Session 2.3: Energy

MEKONG ENERGY METABOLISM: CONNECTING ENERGY DEMAND INTO THE NEXUS OF FOOD-WATER-ENERGY SECURITY

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Abstract

The Greater Mekong Subregion (GMS) is composed of countries and economies described as dynamic, politically, socially and economically diverse, and ambitious in terms of national aspirations, expansion and growth. Until 40 years ago the Mekong River remained a relatively unmodified river system connecting the primary livelihood pursuits of agriculture, fishing and forestry of a predominately rural population. The current portfolio of policy instruments, strategies, and metrics developed in the GMS is generally associated with the expertise and evidence arising from the relatively stable and weak levels of connectivity associated with an unmodified Mekong. Human migration, natural resource flows, and private and State financial investments are amongst a cluster of factors likely to influence the critical dynamics generating increased levels of connectivity between Mekong countries.

High levels of connectivity increase complexity, biasing the reliability of predicted outcomes and increasing the potential for unforeseen consequences of national decisions. Strong connectivity implies that interacting factors transmit the effects of substantial changes from one part of a region or sector to another.

The paper takes high levels of connectivity into account, describing the nexus between energy, water, and food by reviewing one energy development pathway based on large-scale hydropower. By "pathway" we refer to patterns of choices made by public and private actors which lead to intended as well as unintended consequences. By way of literature based insights and review, we describe the consequences of the hydropower pathway on the GMS energy system and the likely interactions and implications of hydropower generation for food security, water security and livelihoods in a strongly connected Greater Mekong Subregion.

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1. Introduction

In this paper we describe energy considerations and policy deliberations when linked to food, livelihood and water security in the "wider Mekong region," which covers all the Greater Mekong Subregion (GMS) as defined by the Asian Development Bank (ADB, 2004), except Guangxi Zhuang Autonomous Region of the People's Republic of China (PRC). The wider Mekong region covers more than 2.3 million km^2 and its population exceeds 278 million (ADB and UNEP, 2004).

The dynamics of connectivity and interdependence between the energy, food and water sectors are changing rapidly. The paper takes high levels of connectivity into account and provides a partial cross-sectoral assessment of development-directed investments in the GMS initiated to satisfy aspirations of national economic growth. We contend that increasing energy demand and national objectives of energy security are central to and catalyze economic growth imperatives. Contingent on a strongly connected region, a singular, linear appraisal of energy security that fails to account for the consequences on food and water security is likely to lead to substantial social cost. The achievement of national energy security objectives may mean either substantially compromised regional energy security or reduced food and water security at both national and regional scales.

The current portfolio of instruments, responses, strategies, and metrics developed in the wider Mekong region is generally associated with the expertise, experience, and evidence arising from the relatively stable and weak levels of connectivity associate with a relatively unmodified Mekong. Periodic amendments have arisen, but have not been subject to notions or threats of redundancy and high probabilities of policy failure due to changed connectivity levels. A tension arises when institutional arrangements and analysis underpinning policy decisions are geared to assumptions of weak connectivity and analysis confined to a single economic sector (De Landa 2006, Molle *et al.* 2009).

Regardless of the level of connectivity, we assume that measures of well-being focused on poverty levels and livelihoods remain the major metrics to appraise policy and governance performance, together with gross domestic product (GDP) and gross national product (GNP).

We illustrate the nexus between energy, water, and food by reviewing one energy development pathway based on large-scale hydropower and a contrasting pathway based on the production of bio-energy. By "pathway" we refer to patterns of choices made by public and private actors, emphasizing governance contexts, which lead to intended as well as unintended consequences. We explore the consequences of the hydropower pathway on the Mekong region's energy system and detail the interactions and implications of hydropower generation for food security, water security and livelihoods in a strongly connected Greater Mekong sub-region.

The remaining six sections of the paper describe existing and foreseeable interactions and connections of hydropower construction, generation and operation in the Mekong mainstream with water security, livelihoods, food security and land-use change.

Section 2 provides background information and theoretical rationale.

Section 3 describes the historical and contemporary factors influencing the dynamics and levels of GMS sectoral and regional connectivity. Central to the background synthesis are the three enabling conditions influencing the degree of regional connectivity: (a) the endowment, scarcity, and accessibility of resources within the connected region; (b) the financial capacity to activate these resources as production factors; and (c) the institutional conditions enabling resource transfers to occur.

Section 4 details the region's energy demand as a catalyst for increased food and water connectivity, focusing on the development of mainstream hydropower construction and operation.

Section 5 describes the interactions of hydropower electricity generation with livelihoods (focusing on occupation and income), migration and food security (emphasizing nutrition) in the Greater Mekong sub-region.

Section 6 reviews the current literature concerned with the potential consequences of hydropower dam construction and operation inclusive proposed irrigation diversions. The discussion focuses on changes to in-stream sediment and nutrient loads; mainstream wet and dry season hydrological characteristics; and the volume, timing and duration of flood pulses (emphasizing the aquatic environs of the Tonle Sap lake).

Section 7 describes likely changes in land use patterns and activities. The paper concludes by synthesizing the previous discussion and points to further research foci.

2. Background

Dynamic, diverse, ambitious, and driven are words central to describing the contemporary Mekong region. The region is dynamic: it has a youthful, growing population, an expanding workforce, and consequently significant movement out of smallholder agriculture. It is economically and politically diverse: there are the three 'least-developed' economies: Cambodia, Lao People's Democratic Republic (Lao PDR), and Myanmar; two large economies, Thailand and Viet Nam; and Yunnan Province of the PRC. It is ambitious: not just in terms of the aspirations of younger people and their parents, but of its leaders and policy makers to expand trade, mining, manufacturing, transport, tourism, and industry. The Mekong region is projected to grow rapidly. For Thailand and Viet Nam, the two largest economies of the region, APEC (2009) projects GDP as growing 4.5% and 6.2% per annum, respectively, during 2005–2030. The 2012 growth projection for Cambodia is 6.7%, for the Lao PDR 6.9%, Thailand 4%, Viet Nam 7.2%, and PRC 8.1% (Business Monitor International, 2011).

The region is driven and stimulated by a number of exogenous influences. These pertain to the Mekong region's position as a purveyor of labor, food, tourist destination, textiles, and other manufactured goods connected to the global economy, but also include such factors as the reality of climate change and the social responses to adapt to those changes.

Until 40 years ago the Mekong River remained a relatively unmodified river system of low impoundment, connecting the primary livelihood pursuits of agriculture, fishing and forestry of a predominately rural population. The Mekong has thus acted as an historical conduit of relatively stable cultural, economic, agricultural and spiritual connection across the Mekong region countries, despite periods of political and economic turbulence (Molle *et al.*, 2010).

Human migration, natural resource flows, and financial investments are amongst a cluster of factors that influence the critical dynamics generating increased levels of connectivity between Mekong countries (Dore, 2003; Harima *et al.*, 2003; Theeravit, 2003; Contreras, 2007).

The three enabling conditions central to the degree of regional connectivity are (a) the endowment, scarcity, and accessibility of resources within the connected region; (b) the financial capacity to activate these resources as production factors; and (c) the institutional conditions enabling resource transfers to occur.

A set of bio-physical and hydrological conditions over the past 40 years has also promoted high levels of economic and political connectivity between Mekong riparian countries (Theeravit, 2003; Molle *et al.*, 2009). The steep elevation gradients of the head waters and upper catchments of the main tributaries have provided opportunities for impoundments and hydropower generation, tentatively coexisting with biodiversity hotpots, small scale localized irrigation, and swidden agriculture. The rapid gradient transition to the extensive plains and deltas has allowed water diversions for agrarian landscapes, including extensive irrigation, fisheries, and river-based transport. Resource endowments, however, are geographically dispersed and characterized by variable extraction costs and relative scarcity at national scales.

Theeravit (2003) claims the financial strength of Chinese, Thai, and Vietnamese private and state companies has accelerated their potential to invest internationally. A political environment conducive to increased direct foreign and private investment is likely to cohere the bio-physical and institutional conditions in neighboring countries to facilitate the supply of demanded resources leading to increased wider Mekong region connectivity.

International financial organizations and aid donors that have historically supported Mekong countries are increasingly being substituted by direct foreign investment, private financiers, and government elites in order to source, and alternatively conserve, natural resources or manufacturing capacity in neighboring countries (Middleton *et al.*, 2009; Molle *et al.*, 2009). Alternate resource financing arrangements can either bypass existing regulatory processes and enforcement statutes, remain undetected as primary agents of connectivity, or challenge the efficacy of institutions geared to historically low levels of connectivity.

High levels of connectivity increase complexity, biasing the reliability of predicted outcomes and performance and increasing the potential for unforeseen consequences of national decisions (Cechich *et al.*, 2003; Sawyer, 2005; De Landa, 2006). The effects of large-scale investments in weakly connected regions are generally constrained to locales proximate to the initial target area within a particular country. In contrast, strong connectivity implies that interacting factors transmit the effects of substantial changes from one part of a region to another.

The constellation of biophysical and socioeconomic factors and dynamics has implications for the political economy of the Mekong (Dore, 2003). Inter-country discussions to activate economic potential and satisfy aspirations of national economic growth can stimulate the development of supra-national institutional arrangements and governance processes that reinforce regional connectivity.

Examples for such reinforcing processes are bilateral agreements to reduce the capital outlays and operational costs of infrastructure necessary for transporting resources. Changes in land-access rights and foreign investment regulations are likely institutional amendments. As a corollary, changes in migration legislation might be required to satisfy labor requirements, further buttressing the connectivity beyond national boundaries. Similar implications arise for the relationships between labor, electricity, water, minerals, and agricultural resources. As these links intensify, regional connectivity increases and over time a highly connected region can emerge, such as the Mekong region.

3. Impending Decisions with Regional Implications

As part of the Exploring Mekong Futures project,[5] two expert panel workshops identified and analyzed six large-scale impending investments with potentially regional implications by altering the degree of sectoral and agency connectivity. The six potential investments represent the final result of extensive consultation and collaboration with regional policy makers, government agencies and decision influencers. The objective of the expert panel process was to articulate the first, second and third order system interactions and influences of the potential Mekong investments with respectively; livelihoods, energy, water resources, food security, mining and large scale land use changes.

The connectivity aspects discussed in this paper focus on one of the identified investments: the development of mainstream hydropower dams as a primary component of national and regional energy generation. The construction of mainstream hydro power dams influences, and in turn, is influenced by the other identified investment proposals. To complete the context of the expert panel process, the six

[5] http://www.csiro.au/resources/Mekong-Futures-brochure.html

impending development decisions, which are interacting and interdependent factors of connectivity in the wider Mekong region, are briefly described below.

1. *Large-scale water diversion, in particular transfers within and between the Lao PDR and Thailand*. Water diversion is already a reality within the wider Mekong region and the Mekong Basin. Several combinations of inter- and intra-basin diversions have been considered (MRC, 2005a, b). The workshop assumed diversions from the Lao PDR Nam Ngum tributary for irrigation in northeastern Thailand, by building a diversion dyke and tunnel under the Mekong (Molle and Floch, 2008).
2. *Investments in response to sea level rise*. Global sea levels are likely to increase in accord with Intergovernmental Panel on Climate Change (IPCC) assumptions on increasing global temperature (Rahmstorf, 2007). Average projections of global sea-level rise are around 20 cm by 2030 (Rahmstorf, 2007), subject to wide geographic variability dependent on surface temperatures. The Vietnamese Institute for Meteorology, Hydrology and Environment assumes 65-100 cm by 2100 (IMHEN, 2010, p. 30). Similarly, IPCC predicts a sea level rise for the Mekong region of up to 100 cm by 2010 (IPCC, 2007, Chapter 5.2), the reference level considered by the Mekong River Commission (MRC, 2009). Salinity intrusion is already a significant problem in the Mekong Delta (MRC, 2003). We assume that a sea level rise of 20 cm will further accelerate salinity intrusion and the severity of storm surge.
3. *Land-use changes in response to accelerated increases in rubber demand*. We assume that by 2050 an additional area of 1.6 million ha will be converted to rubber plantations (Ziegler *et al.*, 2009; Fox *et al.*, 2010). Further we assume that half of the rubber plantations will be managed by small holder farmers and half by large concession holders.
4. *Construction of transport infrastructure, in particular the Kunming-Cambodia railway.* Regional railway lines in all countries are planned for development (or rehabilitated) to further regional integration and connectivity in the Mekong Region. The status of Mekong region transport proposals is highly fluid, with substantial changes or possible abandonment likely. Current proposals include
    - Cambodia: rehabilitation of the railway funded by the Asian Development Bank (ADB) and the Australian Agency for International Development (AusAID);
    - PRC: financing the feasibility study for a rail link between Phnom Penh and the border with Viet Nam;
    - PRC: building a new line to the Viet Nam and Myanmar borders;
    - Thailand: considering improvements to the Thai rail system and development of a high-speed train line and new links to the Lao PDR and onward to Viet Nam;
    - Viet Nam: considering lines to the Lao PDR and Cambodia;
    - A connecting rail link through the Lao PDR to form part of the Association of Southeast Asian Nations (ASEAN)-PRC railway has been proposed but is currently in abeyance. If constructed the link will run from Yunnan Province through the Lao PDR to Thailand, Malaysia, and Singapore.
5. *Mining operations, in particular bauxite mining in the southern Lao PDR, Northeast Cambodia, and Viet Nam highlands*. Deposits of bauxite have been prospected and explored for the last four years in the Bolaven Plateau in the southern Lao PDR (Champasak Province next to the Cambodian border). A commercially viable alumina refinery is feasible, although requiring upwards of 0.5 million tons of alumina output or between 1.0 and 1.5 million tons of raw bauxite per year, dependent on the grade of the bauxite, for a period of not less than 20 years. Such a venture requires a considerable volume of electricity, possibly in the region of 150 megawatts (MW), and large quantities of water (Sekong River and Sekong dams). Processing of the alumina in an aluminum smelting operation into saleable aluminum is not currently an option as it requires 100% reliable electricity in the order of 600–800 MW, dependent on the technology applied and the scale of the operation. It would only be possible if more hydropower development becomes available. The proposed railway linking Kunming and the Lao PDR makes bauxite mining more viable.
6. *Mekong River mainstream dams*. For the purpose of this discussion, we assume that 12 hydropower dams will be built on the Mekong mainstream during 2011–2025 (ICEM, 2010). The estimated total peaking capacity is 12,980 MW, with 64,229 gigawatt hours (GWh) mean annual energy generated (ICEM, 2010, Table 3.1) (Table 1).

Table 1: Assumptions for Mainstream Mekong River Dam Construction

MAINSTREAM DAM		MANAGEMENT STATUS				DESIGN SPECIFICATIONS									DIMENSIONS		
	LOCATION	DEVELOPER	EARLIEST POTENTIAL COMMISSION DATE[68]	DESIGN STATUS	ENVIRONMENTAL ASSESSMENT STATUS	Rated Head (m)	Plant Design Discharge (m3/s)	Installed Capacity (MW)	Peaking Capability (MW)	Mean Annual Energy (GWh)	Firm Annual Energy (GWh)	Full Supply Level (mamsl)	Low Supply Level (Mamsl)	Live Storage (mcm)	RESERVOIR AREA (km2)	Length of dam (m)	Height (m)
Pak Beng	Lao PDR	Datang International Power Generation (China)	2016	MoU, feasibility	IEE submitted	31	7,250	1,230	1,230	5,517	4,073	340	334	442	87	943	76
Luang Prabang	Lao PDR	PetroViet Nam Power Corporation (Viet Nam)	2016	MoU, feasibility	Feasibility study,	40	3,812	1,410	1,412	5,437	4,205	310	308	734	90	1,106	68
Xayaburi	Lao PDR	SEAN & Ch. Karnchang Public Co Ltd (Thailand)	2016	MoU, feasibility	Feasibility & full ESIA submitted	24	6,018	1,260	1,260	6,035	5,139	275	270	225	49	810	32
Pak Lay	Lao PDR	CEIEC and Sino-Hydro (China)	2016	MoU, feasibility	IEE submitted	26	4,500	1,320	1,320	6,460	4,252	240	237	384	108	630	35
Sanakham	Lao PDR	Datang International Power Generation (China)	2016	MoU, feasibility	Not yet	25	5,918	700	1,200	5,015	3,978	220	215	106	81	1,144	38
Pakchom	Lao PDR Thailand	N/a	2017	MasterPlan	Not yet	22	5,720	1,079	1,079	5,318	5,052	192	190	12	74	1,200	55
Ban Koum	Lao PDR Thailand	Italian Thai Asia Corp. Holdings (Thailand)	2017	MoU, feasibility	Not yet	19	11,700	1,872	1,872	8,434	8,012	115	115	0	133	780	53
Lat Sua	Lao PDR	Charoen Energy and Water Asia Co Ltd (Thailand)	2018	MoU, pre-feasibility	Pre-feasibility study submitted	10.6	10,000	686	686	2,668	1,524	97.5	95.5	0	13	1,300	27
Don Sahong	Lao PDR	Mega First (Malaysia)	2016	PDA, detailed planning	Full EIA submitted,	17	2,400	240	240	2,375	1,989	75	72	115	290 (ha)	1820-720-2730	10.6-8.2-8.3
Thakho diversion	Lao PDR	CNR & EDL (France/Lao)	2016	MoU, pre-feasibility	IEE submitted	16	380	50	50	360		71.7	68.7	n/a	n/a	Channel 1,800m	n/a
Stung Treng	Cambodia	Song Da Construction Co. (Viet Nam)	N/a	MoU, pre-feasibility	Not yet	15	18,493	980	591	4,870	2,937	55	50	70	211	10,884	22
Sambor	Cambodia	China Southern Power Grid (China)	2020	MoU, pre-feasibility	Pre-feasibility submitted	33	17,668	2,600	2,030	11,740	9,150	40	39	465	620	18,002	56

Source: ICEM (2010, Annex 1 p. 150)

4. Energy Demand as a Catalyst of Food and Water Connectivity

GDP is projected to grow rapidly in the Mekong region as a function of rapid industrialization and an impetus to export production. The rate of change of electricity demand is correlated with GDP increases, although the magnitude of change is disputed by governments and agents of civil society (Molle *et al.*, 2010). Primary annual energy demand for Thailand and Viet Nam is projected to grow at 3.0% and 3.8% respectively for the period 2005-2030 (Asia Pacific Energy Research Center, 2009). The region is part of ASEAN. An International Energy Agency's reference scenario projected ASEAN's primary energy demand as growing 2.5% per annum between 2007 and 2030, significantly higher than the average rate in the rest of the world (IEA, 2009).

In the reference scenario, ASEAN demand for electricity grows even more rapidly, 4.2%, during the same period (IEA, 2009). The World Bank (2006) estimates electricity demand in Viet Nam is growing at 16% per annum, and will increase by a factor of 4 to 40,700 MW by 2015. Thailand's electricity demand is estimated to double to 58,000 MW by 2021 (EGAT, 2010). Table 2 indicates that energy consumption per capita is more modest in the Lao PDR, Cambodia, and Myanmar. Electricity consumption per capita in Thailand is almost an order of magnitude greater than that of Cambodia, as is energy use per capita.

4.1 Governance Regimes

Hodgson (2006) argues that institutions represent systems of established and prevalent social rules that structure social interactions. Governance systems are the operational expressions of institutions and their dynamics, determining how change is enacted. Governance is therefore central to the selection of which energy/electricity generation pathways are pursued. This section outlines a number of key institutional and governance features of the Mekong energy supply regime.

Technical Preferences. Planners perceive that large-scale supply is the most cost-effective way to meet rapidly growing demand (Foran *et al.*, 2008). For instance, the computer optimization models used by Electricity Generating Authority of Thailand include the following options to meet rising demand (EGAT, 2007):

700 MW coal-fired thermal power plant;
700 MW gas-fired combined cycle power plant;
230 MW gas turbine power plant; and
1,000 MW nuclear power plant

Until recent diversification decisions, the Thai power utility compared imported hydropower solely on a cost basis against the cost of domestic combined cycle natural gas turbine.

Smaller-scale options, such as <100 MW biomass combined heat and power (CHP) plants are introduced into Thailand's final Power Development Plan ex post cost-optimization analysis. In other words, they are not evaluated concurrently and impartially against large-scale generation options. Likewise, energy efficiency is not treated as a "resource", meaning that energy efficiency options are not considered in candidate power plants in the planning model, despite being allocated arbitrary quotas.

Table 2 Greater Mekong Subregion, selected indicators, 2004

	Cambodia	Guangxi	Yunan	Lao PDR	Myanmar	Thailand	Viet Nam
Land Area (1000 km^2)	181.0	236.7	396.8	230.8	657.6	510.9	325.5
Population (million) (2004)	13.8	48.9	44.2	5.8	54.3	64.2	82.1
GDP (current $ in billion)	4.9	40.2	35.9	2.2	13.6	150.1	41.2
GDP per capita (current $)	361	869	813	420	250	2,519	551
GDP per capita (ppp current $)	2,338	4,340	4,061	1,935	2,009	8,179	2,704
Foreign Direct Investment (US$ million)	131	300	142	17	556	1,064	1,610
Electricity Use per capita (KWh)	45	703	838[a]	160	123	1,752[a]	433[a]
Energy use per capita (Kgoe)	180.0	663.0	778.0	355.0	217.0	1,405.7[a]	544.3[a]
Fuelwood share in total primary energy	88%	23%	9%[b]	67%	70%	16%	49%

a 2003 data
b 2000 data
Source: IRM-AG (2008).

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Financial Incentive Structure. Another powerful driver of supply-side solutions stems from the fact that the region's energy organizations operate according to a traditional rate-of-return or "cost-plus" utility model. Under this structure, profitability hinges directly on gross revenues. There is limited incentive to invest in energy savings, and maximum incentive to invest in generation plants owned by the utility.

Meaningful Participation. Decision-making by government elites is common in the region, with limited or negligible public input into a range of important and sensitive issues, ranging from locating power station sites to major privatization initiatives (Greacen and Greacen, 2004; Foran, 2006; Nakhooda *et al.*, 2007).[6] Thai governments have had significant and recurrent problems with gaining public acceptance of new power stations and gas pipelines. Coal is particularly controversial in Thailand, but even small-scale biomass plants have proven difficult. These difficulties are driven by the lack of impartial local consultation processes, occasional corruption of local government, and the perception by civil society organizations that environmental impact assessment processes have little bearing on decision making.

In this context, a review of Mekong hydropower governance found four key sets of development and governance issues (Foran *et al.* 2010b), which together define the "Mekong hydropower regime:" (i) resilience of the Mekong's aquatic ecosystems, in particular its fisheries, which are uncertain but expected to decline as more dams are built throughout the region; (ii) structure of the electricity industry, in particular an electricity supply chain dominated by monopolistic state utilities, in which willingness to pay, consumer choice, and awareness of sustainability issues are limited; (iii) hydropower host country regulation, which has limited accountability to citizens and is constrained in terms of technical and legal enforcement capacity; and (iv) "bottom-up" river basin development, where a range of project sponsors or proponents (multilateral and private financiers and developers), confront relatively weak state regulatory practices. Among various project sponsors, we can detect higher- and lower-risk project design and investment decisions with respect to environmental and social impact mitigation.

[6] In the United States, participation in the affairs of energy organizations occurred as a response to crisis in public utility financing, in the wake of the first and second oil crises.

4.2 Options

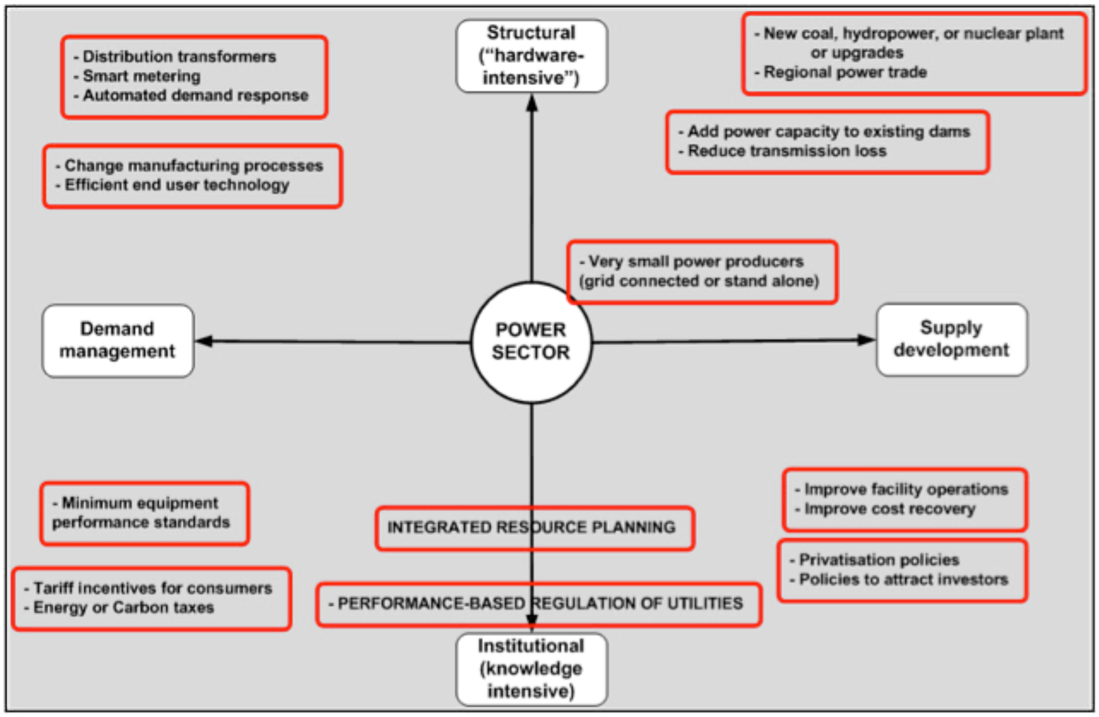
Decision makers are increasingly aware that a range of options exists (Figure 1). Such increasing awareness has many influences, including the explosion of interest in renewable independent power producers (IPPs), the international awards won by Lao-based entrepreneurs for solar home systems, the success of demand-side management programs, local resistance to the siting of large power stations in Thailand, international debates over Mekong mainstream hydropower, and anxiety about the safety and cost of nuclear power post-Fukushima. Furthermore, decision makers, even those with minimal exposure to global climate change policy discourses, would be aware of international efforts to limit the emission of greenhouse gases to 450 ppm in an attempt to avoid dangerous climate change. In this context they are likely to be aware of calls for, as the International Energy Agency (IEA) puts it, a "transformation" of energy systems (IEA, 2009).

Although options exist, combining them into coherent portfolios that expand and evolve over time is no small task. The energy system includes both stationary uses (e.g., process heat, space cooling, industrial motors) and transport uses. Both uses have been dominated by fossil fuels (although noncommercial biomass is actually a leading source of total primary energy supply) and centralized grids.

The complexity of energy options has increased in recent years, due to falling costs of new technologies, rising oil prices, hybrid architectures, the desire to limit negative impacts on ecosystems, and the recognition of renewable energy as an alternate and viable source of employment.

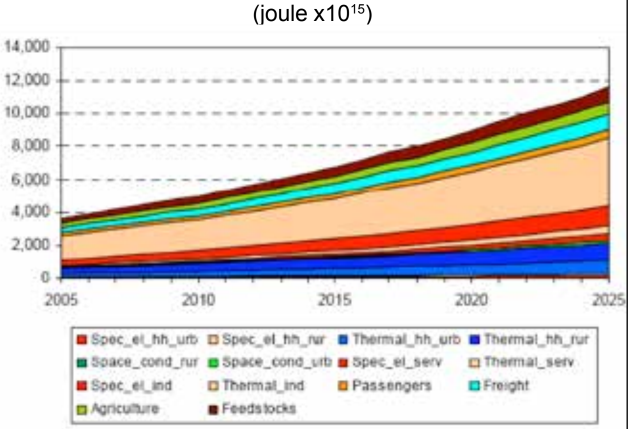
To deal with such complexity, planners have thus far established separate plans or strategies for electric power and transport energy. (No unified energy master plan exists capable of actually allocating energy sources to all of the above end-uses in Figure 2). Multiple options, whole-of-energy-system analysis, if done transparently, would assist in identifying additional pathways. Such analysis is constrained by timing imperatives, resources, and data requirements. It is further constrained by planners' belief systems (i.e., the technical preferences discussed above, as well as restricted planning mandates. For instance, energy planners do not dictate future national industrial policy, even though the latter will influence energy demand).

Figure 1: Examples of Options for Energy Services Development



Source: after Practical Action Consulting (2006).

Figure 2: Mekong Useful Energy Demand, 2005–2025
(joule x10[15])



Source: IRM-AG (2008, p. 96). Notes: el = electricity; hh = household; urb = urban; rur = rural; space_cond = space conditioning; serv = service sector; ind = industry.

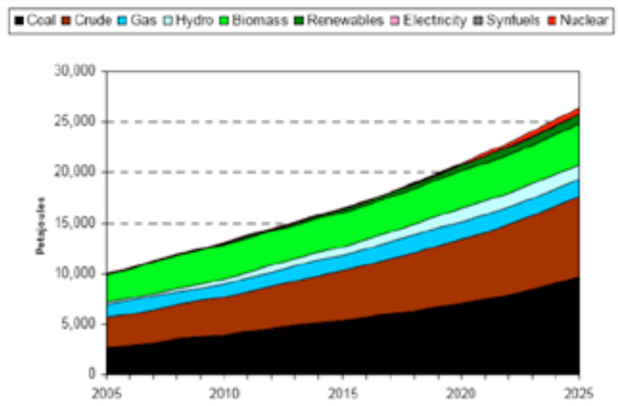
Thus, the most holistic or transitional energy planning tends to be the specialty of academic and international organizations, such as the IEA, while strategic planning by energy operators tends to be more incremental in nature. Figures 3A and 3B show two different perspectives on how the ASEAN or GMS energy systems might evolve.

Figure 3A is from IRM-AG (2008). Commissioned by ADB, this analysis shows Mekong final energy demand by generation source. The trajectories include an estimate of environmental and social damage costs (Nilsson, 2008) and include $/ton estimates for emissions of carbon dioxide (CO_2), methane, nitrous oxide, nitrogen oxides, and sulfur dioxides, as well as $/MWh estimates of damages from hydropower (IRM-AG, 2008, pp. 50–51). The environmental and social costs were introduced incrementally, adding 10% of the full estimated cost per year over a 10 year period beginning 2005. According to IRM-AG, the average price of energy after internalizing the damage costs was approximately 15% greater than not internalizing. This scenario also assumed a -0.20% price elasticity of demand. Accounting for these costs results in a reduced total demand of <5%). The inclusion leads, in particular, to the reduced use of coal, oil, and synthetic liquid hydrocarbons in the least-cost fuel mix, and increased use of bio-fuels, coke,[7] LPG, and natural gas (IRM-AG, 2008, Table 140).

The direct effect of including environmental and social costs on the entire energy portfolio is to add $13 billion

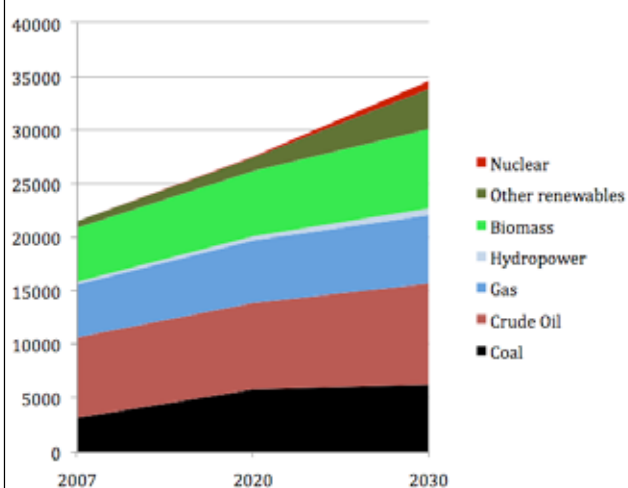
[7] A by-product of heating coal, which can be further used for industrial (and household) heating.

Figure 3A: Mekong Primary Energy Demand, 2005-2025 (joule x10[15]), ADB "Low Carbon" Scenario



Source: IRM-AG (2008, Fig. 100).

Figure 3B: ASEAN Primary Energy Demand, 2007–2030 (joule x10[15]), IEA 450 Scenario



Source: Authors based on IEA (2009, Table 15.12).

dollars to the discounted total portfolio cost of $1,072 billion (IRM-AG, 2008, p. 227).

By contrast, the IEA's so-called 450 Scenario (Figure 3B), produced after the 2008 financial crisis, assumes that countries worldwide implement a number of country-specific policy measures, such as implementing building and appliance efficiency standards (IEA, 2009, Chapter 5). It further assumes all countries implement fuel efficiency (and carbon emission) standards for new light-duty passenger vehicles, with different average targets established for each world region. The PRC is considered part of the "other major economies" (OME) region; the other Mekong countries are classified as "other countries." A similar agreement is assumed to be implemented for the cement, and iron and steel industries.

For power generation, the "other countries" are assumed to make similar, independent decisions to invest more heavily in renewables, nuclear, and hydropower, selling their emissions reductions to regions of the world that are assumed to adopt formal binding reductions targets (i.e., the Organisation for Economic Co-operation and Development [OECD] and, after 2021, the OME).

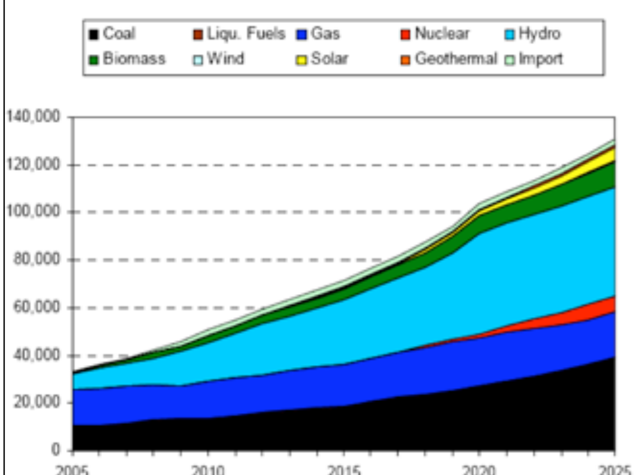
Although world events since 2009 have diverged from the modeling assumptions, the 450 Scenario illustrates one broad strategy to stabilize atmospheric CO_2 to a level believed to provide a 50% chance of limiting global average temperatures to 2°C. Comparing Figures 3A and 3B we see that the 450 Scenario (3B) projects greater expansion of biomass energy, while slowing the rate of increase for coal, oil, and gas energy. The main difference between the IRM-AG and the IEA modeled cases is that the latter is linked to an assumed global 450 parts per million (ppm)-CO_2 constraint whereas the IRM-AG work is not.

