The consumption of biodiesel fuel in Switzerland amounted to about 21.1 million L in 2014 (Table 1). Compared to 2013, this is an increase of 80%. This substantial gain can be contributed to the legal carbon offset obligation for CO_2 emissions that came into effect in 2014. Importers of fossil motor fuel had to compensate in a first step of 2% of CO_2 emissions. They did this partly by blending diesel fuel with biodiesel, resulting in B5.

In the 10 years up through 2014, consumption of biodiesel increased by 230%. Compared to consumption of diesel fuel, however, the amount was still very low, representing a share of 0.66%. Then in 2014, the consumption of PVO fuel dropped to a very low level. After reaching a maximum of 2.2 million L in 2009, consumption of PVO decreased to 0.23 million L in 2014. Biodiesel B100 and PVO fuel are used only in some local diesel fleets (mostly in agriculture) [12].

Table 1 Consumption of Biodiesel and PVO Fuel in Switzerland, 2005–2014 (in 1,000 L/yr) [11, 13]

Year	Biodiesel (1,000 L)			PVO Fuel (1,000 L)		
	National Production	Imports	Total	National Production	Imports	Total
2005	6,180	181	6,361	529	0	529
2006	8,717	116	8,833	845	0	845
2007	9,756	113	9,869	1,846	0	1,846
2008	11,915	12	11,927	849	158	1,007
2009	6,837	679	7,516	808	1,418	2,226
2010	6,945	2,380	9,325	869	950	1,819
2011	7,161	3,101	10,262	641	229	870
2012	7,797	4,594	12,391	496	0	496
2013	5,633	6,076	11,709	293	29	322
2014	5,872	15,200	21,072	232	0	232

Bioethanol

In 2014, the consumption of bioethanol as a motor fuel amounted to about 8.1 million L (Table 2). Compared to the amount in 2013 (4.0 million L), this was an increase of 102%. The reason for this steep upswing was the same as for biodiesel — the petroleum industry's obligation to compensate 2% of CO_2 emissions. It partly fulfilled this target by blending gasoline with ethanol to E5 and E85.

The use of bioethanol as a motor fuel started in Switzerland in 2005. Until 2008, the whole volume was produced in Switzerland by Borregaard Schweiz. The closing down of bioethanol production in Switzerland in 2008 affected consumption in 2009; only Alcosuisse (a Profit Center of the Swiss Alcohol Board) was allowed to import and sell ethanol. There was a large drop in consumption in 2009. The Government resigned its activities related to the trade of bioethanol and opened the market to the private economy in the autumn of 2010. Since then, the whole volume of bioethanol is imported from Norway, The Netherlands, and Germany.

Table 2 Consumption of Bioethanol Fuel in Switzerland, 2005–2014[a] (in 1,000 L/yr) [1, 11]

Year	National Production	Imports	Total
2005	901	0	901
2006	1,060	0	1,060
2007	3,188	0	3,188
2008	3,284	0	3,284
2009	0	1,438	1,438
2010	0	2,593	2,593
2011	0	4,047	4,047
2012	0	4,619	4,619
2013	0	4,004	4,004
2014	0	8,089	8,089

[a] No bioethanol was used as a motor fuel before 2005.

Biogas and Natural Gas

In 2014, the total use of gaseous motor fuels remained at roughly the same level as it was in the previous 5 years (Table 3). Data have been available since 2009. The share of biogas used as a motor fuel in the total amount of gaseous motor fuels decreased slightly, from 23% to 22%. The total amount of upgraded biogas fed into the natural gas grid increased from 9,981 to 15,063 t (+51%), but its use as a motor fuel remained much lower (3,194 t). This is because not all the upgraded biogas could be sold for use in vehicles, and there is an increasing demand for biogas delivered by the gas grid for heating purposes.

However, the total amount of biogas produced in Switzerland in 2014 was much higher (94,070 t) than the amount that has been upgraded and fed into the natural gas grid and used as a motor fuel, as mentioned previously. Most of the biogas is directly used on site for heat and power generation.

Table 3 Use of Biogas and Natural Gas as Motor Fuels (via the gas grid and directly at the fuel pump) in Switzerland, 2009–2014 (in 1,000 kg/yr) [14]

Year	Upgraded Biogas Used as Feed in Gas Grid	Upgraded Biogas Used as Motor Fuel in Cars	Upgraded Biogas: Other Uses	Natural Gas Used as Motor Fuel in Cars	Total Gaseous Motor Fuels Used in Cars	Share of Biogas in Total Amount of Gaseous Motor Fuels
2009	3,152	2,349	803	10,373	12,722	19%
2010	4,505	3,002	1,503	12,080	15,082	20%
2011	6,350	3,210	3,140	12,051	15,711	20%
2012	6,915	3,005	3,910	11,830	14,835	20%
2013	9,981	3,461	6,520	11,599	15,060	23%
2014	15,063	3,194	11,869	11,394	14,588	22%

Energy Research

The Swiss Government supports energy research in the amount of 200 million CHF each year. From this amount, only a small part is dedicated to research in the field of advanced motor fuels. In support of Energy Strategy 2050, the Swiss Parliament in 2011 decided to increase subsidies for pilot and demonstration projects from a yearly amount of 5 million CHF to 35 million CHF in 2014. A second important decision that increased energy-related research activities and competencies in Switzerland was for a grant of an additional 200 million CHF for the period 2013 to 2016. The target was to launch and build the capacity of seven Swiss Competence Centers for Energy Research (SCCERs). Two SCCERs are important with regard to advanced motor fuels: SCCER BIOSWEET (Biomass for Swiss Energy Future) [15] and SCCER Mobility (Efficient Technologies and Systems for Mobility) [16].

The targets of energy research are described in *Energy Concept 2013–2016* [17]. It is published by the Federal Energy Research Commission (CORE), which acts as a consultative body for the Federal Council. On the basis of this publication, the Swiss Federal Office of Energy (SFOE) published a detailed research plan [18] covering 20 topical areas. The following paragraphs give some examples of ongoing research projects related to advanced motor fuels.

Examples of Ongoing Research Projects

Metal-nanoparticles and other nonlegislated emissions from cars with blended gasoline and alcohol fuels [19]. Metal-nanoparticles (including those in sizes below 20 nanometers [nm]) from gasoline cars are being investigated for different engine technologies (12 cars). The investigations focus on the composition and potential of secondary aerosols. Supplementary research is being conducted on nanoparticles at cold start, gaseous nonlimited components (especially nitrogen dioxide [NO_2], ammonia [NH_3], and aldehydes), and operation with alcohols. The project, led by the Laboratory for IC (Internal Combustion) Engines and Exhaust Control (AFHB) at the University of Applied Science Biel/Biennne, is a collaboration with the Paul Scherrer Institute (PSI) and the Swiss Federal Laboratories for Materials Science and Technology (Empa) (Figure 4).

Fig. 4 Test Facility at the Laboratory for IC Engines and Exhaust Control (AFHB)

Effects of gasoline-butanol blend fuels on emissions and combustion in spark ignition (SI) engines. With different butanol blends (BuXX), basic combustion research is being performed on a SI-engine dynamometer with accesses for engine parameterization and pressure indication. In the second part of the project, two vehicles, one with older technology and the other with newer technology, are being investigated on a chassis dynamometer with special consideration of nonlegislated emission components.

Hydrogen-enriched natural gas/biogas in passenger cars — potential by adaptation of the engine control system. Hydrogen-enriched natural gas/biogas is being investigated in a field test of delivery vehicles of Mobility Solutions (Figure 5). It could be shown that an efficiency increase is already occurring without adapting the engine control system. In this project, the impact of adapting the ignition map for constant center of combustion on efficiency is being investigated.

Fig. 5 Euro 4 Passenger Car with 2.0-L Engine and Conventional Three-Way-Catalyst Being Tested with 15% and 25% Vol H_2 in CNG

Characterization of high boiling point/synthetic fuels for homogenous charge compression ignition (HCCI) and partially stratified diesel engine combustion. In this project, partially synthetic high boiling point fuels (Figure 6) are being investigated experimentally in fully homogenous (HCCI) and partially stratified combustion in optically accessible test rigs; corresponding global/reduced reaction models are being developed. Particular emphasis is on the development of a numerical index that accurately characterizes the ignition propensity of these fuels, thus providing guidance on the engine development process.

	Original Fuels			Surrogate Fuels		
	Low CN (≈38)	Mid CN (≈50-55)	High CN (≈70)	Low CN (≈38)	Mid CN (≈50-55)	High CN (≈70)
Non-Oxygenated	CN 39.6 57.5%$_{Vol}$ DK B0 + 42.5%$_{Vol}$ Eurosuper	CN 55.6 DK B0-1	CN>74.6 HVO	**PRF41** (CN 39.6) 41%$_{Vol}$ iso-Octane + 59%$_{Vol}$ n-Heptane)	**n-Heptane** (CN 55.28)	**n-Decane** (CN 76)
Non-Oxygenated	-	CN 55.8 DK B0-2 + EHN	-	-	**TRF 7.3** (CN 51.42) 92.7%$_{Vol}$ n-Heptane + 7.3%$_{Vol}$ Toluene	-
Oxygenated	CN 36.5 66.5%$_{Vol}$ DK B0 + 33.5%$_{Vol}$ ETBE (4.4%$_{Mass}$ O_2 content)	CN 55.2 64%$_{Vol}$ DK B0 + 36%$_{Vol}$ RME (4.2%$_{Mass}$ O_2 content)	-	**BVP 31.8** (CN 37.8) 68.2%$_{Vol}$ n-Heptane + 31.8%$_{Vol}$ n-Butanol (7.67%$_{Mass}$ O_2 content)	**BVP 9.1** (CN 50.05) 90.9%$_{Vol}$ n-Heptane + 9.1%$_{Vol}$ n-Butanol (2.29%$_{Mass}$ O_2 content)	-

Fig. 6 Original Fuels (left) and Corresponding Surrogate Fuels (right) Being Investigated for HCCI and Partially Stratified Diesel Engine Combustion

Investigation of diesel and "dual-fuel" combustion processes at engine-relevant conditions with laser-based optical measurement techniques. The advancement of dual-fuel engines is an attractive solution for both compliance with future emissions standards with optimized efficiency and for increasing fuel flexibility. However, the fundamental in-cylinder phenomena at engine-relevant conditions need to be better understood. Advanced laser-based optical techniques at experimental test rigs for investigations at challenging high pressure and temperature conditions will be implemented (Figure 7).

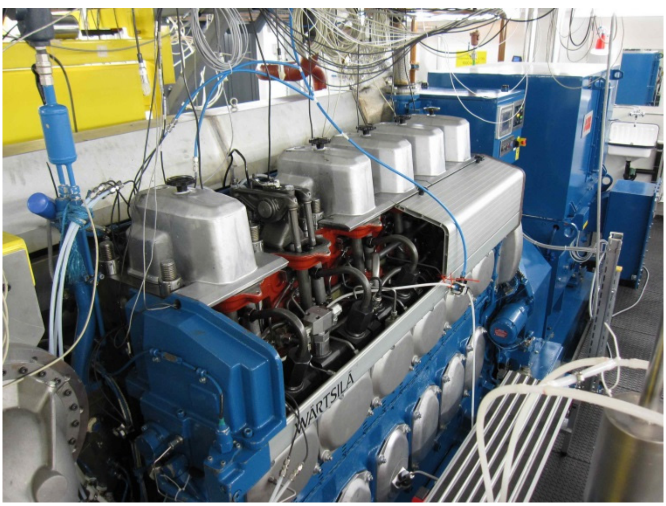

Fig. 7 Large Engine Research Facility at Paul Scherrer Institute (PSI) in Switzerland with a Test Rig for a 1.2-MW Mechanical Output Diesel Engine

Outlook

The doubling of the use of biodiesel and ethanol in 2014 is a promising signal for an increasing share of biofuels in the total amount of motor fuels. An important driver is the obligation of the petrol industry to compensate 10% of CO_2 emissions via domestic measures. Constraints on increasing the use of renewable motor fuels might be caused by the high requirements for tax relief for and a lack of regulations on blending fossil fuel with biodiesel or ethanol. Other than the support for tax exemptions and tax reductions, there is currently no strong political support for using biofuels in the transportation sector in Switzerland.

Food production has priority over fuel production in Switzerland because the country's areas for agricultural production are limited. Waste is thus preferred for the production of biofuels for ecological reasons. The barriers to introducing natural gas and biogas into the market are even higher — the need of special engines for bi-fuel use and building up a filling station infrastructure.

The target of Swiss Energy Strategy 2050, however, is to increase the amount of renewable energy and reduce CO_2 emissions. Drivers for increasing the amount of advanced and sustainable motor fuels could be the regulations as foreseen in Energy Strategy 2050. But they are also drivers for hybrid and electric vehicles. Additional grants for energy research will encourage much research related to the production and use of advanced motor fuels. Important fields of research are wood methanation, power-to-gas,[57] and flexible fuel combustion. [19]

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Major Changes
The consumption of biodiesel and ethanol almost doubled compared to 2013. A driver for this significant increase is the requirement that motor fuels importers compensate 2% of CO_2 emissions. This requirement will increase up to 10% by 2020.

Thailand

Introduction

Thailand's high dependency on foreign energy puts its energy security at risk. In 2015 (January through November), final energy consumption was 71,898 kilotonnes (ktoe), an increase of 2.8% from 2014 [1]. The total value of the final energy consumption was 943,275 million baht ($26,951 million US). Thailand's imported energy consumption amounted to 66,099 ktoe, accounting for 785,830 million baht, an increase of 3.0% from 2014. Thailand's final energy consumption covers all energy supplied to the final consumer for all energy uses. Petroleum products represent the major portion of energy consumption, as shown in Figure 1. The final energy consumption by economic sector covers all energy consumed in five main sectors — agricultural, commercial, residential, industrial, and transportation. In 2015, transportation had the greatest portion of total energy consumption at 36.8%, followed by industrial at 35.7%, residential at 15.1%, commercial at 7.2%, and agricultural at 5.2% [2] (Figure 2).

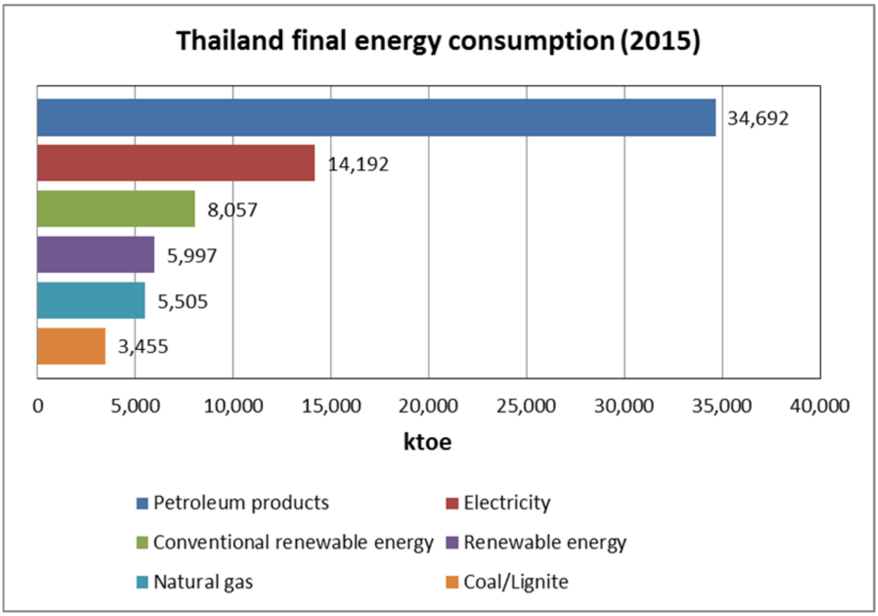

Fig. 1 Energy Consumption in Thailand, January–November 2015 [1]

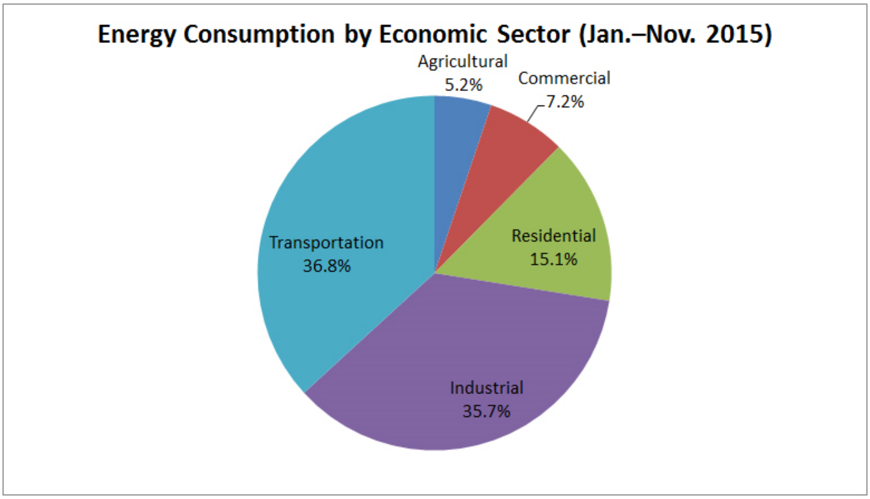

Fig. 2 Final Energy Consumption by Economic Sector in Thailand, January–November 2015 [1]

By the end of December 2015, there were 36,731,023 vehicles in Thailand. Of this number, 2,772,269 were newly registered. Gasoline vehicles accounted for 25,248,828 units, corresponding to 68.74% of the total. Diesel vehicles accounted for 9,507,343 units or 25.88% of the total, and bi-fuel vehicles (gasoline or diesel with liquid petroleum gas [LPG]) accounted for 1,224,539 units or 3.33% of the total. Table 1 shows the total number of vehicles in Thailand, by fuel, as of December 2015 [3].

Table 1 Number of Vehicles, by Fuel, in Thailand as of December 31, 2015 [3]

Fuel Type	Units	Percentage of Total
Gasoline	25,248,828	68.74
Diesel	9,507,343	25.88
Bi-fuel (gasoline or diesel with LPG)	1,224,539	3.33
B-fuel (gasoline or diesel with compressed natural gas [CNG])	350,604	0.95
Hybrid	70,285	0.19
Mono-fuel CNG	65,600	0.18
Mono-fuel LPG	24,136	0.07
Electric	1,820	0.65
Non-fuel and others	237,868	0.01
Total	36,731,023	100.00

The Thai Government has implemented measures and policies to promote the increasing use of alternative energy. By 2015 (January–November), Thailand's alternative energy consumption was 9,096 ktoe, an increase of 9.9% from 2014. At the time this report was prepared, alternative energy consumption as electricity, heat, and biofuel (ethanol and biodiesel) shared 12.65% of the total final energy consumption. Biofuel consumption as biodiesel was 877 ktoe (+3.4% from 2014), while biofuel consumption as ethanol was 849 ktoe (+ 6.4% from 2014) (Figure 3).

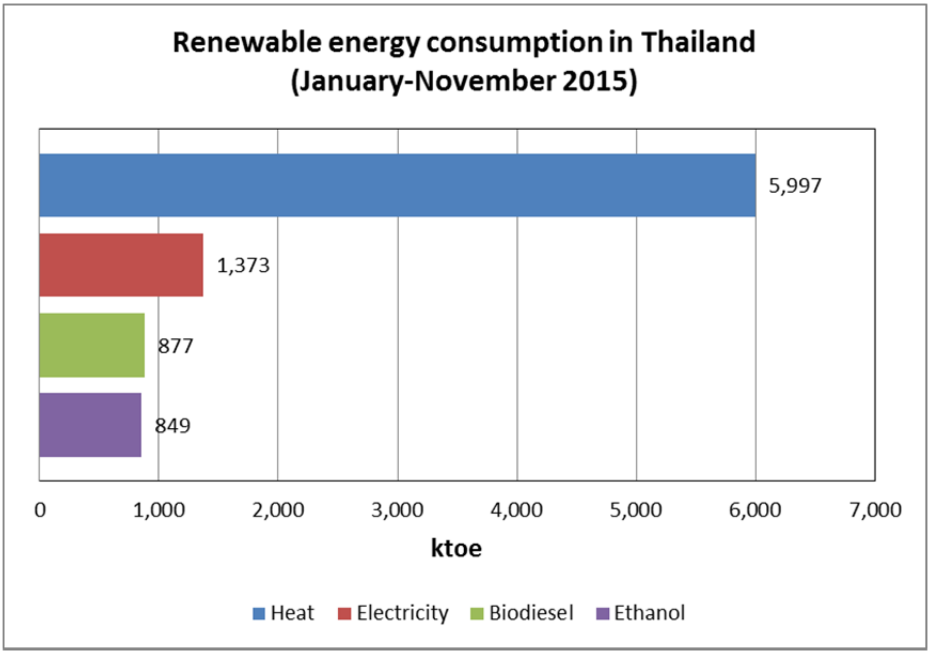

Fig. 3 Renewable Energy Consumption in Thailand, January–November 2015

Policies and Legislation

Climate change and high energy demand have led most countries, including Thailand, to launch national policies and plans to promote the use of renewable energy. Thailand has implemented a Long-term Energy Development Plan 2015–2036. Under this plan, are five plans with the goal of sustaining and supporting the country's mission of a low-carbon society: Power Development Plan (PDP 2015), Energy Efficiency Plan (EEP 2015), Alternative Energy Development Plan (AEDP 2015), Oil Plan 2015, and Gas Plan 2015.

With regard to the EEP, fuel management has been implemented using the following five guidelines to support energy savings.

1. Eleven measures, complying with the EEP, support fuel savings for the transportation sector's target of 46% energy savings in 2036:
    - Cancel or review subsidized fuel prices
    - Promote the use of eco-cars
    - Label the energy efficiency of tires
    - Use logistics and transportation management to save energy
    - Train drivers to be eco-drivers
    - Promote the circulating fund for energy conservation in the transportation sector
    - Promote the results of energy savings in the transportation sector
    - Develop infrastructure for mass transportation and a transit system
    - Develop infrastructure for a double-track railway to cover all 3,165 kilometers (km)
    - Expand the oil pipeline route
    - Use electric vehicles for energy savings

2. Fuel types, including LPG, which the Government does not promote, are being managed. The Government is promoting the use of natural gas vehicles (NGVs) for heavy trucks and public transportation. The price of LPG has started to increase much higher than it used to be.

3. The fuel price structure is being adjusted in order to reflect the actual cost by using a pricing mechanism.

4. The use of biofuels with 11.30 million liters per day (11.30 million L/d) of ethanol consumption and 14 million L/d of biodiesel consumption by 2036 is being advocated.

5. Investment in the fuel infrastructure, including the oil pipeline route and oil reserve, is being supported.

Before January 2016, new vehicles from the automakers or the importers were taxed based on engine size and horsepower. In addition, the tax structure was divided into several rates according to different types of fuels in order to promote the use of alternative fuels (i.e., E10, E20, E85, compressed natural gas [CNG], and hybrid). However, it was found that the tax structure was complex and gave fewer benefits to vehicles with large engines, but that emit lower emissions. Moreover, it did not cover carbon dioxide (CO_2) emissions, an issue of much interest from an environmental perspective. As a result, the Thai Government enacted a new tax structure on

January 1, 2016, that taxes vehicles based on CO_2 emissions, especially vehicles with an engine capacity not exceeding 3,000 cubic centimeters (cc). Table 2 summarizes a comparison of the old and new tax structures [4]. The new tax structure depends on new technology and innovation of alternative energy usage. It also implements the CO_2 emission-based tax that enables automakers to produce vehicles with clean technologies, as well as encourages buyers to go green.

Table 2 Comparison of the Old and New Excise Tax Structures for New Vehicles Sold in Thailand [4]

	Old Tax Structure (before 2016)				New Tax Structure (Jan. 1, 2016)			
		Rate (%)				Rate (%)		
Vehicle Type	Engine (cc)	E10	E20	E85	CO_2 (g/km)	E10/ E20	E85/ NGV	Hybrid
Passenger car	≤ 2,000	30	25	22	≤ 100	–[a]	–	10
	2,001–2,500	35	30	27	101–150	30*	25	20
	2,501–3,000	40	35	32	151–200	35	30	25
					> 200	40	35	30
	> 3,000	50						
Pickup passenger vehicle/double cab/space cab/single cab pickup	≤ 3,250	20/12/-/3.18			≤ 200	25[b]/12/5/3.18		
					> 200	30/15/7/5.18		
	> 3,250	50						
Eco-car (petrol/diesel)/ E85	< 1,300	17			≤ 100	14[b]/12		
					101–120	17		
Electric vehicle/fuel cell/hybrid	≤ 3,000	10/10				10/[c]		
	> 3,000	50						
NGV-original equipment manufacturer (OEM)	≤ 3,000	20				[c]		
	> 3,000	50						

[a] A dash indicates no tax rate.

[b] The rate is applicable if the required safety standards are met.

[c] Based on CO_2 only.

Implementation: Use of Advanced Motor Fuels

Ethanol

The Thai Government indicated that the AEDP (2015–2036) with ethanol remains in place. The plan is still set to increase ethanol consumption up to

11.30 million L/d by 2036. Ethanol consumption sharply increased to 3.18 million L/d in April 2014, up from an average of 2.6 million L/d in 2013, when the Government terminated the sale of octane-91 regular gasoline. The Government is still promoting the use of E20 and E85 gasohol consumption through price incentives. The subsidies make ethanol blends 10% to 85% cheaper than gasoline E0 (ULG95). The price subsidies are paid by the State Oil Fund. In 2016, the Government still provides gasoline station marketing subsidies totaling 2.40 baht/L (approximately $0.23 US/gallon [gal]) and 9.23 baht/L ($0.98 US/gal) [5] to entice stations to expand sales of E20 and E85 gasohol. In addition, the Government continues to support manufacturers of flex-fuel vehicles (FFVs). The excise tax rate for the manufacturing of eco-cars with engines less than 1,300 cc and CO_2 emissions of less than 100 g/km is 14%, compared with 30% for E10 vehicles. In addition, if the eco-car can run with E85, the excise tax will be further reduced to 12%. With regard to feedstock, the plan focuses on improving existing feedstock supplies of molasses and cassava. The target is to increase the cassava and molasses harvest areas by up to 1,360,000 ha and 2,560,000 ha, respectively, with the total ethanol production up to 11.30 million L/d by 2036 [6].