Figure 4 (from IRM-AG, 2008) illustrates the estimated proportions of power generation sources, for the case where environmental and social costs have been included. According to IRM-AG, the effect of internalizing those costs results in significantly less use of coal and biomass, significantly greater use of hydropower, natural gas, and solar energy, and only significantly less use of nuclear power.

4.3 Energy Development Pathways

Notwithstanding the lack of comprehensive energy decision making, relatively rapid growth in the region

Figure 4: Estimated Wider Mekong Region Power Generation Mix, 2005–2025 (MWyear)



Source: IRM-AG (2008, Fig. 99).

Table 3: Examples of Energy Path-Setting Activity

Country/Region	Activity (Targets, Plan, Market)	Policy Frameworks, Instruments, and *Complications*
People's Republic of China	*Electric power*. Target: 362–500 GW renewable power capacity by 2020 (representing 23% to 32% of 1600 GW expected total capacity in 2020), of which: hydropower 300 GW; wind 150 GW; biomass 30 GW; solar photovoltaics 20 GW (Martinot, 2010)	Renewable Energy Law 2005 (revised in 2009) Increased feed-in tariffs for wind and biomass Renewable power purchase obligations for utilities *Needs enabling investment in energy storage systems* (Martinot, 2010)
Regional	*Integration*. Visions: Trans-ASEAN Gas Pipeline Infrastructure Project (series of gas pipelines connecting 10 countries); ASEAN/GMS power grid (ADB, 2009; IEA, 2009; Sovacool, 2009) *Domestic biogas for cooking*. Market: Estimated 360,000 households linked since 1989; additional 1 million planned by 2015 (SNV, 2011) *Multi-scale rural electrification*. Vision: public private partnership business model to deliver services to rural households, funded by independent trust fund (Henschel, 2008)	*Needs harmonization of national rules and standards* *Estimated energy investment required GMS is $15.6 billion (ranging from 0.6% to 8.5% of members' long-term GDP)* (ADB, 2009) *Transnational gas and power grid will require much more explicit consideration of opportunity costs, and of economic and social risks* (Sovacool, 2009)
The Lao PDR	*Large hydropower*. Market: 23 hydropower projects either in advanced planning or under construction. Another 45 preliminary agreements signed with developers. Hydropower revenues projected increase to 4% of GDP by 2024 (Foran *et al.*. 2010b; World Bank, 2010) *Pico-hydropower*. Estimated 60,000 units exist but overlooked by mainstream energy planners (Smits and Bush, 2010)	Commercial project development framework supplemented by environmental impact assessment mechanisms *Needs process to screen high-risk projects at early stage greater transparency in awarding concessions and greater implementation capacity* (World Bank, 2010)
Thailand	*Total primary energy*. 14.1% renewable share of total final energy demand by 2022 (of which 7.6% thermal energy; 4.1% biofuels; 2.4% electric power) (Sutabutr, 2009) *Transport*. 4.5 million liters per day of B100 biodiesel, and 9 million liters of ethanol by 2022 (IEA, 2009, Table 15.9) Potential to set a 33% ethanol blending mandate by 2018 (Damen, 2010) *Electric power*. Reduce natural gas share in fuel mix: GWh from coal (26.6%), imported power (11.3%), and nuclear (11%) (EGAT, 2010b)	Feed-in tariffs Multi-stakeholder consultation around 15-year renewable energy and biofuels target-setting (Sutabutr, 2009)
Viet Nam	*Total primary energy*. 5% renewable share of total commercial primary energy by 2020: giving priority to small hydropower and biomass renewable power (Ölz and Beerepoot, 2010, p. 50) *Electric power*. 100+% increase in total hydropower capacity to 20,178 MW by 2025 (Soussan and Nilsson, 2009) *Transport*. 5% of gasoline and oil demand met by biofuels (Ölz and Beerepoot, 2010, p. 50)	Use of strategic environmental assessment in power development planning

Source: Authors, based on above references plus interviews.

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means that we can identify key energy development pathways that are likely to have ramifications not just for energy but also for food, water, and livelihood systems (Table 3). This section reviews hydropower generation in the Mekong. The development and operation of large-scale hydropower resources benefits power producers in Cambodia, the Lao PDR, Myanmar, and Viet Nam, and electricity consumers in Thailand and Viet Nam.

A second energy pathway involves expanding the production and consumption of bio-energy, for heating energy, electric power, and transport (in increasing order of value). Detailed pathway analysis for bio-energy with implications for food and water security is currently being undertaken as part of the Exploring Mekong Futures project (Smajgl *et al.*, 2011; Foran, forthcoming).

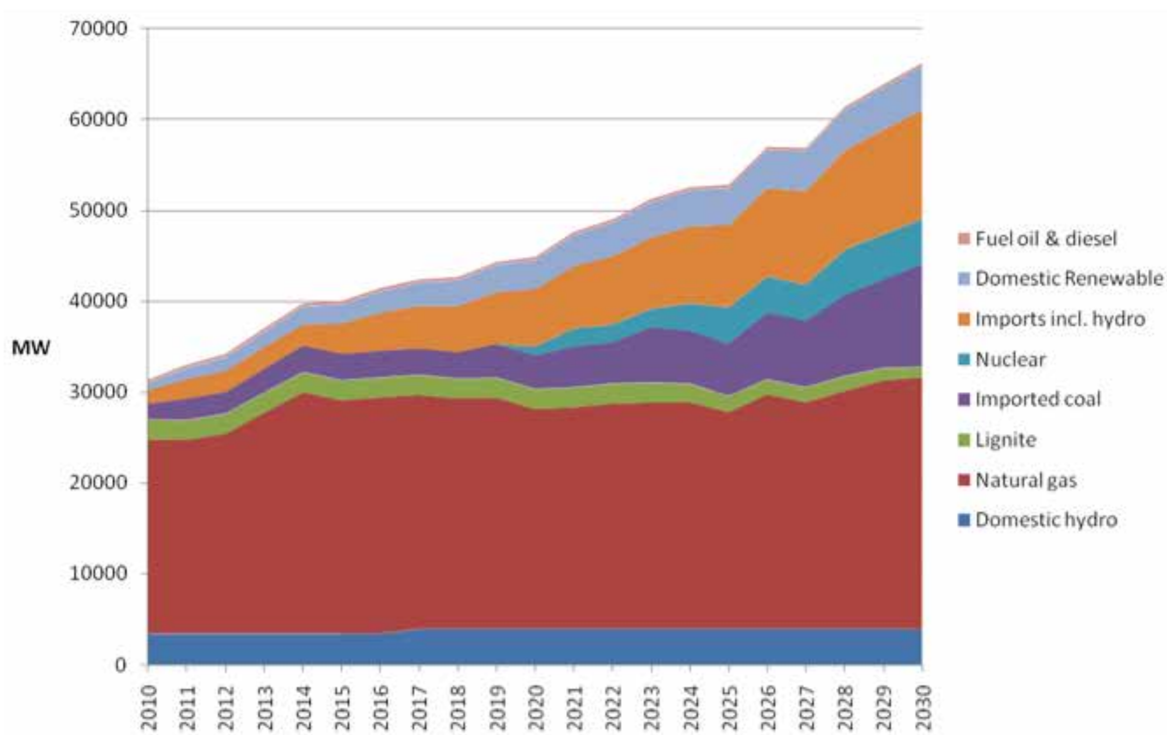
The pathways are quite different in terms of their social dimensions. Large hydropower development, for instance, has higher barriers to entry than bio-energy production. For instance, it requires the negotiation of exclusive rights to develop water resources in a specific river basin, which yields economic rent (above average profit) to the developer. By contrast, most Mekong bio-energy, whether crop based or residue based, is presently sourced from smallholder farmers. Thus, a much greater number of producers (and decision makers) is involved in the supply chain than is the case for hydropower. If sugar cane, cassava, and oil palm plantations were to expand in Cambodia, the Lao PDR, and Myanmar, in a manner characterized by land alienation, it could result in loss of food and energy security. Dispossession has been documented by (Baird, 2009) for rubber in the southern Lao PDR; however, rubber is a higher return crop than all of the above (Damen, 2010).

4.4 Hydropower Pathway and the Consequences on Energy Configurations

Figures 3 and 4 illustrate that large-scale hydropower can be found in the power development pathways of all countries in the region. This section focuses mainly on technical and political impacts of hydropower expansion on the energy system.

Hydropower enables substitution of natural-gas powered end-uses. For energy security of supply reasons, Thailand has a policy of diversifying its power generation fuel mix away from natural gas (Figure 5). The Thai power system turns mainly to imported coal, imported power (orange shape), and nuclear (Figure 5).

Figure 5: Fuel Mix in 2010 Thailand draft Power Development Plan



Source: Based on data from EGAT (2010). Note: Legend reads from bottom to top (domestic hydro at bottom). Fuel oil and diesel is a very small contributor.

According to EGAT's 2010 power development plan, Thailand plans 11,459 MW of imports (EGAT, 2010a). Most of these projects are not yet specified by name or fuel, but based on precedent and preliminary development agreements in the Lao PDR, most are likely to be hydropower (Foran *et al.*, 2010a).

Conservation of natural gas would allow it to be strategically directed toward more high-value, and higher efficiency combined heat and power systems, marginally raising the energy efficiency of commercial buildings. Alternatively, if the same grade of gas used for power generation can be used as transport fuel, this would displace petroleum fuels, reducing transport sector CO_2 emissions.

Controversial nature of hydropower and large thermal power plants in Thai society. Large hydropower development, including schemes located outside the country, is politically controversial. Such controversy is open in Thailand but has also emerged among civil society and some state agencies in Viet Nam. Construction of new schemes is likely to spur transnational advocacy aimed at halting projects, and possibly even local resistance movements, especially for projects along the Thai-Lao or Thai-Myanmar border. Projects might face delays resulting in losses for developers and heightened reputation and political risk for financial sponsors. This combination of resistance and controversy could act as a force for improving the transparency and accountability of decision making around the Thai power system in particular, as well as strengthening calls for small-scale renewable alternatives.

Higher-order impacts of developing hydropower. Releases of peaking power could allow better integration of intermittent renewable energy (e.g., wind and solar). During construction, we can also expect a marginal increase in demand for transport energy required to build the schemes and industrial energy (e.g., demand for concrete, steel and other materials), with multiplier effects on the regional economy. If such demand increases lead to fuel price increases, this would have macro-economic impacts including increased incidence of income poverty.

Higher-order impacts of avoiding hydropower and natural gas. If decisions are made to avoid or postpone large hydropower projects at the same time as conserving natural gas for higher-value uses, this implies more demand and opportunity for energy efficiency measures, small domestic renewable energy, and large thermal plants. With new nuclear plants expected to be vigorously contested in Thailand, the second least-cost alternative for base-load power, from the financial perspective of mainstream planners, is imported bituminous coal. Smaller-scale commercial biomass is regarded as a higher per unit cost option. Coal plants could be sited inside Cambodia near the Thai border.

In summary, hydropower development is likely to contribute to a path-dependent trajectory, where expanding cross-border electricity sales provide electricity to customers who are willing to pay. The conviction that the GMS will benefit in aggregate economic terms from expanded energy trade has already stimulated a series of technical analyses by such agencies as ADB and ASEAN.

The effect of hydropower on this trajectory is mainly to substitute for the use of fossil fuel in the power generation supply mix. However, because Mekong mainstream hydropower development is especially controversial, a decision to proceed with all 12 mainstream projects—as well as domestic coal and nuclear projects—could trigger escalating political opposition demanding a re-evaluation of the dominant energy (socio-technical) regime. In Thailand and Viet Nam, this could lead to increased policy support for renewable energy and energy efficiency, potentially lengthening the already-long hydropower development life cycle, reducing financial returns to sponsors.

5. Connections of Mainstream Dams to Livelihoods and Food Security

Section 5 describes the interactions of hydropower electricity generation with livelihoods (focusing on occupation and income), migration and food security (emphasizing nutrition) in the Greater Mekong sub-region.

Osborne (2010) suggests that the livelihoods of 29.6 million people in Cambodia, the Lao PDR, and Thailand, as well as 14 million people in Viet Nam could be negatively affected if all planned Mekong mainstream dams are constructed. Results of the SIMVA (MRC, 2010a) survey supports the magnitude of estimated impacts, in which 93.3% of households stated that they consumed fish in the preceding week. Twenty five million people live in the 15 km corridor surrounding the Mekong River. Although dependency on fish increases with proximity to the river, the loss of fish affects households well beyond the 15 km corridor (Bouapao and Hall, 2010). About 80% of the fish sold in the local markets of Champasak in the Lao PDR

Table 4: Impacts of Mekong Mainstream Dams

Indicator	Occupation	Income	Food	Migration
Cambodia	No change	Decrease	Decrease	Increased migration into Thailand and Viet Nam
Yunnan, PRC	No direct trans-boundary impacts	No direct trans-boundary impacts	No direct trans-boundary impacts	No direct trans-boundary impacts
Lao PDR	No change	Decrease	Decrease	Increased migration into Thailand and Viet Nam
Myanmar	No change	N.A.	N.A.	N.A.
Thailand	No change	Negligible	Negligible	Negligible
Viet Nam	No change	Decrease	Decrease	Increased migration from Cambodia and the Lao PDR

are from the Khong District of the Mekong (Baird *et al.*, 2001). Twenty five percent of the total fish catch of Tonle Sap in Cambodia is consumed by local fishing households, indicating that most of the catch is for consumers located in centers beyond the lake boundaries, such as Phnom Penh (Hall and Bouapao, 2010).

According to the national consultation workshop on the proposed Xayaburi hydropower dam on the Mekong mainstream, held in Can Tho on 14 January:

> *The Workshop participants expressed their great concerns and worries about the possible impacts of the project on the productivity of the Mekong Delta and the livelihood of millions of people living in the Delta. Potentially [f]acing double impacts, from climate change and sea water level rise, and from the fast development in the Mekong upstream part, especially on the mainstream, the Delta would be adversely threatened by severe impacts resulting in the intrusion of saline sea water far into the inland, immense damage to the fisheries, declination of agro-productivity vital to millions and unpredictable degradation of the invaluable bio-diversity, cited most of the comments at the Workshop (Viet Nam National Mekong Committee, undated).*

5.1 Foreseeable Future Scenario

Based on the estimates of biophysical impacts detailed in the Basin Development Plan Programme, Phase 2 (Podger *et al.* 2004; ICEM 2010; MRC 2010, a,b,c), of all 12 proposed dams proceeding, the livelihood impacts are summarized in Table 4 and subsequently discussed.

5.2 Occupation

Based on the estimated loss of fish reported in the Basin Development Plan Programme, Phase 2 (MRC 2010a), if all dams are built, the overall loss to fish catch in the river and its floodplain is estimated to be 58% of the baseline yield of 593 thousand tons per year. By countries, the decline is 84%, 63%, 41%, and 40% for the Lao PDR, Cambodia, Thailand, and Viet Nam, respectively. This alone does not indicate that fishing households would give up fishing. The SIMVA results (MRC, 2010a) show that 37% of fishing households would give up fishing if the daily catch was less than 1kg. Estimates of fish catch based on the SIMVA data indicate that the decline in all countries does not reduce the catch below 1kg per day. This implies that the number of fishing households in Cambodia, the Lao PDR, Thailand, and Viet Nam would remain stable.

However, by 2030 the proportion of fishing households would decline due to the combination of population growth and further decline in fish. Observations made in the context of tributary dams such as Pak Mun indicate a decline in fish catch of 50%–100%, resulting in a drop of fishing households in areas upstream of the dam ranging from 66.7% to 95.6% (Amornsakchai *et al.*, 2000).

5.3 Food security

The estimated loss of fish due to expected dam construction and operation will result in less food availability. The average calorie intake in the Tonle Sap area in 2009 was 2,121 calories per capita per day, of which fish contribute 335 calories or 16%. A 63% reduction of the fish catch would reduce daily per capita calories to 1,910 (Table 5). This is less than the regional recommended minimum of 2,100 calories.[8] Moreover, fish contain essential micronutrients not found in rice (or other staple food crops), as well as fatty acids that are essential for the development of the brain and body. Other sites will

[8] FAO standard, as supplied by the National Statistics Office of Lao PDR.

Table 5: Calorie Intake by Study Sites

Study Sites	Fish Intake, 2009 (calories)	Total Calorie Intake, 2009	Decline in Fish due to 12 Dams (%)	Impact (calories)
Tonle Sap Lake, Cambodia	335	2,121	63	1,910
Siphandone, Lao PDR	300	3,171	84	2,919
Chiang Saen and Udonthani, Thailand	281	2,471	41	2,356
Mekong Delta, Viet Nam	301	1,864	40	1,744
Total	**303**	**2,407**	**58**	**2,231**

Source: Hall and Bouapao (2010).

Table 6: Income Per Capita per Day

Study Sites	Per Capita Income per Day ($)	Fish Contribution ($)	Decline in Fish Due to 12 Dams (%)	Impact ($)
Tonle Sap Lake, Cambodia	1.02	0.36	63.0	0.80
Siphandone, Lao PDR	1.43	0.08	84.0	1.36
Chiang Saen and Udonthani, Thailand	3.48	0.01	41.0	3.47
Mekong Delta, Viet Nam	1.57	0.05	40.0	1.55

Source: Hall and Bouapao (2010).

also be affected, including the Mekong Delta, where the total daily calorie intake in 2009 was only 1,864 calories per capita.

The total catch from hydropower reservoir fisheries is expected to increase by 10,000–30,000 tonnes or $40 million (MRC, 2010a,b). These gains are offset by estimated reductions in the Mekong capture fishery, currently estimated at 2.1 million tonnes or 22% of world freshwater fisheries. The 2030 scenario without Mekong mainstream dams will reduce the Mekong fishery by 210,000–560,000 tonnes/year (10%–27% reduction) and the development of the 12 mainstream dams will cause additional losses of 340,000 tonnes/year ($476 million) or another 17% of the total catch. Aggregate reservoir fisheries could compensate for approximately 10% of the lost capture fisheries production predicted without mainstream dams. The effects of upstream changes on the Mekong marine fishery are not certain (currently estimated at 0.5 million tonnes/year or replacement value of about US$ 40 million): the multiplier effects on other subsectors, such as boat and fishing tackle manufacture, salt and ice production, and fish processing, estimated at $2–4 billion (MRC, 2010a), also remain uncertain.

5.4 Income

A 63% loss in capture fisheries would have considerable impact on the income of people in the Tonle Sap area. The SIMVA results (MRC, 2010a) show that the average per capita income in the Tonle Sap area was just slightly above $1 per day, less than the current World Bank poverty line of $1.25/day, while US$2 per day is recommended as a more realistic number for development planning.[9] Income from fish and other aquatic organisms contributes 35% to household income. A 63% loss of fish results in an average household income of less than $1 in Tonle Sap (Table 6). In the Thai sites, however, the share of income from fish in the total income is small and there is likely to be very small impact on income.

The projected losses of agricultural lands, riverbank gardens, and biodiversity will further deteriorate food availability and reduce income. With the estimated losses in these resources, it is likely that there will be increased reliance on aquatic organisms, which have been traditionally used during the dry seasons and drought years, when less fish are available (Balzer *et al.*, 2005)

However, in the Mekong Delta, the potential increase in dry season flow may reduce salinity, hence increase rice yield. This could lead to an increase in income from rice production.

5.5 Migration

Losses in access to fish, riverbank gardens, and inundated agricultural areas will be important push factors for migration from rural to urban areas and from Cambodia and the Lao PDR to Thailand. Observations from such cases as the Pak Mun dam (Amornsakchai *et al.*, 2000) show that members of households affected by the loss of agricultural

[9] World Bank (2004), Millennium Development Goals, http://web.worldbank.org/WBSITE/EXTERNAL/EXTABOUTUS/0,,contentMDK:20104132~menuPK:250991~pagePK:43912~piPK:44037~theSitePK:29708,00.html. Accessed on 25 August 2010.

lands, riverbank gardens, and fisheries are likely to migrate to either urban areas or to forest reserve areas (or other common properties), because compensation may not be enough to buy alternate land. These groups will become more acutely vulnerable because of the partial sale of their livelihoods assets due to the shift from farm-based occupation and decline in grazing lands. It is also likely that by 2030, people in Cambodia and the Lao PDR will migrate to Viet Nam for wage employment.

6. Connections of mainstream dams to water security

Section 6 reviews the current literature concerned with the potential consequences of hydropower dam construction and operation inclusive proposed irrigation diversions. The discussion focuses on changes to in-stream sediment and nutrient loads; mainstream wet and dry season hydrological characteristics; and the volume, timing and duration of flood pulses (emphasizing the aquatic environs of the Tonle Sap lake).

The MRC (BDP, 2003) and Pech and Sunada (2008) estimate that by 2025, irrigated agriculture water use will account for about 22% (104,503 [million cubic meters MCM) of the average annual discharge of the Mekong River and about 25% to 30% by 2050 depending on irrigation scale and intensity. Despite estimates of total irrigation demand in the MRB being substantially less than average annual river flow, the estimates neglect uneven distribution of flow in time and space inclusive of flow fluctuation between wet and dry seasons, and from wet year to dry year (BDP, 2003; Pech and Sunada, 2008). In addition, sufficient flows are required to maintain the function of aquatic ecosystems and aesthetic/recreational purposes (Ravenga and Mock, 2000).

Davis (2003) estimated that by 2025 the share of domestic and industrial uses will constitute about 14% and 21%, respectively, of total water withdrawals in Southeast Asia. MRC (2010) estimates domestic and industrial water consumption in the Mekong Basin at 2,773.58 MCM, which is less than 1% of the average annual Mekong flow. The 2050 domestic and industrial water demand is projected to increase to about 11.5%–15.5% of the total average annual Mekong flow (BDP, 2003; Pech and Sunada, 2008). Despite modest demand by current domestic and industrial water uses, aggregate water demand when combined with agriculture will constitute 32%–50% of the total annual flow by 2050 (ibid). This will further increase the competition for water resources during the low flow conditions of drier and driest years.

By 2030, the dams in the Mekong tributaries will have a substantial impact on mainstream river flows and alter the hydrological regime of the entire MRB (MRC, 2010). Active water storage will potentially increase by 700% from 9.9 to 69 km^3 and about 23.7 km^3 or 36% will be within Yunnan Province, mainly from its two largest hydropower dams that have an active storage of about 22.2 km^3 (MRC, 2010b). With the construction of the 11 lower basin mainstream projects, 55% of the total length of mainstream stretch between Chiang Saen (Thailand) and Kratie (Cambodia) will be converted to reservoirs and transform the river into a series of managed impoundments with slow water movement, interspersed with rapid and broad flow fluctuations in response to dam operations (ICEM, 2010).[10] The reduced flood season flows would reduce the extent and duration of the inundation of floodplains and contribute to bank erosion on the critical stretches and infilling of deep pools (MRC, 2009).

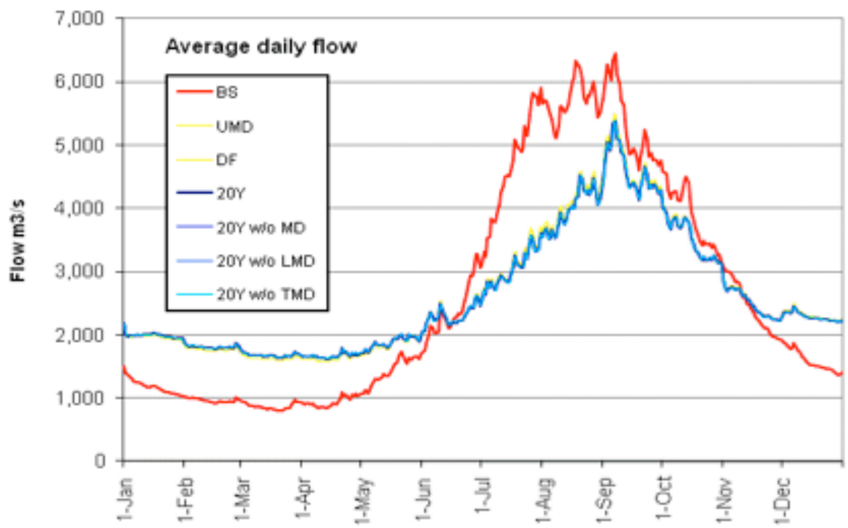
The operation of the mainstream dams can cause significant downstream fluctuations during any one day if they are operated as peaking projects. In this case, water level fluctuations locally may amount to typically 2–4 m or more in extreme cases (MRC, 2010C)[11]. This may have severe implications for local navigation and riverbank gardening.

The increase in dry season flow is estimated to be able to meet a planned increase in irrigation abstractions over current levels depending on location along the mainstream. The construction of dams in the PRC is expected to cause a dramatic increase in mean minimum annual dry season flows at all stations, except for Kratie. Dry season flow increases by 70% at upstream stations, and 10% at the Mekong Delta. The flow increase is lowest in the Mekong Delta where the dry season irrigation demand is highest. About 54% of the riverbank gardens along the mainstream stretches from Chiang Sean to Kratie will be flooded due to higher low flows and reservoir inundation (Ward, P., personal communication).

[10] Ward P, 2010. Power Point Presentation at Regional Consultation Workshop of June 2010: About 66% of the total 1,760 km river distance, Sambor dam (Kratie) site to the upper end of Pak Beng reservoir, will be affected.

[11] Ward P. 2010. Personal communication: The time elapse for a rapid fluctuation from opening the turbines—planned and unplanned circumstances, and breakdowns of plant and electrical transmission systems at the proposed Luang Prabang dam site, will be about 1.0–1.5 hours to the city of LuanPrabang, very little warning time for bank-side residents to prepare for inundation.

Figure 5: Changes in hydrology at Chiang Saen



Source: MRC (2010b).

The increase in dry season flow means more water for irrigation, water supply, and other uses, but expansion and consolidation of agriculture and irrigation will also lead to increased use of chemical fertilizer to offset loss of nutrients and sediments. The production costs of water fees, production inputs, and labor will be potentially much higher.

The change in water surface area will cause a substantial seasonal redistribution of flow from the wet season to the dry season and reduce sediment transport in the Mekong mainstream, especially in the area above Vientiane (MRC, 2010c). The reduction in the maximum water level and an increase in low flow will be observed in the next decades, associated with water storage in large capacity reservoirs. As a result, the overall flow will be smoother, especially in the transition to the flood season (ICEM, 2010).

The onset of the transition from dry to flood season will be significantly reduced by 7-8 weeks earlier in Chiang Saen,[12] 2–4 weeks earlier upstream of Pakse and 1 week at Kratie. This change will see a reduction in the important freshwater 'spates' which drive many ecosystem functions such as fish spawning, larvae dripping, and fish migration.

There has been substantial debate about the roles of reservoirs in regulating flood peak flow ("downstream flood benefit"). Mainstream dams would provide some level of flood protection immediately downstream of the site only (MRC, 2010b, 2010c, 2010d). The peak daily flows will be reduced by -18% (1,100 cubic meters per second [m^3/s]) at Chiang Saen, 15% (-2,381 m^3/s)at Vientiane, 7% (-3,456 m^3/s) at Kratie, and only 4% (-855 m^3/s) in the Mekong Delta in Viet Nam (Tan Chau). The flood reduction functions of the dams may cause a false sense of security in the face of historical floods (100–500 year recurrence floods) and dam failure due to earthquakes. Records from around the world indicate that flood protection (which does not bring in revenue) tends to be neglected in multipurpose projects (Regional Panel of Experts 2010).

There will be an overall 7% reduction in flooded area (309,000 ha) in an average rainfall year. The reduction areas are expected to be smaller in wet years and larger in dry years. The greatest area of reduction occurs in Cambodia (142,000 ha), the Lao PDR, and Thailand (17% and 19% reduction, respectively) (MRC 2009, 2010d).

The 2030 dam development scenarios will result in significant changes in the ecology of Tonle Sap. Lake inundation is predicted to be reduced by 5%–10% (500–600 km^2); the reverse flow in the Tonle Sap river will start at least a week sooner, and the average number of days of reverse flow 8 days shorter. The area of dry season inundation is estimated to increase by 5%–8% turning a seasonal terrestrial ecosystem into a permanent aquatic ecosystem. These changes will affect ecosystem and farming productivity, fish migration, and sediment flushing capacity. The decrease in reverse flow volume to Tonle Sap will result in a reduction of flooded area, flood depth and duration, and a reduction in sediment inflow into

[12] MRC (2010b): At Chiang Saen, peak daily flows will be reduced by 18% (1,100 m^3/s), and dry season flow volume will be increased by about 61% (12,093 MCM); peak daily flows at Kratie will be reduced by 7% and dry season volume will be increased by 23%.

Table 7: Summary of Impacts on Water Sector from 12 Mainstream Hydropower Dams

Water indicators		Estimated changes
Hydrological changes	Water level	Development sector alters the hydrological regime of the entire MRB; active storage increases from 9.9 to 69.8 km^3
	Flow level in dry season at specific locations	Dry season flow increases by 70% at upstream stations and 10% at the Mekong Delta
	Flood timing	Reduction in the onset of dry to flood transition; 7-8 weeks earlier at Ch Saen, 2-4 weeks earlier at Pakse, 1 week at Kratie
	Flood duration	Will affect upper reaches of the lower basin above Pakse and Vientiane
	Flood level and area	Flow decrease by 18% at upstream stations and 2% at the delta; corresponding reduction in flood area
	Reverse flow/water level in Tonle Sap	Reduction in duration and volume of the reverse flow
	Inundated area, duration, and timing	Dry season inundation area increased significantly
	Storage	700% increase in the active storage volume
	Change in water quality (turbidity and relevant quality parameters)	7%-80% Reduced sediment transport. Loss of nutrients in floodplains and coastal estuary.
	Change in salinity intrusion – extent, duration, and concentration	5%-10% increase in flow, but subject to increased water diversion and sea level rise; salinity intrusion may increase.
Other water elements; geo-morphological changes	Barrier effects and dis-connectivity	37%-82% of waterways obstructed
	Sediment and nutrient from upper basin	Reduction in stream velocity and energy moving over stream bed and turbulent flow dissipation. 75%–81% reduction in sediment load
	Reservoir conditions	Changes in siltation and deltaic formation
	Downstream and critical deep pools and habitat	Downstream erosion and long-term impact on 48%–70% of deep pools. Loss of natural fertilizer and food chains
	Mekong Delta	Erosion instability of shore lines; cessation of land mass advances of 60–80 meters annually; annual erosion of 45 meters annually
	Coastal zones	Loss of nutrient and possible reduction in marine fisheries; effects uncertain.

Source: FAO (2004, footnote 12), report on the formulation of a national water vision to action in the union of Myanmar, Bangkok: Regional office for Asia and the Pacific. http://www.fao.org/docrep/008/ae546e/ae546e04.htm

the lake, as well as blockage of fish migration paths by mainstream dams (ICEM, 2010).

With mainstream hydropower power projects operating, there will be reduced water energy to suspend and transport particles, resulting in enhanced sedimentation, with the formation of deltaic type deposits at the head of each of the reservoirs, and middle and lower parts of each reservoir associated with reduced velocities/gradients (ICEM, 2010; MRC, 2010d). Only the load of suspended particles has been measured at several stations on the Mekong mainstream since the 1960s.

The dam development will also potentially reduce fine sediment transport by 70%–80%. (75%–81% reduction in sediment load from upper Mekong Basin (from 90 million to 20 million tons/year at Chiang Sean, and from 165 million to 88 million tons/year at Kratie) (Ward, 2010). The reduction will result in a significant loss of nutrients in floodplains and coastal offshore zones, affecting farming and fisheries within and beyond the Mekong basin as well as long-term changes to river beds and bank erosion. Reduced sediment loads pose a threat to the stability of delta shaping processes, which are potentially exacerbated by sea level rise.[13]

Navigability will be substantially improved with lower requirements for channel improvement to provide cheaper and more affordable means of transport. However, with proposed improvements in road and rail-links, river navigation is not seen as the highest priority. The 2030 dam development scenario will offset navigation benefits by introducing additional navigational barriers and dis-connectivity, because 37%–81% of the watershed is estimated to be obstructed.

[13] Loss of sand-sized sediments to the Mekong Delta and marine environment result in loss of nutrients (phosphates) to agriculture = 3,400 tons/year woth $24 million in replacement value/year, and reduction in nutrient loads to over 18,000 km^2 of Cambodia's floodplain and 5,000–10,000 km^2 of Mekong Delta floodplain and the Mekong marine sediment plume.

7. Connections of mainstream dams to land-use change

The MRC SEA report (ICEM, 2010) identifies increased irrigation area, and loss of forest, farmlands, and aquatic resources as the major land use consequences of mainstream dams.

The Pak Chom, Ban Koum, and Lat sua hydropower dams, located in Loei, Ubon Ratchathani provinces, and the southern Lao PDR, respectively, are planned river impoundments associated with irrigation schemes. The total irrigation area is anticipated to increase by 17,876 hectares primarily for either rice production or cash crops. Irrigation projects associated with the hydropower developments are projected to improve land productivity and rice production, resulting in an estimated increase of 77,701 tons of rice/year or a value of approximately $15.54 million/year (ICEM, 2010).

The loss of land is a direct consequence of hydropower projects. The MRC SEA report (ICEM 2010) shows that the construction of reservoirs, access roads, and transmission lines will result in the loss of approximately 30,886 ha of forest land (mostly degraded forest) and 15,786 ha of agricultural land, inclusive of 829 ha of irrigated land. The report estimates that 11,966 ha of riverbank gardens will be submerged by the reservoirs and wetland loss may amount to about 7% of the wetlands or 73,500 ha within a 50 km corridor of the mainstream Mekong.

Assuming current agricultural productivity levels, an equivalent area of land of similar agricultural potential will be required to maintain the living standard of affected communities that continue to practice farming livelihoods strategies. If the productivity of riverbank gardens is assumed to equate to 50% of farmland, 71,769 ha of replacement farmland will be necessary to maintain current levels of agricultural production.

The potential of hydropower generation in Myanmar is estimated at 39,624 MW compared with 30,000 MW (MRC, 2010a) in the lower Mekong Basin. Based on the previous assumptions, the potential for land use change due to the development of reservoirs would approximately double if the full potential of hydropower generation in Myanmar were to be developed.

8. Conclusion

The past 40 years have provided conditions that promote increasing connectivity of the political economy and economic sectors of Mekong riparian countries. Despite periods of political and economic turbulence, the Mekong River has acted as a conduit of relatively stable cultural, economic, agricultural, and spiritual connection across the countries. The three enabling conditions central to the degree of regional connectivity are (a) the endowment, scarcity, and accessibility of resources within the connected region; (b) the financial capacity to activate these resources as production factors; and (c) the institutional conditions enabling resource transfers to occur.

The financial strength of Chinese, Thai, and Vietnamese private and state companies, a reduced reliance on traditional donors, human migration, natural resource flows, and direct foreign financial investments are amongst the factors cited that influence the critical dynamics generating increased levels of connectivity between Mekong countries. High levels of connectivity increase complexity, biasing the reliability of predicted development outcomes and increasing the potential for unforeseen consequences of national decisions. Strong connectivity implies that interacting factors transmit the effects of substantial development decisions at multiple spatial and temporal scales and across multiple sectors. This paper focuses on the connectivity or nexus of water, food, and energy security because these are jointly articulated as crucial policy objectives of Mekong region countries.

The construction of proposed Mekong River mainstream dams, primarily for hydropower electricity generation has diverse consequences on food and water security, livelihoods, and land-use change across the Mekong region countries. Occupations are predicted to remain relatively unchanged in all the countries. Income, food security (using nutrition as a surrogate metric), and migration levels are estimated to remain relatively stable in Yunnan Province and Thailand. Income and food security are predicted to decrease in Cambodia, the Lao PDR, and Viet Nam. Migration from the Lao PDR and Cambodia into Thailand and Viet Nam is estimated to increase.

Mainstream dams are predicted to have substantial and prolonged consequences on Mekong water resources and security. Predicted hydrological changes include altered flow regimes caused by the construction and operation of mainstream dams, as follows:

- Active storage increases from 9.9-69.8 km^3, altering the hydrological regime of the MRB.
- Dry season flow increases by 70% at upstream stations and 10% at the Mekong Delta.
- Reduction in the onset of the dry to flood season transition.
- Reduced flood area correlated to a flow decrease by 18% at upstream stations and 2% at the delta.
- Reduction in duration and volume of the Tonle Sap reverse flow.
- Dry season flood inundation area increased significantly.
- 70-80% reduced sediment transport; loss of nutrients in floodplains and estuarine sedimentation.
- Subject to increased water diversion and sea level rise, salinity intrusion estimated to increase.
- 37%–82% water ways obstructed, limiting navigation.
- Reduction in stream velocity and energy moving over stream bed and turbulent flow dissipation.
- Downstream erosion and long term impact on 48%-70% of deep pool habitats and a loss of natural fertilizer and food chains.
- Changes in siltation and deltaic formation in reservoirs.
- Increased erosion instability of delta shore lines.

The additional irrigation area associated with dam construction is anticipated to increase by 17,876 hectares, primarily for either rice production or cash crops, resulting in an estimated increase of 77,701 tons of rice/year or a value of approximately $15.54 million/year. Land loss also occurs as a direct result of dam construction. Assuming current agricultural productivity levels, 71,769 ha of replacement farmland will be necessary to maintain current levels of agricultural production and maintain the living standards of affected communities that continue to practice farming livelihood strategies.

We have attempted to account for high levels of connectivity and describe a partial cross-sectoral assessment of development-directed investments in the wider Mekong region. We have argued that increasing energy demand and national objectives of energy security are central to, and catalyze, economic growth imperatives. We have also provided a review of evidence that supports a position of a strongly connected Mekong region.

Contingent on a strongly connected region, reliance on a singular, linear appraisal of energy security policies that fail to account for the consequences on food and water security is likely to overestimate the probability of satisfying policy objectives and underestimate the subsequent social cost. The singular achievement of national energy security objectives may mean either substantially compromised regional energy security or introduce unforeseen impediments to meeting articulated food and water security objectives at both national and regional scales.

Analysis of alternate energy pathways to reveal the magnitude of connectivity with the food-water security nexus is the subject of ongoing research.

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WATER RESOURCES MANAGEMENT IN THE GREATER MEKONG SUBREGION: LINKAGES TO HYDROPOWER PLANNING FOR A SUSTAINABLE FUTURE

Jeremy Bird[1]

Abstract

Challenges for water resources development in the Greater Mekong Subregion (GMS) are increasing as populations rise and rapid economic growth stimulates aspirations for better standards of living and higher levels of consumption. The linkage between growth and degradation of the natural resource base of the region has to be addressed if future demand is to be met. Fortunately the levels of water stress in the GMS are not as acute as in many other parts of the world, yet competition for water does exist and increases in productivity will be required. Cumulative impacts on water availability, water quality and aquatic ecosystems are apparent and the prospect for further deterioration is high given the rapid scale of development. A major driver of change to water resources and the environment of the region is hydropower. Significant hydropower development potential exists and can be exploited sustainably provided changes are made to the way projects are planned and implemented.

The paper argues that achieving optimal outcomes and avoiding unintended consequences requires lessons from within the region and beyond to be incorporated into regulatory and planning systems. There is space for a reinvention of 'master' or 'strategic' planning to achieve sustainability goals and a balance of development and protection. A combination of tools and methods exist to move beyond the current stepwise development model, including use of development scenarios, strategic environmental assessments, sustainability assessments and procedures to facilitate regional dialogue. The framework emerging from the Bonn2011 Conference on Water, Energy and Food Security Nexus identifies six opportunity areas to stimulate a more inter-connected approach. That framework is used to highlight what can be done to promote the sustainable development of hydropower and protection of vital ecosystems and livelihoods. Experience gained in the region and elsewhere demonstrates additional benefits can be achieved from a more inclusive and inter-linked approach.

1. Water resources – status and trends

Global assessments of water resources point to a situation of increasing scarcity and a widening gap between demand and supply. Estimates vary, but the trend is characterized by the report of the Water Resources Group (WRG, 2009) which projects a 40% shortfall in supply by 2050 even after measures to improve efficiency and manage demand have been implemented. Such stark assessments call for more sustainable approaches to water resources planning and management; ones that provide the foundation for economic and social development that is needed, while at the same time avoiding unnecessary conflicts arising over resource use and maintaining the integrity of services provided by aquatic ecosystems. It is an approach consistent with the concept of a Green Economy that aims to decouple resource exploitation and economic growth and move towards a situation where growth *'neither degrades the environment nor imposes costs on others'*, (UNEP, 2011).

Analyses by WRG and others provide a generic indication of stress, but more detailed national and sub-national assessments are needed to provide the basis on which responses can be formulated. Within the Greater Mekong Subregion (GMS), this is certainly true with wide variations in the distribution of water resources, in geography and climate as well as in the development status and aspirations of individual countries. For example, the basinwide analysis prepared by the Mekong River Commission (MRC) suggests that water is available for proposed future irrigation development without compromising other needs, (Lennaerts *et al*, 2012).

Differences exist also in the nature of the issues and challenges being faced and in the inter-connectivity and linkages between decisions in one sector and the consequences and constraints for another. This was recently demonstrated in the 2011 Bonn Conference on the Water, Energy and Food Security Nexus.[2] It argued that these inter-linkages need to be more openly considered and addressed at early stages of policy development and

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[2] See http://www.water-energy-food.org/

project planning, for instance, to avoid price subsidies in one area such as biofuels, having adverse effects on food security, (Rosegrant *et al*, 2012).

This paper starts with a brief summary of the water resources status and trends of river basins within the GMS area, moves on to examine some of the inter-linkages, particularly between energy and water sectors, and then identifies a number of approaches and tools from the region and elsewhere that embrace coordination and start to break down the 'silos' of sectoral thinking.

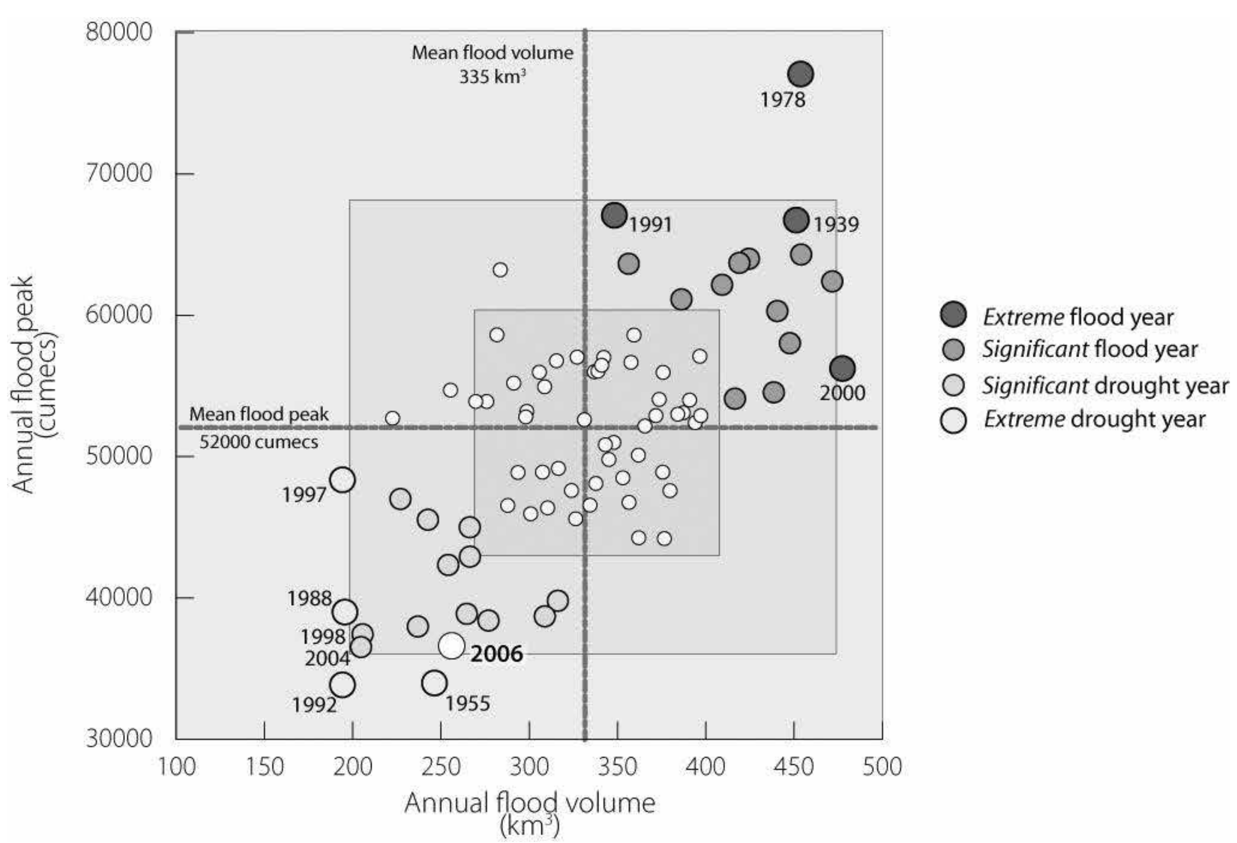
1.1 Overview of GMS Basins

Of the six river basins making up the GMS, two lie wholly within national borders, the Chao Phraya in Thailand and the Pearl River in People's Republic of China, while the other four are transboundary, the Salween, Irrawaddy, Lancang-Mekong and Red Rivers. Basic characteristics of the six basins can be found in the GMS Atlas of the Environment (ADB, 2012) and the MRC's State of the Basin Report, (MRC, 2010).

The Irrawaddy, Lancang-Mekong and Pearl rivers combined represent 85% of the annual river discharge of these six major rivers although the annual average figures mask a significant variability from wet to dry seasons and from year to year. The average wet season flow of the Mekong at its mouth is 52,000 m^3/s, 3.5 times larger than the average dry season flow of 14,500 m^3/s. Figure 1 shows the considerable variability in wet seasons from year to year with a minimum of about 33,000 m^3/s in 1992 to a high of 77,000 m^3/s in 1978 (Adamson *et al*, 2010). This existing natural variability is important when considering climate change adaptation.

Flooding is a frequent occurrence in the river systems of the GMS, both regional flooding in the mainstream rivers (MRC, 2008) and flash floods in the steep tributary rivers. The most recent experience was in the Chao Phraya basin in October/November 2011 in which areas of Ayuthayya and outer Bangok were inundated for weeks with the loss of more than 500 lives and major impacts on industries, agriculture and tourism. Similar extreme events were experienced in Bangkok in 1942, 1983 and 1995. The value

Figure 1: Variability of Mekong Flood Discharge and Flood Volume (Adamson *et al*, 2010)



of infrastructure and assets at risk is now considerably higher. The region is also subject to recurring drought, most recent of which was experienced in the upper part of the Mekong in early 2010 giving rise to regional tensions between upper and lower riparians, (MRC 2010b).[3]

Agricultural land is extensive in each basin and an important factor in the local economy and social fabric of what is still a predominately rural area. In the Lower Mekong, 75% of the population is rural. Agriculture is mainly rainfed, with irrigated land covering on average only 7% or about 15 million ha of the total basin area. This land is located mainly in the productive floodplains. The Chao Phraya basin is the most developed for agriculture with 12.5% of the basin area irrigated. Water withdrawals for agriculture dominate the total abstractions, for example in the range of 68 to 98% of all withdrawals for GMS countries compared to 1 to 26% for industrial uses and 1 to 8% for domestic uses (Johnston, 2012, Table 1). Total withdrawals remain relatively low at about 14% of total renewable water resources, but the rising trend is expected to continue in response to rising demand and agricultural intensification.

At the river basin scale, concerns on water availability in this tropical climate are less severe than in semi-arid regions, but they do exist at sub-basin levels. This was demonstrated in the experience of the Ping river, a tributary of the Chao Phraya, where conflicts between water uses led to mobilization of community action groups and subsequently formation of a river basin committee to resolve upstream – downstream management issues.[4]

Water quality similarly varies across the region from the largely good quality tributary upland streams to areas of high population density and industrial development where untreated wastewater is discharged directly into the river systems. Quality also deteriorates in areas of intensive agriculture and aquaculture where high rates of fertilizer and pesticide applications cause non-point pollution. Public information on water quality is becoming more available in a form that can be understood by non-experts as illustrated by publication of annual report cards for water quality and ecosystem health for the Mekong, (MRC, 2010c, 2010d). They provide a valuable tool to highlight year to year trends to decision-makers and stimulate further investigation and actions where quality is deteriorating.

Hydropower development has a major potential in the region both for meeting domestic demand and for generating export earnings. At the same time, the cumulative development of hydropower projects is a major driver of change for water resources. Although not a consumptive user of water, hydroelectricity generation can significantly alter river flow regimes on a seasonal and daily basis due to reservoir storage and peaking power releases, can reduce sediment flows downstream causing morphological changes in river profiles and can block migration routes for fish moving between upstream breeding grounds and downstream habitats. Measures to mitigate some of these impacts have been introduced on the Nam Theun 2 and Theun Hinboun projects. They include re-regulation reservoirs to smooth out daily peaks in flow, multi-level offtakes and aeration weirs to restore water quality, watershed management programs and support for livelihood development initiatives for affected people.

The GMS region is home to an incredible natural biodiversity both on land and in the rivers. WWF describes it as one of the most diverse on the planet where *"Since 1997, over 1500 new species have been described by science in the jungles, rivers and even urban areas of the Greater Mekong."*[5] The Mekong River is home to at least 850 species of fish, a significant proportion of which are long distant migratory species. Capture fisheries have an annual value of approximately $2.6 billion, (MRC, 2010 p98), and fisheries provide a significant part of the livelihoods of more than one third of the population and a significant protein for many more, (MRC, 2010e). The river is also home to iconic species including the Giant Catfish, Julien's Golden Carp and the Irrawaddy Dolphin.[6] Although the size of fish caught has been getting smaller and effort needed to catch them has increased, the overall biomass of the annual catch of more than 2 million tonnes is considered relatively stable.

Further information on environmental, social and economic conditions and emerging challenges is available in the GMS Environmental Atlas (ADB, 2012) and MRC's State of the Basin Report (MRC, 2010). Such state of the basin reporting provides an important step in making management information more accessible and could be a model for other basins in the GMS.

[3] See also BBC report on the 2010 drought at http://news.bbc.co.uk/1/hi/8603112.stm and WHO report on 2008 flood at http://www.wpro.who.int/sites/eha/disasters/2008/lao_floods/LAO_floods_18082008.htm

[4] See ADB Water Champions at http://www.adb.org/water/champions/jompakdee.asp

[5] http://wwf.panda.org/what_we_do/where_we_work/greatermekong/

[6] See WWF River of Giants http://wwf.panda.org/what_we_do/where_we_work/greatermekong/publications/?194324/River-of-Giants

1.2 Development opportunities and challenges

The discussion on meeting future food demands of an increasing population with changing dietary preferences is presented in GMS2020 by the International Food Policy Research Institute (Rosegrant *et al*, 2012) and the International Water Management Institute (Johnston *et al*, 2012). Policy and pricing reforms and an increase in productivity from rainfed and irrigated land are part of the recommendations. Countries of the region project an increase in irrigated land and demand for more irrigation water.

As part of a recent sector review, countries of the Lower Mekong Basin identified their projections of irrigation land to 2030. The irrigable area is expected to rise approximately 50% from approximately 4 million ha under the Definite Future Scenario to almost 6 million ha in the 20 Year future scenario, (MRC, 2010f, Table 2).[7] Most of the increase was projected in Cambodia, Lao PDR and Thailand, with irrigable areas in Viet Nam already being extensively developed. Although such estimates tend to be optimistic in timescale, there will be a progressive increase in demand for irrigation water from the current 12% of mean annual runoff to 20%. Any change in the dry season, when irrigation is needed most, could have a significant effect on the flow regime in the Mekong Delta and salinity intrusion which in turn influences crop production and availability of water for municipal purposes. In the case of the Mekong however, it is not a zero-sum game. The development of reservoirs on the Lancang in Yunnan is adding about 20 billion cubic meters of storage and, when released for hydropower generation in the dry season, will increase flows to downstream areas offsetting increased demand (Lennaerts *et al*, 2012).

According to the GMS Environmental Atlas, *'growth in energy consumption in the GMS has remained constant over the last decade, averaging at 5% per year between 1999 and 2009. Highest growth in energy consumption was in Guangxi (11%) and Yunnan (9%); energy consumption in the Lao PDR, Myanmar, and Viet Nam grew at an average of 5%, while in Thailand and Cambodia, increase in energy consumption was slightly slower at 4% and 2%, respectively'*,(ADB, 2012, Chapter 13). Still, about 74 million or 24% of the region's population lacks access to electricity and this remains a major development goal. Current development of hydropower in the GMS is 21GW out of an estimated potential of 248GW representing a significant future source of electricity. Biomass is widely used by over 50% of the rural population and has implications for sustainable management of forest resources.

Demand for electricity is projected to reach 237GW in 2025 from 77GW in 2010 (ADB, 2012, Chapter 13). The predominant generating technology in the region will remain conventional thermal followed by hydropower. Coal-fired generation requires water for cooling purposes. For example, the Hongsa lignite project currently being developed in northern Lao PDR is constructing a large dam to supply water to the project.[8]

The GMS Study on Power Interconnection envisages that by 2025, there will be an electricity interconnection between the GMS countries involving export capacity to Thailand and Viet Nam of 10GW from northern Lao PDR, 3.5 GW from southern Lao PDR and 2.5 GW from Cambodia. Exports from Myanmar to People's Republic of China and Thailand would be 28GW, (ADB, 2010. Fig 1.4.1). This suggests a significant increase in cross border trade relying on hydropower development in the next decade. The results are also subject to decisions on mainstream projects on the Mekong for which a cumulative impact assessment is suggested by the Study. The Strategic Environment Assessment of proposed mainstream projects commissioned by MRC provides insight into the complexities and current uncertainties surrounding these developments and recommended deferment and development of other options until the gaps in understanding have been addressed, (MRC, 2010f).

Forest cover in the GMS has reduced by 8 million ha (FAO, 2011) and forest clearance remains relatively constant at 0.4 to 0.5 per cent per annum representing a loss of 8 million hectares between 1990 and 2010. The FAO Outlook report suggests that *'throughout the region forests are becoming increasingly degraded'* and *'unless action is taken to address key drivers of change in forests and forestry, many countries will fall short of forest cover targets and values associated with forests will be lost.'* Associated losses include biodiversity and ecosystems services and there will be changes in hydrology as established forests are replaced by agriculture or rapidly growing plantations.

[7] Irrigable area is defined as the area developed for irrigation. Actual irrigation area in the dry season is currently estimated as 1.2 million hectares and this is also expected to expand by 50% (Lennaerts *et al*, 2012). Larger areas are provided supplemental irrigation in the wet season.

[8] http://www.teamgroup.co.th/en/credentials/projects/environmental-management/171-emp-rap-and-raw-water-system-design-for-hongsa-coal-fired-power-plant-lao-pdr-.html. The law on water and water resources further stipulates that any changes to water flow also need approval from the National Assembly. http://www.na.gov.la/docs/eng/sess5_leg6/250708/apprval_of_lgnite_power.htm

Concessions to large scale multi-national mining companies and smaller scale operators with less capacity for environmental management have increased dramatically. A study of two provinces in Lao PDR conducted in 2009 revealed that 290,000ha of mining concessions had been outsourced in Vientiane Province and estimated there were between 2 to 3 million ha of all types of concessions across the country as a whole (GTZ, 2009). Incidences of water pollution affecting drinking water supplies for communities, livestock and fisheries from poorly regulated operations have been reported, (MRC, 2010, p203). Proposals for large mining operations such as bauxite in the Bolaven Plateau in Lao PDR require significant energy and water supplies placing additional demands on water resources locally and regionally.

The consequences of climate change on temperature and hydrology will be superimposed on what are already highly variable systems (Figure 1). Rainfed farming will be particularly affected and may lead to calls for greater storage of water in small and large scale systems and more supplemental use of groundwater. For irrigated systems the situation is dependent on the source of water. Modeling undertaken as part of the MRC's Basin Development Strategy suggests that the overall climate related changes for Mekong river flows will be offset by those due to dam construction. For example, increased dry season flows due to dams in Yunnan will offset seasonal any reductions in rainfall. However, persistent drought conditions for more than one season as well as the frequency and intensity of tropical storms need to be factored into planning and adaptation processes.

In coastal and delta areas, the main climate threat comes from sea level rise and storm conditions that would significantly exacerbate the flooding risk to coastal communities and major cities. In the Mekong Delta, increases of 0.5 to 1.0m in sea levels have been projected by 2100 potentially affecting millions of people and the most productive agricultural land in Viet Nam.

2. Inter-linkages

2.1 Water, Energy and Food Security Nexus

The inter-connected nature of water resources has long been recognized yet cross-sectoral cooperation remains a challenge. The Bonn2011 Conference on Water, Energy and Food Security Nexus highlighted that the current pathways of development are not only failing to meet targets for access to water and energy services and food security, but also the lack of coordination is resulting in sub-optimum allocation of resources – both financial and natural (SEI, 2011).[9] Bonn2011 concluded that:

A nexus perspective increases the understanding of the interdependencies across water, energy, food and other policies such as climate and biodiversity. The nexus perspective thus helps to move beyond silos and ivory towers that preclude interdisciplinary solutions.… In this way, unintended consequences can be avoided.

Six opportunity areas emerged from the Bonn2011 Conference and will contribute to the overall aims of achieving access to water, sanitation, energy, and food; raising resource productivity; and sustaining ecosystems and biodiversity (see Box).

The Nexus is premised on the understanding that the discourse on development planning within a country, region or basin needs to cut across sectors and engage effectively with all key ministries so that the inter-linkages and connectivity are effectively reflected early in sector planning. It does not argue for major institutional reform so that implementation remains firmly within the mandate of sectoral agencies within an effectively regulated environment.

Later in the paper, the Nexus framework is used to discuss emerging and new initiatives to encourage a more coordinated approach to hydropower development.

2.2 Connectivity in hydropower planning

As utilization of natural resources expands and reaches limits of sustainability, and competition between water uses increases, it is inevitable that more coherence in policy development, planning and management will be required. Private sector finance is essential to meet the development demands of the region and it has achieved results unattainable by the public sector alone. However, in practice, a shift in financing of major projects from public to private sector and limited capacity of regulatory frameworks have combined to strengthen the sectoral perspective. The drive towards Integrated Water Resources Management (IWRM) introduced 20 years ago, and confirmed by countries at the World Summit on Sustainable Develop-

9 http://www.water-energy-food.org/en/bonn_2011_process.html

Bonn2011: Water, Energy and Food Security Nexus – Key messages

Increase policy coherence - by ensuring that synergies and trade-offs among water, energy and food are identified both in design and implementation of policies, plans and investments. And by incentivizing co-operation and coordination for mutually beneficial approaches, multiple benefits and fewer unintended or adverse consequences.

Accelerate access - by progressively realizing – in a more coordinated way – the human rights obligations related to water, sanitation, energy and food to reap the resulting health, productivity and development benefits. And by prioritizing access for the poor and the marginalized in sector strategies, planning and investments.

Create more with less - by increasing resource productivity, establishing mechanisms to identify the optimal allocation of scarce resources for productive purposes, and sustainably intensifying the use of land and water to achieve equitable social, economic and environmentally sound development.

End waste and minimize losses - by reducing waste and losses along supply chains to capture significant economic and environmental gains within and across sectors and reduce demands on water, land and energy. And by changing mindsets and incentivizing technological development to turn waste into a resource and manage it for multiple uses.

Value natural infrastructure - by investing to secure, improve and restore the considerable multi-functional value of biodiversity and ecosystems to provide food and energy, conserve water, sustain livelihoods and contribute to a green economy while strengthening the basic role that nature plays in supporting life, well-being and cultures.

Mobilize consumer influence - by acknowledging and actively utilizing the catalyzing role that individuals have in choosing consumption patterns on water, energy and other resource footprints and improving efficiency of resource use both through their direct actions and in influencing the way business is done.

ment in 2002, aimed to cut across sectoral silos.[10] But the buy-in to these processes by key energy and industry ministries has been limited.

Without an effective regulatory environment and incorporation of water resources, environmental and social considerations early in the process, not only will adverse impacts be frequent, but also the opportunities of attaining multiple benefits will be foregone. On its own, environmental impact assessment of major projects is unlikely to demonstrate a major influence as it is carried out late in the project cycle when the room for considering options including timing or funding are constrained.

There have been some notable exceptions to this characterization, where developers have committed to international good practice and safeguards have been adopted through the involvement of international finance institutions, either as co-financiers or in providing risk guarantees.[11] Pressure from advocacy groups has similarly contributed to improved outcomes.

In Lao PDR, a far reaching policy on social and environmental aspects of hydropower development was approved in 2005,[12] but implementation capacity takes time to develop. In the interim period, the risk is that projects proceed with problems emerging on resettlement, downstream flow, water quality, fisheries and ecosystem health. Steps are being taken to raise the status of the policy and strengthen capacity, but the pace of development and pressure for rapid project implementation remain high.

[10] In the Johannesburg Plan of Action, countries committed to preparing IWRM plans by 2005.

[11] As for the Nam Theun 2 and Theun Hinboun Expansion Projects.

[12] National Policy on Environmental and Social Sustainability of the Hydropower Sector in Lao PDR of 2006.

Conversely, concerns have been voiced that new, more inclusive approaches take too long to implement and are too costly for wider replication. The question in the long term should perhaps be turned around into whether a country could afford not to follow more sustainable practice? Adopting new processes that treat affected people as beneficiaries of a project represents a major shift from the more conventional compensation perspective. Positive experience has been gained that can be used to accelerate implementation and reduce costs on subsequent projects.

3. Risks – from the perspective of the user

Understanding the boundaries within which development occurs is fundamental and argues in favor of a more strategic approach in which some of the potentially divisive questions on water management can be addressed as part of a joint process among riparian countries or provinces, such as:

- how much water can safely be abstracted?
- can multiple benefits be achieved?
- how to best share benefits of development?
- what quality of water is acceptable for specific purposes?
- to what extent can changes to the natural variability of flow be accepted?
- how can peoples' livelihoods be secured and a balance achieved with conservation of ecosystems and biodiversity?
- how can shortfalls in water supply in times of drought be managed?

Regional cooperation frameworks provide an opportunity to move beyond the rather basic question on allocation to consider the broader issue of sharing benefits beyond just the water itself. This can increase the negotiation space[13] as was done in the case of the 1961 Columbia Treaty between the United States and Canada for the development of hydropower and provision of flood management benefits.[14]

The relative emphasis on each of these questions depends on the type of development, for example whether it is consumptive irrigation or non-consumptive use for hydropower or thermal cooling. Given its importance for the region, this paper focuses mainly on hydropower. An understanding of the potential consequences of hydropower development on different users in the conceptual planning stage helps to identify solutions before the timeframe and financial negotiations of project processing begin to constrain options. Increasingly this is of importance to private banks in terms of reducing risk to their investments including reputational risk.

For hydropower, the hydrological issues revolve around a range of issues: downstream flows (whether water is diverted from one river to another or to a location downstream of the dam thereby reducing flows in the intervening reach or river); redistribution of flows from wet to dry season and changes in river hydrograph; attenuation of flood peaks; rapid fluctuations of flow and the daily peaks as projects are 'ramped' up and down in response to peak electricity demand on the grid; and morphological issues related to interruption of sediment flows.

A range of benefits and impacts may occur:

- A farmer may benefit from additional water in the dry season for irrigation but be adversely affected by rapid fluctuations in downstream river levels and lose opportunities for recession agriculture on traditional riverbank gardens.
- Fishers experience difficulties in setting fish traps on rivers that are fluctuating hour to hour rather than on a more gradual seasonal cycle or lose fish stocks due to deteriorating water quality and low oxygen content.
- Communities living in flood prone areas may benefit from reduced flood peaks, whereas important flood pulse triggers for migrating fish may be removed from natural cycle of river flow.
- Species of fish change and capture fisheries reduce as dams provide a barrier to migrations, whereas reservoirs provide an opportunity for reservoir fisheries to develop – the benefits however accrue to different people.
- The trapping of sediment in reservoirs provides "clean" water downstream but disrupts the natural energy of the river system causing bank and bed erosion, reduced delta formation and is a net loss of nutrients to downstream ecosystems.
- Villagers living in reservoir affected areas can lose livelihoods or alternatively benefit from new opportunities and services.
- Navigation may be easier due to higher water levels,

[13] See also Sadoff, C. and Grey, D. (2008). Why share? The benefits (and costs) of transboundary water management. Chapter 2 in, Sadoff, C., Greiber, T., Smith, M. and G. Bergkamp (eds.) SHARE - Managing Water Across Boundaries. IUCN. Gland, Switzerland. 2008.

[14] http://www.bpa.gov/corporate/pubs/Columbia_River_Treaty_Review_-_Feb_2009.pdf

or hindered by rapid level fluctuations on a daily or hourly basis.

- Tourism can be affected positively by creating new eco-attractions or negatively by reducing sites of important diversity.
- Endangered species are more at risk by the opening up of access to remote areas or are benefitted from added protection provided through funding from project revenues.

In the situations above, it is easy to see that risks will be viewed differently depending on the stakeholders' perspectives. This can be further demonstrated in the case of mainstream dam projects constructed on the Lancang River in Yunnan upstream of Lao PDR and Thailand. The first, Manwan hydropower dam, was completed in 1993. The storage is relatively small and the hydropower use non-consumptive, so the project had little impact on the river's hydrography although some sediment was retained in the river. Subsequently, as up to 20 billion cubic meters of storage and hydropower generation capacity are added in the Lancang, further sediment and nutrient flows will be lost whereas low flows in the dry season in the Mekong will increase providing benefits downstream.

Communities along the river in northern Lao PDR and Thailand view the seasonal changes and daily fluctuations in river level as a result of upstream control. Naturally, they then associate these dams as the cause of all future extreme events, whether or not they have natural origins as was the case of the flood in 2008 and drought of 2010.[15] Once public opinion has been formed it is difficult for technical analysis alone to change perceptions. Although there has always been a plan to build a re-regulating reservoir upstream of the border (now to be located at Galanba), this structure will not be completed for several years. The deterioration of relations between these communities and their upstream neighbor has already occurred and will be difficult to turn around.

The issues and challenges around hydropower development are not 'black' or 'white' as typified by either anti-dam advocacy groups or pro-dam promoters. There is a lot of 'grey' in the middle and a balance is needed. The complexity of the issues requires a more inclusive and coordinated approach, bringing in different expertise and capacity. It is one that looks upon hydropower as an integrated development opportunity rather than as a single sector objective. A major concern is that the current institutional setup of relatively weak regulation and planning does not lead to this outcome. As in the case of deteriorating water quality or diminishing fisheries, the cost of retrofitting solutions to fix unanticipated impacts can be significant and greater than making adequate provisions in the planning stages.[16]

Returning to a traditional master planning process may not be suited to the prevailing private sector development model. Other methods and tools are needed that define the boundaries within which development takes place, examine the inter-linkages between sectors, consider cumulative impacts on the environment and set the direction for social inclusion. These are discussed in Section 4.