Biodiesel

In its AEDP (2015–2036), the Thai Government's policy is to increase biodiesel consumption, with a target of 14 million L/d by 2036. The plan focuses on both supply and demand. On the supply side, the Government will promote the expansion of the oil palm harvest area up to 1,632,000 ha, with average biodiesel production of 14 million L/d by 2036. On the demand side, the Government anticipates balancing its compulsory production of biodiesel with domestic palm oil supplies. The Plan also introduces pilot projects for using B10 or B20 blends in fleet trucks and fishery boats. Nonetheless, B100 producers — especially those that are not part of those integrated with crude palm oil processors and petroleum oil refineries — are struggling to survive, primarily because of higher production costs [6].

The list that follows shows the historical implementation of mandatory use for specific biodiesels since 2007 [6]:

- June 2007: Implement mandatory use of B2 and voluntary use of B5,
- June 2010: Implement mandatory use of B3 and voluntary use of B5,
- March 2011: Implement mandatory use of B2 and voluntary use of B5,
- May 2011: Implement mandatory use of B3–B5,
- July 2011: Implement mandatory use of B4,
- January 2012: Implement mandatory use of B5,
- July 19, 2012: Implement mandatory use of B3.5,

- November 1, 2012: Implement mandatory use of B5,
- April 2013: Cabinet agrees to implement mandatory use of B7 commencing on January 1, 2014,
- January 1, 2014: Implement mandatory use of B7,
- February 17, 2014: Adjust mandatory use from B7 to B3.5,
- May 14, 2014: Implement mandatory use of B7,
- January 22, 2015: Adjust mandatory use from B7 to B3.5, and
- April 16, 2015: Return to implement mandatory use of B6.0–7.0.

The Government also intends to support the research and development of other alternative energies, for example, bio oil and hydrogen. Table 3 shows the average sale volume of diesel and gasohol from 2011 through 2015.

Table 3 Average Sale Volume of Diesel and Gasohol in Thailand, 2011–2015 [6]

Fuel	Sale-Quality (million L/d)				
	2011 (avg.)	2012 (avg.)	2013 (avg.)	2014 (avg.)	2015 (avg.)
Gasohol 95	5.82	5.27	8.28	7.38	8.92
Gasohol 91	5.09	5.74	9.12	9.05	10.88
Gasohol E20	0.61	1.00	2.63	3.78	4.02
Gasohol E85	0.02	0.10	0.38	0.93	0.85
High-speed-diesel (HSD)	52.58	55.99	53.34	55.44	58.57

Alternative Energy

As a result of government policy on alternative energy development, alternative energy consumption is continuing to increase. This, in turn, encourages the private sector to invest in alternative energy projects. In 2014, total investment in alternative energy by the Thai Government and private sectors was 84,588 million baht. Wind energy played a major role at 30.4%, followed by biomass at 22.5%, biofuels at 18.0%, municipal solid waste at 10.5%, biogas at 9.6%, solar at 8.7%, and small hydro power at 0.3%.

Outlook

In addition to biofuel production, logistics and transport management (LTM) is another approach to mitigating fossil fuel consumption [7]. The Institute of Industrial Energy conducted the LTM Project with support from the Energy Policy and Planning Office. The aim of the project is to encourage (and consult with) the transportation sector to increase fuel efficiency and fuel economy and decrease the cost of energy for transport. The expert team conveys advice on how to improve transportation management in terms of four dimensions— engineering and technology, management, driving, and task force.

Bioethanol and biodiesel are promising fuels for vehicles, as are LPG and CNG. However, according to the National Oil Plan 2015, the Government has stopped promoting the use of LPG in transportation by cancelling the subsidies to the LPG fund and allowing the price of LPG to vary according to the real market price. The Thai Government prefers to promote the use of CNG rather than LPG in transportation, especially in public and fleet transports [8]. As a result, the demand for natural gas will increase, while exploration and production in Thailand will decrease. The goal of the National Gas Plan 2015 is to manage the level of domestic natural gas consumption and prolong exploration and production [9]. To reduce domestic consumption, the Government has plans to decrease the use of natural gas for producing electricity by increasing the amount of alternative energy used, as described in PDP 2015, AEDP 2015, and EEP 2015. Moreover, to preserve the domestic source of natural gas, it is necessary to import liquefied natural gas (LNG). The National Gas Plan 2015 also explains the management of LNG exploration and logistics in order to optimize domestic need for natural gas.

References

[1] Energy Situation (January–November 2015), Department of Alternative Energy Development and Efficiency, Ministry of Energy (2015), http://www.dede.go.th/ewt_w3c/ewt_news.php?nid=43059&filename=.

[2] Final Modern Energy Consumption (Original Unit), Energy Forecast and Information Technology Center, Energy Policy and Planning Office, Ministry of Energy (2014), http://www.eppo.go.th/info/stat/T01_02_01xls.

[3] Number of vehicles registered by fuel as of December 31, 2015, Transport Statistics Subdivision, Planning Division, Department of Land Transport (2015).

[4] Excise tax rates for merchandise, The Excise Department, Ministry of Finance (2016).

[5] Announcement of Oil Price Subsidies (Issue No. 3/2016), Petroleum and Petrochemical Policy Bureau, Energy Policy and Planning Office, Ministry of Energy (2016).

[6] "Fuel Situation," Energy Policy and Planning Office, Energy Policy Journal, Volume 104 (April–June 2014).

[7] "Logistics and Transport Management," Energy Policy and Planning Office, Energy Policy Journal, Volume 99 (January–March 2013).
[8] Oil Plan 2015, Energy Policy and Planning Office, Ministry of Energy (2016).
[9] Gas Plan 2015, Energy Policy and Planning Office, Ministry of Energy (2016).

Major Changes
As a result of the Thai Government's policy on energy efficiency, a Long-term Energy Development Plan 2015–2036 has been implemented to meet the target of reducing 30% energy intensity (EI) by 2036 (base year 2010). There are five plans under the Long-term Energy Development Plan — Power Development Plan (PDP 2015), Energy Efficiency Plan (EEP 2015), Alternative Energy Development Plan (AEDP 2015), Oil Plan 2015, and Gas Plan 2015. All of these plans have been developed based on the concepts of security, wealth, and sustainability. The goal is to provide supply security, cost competitiveness, and environmental energy to support sustainability, while supporting the socioeconomic needs of the people of Thailand and the transportation sector.

In terms of security, the aim is to maintain electricity and natural gas reserves at a stable and adequate level with a margin of approximately 15% and 2P reserve in 11 to 12 years. Under the concept of wealth, Thailand's energy prices are not expensive compared with neighboring countries, with a target of a 30% reduction in EI by 2036. In terms of sustainability, the Thai Government's policy is to reduce greenhouse gases and use less energy, as well as continuously and strongly increase the use of renewable energy up to 30% of final energy consumption by 2036. With regard to renewable energy, the goal is to continue to use biofuels up to 11.30 million L/d of ethanol consumption and 14 million L/d of biodiesel consumption by 2036 [1].

United States

Introduction

The U.S. Energy Information Agency (EIA) estimated that total U.S. transportation energy consumption in 2015 was about 27,713 trillion Btu.[58] More than 90% of this consumption was petroleum-based fuels (gasoline and diesel), with almost the entire remainder being ethanol blended into gasoline at 10% volume or about 7% by Btu content (>95% of U.S. gasoline in early 2015 consisted of such blends).[59]

The EIA's Annual Energy Outlook for 2015 projects that U.S. light-duty vehicle (LDV) fuel use peaked in 2012 and will decline through 2040 due to increasingly stringent fuel economy/greenhouse gas (GHG) regulations (Figure 1).[60] The EIA projects that total transportation energy consumption will peak in 2017 and decline until around 2034, largely due to the decline in LDV fuel use. Despite Phase 2 fuel economy standards being implemented for medium and heavy-duty vehicles, heavy-duty fuel use is projected to increase through 2040, though not dramatically (from approximately 5.5 quadrillion to 7 quadrillion Btu).[61]

The U.S. net dependence on foreign oil has dropped from approximately 60% of U.S. petroleum use in 2005 to about 27% for 2015, as shown in Figure 2.[62,63] This large reduction was due mainly to increased domestic production of "tight oil," including shale deposits, enhanced recovery at mature conventional fields, rising energy prices, and increases in vehicle efficiency.

The collapse in world oil prices continues to be the main obstacle to additional penetration of alternative fuels in the United States. Much of the impetus for converting to the use of natural gas (almost entirely in heavy-duty vehicles) and other fuels (ethanol and propane) for transportation has been drastically reduced, as has the incentive for purchasing light-duty electric vehicles. Unfavorable economics are expected to continue in the

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58 http://www.eia.gov/totalenergy/data/monthly/pdf/sec2_11.pdf.

59 http://www.eia.gov/totalenergy/data/monthly/pdf/sec10_7.pdf. The EIA shows 1,111 trillion Btu of fuel ethanol consumed in 2014 and 1,056 trillion Btu consumed in the first 11 months of 2015, which is roughly 7% of motor gasoline Btus.

60 http://www.eia.gov/todayinenergy/detail.cfm?id=17171.

61 https://www.eia.gov/forecasts/aeo/workinggroup/transportation/pdf/AEO2016%20Transportation%20Working%20Group%202%20Presentation.pdf, pp. 30–32.

62 http://www.eia.gov/dnav/pet/hist/LeafHandler.ashx?n=PET&s=MTTNTUS2&f=M.

63 See http://www.eia.gov/tools/faqs/faq.cfm?id=727&t=6.

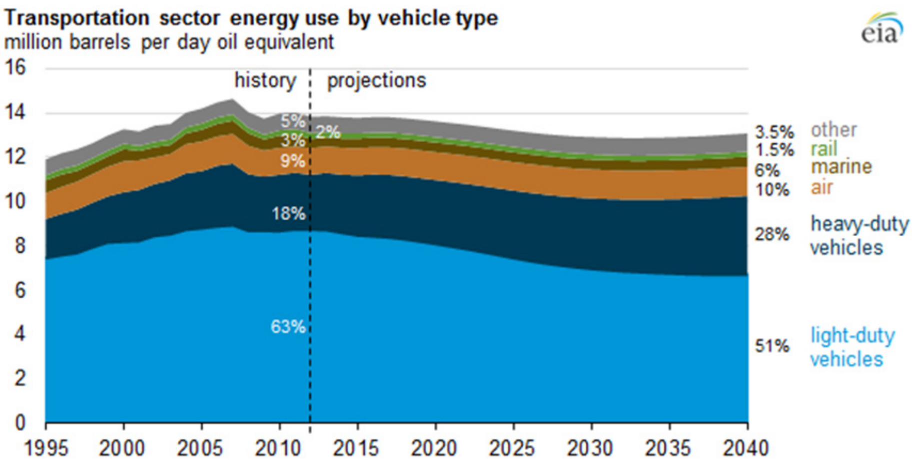

Fig. 1 Transportation Sector Energy Use by Vehicle Type

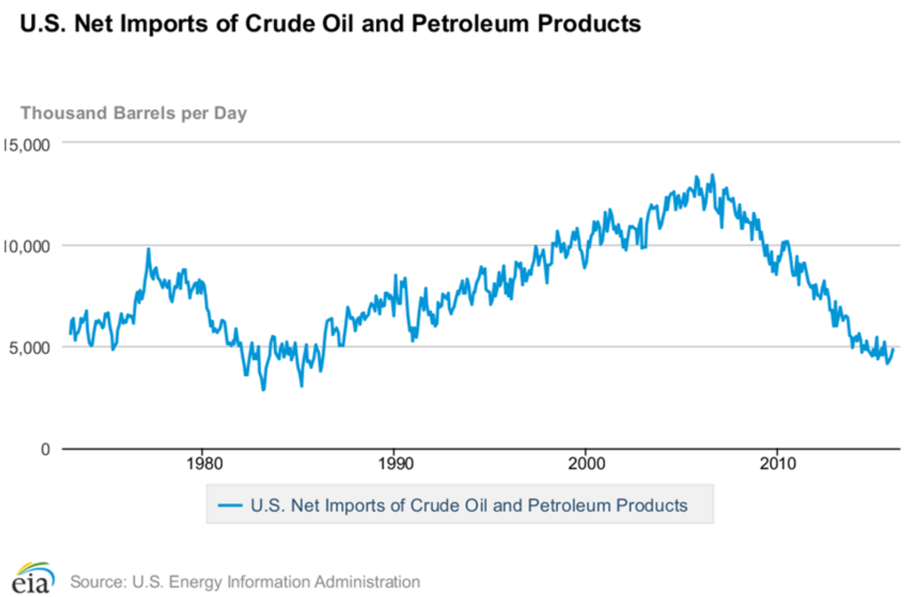

Fig. 2 U.S. Net Imports of Crude Oil and Petroleum Products

near term. Interest in advanced motor fuels continues to be vigorous, despite the likelihood that low prices and abundance will not persist in the long term.

Policies and Legislation

The U.S. Federal Government and state governments provide many incentives for the development, deployment, and use of alternative fuels and alternative fuel vehicles. While they are too numerous to catalog here, some of the more important ones are described below.

The Energy Policy Act of 1992 (EPAct) requires that certain centrally fueled fleets (federal, state, and alternative fuel provider fleets, such as utility companies) acquire light-duty alternative fuel vehicles as most of their new vehicle acquisitions. Fleets of alternative fuel providers must also use alternative fuels in the vehicles, where available for use.

The U.S. Department of Energy (DOE) Clean Cities Program is a government-industry partnership program that supports local decisions to reduce petroleum use in the transportation sector. To accomplish this goal, the program encourages the public and private sectors to reduce petroleum consumption by using alternative fuels and by increasing vehicle efficiency through technologies such as alternative-fueled vehicles, hybrid and electric-drive vehicles, fuel blends, idle reduction technologies, and fuel economy measures. Clean Cities carries out its mission by working in cooperation with nearly 100 geographically diverse, community-based coalitions nationwide. Coalitions form partnerships within their communities to design projects to suit their area's needs, resources, and strengths. At the national level, Clean Cities gives manufacturers, trade associations, national fleets, government agencies, and other stakeholders coordinated strategies and resources that they can leverage to implement effective petroleum reduction practices. Clean Cities also gives coalitions access to information and incentives from DOE, other federal and state agencies, and industry partners that can help fund significant, high-impact projects.

As shown in Figure 3, the Clean Cities coalition users of alternative motor fuels displaced 390 million gallons of gasoline equivalent (MGGE) in 2013 (most recent data), an increase of about 15% from 2012 levels. Over half of the savings came from natural-gas-powered vehicles, typically heavy-duty trucks and city buses. The savings comes from approximately 475,000 vehicles tracked by the Clean Cities coalitions. Note that the consumption quoted by Clean Cities was mainly calculated for fleet vehicles that were in an area tracked by a Clean Cities coalition partner. The

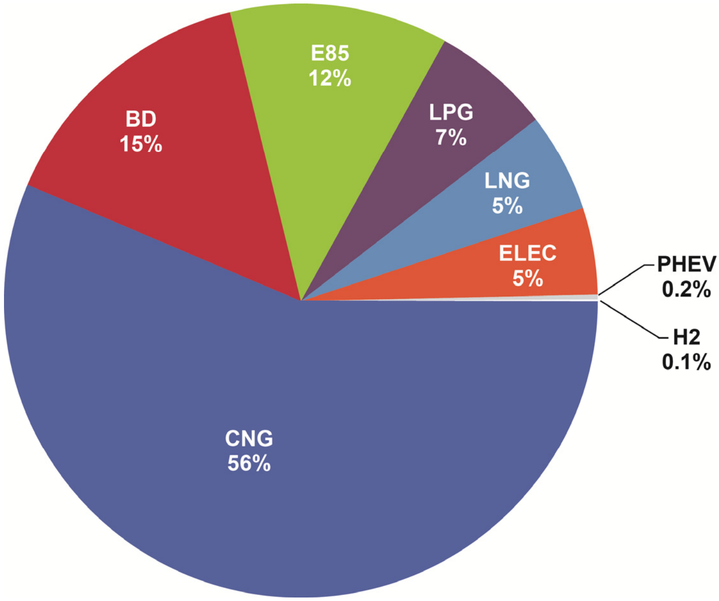

Fig. 3 Clean Cities 2013 Data for Advanced Fuel Vehicles (AFVs) and Petroleum Displacement[64]

U.S. Federal Government does not have an active role in operating the majority of these fleets. More information on the Clean Cities program can be found at www.cleancities.energy.gov.

U.S. Environmental Protection Agency (EPA) Requirements under the Renewable Fuels Standard (RFS)

The primary driver of renewable fuel use in the United States is the RFS, adopted in 2005 and expanded in 2007 (RFS2). It requires increasing volumes of renewable fuel to be used in motor fuels.

On November 30, 2015, the EPA finalized the volume requirements and associated percentage standards under the RFS program in calendar years 2014, 2015, and 2016 for cellulosic biofuel, biomass-based diesel, advanced biofuel, and total renewable fuel. The EPA also finalized the volume requirement for biomass-based diesel for 2017 (see Tables 1 and 2). These volumes were greater than those proposed in 2013 for 2014 compliance, but

[64] See http://www.afdc.energy.gov/uploads/publication/2012_metrics_report.pdf. BD = biodiesel, E85 = ethanol 85, LPG = liquefied petroleum gas, LNG = liquefied natural gas, Elec = electricity, PHEV = plug-in hybrid electric vehicle, H2 = hydrogen, and CNG = compressed natural gas.

significantly lower than those originally targeted in the RFS legislation, which envisioned much more robust growth in cellulosic fuel production than has as yet materialized.

Table 1 EPA Final Renewable Fuel Volumes[a]

Fuel	2014	2015	2016	2017
Cellulosic biofuel (million gallons)	33	123	230	NA[b]
Biomass-based diesel (billion gallons)	1.63	1.73	1.90	2.00
Advanced biofuel (billion gallons)	2.67	2.88	3.61	NA
Renewable fuel (billion gallons)	16.28	16.94	18.11	NA

[a] Units for all volumes are ethanol-equivalent, except for biomass-based diesel volumes which are expressed as physical gallons.

[b] NA = not applicable.

Table 2 EPA Final Percentage Standards

Fuel	2014	2015	2016
Cellulosic biofuel	0.019%	0.069%	0.128%
Biomass-based diesel	1.41%	1.49%	1.59%
Advanced biofuel	1.51%	1.62%	2.01%
Renewable fuel	9.19%	9.52%	10.10%

The final 2016 standard for advanced biofuel is nearly 1 billion gallons, or 35% percent, higher than the actual 2014 volumes, while the total renewable standard requires growth from 2014 to 2016 of more than 1.8 billion gallons of biofuel, or 11% higher than 2014 actual volumes. Biodiesel standards are expected to increase steadily over the next 2 years, increasing to 2 billion gallons in 2017.

The EPA divides renewable fuels into several categories for regulatory purposes, some of which are nested. Liquid cellulosic biofuel is fuel derived from biomass by enzymatic conversion and fermentation, by pyrolysis, or by gasification. The category was created largely with cellulosic ethanol in mind, but cellulosic ethanol production continues to be plagued with problems. Renewable natural gas from landfills and anaerobic digesters, treated as cellulosic biofuel by the EPA through a combination of rulemakings in 2013 and 2014, has dwarfed liquid fuels in that category. Biomass-based diesel is mainly traditional fatty acid methyl ester (FAME) biodiesel, derived from soy, corn, canola, camellia oils, and other vegetable and animal fats and oils. These categories are nested into the category of advanced biofuels, which also includes renewable diesel, biogas, renewable heating oil, and renewable fuels co-processed in petroleum refining. Finally, the broad category "Renewable fuel" includes all of these categories combined with (and dominated by) starch- and sugar-based ethanol.

Other alternative and advanced motor fuels are incentivized by various federal and state programs. Lists of these are available at http://www.afdc.energy.gov/laws/.

Co-Optimization of Fuels and Engines

In fall 2015, DOE introduced a new initiative known as the Co-Optimization of Fuels and Engines, or Co-Optima. The initiative is led jointly by DOE's Vehicle Technologies Office and Bioenergy Technology Office. The goal of Co-Optima is to identify and rigorously evaluate co-optimized technology options for the introduction of high-performance, sustainable, affordable, and scalable fuels and engines. DOE envisions that the effort will span more than 15 years, including not only research on the relationship between fuels and engines to achieve optimum efficiency and GHG reductions, but also fuel production research and pathways for successful commercialization of the products. It includes both spark ignition (SI) technologies (focusing on high-knock resistance for efficiency), targeted for commercialization by 2025, and compression ignition (CI) technologies (including use of kinetically controlled and higher reactivity fuels), targeted for commercialization by 2030. Identified metrics include:

- Reduce per-vehicle petroleum consumption 30%,
- Accelerate deployment of 15 billion gallons/year of advanced biofuels, and
- Enable an additional 9%–14% fleet GHG reduction by 2040.

Program activity is currently organized into six integrated and coordinated teams for:

- Low GHG Fuels: identifying promising bio-derived blendstocks, developing selection criteria for fuel molecules, and identifying viable production pathways.
- Fuel Properties: identifying critical properties and allowable ranges, systematically cataloguing properties, and predicting fuel blending behavior.

- Advanced Engine Development: quantifying interactions between fuel properties and engine design and operating strategies, and enabling optimal design of efficient, emission-compliant engines.
- Modeling and Simulation Tool Kit: extending the range, confidence, and applicability of engine experiments by leveraging high-fidelity simulation capabilities.
- Analysis of Sustainability, Scale, Economics, Risk, and Trade: analyzing energy, economic, and environmental benefits at the U.S. economy level and examining routes to feedstock production at scale through existing biomass markets.
- Market Transformation: identifying and mitigating challenges of moving new fuels and engines to markets and engaging with the full range of stakeholders.

The first major decision point of the program is targeted for March 31, 2017, which marks the end of the fuel discovery phase of "Thrust I" of the program — the low-knock SI fuel and engine. At that point, it will be determined whether any candidate fuel components (other than ethanol) can realistically be expected to be commercially available at large scale in the early 2020s. Though SI fuel and engine research and development (R&D) activities will continue thereafter, regardless of the result, they may not be realistic candidates on the aggressive Co-Optima timeline. The result of this fuel discovery phase of Thrust I will inform the degree to which attention will be shifted to Thrust II — advanced compression ignition (CI) fuels and engines. (Thrusts I and II are being executed in parallel already.)

Smart Mobility

In 2015, the U.S. government announced a broad new inter-agency initiative called Systems and Modeling for Accelerated Research in Transportation (SMART) Mobility. It will utilize a consortium of stakeholders in government and the private sector to examine the nexus of energy and mobility for future transportation systems. Initial research will focus on connected and automated vehicles, urban science, decision science, multi-modal transport, and integrated vehicle-fueling infrastructure systems. DOE's participation in the program will include $5 million in new R&D funding.

Zero Emission Vehicle Sales Mandates

The State of California has adopted requirements that percentages of automaker sales in the state be zero emission vehicles (ZEVs – including battery electric vehicles and fuel cell vehicles), allowing partial credits for various other types of vehicles, including plug-in hybrid electric vehicles and natural gas vehicles. Ten other states have opted to participate in the program — Connecticut, Maine, Massachusetts, Vermont, Rhode Island, New York, New Jersey, Pennsylvania, Maryland, and Oregon. The requirements apply differently based on the sales volumes of manufacturers, but from 2012–2017 they have been only in the thousands of vehicles for the large manufacturers. Effective in 2018, the ZEV requirements triple and then ramp up annually to reach about 15% of new car sales in these states by 2025. This is expected to result in substantially greater volumes of advanced fuel vehicles (AFVs) being sold in these key states.

Implementation: Use of Advanced Motor Fuels

Biofuels

In 2012, the first commercial production of cellulosic ethanol in the United States came on line. Although the total volume remains very small (less than 1 million gallons), several facilities came on line in 2013 and 2014. In order to encourage the use of advanced biofuels, the EPA has defined a system of credits based on the energy content of ethanol. The credit, known as the Renewable Identification Number (RIN), is equivalent to the energy content of 1 U.S. gallon (3.78 L) of ethanol. There are different categories of RINs. Table 3 shows the ones relevant to liquid transportation fuels.

Table 3 RINs Relevant to Liquid Transportation Fuels

Fuel (D Code)	Net RINs Generated
Cellulosic biofuel (D3)	141,309,507
Biomass-based diesel (D4)	2,793,985,198
Advanced biofuel (D5)	146,837,088
Renewable fuel (D6)	14,825,741,926
Cellulosic diesel (D7)	247,785

The EPA shows RINs for 2015 (representing the Btu equivalent of a gallon of ethanol) for "Renewable Fuel" (mostly corn ethanol) at 14,825,741,926 for total "Advanced Biofuel" (mostly sugarcane ethanol imports) at 146,837,008.[65] Of the 142,038,566 cellulosic biofuel (D3) RINs, 139, 857,470 were from renewable natural gas, with the other 2,181,096 (or about 1.5%) being from cellulosic ethanol, and 44,168 were from

[65] https://www.epa.gov/fuels-registration-reporting-and-compliance-help/2015-renewable-fuel-standard-data.

cellulosic gasoline.[66] Renewable natural gas includes both landfill gas and gas from anaerobic digesters using partial cellulosic feeds.

Biomass-based diesel RINs generated in 2015 totaled 2,793,985,198, of which 2,273,100,834 were for biodiesel and 6,877,749 were for other (non-ester) renewable diesel components. No RINs were generated in 2015 for cellulosic diesel fuel.[67]

Blends of greater than 15% ethanol are marketed in the United States at special dispensers for use only in flex-fuel vehicles (FFVs) designed for use with up to E85. There were an estimated 2,815 stations selling FFV fuel in the United States by December 2015, up from 2,472 in 2014. This includes "blender pumps," which sell blends for conventional vehicles and a range of blends for FFVs (e.g., E20, E30, and E85). The FFVs using high-ethanol blends have experienced problems with starting and drivability in winter months in some regions. In 2011, American Society for Testing and Materials (ASTM) International revised its Specification D5798-11 (Standard Specification for Ethanol Fuel Blends for Flexible-Fuel Automotive Spark-Ignition Engines) to allow for blends of down to 51% ethanol to be used as FFV fuel.[68] There is, however, no legal barrier to marketing blends of even lower than 51% for use in FFVs. As noted previously, some marketers are offering lower blends year-round through blender pumps.

In September 2015, the U.S. Department of Agriculture (USDA) announced its Biofuel Infrastructure Partnership (BIP) program to increase availability of higher blends of ethanol. Almost $100 million is directed toward installation of blender pumps under this program.