4. Adopting new approaches for strategic planning

A fundamental question for planners is how to avoid the gradual progression towards unsustainable cumulative consequences of individual project decisions. Such decisions may appear fully justifiable on economic and financial grounds in the short term, but only if externalities are ignored which has often been the case in practice. A related question is whether water resources systems and other natural resources have to reach crisis points, or 'tipping points' before sustainable management practices are implemented. In other words, how is it possible to develop a more strategic framework and operationalize considerations of the Green Economy? To what extent for example, will private sector developers and investors be prepared to join as partners in more integrated regional development programs?

A recent report by the World Bank on the hydropower and mining sector in Lao PDR points to some of the issues facing hydropower development in the region (World Bank, 2010):

The project-by-project approach so far employed will not be appropriate….In particular, the cumulative effects of mining and hydropower need to be addressed through a strategic framework at the national or river-basin level.

Various new approaches have been adopted elsewhere. In Europe, the Water Framework Directive introduced in 2000 requires member states to gradually move towards 'good' river status. Any development proposals need to

[15] See footnote 3.

[16] See costs of remediation of fisheries in the Columbia River, http://www.nwcouncil.org/library/1999/99-3.htm#5

be tested against this requirement during the regulatory processes. The recently approved Danube Water Resources Management Plan sets out a program for gradual improvement in river status.[17]

In Norway, a balanced approach for hydropower development has been operating for 30-40 years and has enabled investments in new schemes as well as increasing efficiency and output of existing systems while protecting sensitive areas. Two plans were adopted by Parliament and work in parallel:[18]

- a protection plan first adopted in 1973 that defines certain tributary systems to be free of future development; and
- a master plan approved in 1986 identifying potential sites across the country that are available for project promoters to develop.

Regulation of the industry in Norway comes under the Water and Energy Regulatory Authority (NVE), combining the two sectoral functions into one agency. Coordination across projects within a regulated river basin is provided through hydropower users associations.[19] The Norwegian experience of parallel protection and master plans appears particularly relevant to parts of the GMS, including Lao PDR. Developing a similar framework protection plan for key aquatic systems, either whole tributaries or critical reaches, would complement long existing terrestrial protected areas. Importantly it could help frame the environmental debate which is currently repeated on each individual project, (rarely with satisfactory results), and facilitate projects in non-protected areas to be pursued with greater confidence and reduced conflict. Biodiversity and conservation objectives would be accommodated to the extent possible in the prior discussion on protected areas.

The Lower Mekong Basin already has procedures in place under the 1995 Mekong Agreement through which large projects are considered. The Procedures for Maintenance of Mainstream Flows (PMFM) sets thresholds for minimum flows at key points in the river system and for the timing of flow reversal into and out of Tonle Sap Lake that is so important for fisheries and biodiversity.[20] Similarly, the Procedures for Water Quality (PWQ) derived from negotiations among the four member countries define agreed water quality parameters that should not be violated.[21]

The process for notifying countries of prospective projects and requesting feedback is achieved through the Procedures for Notification, Prior Consultation and Agreement (PNPCA).[22] Although a significant step forward in regional cooperation and consultation on major projects, the PNPCA also comes rather later in the project cycle and therefore needs to be supplemented by a strategic and cumulative assessment. For proposed mainstream projects, the MRC commissioned a Strategic Environmental Assessment (SEA) (ICEM, 2011) and the IWRM-based Basin Development Strategy have undertaken extensive modeling and flow assessments under different scenarios to identify what has been termed a 'Development Opportunity Space' within which individual projects can then be considered.[23] In terms of tributary development, the Strategy states:

There is considerable potential for further development of tributary hydropower in the LMB, especially in Lao PDR and Cambodia, as well as for improvement in operation of existing hydropower projects. Utilising this opportunity requires a focus on sustainability both at project and transboundary levels…[24]

The Strategy, approved by MRC Council (of Ministers) in January 2011, then sets out the opportunities and safeguards that should govern future sustainable hydropower development on the tributaries, including:

- Identifying sub-basins with high ecological value to be protected and those where hydropower can be developed with limited social and environmental impacts;
- Evaluating hydropower projects from a multi-purpose perspective to increase overall economic benefits and decrease adverse effects on other water uses;
- Mitigating negative impacts of hydropower, such as through: re-regulation reservoirs downstream of peaking projects; multi-level water intakes or aeration facilities to manage water quality/temperature; fish passage; and minimizing sediment entrapment;

[17] http://www.icpdr.org/icpdr-pages/river_basin_management.htm

[18] See licensing history in Norway at http://www.nve.no/en/Licensing/History/

[19] http://www.sustainablehydropower.org/site/siteresource_pages/schemes_pdfs/glomma.pdf

[20] http://www.mrcmekong.org/assets/Publications/policies/Procedures-Maintenance-Flows.pdf

[21] http://www.mrcmekong.org/assets/Publications/policies/Procedures-for-Water-Quality-council-approved260111.pdf

[22] http://www.mrcmekong.org/assets/Publications/policies/Procedures-Notification-Prior-Consultation-Agreement.pdf

[23] http://www.mrcmekong.org/assets/Publications/strategies-workprog/BDP-Strategic-Plan-2011.pdf

[24] IWRM-based Basin Development Strategy, Section 4.1.

- Developing management plans for environmental hotspots impacted by changed flow regimes; and
- Evaluating benefit-sharing options, such as watershed development and management benefitting hydropower generation and funded from hydropower revenues.

Adopting a modified form of the Norwegian experience of parallel master and protection plans could result in a more coordinated development path for hydropower in line with the Strategy and provide a space for dialogue on introducing multiple benefits into what are currently typically conceived as single purpose projects. Without it, there would be uncoordinated project development and higher levels of impact on vital ecosystems and biodiversity than would otherwise be necessary.

GMS is a dynamic and innovative area. Where political commitment exists, innovations can be taken up in a relatively short timeframe. For example, the requirement in Viet Nam under the National Water Resources Strategy for projects to consider environmental flows is a major step forward for downstream communities that was not previously a regulated consideration, (GoV, 2006).[25]

4.1 Recommendations

There are a number of innovations and new tools relevant to the GMS that can be used to address interconnectedness surrounding water decisions. The Bonn2011 framework of six opportunity areas (Section 2) is used here to present some of these with emphasis given to those related to energy and hydropower.

Increase policy coherence

- Use Strategic Environmental Assessments to identify the key development issues and challenges (including economic and social) at an early stage of planning and programme development. Examples include the SEA of the Hydropower Master Plan in Viet Nam (SEI, 2009)[26] and the SEA of proposed mainstream dams on the Mekong (ICEM, 2010). The outcomes of these assessments and the subsequent dialogue they stimulate can identify opportunities for multiple benefits beyond electricity generation, lead to more effective environmental management and feed into other long term planning studies such as for regional power interconnection.
- Consider adaptation of the master plan and protection plan model for strategic planning pioneered in Norway.
- Apply sustainability assessment tools to rapidly identify the key issues for new developments. These include:
  - the project-oriented Sustainability Assessment Protocol[27] of the International Hydropower Association (IHA) that was developed and tested through a global multi-stakeholder dialogue process over several years; and
  - the Rapid Basinwide Sustainability Assessment Tool (RSAT)[28] which was designed through collaboration of ADB, MRC and WWF to supplement the IHA Protocol by providing a cumulative perspective within sub-basins. The RSAT has been tested in a number of sub-basins in the Mekong.
- Ensure that a process for cross-sectoral policy dialogue exists, e.g. on pricing policy and incentives for biofuels as raised by IFPRI and the resulting consequences for food production and food prices, (Rosegrant *et al*, 2012).

Accelerate access

- Move beyond conventional development orientations to include affected communities as part of a broader integrated approach including emphasis on benefit sharing from project revenues, providing basic water and electricity services and support to livelihood opportunities.[29]
- Explore the multiple options that hydropower development presents, including the benefits of using storage to supplement dry season irrigation flows and improve resilience to increased hydrological variability in the long term due to climate change. Currently these opportunities tend not to be factored into project concepts due to the single sector focus.

[25] Vietnam National Water Resources Strategy 2006, GoV MoNRE, - section 2.2a http://www.vnwatersectorreview.com/files/NWRS_FINAL_VERSION.pdf

[26] http://www.sei-international.org/mediamanager/documents/Publications/Policy-institutions/sea_hydropower_vietnam_full%20report.pdf

[27] http://www.hydropower.org/sustainable_hydropower/HSAF.html

[28] http://www.mrcmekong.org/assets/Publications/Reports/RSAT-Revision-3-for-printingOCT-3-2010-Corrected-FINAL.PDF

[29] An extensive review and knowledge base of benefit sharing mechanisms has been prepared by MRC under its Initiative on Sustainable Hydropower and is scheduled for web publication in due course. http://www.mrcmekong.org/about-the-mrc/programmes/initiative-on-sustainable-hydropower/. See also Haas, L.J.M., D.V. Tung. 2007. Benefit Sharing Mechanisms for People Adversely Affected by Power Generation Projects in Viet Nam. Final Report of ADB TA4689-VIE. Manila.

- Integrate sustainable community management of reservoir fisheries into project planning and conduct further research on options for migratory fish passage in the context of highly diverse tropical river systems.

Create more with less

- Explore the potential for upgrading existing hydropower projects with new more efficient generating equipment and technology and adding capacity where possible.[30]
- Use basin modeling techniques to optimize production from the group of hydropower projects within a sub-basin and explore opportunities to identify win-win solutions that can be integrated into existing and future concession agreements, (see also objectives of ecosystem protection below).
- Consider how irrigation system rehabilitation and expansion can be linked to hydropower development including low head energy generation and other productivity improvements encouraged such as more efficient agricultural practices and intensification programs.[31]

End waste and minimize losses

- Actively pursue policies for demand management and application of low energy technology and appliances for consumers.[32]
- Reduce the considerable losses experienced in post-harvest processing, transport and marketing.[33]
- Intensify assessment of opportunities for second generation biofuels and use of waste products for energy generation and wastewater for irrigation, particularly in peri-urban areas in cooperation with municipal authorities.

Value natural infrastructure

- Recognize the value of the environment in regulating and providing essential services to hydropower production and its physical sustainability by adopting the model of Payment for Ecosystems Services.[34] Similarly explore the opportunities for a coordinated approach with projects under REDD+.[35]
- Avoid daily disruption of river flows and resulting community opposition due to peaking operation by incorporating re-regulating reservoirs and related mitigation measures as a matter of development policy and design standards (Locher, undated).
- Use re-operation software to explore the multiple benefits that can accrue from greater inter-linkage between economic, environmental and social considerations.[36]
- Build capacity and financing arrangements for existing and new aquatic protection areas such as the Tonle Sap Biosphere Reserve and other key wetland areas.
- Support a research agenda that addresses gaps in knowledge identified in the SEA on mainstream dams and review reports prepared during the PNPCA of the Xayaburi project (MRC, 2011).
- Identify options for reversing the trend in water quality degradation in rivers learning from successful programs elsewhere.[37]

Mobilize consumer influence

- Recognize that it is more efficient to “avoid” problems rather than to “remediate” them. Learn lessons from sub-basins where conflicts have already emerged including appropriate institutional structures that can facilitate better understanding and dialogue on solutions.
- Work with civil society at an early stage in project planning to address areas of concern rather than wait until conflicts intensify.

[30] See for example the initiative of multiple agencies in the US Government for increasing the potential at existing hydropower facilities http://www.usbr.gov/power/data/1834/Sec1834_EPA.pdf

[31] Examples include improved productivity of water at the Zhang He Irrigation Project in People’s Republic of China, and effective rationing of power supplies for groundwater pumping in Gujarat under the Jyotirgram Sheme, see http://www.lk.iwmi.org/china/china.htm#zan and http://www.iwmi.cgiar.org/Publications/Other/PDF/NRLP%20Proceeding-2%20Paper%2015.pdf

[32] See focus on efficiency and demand management in People’s Republic of China. Jiang Kejun (undated) Management of Energy Resources in China. Energy Research Institutehttp://siteresources.worldbank.org/DEC/Resources/84797-1251813753820/6415739-1251814084145/Kejun_Energy_China.pdf

[33] See the focus on ‘more crop per drop’ and reducing ‘field to fork’ losses in the concluding statement of the 2011 Stock.

[34] See Smith, M., de Groot, D., Perrot-Maîte, D. and Bergkamp, G. (2006). Pay – Establishing payments for watershed services. IUCN. Gland. Reprint 2008. http://data.iucn.org/dbtw-wpd/edocs/2006-054.pdf . Also watershed management program under the Nam Theun 2 project http://www.namtheun2.com/index.php?option=com_content&view=article&id=62&Itemid=72

[35] UN Reduced Emissions from Deforestation and Forest Degradation

[36] See Global Dam Reoperation Initiative coordinated by the Natural Heritage Institute. http://www.global-dam-re-operation.org/resources/documents-presentations.html

[37] See for example http://www.adb.org/water/actions/prc/changing-community-mindsets.asp

- Be transparent on availability of data and river basin status in terms of quantity and quality. Promote openness and transparency of information as a vehicle to bring about changes in public attitude and changes in behavior.

5. Concluding remarks

Underlying the call for a more inter-linked approach to water resources and energy planning is the premise that current single-sector dominated viewpoint and relatively unregulated development of the private sector is leading to avoidable social and environmental impacts and is not providing the multiple development benefits that are possible. The gradual increase in impacts of a cumulative nature could eventually lead to exceeding 'tipping points' for critical ecosystems and undermine the livelihoods they support. A number of progressive solutions have been demonstrated to deliver better outcomes, but require a more integrated and 'joined up' approach.

Greater coordination and inter-linkage are inherent to the principles of integrated water resources management (IWRM). Unfortunately these principles have tended to stay within the domains of the water, agriculture and environment professionals and not had much traction with energy sector professionals. They appear to have had little effect on early planning of hydropower projects in the Mekong region to date. IWRM therefore needs a new stimulus and pragmatism to move from policy formulation to implementation. The Nexus perspective highlighted through the Bonn2011 process attempts to do that by opening up discussion on specific inter-linkages at an early stage of planning, while retaining implementation responsibility within existing sectoral agencies.

The separate planning processes for water resources and the energy sector need to be aligned at an earlier stage rather than wait for provisions of current regulatory frameowrks that tend to be applied late in the planning and project cycles at a time when the flexibility for introducing changes and examining other options is minimal.

Responding to diverging stakeholder perspectives requires more open and accessible information, inclusive debate, and commitment to sustainable outcomes that consider externalities. Rather than dealing with the recurring issues of hydropower development on a case by case project basis, many of the generic problems can be dealt with up-front and avoided or mitigated. Strategic planning exercises, SEAs and basin-wide sustainability assessments are available tools to improve the knowledge base, stimulate regional dialogue and provide the basis upon which options can be considered and decisions taken. Similarly, the combined 'master plan' and 'protection plan' model adopted by Norway for its hydropower development is one that is worth adapting in the context of GMS countries where a significant proportion of hydropower potential is yet to be developed. At project-level, tools exist to share benefits more equitably and provide financing for sustaining ecosystems services.

Although controversial by nature, expanding tributary hydropower development in the GMS provides considerable benefits and stimulus for economic growth and provision of basic services. Evidence exists that current planning approaches can be considerably enhanced to improve social and environmental outcomes and done so in a timeframe and budget that is not restrictive. The policy framework is generally in place, now the focus needs to shift to how it is implemented to achieve sustainable outcomes.

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THE ROLE OF CLEAN COAL TECHNOLOGIES IN THE GREATER MEKONG SUBREGION COUNTRIES

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Abstract

Worldwide, the combination of abundant coal reserves at relatively low prices and a need to reduce greenhouse gas (GHG) emissions reinforce the critical importance of clean coal technologies (CCTs) and appropriate climate change policies to promote such technologies. In order to meet a rapidly growing need for economic development and power generation, coal will play an increasingly major role in the Greater Mekong Subregion (GMS) countries in coming years. All the GMS countries are building or have in place coal power stations, which once built will be operating for another 40–50 years.

Rising populations, food prices, and competing needs for water in the GMS for power and food will increase the pressure on policymakers to identify strategies to develop a sustainable development pathway for the GMS. Energy production is top priority, but declining freshwater supplies could impede future new energy development. Water needs within the GMS by coal, oil, and gas producers could take precedence over other economic sectors.

This paper describes the coal reserves and existing and planned coal-fired power generation in the GMS and examines the use of coal, clean coal technologies, and competition with water and food in the subregion. To achieve a low carbon pathway, the energy development decisions made now will play a key role in the GMS. The trend toward implementing policies that reduce greenhouse gas emissions inevitably brings regulatory, environmental and technical pressure on the electricity industries, where coal-based power production remains an essential source. It is widely accepted that coal will continue to play a major role in securing power supply for many emerging economies in the foreseeable future. This paper uses the IEA definition for clean coal technologies which encompasses "technologies designed to enhance the efficiency and the environmental acceptability of coal extraction, preparation and use", which includes CO_2 capture and storage.

Globally older coal-fired power plants operate at an average of 32-35% efficiency due to the current international coal fleet consisting mostly of subcritical pulverised coal units and even lower efficiencies where unwashed and/or low grade coals are used. The state-of-the-art PCC power plant based on supercritical or ultra-supercritical technology, can achieve generating efficiency of 42-45% for hard coal or lignite. Continued improvements in power station component materials are being developed allowing for higher steam temperatures and pressures, pushing materials and generation efficiencies to ever greater limits. It is expected that advanced nickel-based alloys for boilers, high pressure turbines and piping will be available in decades to come, such that efficiencies may reach values of today's modern gas-fired CCGT at around 55%.

For the period to 2012, the Kyoto Protocol under the United Nations Framework Convention on Climate Change (UNFCCC) is the main international climate policy instrument. There are several proposals for post-2012 climate policy frameworks covering a broad spectrum from Kyoto-type agreements with mandatory targets to technology cooperation with voluntary commitments, such as national appropriate mitigation actions (NAMAs) that could have a role for CCT in the GMS region.

In order to achieve higher efficiencies for CCT in the GMS over the next decade, several elements are needed: incentive schemes for CCTs, international cooperation on research and development and technology transfer, additional incentives for the GMS region, and minimum performance standards for existing and/or new coal plants.

It is not necessary that all these elements are included if other policies cover some elements. It is important to set any incentives over a time horizon that takes into account the long turnover time of capital. The GMS requires ongoing cooperation in information, data, research and development, and technology transfer to obtain the best use of its resources. Additional incentives could be available through the new technology mechanism and Green Climate Fund under development by the UNFCCC members. Implementation of minimum standards for all new and, if possible, existing coal-fired power plants will enable improvements in use of water, air quality, and security of supply up to 2020.

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1. Introduction

Coal can play a key role in contributing to energy security, recognizing that a combination of providing energy security as well as climate change mitigation measures to limit greenhouse gas (GHG) emissions requires a balanced policy. In the Greater Mekong Subregion (GMS), there are several countries where the economy is growing rapidly and that have abundant coal supplies with low prices, such as the People's Republic of China (PRC) and Viet Nam.

Governments and companies within the Greater Mekong Subregion (GMS) will need to make key decisions over the next few years on investment in energy supply, which is likely to include a combination of energy sources (fossil, renewable, and nuclear). Consequently, it is important that when this investment takes place that the issues of energy security, water scarcity, increasing environmental sensitivity, and climate change mitigation are considered by decision makers. In recent years, there have been several major changes to energy supply with increasing gas, oil, and coal prices.

The Mekong area has long been regarded as the foundation of Southeast Asia's economic growth and prosperity, necessitating cooperation between the countries. In 1995, the "Agreement on the Cooperation for the Sustainable Development of the Mekong River Basin" signed by the governments of Cambodia, the Lao People's Democratic Republic (Lao PDR), Thailand, and Viet Nam formed the Mekong River Commission (MRC). The MRC facilitated joint management of shared water resources and collaboration on development issues, such as hydropower development. In 1996, the PRC and Myanmar (Burma) became Dialogue Partners of the MRC. In the PRC, the Guangxi Zhuang Autonomous Region and Yunnan Province are the areas pertaining to the Mekong.

The five countries and two provinces of the Greater Mekong Subregion (GMS) have a combined land area of 2.6 million km^2 and a total population in 2009 of around 320 million people, mostly living in rural areas; 45 million people still live in poverty. Approximately 74 million or around 20% of the population do not have access to electricity (ADB, 2009a). All share in some manner the Mekong River, which flows for 4,200 km through the GMS into the South China Sea. The basin of the river is 795,000 km^2, through which some 475,000 million m^3 of water flows annually (UNEP, 2007).

The countries within the Mekong region have different types of energy resources. The Lao PDR, Myanmar, and Yunnan Province have large hydropower resources. It is expected that hydropower will meet their energy needs for the foreseeable future. The total hydropower potential of the Mekong River Basin is estimated to be 53,000 megawatts (MW). In the four lower Mekong countries of Cambodia, the Lao PDR, Thailand, and Viet Nam, an estimated 30,000 MW of hydropower are technically available (ICEM, 2010).

A 2009 Asian Development Bank (ADB) report on "Building a Sustainable Energy Future: The Greater Mekong Subregion" failed to recognize clean coal technologies (CCTs) as an option in the low carbon scenario due to carbon and other damage costs. There was also an argument that CCTs have higher capital costs and require international financial support. This is partially correct but the example of the PRC and Viet Nam investing in supercritical coal-fired power stations indicates this is not always the case. This report describes CCTs, discusses the use of coal in the four lower GMS countries, and proposes inclusion of CCTs in national appropriate mitigation actions (NAMAs) as a form of mitigation of emissions.

To ensure the use of coal in contributing to energy security and mitigation of carbon dioxide (CO_2) emissions and air pollution requires the deployment of CCTs, because they can increase the efficiency[2] of power stations. A 1% increase in thermal efficiency can reduce CO_2 emissions between 2% and 3% depending on the coal and technology.

Supercritical coal combustion (SPCC) and integrated gasification combined cycle (IGCC) with CO_2 capture and storage are key CCTs. In addition, the increasing use of low-rank coals with high ash will make the implementation of circulating fluidized bed combustion (CFBC) more attractive. However, CFBC currently makes up only 2% of the world's coal fleet and so has a limited role. Fluidized bed combustion (FBC) operates at a lower temperature than conventional pulverized boilers and this reduces the amount of nitrogen oxides (NOx) formed. Sulfur oxides (SOx) can also be controlled by using limestone added to the coal. The limestone is injected into the combustion chamber with the coal and this can result in up to 90% of the sulfur being absorbed and removed as a solid compound with the ashes. The use of FBC is ideal for poor

[2] Efficiencies are given in Lower Heating Value (LHV). As opposed to Higher Heating Value (HHV), LHV does not include the condensation heat of the water produced in the combustion process.

quality fuels with high moisture content and low heating value, such as biomass, municipal wastes, and paper and pulp industry wastes and sludge.

The term supercritical refers to power plants that have operating pressures above the normal boiling point. The water changes from liquid to vapor without nucleate boiling. The supercritical point of the water occurs at pressures in excess of 22.1 megapascals (MPa). This allows supercritical units to achieve thermal efficiencies of above 45%, compared with typical subcritical plants of 30%–38%. The key features of supercritical power generation units are once-through boilers designed to operate with pressures of 22.1 MPa to 30 MPa, compared to a high of 19 MPa with subcritical boilers. There are many new power plants being proposed and built worldwide to perform at “supercritical” and “ultra-supercritical” conditions of temperature and pressure. The result could be an increase in electricity generation efficiency to 40%–50% and higher.

Energy capital stock has a long life; coal-fired power plants last up to 40 years and beyond. Decisions on the development of CCTs will thus have far-reaching impacts. There are long-term economic and environmental benefits to countries using CCTs, such as supercritical power plants, including

- higher thermal efficiency;
- reduction of SO_x, NO_x, and particulate matter emission due to improved efficiency and combustion resulting in better air quality;
- costs are comparable with subcritical technology if flue gas desulphurization and selective catalytic reduction are used;
- reduced fuel costs that can represent up to two thirds of the total operating costs of a plant;
- reduction of CO_2 emissions as less fuel is required per unit of electricity generated;
- plant efficiencies are less affected by part load operation and the availability can average up to 85%;
- plant at a future date could be integrated or retrofitted with new CCS technology (Nalbandian, 2008).

2. Greater Mekong Subregion Coal Resources and Use

The GMS faces several important development challenges. A large part of the population relies on traditional sources of energy, such as biomass. There is also a difference between rural and urban areas in terms of energy access and services. Cambodia and Thailand are becoming more dependent on importing energy. To meet this energy demand there is an increasing growth of fossil fuel use. Yunnan Province has coal resources that could potentially generate 125 gigawatt hour (GWh), of electricity over a 30-year period (ADB, 2008).

There are also other countries that have sizeable coal reserves, including the Lao PDR, Thailand, and Viet Nam. Next to the PRC, northern Thailand has the largest coal-fired power station at the Mae Moh lignite mine site. This is followed by Viet Nam with large quantities of anthracite and brown coal reserves. In the Lao PDR, there are large lignite reserves totaling about 810 million tons.

The Mekong River provides livelihoods for over 60 million people, many of whom still live in poverty and are reliant on the river for fish and other resources. The river is used for energy production, transportation, and water for cooking, irrigation, cleaning, and sanitation. A key issue in the Mekong area is energy and hydropower development. Coal is also a key resource, with several countries along the Mekong River proposing, developing, or already building coal-fired power stations. Along with hydropower, the further use of coal will increase the demands on the Mekong River. This paper focuses on development of coal-fired power in the four lower Mekong countries. Up to 17 new coal-fired power stations are being built, including a 1,200 MW power station in Viet Nam— the first of possibly many—due for completion on the Mekong River in 2014 (ICEM, 2010). Viet Nam and Thailand will make up 96% of energy demand by 2025 (Table 2).

From 2010 to 2025, the overall growth in electricity demand is estimated to grow from 45 GW to 130 GW. The majority of this demand will be met by nuclear, gas, coal, and hydropower (ICEM, 2010).

2.1 Viet Nam

Key Coal facts

Total coal production (2009, estimated)	:	43 million tons (Mt)
Total coal demand (2008, estimated)	:	20–25 Mt
Exports (2008, estimated)	:	20 Mt
Imports (2006)	:	0.3 Mt

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Table 1: Electricity Demand Forecast in Lower GMS Countries (ICEM, 2010)

		2010	2015	2020	2025
Cambodia	Peak Demand (MW)	467	1,008	1,610	2,401
	Annual Growth		16.6%	9.8%	8.3%
	Estimated Load Factor	65%	66%	68%	67%
	Energy Demand (GWh)	2,659	5,828	9,449	14,302
Lao People's Democratic Republic	Peak Demand (MW)	618	1,911	2,665	2,696
	Annual Growth		25.3%	6.9%	0.2%
	Estimated Load Factor	65%	66%	67%	68%
	Energy Demand (GWh)	3,519	11,049	15,641	16,060
Thailand	Peak Demand (MW)	23,936	31,734	42,024	53,824
	Annual Growth		5.8%	5.8%	5.1%
	Estimated Load Factor	72%	72%	72%	72%
	Energy Demand (GWh)	150,969	200,153	265,054	339,479
Viet Nam	Peak Demand (MW)	19,544	32,210	48,662	71,445
	Annual Growth		10.5%	8.6%	8.0%
	Estimated Load Factor	72%	72%	72%	72%
	Energy Demand (GWh)	123,268	203,155	306,921	450,618
All Countries	Peak Demand (MW)	44,565	66,863	94,961	130,366
	Annual Growth		8.5%	7.3%	6.5%
	Estimated Load Factor	72%	72%	72%	72%
	Energy Demand (GWh)	280,415	420,184	597,066	820,458

Recoverable reserves (2006, estimated)	:	2,000–3,000 Mt
Port capacities (2008, estimated)	:	34 Mt

Much of the following is drawn from an IEA Clean Coal Centre report on Viet Nam (Baruya, 2010). Coal in Viet Nam is seen as an important aspect of energy policy, with a substantial domestic mining industry that currently exports half its output; however, this is set to decline. The coal export business is encouraged now in order to earn foreign currency revenues to help finance development in the economy. The coal industry is highly strategic, being geared toward exports or the domestic market whenever it is necessary to do so. The state-run Viet Nam Electricity (EVN) intends to build a great deal more coal-fired power. New coal-fired power projects are being urged by the Government in order to bring a reliable supply of electricity to the main demand centers in the north and south.

While the state coal and mining company Vinacomin will endeavor to expand exploration, surveys, and production, there is a possibility that coal that was once destined for the export market will be retained within the country for use by Viet Nam's power stations. Every coal rank is found in Viet Nam, from large amounts of anthracite already mined, to bituminous and subbituminous coals, lignite coals, and peat. Current proven reserves, totaling 6 gigatons (Gt), are anthracite (67%), subbitumous (26%), peat (5%), and brown coal (2%) (Thanh Son, 2006; Baruya, 2010)).

According to Viet Nam's Second National Communication, energy-related emissions are projected to increase from 113 Mt by 2010, to 251 Mt by 2020 and to 471 Mt by 2030. Theenergy sector's share of total emissions has risen 35% since 2000 and could rise by 90% in 2030 (MONRE, 2010).

The Sixth Master Plan for Power Sector Development, for 2006–2015 (with a perspective to 2025), envisages power generation capacity to increase from 13,138 MW in 2007 to 85,200 MW in 2025. Viet Nam's total generating capacity is around 13 gigawatts (GW) with annual electricity production in excess of 60 terawatt hour (TWh). Hydropower accounts for 42% of this total, natural gas for 42% and coal for 14% (ASEM, 2009). In the past, the country relied heavily on hydropower; in the future, a combination of nuclear power and coal-fired plants is expected to account for a growing proportion of total electricity production.

Water reservoir capacity is limited in Viet Nam, and current facilities can supply power for up to a week under normal use. Dry seasons lead to limited hydropower availability in succeeding months and create major shortages in the availability of electricity (Baruya, 2010). Hydropower increases are unlikely because most sites are already being exploited, and gas and oil reserves are limited.

There are plans to build 13 nuclear reactors by 2030, with a combined capacity of 15 GW. Coal-based capacity was boosted recently by the announcement in December 2010 that Doosan Heavy Industries is to build two new power plants, each of 1,200 MW. Electricity demand is forecast to increase at a yearly rate of 9%–10% during 2011–2025. The structure of the power sector is forecast to change as more coal is used, generating 49% of the country's electricity in 2015, 55% in 2020, and stabilizing at 68% by 2025. The resultant domestic coal demand is expected to be (Van Can, 2007):

- 2010: 29–32 Mt/year;
- 2015: 47–50 Mt/ year;
- 2020: 69–72 Mt/ year;
- 2025: 112–115 Mt/ year.

Coal is set to become the most significant source of energy. Coal-based power generation capacity is expected to expand 20-fold to reach 35,600 MW in 2025 or 42 % of total capacity (compared to 13 % in 2007). Imports of coal will become increasingly important. To meet domestic demand for coal, Viet Nam is planning to reduce exports of coal from around 29 million tons in 2006 (mainly to the PRC and Japan) to 12 million tons in 2010 and stop exports from 2015, thus turning one of Asia's main coal exporters of anthracite into a net importer of steam bituminous coal. Demand for coal in the power sector for 2008 was estimated to be 6.5 Mt, with a possible 2.5 Mt rise in 2009. Under the Viet Nam Coal Industry Development Strategy, coal production could reach 48–50 Mt in 2010, 60–65 Mt in 2015, and 70–75 Mt in 2020, and 80 Mt in 2025 (Baruya, 2010).

In 2005, the Transport Development and Strategic Institute carried out a study on inland waterways in northern Viet Nam, part of which encompassed the coal-producing region of Quang Ninh, but concentrated mainly on the demand and economic centers around Ha Noi. According to this study, some 20 Mt of coal was transported by river barge (World Bank, 2008). This makes river transportation a significant provider of infrastructure for the coal mines and power stations, possibly contributing to the movement of a quarter of the country's coal and also a quarter of the tonnage carried by the waterways (legally) in 2005. Coal-fired stations and cement works may be sited close to such waterways, partly for coal transport, but power stations are often adjacent to rivers for cooling water.

One of the most important outcomes of the study is the projected growth in volumes of coal, and coal-related goods that will make use of inland waterways, recognizing a massive need for investment in improving equipment and services throughout all the main courses, tributaries, and canals in and around the Red River, Duong River, and Da Bach River regions. By 2020, coal movements could rise to a considerable 50 Mt/year, resulting primarily from the demand for coal from power stations within Viet Nam, as well as the potential for exports. Barge capacities are little more than 2,500 deadweight tons, and so shipments are small. With the first coal-fired power station being built on the Mekong River, there will be an increase in the growth of related services on the river.

Table 1 lists the 9 coal-fired power plants, in chronological order, that were in operation in 2008. Uong Bi 7 is separated from the other units as it was built 30 years after the remainder of the site. Uong Bi 5-7 410 megawatt hour electrical (MWe), Pha Lai 1 & 2 1,040 MWe, and Ninh Binh 220 MWe are owned by EVN subsidiaries. This leaves three smaller power stations of 12–126 MWe, totaling 370 MWe that are operated by independent power producers (IPPs). IPPs provide around 18% of the total coal-fired capacity. Na Duong (100 MWe) and Cao Ngan (100 MWe) are still owned by the state via Vinacomin and so are independent of EVN, but not privately owned.

Coal-fired power development in Viet Nam was slow before 2000. It took almost 20 years to build 800 MWe of coal-fired capacity. Some 1.2 GWe were built between 2001 and 2006 with the construction of Pha Lai 2 and Uong Bi under EVN, and a number of plants owned by Vinacomin, Formosa, and Ha Bac Nitrogen Fertilizer.

Table 2: Coal-fired Power Plants in Viet Nam

Plant name	Owner or operator	Mwe	Fuel	Date of commissioning
Uong Bi 5 & 6	Uong Bi Thermal Power Co	110	Anthracite	1965 & 1974
Ninh Binh	Ninh Binh Power Co	220	Anthracite	1974-1976
Pha Lai-1	Pha Lai Thermal Power JSC	440	Anthracite	1983-1987
Bai Bang Mill	Bai Bang Paper Co	28	Anthracite	1982
Pha Lai-2	Pha Lai Thermal Power	600	Anthracite	2001
Na Duong	Vinacomin	100	Lignite	2004
Nhon Trach Formosa	Hung Nghiep Formosa	126	Anthracite	2004
Cao Ngan	Vinacomin	100	Anthracite	2006
Uong Bi 7	Uong Bi Thermal Power Co	300	Anthracite	2006
Ha Bac Plant	Ha Bac Nitrogen Fertilizer	12	Anthracite	

Source: Baruya (2010).

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Coal is likely to take over from hydropower as the main energy supply. The latest development on the Mekong Delta is the construction of a $1.4 billion coal-fired power plant. The 1,200-megawatt plant will be built in the Long Phu District, and supply electricity to 16 million people in the delta. It is scheduled to be completed in 2014. The Government is planning to build 90 coal-fired plants by 2025, investing $83 billion.

There appears to be little research carried out on the implications of increasing the use of coal versus hydropower on the Mekong River.

2.2 Lao PDR

The total land area of the Lao PDR is 236,800 km^2; the country is land locked, surrounded by Cambodia, the PRC, Myanmar, Thailand, and Viet Nam. The Lao PDR has a population of around 6.4 million living in 16 provinces (CIA, 2011a). The main energy source is almost entirely hydropower. The Mekong River flows through 1,835 km of the Lao PDR and it has been estimated that over half the hydropower potential in the lower Mekong Basin is within the Lao PDR. The country has no developed infrastructure or railway network and currently a low energy consumption pattern, with wood making up the major share of total primary energy consumption (Watcharejyothin and Shrestha, 2009).

There is an estimated 810 Mt of proven lignite reserves at Hongsa in the northwest. Around 530 Mt is economically recoverable. There is also an estimated 100 Mt of proven anthracite reserves. Based on the reserves of coal it has been estimated that a 2,000 MW coal-fired power station for lignite could be built and a 500 MW one for anthracite (ADB, 2009b). The Hongsa thermal plant will likely be the only lignite fired power station built unless more reserves of lignite are discovered.

The annual growth of Lao PDR primary energy up to 2030 will be around 21% from coal due to development of the Hongsa thermal plant with an installed capacity of 1,800 MW (ASEAN, 2009). However, the sole purpose of the coal power plant on its completion in 2015 is to export electricity to Thailand. There are several developments underway to use the Lao PDR's energy resources in Thailand.

Hydropower is the main indigenous energy resource, with a technical potential estimated at 18,000 MW. A major government goal is to provide substantial exports after the countries generation needs are met. The Nam Theun 2 hydropower project is intended to enable the Lao PDR to export 995 MW to Thailand and use the remaining 75 MW for domestic use. There is also the thermal Hongsa Project, a joint investment with Banpu, Rathaburi Electricity Generating Holdings, and Holding State Enterprise, for a 1,878 MW lignite-fired thermal plant. The Lao PDR Government also intends to build up to 30 new dams by 2020. In northeastern Thailand, there are currently 5 transmission lines already supplying power from the Lao PDR, with a further 2 lines under construction and 4 more planned.

2.3 Cambodia

Cambodia, with a total land area of 181,035 km^2, is bordered by Thailand, Viet Nam, and the Lao PDR. Cambodia has a population of around 14.8 million (CIA, 2011b). Cambodia has no national power grid; provincial towns and cities have their own power generation plants using mainly diesel. Only 20% of the population has access to mains electricity. There are government plans to triple Cambodia's energy output from around 800 MW in 2009 to up to 3,000 MW by 2020. This would supply electricity to 70% of the population. The Cambodian Government's power development plan to 2020 includes the construction of 9 hydro dams and 9 coal plants. Once operational, the combined plants will provide an estimated 3,000 MW of energy. The 193 MW Kamchay hydropower dam on the Mekong River is due to be completed in 2013.

In recent years there have been discoveries of coal reserves of around 150 Mt or enough coal to supply a 400 MW coal-fired power for more than 30 years. A Malaysian company is building a 100 MW coal-fired power station due for completion in 2012 and discussions are underway about construction of a further 700 MW using imported coal. This is likely to be needed as the hydropower capacity is only full during the rainy season; in the rest of the year capacity is reduced to one third.

2.4 Thailand

The total land area of Thailand is 513,115 km^2; the country is bordered by Cambodia, the Lao PDR, Malaysia, and Myanmar. Thailand has a population of around 65.5 million living in 76 provinces (CIA, 2009). Increasingly, coal could play a major role in the future energy mix of Thailand. The energy sector over the last decade has undergone a period of restructuring and privatization.

Key coal facts

Total coal production (2008 estimate)	:	18–19	Mt
Total coal demand (2008 estimate)	:	32–36	Mt
Imports (2008 estimate)	:	17–18	Mt
Proven reserves (2008 estimate)	:	2,000	Mt

In 2007, the installed generating capacity of Thailand was around 29 GW. The generation capacity of the Electricity Generating Authority of Thailand (EGAT) power plants was 16 GW, or 55 % of the country's total generation capacity. Private power sector facilities as well as sources in nearby countries provided the remainder. This was made up of 10 GW from domestic IPPs, 2 GW from small power producers under firm energy purchase contracts, and 640 MW imported from the Lao PDR and Malaysia (EGAT, 2009).

A major challenge facing energy planners in Thailand is the issue of energy security with its heavy reliance on natural gas for power generation and increasing environmental concerns from the public and environmental nongovernment organizations. In recent years, the Government has begun to explore a strategy of energy security diversification and increasing consultation with the public over energy projects.

In 2007, the Ministry of Energy and EGAT produced the latest power development plan (PDP) to provide a framework for long-term power development (2007–2021). The PDP outlines an objective to increase coal-fired power stations during 2011–2021 from 7,000 to 11,900 MW. The PDP includes nuclear power plants with a total generating capacity of 4,000 MW by 2021(Kessels, 2010). The rationale behind increasing the use of coal and nuclear power stations is to reduce reliance on natural gas, which currently generates nearly 70% of Thailand's power.

The largest coal power plant in Thailand is the Mae Moh lignite thermal power plant made up of ten 300 megawatt (MW) units and able to produce more than 2,500 MW. In the 1990s, there were serious problems with SO2 pollution which led to environmental protests and more stringent air quality standards being introduced. As a result, all the operating units are now equipped with ionizing wet scrubbers for the collection of fly ash. Lime (calcium oxide) desulfurization was also added to remove sulfur oxides from the flue gases. Six of the units supply fly ash to the cement industry with the remainder of fly ash disposed of at a disused mine.

The BLCP power plant, commissioned in 2007, consists of two coal-fired conventional units. The rated output per plant is 717 MW with the total power generation capacity of the two plants up to 1,434 MW. The coal used is from low-sulfur bituminous coals imported from Australia and Indonesia; diesel oil is used as the start-up fuel. The plant is located in the Map Ta Phut Industrial Estate in Rayong Province in southeastern Thailand. The power station is on reclaimed land 3 km from the eastern coastline of Map Ta Phut Port and is surrounded by sea, considering the entry of large coal ships. The project is under a 25-year power purchase agreement between EGAT and BLCP (Kessels, 2010). The demand for coal in Thailand is projected to increase (Table 3).

There are also several other thermal plants, including some circulating fluidized bed (CFB) plants operating since 1998 with an installed capacity of 2x150 MWe and fed with bituminous coal and anthracite. They are compact boilers and include a reheat steam by-pass system. The National Power Supply (NPS) Company operates a power plant in Tha Toom village of Prachinburi Province. It began commercial operation in February 1999. The power plant has two identical units of 150 MWe. The boilers are designed to use coal and biomass with rice husks purchased from local suppliers and eucalyptus bark from a nearby pulp and paper mill. The NPS Power Plant sells 60% of its power output to EGAT. The process steam and the remainder of the power are sold to local customers at an Industrial Park and a pulp and paper mill (Barisic *et al.*, 2008).

Table 3: Thailand Coal Demand and Future Outlook ('000 ton)

Year		2006	2007	2011	2016	2021
Supply: Domestic		18,867	19,746	17,525	16,183	15,722
Import		11,472	15,229	20,643	33,209	39,654
Total Supply		**30,339**	**34,975**	**38,168**	**49,392**	**55, 376**
Domestic Demand	Power	19,304	22,821	22,775	28,751	27,805
	Cement	7,724	8,508	10,142	13,615	18,233
	Others	3,310	3,646	5,251	7,026	9,338
Total Demand		**30,339**	**34,975**	**38,168**	**49,392**	**55, 376**

Source: Suksumek (2007).

3. GMS National Appropriate Mitigation Actions

Figure 1 below makes a distinction (in dashed boxes) between three important groups of countries in the climate negotiations: 1) countries that have not ratified Kyoto; 2) industrialized countries that have ratified Kyoto; 3) developing countries that have ratified Kyoto. In addition to preventing dangerous climate change, these groups have some common and different interests and goals, expressed in the ovals. Although the issues in the ovals are not exhaustive, they represent the major issues at this time. Energy security and air quality appear to be common interests for all countries, whereas GHG targets are currently mostly desired by Kyoto industrialized countries.

Post 2012 climate policy will be driven by several economic, environmental, social and political factors. The horizontal arrow should not be regarded as a timeline, more as the general direction of the process towards a post-2012 climate policy framework.

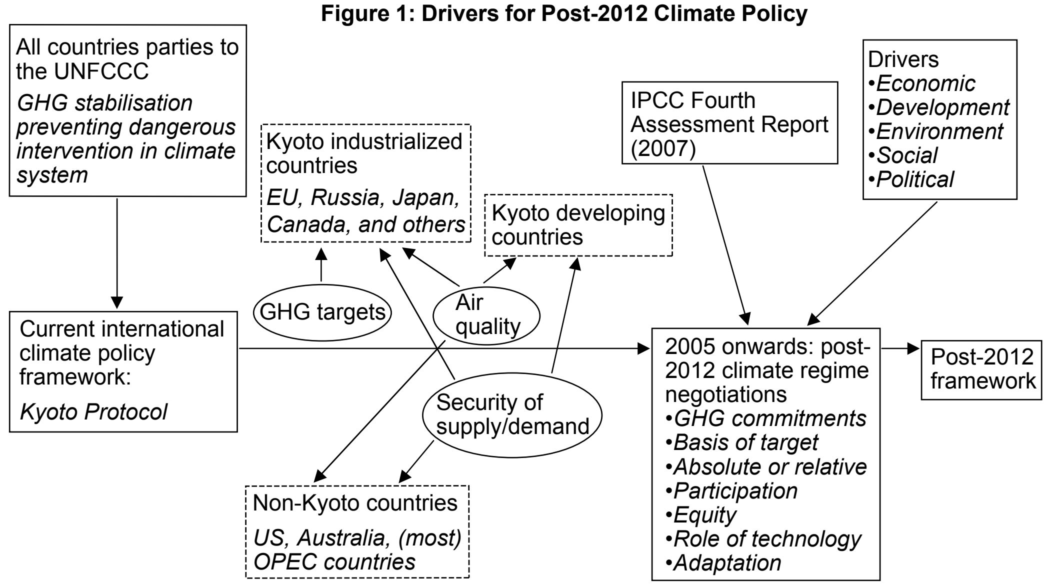
A recent development to mitigate GHG emissions in developing countries is national appropriate mitigation actions (NAMAs). The 2007 Bali Action Plan called for NAMAs by developing country parties in the context of sustainable development, supported and enabled by technology, financing, and capacity building, in a measurable and verifiable manner. There is as yet no recognized NAMA, but several countries including Brazil, the PRC, India, and South Africa are working on or are considering a NAMA.

Three types of NAMA have been under discussion:

- unilateral or autonomous actions that developing countries implement without support from developed countries;
- conditional actions that developing countries agree to undertake with support from developed countries; and
- actions that could be partially or fully credited for sale in the global carbon market.

An example of a unilateral action is one that a country intends to follow for reasons other than just climate change mitigation, which could have other benefits, such as energy security or reducing poverty. However, actions may cross over into mitigation, such as by increasing energy efficiency. A NAMA with conditional actions is one where a developing country agrees to undertake mitigation action with financial or technology support from developed countries. The mitigation actions could involve those with higher costs or needing specific assistance, such as carbon capture and storage projects. The last category of NAMA is one that generates credits to be sold on the global carbon market. The developing country would need to set a crediting baseline for their actions and credit only the actions implemented in addition to this baseline level of activity.

Figure 1: Drivers for Post-2012 Climate Policy



Source: author.

The design of the NAMA could include supercritical pulverized coal combustion (SPCC) and integrated gasification combined cycle (IGCC) technologies capable of:

- *Power plant efficiency improvements*. Globally, efficiency improvements provide scope for achieving CO_2 emission reductions of 10% through the gradual replacement of existing plants and the increasing use of state-of-the-art technology.
- *Carbon dioxide capture and storage*. CCS technology may prevent up to 90% of coal-based CO_2 emissions from electricity generation, if applied to all coal power plants worldwide.

However, there should be scope in the NAMA to include other CCTs if they can improve efficiency or provide an option for CCS, such as ultra-SPCC or use of biomass.

An option to consider to improve the likelihood of accelerated implementation of CCTs in the GMS could be to include CCTs either in individual countries or if feasible a regional NAMA. A first step is to determine each country's power and industrial sector coal-based CO_2 emissions as a baseline. This would make it possible to calculate emission savings in the future.

The implementation and development of CCTs in the lower GMS within a NAMA will require consideration of several factors. First is the lengthy timescale for deployment of advanced CCTs, up to 4–7 years and considerably longer for CCS, which is not occurring anywhere in the GMS. Second is the range of barriers that CCTs must successfully overcome in the lower GMS to enter into widespread commercial use. Third is the role of the lower GMS countries in creating an enabling policy framework to encourage the construction of CCTs by private companies and research by universities. There are many technical and market issues that CCTs must overcome to enter into widespread commercial use, including performance, cost, consumer acceptance, safety, training, enabling infrastructure, incentive structures for firms (e.g., licensing fees, royalties), regulatory compliance, and environmental impacts (IPCC, 2004).

The IEA and ADB could play a role in providing objective data and assist in the formulation of the rules and monitoring and verification requirements needed for the NAMA. The IEA Clean Coal Centre database could be used for accurate and impartial measurement of average and higher coal plant efficiency by individual countries and regions. Countries participating in this type of NAMA would have to provide information on current coal use and technologies being used. Consequently, new plants built with higher efficiencies or CCS technology would receive incentives based on the NAMA. This would also create an economic incentive for application of new CCTs within the GMS.

4. Conclusions

Coal will continue to play a key role in providing energy in the long term in the GMS. Policymakers, specialists, and scientists point out that the expansion of coal usage faces a number of sizeable environmental barriers. Simultaneously, it is recognized that the technical potential exists for large-scale emission reduction from coal-fired power plants through the use of CCTs, in particular improved power plant efficiencies and CCS technology. Lacking, however, is a framework or agreement providing the incentives necessary for CCT deployment in the subregion.

The decisions on the use of coal and clean coal technologies in the GMS will have an impact on how the future energy mix will develop. An integrated strategy that takes into consideration the competition with water and food could result in a low carbon pathway. To achieve this will require decisions and policies that recognize the value and use of clean coal technologies in current and future energy developments in the GMS, particularly in Viet Nam and Thailand.

The use of the proposed new NAMA structure as discussed in this paper could stimulate the commercial deployment of clean coal technologies. To date, the Kyoto Protocol has failed to encourage the large-scale use of CCTs. Designing a NAMA oriented toward CCT implementation in the lower GMS could be a way forward to increase the uptake of CCT. As a starting point, countries within the lower GMS could develop a plan with historic, current, and projected emissions from the coal sector, based on IPCC inventory guidelines. This plan should in the first instance apply to all the existing, and future additional, large coal-based GHG emission point sources. Due to the projected growth in coal-based power plants in Viet Nam and in other lower GMS countries it is important to encourage the uptake and deployment of all types of CCT as early as possible.

The core of the NAMA would be an increase in efficiency of coal-based power production over time in all participating countries and support for carbon capture and storage where suitable. The baseline to measure emission reductions could vary from country to country depending on such factors as best unit in operation in 2010, noting that coal quality, availability of cooling water at specific temperatures, and other factors will all affect efficiencies as well as steam conditions.

Solely relying on the Clean Development Mechanism to encourage CCTs results in a piecemeal approach to the problem of climate change and leads to few projects involving the use of CCTs. Developing a new framework for the stimulation of CCTs through the use of NAMAs could be a step forward for the GMS on the path to energy security and mitigation of climate change.

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BIOFUELS IN THE GREATER MEKONG SUBREGION: ENERGY SUFFICIENCY, FOOD SECURITY, AND ENVIRONMENTAL MANAGEMENT

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Abstract

Global production and trade of biofuels have expanded rapidly in the last decade, spurred on by the adoption of policies and incentives to support their increased use in the European Union and the United States. In the Greater Mekong Subregion (GMS), growing demand for biofuels could help support the agriculture sector and provide an alternative source of energy. However, experience from the subregion and elsewhere has shown that, if deployed unsustainably, biofuel development can be associated with numerous risks, particularly in terms of food security, impacts on soil and water quality, and biodiversity, which in turn have negative ramifications for human development. This paper draws extensively on existing literature and integrates various themes to provide an overview of four main issues related to biofuels deployment in the GMS: the need for alternative energy sources, risks to food security, considerations for environmental management, and opportunities for rural development. The paper finds that with increasing fuel demand projected for the GMS, biofuels could make a significant contribution to offsetting oil demand and to increased agricultural and rural incomes, though the overall benefits to the region's population depends largely on how risks to food security are managed and on the production system that is adopted. Using examples from within the GMS, the paper illustrates that expansion involving surplus land, smallholder-based production, and an emphasis on non-food crops and second-generation biofuels could pave the way for sustainable utilization of biofuels in the GMS.

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1. Introduction

Biofuels have been the focus of intense interest, discussion, and debate in recent years. Spurred on by the adoption of policies and incentives to support their increased use in the European Union (EU) and the United States (US), both global production and trade of biofuels have expanded rapidly in the last decade (IEA 2010a). In response, several Asian governments announced ambitious plans to promote biofuels production for both domestic consumption and export (Zhou and Thomson 2009) and, as a result, the total production of biofuels in Asia increased from just over 5 billion liters in 2002 to almost 11 billion liters in 2010 (OECD-FAO 2011).

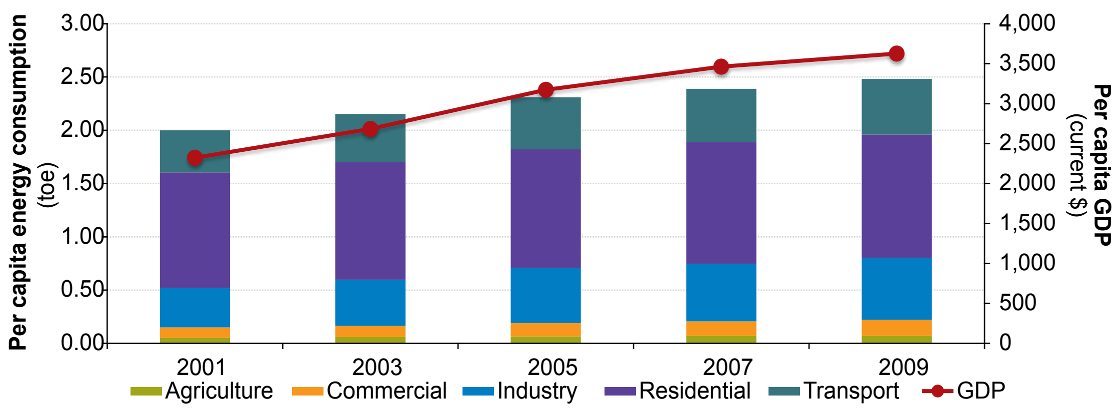
For decision makers in the Greater Mekong Subregion (GMS)[5], growing global demand, particularly for first-generation biofuels,[6] could provide a new market for existing agricultural products, and help support the agriculture sector, which sustains the majority of the region's population. It has been argued that due to the availability of farm land, abundant labor, and favorable weather conditions in the subregion, biofuel expansion could help farmers diversify their activities and earn additional income (Malik et al. 2009). Conversely, experience from the subregion and elsewhere has shown that, if deployed unsustainably, biofuels development can be associated with numerous risks, particularly in terms of food security, impacts on soil and water quality, and biodiversity, which in turn have negative ramifications for human development (USAID 2009).

Much work has been done on the regional impacts of biofuel deployment in Southeast Asia (Elder et al. 2008; USAID 2009; Zhou and Thomson 2009). Much of the work considering the GMS, however, has either focused on an individual aspect of biofuel deployment, such as impacts on trade (Yang et al. 2009) and employment (Malik et al. 2009), or has presented results of case studies from individual countries (ERIA 2009; Shepley et al. 2009). This paper draws extensively on existing literature and integrates various themes to provide an overview of three main issues related to biofuels deployment within the overall

[5] The Greater Mekong Subregion (GMS) is a natural economic area bound together by the Mekong River, covering 2.6 million square kilometers and a combined population of around 326 million. The GMS countries are Cambodia, the People's Republic of China (PRC, specifically Yunnan Province and Guangxi Zhuang Autonomous Region), Lao People's Democratic Republic (Lao PDR), Myanmar, Thailand, and Viet Nam.

[6] First-generation biofuels are primarily derived from food crops, such as grain (corn, wheat, etc.), sugarcane for bio-ethanol, and oil seeds (such as palm oil) for biodiesel production.

Figure 1: GDP and Energy Consumption in the GMS, excluding the PRC



toe = ton of oil equivalent.
Note: These figures exclude the People's Republic of China.
Source: GDP data from ADB (2011); energy data from IEA (2011) and national ministries.

context of energy demand and environmental trends in the GMS. The initial sections of the paper describe the energy utilization context and biofuels industry in the subregion, and analyze the extent to which biofuels development in the GMS could offset fossil fuel demand under different scenarios. Subsequent sections of the paper discuss three major issues related to biofuels development in the GMS—food security, environmental management, and rural development. Finally, recommendations are made on how policies need to be designed and implemented to ensure that the production and utilization of biofuels in the GMS may be sustainable.

2. Energy Demand, Supply, and Security in the GMS—the Need for Alternatives

GMS countries have seen a rapid growth in their gross domestic product over the last 2 decades. Concomitantly, energy demand has risen as well (Figure 1). Across the region, while electricity demands are met through coal and hydropower, the transport and industry sectors are primarily dependent on diesel and gasoline, and therefore account for the largest share of energy demand from fossil fuels. These sectors are constantly growing—for example, transport energy demand in the GMS (excluding the People's Republic of China [PRC]) increased 50% between 2000 and 2009, from 20 million to 30 million tons oil equivalent (IEA 2011). Throughout GMS countries, the consumption of energy outstrips production, which indicates a heavy dependence on fossil fuel and other energy imports. Larger energy consumers such as Thailand imported over 60% of its domestic energy needs between 2002 and 2006 (Chirapanda et al. 2009), while Cambodia and the Lao People's Democratic Republic (Lao PDR) imported all their commercial fossil fuels in 2006.

Under a business-as-usual (BAU) scenario over the next decade, energy consumption in the subregion is expected to increase between 7% and 16% per annum, at rates much higher than that of increases in economic growth (ADB 2006). Within the transport sector, gasoline and diesel consumption over the next decade is also expected to increase as illustrated by current trends in vehicle sales and registration. In Myanmar, for example, the number of vehicles registered is increasing at 19% per year, and in Cambodia, the energy demand from transport is expected to grow between four- and fivefold by 2030 (Kyaw et al. 2009; Luyna et al. 2009).

The consumption of petroleum and dependence on imports impact national budgets, trade balances, and household incomes. Most countries have to subsidize fuel costs in order to protect their populations and industries from fluctuating fuel prices. Even so, changes in fuel subsidies and increasing fuel prices do affect consumers and can cause significant civil unrest.[7] Diversifying sources of energy, and in particular identifying new indigenous sources for the transport and industry sectors, is important if GMS countries want to increase their energy security.

The use of fossil fuels in the subregion is also associated with environmental and health impacts. Over 21% of energy-related greenhouse gas (GHG) emissions in the GMS (excluding the PRC) in 2007 were from the transport

[7] Recent examples of fuel price hikes and associated civil riots include riots in Indonesia in 2005 in response to government reduction in fuel subsidies, and protests in Myanmar in 2007 in response to a fuel price increase.

sector, which highlights the significant role that transport plays in driving climate change (WRI 2010). These emissions are a direct result of the current modal split in GMS countries that favors road transport systems, and the dependence of road transport on fossil fuels. Other air pollutants associated with fossil fuels, particularly from the road sector, include emissions of particulates, and nitrogen and sulfur oxides, which have significant health impacts, particularly in urban and peri-urban areas. Figure 2 shows particulate emission levels in urban areas in the GMS compared to World Health Organization (WHO) guidelines and illustrates that air pollution in GMS countries is still a concern with serious ramifications for human health.

In summary, there is a significant need for introducing alternative fuels to the GMS, particularly for the transport sector, including bio-ethanol and biodiesel, to offset projected demand using energy produced from local resources, with fewer environmental impacts.[8]

3. Current Development and Potential Production of Biofuels in the GMS

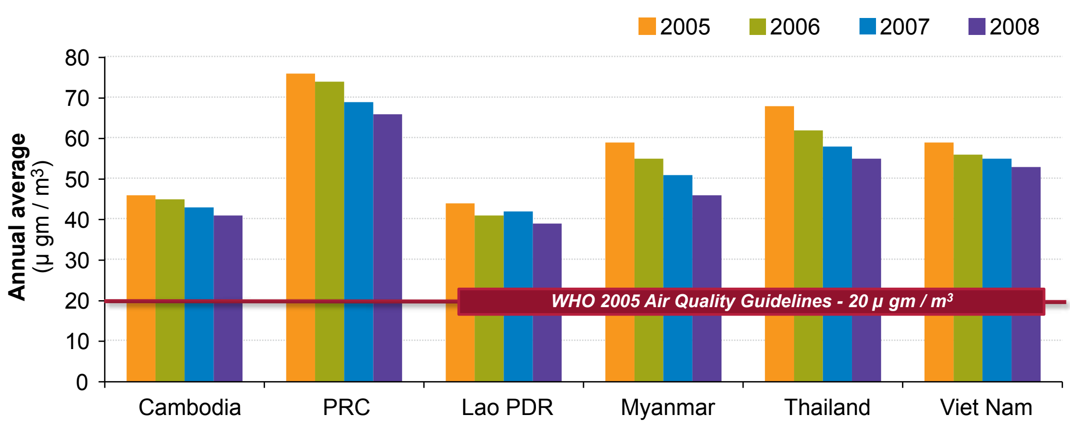
3.1. Current Status

Following the market demand for biofuels, the GMS countries have responded or are responding with strong national biofuel programs to support energy security, renewable energy, and a new attractive growing market for the agriculture sector (Malik et al. 2009; Yang et al. 2009). National biofuel programs, production capacity, and industry development vary greatly across the GMS countries, with the PRC, Thailand, and Viet Nam taking the lead with established policies, targets, and incentives. Table 1 presents a summary of biofuels policies in the GMS. Policy mechanisms include regulatory instruments like blending targets and mandates to create demand coupled with incentives for the private sector to get involved in biofuel development and, finally, provision of subsidies to reduce the cost of production so that biofuels are favorable when compared with fossil fuels. In all countries, the biofuels industry is still dependent on government incentives due to higher production costs when compared with fossil fuels.

The PRC is the third largest producer of bio-ethanol in the world, producing just over 1.78 million (metric) tons of liquid biofuels in 2008 using mostly maize and wheat (IEA 2011). Biodiesel production is much lower, 0.2 million tons per year based mainly on waste vegetable oil. One of PRC's five main bio-ethanol producing plants is located in Guangxi Zhuang Autonomous Region and had a production of 0.2 million tons in 2007 using only cassava (Malik et al. 2009; Huang, Qiu, et al. 2009). The government targets for the whole country are to produce 5 million tons per year of bio-ethanol by 2012 and 12 million tons per year by 2020. The PRC is also the only GMS country with experience on second-generation biofuels (IEA 2010b).[9]

Session 2.3

Figure 2: Particulate Emissions in Urban Areas in the GMS Compared with WHO Guidelines



μ gm/m³ = microgram per cubic meter
Note: The data are averaged over all areas within a country with populations of over 100,000 inhabitants.
Source: World Bank Environment and Data Statistics (accessed 23.09.11).

[8] In terms of impact on air pollution, biofuels have been shown to lead to lower volatile organic chemicals (VOCs), sulfur, and carbon monoxide (CO) emissions, but also to potentially increased nitrogen oxide (NOx) emissions and ozone, and in some cases particulates (USAID 2009). Overall, if land clearing and the burning of vegetation burning are avoided, biofuels would have a smaller impact on air pollution than fossil fuels.

[9] Second-generation biofuel: biofuels produced from cellulose, hemicellulose, or lignin (IEA 2010b).

Table 1: Summary of Biofuel Policies and Targets in the GMS

Country	Policies / Incentives	Policy Targets (million liter per year)
Cambodia	No policies	N.A.
PRC[a]	E10 Subsidies for producers	Bio-ethanol: 12 by 2020[b] Biodiesel: 6 by 2020[b]
Lao PDR	E10 by 2015 E20 by 2020	Insufficient information
Myanmar	E5 and E15 B5 to B20	Insufficient information
Thailand	E10 and E20 B5 Tax incentives	Bio-ethanol: 3,285 by 2022[c] Biodiesel: 1,643 by 2022[d]
Viet Nam	1% of total fuel demand in the transportation sector in 2015 and 5% by 2025 E5	Bio-ethanol: 684 by 2020 Biodiesel: 128 by 2020

N.A. = not available

Notes:

1. Bio-ethanol and biodiesel density assumed to be 789 tons/million liter and 845 tons/million liter (USAID 2009), respectively.
2. B5 and B20 refer to percentage of biodiesel in diesel fuel.
3. E5 and E10 refer to percentage of bio-ethanol in gasoline.

a These policies cover the whole of PRC.
b million tonnes per year
c Suryadi 2010.
d Department of Alternative Energy Development and Efficiency (DEDE) 2009.

Source: Authors.

The target for biodiesel is to use Jatropha and reach 6 million tons per year in 2020 (Malik et al. 2009). Yunnan province is the national Jatropha demonstration province for the PRC. The provincial government has proposed 14 biodiesel refining plants with a production capacity of 3.2 million tons of biodiesel per year. Table 2 provides an indication of production and yield of different feedstock in the three major biofuel-producing countries in the GMS, and shows that sugarcane is a good potential source for bio-ethanol in Yunnan and Guangxi.

Thailand is one of the top eight global biofuel producers and has sufficient feedstock for both biofuel and other uses as illustrated by the country reporting a net surplus of bio-ethanol feedstock production in recent years (Chirapanda et al. 2009). The government has established a biofuels

Table 2: Feedstock Production and Yield in the PRC, Thailand, and Viet Nam

	Yunnan and Guangxi PRC		Thailand		Viet Nam	
	Land used ('000 ha)	Yield (t/ha)	Land used ('000 ha)	Yield (t/ha)	Land used ('000 ha)	Yield (t/ha)
Bio-ethanol						
Cassava	320	19.8	1,148	21.0	492	16.5
Maize	1,698	3.8	1,021	4.0	1,079	3.9
Rice	3,801	7.2	10,541	2.9	7,343	5.0
Sorghum	5	2.2	36	1.8	–	–
Sugar beet	–	–	–	–	–	–
Sugarcane	1,126	69.7	996	60.8	276	58.3
Sweet potato	23	20.0	–	–	170	8.1
Wheat	1,102	6.0	–	–	–	–
Biodiesel						
Castor	–	–	13	0.8	7	0.8
Coconuts	–	–	253	6.5	120	8.7
Jatropha	40	0.0	–	–	30	0.0
Oil palm	–	–	420	16.8	–	–
Rapeseed	226	1.5	–	–	–	–
Soybean	–	–	131	1.7	183	1.4

ha = hectare, t = metric ton

Source: FAO 2011.

program whereby bio-ethanol has been introduced for the transport sector in the form of E10[10] gasoline. In 2010, bio-ethanol consumption was approximately 329 kiloton oil equivalent (ktoe) (approximately 648 million liters) and average production of bio-ethanol was estimated at 1.16 million liters per day. Moreover, the government has mandated the use of B5[11] since 2011 and B10 should become available by 2014. The main source for biodiesel has been oil palm while Jatropha is being used for small-scale applications. In 2010, biodiesel consumption was approximately 475 ktoe (589 million liters) (Chirapanda et al. 2009; Malik et al. 2009; USAID 2009; Yang et al. 2009; DEDE 2011a, 2011b).

In 2007, the Government of Viet Nam put forward their target for biofuels: 1% of total fuel demand in the transport sector in 2015 and 5% by 2025.[12] The volume of biofuels needed to meet 5% of total petroleum demand by 2020 is estimated to be around 1.6 million tons (540 million tons of bio-ethanol and 1.09 million tons of biodiesel) (Nguyen et al. 2009; Yang et al. 2009). Bio-ethanol is to be sourced from sugarcane, sweet sorghum, and molasses, and biodiesel from catfish oil and Jatropha. Bio-ethanol production capacity from sugar factories is estimated at 53 million liters per year and from cassava 320 million liters per year (Nguyen et al. 2009).

In Cambodia and the Lao PDR, food security is a critical issue for decision makers and the current focus has been on pilot biofuel projects using Jatropha to raise awareness on process and technology. In Cambodia, policies are particularly directed at rural electrification and there are no particular policies and targets regarding biofuels (Luyna et al. 2009). In the Lao PDR, the government is planning to promote biofuels and has stated that it expects E10 to be commercially available by 2015 and E20 by 2020. In terms of biodiesel, the Lao PDR has already been producing biodiesel from Jatropha, coconut, oil palm (low potential), and castor oil plants, although these are currently at a pilot stage (Sanatem et al. 2009).