Natural Gas

The growth of hydraulic fracking in the United States has revolutionized the energy industry, created infrastructure problems, and been the focus of political and economic debate. Natural gas production in the United States has increased steadily in recent years and is projected to continue grow, though at reduced rates of growth (Figure 4).

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[66] Ibid.

[67] Ibid.

[68] Of this D3 RIN total, the EPA shows 729,059 RIN correction errors for a corrected total of 141,309,507. It does not show such corrections for the specific fuel types generating RINS, however. Thus the uncorrected number is shown above to illustrate how the specific fuel types compare as shares of the total. See http://www.afdc.energy.gov/fuels/ethanol_locations.html.

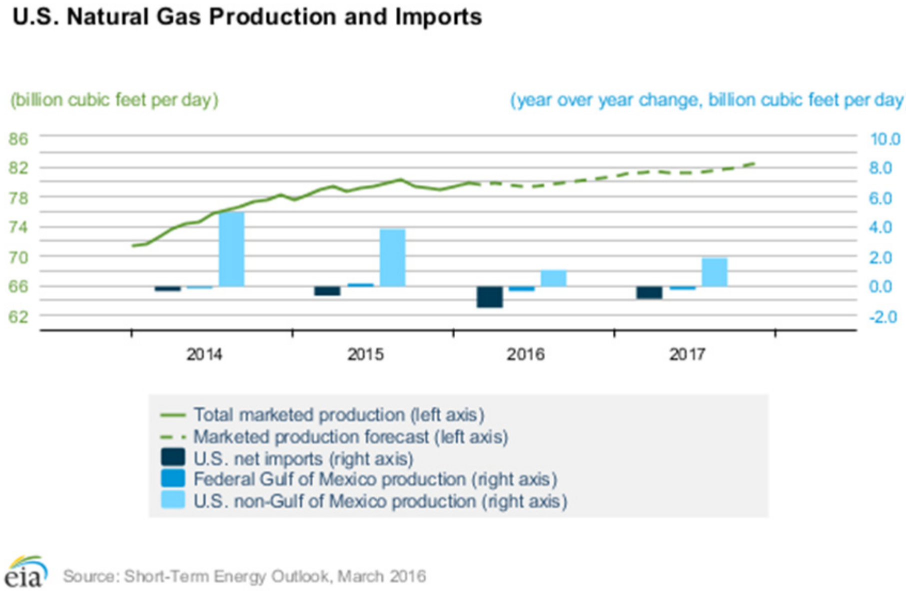

Fig. 4 Natural Gas and Crude Oil Production in the United States, 2014–2017[69]

Use of natural gas for transportation had been expected to grow in the coming decades, mainly in the heavy-duty vehicle sector, but the collapse of oil prices has called those projections into question, at least regarding the rate of such growth. Other problems surrounding the use of natural gas as a motor fuel are mainly infrastructure-related rather than vehicle-related.

In 2011, the EPA revised its regulations governing the conversion of conventional vehicles to alternative fuels, making it easier for conversion systems for natural gas and propane to get approval for vehicles older than 2 years. This revision has resulted in many more AFV conversion systems being registered with the EPA.

Electric Vehicles

Sales of plug-in electric vehicles (EVs) (plug-in hybrids and battery electric models) in 2015 continued to fluctuate on a month-to-month basis but were down slightly overall from 2014, totaling 114,022 compared with 118,773 in 2014. In addition, 384,404 hybrid electric vehicles (non-plug-in) were sold

[69] EIA, 2015, Short Term Energy Outlook, March 2016, https://www.eia.gov/forecasts/steo/report/natgas.cfm.

in 2015, down from 452,172 in 2014.[70] Available plug-in models totaled 73 as of the end of March 2016.[71]

Alternative Fuel Infrastructure

Table 4 provides the counts of alternative fuel refueling stations, including private stations, in the United States according to DOE's Alternative Fuels Data Center.[72] Updated information, with a breakdown by state and individual station locations, can also be accessed on the Alternative Fuels Data Center site.

Table 4 Counts for U.S. Alternative Fuel Refueling Stations by Type in 2012–2013, and 2014 (including public and private stations)

Year	B20	CNG	E85	Electric Outlets[a]	H_2	LNG	LPG	Total	Total Non-electric
2012	675	1,107	2,553	13,392	58	59	2,654	20,498	7,106
2013	757	1,263	2,639	19,410	53	81	2,956	27,159	7,749
2014	784	1,489	2,780	25,511	51	102	2,916	33,633	8,122
2015	721	1,563	2,990	30,945	39	111	3,594	39,963	9,018

[a] Numbers for 2012 and 2013 and the first number for 2014 are total number of recharging outlets, not sites.

As can be seen in Table 4, the total number of alternative fueling stations, exclusive of electric recharging stations, in the United States increased by 27% between 2012 and 2015. The total number of public and private nonresidential EV recharging outlets jumped by more than 131% over this same 3-year period, indicating not only an emphasis being placed on vehicle electrification by public and private entities, but the rapid growth in the number of motorists choosing EVs.

Advanced Fuels and Engines

The DOE Vehicle Technologies Office sponsors research in fuels and advanced combustion engines for the purposes of displacing petroleum-derived fuels, matching engines and fuel characteristics better, and increasing engine and vehicle efficiencies. This research covers a very broad range of fuel, engine, and vehicle technologies. The brief summary provided here focuses on fuels and fuel effects and is based on recent DOE annual

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70 See http://www.electricdrive.org/index.php?ht=d/sp/i/20952/pid/20952.
71 http://www.afdc.energy.gov/vehicles/electric_availability.html.
72 See http://www.afdc.energy.gov/fuels/stations_counts.html.

program reports.[73,74] Fuels can affect combustion and efficiency by altering in-cylinder mixing of fuel and air, enabling a higher compression ratio through high octane, and changing other important properties, such as burning velocity and ignitability.

Much of the research on the benefits of higher octane in the United States for SI engines has centered on ethanol, a readily available, high-octane gasoline component. In one study by Anderson et al.,[75] ethanol blends were found to outperform high-octane gasoline relative to knock-limited spark timing at high loads, thus allowing for both higher loads and improved fuel economy. In several studies,[76] it was also proposed to use ethanol selectively in a vehicle for high-load operation, either through the use of two fuel tanks or onboard separation. These studies reported a significant margin for further engine optimization by spark advance, an increase in the compression ratio, and engine downsizing for blends of ethanol in gasoline from 51% to 85%, such as those used in FFVs.

While high-octane fuel is desirable for traditional SI engines, it might not be ideal for kinetically controlled engines using homogeneous charge compression ignition (HCCI) or premixed charge compression ignition (PCCI) combustion. Such engines depend on a combination of fuel volatility and ignitability to allow optimum fuel-air mixing before combustion. Although the research regarding this conclusion is still preliminary, HCCI or PCCI engines will likely not benefit from higher-octane fuels. They may, however, actually benefit from lower-octane fuels that are somewhere between current diesel and gasoline for cetane and octane ratings. The more likely scenario would be HCCI or PCCI engines benefiting from a range of octane and cetane for different operating conditions.

For diesel engines, efficient, dilute combustion can be achieved by delaying ignition in the diesel spray, resulting in a combustion mode described as

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73 DOE Vehicle Technologies Office, 2013, *Fuels and Lubricant Technologies 2012 Annual Progress Report*, DOE/EE-0911, June.

74 DOE Vehicle Technologies Office, 2012, *Advanced Combustion Engine Research and Development 2012 Annual Progress Report*, DOE/EE-0872, December.

75 Anderson, J.E., et al., 2012, “High Octane Number Ethanol–Gasoline Blends: Quantifying the Potential Benefits in the United States,” *Fuel* 97:585–594, July, http://www.sciencedirect.com/science/journal/00162361/97.

76 Blumberg, P.N., et al., 2008, “Simulation of High Efficiency Heavy Duty SI Engines Using Direct Injection of Alcohol for Knock Avoidance,” SAE paper 2008-01-2447, October 6; Partridge, R.D., et al., 2014, “Onboard Gasoline Separation for Improved Vehicle Efficiency,” SAE paper 2014-01-1200, April 1; Moore, W., et al., 2011, “Engine Efficiency Improvements Enabled by Ethanol Fuel Blends in a GDi VVA Flex Fuel Engine,” SAE paper 2011-01-0900, April 12.

"lifted flame." Several projects (DOE-Sandia National Laboratories and Ford Motor Company through DOE award under solicitation DE-FOA-0000239) are investigating this strategy, including the use of oxygenated fuel components that could be derived from bio-feedstocks.

Several DOE and industry projects are developing surrogate fuels for new or emerging fuels. Surrogate fuels allow more accurate kinetic modeling of fuel effects, since they are normally built of components for which detailed kinetic mechanisms exist. The development of surrogates also leads to a deeper understanding of the relative importance of fuel properties, chemistry, and molecular structure in engine combustion. This knowledge can then be used to predict performance and optimize fuels and fuel components for emerging fuels.

The DOE Bioenergy Technology Office promotes the development of new fuels from initial concepts, laboratory R&D, and pilot and demonstration plant phases. Research areas include feedstocks, algae, biochemical conversion, and thermochemical conversion for both fuels and high-value chemicals.[77]

The Bioenergy Technologies Office has estimated there is the potential for converting 1 billion tons/year of biomass. Various pricing and yield assumptions predict there is the potential for producing 20 to 70 billion gal/year of advanced biofuels by 2022.[78] Other highlights[79] include demonstrating that cellulosic ethanol is cost-competitive with petroleum, assisting in the support of 25 integrated bio-refineries, and helping support the development of co-processing of pyrolysis oil with petroleum.

Standards for Alternative Fuels

The ASTM published standard specifications for a number of alternative fuels. These include the ones shown in Table 5.

[77] DOE Bioenergy Technologies Office, 2013, *Peer Review 2013*, May 20–23.
[78] Perlack, R.D., and B.J. Stokes (leads), 2011, *2011 US Billion-Ton Update: Biomass Supply for a Bioenergy and Bioproducts Industry*, ORNL/TM-2011/224, Oak Ridge National Laboratory, Oak Ridge, TN, Aug.
[79] DOE Bioenergy Technologies Office, *Bioenergy Successes*, www.eere.energy.gov.

Table 5 ASTM Fuel Specifications

Fuel	Specification No.
Ethanol fuel blends for flexible fuel SI engines (51–83%)	ASTM D-5798-13a
Mid-level ethanol fuel blends for SI engines (16–50%)	ASTM D-7794-12
Biodiesel blends (6–20%)	ASTM D-7467-13
Biodiesel 100% stock for blending	ASTM D-6751-12
Dimethyl ether (for CI engines)	ASTM D-7901-14
Methanol (for SI engines)	ASTM-D5797-13

Outlook

The outlook for all alternatives to petroleum motor fuel has been made uncertain by the 2014 collapse of oil prices. The EIA's Annual Energy Outlook 2015 shows the net ratio of import share of U.S. total crude oil to petroleum product supplied continuing to decline in all scenarios through 2018. Beyond that, it levels off in the reference case and starts rising slightly in the low oil price case, while continuing to decline in the high oil price case (until 2027) and high resource case (indefinitely).[80]

Apart from being affected by lower oil prices, it is expected that ethanol, the principal U.S. alternative fuel, will continue being constrained in 2016 by the challenges associated with blending at levels over 10% in gasoline, as well as concerns over misfueling, compatible systems, and other issues.

Benefits of Participation in the AMF TCP

DOE's Vehicle Technologies Program is an active part of the AMF TCP through the Fuels and Lubricants subprogram. The U.S. Government benefits from participation in several ways. One major way is through its ability to leverage finances and technical expertise on research programs of mutual interest. U.S. Government researchers also benefit from their ability to maintain contacts with international experts and to interact with them in research and policy discussions. Many of the countries participating in the AMF TCP are facing the same fuel-related issues as the United States and are active in international import and export markets for fuels, renewable fuels, and fuel components. Mutual cooperation has proven beneficial in the past and should continue to do so in the future.

[80] http://www.eia.gov/forecasts/aeo/executive_summary.cfm.

3

Ongoing AMF TCP Annexes

3.a Overview of Annexes

Ongoing Annexes in 2015

Annex Number	Title	Operating Agent
28	Information Service and AMF Website	Dina Bacovsky
43	Performance Evaluation of Passenger Car Fuel and Powerplant Options	Juhani Laurikko
44	Research on Unregulated Pollutants Emissions of Vehicles Fuelled with Alcohol Alternative Fuels	Fan Zhang
47	Reconsideration of DME Fuel Specifications for Vehicles	Mitsuharu Oguma
48	Value Proposition Study on Natural Gas Pathways for Road Vehicles	Ralph McGill
49	COMVEC – Fuel and Technology Alternatives for Commercial Vehicles	Nils-Olof Nylund
50	Fuel and Technology Alternatives in Non-Road Engines	Magnus Lindgren
51	Methane Emission Control	Jesper Schramm
52	Fuels for Efficiency	Somnuek Jaroonjitsathian
53	Sustainable Bus Systems	Alfonso Cadiz
54	GDI Engines and Alcohol Fuels	Debbie Rosenblatt
55	Real Driving Emissions and Fuel Consumption	Kevin Stork

Recently Completed Annexes

Annex Number	Title	Operating Agent
42	Toxicity of Exhaust Gases and Particles from IC- Engines – International Activities Survey (EngToxIn)	Jan Czerwinski
46	Alcohol Application in CI Engines	Jesper Schramm

The Final Reports for recently completed Annexes 42 and 46 can be found on the AMF TCP website.

3.b
Annex Reports

Annex 28: Information Service and AMF Website

Project Duration	January 28, 2004–Continuous
Participants **Task Sharing** **Cost Sharing**	 None All contracting parties: Austria, Canada, Chile, China, Denmark, Finland, France, Germany, Israel, Italy, Japan, South Korea, Spain, Sweden, Switzerland, Thailand, United States
Total Budget	€61,000 ($69,233 US) for 2015 €59,800 ($68,897 US) for 2016
Operating Agent	Dina Bacovsky BIOENERGY 2020+ Email: dina.bacovsky@bioenergy2020.eu

Background

Today, a wealth of information on thousands of topics is easily available on the worldwide web. So much information is available that filtering out all the irrelevant items can be very time-consuming. In theory, everyone can access the information, even the information being published on the other side of the globe. However, someone may not know where to look for it or may need it to be translated.

Purpose and Objectives

The purpose of Annex 28 is to collate information in the field of advanced motor fuels and make it available to a targeted audience of experts in a concise manner.

Activities

- Review relevant sources of news on advanced motor fuels, vehicles, and energy and environmental issues in general. News articles are provided by experts in North America, Asia, and Europe.
- Publish four electronic newsletters per year (on average) on the AMF TCP website, and use an email alert system to disseminate information about the latest issues (Figure 1).
- Prepare an Alternative Fuels Information System. The goal of this effort is to collate relevant information on alternative fuels and their use for transport. The system covers information on the performance of cars, effects of fuels on exhaust emissions, and compatibility of fuels with the needs of the transportation infrastructure. The system does not cover information on fuel resources, fuel production, or greenhouse gas emissions. Different organizations are working together in close cooperation to build a guidebook on advanced motor fuels that is accessible electronically on the AMF TCP website (Figure 2).
- Update the AMF TCP website to provide information on issues related to transportation fuels, especially those associated with the work being done under the AMF TCP. The website (Figure 3), in addition to providing public information, has a special password-protected area that is used for storing and distributing internal information for Delegates, Alternates, and Operating Agents on various topics (strategies, proposals, decisions, Executive Committee meetings of the AMF TCP, etc.).

Results and Reports/Deliverables

- In 2015, four electronic newsletters were published on the AMF TCP website: one each in April, July, October, and December.
- The Alternative Fuels Information System is available on the AMF TCP website.
- The AMF TCP website was updated frequently with information from Annexes and Executive Committee meetings.

ADVANCED MOTOR FUELS IEA-AMF

April 2015, issue no. 1/2015

AMFI Newsletter

Kyoto buses will run on HVO more

The AMFI Newsletter is prepared for the members of the Implementing Agreement for Advanced Motor Fuels of the International Energy Agency (IEA/AMF).
The AMFI releases four electronic newsletters each year.
A group of authors prepares contributions to this newsletter:
- Ralph MCGILL, FEEC
- Werner TOBER and Robert ROSENITSCH, TU Vienna
- Shinichi GOTO, AIST
- Manfred WÖRGETTER, BIOENERGY 2020+

Editing by Dina Bacovsky and Nikolaus Luwiczek, BIOENERGY 2020+.
Checking by Ralph McGill, FEEC and Päivi Aakko-Saksa, VTT.
The AMFI Newsletter is available online at: www.iea-amf.org

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ADVANCED MOTOR FUELS IEA-AMF iea Energy Technology Network

July 2015, issue no. 2/2015

AMFI Newsletter

IEA-Advanced Motor Fuels ANNUAL REPORT 2014

AMF Annual Report and other publications

The AMFI Newsletter is prepared for the members of the Implementing Agreement for Advanced Motor Fuels of the International Energy Agency (IEA/AMF).
The AMFI releases four electronic newsletters each year.
A group of authors prepares contributions to this newsletter:
- Ralph MCGILL, FEEC
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ADVANCED MOTOR FUELS IEA-AMF iea Energy Technology Network

October 2015, issue no. 3/2015

AMFI Newsletter

First DME Truck Registered in Japan

The AMFI Newsletter is prepared for the members of the Implementing Agreement for Advanced Motor Fuels of the International Energy Agency (IEA/AMF).
The AMFI releases four electronic newsletters each year.
A group of authors prepares contributions to this newsletter:
- Ralph MCGILL, FEEC
- Werner TOBER and Robert ROSENITSCH, TU Vienna
- Shinichi GOTO, AIST
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ADVANCED MOTOR FUELS IEA-AMF iea Energy Technology Network

Dec 2015/Jan 2016, issue no. 4/2015

AMFI Newsletter

DuPont opens commercial-scale cellulosic ethanol plant in Iowa

The AMFI Newsletter is prepared for the members of the Implementing Agreement for Advanced Motor Fuels of the International Energy Agency (IEA/AMF).
The AMFI releases four electronic newsletters each year.
A group of authors prepares contributions to this newsletter:
- Ralph MCGILL, FEEC
- Werner TOBER and Robert ROSENITSCH, TU Vienna
- Shinichi GOTO, AIST
- Manfred WÖRGETTER, BIOENERGY 2020+

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Fig. 1 AMF TCP Newsletters Published in 2015

Home > FUEL INFORMATION > Fuel Info Home

Introduction

The "AMF Fuel Information System" focuses on the end-use aspects of advanced motor fuels. Performance of cars, effects on emissions and compatibility with infrastructure are included, whereas resources, production and GHG emissions are excluded. When the end-use aspects are evaluated, the complex field of engine/aftertreatment options, uncertainties of measurement methods and incomparability of measurement campaigns has to be taken into account. Priority is given to new studies; however, these represent only minor part of published studies.

The aim of the "AMF Fuel Information System" is to provide easy access to all end-use related aspects of advanced motor fuels.

Available content:

- Diesel and Gasoline
- Bio/synthetic gasoline
- Bio/synthetic diesel (paraffins)
- Fatty Acid Esters (biodiesel)
- Oils and fats
- Oxygenates
- Ethanol
- Ethers
- Methanol
- Butanol
- Methane
- LPG
- DME
- Fuel comparisons

Fig. 2 Screenshot of the Fuel Information System

Fig. 3 Screenshot of the AMF Website

Future Plans

Future plans include updating the Alternative Fuels Information System on the AMF TCP website, continuing to publish four electronic newsletters each year, and updating the website frequently.

Annex 43: Performance Evaluation of Passenger Car Fuel and Powerplant Options

Project Duration	January 2011–February 2016
Participants	
Task Sharing	Canada, China, Finland, Japan, Sweden, United States
Cost Sharing	None
Total Budget	~€450,000 ($622,755 US)
Operating Agent	Juhani Laurikko[81] VTT Technical Research Centre of Finland Email: mjuhani.laurikko@vtt.fi

Background

Major de-carbonizing actions need to take place in the road transport sector. There is no single solution that could solve the de-carbonization challenge. Multiple technologies must be considered in order to find the alternatives that are best suited for each given set of boundary conditions. Moreover, the importance of energy efficiency is increasing. Engine downsizing, switching to diesel fuel, and opting for hybridization contribute to fuel efficiency. Renewable energy can be introduced, either through biofuels or through electricity from renewable sources.

Passenger cars are a major class of on-road vehicles. Since the number of individual vehicle types, makes, and models is very large, the evaluation of future options is quite challenging. The goal of this research project is to deliver first-hand primary data for this type of evaluation, which could improve the possibilities for making appropriate choices among the many available options. The available technology options are increasing for both powertrain and fuel alternatives. Therefore, unbiased data sanctioned by the IEA on the performance (energy use and emissions) of new technologies is needed for decision makers at all levels.

Purpose and Objectives

The core of the study consists of benchmarking a set of makes and models of passenger cars that offer multiple options for fuels and powerplants. A project goal is also to demonstrate the differences in efficiency that arise

[81] Since November 2014 (Executive Committee [ExCo] 48 meeting in Paris); original Operating Agent, Jukka Nuotimäki.

from engine types and sizes by testing engines with different power outputs offered on the same vehicle platform.

The test matrix allows for modulation of the duty cycle and ambient temperature in order to obtain more application-specific and environment-specific data. To make the assessment as realistic as possible, the evaluation is based on a set of different operating conditions and duty cycles. This varying of conditions is important, since previous experience has shown that cars tend to be optimized to type-approval conditions and common driving cycles.

The primary objective of the project is to produce comparable information about different powerplant options with regard to fuel efficiency, energy efficiency, and tailpipe emissions. By using selected vehicle platforms and by basically performing "internal" comparisons between powerplant options, the vehicles themselves can be "nullified." This approach emphasizes the differences between alternative engine technologies, rather than the differences between car makes and models. Full fuel cycle performance will be calculated by combining well-to-tank (WTT) data for various fuels generated in Annex 37.

Activities

The activities carried out under Annex 43 during 2015 concentrated mainly on analysis and reporting.

Literature Review

WTT analyses conducted in this project are based on the information generated in Annex 37. However, since the main scientific basis for this part of the exercise is the Joint European well-to-wheel (WTW) analysis,[82] an update[83] of which was released in May 2014, that needs to be taken into account.

Method Development

Agreement on common test protocols was essential for this project, and work on this had already been done in 2011. The purpose of common test protocols is to ensure that the baselines for test results will be comparable, although participant-specific test conditions were also allowed and encouraged.

[82] http://setis.ec.europa.eu/newsroom-items-folder/jec-well-to-wheels-wtw-analysis-of-future-automotive-fuels-and-powertrains-in-the-european-context.

[83] http://iet.jrc.ec.europa.eu/about-jec/.

Data Collection

Japan and the United States are participating in this Annex by sharing existing data. Due to different test protocols (mainly the use of different driving cycles), these data are not directly comparable with other experimental test results. However, the data from Japanese and American participants were accepted because they supplement the test matrix with valuable information on hybrid powertrains and liquefied petroleum gas (LPG) as a fuel.

Experimental Work

Canada, China, Finland, and Sweden have conducted new experimental work for this Annex. Experimental work has been carried out in a laboratory environment by using chassis dynamometer and emission measurement equipment. The test vehicles have represented the types of passenger cars typical of each participating country. The test matrix has also included various test fuels and drive cycles.

Finland and Sweden concluded their tests in 2012 and have submitted their results. China concluded measurements in 2013 and submitted a preliminary sub-report which is still going to be supplemented. Also, Canada has finished its tests and submitted a final release of its data in May 2015.

Table 1 summarizes the dimensions of the activities of the participants in terms of number of different cars (or powerplant options on a single vehicle platform), duty cycles, fuels, and ambient temperatures used in the measurements

Table 1 Summary of the Elements Used for Measurement Activities by the Participants

Participant	No. of Different Cars	No. of Duty Cycles	No. of Fuels	No. of Ambient Temperatures Used
Japan	1	4	2	1
Canada	4	5	7	2
China	6	1	5	1
Sweden	3	4	2+EV	2
Finland	7	4	6+EV	2
USA	4	4	2	1

Data Assessment

Data are evaluated in two steps. First an evaluation of the end-use performance is done by each individual participating country within the tested vehicle model's family. The second evaluation is done in the Final Report based on all the information generated. This second evaluation phase combines the WTT data of the test fuels with end-use performance data to provide information on the complete fuel cycle.

Information Dissemination

Information will be disseminated in AMF TCP ExCo meetings, in the Final Report, and possibly also at suitable conferences. A short summary of the idea behind the project and of the Finnish test results was presented at the 2014 FISITA Congress in June of that year.

Participants

Policy-Related Participants

- Finnish Transport Agency (Finland)
- Organization for the Promotion of Low Emission Vehicles (LEVO) (Japan)
- Swedish Energy Agency, Swedish Road Administration Agency (Sweden)
- Tekes – The Finnish Funding Agency for Innovation (Finland)

Industry Participants

- European Batteries (Finland)
- Gasum (Finland)
- Neste Oil (Finland)
- Nikki Co. Ltd. (Japan)
- St1 (Finland)

Academia and Test Laboratory Participants

- Argonne National Laboratory (United States)
- AVL MTC Motortestcenter AB (Sweden)
- Beijing Institute of Technology (China)
- China Automotive Technology and Research Centre (China)
- Environment Canada (Canada)
- National Traffic Safety and Environment Laboratory (NTSEL) (Japan)
- VTT Technical Research Centre of Finland (Finland)

Time Schedule

The duration of the project was prolonged in order to reserve time for participants to deliver their sub-reports. The remaining sub-reports were expected to be delivered early in 2014, and originally the Final Report was scheduled to be ready by summer 2014. However, the Operating Agent at VTT resigned and due to the internal situation at VTT, a new one could not be appointed, only a deputy was appointed. For this reason an extension was requested, and the ExCo accepted prolonging the project to the end of 2015.

The first draft of the Final Report has been compiled and was sent to selected reviewers in January 2016. The report is expected to be finalized in April 2016.

Results/Key Messages

The summary of results indicates that there is no single solution that could solve all the challenges of road transport. Instead, there seem to be pros and cons with regard to the tested fuel and powertrain alternatives depending on their operating environment. Electric vehicles are an energy-efficient option for various driving conditions, but they have a limited driving range. In addition, the WTW carbon dioxide (CO_2) emissions of electric vehicles seem to be most sensitive to upstream energy production among the available powertrain options. The most suitable option thus seems to vary with driving conditions and user needs. However, the results indicate that sophisticated fuels may help to reduce tailpipe emissions and WTW CO_2 emissions of traditional vehicles.