The Government of Myanmar has tested some programs for biofuel development in parts of the country and plans to replace gasoline with E5 for use at the community level and E15 (using anhydrous bio-ethanol) nationwide (Khaing 2010). Diesel is to be replaced by B5 to B20 at both community and national levels (Suryadi 2010). Biofuel production and commercialization only started in 2008 and, consequently, production is relatively low compared to other GMS countries. In 2009, the production capacity of anhydrous bio-ethanol was estimated at least 659,000 liters per year. Sugarcane is the main source of bio-ethanol followed by maize, cassava, and sweet sorghum. Biodiesel production is still at the demonstration level and the main source is Jatropha (Kyaw et al. 2009; Yang et al. 2009; Khaing 2010). The government initially introduced a 3-year plan for Jatropha for 2006–2008, which raised a lot of interest initially due to the increase in diesel prices at the time. However, plantations were seen to conflict with demand for land for food production in poor areas and proved to be unsuccessful in matching national biofuel demand (Cushion et al. 2010; Suryadi 2010).

3.2. Potential for Expanded Biofuels Production in the GMS

An initial analysis of potential production of biofuels in GMS countries is given in Table 3. The analysis estimates the amount of biofuels that could be produced in each country if a) 10% of available land in the countries were converted to biofuel feedstock production,[13] b) all the crop production that is currently lost on-site postharvest (referred to as "wasted grain or crop") were converted into bio-ethanol using current technologies,[14] and c) crop residues were recovered and converted to bio-ethanol using emerging technologies.[15]

[10] E10: terminology used to indicate the percentage of ethanol in gasoline. In this case, 10% ethanol mixed with 90% gasoline.

[11] B5: diesel blended with 5% of biodiesel.

[12] Target stated under Decision 177/QD-TTG on "Strategy for Developing Biofuel for the Period 2005–2015 and Vision to 2025."

[13] This analysis assumes a production of a certain mix of crops and land intensity per crop on available land in each country. These figures are based on national data and current crop production trends. Land intensity (liter/ha) is taken from USAID (2009) and available land (for crop production) from Malik et al. (2009). The following assumptions have been used. Split of crop types: Cambodia (cassava – 20%, Jatropha – 20%, oil palm – 20%, sugarcane – 20%, maize – 20%); PRC (cassava – 25%, Jatropha – 25%, sugarcane – 25%, sweet sorghum – 25%); Lao PDR (cassava – 25%, coconut – 25%, Jatropha – 25%, sugarcane – 25%); Myanmar (cassava – 8.5%, Jatropha – 33%, sugarcane – 25%, maize – 8.5%, sweet sorghum – 25%); Thailand (cassava – 33%, oil palm – 33%, sugarcane – 33%); and Viet Nam (cassava – 33%, Jatropha – 33%, sugarcane – 33%).

[14] This analysis is based on USAID (2009) and assumes that between 1% and 7% of various crops are wasted due to inefficiencies in collection, processing, and transportation. The estimates of total ethanol volumes that could be produced in each country from wasted crop were developed using data on harvested area, crop production, and yields for various food crops and cereals obtained from FAO's database and from national ministries in each country.

[15] This analysis is based on crop residue estimates for different crop types and locations from Lal (2005) and Gadde, Menke, and Wassmann (2007). Crop residues are defined as the non-edible plant parts that are left in the field after harvest and can include both above-ground and below-ground biomass.

Table 3: Summary of Potential Biofuel Production in the GMS

Country	Possible Production of Biofuels from Conversion of 10% Available Land (million liter)		Possible Production of Biofuels from Wasted Crop (million liter)		Lignocellulosic (million liter)	
	Biodiesel	Bio-ethanol	Biodiesel	Bio-ethanol	Biodiesel	Bio-ethanol
Cambodia	182	257		138		845
PRC, Yunnan and Guangxi	219	1,298		873		20,472
Lao PDR	87	145		70		504
Myanmar	238	962		626		4,901
Thailand	130	176		773		14,609
Viet Nam	26	142		857		7,803

Source: Authors.

The analysis in the first case serves to show that due to apparent land availability in the GMS, countries like Myanmar, and Yunnan Province and Guangxi Zhuang Autonomous Region in the PRC have the potential to produce large volumes of biofuels (over 900 million and 1.2 billion liters, respectively), without impinging on current cropland. However, this is based on the assumption that land availability figures used accurately reflect the situation in the countries, which is not always the case as competition for land resources in the GMS is often a serious concern. The second case shows that feedstock of first-generation biofuels in the form of wasted grain/crop, if recovered, could also be converted into considerable amounts of bio-ethanol—ranging from 70 million liters in the Lao PDR to 873 million liters in Yunnan and Guangxi in the PRC annually—depending on the agricultural activity in each country. In the third scenario, potential bio-ethanol production from crop residues is shown to be an order of magnitude higher than the other two scenarios, ranging from 500 million liters in the Lao PDR to 20 billion liters in the PRC. However, these numbers are purely hypothetical as the technologies to produce these biofuels are still under development and are not commercially viable as yet. Additionally, a proportion of biomass residues is currently used to revitalize the soil or as a local fuel source, and an abundance of residues (as is assumed here) may not be available.

The aim of the analysis is to understand the extent of the difference biofuels could make to the overall energy mix of the GMS countries, particularly to diesel and gasoline demand from the transport sector, based on current land and crop production trends. Table 4 compares the potential production of biofuels from the first two cases, i.e. conversion of 10% of available land and wasted grains in the GMS, to current and projected gasoline and diesel demand in 2020. It shows biofuels could offset some of the transport energy demand, though there is considerable variation across GMS countries. In Thailand and Viet Nam, when compared to current demand, bio-ethanol could offset demand up to 13% and 20%, respectively, though these numbers are somewhat more conservative when compared to demand in 2020 (3% and 10%, respectively). Biodiesel using feedstock grown on currently available land is seen to have much less potential in these two countries, partially due to the significant demand for diesel

Table 4: Potential Biofuel Production in the GMS Compared with Demand

Country	Transport Demand (million liter)				Share of Transport Demand Met through Biofuels (%)			
	Gasoline		Diesel		Bio-ethanol[a]		Biodiesel[b]	
	2009	2020	2009	2020	2009	2020	2009	2020
Cambodia	903	1,729	2,235	4,396	44	23	8	4
PRC, Yunnan and Guangxi	2,978	5,404	4,970	8,518	73	40	4	3
Lao PDR	208	540	323	839	104	40	27	10
Myanmar	590	1,656	702	856	269	96	34	28
Thailand	7,417	27,692	1,8480	64,049	13	3	1	0
Viet Nam	5,095	10,132	8,533	14,667	20	10	0	0

Note: For all GMS countries except Cambodia, linear regression analysis was used to forecast the future demand of gasoline and diesel consumption based on the current consumption trends. For Cambodia, International Energy Agency (IEA) projections (IEA 2010a) for Association of Southeast Asian Nations (ASEAN) countries were used.

a This includes bio-ethanol produced from converting 10% of available land and from wasted grain/crops.

b This includes biodiesel produced from converting 10% of available land.

Source: Authors.

in the future. In the rest of the GMS, biofuels seems to have more potential to offset fossil fuels—bio-ethanol could make up over 40% of gasoline demand in 2010 (Cambodia) and between 20% and 40% of demand in 2020 (in Cambodia, Lao PDR, and Yunnan and Guangxi). Based on this analysis, biofuel potential could overshoot transport demand in Myanmar, though this is largely due to the availability of land in the country and comparatively low demand for transport fuels.

The assessment given here is based purely on crop production and land availability data for the GMS countries and considers production of feedstock in isolation. It does not take into account the social ramifications of feedstock production, or the economic feasibility of any of the scenarios. In reality, the feasibility of biofuel production is very much dependent on both these aspects. As a result, the figures shown are an overestimate and provide an upper boundary for production potential. Overall, the analysis serves to show that biofuels (based on current land and crop trends in the GMS) have the potential to offset fossil fuel demand, particularly in countries such as Cambodia and the Lao PDR, and provide an opportunity for GMS countries to diversify the sources of their fuels. Other similar analyses for Asian countries have demonstrated that biofuels will not be able to offset all the demand for transport fuels (Elder et al. 2009; USAID 2009), and the estimates developed in this paper echo those as well. In order to meet future demand, the expanded use of biofuels will need to be complemented with energy efficiency improvements, such as improvements in vehicle fuel efficiency and use of electric and/or hybrid vehicles.

4. Overview of Sustainability Issues Related to Biofuel Deployment

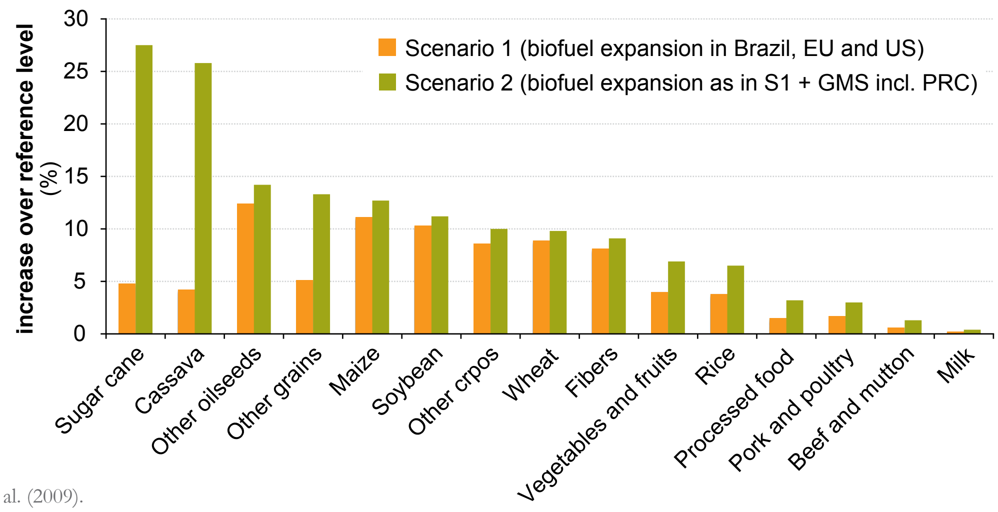
The main drivers for increasing biofuels in the GMS and other Asian economies are the desire to increase energy security, address environmental issues and climate change, and provide income opportunities for the rural population and agriculture sector (Zhou and Thomson 2009). Alternatively, biofuels have also been known to entail significant social and environmental risks by increasing food insecurity, negatively impacting biodiversity, and requiring significant subsidies (USAID 2009). A review of the main issues related to the sustainability of biofuels is presented in the following section.

4.1. Biofuels and Risks to Food Security

Soaring food prices in early 2011 brought into sharp focus the need for countries to increase the security and sustainability of their food supply (FAO 2011). Rising food prices, particularly for commodities like sugarcane and corn, have been attributed to biofuel expansion. However, in the GMS there is still some debate on the extent to which biofuels could impact food prices. Huang, Yang, et al. (2009) used a general equilibrium model to assess the impact of increasing global bio-ethanol and biodiesel production on agricultural production, trade, and prices in the GMS and found that although biofuel expansion would significantly increase the prices of agricultural products (Figure 3), this could be beneficial to countries that were increasing their feedstock production. For example, due to increasing prices of biofuel feedstock, the study argues that countries that increase production and exports to the rest of the world would raise the national self-sufficiency of these commodities—a benefit for the agriculture sector. In reality, this is only one side of the equation, because a dramatic increase in biofuel production would have an impact on the structure of agricultural production and trade, potentially at the expense of other crops. Additionally, apart from direct impacts on food prices, increasing biofuel exports could also have an indirect impact by increasing the prices of feedstock for other food commodities. For example, the PRC is currently increasing its bio-ethanol production from cassava and as a result is sourcing this feedstock from neighboring countries like Cambodia, the Lao PDR, and Thailand (Rosenthal 2011). Though not a main component of food commodities in the GMS, cassava has been used for animal feeds, and increasing demand for biofuels in the PRC could lead to an increase in the price of meat or dairy products in other GMS countries.

Additionally, even with current policy responses to this issue in place, an expansion of biofuels would have impacts in terms of competition for resources. As described in Section 3, in response to food security concerns, some GMS countries (e.g., Cambodia and the Lao PDR) are promoting those biofuels that do not directly conflict with food crops, i.e., biofuels based on energy crops like Jatropha. The advantages of such crops are that they could be grown on marginal land or wasteland, and, in the case of Jatropha, may not require as much water as other feedstock. However, in reality, the yields from Jatropha on marginal land have been far less than forecasts predicted 5 years ago, and in order to produce enough biofuel to displace a significant proportion of fossil fuel demand, energy crops will likely need to be cultivated on cropland and would pose

Figure 3: Increase in Prices of Agricultural Commodities in 2020 against a Reference Level



Source: Huang et al. (2009).

a risk as they compete with other agricultural products for land, water, and agrichemicals. Although land availability is not a serious concern in the GMS at the moment, the subregion's population is expected to increase to 340 million by 2050[16] and Johnston et al. (2010) estimate that demand for food, and therefore land, could increase 25% by 2050.

Increasing yields of biofuel feedstock to increase production is another approach to ensure additional volume of feedstock for biofuel use without requiring expansion of cultivation areas. Yields between GMS countries vary, and as shown in Table 5, Cambodia, Lao PDR, and Myanmar could potentially improve their production yields by learning and adopting more advanced farming practices and use of

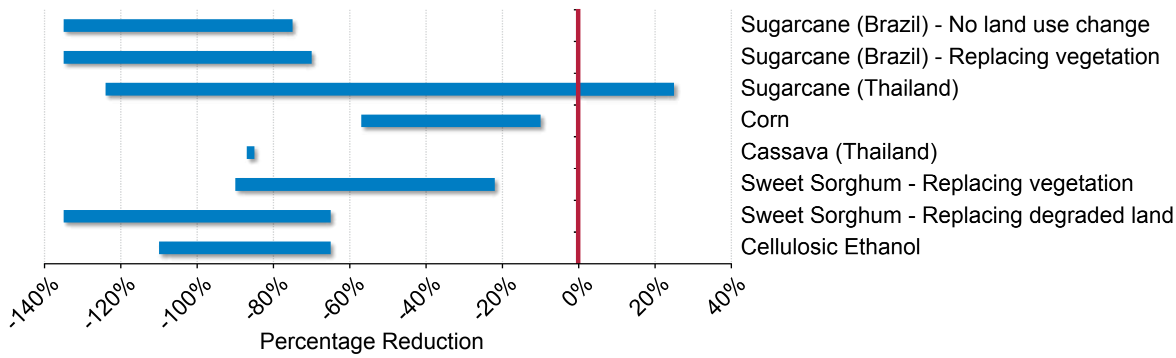
Table 5: Total Production of Selected Energy Feedstock Crops, by Yield and Area Harvested in the GMS, 2005–2009

	Production (ton)	Area harvested ('000 ha)	Yield (ton/hectare)
Sugarcane			
Cambodia	245,253	10.21	24.02
PRC, Yunnan and Guangxi	78,487,123	1,125.60	69.73
Lao PDR	322,640	9.15	35.28
Myanmar	8,492,329	157.90	53.78
Thailand	60,595,791	996.10	60.83
Viet Nam	16,083,007	275.80	58.31
Cassava			
Cambodia	2,370,320	114.25	20.75
PRC, Yunnan and Guangxi	6,320,000	320.00	19.75
Lao PDR	171,180	12.01	14.26
Myanmar	275,880	20.87	13.22
Thailand	24,142,055	1,148.20	21.03
Viet Nam	8,112,616	492.10	16.48
Palm Oil			
Cambodia	–	–	–
PRC, Yunnan and Guangxi	–	–	–
Lao PDR	–	–	–
Myanmar	–	–	–
Thailand	7,078,293	420.40	16.84
Viet Nam	–	–	–

Source: FAO statistics 2011, data presented are averages of values for 2005–2009.

[16] This figure excludes Guangxi Zhuang Autonomous Region.

Figure 4: Range of Greenhouse Gas Reduction from Biofuels When Compared with Fossil Fuels – Bio-ethanol Systems



better plant varieties from Thailand, PRC, and Viet Nam. However, it must be noted that increasing the intensity of agricultural production comes with its own impacts, including those on biodiversity (Section 4.2).

It is also important to note that irrespective of biofuels programs, food security is an issue that is increasingly coming to the forefront in the GMS due to a number of external factors. Increasing incidence of extreme weather events and the looming threat of climate change are expected to affect agricultural productivity and the supply of food. Underdeveloped domestic storage and processing systems, deficient distribution, and infrastructure constraints mean that food deficits still occur in countries like Cambodia, the Lao PDR, and Viet Nam, even when the country as a whole records a food surplus (GMS Phnom Penh Plan 2008). In Myanmar, over 60% of townships were classified as being vulnerable with respect to food security in 2003 (Kyaw et al. 2009). Food wastage is another key issue to be considered. Gustavsson et al. (2011) estimates that 125 kilograms of food per person are lost every year in Southeast Asian countries, most of which occurs at upstream stages in the food supply chain (i.e., post-harvest, processing, distribution and storage, etc.).

In summary, biofuels expansion in the GMS will likely impact crop and food prices, both directly and indirectly, and the current biofuels policy framework in countries needs to be strengthened and improved based on regional experiences to take account of this. Additionally, other risks to food security need to also be assessed, and integrated policies that take into account storage and distribution, waste, and climate change and natural disasters need to be defined to reduce the vulnerability of poorer communities.

4.2. Biofuels and Reduction in Greenhouse Gases

With the increasing awareness of the risks and impacts of climate change, one main advantage of applying biofuels over fossil fuels is that they can (theoretically) significantly reduce GHG emissions. Life-cycle analyses (LCA)[17] conducted for multiple biofuel feedstock and fuels show a considerable variation in results when compared with fossil fuels, with some studies showing significant positive results and others showing negative results (Elder et al. 2008). One fact that is clear across the literature is that GHG balances produced from LCA studies vary significantly by country and region. USAID (2009) compared GHG balances from bio-ethanol and biodiesel production systems in Asia against a baseline fossil fuel production system, taking into account a range of production conditions for biofuels.[18] Figure 4 presents the percentage reduction in GHG emissions for bio-ethanol systems based on their study.

As demonstrated by USAID (2009), the benefits from greenhouse gas reductions are significant for most different feedstock for bio-ethanol systems, though the production conditions used clearly impact the magnitude of emission reductions. Particularly, plantation on existing crop land or degraded land produces the greatest savings

[17] Life-cycle analysis is a holistic inventory of the environmental impacts of a given product along its production chain (extraction and processing of raw materials, transport, end use, and disposal) including all resource inputs and discharges to the environment.

[18] Best-case production conditions assumed low fertilizer and pesticide inputs, plantation on degraded lands, optimal process efficiency, utilization of co-products, and the treatment of wastes. Worst-case production conditions assumed high fertilizer and pesticide inputs, replacement of native vegetation (primarily forests and grasslands), poor process efficiency, poor co-product utilization, and no treatment of wastes (USAID 2009).

in emissions. Also, although savings can be achieved from all feedstock, some are more favorable than others. For example, in Asia, sugarcane and cassava produce higher savings than corn for bio-ethanol systems (Elder et al. 2008). For biodiesel systems, the analysis shows that where palm is planted on areas of peat, shrub, or existing forest, there are no GHG reductions, and in fact the GHG balances for all feedstock become unfavorable against fossil fuel systems under such conditions (USAID 2009).[19]

Another factor to be considered in relation to GHG emission savings is carbon debt and payback periods. These are affected by the previous use of the land for biofuel development. USAID (2009) shows the carbon payback period when planting on cropland to be around 1 year, whereas when planting on secondary tropical forest, the carbon payback period could range from 10 to 1,000 years, depending on the forest type and location. The analysis demonstrates that there is no justification in terms of GHG savings for planting biofuels on forestland.

4.3. Biofuel Impact on Biodiversity

Within the GMS, biodiversity is a key concern that must be taken into account when developing biofuels policies. The subregion is a biodiversity hotspot and home to a number of globally significant populations of threatened species and new species. Between 1997 and 2008, 1,231 new species were discovered across the GMS, with 308 new species identified in 2008–2009 alone (WWF, 2011). Concurrently, forest loss in the subregion has been a serious threat to biodiversity with over 8 million hectares of forest being lost in the last 2 decades (FAO 2010). The primary drivers of forest and biodiversity loss in the subregion are demand for natural resources, particularly expansion of agricultural land. The concern is that biofuel development could exacerbate these trends as has been the case in neighboring countries. In Indonesia and Malaysia, for example, it has been estimated that slightly more than half the oil palm expansion has occurred at the expense of forest area (USAID 2009). Additionally, development of large-scale monoculture plantations for biofuels may have an additional impact in that they could reduce biodiversity within the existing agriculture systems in the GMS.

[19] Removal of forest and disturbance of peatlands result in reduced carbon sequestration and a net flux of CO_2 from soil reservoirs to the atmosphere. In these situations, the GHG savings attributed to reducing fossil fuel use are negated by these additional emission sources.

4.4. Biofuels and Poverty Reduction: Small- vs. Large-Scale Deployment

One main driver for the expansion of biofuels in the GMS is the opportunity to provide access to global markets for agricultural products and increase livelihood opportunities for rural farmers. This opportunity, however, is affected by a number of factors, not least of which is the scale at which biofuels are deployed.

Economies of scale within biofuel production systems may mean that these systems are more suited to large-scale operations. Bio-ethanol production from modern processing plants, for example, has been seen to require a steady input of a large amount of feedstock in order to produce fuels at competitive prices (USAID 2009). However, a biofuel industry dominated by large-scale producers in the GMS may not positively impact rural development and poverty reduction. Larger-scale operations are likely to focus on achieving low costs of production, not on generating rural employment, and may increase income disparity and vulnerability of rural farmers. This is particularly relevant in the GMS, where the agricultural industry has been at the heart of conflicts between large-scale private developers and rural farmers. Economic land concessions in Cambodia, for example, where private companies have been given access to land for agricultural and other development, have faced issues due to a lack of transparency and uncertainties related to consultation with rural users of the land (UN-OHCHR 2007). Attributed to "poor enforcement" of existing legislation, these issues have affected the engagement of development partners in Cambodia. The granting of these concessions highlights the risks to rural development and local livelihoods from developing large-scale agricultural systems.

Many reports on biofuels in GMS countries stress the importance of investing in "pro-poor" or smallholder-based biofuel systems in order to achieve maximum benefits for rural development (Nivitchanyong et al. 2008; Malik et al. 2009; Shepley et al. 2009). By integrating smallholders in the supply chain of biofuels, additional income for farmers could make a significant difference to their socioeconomic situation. For example, Markandya and Setboonsarng (2008) compared Jatropha development projects involving both concessionaires and smallholders in Cambodia and the Lao PDR and found that the latter had the potential to lift four times as many farmers out of poverty as the former. A series of case studies of biofuel development at the community scale in the lower Mekong countries also revealed that smallholders benefited significantly from community-based biofuel initiatives, particularly in cases where biofuel systems were locally oriented and a proportion of fuel generated was locally used (Shepley et al. 2009).

Even with the potential benefits for smallholder-based biofuels, some significant challenges remain. Small-scale biofuels initiatives require significant support and established market systems in order to succeed. A study of small-scale Jatropha development in Yunnan showed that as there are currently no alternative uses for the plant, farmers engaged in these activities are vulnerable to uncertainties in the currently immature Jatropha market, and that remote villages face reduced revenues from planting Jatropha due to high transportation costs (Sano, Romero, and Elder 2011). In Myanmar, Jatropha expansion by the government has focused on smallholders. However, due to the lack of refineries and processing infrastructure and limited technical support and awareness raising of farmers, benefits from the program have been restricted (ECDF, 2008; Cushion et al. 2010).

Current established agri-business models in the GMS which may hinder the development of efficient and profitable smallholder biofuel production pose another challenge. The concession model, as in Cambodia and the Lao PDR, utilizes farmers only as daily wage labor and may not achieve rural development outcomes in the long run (Malik et al. 2009). However, a case study of biofuels initiatives in Tay Ninh province in Viet Nam revealed that biofuel processing enterprises that relied solely on the supply of feedstock from unorganized smallholder farms experienced constraints with raw materials, optimal capacity utilization of their machinery, and difficulty in meeting their profit margins (Shepley et al. 2009).

One community-based business model that has had initial positive results for both rural development and efficiency in the agriculture sector is the cooperative or association model. In Thailand, for example, the government has supported the organization of villagers into community enterprises to enable them to buy and manage their own small-scale biofuel extraction facilities. This has allowed farmers to collect and extract fuel from their crop and sell the finished product blended with diesel as biodiesel (Chirapanda et al. 2009). In this way, smaller communities retain the returns from value-added processing. However, the development of such projects was resource-intensive as skilled management staff were seen to be necessary to run the cooperatives and the plant, and a regular supply of feedstock was required to achieve a base level of efficiency.

The final issue that tends to arise out of small-scale biofuel development is the availability of land. In order to counteract issues of food security, some GMS governments are promoting the use of marginal land, i.e., plantations of Jatropha along roads and as hedges between farm properties. In practice, these policies have had mixed results. In Yunnan, the government's prohibition of land clearing and the use of farmland were seen to be followed by villages reviewed in one study (Sano, Romero, and Elder 2011), while in the Lao PDR, in a contract farming system involving smallholders in the production of Jatropha, farmers encroached on forest areas to develop plantations rather than adhere to marginal lands. This was attributed to poor enforcement of the principle by the enterprise hiring the farmers (Shepley et al. 2009).

5. Discussion: How Can Biofuels Be Sustainably Deployed in the GMS?

The current energy situation in the GMS is not sustainable. The extensive use of fossil fuels, dependence on oil imports and increasing per capita demand mean that if the GMS is to continue on its current path of economic development and progress, significant changes are necessary within the energy supply and demand dynamics. Some improvement from energy efficiency measures can be expected in terms of reducing energy demand, but alternative sources of supply also need to be identified and developed. In this context, biofuels present an opportunity that GMS countries should take into account.

Currently the production of biofuels varies within the GMS, with the PRC and Thailand, and to a smaller extent, Viet Nam, having well developed biofuels systems in place, and Myanmar, the Lao PDR, and Cambodia currently pilot-testing biofuels production. Based on the assumptions and scenarios in this paper, if biofuels were to be deployed they would be able to meet 3%–40% of the demand for gasoline from the transport sector in 2020, and under 10% of the demand for diesel in 2020 (excluding Myanmar). These figures show that although locally sourced biofuels will probably never be able to fulfill all the demand for transport fuels in GMS countries, they will be able to replace a significant fraction of gasoline and could help countries diversify their current, fossil-fuel heavy, energy mix. Additionally, in countries like the Lao PDR and Cambodia (in which biofuels are seen to have greater potential to replace fossil fuels), as long as countries prioritize the use of biofuels to meet internal demand over export, economic sectors would be less vulnerable to fluctuations in oil prices.

However, biofuel development is associated with significant negative impacts; and if the deployment of this source of energy is not planned and implemented with careful consideration of these impacts, current negative trends in countries will have a real chance of being exacerbated rather than improved. Particularly the issues of deforestation and climate change, food security, and rural development are key concerns for GMS countries at the moment, and, as has been demonstrated by a number of local case studies, biofuels have the potential to both negatively and positively impact these issues. Some recommendations relating to these issues emerging from this review paper are below.

Food Security: Even with the wealth of literature focusing on this issue, the links between biofuels and global food prices (and therefore food security) are not clear. Within the GMS, the situation is even more ambiguous and the balance between an opportunity to gain additional revenues for the agriculture sector and potential risks to food prices must be weighed carefully. The current situation of food security in GMS countries is hampered with issues of distribution and storage of food, as well as underlying prevailing conditions of poverty, and GMS countries will need to put in place integrated policies that target the supply of food and risks related to biofuels, climate change, waste, and distribution. In terms of safeguards related to biofuels, some countries are already taking measures to promote energy crops over food crops for biofuels and utilizing marginal rather than core agricultural land, but better enforcement of these regulations will be needed in the future. Additionally, promotion of second-generation biofuels which rely on non-food crops as feedstock could help reduce some direct pressure on food crop production in the near future (though the indirect impact of these would remain), and more investment in developing so-called third-generation biofuel technologies could reduce this further over the long run.

Deforestation and Climate Change: Current trends of deforestation and forest degradation in GMS countries are significantly impacting biodiversity, threatening local communities that are dependent on forest resources, and are a significant source of GHG emissions.[20] For biofuels to have a positive impact in terms of climate change, biofuels policies must include some consideration of current prevailing trends of deforestation and should include measures to discourage biofuels development on forestland. While GMS countries are making efforts to focus biofuel expansion on underutilized and marginal land, the enforcement of regulations protecting forest areas in these countries is weak, and these areas remain vulnerable to both smallholder and large-scale biofuel development. The development of standards for biofuels and certification systems that take into account land-use change and chain of custody may help in checking the replacement of forests with agricultural land for biofuels. Additionally, increasing production yields and efficient collection of waste crops could substantially increase the volume of biofuel feedstock without expanding cultivation into forestlands.

Rural Development Benefits: The opportunities for rural development from smallholder-based biofuel production in the GMS are clearly significant, but the realization of benefits is dependent on the mode of deployment. There are many lessons to be learned from pilot-testing different models in GMS countries, and it is important that future development builds on them and that GMS countries learn from each other's examples. Irrespective of the model chosen, when promoting biofuels from smallholders, GMS countries will need to invest in developing the supply chain for biofuels, and proper research and development should be carried out prior to introduction of new crops for mass propagation, especially in rural areas with subsistence farming. Countries will also need to invest in developing the necessary skills and capacities needed for smallholders to produce and extract biofuels themselves, which would allow them to capture the largest share of the benefits from the production of such fuels. Capacity development would need to be focused at different levels—institutional capacity to develop and support schemes and local capacity to implement successful enterprises.

5.1 Further Issues to Consider

Though this paper considers the potential to produce biofuels from current resources in the GMS, the analysis given here does not comment on whether GMS countries should allocate these resources to biofuel production. A social cost–benefit analysis which quantifies the trade-off between benefits to the agriculture sector, negative impacts on health and well-being due to changes in food prices and environmental impacts of biofuel production would be able to complement the analysis provided here and may provide more insight into this crucial issue.

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[20] Land-use change and forestry was responsible for 26% of all GHG emissions in the GMS (excluding the PRC) in 2005 (WRI 2010).

6. Conclusion

This review demonstrates that biofuels could make a significant contribution to the primary energy demand (especially in the transport sector) in several GMS countries, leading to increased agricultural and rural incomes and prospects for regional energy trade, while ameliorating several of the prevailing negative environmental conditions. The extent to which this potential can be realized will depend on the type of production system that is pursued. Expansion in the form of industrial-scale plantations would quickly lead to several of the linked social–environmental–political problems that have been observed elsewhere in Asia and outside Asia, namely food versus fuel conflicts, land grab, destruction of forests, and detrimental impacts on soil and water quality. Expansion involving surplus land, smallholder-based production, and an emphasis on non-food crops and second-generation biofuels could pave the way for sustainable utilization of biofuels in the GMS. However, this latter approach will require significant policy interventions, and dedicated support to the farm sector, much of which is missing currently, and will need to be put in place.

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GLOBAL ENVIRONMENT AND NATIONAL INFORMATION EVALUATION SYSTEM (GENIES) FOR URBAN IMPACT ANALYSIS

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Abstract

The urban areas of Asia are growing and will, in all likelihood, continue to grow at a rapid rate. This process could result in unprecedented risks to urbanized populations from climate change impacts, such as sea level rise, storm surge, extreme rainfall and temperature events, and cascading secondary effects.

A toolkit concept to support policy-making and planning based on a Global Environment and National Information Evaluation System (GENIES) has been developed that focuses on the core issues of adaptation, mitigation, risk, and economics of climate change and how they interrelate with aspects of water, energy, the built environment, transport, waste, and ecosystems. While recognizing the plethora of methodological perspectives that pertain to each sector, a system dynamics method is proposed, which lends itself to integrated assessment, given its flexibility and ease of extension and revision as new policy and planning questions emerge. The framework design starts with a clear definition of a problem and then draws together the appropriate models and data, to enable relationships to be defined and processed in a scientifically robust manner to evaluate adaptation and mitigation options.

The tool will be macro in its scale of engagement and represent a "first cut" method for conducting an indicative assessment of risks and potential costs and benefits of different adaptation options that could be applied to the risks posed by climate change. The tool development would have the highest chance for success if it were developed in a staged manner with an initial focus on one or two high priority issues in one or, at most, two cities. The political will of the pilot cities to engage in the process and carry it through to completion would be critical to the initial success of the project.

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1. Introduction

The challenges facing Asia from urbanization are unprecedented—some 1.1 billion people could migrate from the countryside to the region's cities in the next 20 years. In addition, urban areas are becoming riskier owing to the threat of climate change, characterized by reduced agricultural productivity; urban, rural, and international migration; coastal inundation; and increasing vulnerability and damage from extreme climate events. Urban areas concentrate populations, economic activities, and infrastructure. These can be seen not only as vulnerabilities but also as opportunities to synergize resources for creating innovative risk management strategies. There is, however, a particularly urgent need to recognize such opportunities, develop them, and extend them to the wider urban community. Delays in incorporating climate change into urban development planning will reduce the efficient functioning of urban areas as centers of economic activity and aggravate the negative consequences of climate change.

There are barriers to making and implementing climate change policy in our rapidly growing urban centers. These include the lack of knowledge and uncertainties of climate change impacts and risks, and the absence of tools to guide decision making that integrate climate change considerations into overall urban development planning. This paper lays out the case for an urban policy-making support system to address the planning challenges related to the interplay of climate change, disaster risk management, and urbanization. By integrating various assessment models into a toolkit, a city can be in a better position to identify priority actions and, based on this information, implement policies to guide specific urban actions to improve resilience.

Currently, many models and tools are available related to climate change impact assessment, including risk and vulnerability assessment, and adaptation and mitigation tools. However, these models and tools mainly focus on (i) frameworks, lacking in-depth assessment models; (ii) a single sector, thus lacking integration; and (iii) sector processes, lacking a clear climate risk assessment component. None bring together local climate change projections, multisector impact analysis, and urban systems models to provide a set of integrated tools for urban decision makers to use in comparing adaptation and mitigation options in the context of local development plans in an open framework[3] that applies local, regional and global data. However, existing models do provide a basis for the development of an open framework system as a more comprehensive policy-making support toolkit that can provide an integrated and systematic assessment environment.