Publications

The Final Report is now planned to be finalized in March 2016. A short summary of VTT's test results was presented at the 2014 FISITA Congress under the title "Performance Evaluation of Passenger Car, Fuel and Powerplant Options."[84]

Success Stories

The outputs of this study were used as inputs in the Finnish Transport Agency's final report, *Alternative Propulsion for the Transport of the*

[84] Nuottimäki, J., J. Laurikko, and N.-O. Nylund, 2014, "Performance Evaluation of Passenger Car, Fuel and Powerplant Options," Paper F2014-CET-040, published in *Proceedings of 2014 FISITA World Automotive Congress,* Maastricht, Belgium, June.

Future. The report is used in national policy making, and it sets objectives and recommendations for the transport of the future.

Annex 44: Research on Unregulated Pollutant Emissions of Vehicles Fuelled with Alcohol Alternative Fuels

Project Duration	July 2012–December 2015 (3 years)
Participants **Task Sharing** **Cost Sharing**	 Canada, China, Finland, Israel, Sweden, China, Finland, Sweden,
Total Budget	€80,000 ($103,000 US)
Operating Agent	Fan Zhang China Automotive Technology & Research Center (CATARC) Email: zhangfan@catarc.ac.cn

Background

The gradual depletion of petroleum resources throughout the world has generated an increased urgency to develop alternative energy sources. Alcohol fuels have the advantage of having a wide range of sources. These fuels can be manufactured from biomass raw materials, agricultural raw materials (e.g., sugar cane, cereals, and rice), timber and urban waste, and fossil fuels (e.g., natural gas, petrochemical, and coal). A number of countries support the use of alcohol alternative fuels. For example, the United States, Brazil, and Sweden encourage the use of ethanol fuel made from biomass materials. In addition, several regions in China, including Shanxi Province and Shanghai, have initiated a pilot program to promote the use of methanol fuel.

Due to reductions in the limits for regulated pollutant emissions, unregulated pollutant emissions in vehicle exhaust have attracted an increasing amount of attention. Studies indicate that the use of alcohol fuels blended with gasoline in vehicles can reduce engine-out hydrocarbon (HC) and carbon monoxide (CO) emissions to some extent. The reduction occurs because the oxygen content in the fuel can promote the fuel's complete combustion. However, more unregulated pollutants may be emitted, such as polycyclic aromatic hydrocarbons, aldehydes, and ketones. These substances stimulate strong negative reactions in sensitive recipients. They could also have genetic toxicity and carcinogenic activity that could significantly affect human health. This factor is an important one that could hinder further development of alcohol alternative fuels.

As a result of these concerns, it is necessary to investigate the unregulated pollutant emissions from vehicles fuelled with alcohol alternative fuels. This type of research would serve to promote the application of alcohol alternative fuels in a more expedient manner.

Purpose and Objectives

The two main purposes of this project are to take measurements in order to (1) obtain the unregulated pollutant emission levels of alcohol-fuelled vehicles and (2) gradually establish the measurement methods and limits of unregulated pollutant emissions. Furthermore, the research in Annex 44 will be conducted so as to examine the influences that the measurement methods, automotive technologies, alcohol contents in the fuels, ambient temperatures, test cycles, and other relevant factors have on the unregulated pollutant emissions of vehicles.

Activities

Researchers in China conducted emissions tests on a chassis dynamometer by using a gasoline direct injection (GDI) vehicle fuelled with gasoline, E10, E20, M15, and M30. The driving cycle was the New European Driving Cycle (NEDC). Fourier transform infrared radiation (FTIR), high-performance liquid chromatography (HPLC), and gas chromatography-mass spectrometry (GC-MS) were used to synchronously measure regulated and unregulated emissions from the vehicle. The results for methanol, formaldehyde, acetaldehyde, acetone, benzene, toluene, xylene, and other unregulated emissions at a temperature of 25°C were quantitatively determined. The results for unregulated emissions are still in analysis. In addition, evaporative emissions tests were conducted by using a port fuel injection (PFI) vehicle fuelled with gasoline, E10, and M15. HPLC and GC-MS were used to measure the unregulated emissions.

Researchers in Sweden conducted a literature review on the low blending of alcohol fuels in passenger cars. The report was finalized in October 2013, and it was delivered for the task-sharing contribution of Annex 44. The report covers both regulated and unregulated emissions, as well as experiences related to the use of alcohol fuels. The focus was on methanol.

Researchers in Finland conducted emissions tests on a chassis dynamometer by using two vehicles and three fuels (E10, E85, and E100). Measurements were made at ambient temperatures of +23°C and –7°C. In addition to regulated emissions, selected individual HCs, aldehydes

(2,4-dinitrophenylhydrazine [DNPH] by HPLC), and particulate mass were measured (GC). The driving cycles were cold-start NEDC and hot-start Federal Test Procedure (FTP)-5 (of the U.S. Environmental Protection Agency).

Researchers in Canada conducted emissions tests on a model year 2012 Ford Focus flex-fuelled vehicle (FFV) with a 2.0-L, wall-guided, GDI engine. Test cycles included FTP-75, US06, and a limited set of NEDCs. All tests were conducted at 25°C. In addition, FTP-75 tests were performed at ambient temperatures of –7°C and –18°C. Analysis is ongoing. In addition to regulated emissions, unregulated pollutant emissions of CO, nitrogen oxides (NO_x), HCs, and carbon dioxide (CO_2) were collected by using HPLC and GC-flame ionization detection (FID) for compounds such as acetaldehyde, formaldehyde, acetone, benzene, and toluene. Test fuels were E0, E10, and E85.

Researchers in Israel conducted a test program in which M15 fuel was used in four different car models. During this program, they measured regulated and unregulated (focusing on formaldehyde and acetaldehyde) emissions. All tests were performed in a closed climatic chamber on a chassis dynamometer. Two driving cycles were used: NEDC and US06. The main objective was to compare the emissions of normal 95-octane gasoline and M15.

Results/Key Messages

China

Figure 1 shows, respectively, the average emissions levels of CO, HC, NO_X, CO_2, methane (CH_4)-regulated pollutants and methanol, formaldehyde, acetaldehyde, acetone, benzene, toluene, dimethylbenzene, ethylene, propylene, 1,3-butadiene, and isobutene unregulated pollutants during different cycles. The test results indicate that, although there are differences in the average emission levels during different driving cycles, the largest average emission level is no more than 2 times the smallest one. The average levels of CO, HC, CO_2, and CH_4 emissions using the same light-duty vehicle have the same tendency: Japanese JC08> European NEDC> American FTP75, while NO_X emissions have the opposite tendency: American FTP75> European NEDC> Japanese JC08. Figure 1 shows that the average emissions levels of alcohols, aldehydes, ketones, aromatic hydrocarbons, and olefins unregulated pollutants have the same tendency as HC and CO emissions: Japanese JC08> European NEDC> American FTP75. The task-sharing report was finalized on November 16, 2014.

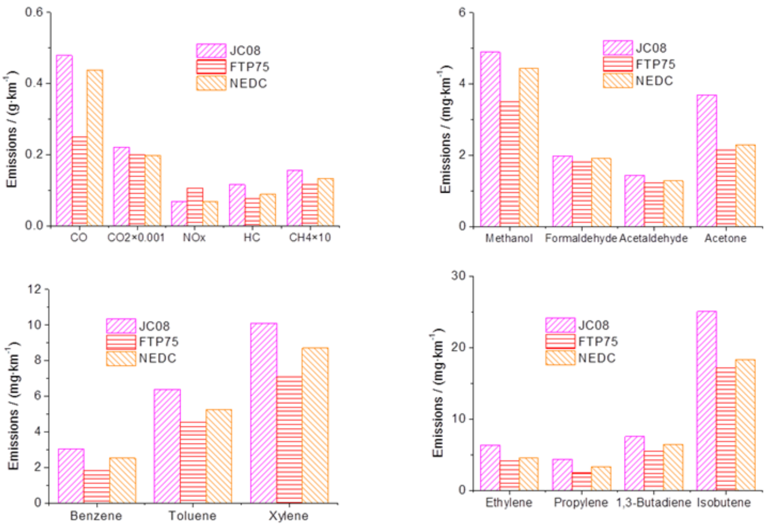


Fig. 1 Cycle Average Unregulated Emissions of Different Cycles

VTT

Figure 2 gives a summary of the selected results. The effect of test temperature was evident for most emissions. CO and HC emissions were higher at −7°C than at +23°C in the cold-start NEDC test, particularly with the MPI car. E85 reduced CO emissions, but increased HC emissions when compared with E10. The dominating HCs present were CH_4, ethene, xylenes, and acetylene for E85, whereas aromatics, CH_4, and ethene dominated for E10. Ethanol emission was huge for the E85 fuel at −7°C. Formaldehyde and acetaldehyde emissions were higher for the E85 fuel than for the E10 fuel in the cold-start NEDC test. Acetaldehyde was formed in substantial concentrations in 3 minutes after the cold start of the car, whereas emission levels were low with a warmed-up engine. The task-sharing report was finalized on September 15, 2014.

Israel

Figure 3 shows an overview of the results of carbonyls emissions using different vehicles and fuels during different driving cycles. The test results show that oxygenated fuels tested at this research did not change the amount of emitted formaldehyde compared to research octane number (RON)95. Oxygenated fuels tested at this research may decrease the amount of emitted acetaldehyde compared to RON95. Oxygenated fuels tested at this research did not change the amount of emitted carbonyls compared to RON95. The task-sharing report was finalized on December 2, 2015.

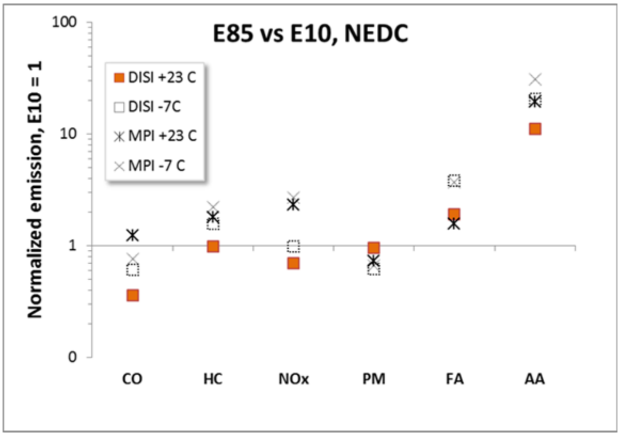


Fig. 2 Summary of Select Emission Results over the NEDC Test

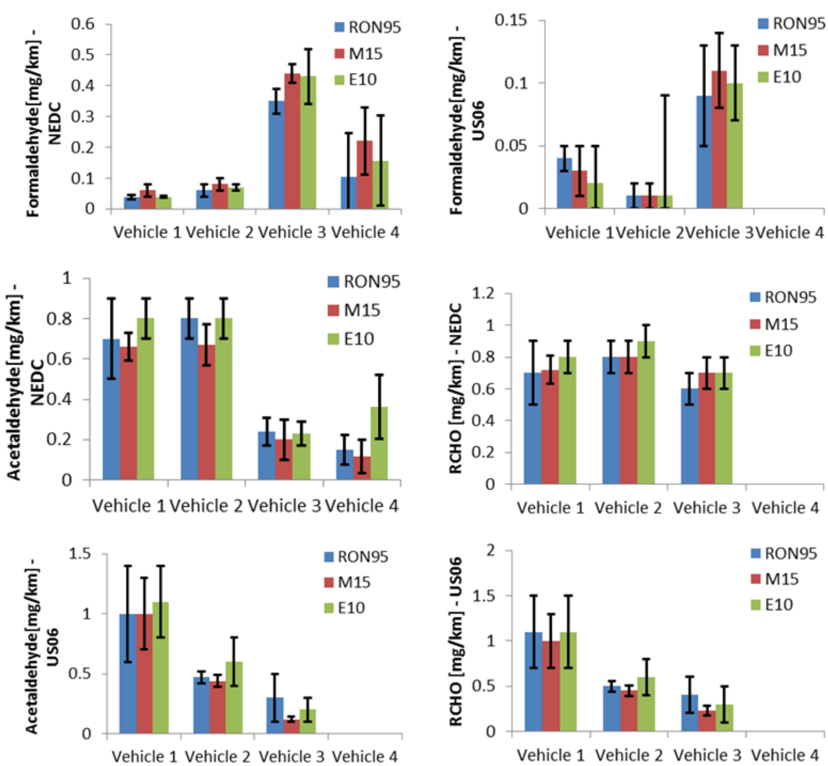


Fig. 3 Plots of Carbonyl Emissions (NEDC and US06)

Canada

Figure 4 shows the select carbonyl compounds test results of two vehicles (PFI and GDI) during the FTP-75 cycle. The largest differences measured due to the use of E10 were increases in the acetaldehyde and formaldehyde emissions rates of up to 594% and 124%, respectively, during cold temperature testing. The PFI acetaldehyde emission rate increased more than 100% at 22°C. The increases in carbonyls contributed to an increase in the nonmethane organic gas (NMOG) and total hydrocarbons (THC) emission rates of 5% and 6%. The task-sharing report was finalized before the end of 2014.

Participants

- CanmetENERGY (Canada)
- China Automotive Technology and Research Center (CATARC)
- Israeli Ministry of Energy and Water Resources
- The Technical Research Centre of Finland (VTT)
- Swedish Transport Administration (STA)

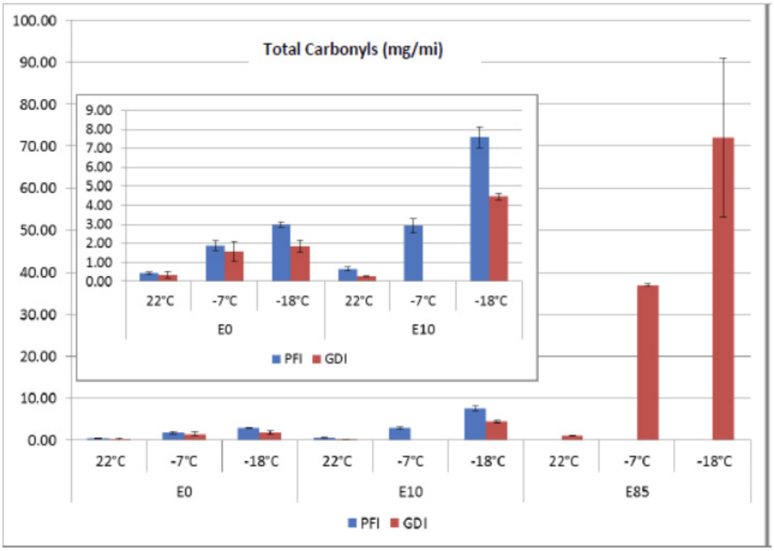
Time Schedule

The estimated project duration is 3 years, beginning in July 2012. The main breakdown of the schedule is as follows:

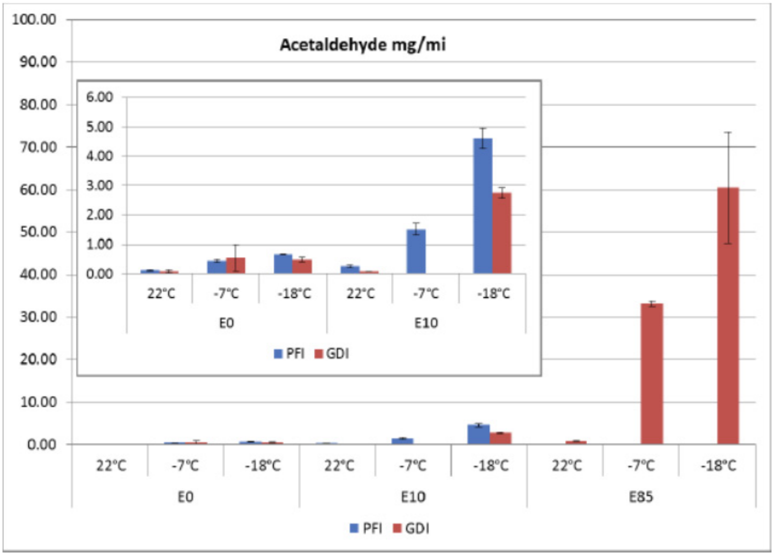
• Preparation of project:	July 2012	~Sept. 2012
• Literature survey:	Oct. 2012	~Dec. 2012
• Measurement with methanol fuels:	Jan. 2013	~Sept. 2015
• Measurement with ethanol fuels:	Mar. 2013	~Sept. 2015
• Final report:	Oct. 2015	~April 2016

Publications

The Final Report is expected to be published before April 2016.

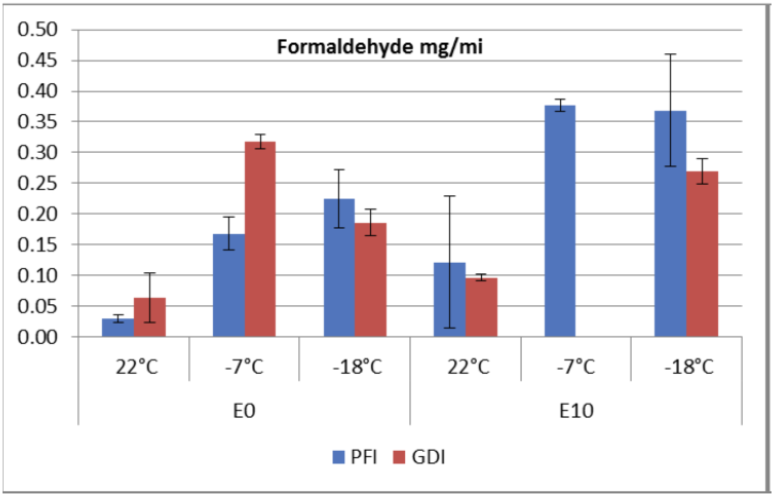


(a) Total Carbonyls

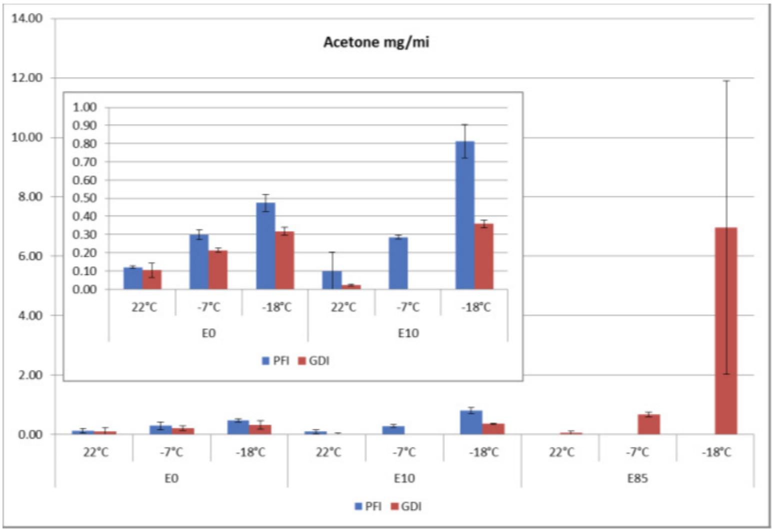


(b) Acetaldehyde

Fig. 4 Select Carbonyl Compounds Results of the FTP-75 Cycle



(c) Formaldehyde



(d) Acetone

Fig. 4 Select Carbonyl Compounds Results of the FTP-75 Cycle (Cont.)

Annex 46: Alcohol Application in CI Engines

Project Duration	March 2013–February 2015
Participants **Task Sharing** **Cost Sharing**	 Denmark, Finland, Sweden None
Total Budget	~€300,000 ($398,460 US)
Operating Agent	Jesper Schramm DTU Technical University of Denmark Email: js@mek.dtu.dk

Background

In Europe, Directive 2009/28/EC on renewable energy sets the transport bioenergy obligation in 2020 at a minimum of 10% of the transport energy use. Modern spark ignition (SI) vehicles are compatible with 10% ethanol in gasoline (E10), which represents 6% bioenergy content. Since a higher ethanol content can be used only with a limited car population, ethanol use is limited — even if higher amounts are commercially available (the so-called ”blending wall”).

Alcohols represent superior fuels for the SI engine with respect to key properties, such as octane number and latent heat of vaporization. Basically, alcohols can withstand high pressures and temperatures without igniting uncontrollably. In many parts of the world, ethanol is widely used in low-concentration blends with gasoline, and it has a more limited use in high-concentration blends. In the case of low-ethanol blends (E5–E10), it is possible to produce fuels with a slightly higher or similar octane number compared to that for regular gasoline. Most modern cars are able to regulate the ignition timing and advance the timing to a degree that increases engine efficiency by a few percentage points. A high share of ethanol, up to 85%, can be used in special SI flexible-fuel vehicles.

Fuel economy is an increasingly important issue. An obvious goal is to achieve efficiencies similar to diesel engines with the alcohol applications. However, the application of alcohols in a diesel engine requires a fuel additive to ignite the unburned mixture. An option is to use additised ethanol in heavy-duty ethanol diesel engines, which are now manufactured by Scania. These engines run with so-called Etamax D fuel that consists of 95% hydrous ethanol, together with an ignition improver, a corrosion inhibitor, and denaturants (i.e., methyl tertiary-butyl ether and isobutanol).

This fuel is manufactured by SEKAB in Sweden. With this concept, relatively small modifications are required in the engine. The compression ratio is increased, and the fuel system modified. The exhaust catalyst is developed to prevent excessive aldehyde emissions. This concept is used, for example, in buses in Stockholm. In total, around 1,000 heavy-duty vehicles are running with Scania's ethanol engines.

The most interesting option would be a "flex fuel" diesel engine capable of running with both ethanol and diesel fuel without pilot injection technology. Engines that can use only ethanol would be suitable only in restricted areas, where the availability of fuel can be controlled. Diesel engines and their control technologies have advanced considerably in recent years. For example, the common-rail system enables fine adjustments of injection. Ethanol diesel engines could be used in road transport, machinery, and the marine sector — especially in countries where ethanol is produced on a large scale.

Alcohols, particularly those produced from biomass, are the obvious fuels for more intense combustion engine application in the near future. Therefore, it relevant to initiate a general study on the best way to produce alcohols from biomass. The goal is to combine good fuel economy with low emissions. The project is suited for an IEA AMF study, since many member countries are interested in fuel/additive development. For example, Brazil, Finland, and Thailand would like to consider alternative, locally produced additive packages. In addition, there are ideas for new combustion schemes (e.g., reactant controlled combustion), which could eliminate the need for the dedicated ignition improver additive. Scania's current technology is based on an additive package that includes an ignition improver and a lubricity additive, as well as a high compression ratio of the engine.

Purpose and Objectives

The goal was to report the best possibilities for the implementation of alcohols in diesel engines. One of the main objectives of the project was to secure the supply of fuels for diesel engines, in this way by focusing on sustainable biofuels in the form of alcohols. The project involved one of the main diesel engine producers in Europe, as well as some of the most powerful research institutions and universities in Europe. The project resulted in worldwide frontline experiences, and it will have a large influence on the strategy for implementation of alternative fuels in many countries. Thus, the project will contribute to the achievement of many relevant political goals, such as support of a sustainable energy policy, independency of fossil energy, and reduced emissions — including carbon dioxide.

Activities

The work was divided into the following work packages (WPs):

WP 1: Review of Alcohol Application in Diesel Engines

Fuels, additives, and engine concepts were reviewed on the basis of existing literature, experimental data, and information from engine manufacturers. In this context, the focus was fuels with an alcohol content over 50%. The review of additives was divided into ignition improvers, emulsifiers, and other additives. Special attention was given to bio-origin additives.

WP 2: Ethanol Application in a Diesel Engine

New ethanol fuel formulations and additive options were studied with the VTT Scania ethanol engine, which is instrumented to study injection and combustion parameters. In the fuel development, priority was given to bio-origin additives. Both additives and denaturants could be bio-components. In addition, vegetable oil esters and bio-oxygenates could be considered as fuel components. Physical properties can be changed, for example, with high-viscosity components. Commercial Etamax D fuel was used as a reference.

The fuel matrix covered approximately 15 fuel combinations by varying ethanol content, additives, and other components. The ethanol content was a minimum of 50%. Basic fuel properties were analyzed from samples.

In the engine tests, combustion parameters were monitored, as well as regulated gaseous emissions. High emissions of unburned fuel and rough engine running indicated an inefficient combustion process. The best fuel candidates were selected for more detailed analysis, including particulate matter emissions. This activity was carried out in cooperation with Scania and the Finnish energy company, St1, which produces ethanol from waste.

WP 3: Analysis of Applicability of Ethanol in a Diesel Engine

The project included analyses of the obtained experimental data in order to optimize the fuel conversion with respect to fuel economy and emissions. To characterize the best possible operation area, it was essential to characterize and understand the spray formation and heat release pattern during engine operation for different fuels/additives.

This WP resulted in an evaluation of possibilities and limitations to operate a diesel engine on ethanol-based fuels. The evaluation was based on emission and fuel consumption perspectives, as well as the potential to operate the engine as a normal diesel-fuelled engine.

WP 4: Project Organization and Compilation of Results

The project was carried out under the umbrella of the AMF TCP and in collaboration with the Combustion TCP. The work resulted in a Final Report that gathered information from the mentioned WPs. The report also includes information about related work from the Combustion TCP. In addition, the overall management of the project was part of this WP.

Results/Key Messages

The key findings of this annex can be summarized as follows:

New ignition improvers for alcohol application in diesel engines are available. These ignition improvers have been found to work well with ethanol in a Scania compression ignition engine with a very high compression ratio (28:1). For methanol, the fuel system of the engine needs to be modified in order to manage the higher amounts of fuel flow needed due to the lower calorific value of the fuel. The injection timing needs to be optimized for the individual fuels (alcohol + ignition improver), since the rate of heat release was found to differ from one fuel to the other. In addition, different blends of diesel and alcohols (methanol, ethanol, and butanol) were tested in another Scania heavy-duty diesel engine with a lower compression ratio (16:1). Blending of alcohols and diesel was found to decrease particulate emissions in general. The gaseous emissions were unchanged, except at idle operation, during which aldehyde, carbon monoxide, and hydrocarbon emissions increased.

Publications

Nylund, N.O., T. Murtonen, M. Westerholm, C. Söderström, and G. Singh, 2015, "Testing of Various Fuel and Additive Options in a Compression-ignited Heavy-duty Alcohol Engine," Proceedings of the 21st International Symposium on Alcohol Fuels (ISAF XVI), March 10–14, Gwangju, Korea.

Schramm, J., 2016, "Alcohol Application in CI Engines," IEA Advanced Motor Fuels Technology Collaboration Programme, Annex 46 – Final Report.

Schramm J., and M.C. Jørgensen, 2015, “Detailed Investigations of Alcohol Fuels in Diesel-type Combustion,” Proceedings of the 21st International Symposium on Alcohol Fuels (ISAF XVI), March 10–14, Gwangju, Korea.

Annex 47: Reconsideration of DME Fuel Specifications for Vehicles

Project Duration	July 2013–December 2015
Participants	
Task Sharing	Japan, Korea, Sweden, Thailand
Cost Sharing	Not provided
Total Budget	5,000,000 JPY or €38,546 ($41,924 US)
Operating Agent	Mitsuharu Oguma National Institute of Advanced Industrial Science and Technology (AIST) Email: mitsu.oguma@aist.go.jp

Background

Although the price of crude oil has stabilized, energy security is still imperative worldwide. As the environmental impacts from vehicles have been reduced and oil dependency allayed, expectations for using dimethyl ether (DME) remain high. Currently, DME is produced from coal and natural gas. If the techniques for producing DME using synthetic gases from waste paper fluid (black liquor) or wood-based biomass from unused wood (including thinned wood), could be realized, a dramatic well-to-tank reduction in greenhouse gases would be achieved, making DME the most attractive next-generation biofuel.

The IEA AMF investigated the potential of DME as an alternative fuel for diesel engines through some Annexes (e.g., Annexes 14, 20, and 27) from 1997 to 2004. Since there was no DME market for vehicles at that time, the investigations were based on the supposition that the DME market for vehicles would be established in the near future.

Currently, China is developing the DME market for vehicles, and production capacity has reached 13 million tons. It is field testing 10 city buses running on DME on a commercial bus line in Shanghai City. Sweden is now operating the BioDME project, in which 14 trucks running on DME are being field tested. In Japan, two trucks with business license plates are running on DME; the goal is to build technical regulations for DME vehicles. With such developments taking place, commercialization of DME fuel is being accelerated.

The International Organization for Standardization (ISO) has been discussing standardization of DME fuel through TC28/SC4/WG13 since 2007. Mitsuharu Oguma, who proposed Annex 47, is the convenor of WG13. The scope of the DME standardization effort can be classified into three use categories: (1) as a feedstock for home and industrial use; (2) as a blendstock with liquefied petroleum gas (LPG); and (3) as an alternative to diesel fuel for power systems, including vehicles. WG13 has established a draft value for DME fuel specifications. However, the value is not for final DME product for vehicles, but rather for the base fuel to be used in various applications. Thus, it is necessary to standardize the DME specifications for vehicles. Now is the time to do so, in an Annex that considers the current situation of DME fuel commercialization.

Purpose and Objectives

The objective of Annex 47 is to conduct an "investigation of DME fuel specifications for vehicles." The basic specifications were derived from the draft value of ISO/TC28/SC4/WG13 (shown in Table 1). The main issues to be investigated in this Annex are (1) the effects of fuel impurities and (2) the effects of additives (e.g., lubricity improvers, odorants, if any) on DME diesel engine systems.

Table 1 DME Fuel Specifications for Base Fuel[a]

<table>
<tr><th>Characteristic</th><th>Unit</th><th>Limit</th><th>ISO/DIS16861</th><th>Mutual Agreement Value of AMF Annex (1998)</th></tr>
<tr><td>Purity</td><td>Mass %</td><td>Minimum</td><td>98.5</td><td>99.6</td></tr>
<tr><td>Methanol</td><td>Mass %</td><td>Maximum</td><td>0.050</td><td>0.05</td></tr>
<tr><td>Water</td><td>Mass %</td><td>Maximum</td><td>0.030</td><td>0.01</td></tr>
<tr><td>Hydrocarbons (up to C_4)</td><td>Mass %</td><td>Maximum</td><td>1.00</td><td rowspan="7">Others
Methyl ethyl ether <0.2
Higher alcohol <0.05
Higher ether <0.05
Ketones <0.05
Lubricity improver <0.2
Odorant <0.002</td></tr>
<tr><td>CO_2</td><td>Mass %</td><td>Maximum</td><td>0.10</td></tr>
<tr><td>CO</td><td>Mass %</td><td>Maximum</td><td>0.010</td></tr>
<tr><td>Methyl formate</td><td>Mass %</td><td>Maximum</td><td>0.050</td></tr>
<tr><td>Ethyl methyl ether</td><td>Mass %</td><td>Maximum</td><td>0.20</td></tr>
<tr><td>Residue after evaporation</td><td>Mass %</td><td>Maximum</td><td>0.0070</td></tr>
<tr><td>Sulfur</td><td>mg/kg</td><td>Maximum</td><td>3.0</td></tr>
</table>

[a] Draft values were derived from ISO/TC28/SC4/WG13.

Activities

The effects of fuel impurities and additives on DME diesel engine systems were discussed in 2014 as follows:

- On March 20, at a face-to-face meeting with Sweden, Japan, and Korea and
- On December 9, in a phone call involving Sweden and Japan.

The minutes from these discussions are summarized here:

- A potential way to move forward in this effort could be to connect the lubricity test evaluation proposal to the work being done toward achieving a "final fuel for engine standard."
- The Japanese are working toward such a standard, including:
  - Specifying a lubricity improver and its concentration range and
  - Describing the multi-pressure/temperature high frequency reciprocating rig (MPT-HFRR) lubricity test in an Annex.
- Participants should connect the work being done in Japan, the European Union, and the United States to achieve regional final fuel standards into a combined fuel standard effort.
- Lubricity test participants can start working on describing the three methods, which could be included in the Annex for a final fuel standard, and then conducting a round of testing for the three methods with the same lubricity improver concentrations. These results could be included in the final fuel standard Annex.

The next steps are listed here:

- Japan will comment on the lubricity test proposal.
- Sweden will check on the next steps for a European standard for final fuel.
- The United States will work toward achieving a U.S. final fuel standard (or check if the current American Society for Testing and Materials International [ASTM] standard is sufficient).
- Some meetings will be continued.

Participants

- DENSO CORPORATION (Japan)
- Isuzu Advanced Engineering Center, Ltd. (Japan)
- Korea Automotive Technology Institute (KATECH) (Korea)
- National Institute of Advanced Industrial Science and Technology (AIST) (Japan)
- PTT Research and Technology Institute (Thailand)
- Shanghai Jiao Tong University (China)
- Swedish Energy Agency (Sweden)

- Swedish Transport Administration (STA) (Sweden)
- University of Ulsan (Korea)
- Volvo (Sweden)

Time Schedule

- Discuss the DME fuel specification for vehicles: June 2015
- Prepare a draft of the DME fuel specification for the ISO new work item proposal: June–October 2016
- Deliver a Final Report: October–November 2015
- Follow up on the ISO discussion: End of 2016

Results/Key Messages

The following ISO DME fuel specifications for basic fuel (not for vehicles only, but included for diesel engines) and the test methods were published in 2015.

ISO 16861:2015, Petroleum products — Fuels (class F) – Specifications of dimethyl ether (DME), 2015-05-15

ISO 17196:2014, Dimethyl ether (DME) for fuels – Determination of impurities – Gas chromatographic method, 2014-11-15

ISO 17197:2014, Dimethyl ether (DME) for fuels – Determination of water content – Karl Fischer titration method, 2014-11-15

ISO 17198:2014, Dimethyl ether (DME) for fuels – Determination of total sulfur, ultraviolet fluorescence method, 2014-11-15

ISO 17786:2015, Dimethyl ether (DME) for fuels – Determination of high temperature (105°C) evaporation residues, mass analysis method, 2015-05-01

The idea for DME fuel specifications for vehicles is that ISO16861:2015 will be based on revising the “Residue after Evaporation” standard for a lubricity improver. Test methods for lubricity will be explained in the Annex, because it is currently difficult to standardize the test method for lubricity by special HFRR. The Japanese Industrial Standard (JIS) will be revised similarly. Discussions with Volvo regarding the lubricity test method should continue.

Two laboratories in Japan have conducted a new set of round robin tests of DME fuel specification; other laboratories, including a few foreign countries, will begin such testing in 2016. These data will be used for future regular revisions of the ISO test methods.

Publications

There is no publication for Annex 47.

Success Stories

A good relationship was established between the IEA AMF and ISO/TC28/SC4/WG13 (The operating agent, Mitsuharu Oguma, is the convenor of WG13). However, unfortunately, the activities were insufficient.

The operating agent will be a convenor of WG13 in another 3 years, at which time the information exchange can continue.

Future Plans

Annex 47 would like to close. Further discussion will be continued in ISO/TC28/SC4/WG13 and WG14.

Annex 48: Value Proposition Study on Natural Gas Pathways for Road Vehicles

Project Duration	October 2013–July 2015
Participants **Task Sharing** **Cost Sharing**	 Canada, China, Denmark, Finland, Israel, United States Canada, Denmark, United States
Total Budget	Canada – $24,000 US (€22,448) Denmark – $10,000 US (€9.353) United States – $160,000 US (€149,652)
Operating Agent	Ralph McGill Fuels Engines and Emissions Consulting Email: mcgillralph@yahoo.com

Background

Compressed natural gas (CNG) vehicles have achieved moderate popularity throughout the world; however, they continue to suffer from limited range and, possibly, excessive weight. Liquefied natural gas (LNG) has demonstrated some practicality for use in heavy-duty vehicles (HDVs), but it is currently too heavy to store onboard in light-duty vehicles (LDVs). A third candidate, synthetic fuels derived from natural gas (synfuels), possibly represents a more feasible utilization of available energy; to date, however, such fuels have typically been more expensive to produce than CNG or LNG. Electricity derived from natural gas offers a fourth candidate for fuelling vehicles, especially with the current emergence of electric vehicles (EVs) and their accompanying infrastructure worldwide.

A key advantage that CNG and LNG combustion offers is the avoidance of an intermediate conversion/processing step into a secondary fuel prior to fuelling the vehicle — a step that introduces extra cost and fuel efficiency losses.

The production of synfuels, on the other hand, is likely to result in energy loss in the synthesis conversion process. Some of this expense will likely be offset, in part, by the elimination of other costs due to the fact that they provide simpler transport of fuels, higher vehicle efficiencies, and so forth. Synthetic fuels derived from natural gas offer additional benefits, including the use of a fuel that resembles petroleum fuels (also referred to as “drop-in” fuels for use in legacy vehicles) in some cases, and the use of a fuel that can often be delivered through the existing pipeline infrastructure.

Using natural gas to generate electricity for use in EVs also presents unique benefits, including power generation and transmission through power lines rather than pipelines, the ongoing development of the charging infrastructure, and favorable vehicle efficiencies. New EVs with improved range and fuel economies have been regularly introduced in recent years, and much momentum has been building in this market segment throughout the world.

For the benefits of natural-gas-derived fuels to be realized, the resultant fuels would have to be produced, delivered, and used in vehicles at prices that are competitive with those of petroleum-based fuels. Balancing the trade-offs on an economic basis will help drive the selection of fuels for road transportation. Also, in addition to cost, emphasis should be placed on the environmental benefits, energy consumption, and energy security that each fuel pathway can offer to a particular nation.

Purpose and Objectives

Canada, Denmark, and the U.S. Department of Energy (DOE), with support from task-sharing AMF countries, conducted a value proposition study that investigated different natural gas pathways for on-road vehicles in order to assess the advantages and disadvantages of the various options. Aspects studied included, but were not limited to, the options' cost, life-cycle emissions, energy consumption, and societal implications. The goal was to identify the most cost-effective and technically feasible way to use natural gas in transportation, so that in many countries, natural gas would have the potential to emerge into the mainstream market rather than just continue being a niche market.

Activities

Natural gas is highly versatile in nature, meaning that a large number of fuels can be derived from it, as shown in Figure 1. These fuels are designed to operate in a variety of vehicle powertrains, further diversifying the alternative fuel chains attainable through natural gas. Because there are so many natural gas fuel pathways, only select fuel/powertrain combinations were investigated thoroughly in this study for both LDVs and HDVs.

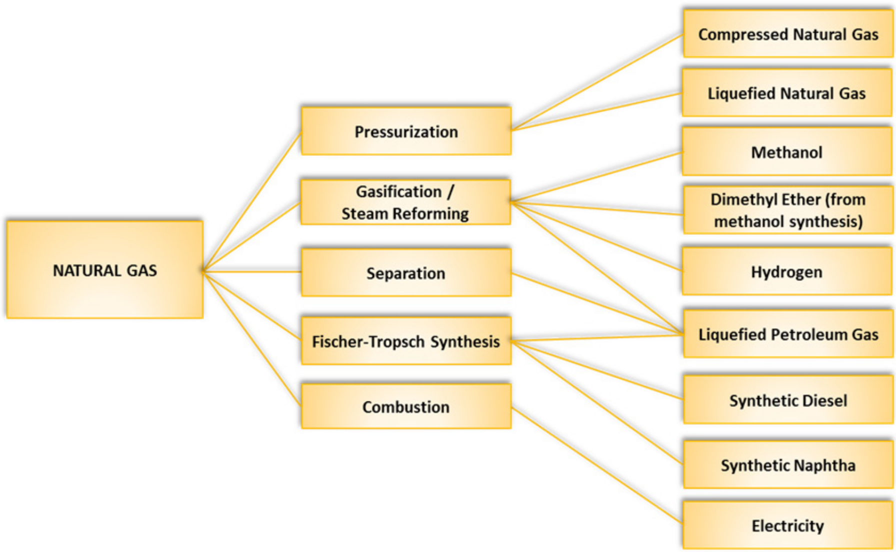


Fig. 1 Major On-road Transportation Fuels Derived from Raw Natural Gas

Since the viability of different natural-gas-derived fuel pathways is likely to vary across different geographic settings, six country-specific case studies — Canada, China, Denmark, Finland, Israel, and the United States — were conducted. Each case study demonstrates the widely varying scenarios for using natural gas as the basis for transportation fuel. Key factors that play a role in the feasibility of natural gas or a natural-gas-derived transportation fuel include:

- Natural gas production, consumption, reserves, and trade levels/practices;
- Size of natural gas vehicle (NGV) fleet and supporting infrastructure;
- Presence of fuel production plants (for domestic production);
- Electricity generation mix;
- Governmental stance, through policy support and regulations;
- Market accelerators and barriers; and
- Price of natural gas relative to traditional fuels.

Life-cycle emissions were also compared across each natural gas pathway investigated in this study. As expected, these emissions varied across fuel pathways due to differing upstream operations, fuel production and transport conditions, and vehicle operation (depending on engine design). Also, the composition of natural gas varied, in some cases, across different reserves, although the primary component was assumed to be methane; therefore, emission factors were researched for each case study.

Some countries — like Canada, China, and the United States — are leading fossil natural gas producers and consumers, while others, like Finland, rely 100% on imports or domestically produced biomethane. Israel's newly discovered offshore natural gas reserves have shifted the country's views on which transportation fuels may be most suitable. The countries also widely range in population, from China with 1.3 billion people (the world's largest population), to Finland with 5.4 million (The World Bank 2015). Countries with larger populations — like China and the United States — have the potential to make a higher overall global impact when transitioning to new fuels. However, the magnitude of implementing new fuels nationwide may be more challenging than for countries with smaller vehicle fleets. Geographically speaking, the case studies cover three continents — Asia, Europe, and North America.

The makeup of NGV fleets is quite different in the case study countries. With respect to drivetrains, passenger cars and other LDVs account for over half of each country's NGV fleet. For Canada and Finland, LDVs account for more than 80% of the NGV fleet; for Denmark and the United States, LDVs only account for 50% to 60% of the fleet. Natural gas refuelling stations vary in prevalence; Denmark and Israel, for example, have hardly any natural gas refuelling stations to support NGVs, while China houses more than 24% of the world's stations. Also, some countries have extensive natural gas pipeline networks to distribute fuel nationwide, while others rely heavily on roads to transport fuel.

Also, the energy mix used by each country to produce electricity varies greatly, which can significantly impact emissions. Canada, Denmark, and Finland all use sizeable amounts (40%–65%) of renewables in their electricity generation production, while Israel, China, and the United States largely rely on fossil fuels.

From an economic standpoint, the relative retail cost of natural gas for the consumer varies significantly across countries, and even the cost of conventional fuels (i.e., gasoline and diesel) varies by a factor of 2 across some of the case study countries. Consumers in Canada, China, and the United States, for example, benefit from relatively low CNG prices, while consumers in Denmark and Finland pay roughly double. To help increase the use of alternative fuels into their fleets, some countries have established supportive vehicle incentives (e.g., China, Denmark, and the United States), while others (e.g., Israel) prefer to allow the market to play out naturally.

With the framework now established, GHGenius (a spreadsheet-based model parameterized for North America and expanded to model additional fuel pathways and country scenarios) simulations were run to calculate costs and benefits for each fuel pathway of interest. Results were analyzed to determine which natural gas pathways appear most environmentally friendly and economically feasible for the consumer for each case study. The results were also compared to traditional oil-based transportation options (e.g., petroleum-derived gasoline, diesel) to see which natural gas pathways are competitive within existing markets. It should be noted that the results below were based on a specific set of assumptions that are subject to variations; therefore, changes to these assumptions can alter the results, and, consequently, the conclusions.

Table 1 summarizes results across all six countries of the most feasible natural gas pathways in comparison to baseline fuels. Green and yellow cells indicate clear and marginal winners, respectively, relative to the baseline fuel (gasoline for LDVs and diesel for HDVs). It is important to note that, for cost simulations, GHGenius assumes fully realized infrastructure and does not account for the cost to establish it.

Results and Reports/Deliverables

The project was completed in 2015, and a Final Report was published in August 2015, see http://iea-amf.org/content/projects/annexes/48.

Reference

The World Bank, 2015, data retrieved from http://data.worldbank.org/

Table 1 Modeling Results of the Most Feasible Natural Gas Pathways from an Economic and Environmental Perspective[a,b]

Canada	LDV Emissions Winners (based on g CO_2eq/km)	LDV Cost Winners (from a cents/km standpoint)	HDV Emissions Winners (based on g CO_2eq/km)	HDV Cost Winners (from a cents/km standpoint)	China	LDV Emissions Winners (based on g CO_2eq/km)	LDV Cost Winners (from a cents/km standpoint)	HDV Emissions Winners (based on g CO_2eq/km)	HDV Cost Winners (from a cents/km standpoint)
CNG (fossil)					CNG (fossil)				
CNG (AD)					CNG (LFG)				
LNG (fossil)					LNG (fossil)				
LNG (AD)					LNG (LFG)				
LPG					LPG				
FT Diesel					FT Diesel				
Synthetic Gasoline					Synthetic Gasoline				
DME					DME				
Methanol (M85)					Methanol (M85)				
Compressed H_2 – Fuel Cell					Compressed H_2 – Fuel Cell				
Electricity PHEV (40/50 km)					Electricity PHEV (40/50 km)				
Electricity EV					Electricity EV				

Table 1 (Cont.)

Denmark	**LDV Emissions Winners** (based on g CO_2eq/km)	**LDV Cost Winners** (from a cents/km standpoint)	**HDV Emissions Winners** (based on g CO_2eq/km)	**HDV Cost Winners** (from a cents/km standpoint)	Finland	**LDV Emissions Winners** (based on g CO_2eq/km)	**LDV Cost Winners** (from a cents/km standpoint)	**HDV Emissions Winners** (based on g CO_2eq/km)	**HDV Cost Winners** (from a cents/km standpoint)
CNG (fossil)					CNG (fossil)				
CNG (AD/LFG)					CNG (AD)				
LNG (fossil)					LNG (fossil)				
LNG (AD/LFG)					LNG (AD)				
LPG					LPG				
FT Diesel					FT Diesel				
Synthetic Gasoline					Synthetic Gasoline				
DME					DME				
Methanol (M85)					Methanol (M85)				
Compressed H_2 – Fuel Cell					Compressed H_2 – Fuel Cell				
Electricity PHEV (40/50 km)					Electricity PHEV (40/50 km)				
Electricity EV					Electricity EV				

Table 1 (Cont.)

Israel	LDV Emissions Winners (based on g CO_2eq/km)	LDV Cost Winners (from a cents/km standpoint)	HDV Emissions Winners (based on g CO_2eq/km)	HDV Cost Winners (from a cents/km standpoint)
CNG (fossil)	Marginal Winners	Clear Winners	Marginal Winners	Clear Winners
CNG (AD)	Clear Winners	Clear Winners	Clear Winners	Clear Winners
LNG (fossil)	Not Investigated	Not Investigated	Marginal Winners	Clear Winners
LNG (AD)	Not Investigated	Not Investigated	Clear Winners	Clear Winners
LPG	Clear Winners	Marginal Winners	Baseline is Superior	Marginal Winners
FT Diesel	Baseline is Superior	Marginal Winners	Baseline is Superior	Clear Winners
Synthetic Gasoline	Baseline is Superior	Clear Winners	Baseline is Superior	Clear Winners
DME	Not Investigated	Not Investigated	Marginal Winners	Marginal Winners
Methanol (M85)	Marginal Winners	Clear Winners	Baseline is Superior	Clear Winners
Compressed H_2 – Fuel Cell	Clear Winners	Baseline is Superior	Marginal Winners	Marginal Winners
Electricity PHEV (40/50 km)	Clear Winners	Baseline is Superior	Not Investigated	Not Investigated
Electricity EV	Clear Winners	Clear Winners	Not Investigated	Not Investigated

United States	LDV Emissions Winners (based on g CO_2eq/km)	LDV Cost Winners (from a cents/km standpoint)	HDV Emissions Winners (based on g CO_2eq/km)	HDV Cost Winners (from a cents/km standpoint)
CNG (fossil)	Marginal Winners	Baseline is Superior	Marginal Winners	Marginal Winners
CNG (AD)	Clear Winners	Clear Winners	Clear Winners	Clear Winners
LNG (fossil)	Not Investigated	Not Investigated	Marginal Winners	Marginal Winners
LNG (AD)	Not Investigated	Not Investigated	Clear Winners	Clear Winners
LPG	Marginal Winners	Baseline is Superior	Marginal Winners	Baseline is Superior
FT Diesel	Marginal Winners	Clear Winners	Baseline is Superior	Clear Winners
Synthetic Gasoline	Baseline is Superior	Clear Winners	Baseline is Superior	Clear Winners
DME	Not Investigated	Not Investigated	Marginal Winners	Baseline is Superior
Methanol (M85)	Marginal Winners	Marginal Winners	Baseline is Superior	Baseline is Superior
Compressed H_2 – Fuel Cell	Marginal Winners	Baseline is Superior	Marginal Winners	Baseline is Superior
Electricity PHEV (40/50 km)	Clear Winners	Baseline is Superior	Not Investigated	Not Investigated
Electricity EV	Clear Winners	Marginal Winners	Not Investigated	Not Investigated

Clear Winners — Marginal Winners — Baseline is Superior — Not Investigated

[a] Green and yellow cells indicate clear and marginal winners, respectively, relative to the baseline fuel (gasoline for LDVs and diesel for HDVs).

[b] Abbreviations: CNG = compressed natural gas; CO_2e = carbon dioxide equivalent; DME = dimethyl ether; EV = electric vehicle, FT = Fischer-Tropsch; g = gram; H_2 = hydrogen; ICE = internal combustion engine; km = kilometer; LNG = liquefied natural gas; PHEV = plug-in hybrid electric vehicle.

Annex 49: COMVEC – Fuel and Technology Alternatives for Commercial Vehicles

Project Duration	July 2013–December 2015
Participants	
Task Sharing	Canada, Chile, China, Denmark, Finland, Japan, Korea, Sweden, Thailand
Cost Sharing	None
Total Budget	~€900,000 ($1,245,510 US)
Operating Agent	Nils-Olof Nylund VTT Technical Research Centre of Finland Email: nils-olof.nylund@vtt.fi

Background

Major de-carbonizing actions need to take place in the transport sector. There is no single solution that could solve the de-carbonization challenge, however. To get the best possible results, all transport subsectors should be taken into consideration. Due to scarce resources of advanced and carbon-neutral fuels, information on the usability of alternative fuels and technologies and on their impacts on energy consumption and emissions in a given transport task must be obtained. In addition, an overall assessment of these alternatives and their full fuel-cycle performance is needed. This would provide insight into where certain technologies could be best utilized, thus leading to the "optimal allocation" of various alternatives.

Previous Annexes have assessed the performance of buses (Annex 37) and passenger cars (Annex 43). This Annex, Annex 49, focuses on commercial vehicles, vans, and trucks. Annex 38 covered biodiesel options, and Annex 39 covered heavy-duty methane engines.

With regard to tailpipe emissions, one could say that the game is changing. Euro VI/US 2010 emission regulations have decreased emission levels close to zero. This means that differences arising from the fuel itself are diminishing, and that overall energy consumption and greenhouse gas emissions are becoming increasingly important issues.

Purpose and Objectives

This project aims to deliver comparable data on the tailpipe emissions and energy consumption of commercial light- and heavy-duty vehicles. This study also provides data on well-to-wheel (WTW) energy consumption and emissions, to supplement the information already generated in Annexes 37, 38, 39, and 43.

In combination with the information generated in previous Annexes, the goal of this study is to gain further knowledge of the optimum allocation of alternative fuels and technologies for road transport. (In other words, this Annex exists because the optimal solutions for passenger cars differ significantly from those for heavy-duty long haul tractor and trailer combinations.)

Several governments are developing road maps for the introduction of alternative and carbon-neutral fuels. For example, Sweden is aiming at a vehicle fleet independent of fossil fuels, and Finland has set a very ambitious biofuels target of 20% by 2020. This project will support the development of strategies for alternative fuels and energy.

Activities

The modus operandi of the project is equivalent to the one used in Annex 43. Several laboratories add to a common pool of test data by running tests according to jointly defined test programs and test protocols. The development of common test procedures for use by the research partners is thus a key element in the project. At least one common test cycle should be used for all vehicle categories. The project consists of eight work packages (WPs), as follows:

WP 0: Collection and Consolidation of Existing Data

WP 1: Development of Common Test Procedures and Protocols

WP 2: Vehicle Testing

- Three different vehicle categories (light-duty commercial vehicles (vans), medium heavy-duty trucks, and long-haul semi-trailer tractors) that include several alternative fuel and vehicle technologies.
- Parameters to be varied: fuel composition, driving cycle, payload (0, 50, and 100%), environmental conditions (ambient temperature).