2. Objectives

The objective of the toolkit is to become an integrated climate change impact assessment tool for urban policy makers, which will allow them to assess the costs and benefits of mitigation and adaptation measures in light of the local development opportunities and constraints pertinent to the city, including for example, pollution problems and expected climate variability. The Asian Development Bank (ADB) proposes to develop this tool in partnership with international agencies and institutions with expertise in evaluating the environmental and socio economic impacts of climate change such as infrastructure, water security, and human health impacts due to air pollution and climate change, among others.

The deployment of the tool should speed up problem solving with pre-loaded data, models, rapid analysis functionalities, and a user-friendly interface; facilitate interpersonal communication and learning by allowing all groups to work with the same data, platform, and models; reveal new approaches to the formulation of problems and generate new evidence for decisions; and encourage exploration and discovery on the part of the decision maker. The features of the system include:

- modular design to build on and link to existing models and related applications;
- integrated analysis, enabling testing of adaptation and mitigation options against socioeconomic drivers, likely sectoral impacts, and existing goals for sustainable development;
- open framework, allowing multiscale, multidisciplinary impact assessment, which can be customized on a case-by-case basis to suit each city;
- climate change uncertainty analysis, building on General Circulation Model (hereafter GCM) and Regional Climate Model (hereafter RCM) climate change scenarios;
- geographic information system (hereafter GIS) integration, which is not heavily reliant on third-party software;
- visualization and further analysis options for the assessment of results; and
- Integration of risk analysis and cost-benefit analysis tools.

The tool is intended to answer questions like:

- How to characterize the impacts of climate change?
- Which sectors are likely to be most affected?
- What actions could reduce the intensity of these impacts?
- How could cities evaluate the future costs of such impacts?
- Are other cities experiencing similar impacts and how are they responding?
- What are the expected benefits and co-benefits of an action plan?
- How can this information support adaptation funding and its prioritization?

3. How Can the Tool Help in the Policy-Making Process?

With the raised awareness of climate change challenges, top-down and bottom-up synergetic approaches are eventually adopted by countries (Pulhin 2010, 2011). Based on understanding the key vulnerability caused by climate change at different scales and correlation with other natural and socioeconomic contexts, climate policy can be made from the national to local, urban level. Through a synergetic process—including single and cross-sector assessment—financing, in alignment with the national and local development strategies, can meet the critical challenges (Lawler, *et al*. 2011).

Climate change issues can be addressed appropriately and be mainstreamed into the policy making and planning process for maximizing the values of human well-being (Figure 1). The notion of good governance is related to effective public institutions. At the local level, this involves the development of partnerships between top-down government initiatives and bottom-up local institutions and policies (Urich, Quirog and Granert, 2009). Empowering local citizens and community organizations in the decision-making processes not only increases efficiency but also provides a real possibility for individuals or groups to transform their choices into desired actions and outcomes

[3] Open framework is used here to describe a system that permits the end user to either select from a suite of models or add new models and to import local data to run the models in a system that evolves into a customised version of the toolkit for the particular urban environment.

Session 2.3

Figure 1: Top-Down and Bottom-Up Multi-Level Climate Change Policy-Making Support and Value Maximization

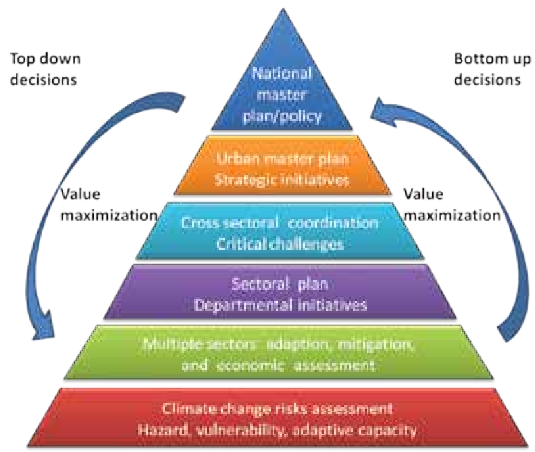
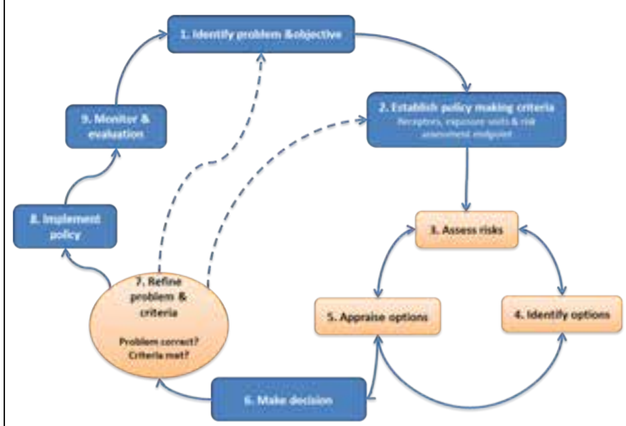


Figure 2: Risk, uncertainty and decision-making framework (Modified from Willows and Connell, 2003)



(Pulhin, 2011). The ultimate goal for adopting a synergetic approach is to strengthen the livelihood strategies of both national and urban communities.

Regarding the nature of climate change, for decision making on climate change adaptation actions, a risk, uncertainty, and decision-making framework (RUD) (Figure 2) can be deployed to explain how such a tool forms a decision support system (DSS). RUD enables decision makers to recognize and evaluate the risks posed by a changing climate, making the best use of available information about climate change, its impacts, and appropriate adaptive responses.

The process is circular, emphasizing the importance of the adaptive approach to managing climate change problems and implementing response measures. Decisions should be revisited in the light of new information on climate change and its impacts; for instance, when new climate scenarios are published.

Feedback and iteration are encouraged, so that the problem, objectives, and decision-making criteria can be refined (stages 1 and 2), and further options identified and refined to better reduce and manage climate change risks (stages 3, 4, and 5). Iteration is important to achieving robust decisions.

Certain stages (3, 4, and 5) are tiered. This allows the decision maker to identify, screen, prioritize, and evaluate climate and non-climate risks and options before deciding whether more detailed risk assessments and options appraisals are required.

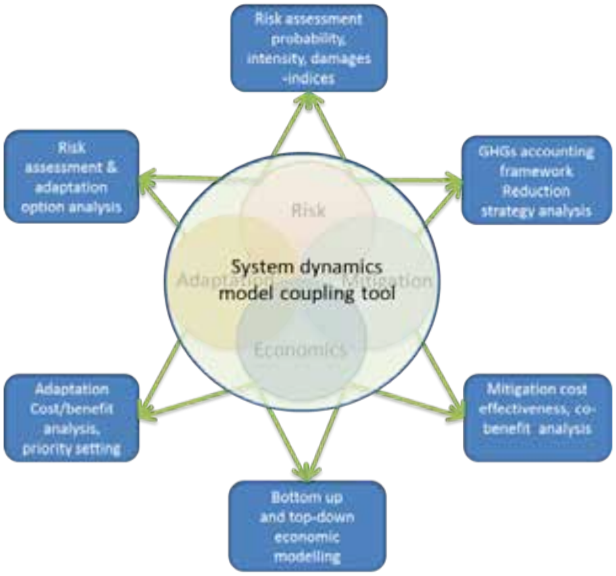
4. What Methodologies can Help Simplify Complicated Systems?

Climate change can affect every sector of an urban system with varied extent and intensity. A decrease in precipitation but increase in extremes can have a series of impacts on water, transport, energy, health, buildings, and other sectors. And by the urban system's nature, all sectors are closely correlated and working as a human life-supporting system. Therefore, for policy and decision making regarding climate change, the sectors also need to be seen systemically. However, to a large extent, climate change is still viewed as an add-on component to the routine of traditional policy making with its management of uncertainty, challenge, and opportunities.

Different from other sectoral DSSs or models, a Global Environment and National Information Evaluation system (hereafter GENIES) is framed by climate change issues, including risk, adaptation, mitigation, and related economic analysis, with a clear expression of urban planning and policy making; all sectors link to climate change issues, although each sector has a potentially long list of risks and opportunities.

During the last few decades, many modeling methodologies and tools have been developed for each climate change topic (i.e., risk, adaptation, mitigation, and economics). Many combined modeling methodologies also have been explored for the relationship among topics. The main quantitative modeling methodologies can be summarized as follows (Figure 3 and Table 1).

Figure 3: Structure of the Modeling Methodology



Other than quantitative modeling approaches, guidance or instructive tools have also been developed by various agencies, including ADB, Clean Development Mechanism, Inter-American Development Bank, international and national nongovernment organizations, the United Nations system, and World Bank.

5. Model Integration Tool

Given the large number of existing but independent models and tools, GENIES would act as a harvesting system that can integrate the existing and emerging technologies to make them work together as a system to provide better climate change policy-making support. A system dynamics approach and object-oriented system modeling (OSM) can serve this purpose effectively (Box 1), although GENIES would not be a typical system dynamics software.

There is a need for a new framework of model development that can integrate existing and future natural resource models into a common, collaborative, and flexible system. Such a system will maintain modularity, reusability, and interoperability or compatibility of both science and auxiliary components. The system will also recognize the fact that different categories of applications may require different levels of scientific detail and comprehensiveness, driven by problem objectives, scale of application, and data constraints. These functionalities of the system will be obtained by establishing standard libraries of interoperable science and auxiliary components or modules that provide the building blocks for a number of similar applications. Module libraries have been successfully used in several domains, such as the manufacturing, transport, and other systems. The development of an individual model will follow the standard of OpenMI (http://www.openmi.org/).

To summarize, an approach for GENIES is needed that will

- reduce duplication of development effort and improve the quality and currency of model codes;
- make natural resource models much easier to build, access, understand, and use;
- facilitate long-term maintainability of existing and new natural resource models;
- lead to greater consistency of modeling for particular problems and scales;

Table 1: Summary of Quantitative Modeling Methodologies

Topic	Methodologies
Risk Assessment	Vulnerability and risk indicators and profiles; past and present climate risks; probability analysis; livelihood analysis; agent-based methods; narrative methods; risk perception, including critical thresholds; relationship of adaptive capacity to sustainable development.
Risk and Adaptation	Cross-sectoral interactions; integration of climate with other drivers; linking models across types and scales; combining assessment approaches/methods; adaptation option analysis; cost-benefit analysis, cost effectiveness, priority setting, and ranking.
Mitigation	Top-down models are most useful for studying broad macroeconomic and fiscal policies for mitigation, such as carbon or other environmental taxes. Bottom-up models comprise three basic types: optimization, simulation, and accounting frameworks. There are various hybrid models that combine elements of these three approaches.
Economics	Top-down and bottom-up economic modeling; integrated assessment models simulate the process of human-induced climate change, from emissions of greenhouse gases to the socioeconomic impacts of climate change; cost simulations across the widest range of possible impacts, taking into account the risks of the more damaging impacts suggested by new scientific evidence; analyzing changes to economies and societies that are large, uncertain, unevenly distributed, and that occur over a very long period of time.

Box 1: System Dynamics Approach

System dynamics is a computer-aided approach for policy analysis and design that applies to problems arising in complex social, managerial, economic, or ecological systems. The approach is appropriate for any dynamic system characterized by interdependence, mutual interaction, information feedback, and circular causality. It emphasizes wholes rather than parts, and stresses the role of interconnections, including the role each person plays in the systems at work in our lives. It emphasizes circular feedback (for example, A leads to B, which leads to C, which leads back to A) rather than linear cause and effect (A leads to B, which leads to C, which leads to D, etc.). It contains special terminology that describes system behavior, such as reinforcing process (a feedback flow that generates exponential growth or collapse) and balancing process (a feedback flow that controls change and helps a system maintain stability).

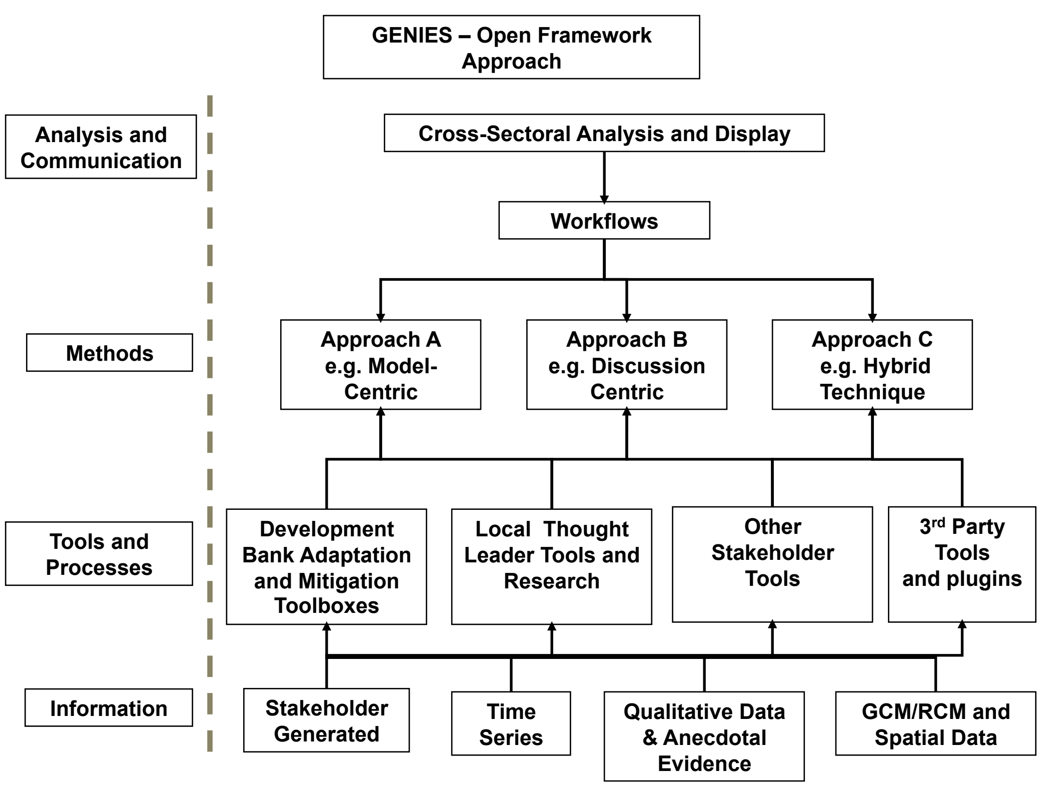
Source: http://www.systemdynamics.org/what_is_system_dynamics.html

- improve response and delivery times in scientific modeling projects; and,
- ensure credibility and security of model implementations.

Climate change planning can, and should, augment and be integrated with existing planning and development activities across all sectors. All the features of a system dynamics approach can make climate change issues clearer in urban planning and can help us see how to change them effectively with the aim of overcoming the complexities of decision making.

A unique advantage of applying system dynamics models is the ease of extension and revision as additional questions arise. The system could allow users to add models, input and output of the model, use a visual coupling tool for data conversion, and define, run , and monitor workflows. Figure 4 illustrates the inclusive open framework of GENIES.

Figure 4: GENIES Open Framework Approach



The inclusive framework of GENIES information and model/tools has (i) a layer of different methods or approaches to problem solving—probably tailored to each individual sector (water, transport, health, etc.); hence, they do not need to be generic, and can be different for each outcome; (ii) a layer of tools, in which again each tool is sector and process specific. Where we do not have a tool, one can be built; and (iii) a layer of information.

6. How Will the Toolkit be Developed?

The toolkit needs to focus only on climate change related issues, through a case study approach to define the audience and learning by doing (i.e., not in a one-off project; continuous support from commercial operations is needed). Many attempts to develop integrated climate change impact assessment tools stopped at the blueprint or pilot stage because of the loss of focus and continuous support. The development methodologies and operational approach for this project need to be clearly defined to ensure its completion.

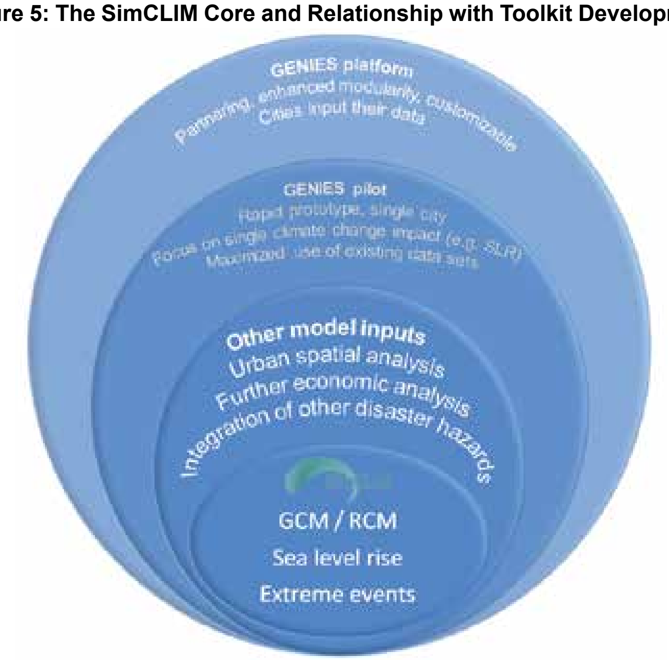
The foundational pieces of this toolkit are the existing integrated climate change impact assessment software SimCLIM (Figure 5) (Warrick, 2009a; Warrick and Urich, 2011). The integration of data, graphic user interface, impact models, and open framework makes SimCLIM a co-evolutionary decision support system that can be upgraded and improved through the interaction between end users and toolkit developers (Li., *et al*. 2009; Li, Ye and Yan, 2011). The main features of SimCLIM are that it allows for multi-scale, multi-disciplinary impact assessment; climate change scenario uncertainty analysis; and, with a built-in GIS tool, visualization and further analysis of the assessment results. A series of models, tools, and datasets have been integrated into SimCLIM (Masike and Urich, 2008; Masike and Urich, 2009; Warrick, 2009b).

7. Agile Development Methodologies

Given the complexity of the toolkit, it needs to be a test-driven development process. We need to release workable software regularly using a staged approach with prompt stakeholder/end-user/developer communication, quickly adapted to new demands/changes, and the process repeated until the strategic goal is fulfilled (Box 2). The stages are as follows.

Stage 1: Develop a broad framework and core models as the foundational piece in the primary stage. SimCLIM and its impact model library already provide a unique platform for the development of GENIES. The methodologies and functionalities that are important but not existing or inadequate can be prioritized for the first stage development. Some of the development needs have already been identified, such as the enhancement of economic analysis, including cost-benefit, co-benefit,

Figure 5: The SimCLIM Core and Relationship with Toolkit Development



cost effectiveness analysis, and development of integration tools using the system dynamics approach. An international technical support group needs to collaborate closely with the policy-making group. Scientists, modelers, and software developers need to work seamlessly with their counterparts in urban policy-making groups. This stage also needs to be relatively short in order to provide workable software for the user to evaluate and to attract funding.

Stage 2: Build up more new models through a co-evolutionary process, projects, and end user demand. Provide inclusive linking methods for other models following the OpenMI standard. The software needs to be developed continuously and maintained efficiently; therefore, funding for such a toolkit needs to be well sourced, including projects from international financing institutions, and international and national agencies. GENIES has to be a collaborative development initiative of interested stakeholders. Stakeholder engagement needs to be stressed from the beginning. Table 2 provides an example of a stakeholder engagement approach.

Stage 3: The further development and application of the toolkit extends to a broader scope to fulfill the strategic goal of this initiative.

Table 2: Stakeholder Engagement Approaches to GENIES Development

Stakeholder Identification and Analysis	Invest time in identifying and prioritizing stakeholders and assessing their interests and concerns.
Information Disclosure	Communicate information to stakeholders early in the decision-making process in ways that are meaningful and accessible, and continue this communication throughout the project life.
Stakeholder Consultation	Plan each consultation process, consult inclusively, document the process, and communicate with stakeholders.
Management Functions	Build and maintain sufficient capacity within the provider to manage the process of stakeholder engagement, track commitment, and report on progress.
Reporting to Stakeholders	Report back to stakeholders on environmental, social, and economic performance, both to those consulted and those with more general interest.
Discussion and Partnership	For controversial and complex issues, enter into open discussions that satisfy the interests of all parties by forming a strategic partnership.
Concerns Management	Establish accessible and responsive means for stakeholders to raise concerns and demand changes about the project throughout its life.
Stakeholder Involvement in Project Monitoring	Involve directly affected stakeholders in monitoring project impact, mitigation, and benefits, and involve external monitors where they can enhance transparency and credibility.

Box 2: Agile Software Development

Agile development is a different way of managing software development projects. Ten key principles of agile software development illustrate how it fundamentally differs from a more traditional waterfall approach to software development, and are:

1. Active user involvement is imperative.
2. The team must be empowered to make decisions.
3. Requirements evolve but the time scale is fixed.
4. Requirements are captured at a high level; lightweight and visual.
5. Develop small, incremental releases and iterate.
6. Focus on frequent delivery of products.
7. Complete each feature before moving on to the next.
8. Apply the 80/20 rule.
9. Testing is integrated throughout the project lifecycle— test early and often.
10. A collaborative and cooperative approach between all stakeholders is essential.

Source: http://www.allaboutagile.com/10-key-principles-of-agile-software-development/

8. Conclusion

A framework for GENIES uses a system dynamics-like approach. It acts as a combined harvesting system that can integrate existing and emerging technologies to make them work together as a system to provide climate change policy-making and planning support. The integrated toolkit will provide an opportunity to maximize the co-benefits of mitigation actions and location-specific adaptation policies at the local level, keeping in mind interactions between sectors. Given the complexity of the toolkit, it needs to be a test-driven development process. We need to release workable software regularly using a staged approach with prompt stakeholder/end user/developer communication, agilely adapted to the new demands and changes in need and climate science. This process needs to be repeated until the strategic goal is fulfilled.

An investment will need to be made to develop the tool to attain its maximum utility, building on existing resources and initiatives, to enable enhanced applications for urban impact analysis. This investment will need to be extended to improve data collection and build local capacities for analysis and planning.

The tool will be macro in its scale of engagement and represent a "first cut" method for conducting an indicative assessment of risks and potential costs and benefits of different adaptation options that could be applied to the risks posed by climate change. The tool development would have the highest chance for success if it were developed in a staged manner with an initial focus on one or two high priority issues in one or, at most, two cities. The political will of the pilot cities to engage in the process and carry it through to completion would be critical to the initial success of the project.

A more global perspective for development and deployment of the software toolkit could be explored with the World Bank,Inter-American Development Bank and African Development Bank. Further sharing of perspectives and tools and integration with programs currently being run by other international financial institutions would be desirable to avoid duplication in such an important area of tool development.

The first steps involve discussing needs of urban policy makers, mapping existing tools, and resources, undertaking a high-level functional design, developing the integrated tool, identifying pilot cities for initial application, and supporting the ongoing development and use of the system by a growing number of interested cities.

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INTERNALIZING THE EXTERNALITIES – STRATEGIC ENVIRONMENTAL ASSESSMENT OF POWER DEVELOPMENT PLANS IN VIET NAM: IMPLICATIONS FOR THE GMS

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Abstract

This paper reviews the experience of developing a strategic environmental assessment (SEA) as an integral part of the preparation of the seventh power development plan for Viet Nam. The implications of the use of SEA in strategic planning of the power sector are discussed in the context of regional power demand trends and in relation to efforts to strengthen strategic planning efforts within the power sector across the Greater Mekong Subregion. The focus of the SEA was on the identification, assessment, and valuation of all principle social and environmental costs and benefits that would be likely to accrue from different power generation alternatives, including thermal power (especially coal-fired generation), hydropower, nuclear power, and renewable energy. The analysis in the SEA provides a basis for the internalization of these factors that have traditionally been treated as externalities. The results of the SEA emphasize the need to strengthen existing efforts to improve energy efficiency and encourage renewable energy if there is to be any significant progress made in mitigating the likely future negative impacts of the increased use of coal in the power generation sector.

1. Introduction

The development of enough power generation capacity to meet demand while minimizing the potentially negative impacts of the power sector on people and the environment is one of the key sustainable development challenges facing the Greater Mekong Subregion (GMS). The ability to meet the rapidly-growing demand for electricity has been fundamental to the subregion's growth and development, but planners face difficult choices in deciding which are the right power generation sources. Thermal power generation, especially coal but also oil and gas, dominates the generation mix, but hydropower is also significant while the potential of nuclear power is being explored and the potential of different types of renewable energy (especially wind and solar) is significant. Demand management and system improvement are also important, with the power sector in all Mekong countries having great potential for improved efficiency so that real future demand can be met with a slower rate of expansion of power generation capacity.

Each of these generation sources has different costs and benefits in economic, social, and environmental terms. Balancing these different costs and benefits is the key challenge that power sector planners face. All countries in the subregion have a power sector planning system in place. In both Viet Nam and Thailand, this takes the form of power development plans, with new plans produced every 10 years and the plans having a 20 year planning horizon. These planning systems are in general effective in "traditional" terms, being based on projection of future demand scenarios and the identification of the least-cost mixes of generation sources to meet these demand projections. The basis for the identification of generation sources and the calculation of the costs have in the past been primarily based on technical and direct financial costs; however, it is recognized that indirect costs, especially those associated with social and environmental impacts, have not been adequately integrated into the power sector strategic planning systems in the GMS.

Steps are being taken to improve this situation, including the introduction of strategic environmental assessment (SEA) as an integral part of the strategic planning system for the power sector. SEA is increasingly becoming mandatory for strategic planning in the region; the People's Republic of China, Thailand, and Viet Nam have legal requirements for its conduct and the Lao People's Democratic Republic (Lao PDR) is working toward the promulgation of a SEA decree. Experiences of and capacities for undertaking SEAs are limited, however, and international development partners. such as the Asian Development Bank (ADB) are providing active support to the development of such capabilities. This paper presents the outcomes of one such effort, the SEA undertaken as part of the seventh power development plan (PDP VII) in Viet Nam. PDP VII has recently been approved by the Government, with a comprehensive SEA fully integrated into the PDP VII planning process for the first time. The outcomes of the SEA have led to important new thinking for the power sector in Viet Nam, including the

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reconsideration of the best balance of power source mixes, the viability of individual schemes, and, perhaps in the long term most significantly, how to improve energy efficiency and expand the use of renewable energy sources in power generation.

2. Context: The Power Sector in the Mekong Region

By 2025, electricity demand for the GMS is expected to reach 237,000 megawatts (MW), a threefold increase compared to the 77,000 MW used in 2010 (Figure 1). Demand for electricity is predicted to grow in all countries in the GMS in this period, presently a formidable and shared development challenge if overall economic growth and sustainable development goals are to be realized.

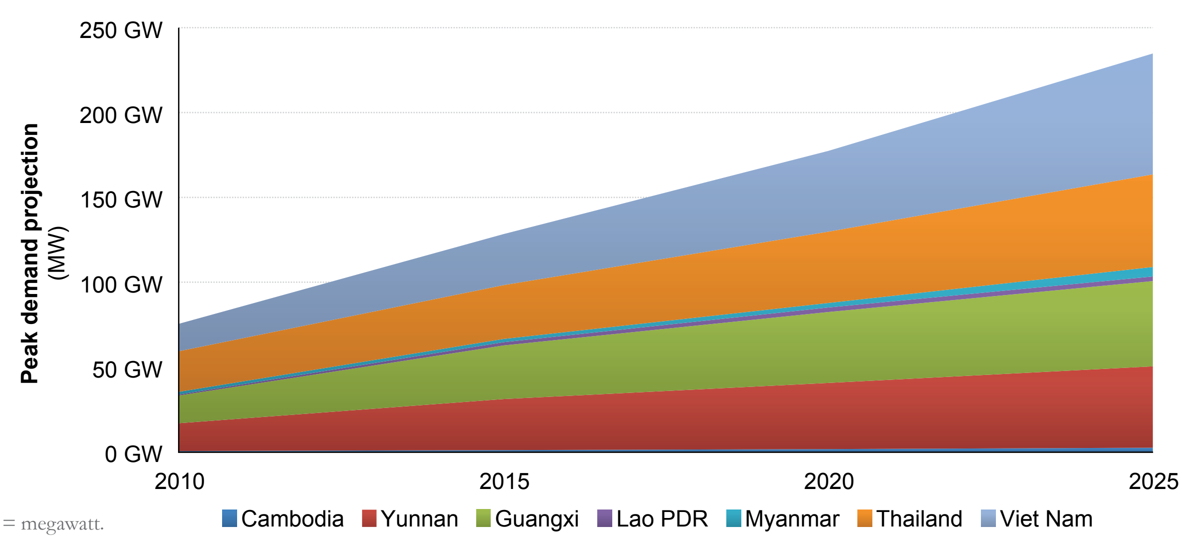
Meeting this demand will require substantial financial investments and could potentially cause large social and environmental costs unless effective actions are taken to reduce economical, social and environmental risks to the investments. All power generation options present some risks: the challenge for strategic planning in the sector is to balance the full range of economic, social, and environmental costs in the choices made. The GMS countries are making substantial investments in power development. Figure 2 shows the projected evolution of demand and supply options in the GMS (except Myanmar; Myanmar data only include export oriented projects). These data show that thermal power is the dominant element in regional supply mixes, followed by hydropower. This will be especially true in the future as demand continues to grow but potential expansion of hydropower is increasingly limited by the lack of viable sites.

The relatively advanced economies in the region are expected to harness all their indigenous supply options and will be increasingly importing power from neighboring countries (Figure 3) and fuel supplies from further afield. The evolution of regional power trade is currently being facilitated by the GMS Regional Power Trade Coordination Committee, the importance of which can be expected to grow in coming decades. A regional power trade agreement has been signed and is expected to increase investments in regional power trade facilitation.

3. The SEA in PDP VII: Approach and Structure

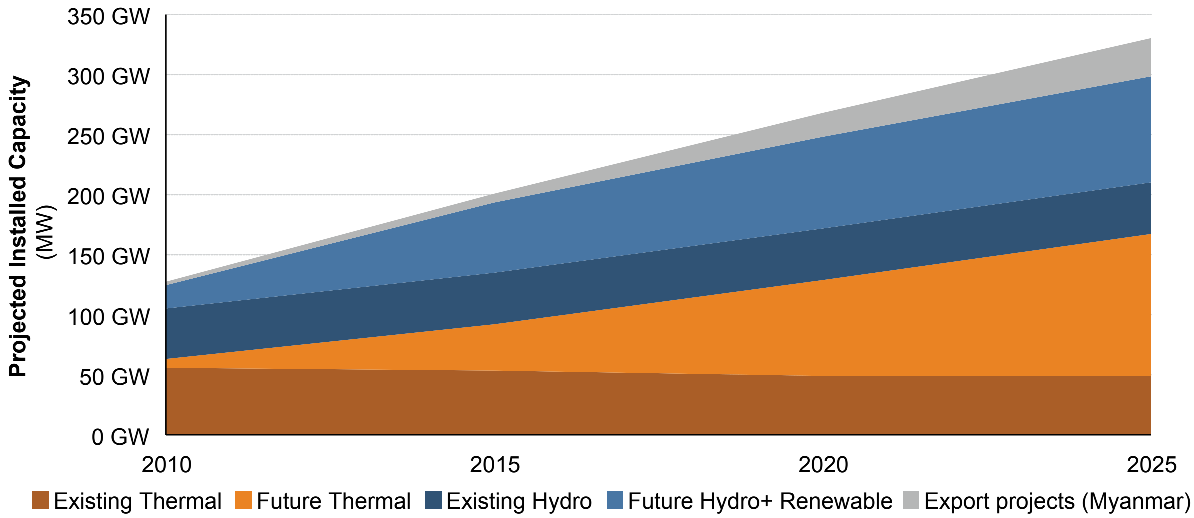
The PDP is the national strategic development plan for power production and utilization in Viet Nam. The PDP VII provides a long-term strategic framework to guide the development of the power sector during 2011–2030. It analyses likely future electricity demand scenarios by sector and takes into account likely future economic and social development trends. It also assesses the most effective, least-cost (taking into account full economic costs) methods for meeting the likely future demand. The SEA's focus was on optimizing the potential contribution of power generation to national development through a strategic planning approach that balanced economic development, social equity, and environmental sustainability. The central

Figure 1: Power Demand Projections for the GMS Region



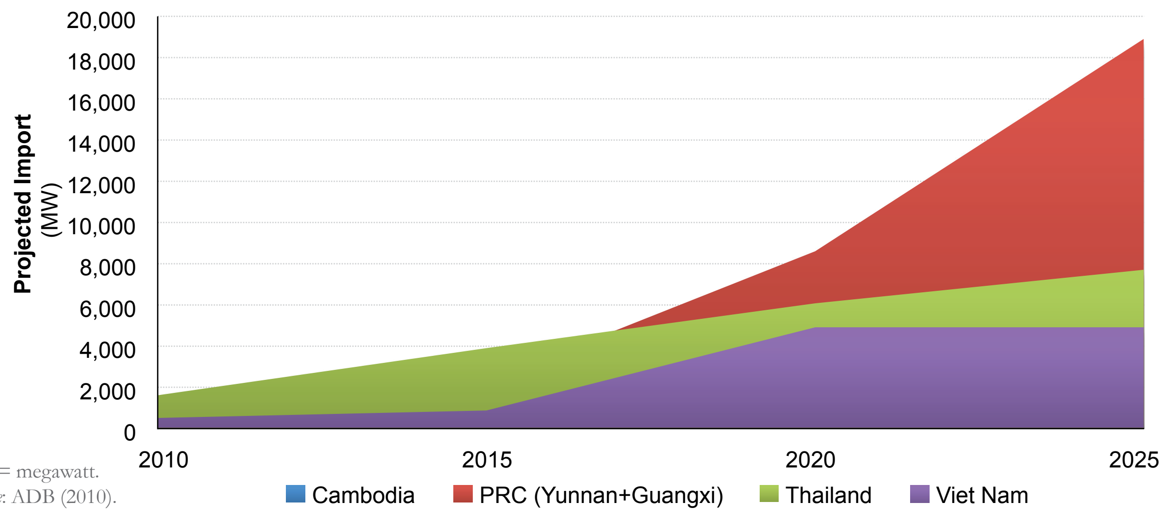
MW = megawatt.
Source: ADB (2010).