WP 3: Aggregation of Well-to-Tank Information

- Based on test fuel matrix and information gathered in Annexes 37 and 43.

WP 4: Regional information on the Energy Options in the Transport Sector

- Information from project participants on regional challenges and opportunities that drive the development of energy options in the transport sector and affect the available fuel selection. This regional information will also clarify what the potentials of alternative technologies are in different locations.

WP 5: Full Fuel-cycle Evaluation (integration of WP 2 and WP 3)

- WTW fuel consumption, energy efficiency, and emissions.

WP 6: Life-cycle Cost Analysis

- Determine how alternative fuels and vehicle technologies, together with the operation of the vehicles, influence life-cycle costs. The objective is to find a cost-effective way to reduce emissions and energy consumption for a given commercial vehicle application.

WP 7: Coordination of the Project, Synthesis, and Reporting

- Administrative coordination, communication with the IEA AMF TCP Executive Committee (ExCo), synthesis of the data, compilation of the Final Report, and dissemination of results.

WP 1 was finalized in 2013. By the end of 2014, a significant part of the actual vehicle testing had been carried out. At the end of 2015, a first draft report was available. Reporting is expected to be completed in February or March 2016, and this Annex will be closed at the May 2016 IEA AMF ExCo meeting.

Participants

Policy-Related Participants

- Danish Energy Agency
- Finnish Transport Agency
- Natural Resources Canada
- Organization for the Promotion of Low Emission Vehicles (LEVO) (Japan)

- Swedish Road Administration Agency
- Tekes – The Finnish Funding Agency for Innovation

Industry Participants
- Gasum (Finland)
- Neste Oil (Finland)
- PTT Public Company Limited (Thailand)
- St1 (Finland)
- UPM (Finland)

Academia and Test Laboratory Participants
- AVL MTC Motortestcenter AB (Sweden)
- Centro Mario Molina Chile
- China Automotive Technology and Research Centre (CATARC)
- Environment and Climate Change (Canada)
- Danish Technological Institute
- Korean Automotive Technology Institute (KATECH)
- National Traffic Safety and Environment Laboratory (NTSEL) (Japan)
- Vehicle Control and Certification Center (3CV) (Chile)
- VTT Technical Research Centre of Finland

Results/Key Messages

WP 1, the development of common test procedures, was completed during year one (2013), as planned. WP 1 defined the test methods and minimum requirements for emissions to be measured. The work of WP 1 also covered the minimum requirements for one baseline test fuel and mandatory requirements for reporting the test results. Figure 1 shows the World Harmonized Vehicle Cycle (WHVC), which was chosen to be used as the common test cycle in the vehicle testing phase (WP 2).

Most of the actual vehicle testing was carried out during year two (2014).

All in all, the partners made data available for 45 different vehicles and three different testbed engines. In addition, some partners tested various drop-in type fuel alternatives.

Figures 2 through 5 show examples of collated results. The results are presented as a function of test weight (recommended weight vehicles at 50% load).

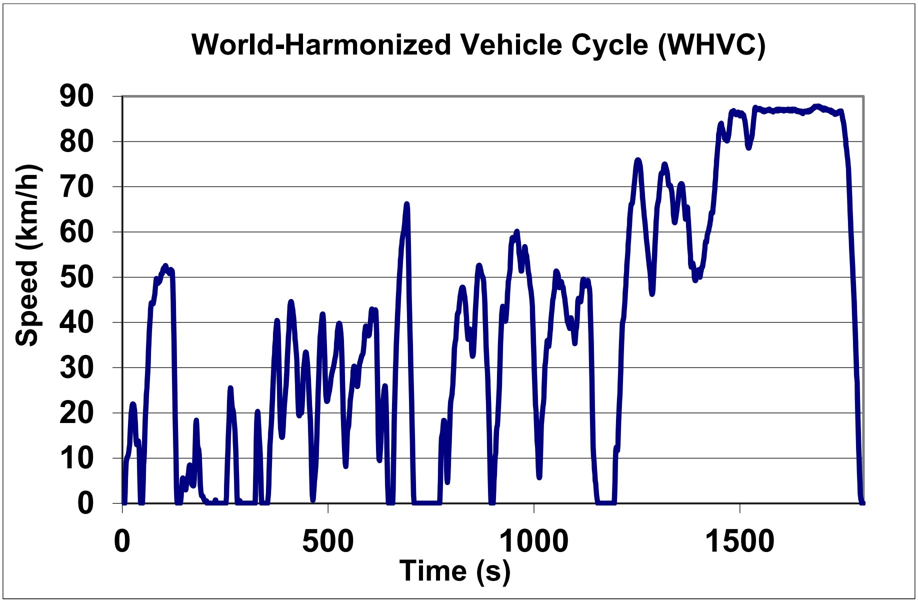


Fig. 1 World Harmonized Vehicle Cycle

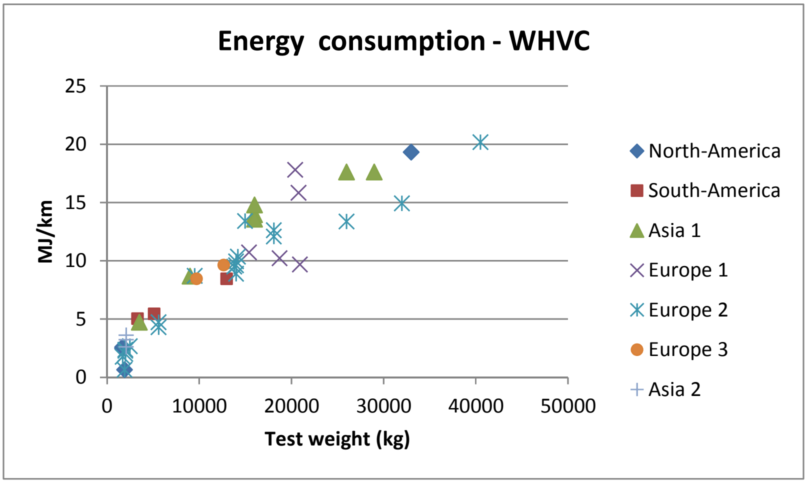


Fig. 2 Energy Consumption by Laboratory and Country

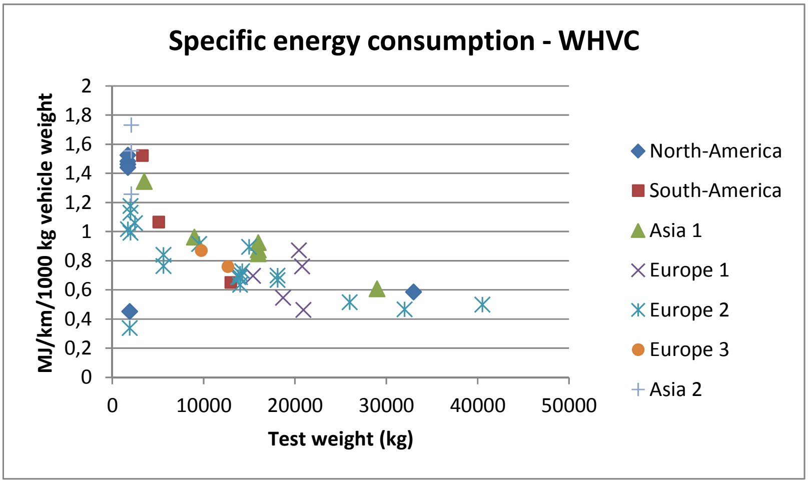


Fig. 3 Specific Energy Consumption by Laboratory and Country

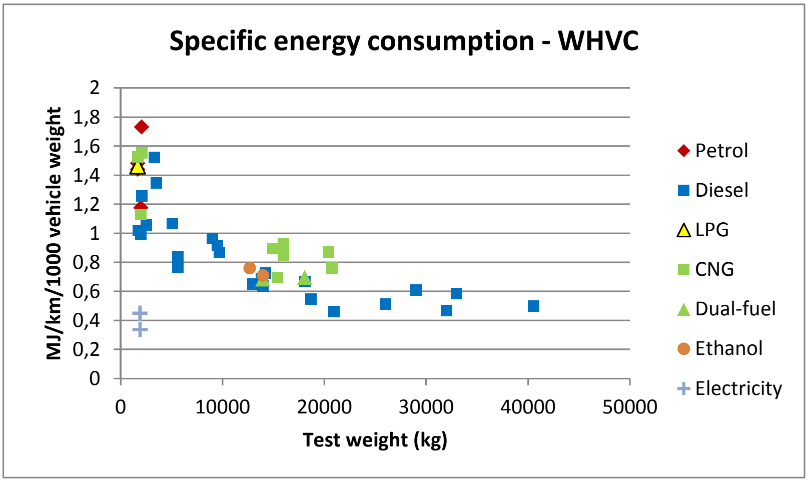


Fig. 4 Specific Energy Consumption by Fuel

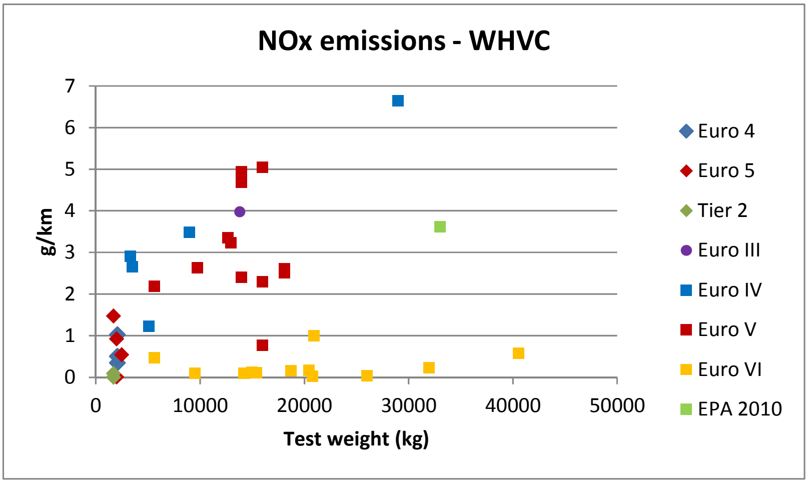


Fig. 5 Nitrogen Oxides (NO_x) Emissions by Emission Class

Figure 2 shows that energy consumption (in absolute terms, megajoules per kilometer [MJ/km]) is first and foremost determined by vehicle weight. Specific energy consumption (energy consumption relative to vehicle weight, Figure 3), on the other hand, is reduced with increasing vehicle weight.

Relative load has a huge impact on energy consumption and carbon dioxide (CO_2) emissions per ton-kilometer (infinitely high with zero load). With full load energy consumption, a truck and trailer combination approaches 0.5 MJ/ton-kilometer and CO_2 emission of 40 grams (g)/ton-kilometer. For a diesel van at 50% load, the values are 4 MJ/ton-kilometer and 300 g CO_2/ton-kilometer.

For energy consumption, two technologies differ from average values — electric vehicles are significantly lower than average, and gas-fuelled vehicles are somewhat higher than average (Figure 4).

Figure 5 clearly demonstrates that in the case of NO_x emissions, the decisive factor is emission certification class, not vehicle weight. Even the heaviest vehicles can deliver very low emissions.

Publications

The Final Report is expected to be completed in March 2016.

Success Stories

The project has attracted several IEA AMF member countries. Chile took part in the work, even before joining AMF officially at the end of 2015. What is unique about this project is that vehicle laboratories on four continents — Asia, Europe, North America, and South America — are jointly creating a database on commercial vehicle performance. Using a common methodology, the project is generating new first-line AMF data to support decision making and policy.

Annex 50: Fuel and Technology Alternatives in Non-Road Engines

Project Duration	May 2014–June 2017
Participants **Task Sharing** **Cost Sharing**	 Canada, Finland, Germany, Sweden, Switzerland None
Total Budget	More than €200,000 ($312,145 US)
Operating Agent	Magnus Lindgren Swedish Transport Administration Email: Magnus.Lindgren@trafikverket.se

Background

Non-road mobile machinery is used to produce food, feed, and industrial material. Based on several different studies (mostly U.S. and European), this sector is often responsible for between 10% and 25% of diesel consumption and contributes significantly to overall emissions. However, discussions on alternative fuels and greenhouse gas emissions, both general and within the AMF TCP, have focused on on-road vehicles.

Purpose and Objectives

The purpose and first objective of Annex 50 is to evaluate the fuel efficiencies and emissions performance associated with different engine technologies, fuel specifications, and machinery applications, including a consideration of engine load cycles. A second objective is to develop emission factors for inventories of non-road mobile machinery in the participating countries and to investigate the potential that technology developed in the on-road sector would be useful for non-road applications (hybridization, exhaust gas after-treater, and friction reduction). A third objective is to assess the possible effects of retrofitting the legacy fleet on fuel efficiency and emissions.

Activities

Literature Review

- Compare non-road and on-road emissions legislation (Work Package or WP 1).

- Determine the availability and applicability of alternative technologies (e.g., alternative fuels, hybridization, electrification, and fuel cell technology) (WP 2).
- Obtain national and regional information on non-road mobile machinery policy options (WP 4).

Method Development

- Develop common test procedures and protocols (WP 6).
- Simulate components and/or machinery in order to address fuel consumption (WP 8).

Collation of Existing Data

- Collect existing data (on the number of machines, working hours, engine power, etc.) for fuel consumption and emission inventories (WP 3).

Experimental Work To Generate New Data

- Test machinery (e.g., conduct portable emissions measurement system [PEMS] testing of complete machinery, chassis dynamometer testing of road-vehicle-like machinery, and engine dynamometer testing of standalone engines) (WP 7).

Data Assessment/Evaluation

- Included in the earlier activities.

Information Dissemination

- Write and distribute reports, including both a Final Report and a two-page summary (WP 9).

Participants

Policy-Related Participants

- Agency for Renewable Resources (FNR) (Germany)
- Natural Resources Canada
- Swedish Transport Administration
- VTT Technical Research Centre of Finland

Industry Participants

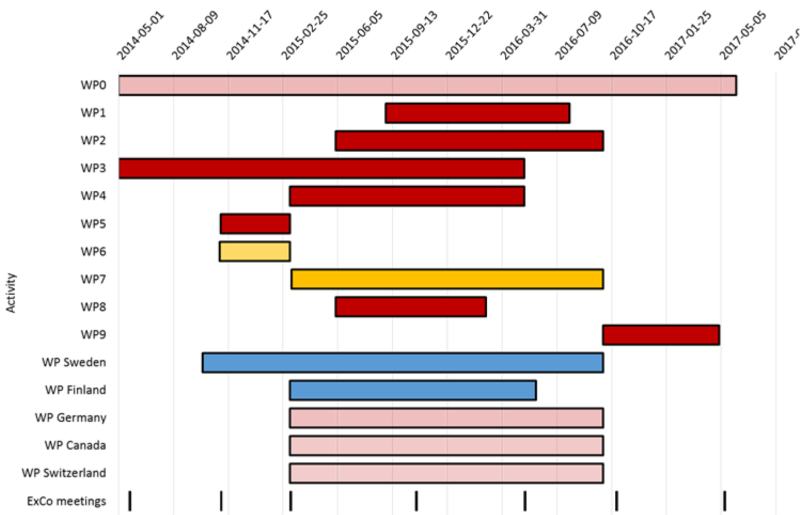
- Agco (Finland)
- John Deere GmbH & Co. KG (Germany)
- Neste Oil (Finland)
- Proventia Emission Control OY (Finland)

- Skanska (Sweden)
- Volvo Construction Equipment (Sweden)

Academia and Test Laboratories

- AVL MTC Motortestcenter AB (Sweden)
- Environment and Climate Change Canada
- VTT Technical Research Centre of Finland

Time Schedule



Results/Key Messages

The results and deliverables of Annex 50 will be a written report presenting data on fuel consumption and emissions from various types of non-road mobile machinery. It will cover:

- Emissions stages,
- Technology and alternative fuels, and
- Machinery operation.

For most road vehicles, such as passenger cars, busses, and heavy duty trucks, the normal usage/driving pattern can be represented by a fairly limited number of cycles. Non-road mobile machinery consists of a much broader group of applications with a highly variable usage pattern; thus the usage of non-road mobile machinery cannot easily be described by a few general test cycles. Studies of wheel loaders conducted within Annex 50 show a significant reduction in emissions of air pollution with increasing emission standards. Tests on a wheel loader with a pre-Stage V engine have shown that emissions are kept at an acceptable low level at all tested usage patterns — from low loads to highly transient operation. One of the new requirements for Stage V emission regulations is in-use testing, which can be compared with real driving emissions currently under discussion for passenger cars.

Tests with hydrotreated vegetable oil (HVO) have shown good drivability and reduced air pollutant emissions compared with conventional diesel (fulfilling EN 590). Emissions of particle mass were reduced by up to 10% on a Stage IV engine without a diesel particulate filter. On the same engine, emission of nitrogen oxides (NO_x) was reduced by up to 15% with HVO during normal operation with a warm engine.

Publications

The following national project reports have been presented:

- TEST REPORT OMT 4005, On-board Emission Measurement on Wheel Loaders with Different Emission Standards, Sweden, AVL MTC
- TEST REPORT OMT 5005, On-board Emission Measurement on Wheel Loaders in Different Test Cycles, Sweden, AVL MTC

Success Stories

Annex 50 is ongoing but has delivered input to the European Commission for the development of Stage V emission standards. For the first time in Europe, Stage V regulations include a proposal for test procedures for alternative fuels and in-service testing of engines.

Annex 51: Methane Emission Control

Project Duration	May 2013–December 2018
Participants	
Task Sharing	Denmark, Finland, Germany, Japan (LEVO), Korea, Sweden, Switzerland
Cost Sharing	No cost sharing
Total Budget	To be determined
Operating Agent	Jesper Schramm DTU – Technical University of Denmark Email: js@mek.dtu.dk

Background

The use of methane (natural gas, biogas) for transport will increase. Although dual diesel fuel (DDF) technology could bring the efficiency of gas engines close to the efficiency of diesel engines, Annex 39 clearly demonstrated that methane slip is still a serious problem for current DDF engines. Alternatively, advanced spark ignition (SI) technologies (e.g., variable valve trains, cylinder deactivation, and high-level exhaust gas recirculation) could be applied to increase engine efficiency. However, there would still be a need for methane catalysts, but the performance and durability of current methane catalysts are not satisfactory.

Annex 51 is based on the experience of Annex 39, with a goal of improving engine-out methane emissions, methane catalyst efficiency, and methane emissions from other parts of the vehicle. The Annex will also continue to follow up on any information about methane heavy-duty vehicle (HDV) fleets, thus adding to the data already available.

Purpose and Objectives

Combustion engines for vehicles can be replaced by or converted to liquefied natural gas (LNG) operation. This has benefits in terms of emissions of carbon dioxide (CO_2), nitrogen oxides (NO_x), and particulates. Reductions in CO_2 occur partly because the ratio between carbon and hydrogen is less for natural gas than for liquid hydrocarbons (diesel, gasoline, etc.), and partly because the LNG engines can be more efficient than the traditional ones, depending on the combustion principle chosen. With regard to greenhouse gas (GHG) effects, it is a disadvantage that LNG engines emit significantly larger quantities of unburned methane than do traditional engines. Because methane is a 20-times more powerful GHG than CO_2, the overall result could easily be an increase in GHG emissions from vehicles if their engines were converted to run on LNG.

Researchers have a lot of experience in studying unburned hydrocarbons in automobile engines. This experience has motivated them to develop engines that emit very low levels of hydrocarbons. Methane, however, is a particularly stable hydrocarbon and is not converted as efficiently as are the other hydrocarbons in combustion engines. At the higher temperatures that occur during the main combustion, the methane is burned as completely as the other hydrocarbons. In colder areas near the walls and in crevices, however, some unburned hydrocarbons escape the main combustion. These hydrocarbons are normally post-oxidized in the hot combustion gas, but methane molecules are too stable to be converted at these lower temperatures. This stability also causes problems with regard to converting methane in after-treatment systems, like three-way catalytic converters. The onboard storage system for methane (either compressed or liquefied) can also be a source of methane emissions from a vehicle.

The purpose of this project is to identify and understand what causes high emissions of unburned methane or what causes emissions of methane from vehicle parts other than the engine and to then determine the best ways to reduce these emissions.

Activities

Work Package (WP) 0: Project Management

The project management will be done by DTU – the Technical University of Denmark.

WP 1: Application of Natural Gas in Combustion Engines

An overview of the application of natural gas in combustion engines for transportation purposes will be given. The WP will focus on road and marine transportation, since these are the transport sectors in which the idea of implementing methane in the form of natural gas or biogas dominates.

WP 2: Fundamental Investigations of Methane Combustion

The project will be carried out partly as a theoretical study of the fundamental physical and chemical processes that occur in a natural gas engine. Mathematical models of the processes will be formulated to describe the phenomena that occur during the conversion of the fuel in the engine. The models will describe the influence of the combustion principle (SI or dual-fuel), the combustion chamber geometry, and the application of mixed fuels. For example, we know that mixtures of natural gas and a smaller amount of hydrogen make it possible to reduce unburned methane emissions because the hydrogen promotes the combustion of methane. Dimethyl ether (DME) is another fuel option to promote methane conversion. The models will be verified in experiments in which the relevant engine parameters will be varied**.**

The unburned methane from engines can be reduced by after-treatment in a catalytic converter in the exhaust pipe. However, it is still difficult to convert the methane at the temperatures that are available. Studies of the most suitable catalyst materials and systems will be carried out, as will studies of the conversion of methane at different concentrations, temperatures, and pressures.

WP 3: Methane Emissions from Parts of the Vehicle Other Than the Engine and Exhaust System

Compared with liquid fuels like diesel, gaseous fuels are more likely to escape from the vehicle. During refuelling, the connection and disconnection of the dispensing nozzle could result in small amounts of methane escaping to the ambient air. When both liquefied and compressed methane fuel are being stored, they could be vented out to the atmosphere to avoid overpressure. High-pressure fuel lines and joints could also be a source of leakage that need to be investigated. The purpose of this WP is to study the possibility of methane emissions from parts of the vehicle other than the engine or exhaust system. If possible, the emissions will be quantified.

WP 4: Natural Gas Application in Light-Duty Vehicles

An overview of the knowledge about unburned methane from today's light-duty vehicle (LDV) engines will be given. The study will reveal the available data that can be used for verifying the models that are developed in WP 2. Furthermore, the study will focus on both the present technologies that are available and any policies or future plans for using methane-containing fuels in these vehicles.

WP 5: Natural Gas Application in Heavy-Duty Vehicles

An overview of the knowledge about unburned methane from today's HDV engines will be given. The study will reveal the available data that can be used for verifying the models that are developed in WP 2. Furthermore, the study will focus on both the present technologies that are available and any policies or future plans for using methane-containing fuels in these vehicles.

WP 6: Natural Gas Application in Marine Engines

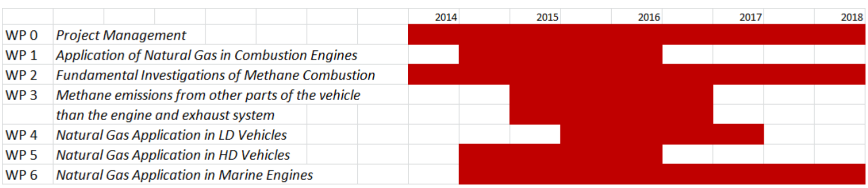
An overview of the knowledge about unburned methane from today's marine engines will be given. The study will reveal the available data that can be used for verifying the models that are developed in WP 2. Furthermore, the study will focus on both the present technologies that are available and any policies or future plans for using methane-containing fuels in the marine sector.

Results and Reports/Deliverables

The results will be published in a common report that will be delivered at the end of the project period. In addition, the results will be published at international conferences and in international journals.

Time Schedule

The project runs from 2014 through 2018. The following time schedule is foreseen:



Annex 52: Fuels for Efficiency

Project Duration	April 2015–March 2017
Participants **Task Sharing** **Cost Sharing**	 Denmark, Finland, Germany, Israel, Thailand IEA Bioenergy Task 39 No cost sharing
Total Budget	€450,000
Operating Agent	Dr. Somnuek Jaroonjitsathian PTT Public Company Limited Email: somnuek.j@pttplc.com

Background

Annex 52, Fuels for Efficiency, has been initiated in compliance with the global requirement of improving fuel efficiency for road transport fuel application. In general, automotive original equipment manufacturers (OEMs) try to improve their engines' efficiency while controlling the exhaust emission with regard to the country's requirement. The implication for advanced motor fuels, or the method for optimizing the fuels in order to maximize engine efficiency, has rarely been discussed worldwide. All members expect that the results will enable a new approach to automotive fuel optimization.

Purpose and Objectives

Annex 52 intends to demonstrate how to optimize fuel with specific engines in terms of thermal efficiency gain without any constraint on the format of fuel utilization, engine technology, or chemical additives. All task-sharing members will conduct the experiment based upon their experience and interests. Thus, the format of experiments is fully flexible but needs to be focused on scientific and statistical method.

Activities

Work Package (WP) 0: Project Management

- Project management will be done by the Operating Agent.

WP 1: Literature Surveys — Recent Research in the Area of Fuels for Efficiency

- This activity will be completed by the end of May 2016.

WP 2: Information Exchange with IEA Bioenergy Task 39 (Survey on Advanced Fuels for Advanced Engines) and Others (IEA-AMT)

- IEA Bioenergy Task 39 has shared the work scope of "A Review of Advanced Fuels for Advanced Engines" with Annex 52, which will be very helpful and can be matched with the concept "Fuels for Efficiency."
- The IEA-AMT indicated its intention to share the advance materials for use with the Waste Heat Recovery concept. An Information exchange is in progress.

WP 3: Performance Evaluation of Chemical Friction Modifiers for Diesel and Gasoline Fuels (Denmark)

- The engine experiments have been completed. For gasoline engines, it seems that friction modifiers help improve fuel economy by a few percentages in the best case. However, for diesel engines, there are no frictions modifiers available, so the experiment was conducted with cetane improvers. The result is negative regarding fuel-saving effects.

WP 4: Waste Heat Recovery – Thermodynamic Potential of Fuels Reforming (Technion – Israel)

- First, we are applying direct injection of the reformate gas, together with a high-pressure steam-reforming process. Second, we aim to develop a reformer-internal combustion engine (ICE) set as a part of a series hybrid propulsion system, thus alleviating the acute problems of the reformer's startup and transient behavior. The engine prototype operating in accordance with the above principles and fed by the separately prepared methanol reforming products was successfully developed and tested in our laboratory.
- The obtained experimental results show a possibility of engine efficiency improvement of up to 70% (higher improvement at lower loads) and dramatic reduction of pollutant emissions, when compared with gasoline. Harmful emissions of the gaseous pollutants carbon monoxide (CO) and nitrogen oxides (NO_x) are reduced by 96% and 85%, respectively. Emissions of ultrafine particles are decreased by more than 99%.
- We are developing a first laboratory model of a high-pressure methanol reformer and are starting a study of the "reformer-direct injection ICE" system.

WP 5: Performance Assessment of Various Paraffinic Diesel Fuels (Finland)

- The work of collating existing Finnish data on renewable paraffinic diesel, the fully controllable four-cylinder common-rail engine experiment with various paraffinic diesels, will be done to explore the potential of performance enhancement through optimized engine calibration for paraffinic fuels, within 2016.

WP 6: Opportunity for Enhancing Fuels Efficiency by Ethanol Blended Gasoline Fuels (Thailand)

- The test bench has been installed and prepared for testing. The first reference test will be done in May 2016.

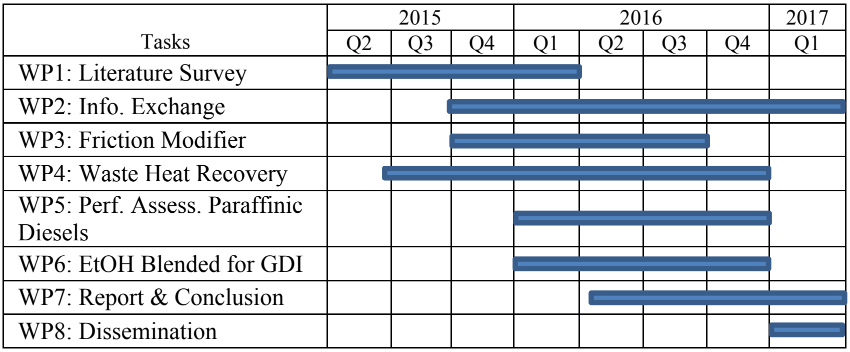
WP 7: Data Assessment and Final Report

WP 8: Report Dissemination

Participants

Organization	Country	Contribution
Danish Technological Institute	Denmark	Task Sharing: Performance evaluation of chemical friction modifiers for diesel and gasoline fuels
IEA Bioenergy Task 39	Germany	Information Sharing: Survey of advanced fuels for advanced engines
The Technical Research Centre of Finland (VTT)	Finland	Task Sharing: Performance assessment of various paraffinic diesel fuels
Israel Institute of Technology (Technion) Supported by Ministry of Energy and Water Resources	Israel	Task Sharing: Waste heat recovery – thermodynamic potential of fuels reforming
PTT Research and Technology Institute	Thailand	Task Sharing: Opportunity for enhancing fuel efficiency by ethanol blended gasoline fuels

Time Schedule



Results/Key Messages

WP 3: Performance Evaluation of Chemical Friction Modifiers for Diesel and Gasoline Fuels

The test regarding gasoline fuel was conducted with a one-cylinder 125-cm^3 fuel-injected engine found in motorcycles, such as the Yamaha WR125 (Figure 1). Diesel fuel was tested on a 4-cylinder 9HX passenger car engine produced by PSA.

Tests were conducted on two dynamometers suitable for the engine types. Fuel inputs were measured by an electronic balance and a coriolis fuel flow meter, both of which are very accurate.

All tests were conducted as steady-state tests. The test points for each engine, along with some specifications, are shown in Figure 2.

To obtain reliable results, each load point test was repeated 9 to 15 times, depending on the observed variance. The final uncertainty shown in the graphs was calculated from the observed variance and number of tests according to the International Organization for Standardization (ISO) Joint Committee for Guides in Metrology (JCGM) 100 series.

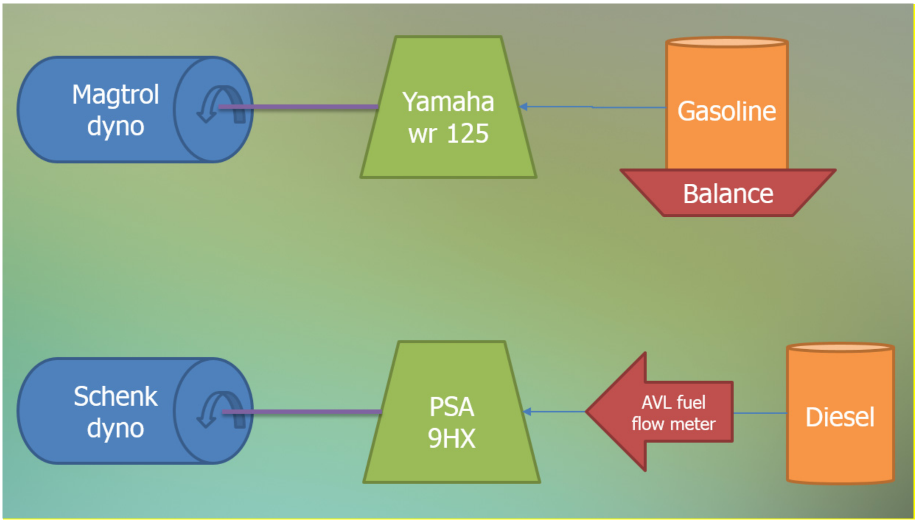


Fig. 1 Performance Evaluation of Chemical Friction Modifiers for Diesel and Gasoline Fuels

Results showed that 330-ppm friction modifier no. 9525A lowered the specific gasoline consumption by 2.7% in the best case. However, the benefit was not clear in all test points. One of the seven tests points showed a negative effect. The average improvement was only 0.9%.

Diesel results showed that 125-ppm wt./wt. of cetane improver LZ 8090 did not improve the specific fuel consumption significantly at load. Idle consumption, however, was apparently improved by 5 to 10%.

Overall, the benefits in terms of fuel consumption were quite small and not entirely consistent (Figures 3 and 4). The test results do not justify a recommendation for widespread use.

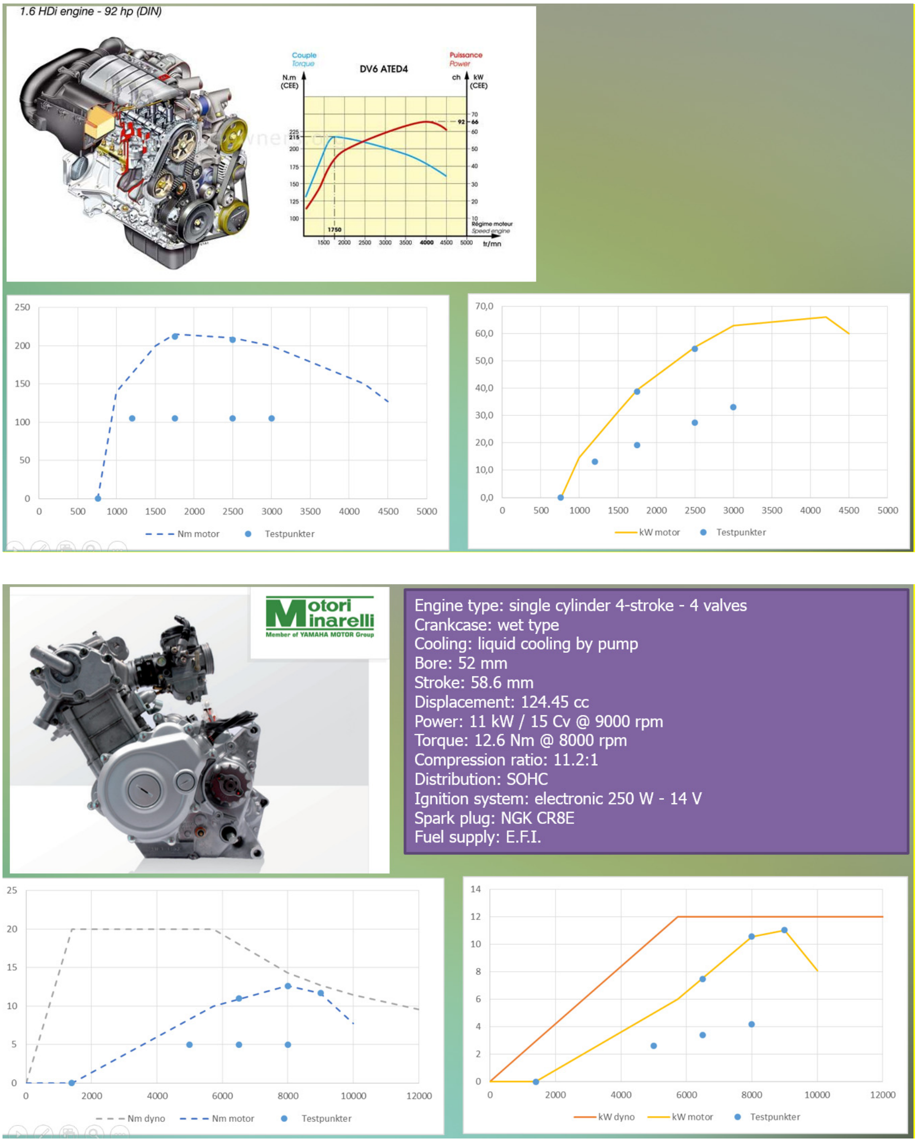


Fig. 2 Test Points and Specifications for 1.6 HDI Engine and Single-Cylinder Engine

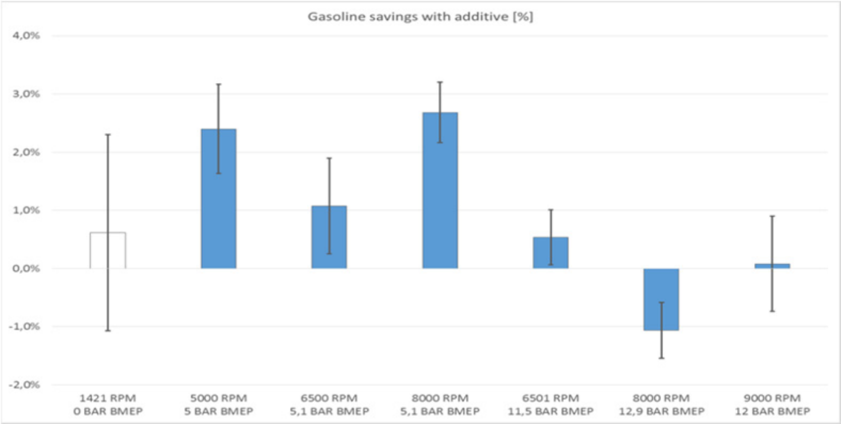


Fig. 3 Effect of Chemical Friction Modifiers on Gasoline-Specific Fuel Consumption

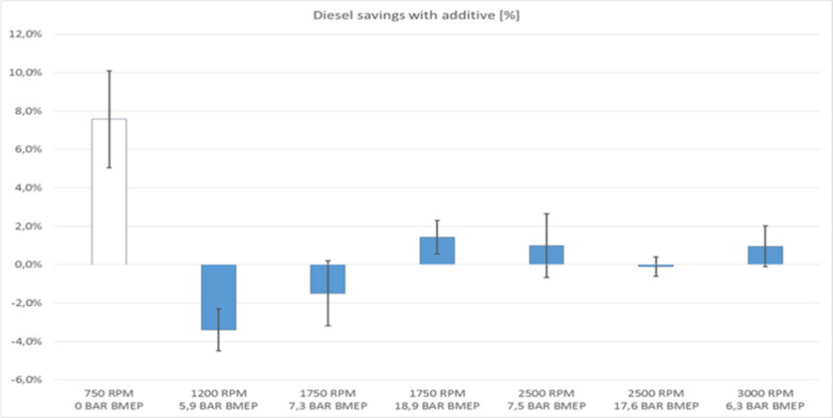


Fig. 4 Effect of Chemical Friction Modifiers on Diesel-Specific Fuel Consumption

Publications

The Final Report is expected to be published by March 2017; several technical publications will result from Annex 52.

Success Stories

WP 4: Waste Heat Recovery — Thermodynamic Potential of Fuels Reforming

WP4: The experimental results show a possibility of engine efficiency improvement up to 70% (higher improvement at lower loads) and dramatic reduction of pollutant emissions when compared with gasoline. Harmful emissions of the gaseous pollutants CO and NO_x are reduced by 96% and 85%, respectively. Emissions of ultrafine particles are decreased by more than 99%.

Future Plans

The collaborative framework among IEA Bioenergy Task 39, IEA/AMF Annex 52, and IEA/AMT will be established to strengthen the knowledge among the experts.

Germany’s contribution has just been proposed in the ExCo 51 meeting as an alternative fuel for the Range Extender. It will be considered and then finalized by ExCo 52.

IEA Bioenergy Task 39 currently shares the progress of its contribution, “Survey on Advanced Fuels for Advanced Engines,” which comprises all aspects of biofuels application, which is really helpful with the experts in this area.

The connection between IEA/AMT and Technion will be established by transferring the know-how on advance materials for waste heat recovery insulation.

Annex 53: Sustainable Bus Systems

Project Duration	November 15–December 2017
Participants **Task Sharing** **Cost Sharing**	 Canada, Chile, Finland, Israel, Sweden, United States To be determined
Total Budget	To be determined
Operating Agent	Alfonso Cádiz Technical Secretary of 3CV Ministry of Transport and Telecommunications of Chile Email: acadiz@mtt.gob.cl

Background

Some of the biggest cities in Latin American are facing the renewal of their bus fleets. For example, the City of Santiago, Chile, will initiate the replacement of part of its bus fleet, and the City of Sao Paulo, Brazil, will replace around 15,000 older buses. These processes are key to introducing energy-efficient, low-polluting, and soot-free buses into the world market.

In this context, advanced technologies require an appropriate characterization of their advantages in terms of emissions, operational costs, and fuel economy in comparison with conventional diesel buses that remain the backbone of public transportation systems. However, there is considerable variation in local operating conditions, emission regulations, fuel quality, and type of service provided by buses. Verified performance data are needed regarding new technologies and fuels entering the market. There is also a clear need to develop test and assessment methodologies that reflect local needs and conditions.

Purpose and Objectives

The main objective of Annex 53 is to develop a methodology for establishing requirements for clean and energy-efficient buses that can be used in the tendering process for public transportation operators in developing regions. Such a methodology would include guidance and recommendations on control and follow-up of the buses in operation. A methodology to assess emission stability over time also should be considered. Only original equipment manufacturer (OEM) products will be considered; no retrofit solutions will be addressed.

Activities *(as listed in http://www.iea-amf.org/content/projects/annexes/53)*

Work Package (WP) 0: Collection of Data from Existing Buses

WP 1: Evaluation of Operational Conditions in Cities in Developing Countries. (The city of Santiago de Chile is the first target as a pilot for other cities.)

WP 2: Analysis of Existing Test Cycles versus Local Operation Conditions in Developing Cities

WP 3: Development of a Common Test Methodology and Protocols for Reporting of Data

WP 4: Selection of bus technologies (Euro III and later) and fuels to be considered for the tests

WP 5: Execution of Tests According to the Developed Methodology on Vehicles and Fuels as Selected

WP 6: Analysis of Data from Both the Own Measurements and the Collated Existing Data

WP 7: Development of Guidelines for Busses in Sustainable Bus Transport Systems, including Certification, Tendering and Periodic Inspection

WP 8: Work Exchange of Researchers between Europe and South-America

WP 9: Co-Ordination of the Project, Synthesis and Reporting

Participants

- Center for Vehicle Control and Certification (3CV) Laboratory, Ministry of Transport and Telecommunications (Chile)
- Centro Mario Molina (Chile)
- Environment and Climate Change Canada (Canada)
- Ministry of Energy (Chile)
- Swedish Transport Administration (Trafikverket) (Sweden)
- VTT Technical Research Centre of Finland (VTT) (Finland)

Time Schedule

	2017		2017	
Activity	**S1**	**S2**	**S3**	**S4**
Work Package (WP) 0: Collection of Data from Existing Buses				
WP 1: Evaluation of Operational Conditions in Cities in Developing Countries. (The city of Santiago de Chile is the first target as a pilot for other cities.)				
WP 2: Analysis of Existing Test Cycles versus Local Operation Conditions in Developing Cities				
WP 3: Development of a Common Test Methodology and Protocols for Reporting of Data				
WP 4: Selection of bus technologies (Euro III and later) and fuels to be considered for the tests				
WP 5: Execution of Tests According to the Developed Methodology on Vehicles and Fuels as Selected				
WP 6: Analysis of Data from Both the Own Measurements and the Collated Existing Data				
WP 7: Development of Guidelines for Busses in Sustainable Bus Transport Systems, including Certification, Tendering and Periodic Inspection				
WP 8: Work Exchange of Researchers between Europe and South-America				
WP 9: Co-Ordination of the Project, Synthesis and Reporting				

Results/Key Messages

Annex 53 is starting with activities WP 0 and WP 1. The public transportation system of Santiago, Chile, is the first target. A comprehensive analysis of bus fleets and routes was conducted by the Ministry of Transport in cooperation with the Ministry of Energy and Centro Mario Molina, to get a preliminary sample of 19 routes that total over 800 km. The routes were selected based on the following criteria:

- Average speed
- Length
- Rate of occupancy
- Number of bus stops

In cooperation with VTT, 5 of the 19 routes were selected for vehicle instrumentation. Data on time, speed, position, altitude, rate of occupancy, and bus condition will be collected for every selected route during April 2017.

These data will be used for activity WP 2, in which the representativeness of Santiago for existing international bus driving cycles will be discussed.

A second set of data will be collected for characterizing the different kinds of bus route infrastructure available in the South American region (bus rapid transit [BRT] corridors, exclusive lines for buses without physical segregation, and streets with mixed traffic with private cars). This second set of data will include other cities, like Lima, Peru.

Annex 54: GDI Engines and Alcohol Fuels

Project Duration	April 2016–April 2019
Participants **Task Sharing** **Cost Sharing**	Canada, Chile, Israel, United States
Total Budget	Task Sharing
Operating Agent	Debbie Rosenblatt Emissions Research and Measurement Section Environment and Climate Change Canada Email: Debbie.Rosenblatt@Canada.ca

Background

The availability of gasoline direct injection (GDI) technologies in light-duty vehicle markets is increasing, and GDI vehicles are being adopted by consumers as they provide fuel economy benefits. Nevertheless, these technologies are facing questions in terms of their impacts on air quality and human health.

It has been shown that under certain conditions, GDI may increase particle emissions in comparison with port fuel injection (PFI) engine technologies, up to levels that are over the emissions from diesel vehicles equipped with diesel particle filters (DPFs). Both gasoline particulate filters (GPFs) and alcohol fuel blends, mainly E85 (85% ethanol in gasoline fuel), have shown the potential to reduce particulate matter (PM) emissions from GDI vehicles. Along with tailpipe emissions measurements, the chemical composition of vehicular secondary organic aerosol (SOA), that is, aged emissions formed by the reaction of primary vehicular gases with ozone and other radicals under the influence of sunlight in the atmosphere, will be studied. In the real world, humans are exposed to aged pollutants on a regular basis, and information that would enhance our knowledge of these particles is of particular importance.

This Annex builds on Annex 35-2 “Particulate Measurements: Ethanol and Isobutanol in Direct Injection Spark Ignited Engines” and includes the use of methanol blends.

Purpose and Objectives

The objective of this Annex is to determine the impacts of alcohol fuels on emissions from GDI engines. In addition to gaseous emissions, the focus will be on the tailpipe emissions of PM and black carbon (BC), along with the SOA formation potential. The fuels investigated include ethanol blends, E10 and E85, and methanol blends, M56, M15, and M30). The impacts of GPFs on particles from GDI engines with varying fuels will also be investigated.

Activities

The main activities of this Annex are chassis dynamometer tests of vehicles with GDI engines and comparable counterpart engines. These vehicles will be chassis dynamometer tested over varying drive cycles and ambient temperatures. The vehicles will also be tested with fuels of varying alcohol content (e.g., ethanol and methanol) to assess the impact of alcohol fuels on emissions from GDI engines. Some vehicles will be equipped with GPFs in order to determine the efficiency of GPFs on emissions reduction from GDI engines.

The focus of this project is to obtain detailed information about particulate and particle emissions from GDI technologies; along with gaseous emissions, fuel economy and efficiency will also be quantified.

The impact of alcohol fuels and GPFs on PM, particle number (PN), and BC emission rates will be measured. Also, the SOA formation potential of different vehicle fuel and technology combinations will be assessed.

Canada's Task-Sharing Contribution

Experiments will be carried out at the Emissions Research and Measurement Section of Environment and Climate Change Canada. A light-duty GDI vehicle will be tested on a chassis dynamometer with both low-level ethanol and high-level ethanol blends. The drive cycle used will be the Federal Test Procedure (FTP) with cold start at 25°C, −7°C, and −18°C. The US06 cycle will also be conducted at 25°C. Additional tests will be conducted with the GDI vehicle equipped with a GPF.

Along with fuel economy and criteria air contaminants, detailed characterization of PM and particle emissions will be undertaken. This characterization will include gravimetric PM, organic and elemental carbon, PN per mile, and particle size distribution.

Chile's Task-Sharing Contribution

Chile's contribution will be led by the Centro Mario Molin (CMMCh). Experiments will be carried out at the Center for Vehicle Control and Certification (3CV) laboratory and photochemical chamber at the Ministry for Transport and Telecommunication (MTT). Chassis dynamometer tests will be conducted with light-duty vehicles using the New European Driving Cycle (NEDC) and FTP test cycle, with varying blends of ethanol fuel (E0, E10, and E85). In addition, one vehicle will be equipped with a GPF and tested with and without a GPF. Along with measurements of nitrogen oxides (NO_x) and nonmethane hydrocarbons (NMHCs), particle chemical composition and PN size distribution will be quantified for ultraviolet (UV) irradiation-aged emissions. Determinations of SOA formation potential for each vehicle fuel combination will be made. A light-duty diesel vehicle will also be tested for comparative purposes.

Israel's Task-Sharing Contribution

Emissions tests will be conducted with GDI vehicles fueled with methanol gasoline and ethanol gasoline fuel mixtures (M56, E85, M15, E10, and M30). Emission testing will be performed according to NEDC and US06 cycles. Emissions characterization will include NO_x, HC, carbon monoxide (CO), PM, PN, and formaldehyde. The test vehicles will include both GDI and PFI engines.

United States' Task-Sharing Contribution

This contribution will be provided by Argonne National Laboratory's Center for Transportation Research, Advanced Powertrain Research Facility. Tasks will include chassis dynamometer tests of two vehicles of the same model types — one vehicle with a GDI engine powertrain with a GPF and one vehicle with a GDI engine powertrain without a GPF. The test protocol will include an FTP with cold start and the NEDC with hot start at 22°C (72°F) ambient temperature. Detailed characterization of PM will include transient soot mass, particle size distributions, primary total solid PN, and emissions of heavy hydrocarbons known to have high SOA potential.

Participants

- Argonne National Laboratory (United States)
- Centro Mario Molin (Chile)
- Environment and Climate Change Canada (Canada)
- Ministry for Transport and Telecommunication (Chile)
- Ministry of Natural Infrastructure, Energy and Water Resources (Israel)
- Natural Resources Canada (Canada)

Time Schedule

A time schedule is currently being developed.

Results/Key Messages

This Annex will result in the following:

- Comparative emissions rates of PM and particles from GDI test vehicles operated under varying conditions with different blends of alcohol fuels;
- Criteria air contaminant emissions, along with fuel consumption will be reported; and
- For a select set of vehicle tests, comparative information will be provided on the SOA forming potential.

The overall outcome will focus on the impacts of alcohol fuels and exhaust emission controls on PM, particles, BC, and the SOA forming potential from GDI and comparable technology vehicles.

Publications

Annex 54 work will result in a Final Report, “GDI Engines and Alcohol Fuel.”

4 Further Information

4.a
AMF TCP Executive Committee (ExCo) Meetings

ExCo 49, March 10–13, 2015, Gwangju, South Korea

The 49th Meeting of the AMF TCP ExCo was held March 10–13, 2015, in Gwangju, South Korea. There were 17 participants, including representatives of the Methanol Institute and of IEA Bioenergy Task 39. The meeting was held in conjunction with International Symposium on Applications of Ferroelectric (ISAF) 2015. AMF delegates presented findings of their work in a separate AMF conference session.

Technology Subcommittee

The Technology Subcommittee discussed the annex proposals and pre-proposals and provided feedback to the proposers.

Strategy Subcommittee

The Strategy Subcommittee reviewed drivers for advanced motor fuels and found that reducing dependence on oil imports is decreasing in importance as oil prices are low. Promising fuels identified were methane, ethanol, hydrogen, drop-in fuels, and a diesel replacement for heavy-duty vehicles (HDVs).

Outreach Subcommittee

The Outreach Subcommittee worked on a template for key messages that should condense the results and conclusions from annexes to two pages and should serve to convey the resulting messages to a larger audience.

Management

Yutaka Takada, alternate representative for Japan Organization for the Promotion of Low-Emission Vehicles (LEVO), was nominated ExCo Vice-Chair for Asia.

Annex Proposals

The following annex proposals were discussed:

- Fuel technologies for high-efficiency engine operation
- Advanced fuels in advanced engines
- Hydrogen-enriched methane

- Sustainable bus systems
- Real driving emissions and fuel consumption
- Gasoline direct injection engines and ethanol fuels

The first one was started up as Annex 52: Fuels for Efficiency, with Thailand as the Operating Agent. The second proposal on advanced fuels in advanced engines was integrated into Annex 52.
The third proposal on hydrogen-enriched methane was integrated into existing Annex 51: Methane Emission Control.

The other proposals were discussed and positively viewed. However, decisions were postponed to ExCo 50, as several of the key partners were not present at the current ExCo Meeting.

Prolongation of Annexes

The following annexes were prolonged until June 30, 2015:

- Annex 43: Performance Evaluation of Passenger Car Fuel and Powerplant Options
- Annex 44: Research on Unregulated Pollutants Emissions of Vehicles Fuelled with Alcohol Alternative Fuels
- Annex 48: Value Proposition Study on Natural Gas Pathways for Road Vehicles

Membership

The National Traffic Safety and Environment Laboratory (NTSEL) was invited to join AMF as the third contracting party for Japan. NTSEL has already successfully conducted Annex 38, and its work scope matches the scope of AMF.

ExCo 50, October 26–29, 2015, Jerusalem, Israel

The 50th Meeting of the AMF TCP ExCo was held October 26–29, 2015, in Jerusalem, Israel. There were 30 participants, including 15 experts and ministry representatives from Israel who participated in an intense information exchange during the informal meeting. The study tour provided visits to a small-scale gas-to-liquid (GTL) pilot plant and to the Weizmann Institute of Science.

Regional Overviews
Several delegates presented regional overviews on AMF-related policy. Thailand has a brand new energy policy, with a 20%–25% target for renewable energy in transportation by 2036. Alternative fuels in use are biodiesel, ethanol blends, and compressed natural gas (CNG). Korea has a target of 11% of renewable energy in primary energy supply by 2035. The resource base for biofuels is small, yet biodiesel is already used in blends, and ethanol shall be used in the future as well. Japan is focusing on increasing the number of environmentally friendly vehicles; the use of CNG and liquefied natural gas (LNG) for trucks and buses is important for diversification. Chinese policy focuses on electric vehicles.

The major pieces of legislation in the United States are the Renewable Fuel Standard (RFS), the light-duty vehicle (LDV) Tier 3 emission standards for fuels and vehicles, and the corporate average fuel economy (CAFE) standards. Almost all gasoline fuel in use is E10. Canada´s policy is in line with U.S. policy. In the European Union, the Renewable Energy Directive (RED) and the Fuel Quality Directive (FQD) set a target of 10% renewable energy in transport by 2020, with first-generation biofuels accounting for a maximum of 7%. The market introduction of environmentally friendly vehicles is facilitated by the Clean Vehicles Directive and by regulation of carbon dioxide (CO_2) emission limits for passenger cars. Alternative fuels in use are biodiesel and ethanol blends, which together cover around 5% of fuel demand.

Technology Subcommittee
The Technology Subcommittee discussed the annex proposals and recommended to start the proposed work on real driving emissions. In light of the Volkswagen incident, AMF should provide an understanding as to whether this is just a problem of Volkswagen or also of other manufacturers. The availability of technology in the event that it is a widespread issue should be investigated. For the proposed work on sustainable bus systems, the Technology Subcommittee recommended an emphasis on alternative fuels.

Strategy Subcommittee
The Strategy Subcommittee encouraged all delegates to become ambassadors for advanced motor fuels by disseminating AMF results at conferences and by deriving key messages for decision makers from Annex work. The subcommittee will continue to work on identifying bottlenecks for advanced motor fuels that need to be addressed.

Outreach Subcommittee

The Outreach Subcommittee initiated a review of outreach tools (newsletter, website, annex reports, and annual report), the results of which will be presented at the next ExCo Meeting. Argonne National Laboratory is already working on a template for key messages from Annexes, which all operating agents should use upon completion of an Annex. It was decided to start up a LinkedIn group for AMF.

Management

The new delegate for the United States is Kevin Stork of the U.S. Department of Energy. Marine Gorner is the new IEA desk officer for AMF. Chile and NTSEL (Japan) are in the process of joining AMF. Agence de l'Environnement et de la Maîtrise de l'Energie (ADEME, France) and Eni (Italy) have indicated their withdrawal from AMF.

Annex Proposals

Finland presented a pre-proposal to work on the use of methanol. Since Israel already has reviewed related literature, it was decided that Finland and Israel should work together on a proposal for the next ExCo Meeting.

Annex proposals from the last ExCo Meeting were briefly discussed, and the following new annexes were started up:

- Annex 53: Sustainable Bus Systems
- Annex 54: GDI Engines and Alcohol Fuels
- Annex 55: Real Driving Emissions and Fuel Consumption[85]

Prolongation of Annexes

Annex 43: Performance Evaluation of Passenger Car, Fuel, and Powerplant Options and Annex 44: Research on Unregulated Pollutants Emissions of Vehicles Fuelled with Alcohol Alternative Fuels were prolonged until December 31, 2015.

Closing of Annexes

Annex 42: Toxicity of Diesel Exhaust and Annex 46: Alcohol Application in CI Engines were closed.

[85] Annex 55 not submitted for 2015 Annual Report.

4.b
AMF TCP Contact Information

4.b.i
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[a] Alphabetical order by country name.

4.b.ii
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[a] Numerical order by annex.

4.b.iii
Chairs and Secretariat

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Dina	Bacovsky	Austria	Secretary	dina.bacovsky@bioenergy2020.eu

4.c
AMF TCP Publications in 2015

Annex 45: Synthesis, Characterization and Use of Hydro Treated Oils and Fats for Engine Operation

Synthesis, Characterization and Use of Hydrotreated Oils and Fats for Engine Operation. Final Report. February 2015.

Annex 48: Value Proposition Study on Natural Gas Pathways for Road Vehicles

Feasibility of Natural Gas Pathways for Motor Vehicles - An International Comparison. Final Report. August 2015.

Glossary

Advanced Motor Fuels (AMF)

The Advanced Motor Fuels Technology Collaboration Programme (AMF TCP) is one of the multilateral technology initiatives supported by the International Energy Agency (IEA). Formally these are also known as Implementing Agreements. The AMF TCP promotes more advanced vehicle technologies, along with cleaner and more-efficient fuels. Transportation is responsible for approximately 20%–30% of all the energy consumed and is considered to be the main producer of harmful emissions. Although the transportation sector is still highly dependent upon crude oil, advances are being made to allow for domestically made biofuels and other forms of energy.

Biodiesel Fuel (BDF)

A form of diesel fuel (methyl ether) derived from biomass; BDF has benefits over petroleum-derived diesel because it can be created from renewable and sustainable sources. Such blends of biodiesel include fatty acid methyl esters, soy methyl esters, and rapeseed methyl esters. In Brazil, ethyl ester or fatty acid alkyl ester are referred to as biodiesels.

Biomass to Liquid (BTL) (Fuels)

BTL fuel is a type of fuel derived from refining biomass, whether it is a renewable or waste material. Waste animal fats and vegetable oils can be used to create biodiesel. Ethanol can be derived from a vast array of renewable and sustainable sources, including switchgrass, corn, and even sugarcane. Switchgrass is a popular alternative to corn because it does not affect food supplies. Brazil, for example, derives its ethanol from sugarcane. In Europe, BTL fuels are usually used to name synthetic fuels that are produced from lignocellulosic biomass (usually wood chips) via gasification.

Diesel Dual Fuel (DDF)

DDF is a fuelling strategy currently being researched in diesel engines. A fuel resistant to auto-ignition, such as gasoline, is delivered to the combustion chamber through port fuel injection. A fuel that has a propensity to auto-ignite, such as diesel, is injected directly into the combustion chamber. This charge of diesel fuel is used to ignite the air-fuel mixture. Preliminary results show that by using diesel dual-fuel strategies, spark-ignited engine emission levels can be achieved along with the high thermal efficiencies of diesel engines.

Dimethyl Ether (DME)

DME is a fuel created from natural gas, coal, or biomass, which is noted for producing low levels of NO_x emissions and low smoke levels when compared to petroleum-derived diesel fuels. DME does not have some of the transportation issues associated with other alternative fuels, such as ethanol, which causes corrosion in pipelines. Because DME is a gas at room temperature, it must be put under pressure in large tanks for transportation and storage, unlike ethanol.

Direct Injection Spark Ignition (DISI)

DISI is a fuelling strategy currently being implemented in light-duty vehicles on the road today. A fuel resistant to auto-ignition, such as gasoline, is injected directly into the combustion chamber of a spark-ignited internal combustion engine. This fuel delivery process is more efficient than its port fuel injection predecessor because it creates a charge cooling effect in the combustion chamber, allowing for higher compression ratios to be run.

E85

E85 is composed of 85% ethanol and 15% gasoline by volume. This type of fuel is used in flex-fuel vehicles, which are compatible with pump gasoline and available alternative fuels. Consequent fuels, such as E0, E5, and E20, contain a certain vol% of ethanol, denoted by the number in their name, with the rest of the mixture being gasoline.

ED95/RED95

ED95 is a blend of diesel fuel consisting of 95% bio-ethanol and 5% of an ignition improver for the fuel. Sweden’s transportation sector has adapted some of its heavy-duty diesel buses to run on this biofuel blend.

The RED95 Ethanol-Diesel project is a 3-year joint project of NEOT, ST1, VTT, Scania, HSL, and Helsingin Bussiliikenne Oy that concentrates on the environmental impacts and energy consumption of waste-ethanol-powered buses. The aim is to demonstrate that ethanol can be utilized as bus traffic fuel, thereby significantly reducing peri-urban emissions and greenhouse gases. Since November 2013, two ethanol-powered buses have been used on HSL Route 41(source of information for RED95: http://www.neot.fi/en/neot-en/current-projects).

Ethanol (C_2H_5OH)

An alcohol fuel derived from plant matter, commonly feed corn, ethanol is blended into pump gasoline as an oxygenate. Changes to the engine and exhaust systems have to be made in order to run a higher ethanol blend. Ethanol is a popular alternative fuel because of its propensity to increase an engine's thermal efficiency. Ethanol is also popular because it can be domestically produced, despite discussions of its impact on food supplies. By law, ethanol must be denatured by using gasoline to prevent human consumption.

Ethyl Tertiary-Butyl Ether (ETBE)

ETBE is an additive introduced into gasoline during the production process. As an additive, ETBE can be used to create some of the emission benefits that are inherent with oxygenates. ETBE can be derived from ethanol, which allows it to be included as a biofuel.

Fatty Acid Methyl Ester (FAME)

FAME is a form of biodiesel derived from waste biomass, such as animal fats, recycled vegetable oils, and virgin oils. Pure biodiesel, B100, must meet standards before it can be blended into diesel fuels. In the United States, different blends of biodiesel can be found across the nation, ranging from 5% to 20% biodiesel. Manufacturers are now creating engines compatible with biodiesel blends up to B20. Under European standards, the terms FAME and biodiesel are used synonymously. B100 may be used as a pure fuel as well, with only minor adaptations to vehicles.

Fischer-Tropsch

The Fischer-Tropsch process involves taking low-value refinery products, such as coal, and converting them into high-value fuels that can be produced from biomass gasification. The resulting Fischer-Tropsch fuels, when compared to standard diesel fuels, can reduce nitrogen oxides, carbon dioxide, and particulate matter. Fischer-Tropsch fuels can also be produced from biomass gasification. Again, the properties of the resulting fuels are better than those of conventional diesel fuels. The cetane number, a measure of diesel fuels' propensity to auto ignite, is higher with Fischer-Tropsch fuels than it is with conventional petroleum-based diesels.

Flex-Fuel Vehicle (FFV)

FFVs are capable of safely handling various fuels, ranging from gasoline to high-ethanol-content blends. The fuel system in an FFV vehicle is dedicated to handle the flow of ethanol, which would harm a normal vehicle. General Motors is a major producer of FFVs. These vehicles do see a loss in fuel economy when running on alternative fuels, due to the lower energy content of ethanol.

Fuel Cell Vehicle (FCV)

An FCV is a type of hybrid that uses a hydrogen-powered fuel cell to produce electrical energy, which then powers electric motors that drive the vehicle. FCVs have the potential to lower harmful emissions in comparison to internal combustion engines.

Greenhouse Gas (GHG)

GHGs are emissions that increase the harmful greenhouse effect in the Earth's atmosphere. The emission of carbon dioxide, a common GHG, is a direct product of combustion. GHGs are responsible for trapping heat in the Earth's atmosphere. Methane, another powerful GHG, can remain in the atmosphere for longer than a decade and is at least 20 times more effective than carbon dioxide at trapping heat. GHGs have been a topic of great debate concerning global climate change in years past.

Hydro Treated Vegetable Oil (HVO)

HVO is a bio-based diesel fuel that is derived through the hydrotreatment (a reaction with hydrogen) of vegetable oils. HVO can be used as a renewable diesel fuel, and it can also be blended with regular diesel to create varying blends on a volume basis.

Internal Combustion Engine (ICE)

An ICE is a device that uses stored chemical energy in a fuel to produce a mechanical work output. There are more than 600 million ICEs in existence today, used for transportation and stationary purposes. Typical peak efficiencies for gasoline, diesel, and stationary engines are 37%, 42%, and 50%, respectively. Efficiencies of transportation gasoline and diesel engines are lower than their peak efficiencies, because they do not operate in the peak range.

Liquefied Natural Gas (LNG)

LNG is produced through the liquefaction process of natural gas, which can be used to power heavy-duty vehicles, such as transit buses. LNG is composed primarily of methane (CH_4), with impurities being removed during the liquefaction process.

Liquefied Petroleum Gas (LPG)

LPG is composed of propane (C_3H_{10}) and butane (C_4H_{10}), with its exact composition varying by region. This clean-burning fossil fuel can be used, with modification, to power current vehicles equipped with internal combustion engines, as an alternative to gasoline. LPG can also be produced domestically.

Methyl Tertiary-Butyl Ether (MTBE)

MTBE is an additive derived from methanol, which can be used to oxygenate and increase the octane rating of gasoline. MTBE is not commonly used anymore due to the risk of it contaminating groundwater supplies.

Natural Gas

Natural gas is a gas primarily consisting of methane (CH_4), which can be used as a fuel, after a refining process. This fossil fuel is extracted from the ground and burns relatively clean. Natural gas is not only less expensive than gasoline, but it also contributes to lower greenhouse gas emissions and smog-forming pollutants. Current gasoline and diesel vehicles can be converted to run on natural gas.

Natural Gas Vehicle (NGV)

NGVs are alternative fuel vehicles that use compressed or liquid natural gas, which are much cleaner-burning than traditional fuels. Current vehicles can be converted to run on natural gas, and such conversion is a popular trend among fleet vehicles. The only new original equipment manufacturer (OEM) NGV available in the U.S. market is the Honda Civic GX compressed natural gas car; in years past, by comparison, multiple vehicles were available. Countries in Europe and Asia offer a much wider selection of OEM NGVs.

NEXBTL

NEXBTL is a renewable diesel production process commercialized by the Finnish oil and refining company Neste Oil.

Nitrogen Oxides (NO_x)

Nitrogen oxides are composed of nitric oxide (NO) and nitrogen dioxide (NO_2). NO_x is formed from the nitrogen and oxygen molecules in the air and is a product of high combustion temperatures. NO_x is responsible for the formation of acid rain and smog. The three-way catalyst, which operates most efficiently at stoichiometric air-fuel ratios, has tremendously reduced NO_x emissions in spark-ignited engines. A leanburn after-treatment system is needed for compression-ignition engines, because they do not operate at stoichiometric conditions.

Particulate Matter (PM)

PM is an emission produced through the combustion process. PM less than 10 micrometers in diameter can cause serious health issues, because it can be inhaled and trapped in a person's lungs. With the advent of diesel particulate filters, PM emissions have been tremendously reduced.

Plug-in Hybrid Electric Vehicle (PHEV)

A PHEV is a type of hybrid electric vehicle equipped with an internal battery pack, which can be charged by plugging the vehicle into an outlet and drawing power from the electrical grid. These vehicles are becoming popular, because the vehicle itself produces very low emission levels.

Port Fuel Injection (PFI)

PFI is a type of fuel delivery system in which fuel is injected into the intake manifold before the intake valve. This method of fuel injection is being replaced in newer vehicles by direct fuel injection. PFI is typically found in spark ignition engines.

Rapeseed Methyl Ester (RME)

RME is a form of biodiesel derived from rapeseed (canola) oil. This form of biodiesel is also renewable, allowing it to be produced domestically. RME can then be blended with petroleum-based diesel to produce varying blends of biodiesel.

Well-to-Wheel (WTW)

The WTW concept takes into account all of the emissions created from the initial energy source to the end system for the desired mode of transport. For instance, an electric vehicle will create lower greenhouse gas emissions than a gasoline-powered vehicle. If the electricity used to charge the electric vehicle came from a combustion power plant and if other transmissions of power were taken into account, the electric-vehicle-related emissions could, in fact, exceed the emissions of the gasoline counterpart.

xTL

Synthetic liquid transportation fuels, collectively known as xTL fuels, are produced through specialized conversion processes.

Notation and Units of Measure

ADEME	Agence de l'Environnement et de la Maîtrise de l'Energie (France)
AEDP	Alternative Energy Development Plan (Thailand)
AFHB	Laboratory for Exhaust Gas Control, University of Applied Sciences, Biel/Bienne, Switzerland
AIST	National Institute of Advanced Industrial Science and Technology (Japan)
AMF TCP	Advanced Motor Fuels Technology Collaboration Programme
AMFI	Advanced Motor Fuels Information System
AMT	Advanced Materials Transport
ANGVA	Asia Pacific Natural Gas Vehicles Association
ANR	Agence Nationale de la Recherche (French National Research Agency, same as NRA)
ASTM	American Society for Testing and Materials International
BAFA	Federal Office for Economic Affairs and Export Control (Germany)
BC	black carbon
BD	biodiesel
BD100	100% pure biodiesel (blendstock)
BD2	2% biodiesel, 98% petrodiese blend
BD5	5% biodiesel, 95% petrodiesel blend
BDF	biodiesel fuel
BE	bioethanol
BE5	5% bioethanol, 95% gasoline
BEV	battery electric vehicle
BG	biogas
BIO	10% biofuel, 90% diesel
bioSNG	synthetic natural gas made of renewable resources
BMEL	Federal Ministry of Food and Agriculture (Germany)
BMVI	Federal Ministry of Transport and Digital Infrastructure (Germany)
BMVIT	Federal Ministry for Transport Innovation and Technology (Austria)
BTL	biomass-to-liquid (fuel) (method, plant, process)

3CV	Center for Vehicle Control and Certification (Chile)
CATARC	China Automotive Technology and Research Center
CEA	Commissariat à l'Énergie Atomique et aux Énergies Alternatives (French Alternative Energies and Atomic Energy Commission)
CEC	Climate Energy Contribution
CEN	European Committee for Standardization
CERT	Committee on Energy Research and Technology (IEA)
CH_4	methane
CHP	combined heat and power
CI	compression ignition
CNG	compressed natural gas
CO	carbon monoxide
CO_2	carbon dioxide
CO_2e	carbon dioxide equivalent
COP21	21st Session of the Conference of Parties to the 1992 United Nations Framework on Climate Change
CORES	Corporación de Reservas Estratégicas
DDF	diesel dual fuel
DENE	Agency for Renewable Energy (Germany)
DG	Directorate General (European Union)
DGAC	Direction Générale de l'Aviation Civile (France)
DI	direct injection
DISI	direct injection spark ignition
DME	dimethyl ether
DOE	U.S. Department of Energy (United States)
E5	5% ethanol, 95% gasoline blend
E10	10% ethanol, 90% gasoline blend
E85	85% ethanol, 15% gasoline blend
EC	elemental carbon, Environment Canada, European Commission
ECN	European Combustion Network
ECU	engine control unit
ED95	ethanol diesel fuel mix of 95% ethanol and 5% ignition improver
EED	Energy Efficiency Directive
EEP	Energy Efficiency Plan (Thailand)
eFAME	enzymatic fatty acid methyl ester
EGR	exhaust gas recirculation
EI	energy intensity
EngToxNet	Engine Toxicity Network

EPA	U.S. Environmental Protection Agency (United States)
ERDF	European Regional Development Fund
EST	Eni Slurry Technology
ETBE	ethyl tertiary-butyl ether
ETS	emission trading scheme
eTV	ecoTECHNOLOGY for Vehicles Program
EU	European Union
EUWP	Working Party on Energy End Use Technologies
EV	electric vehicle
EVE	Electric Vehicles Systems Programme
ExCo	Executive Committee
FAME	fatty acid methyl ester; conventional esterified biodiesel
FCA	Fiat Chrysler Automobiles
FCEV	fuel cell electric vehicle
FCV	fuel cell vehicle
FFV	flex-fuel vehicle
FID	flame ionization detection
FQD	Fuel Quality Directive
FTIR	Fourier transform infrared radiation
FTP	Federal Test Procedure (U.S. Environmental Protection Agency)
FUI	Fond Unique Interministériel (France), France-UK-Ireland
GC	gas chromatography
GDI	gasoline direct injection
GDP	gross domestic product
GHG	greenhouse gas
GPF	gasoline particulate filter
GTL	(natural) gas-to-liquid (fuel) (method, plant, process)
GWP	global warming potential
H_2	hydrogen
HC	hydrocarbon
HCCI	homogeneous charge compression ignition
HCNG	hydrogen-compressed natural gas
HD	heavy duty
HDV	heavy-duty vehicle
HEV	hybrid electric vehicle
HPLC	high-performance liquid chromatography
HSL	Helsinki Regional Transport Authority
HVO	hydrotreated vegetable oil

IC	internal combustion
ICE	internal combustion engine
IEA	International Energy Agency
IFP	French Institute of Petroleum (Institut Français du Pétrole)
IFPEN	Energies Nouvelles
ISO	International Organization for Standardization
JGA	Japan Gas Association
KBA	Kraftfhart-Bundesamt - Federal Motor Transport Authority (Germany)
LDV	light-duty vehicle
LEVO	Organization for the Promotion of Low-Emission Vehicles (Japan)
LHV	lower heating value
LMFA	Laboratoire de Mécanique des Fluides et d'Acoustique
LNG	liquefied natural gas
LPG	liquefied petroleum gas
LTE	Law on Energy Transition (France)
LTM	logistics and transport management (Thailand)
M85	85% methanol, 15% gasoline blend
MAFF	Ministry of Agriculture, Forestry and Fisheries (Japan)
METI	Ministry of Economy, Trade, and Industry (Japan)
MOEVA	Mobility with Alternative Energy Vehicles (Spain)
MON	motor octane number
MS	mass spectrometry
MTBE	methyl tertiary-butyl ether
NEDC	New European Driving Cycle
NDC	nationally determined contribution
NEDO	New Energy and Industrial Technology Development
NGA	Natural Gas Authority
NGL	natural gas liquid
NGO	nongovernmental organization
NGV	natural gas vehicle
NMOG	nonmethane organic gas
NO_x	nitrogen oxides, composed of nitric oxide (NO) and nitrogen dioxide (NO_2)
NoVA	Normverbrauchsabgabe (Austria)
NPE	Nationale Plattform Elektromobilität (Germany)
NRA	National Research Agency (France, same as ANR)

NTSEL	National Traffic Safety and Environment Laboratory (Japan)
OC	organic carbon
OECD	Organisation for Economic Co-operation and Development
OEM	original equipment manufacturer
PCCI	premixed charge compression ignition
PDP	Power Development Plan (Thailand)
PEMS	Portable Emission Measurement System (Japan)
PERD	Program of Energy Research and Development (Canada)
PFI	port fuel injection
PHEV	plug-in hybrid electric vehicle
PIA	Investissements d'Avenir (France)
PM	particulate matter
PROGELEC	Renewable Generation and Management of Electricity (France)
PVO	pure vegetable oil
R&D	research and development
RD&D	research, development, and demonstration
RED	Renewable Energy Directive
RFS	Renewable Fuel Standard
RIN	Renewable Identification Number
RIVM	National Institute of Public Health and Environment (The Netherlands)
RE85	high-concentration ethanol fuel (similar to E85), manufactured from bio-waste (helps to reduce CO_2 emissions); sold by St1
RME	rapeseed methyl ester
RON	research octane number
SAE	Society of Automotive Engineers
SCCER	Swiss Competence Center for Energy Research
SFOE	Swiss Federal Office of Energy
SI	spark ignition
SOA	secondary organic aerosol
SOR	Statuatory Orders and Regulations (Canada)
TAME	tertiary amyl butyl ester
Tekes	Finnish Funding Agency for Technology and Innovation
TGAP	Taxe Générale sur les Activités Polluantes (French tax on polluting activities)

THC	total hydrocarbon
TIC	Taxe Intérieure sur la Consommation (French tax on consumption)
TICPE	Taxe Intérieure de Consommation sur les Produits Énergétiques (French tax on energy product consumption)
TransSmart	Smart Mobility Integrated with Low-Carbon Energy
UNECE	United Nations Economic Commission for Europe
VELROUE	Véhicule Utilitaire Léger Hybride Bimode (France)
VTT	VTT Technical Research Centre of Finland
WIFO	Austrian Institute of Economic Research
WP	work package
WTT	well-to-tank
WTW	well-to-wheel
WVTA	Whole Vehicle Type Approval (EU certificate)
xTL	synthetic liquid transportation fuels
ZEV	zero emission vehicle

Units of Measure

baht	Thai currency
bbl	barrel(s)
°C	degree(s) Celsius
cc	cubic centimeter(s)
CHF	Swiss franc(s) (currency)
cm	centimeter(s)
cm^3	cubic centimeter(s)
d	day(s)
DKK	Danish krone(s) (currency)
euro(s)	European Union currency
°F	degree(s) Fahrenheit
ft	foot (feet)
ft^3	cubic foot (feet)

g	gram(s)
GW	gigawatt(s)
GWh	gigawatt-hour(s)
h	hour(s)
ha	hectare(s)
hL	hectoliter(s)
hp	horsepower
kcal	kilocalorie(s)
kg	kilogram(s)
kg/h	kilogram(s) per hour
kL	kiloliter(s)
km	kilometer(s)
km^2	square kilometer(s)
kt	kilotonne(s)
kt/a	kilotonne(s) per year (annum)
ktoe	kilotonne(s) of oil equivalent
kW	kilowatt(s)
kWh	kilowatt-hour(s)
L	liter(s)
m^3	cubic meters
Mboe	million barrels of oil equivalent
mg	milligram(s)
mi	mile(s)
MJ	megajoule(s)
MMBtu	million British thermal units
Mt	megatonne(s) or million metric ton(s)
Mt/a	megatonne(s) per year (annum)
Mtpe	megatonne(s) of petroleum equivalent
Mtoe	megatonne(s) of oil equivalent
MW	megawatt(s)
nm	nanometer(s)
Nm	Newton-meter(s) (torque)
Nm^3	normal cubic meter(s)
PJ	petajoule(s) (1×10^{15} joules)
ppm	part(s) per million

t	metric ton(s) or tonne(s) (1,000 kg)
t/a	metric ton(s) per year (annum)
TJ	terajoule(s)
ton	U.S. ton (907 kg or 2,000 lb, not abbreviated)
tonne	metric ton or t (1,000 kg)
TWh	terawatt-hour(s)
v	volt(s)
vol%	volume percent
yr	year(s)
€	euro(s) (currency)
€/a	euro(s) per year (annum)
$	dollar(s) (currency)