Figure 2: Power Supply Options for the GMS



MW = megawatt.
Source: ADB (2010).

Figure 3: Projected Regional Power Imports



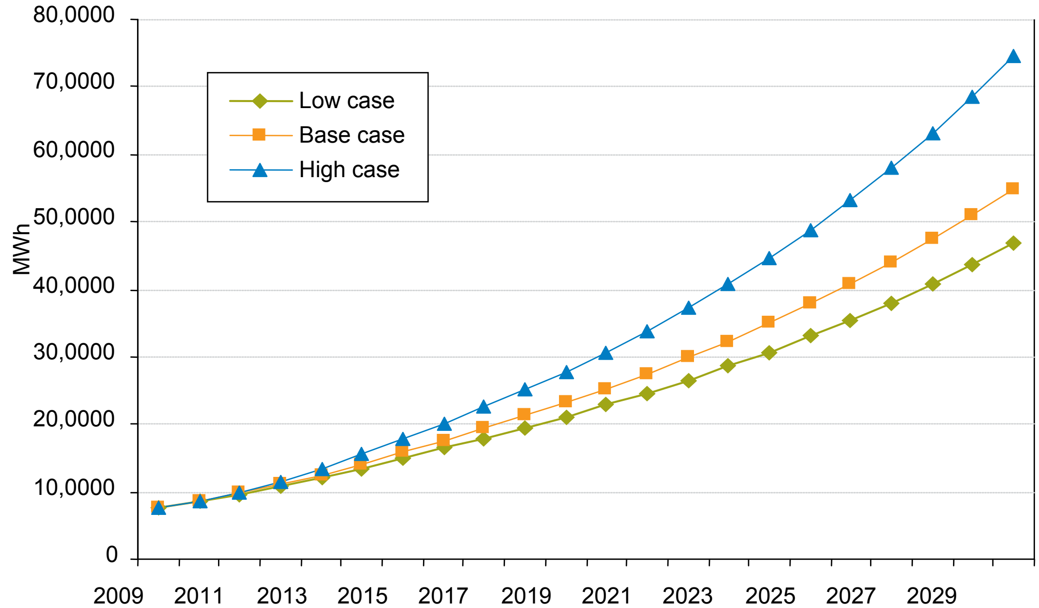
MW = megawatt.
Source: ADB (2010).

goal of PDP VII is to meet future demand through the most effective and responsible strategy for the expansion of generation capacity and the power transmission system, requires trade-offs between the costs and benefits of different types of power generation.

The SEA analyzed the potential social and environmental impacts of the package of generation development options contained in the PDP VII base case, valued where possible in economic terms that could be internalized into the PDP VII least-cost calculations. The assessment of power demand was based on existing power consumption data for each sector, combined with assumptions on the speed and character of socioeconomic development during the plan period, and on savings from energy efficiency improvements (Figure 4[4]).

[4] These and most other data in this paper are taken from "Strategic Environmental Assessment report of Vietnam National Power Development Master Plan for the period of 2011-2020 with perspective to 2030, Ministry of Industry and Trade, 2011".

Figure 4: Power Demand Forecasts, 2010–2030



MWh = megawatt hour

The PDP estimated that meeting this demand would require an expansion of the country's generation capacity to a projected installed capacity of 75,000 MW by 2020 and 146,800 MW by 2030. The projected financial costs of these expansions are huge: $69.5 billion by 2020 and $156.2 billion by 2030.

4. Main Findings of the SEA

4.1 Thermal Power

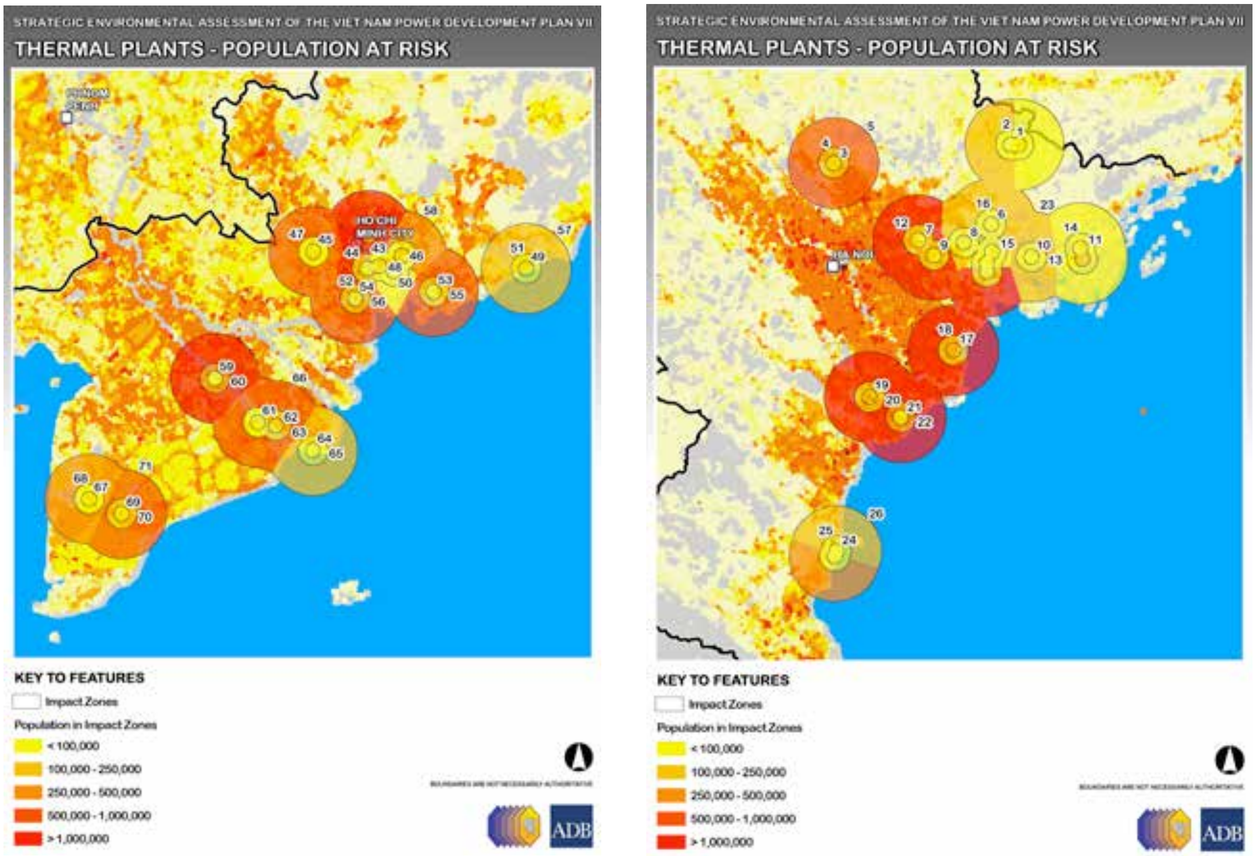
Thermal power constitutes by far the largest component of the power generation sector in Viet Nam, so it is no surprise that it is also the source of by far the largest social and environmental impacts. The most significant are the impacts of the atmospheric pollution from the combustion of fossil fuels and especially of coal. Under the plans in PDP VII, carbon dioxide (CO_2) and particulate matter releases will increase more than ten-fold during the PDP VII period up to 2030 and those for sulfur dioxide (SO_2) and nitrogen oxides will increase several fold. The impacts of these atmospheric pollutants will be severe and widespread. It is estimated that these impacts will cost Viet Nam nearly $9.0 billion per annum by 2030 unless actions are taken to reduce the levels of atmospheric pollutant releases from, in particular, coal-fired power generation (Table 1).

The impact of atmospheric pollutants from thermal power is most critical where the stations are planned to near major urban areas, where existing ambient air quality is often poor and, of course, much larger concentrations of people are found. This is particularly true for the planned clusters of thermal stations close to Ho Chi Minh City and, to a lesser extent, in the northern region southeast of Hanoi (Figure 5). These planned clusters lead to a cumulative effect, where the impact of one station may not be so severe but the effects of several stations located close to each other in the proximity of large population clusters is a serious issue that should be addressed in the PDP VII plans.

Table 1: Total Environmental Costs for Each Pollutant ($ million)

Year	2011	2015	2020	2025	2030
Particulate matter	98.86	134.95	289.57	439.40	710.24
Sulfur dioxide	93.77	148.09	311.85	448.18	728.74
Nitrogen oxides	234.15	274.48	386.09	494.30	638.86
Carbon dioxide	1,215.5	2,190.5	4,118.7	6,075.9	9,071.9

Figure 5: Thermal Power Station Clusters in North and South Viet Nam



4.2 Hydropower

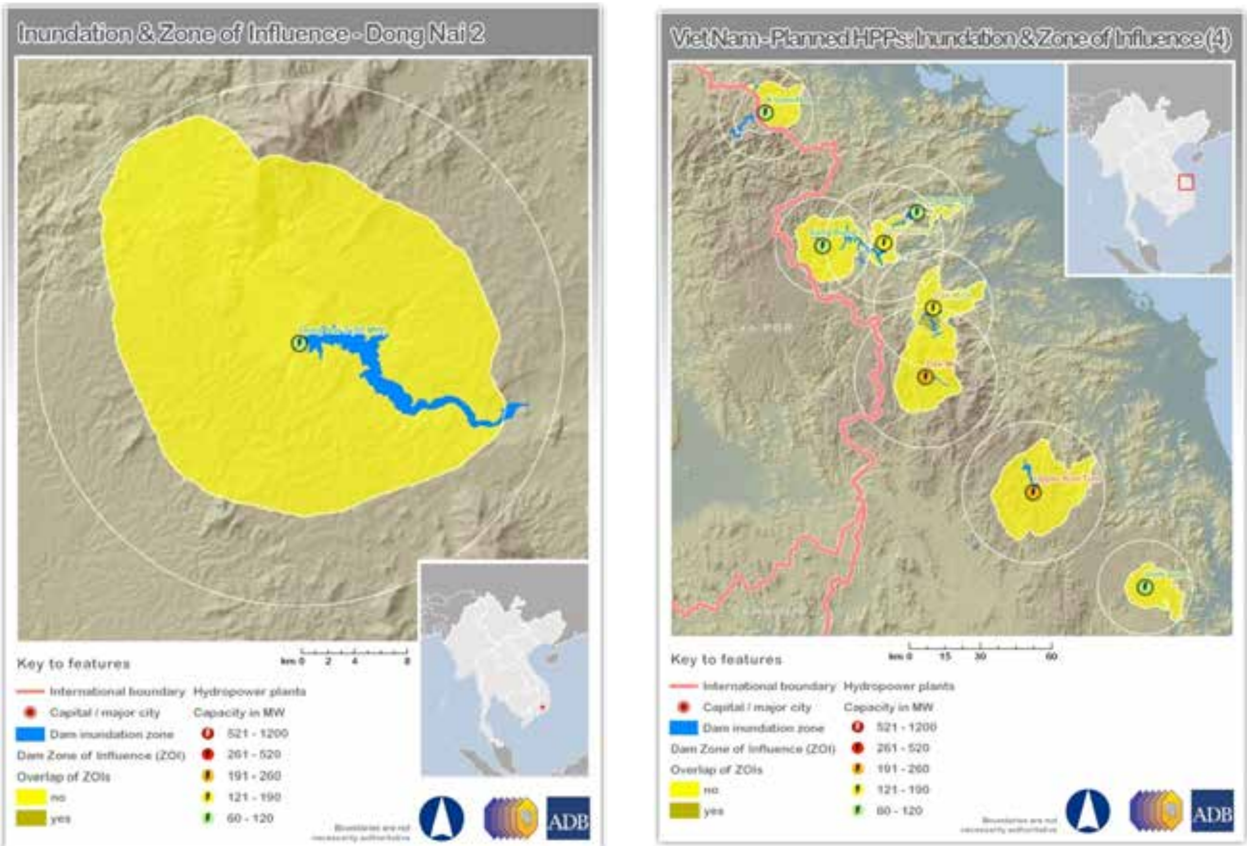
Hydropower can produce adverse social and environmental impacts, including the loss of land and disruption of sensitive ecosystems, the displacement of people and effects on the culture and livelihoods of communities not physically displaced, disruption to hydrological systems and ecosystems that depend on them, and other effects. With hydropower, most of the social and environmental impacts are associated with the development of the scheme. The wider effects on people and the environment are a mixture of both positive and negative impacts, with potential improvements to dry season water flows having positive benefits over whole river basins but several river ecosystems vulnerable to degradation in the immediate vicinity of hydropower schemes.

An area of 25,133 hectares (ha) will be submerged in the 21 schemes in the PDP, with an estimated economic value of goods and services of around $75 million a year. A total of 61,571 people would be displaced if all 21 schemes are constructed, two thirds of them displaced due to four schemes with more than 7,000 displaced people each (Ban Chat, Bac Me, Huoi Quang, and Lai Chau). Over 90% of the displaced people are ethnic minorities with a poverty rate well above double the national average. These people are highly dependent on access to natural resources (including forests) for their livelihoods and a close connection to where they live is an integral part of their cultural identity.

4.3 Nuclear Power

Nuclear power will be a new development for Viet Nam. It is a source of power generation characterized by risks of low probability but extremely high in impact, reflecting the extreme hazards associated with radiological materials. It is essential that Viet Nam develops the management systems to handle radiological materials before nuclear power development starts. There are additional predicable impacts that are a cause for concern, especially associated with the use and release of cooling waters. The site selection of power stations is the key issue here: any locations in the proximity of sensitive or high value

Figure 6: Examples of Zones of Influence around Hydropower Schemes



Dong Nai 2 Zone of Influence | **Clustered Zones of Influence in Central Viet Nam**

ecological areas must be avoided and the possible impacts of cooling water on riverine and marine ecosystems must be carefully assessed, while recent events in Japan have shown the importance of taking the risk of natural disasters affecting nuclear power stations into account.

4.4 Transmission Lines

Transmission line investments will generate adverse impacts, especially associated with the clearance of land along the routes of the transmission lines. The value of the forests that will be lost in implementing PDP VII is estimated at $218 million. The line routes will pass through 59 protected areas and 39 key biodiversity areas, with risks of the fragmentation of habitats that could compromise the integrity of high value biodiversity areas. The consequences of the routing of transmission lines need to be carefully examined.

5. Considering Alternatives

5.1. Improved Energy Efficiency

Although challenging, it is possible to significantly improve energy efficiency in Viet Nam. The Electricity of Viet Nam (EVN) demand side management assessment study shows that the savings potential of around 36% could be achieved in the residential sector and more than 20% and 12% could be attained in the industrial and commercial sectors, while the World Bank's Commercial Energy Efficiency Program (CEEP) shows project savings of 15%–30%. This study considered achieving the 5%–8% electricity savings target set under the Vietnam Energy Efficiency Program (VEEP) for 2010–2015, gradually increasing this savings target to 20% of the total electricity demand during 2015–2030. These targets would bring down the country's electricity elasticity (ratio of growth rate of electricity demand and growth rate of GDP demand) from a high of 1.90 in 2010 to 0.85 in 2030, which is consistent with those of many efficient developing and developed countries.

A scenario was analyzed in which the plans in the PDP VII base case were adjusted to increase energy efficiency according to the national strategy. Under this scenario, electricity generation savings increase from 1,639 gigawatt hours (GWh) in 2015 to more than 22,000 GWh by 2030. The reduction of electricity demand would potentially greatly reduce dependency on coal-fired power generation: 16 coal-fired power plants throughout the country that are presently planned to be commissioned in 2027–2030 that are identified in the PD VII baseline scenario will no longer be needed.

The results show the potential of a sustained effort to increase energy efficiency as a key element in reducing the negative impacts of coal-fired power generation. The energy savings would save over 56 million tons of coal a year by 2030 (Table 2). This in turn would reduce CO_2 emissions by over 100 million tons a year, SO_2 emissions by over 72 million tons, NO_x emissions by over 42 million tons, and particulate matter emissions by nearly 10 million tons (Table 3). These reduced emissions would have huge benefits in terms of reduced climate change and acidification impacts and greatly reduced risks to human health from the power generation sector. The economic value of these reduced social and environmental impacts is calculated to be over $3.3 billion (Table 4), a figure that would be much higher than any likely costs of the energy efficiency measures and investments implemented.

One of the critical factors, in addition to the regulatory and management measures, is financing of energy efficiency activities and projects. An energy efficiency fund could be established to support activities and leverage private sector investments. Similarly, the market for energy efficiency services and the establishment of energy efficiency service companies should be stimulated and supported by the Government.

5.2. Increased Renewable Energy in Power Generation

The second major element of any strategy to reduce the levels of coal-fired power generation needed in the future is to generate the electricity from other sources. Under the existing base case of PDP VII, large-scale hydropower will be close to maximized in terms of feasible hydropower construction sites; nuclear power will be developed at as fast a rate as is feasible for Viet Nam, and both oil and gas will be at levels that are as high as is likely to be economically and technically feasible. This leaves the further rapid expansion of power generation from renewable energy sources as the outstanding option for reducing coal consumption and impacts through substituting alternative power generation sources.

Under the baseline scenario, the share of renewable energies increases from 3.6% in 2015 to 5.8% in 2025 but declines to 4.4 % in 2030 due to the rapid growth of coal-fired power generation. In absolute terms, renewable energy capacity improves from 1,679 MW in 2015 to 6,029

Table 2: Energy Efficiency Scenario: Reductions in Demand for Coal, 2011–2030

Year	2011	2015	2020	2025	2030
Coal (million ton)	10.9	28.2	57.9	89.6	135.1
Domestic	10.6	26.2	39.8	53.2	69.5
Imported	0.34	2	18.1	36.4	65.6
Coal reduction (million tons)	0.6	3.8	19.2	26.9	56.3

Table 3: Reduction of Pollutant Emissions Compared to the Base Case (Carbon dioxide, `000 ton)

Year	2011	2015	2020	2025	2030
Particulate matter	312.91	995.04	3,552.45	4,933.26	9,873.90
Sulfur dioxide	4,538.23	5,837.31	22,184.68	32,609.93	72,868.86
Nitrogen oxides	12,140.97	113,65.97	20,593.53	29,154.38	41,291.30
Carbon dioxide	6,921.10	115,08.16	39,806.59	49,275.07	104,685.02

Table 4: Reduction of Health Costs ($ million)

Year	2011	2015	2020	2025	2030
Particulate matter	-45.05	9.72	73.19	101.65	203.47
Sulfur dioxide	13.19	17.21	65.59	96.41	215.45
Nitrogen oxides	31.55	36.14	66.38	93.97	133.09
Carbon dioxide	644.40	791.70	1,578.70	2,195.80	3,348.10

MW in 2030. Although significant, these figures can be regarded as conservative and are far below the levels of renewable energy development that would be possible given the potential resource base of these energy sources, especially wind, solar power, and small-scale hydropower.

The increase in the proportion of renewable energy from 4.1% in the base case to 8%–10% has been considered, which would mean a capacity expansion of an additional 7,800 MW by 2030 compared to the base case. The target is to attain almost 5% share in 2015, 8% in 2020 and close to 10% in 2030. This entails raising the capacity from 1,979 MW in 2015 to 13,829 MW in 2030, more than double the level presently found in the PDP VII base case scenario. At present, grid-connected renewable energy is mainly from small hydropower systems, which are projected to increase from 461 MW in 2011 to 3,129 MW in 2030. Wind power generation will increase from a minimal level at present to 2,900 MW by 2030. For this renewable energy scenario, an additional 4,800 MW of small hydropower systems and 3,000 MW of wind power plants are to be installed. This expansion would result in the reduction in use of coal for power generation shown in Table 5 and the reduction in atmospheric pollution shown in Table 6.

These reduced emissions would in turn produce a significant reduction in environmental costs compared to the base scenario (Table 7) of over $1.7 billion by the year 2030, reflecting the significant reductions in environmental and human health impacts from the power generation sector. These savings would be permanent and sustained and would far outweigh any likely increase in the direct financial cost of power generation associated with the use of renewable energy in present conditions. It is in any case likely that the relative economics of renewable energy and conventional power generation sources will change in coming decades with technological developments and economies of scale as the global level of renewable energy continues to increase.

6. Recommendations from the SEA

The SEA produced a wide range of recommendations on both the content of PDP VII and the enhancement of the power sector planning process. A key step in the full integration of social and environmental issues into the PDP VII is the internalization of all economic costs into the calculation of the least-cost alternatives for power generation. Important steps toward this have been taken in this SEA but the full internalization into the base case scenario calculations has not yet been possible. This should be developed for future PDPs so that a more rigorous and transparent means to compare the full implications of the different power generation options is available within the core structure of the PDP.

Key recommendations relate to the reduction of future dependency on coal as a principle means to generate electricity. The greatest impacts come from coal-fired power generation, with impacts that will cost several billion dollars per year by 2030. A strategy that combines improved energy efficiency and accelerated renewable energy development would go far to reducing these

Table 5: Reduction in Demand for Coal with Expanded Renewable Energy

Year	2011	2015	2020	2025	2030
Coal (million ton)	11.2	31.9	75.8	111.9	177.5
Domestic	10.8	29.9	46.2	61.9	64.8
Imported	0.38	2	29.7	50	112.7
Coal reduction (million ton)	0	0.1	1.2	4.6	10.6

Table 6: Reduction of Atmospheric Pollution from Expanded Renewable Energy (Carbon dioxide `000 ton)

Year	2011	2015	2020	2025	2030
Particulate matter	-7.03	35.23	223.81	849.02	1,941.73
Sulfur dioxide	377.61	818.72	940.08	4,865.65	13,575.04
Nitrogen oxides	12,356.55	11,253.20	10,166.70	13,561.26	14,575.81
Carbon dioxide	7,440.86	6,635.29	7,056.78	14,736.98	26,264.91

Table 7: Reduction of Health Costs due to Reduced Emissions ($ million)

Year	2011	2015	2020	2025	2030
Particulate matter	-57.42	-15.65	4.59	17.48	40.00
Sulfur dioxide	0.87	2.34	2.76	14.37	40.12
Nitrogen oxides	31.33	35.43	32.77	43.71	46.98
Carbon dioxide	638.50	694.20	938.80	1,472.50	1,739.90

impacts and it is recommended that such a strategy is elaborated. This would include further assessments of the potential scale and best sites for renewable energy development as well as the means through which greater energy efficiency can be achieved.

For hydropower, specific recommendations include the improvement of the existing package of support and compensation for displaced people, the multi-purpose management of reservoirs to ensure an integrated approach to water resources management, the development of community forestry and protected area plans for the areas surrounding hydropower site,s and the preparation of biodiversity management plans in localities of high ecological value. It was further recommended that two planned schemes, at Dak Mi 1 and Dong Nai 5, are actively examined for cancellation because of their likely severe biodiversity impacts in areas of unique ecological significance.

Further recommendations relating to the technical content of the PDP VII include approaches to improve management and operational efficiency; on ensuring that nuclear power is developed in a safe and rigorously managed manner; and on mitigating potential environmental damage from transmission line development.

Taken together, these recommendations will ensure that the development of the power sector takes place in accordance with rules and regulations on environmental sustanability and to reflect wider principles of environmental protection. These recommendations would make a significant contribution to reducing the adverse social and environmental impacts of the necessary expansion of Viet Nam's power sector. Many negative impacts can be reduced and vigorous actions to ensure that this takes place are essential. Of course, all such impacts cannot be eliminated altogether and there should be a transparent recognition of the likely trade-offs needed for the effective development of the sector. Further analysis of costs and benefits and further consultations with relevant stakeholders are both essential and should be continued.

SEAs are a relatively new process in Viet Nam. Experience is growing but their effective integration into strategic planning is still limited. The use of SEA as an integral part of the preparation of PDP VII has demonstrated the utility of this approach, providing a means through which possible issues can be identified and alternative approaches explored before the plan is finalized. The integration of the SEA process also provides a means through which key stakeholders can be consulted during plan preparation.

7. Implications for SEAs and Power Sector Planning in the GMS

Executing an SEA requires capabilities that are often beyond those found in many planning agencies. Sustained capacity development activities are needed in Viet Nam and in other countries if the experience of the SEA in PDP VII is to be widely replicated. There is great potential for sharing experience and capacities between the institutes of the different countries in such sectors as power development where SEAs are of particular importance. Project environmental impact assessments remain insufficient to evaluate the implications of national, regional, and sectoral development policies, plans, and programs, where SEAs are the most effective approach to ensure the full integration of social and environmental issues into decision making. The SEA of PDP VII was successful in establishing a robust analytical framework consisting of scenarios, alternatives, and valuations leading to clear and transparent re-assessment of the costs and benefits of different generation alternatives.

The revision of the renewable energy and energy efficiency targets was the major recommendation coming out from the SEA of PDP VII. This recommendation will hold true for other GMS countries. It is essential that a limited approach based only on immediate financial criteria is not used. This is where GMS subregional energy forum can play an active role, as a part of renewable energy (RE) and energy efficiency (EE) - subregional plans, as well as looking to remove policy, market and financial barriers.

Environmental Operations Center (EOC), as a regional environmental platform to mainstream environmental considerations in sector development processes, should continue to act as a regional referral center (clearing house) and support countries to build their SEA capacities to conduct scientifically robust SEAs underpinned by enhancing the technical capacities of line agencies, harmonizing SEA methods and producing SEA guidelines and manuals. Support is also needed to strengthen SEA policy and regulatory frameworks in many countries, including enhanced monitoring and appraisal capacities amongst responsible agencies. Finally, investments in information generation and dissemination must be made as an integral part of any process to ensure the potential of SEA approaches in strategic planning in the region is realized.

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STATUS OF ENERGY USE, POWER SECTOR EXPANSION PLANS AND RELATED POLICIES IN THE GMS: CHALLENGES AND OPPORTUNITIES

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and Pradeep J Tharakan[3]*

Abstract

The economies of the Greater Mekong Subregion (GMS) are rich in natural resources and are witnessing unprecedented growth and transformation. Further growth is contingent on access to additional reliable sources of energy. The total primary energy consumption in the region is expected to double between the years 2010 and 2025. The two main sectors driving this increased energy demand are transportation and electricity generation. It is estimated that 238 gigawatts (GW) of new electricity generation capacity would be needed by 2025.

Currently, the larger economies in the region are net importers of energy (from outside the region), while the smaller economies have sufficient indigenous energy resources to support significant regional trade, once these resources are developed. The varying states of economic development and unequal distribution of energy resources thus provides the ideal setting to increase regional energy trade in pursuit of sustained and equitable economic growth for all nations involved. Specifically, Thailand and Viet Nam could benefit from increased regional imports, while Cambodia. Lao PDR and Myanmar could gain from trading in surplus power. A regionally integrated energy sector thereby provides a key opportunity to reduce the energy dependence of the GMS on the rest of the world.

The development of an optimum regional energy trading policy is however, contingent on several pre-requisites. Each country must strive to fully realize its energy conservation potential and renewable energy potential while participating in regional efforts to identify and support regional interconnection projects, and improved energy transmission and transport modes that will allow for cost-effective regional trade. Given the overall investment needs in the sector, it is unlikely that governments alone would have the requisite financial resources. The private sector would have a key role to play in any significant expansion of the GMS energy trade.

1. GMS – A Cradle of Transformation

The Mekong River has six riparian states in Southeast Asia: Cambodia, People's Republic of China (PRC), Lao People's Democratic Republic (Lao PDR), Myanmar, Thailand, and Viet Nam, which constitute the Greater Mekong Subregion (GMS). Yunnan Province (Yunnan) and Guangxi Zhuang Autonomous Region (Guangxi) represent the interests of the PRC at various GMS forums. In total, the GMS spans over 2.52 million sq.km of land area and sustains a population of about 321 million. The GMS is one of the most dynamic areas of the developing world having exhibited a high growth rate over the last decade. The sub-region is characterized by uneven distribution energy resources, diverse cultures, and distinct Government systems. It has abundant biodiversity but the pace of transformation of the economies, while aided by the rich natural resource base of the region, also exerts immense pressure on human and the fragile ecosystems. The common challenge to all countries of the sub-region is to sustain their economic growth while limiting the adverse environmental impact.

The geographic positioning of the GMS countries, within Southeast Asia offers an opportunity for co-operation in various areas of economic development. Recognizing the potential for synergistic gains that could be achieved, the six member countries, in 1992, formulated the GMS Economic Cooperation Program (ECP). Between 1993 and 2005, GMS witnessed an overall energy consumption growth of 8% p.a. (ADB, 2009a). However, there is an enormous gap between the economic realities of the various states as can be seen from the variation in the per capita electricity consumption levels (Table 1) and ranges from 97 kWh in Myanmar to 2,079 kWh in Thailand. Even when viewed as a whole, the GMS region has a per capita consumption of only 863 kWh, significantly lower than the world average of 2,876 kWh (WDI, 2011).

The varying energy consumption levels between the nations can be attributed to the unequal economic growth and different stages of development. Barring Myanmar,

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Table 1: Land area, population and energy consumption per capita for GMS countries

Country/Region	Land Area (1,000 km²)	Population (2010) million	Population (2010) Density (people per km² of land area)	kWh/capita[a]
Cambodia	177	14	80.1	113
PRC[b]				
Guangxi	237	51	205.0	1,771
Yunnan	397	46	115.1	751
Lao PDR	231	6	26.9	429
Myanmar	654	48	73.4	97
Thailand	511	69	135.3	2,079
Viet Nam	310	87	280.4	799
Total	**2,515**	**321**		

a Mekong Delta River Wetland Ecosystem Assessment
b Nguyen Tan Phuong, Forest valuation in Viet Nam
Source: WDI (2011); National Bureau of Statistics (2010).

the rest of the GMS countries have relatively established power sector development plan which provides opportunities in the long-term to effect change (ADB, 2009a).

The exploitable hydropower resources in Lao PDR, Myanmar and Yunnan are expected to exceed their own demand and surplus can be exported in the future (ADB, 2008a). A similar case is in the use of fossil fuel sources - large offshore natural gas reserves in Myanmar and Viet Nam when compared to their domestic demand and coal reserves of Yunnan and Guangxi provinces of the PRC (ADB, 2008a; ADB, 2009a). Therefore, it is necessary to have effective cooperation and coordination between the countries in GMS in order to tap into these energy resources combined with technology and knowledge sharing, given the similarities in the implementation environment that exists on the ground.

The distribution of energy resources is varied and uneven among and within the countries that constitute the GMS. As demonstrated earlier, the per capita consumption is extremely low in the GMS and any demand estimation is likely to fall short of the true demand for energy sources, as there is no awareness in the larger population of the possibilities that open up with greater electricity and energy access and supply. Overall, the lack of policies for the aggressive promotion of energy sector development, of effective coordination between various countries in sharing technology and resources, of financial incentives to tap into renewable energy source and the poor standards of environmental legislation add to the plethora of issues that plague the consumers in this densely populated region.

ADB commissioned a study of the energy sector in the GMS, which was carried out by Integriertes Ressourcen Management (IRM), in late 2007. The base scenario of the study is business as usual with each country pursuing a high growth strategy without any increased levels of cooperation in the energy sector, by way of trade or sharing of resources. The reference scenario used in the model, treats the GMS as one economy with expanded cooperation, through multilateral trading agreements and sharing of resources and knowledge. This report predominantly looks at the needs of the GMS as seen in the base scenario and highlights the advantages of pursuing shared growth as illustrated by the reference scenario.

2. Energy Supply-Demand Outlook in the GMS

Statistical data pertaining to historical demand and supply of energy were obtained from an array of sources ranging from publications within the respective countries (ministry sources), World Development Indicators (WDI) as published by the World Bank, International Energy Agency (IEA) Statistics etc. Data for Thailand and Viet Nam were obtained from the Asia Pacific Energy Research Centre (APERC). Projections for the future energy demand were obtained from earlier publications by ADB and IRM, with 2010 forming the base year for comparative purposes. IRM used the MESSAGE model to arrive at projections for GMS as a whole. There are different scenarios listed in these reports while making projections, wherein medium growth scenario with business as usual scenario was the base case considered for analysis.

The following sections analyses the existing conventional energy resource base within the GMS, total final energy consumption (TFEC) and (inter alia) transportation and electricity demand in the GMS and finally the total primary energy production within the GMS.

2.1. Conventional Energy Resources within the GMS

The region has a significant resource base when it comes to coal. Viet Nam has large reserves of anthracite coal, but the inefficiencies associated with burning this form of coal do not permit its full exploitation. The coal found in Lao PDR is of high ash content as in Thailand which is also high in sulphur content (ADB, 2008a). Coal resources in Yunnan Province can generate around 32,850 TWh of electricity but the PRC may not open this resource for regional trading, considering its internal energy demand in other provinces.

Most of the oil resources in the region are used to meet transport energy demand, but significant imports are necessitated as the region is poorly endowed when one considers oil. Thailand has the largest natural gas and crude oil reserve base. Cambodia and Lao PDR rely entirely on imported gasoline and diesel (ADB, 2008a) to meet their transportation energy demand, which can be attributed to the lack of refineries in these countries. Cambodia uses diesel for producing power which is highly vulnerable to international supply and price volatilities of crude oil. This is one of the reasons for high electricity tariffs in Cambodia as compared to the rest of the GMS.

Myanmar has proven gas reserves of 17 trillion cubic feet which are mostly in offshore fields (ADB, 2008a) while Thailand has the largest installed gas based power generation capacity. Table 2 provides a summary of the energy resources in the GMS.

Myanmar and Yunnan have the highest hydropower potential in the region, while only Thailand and Viet Nam have exploited their hydropower resources to a substantial degree. Over the past decade, Lao PDR and Cambodia have started tapping into their hydropower potential, but only Lao PDR is currently in a position to export surplus electricity to Thailand after meeting domestic demand (ADB, 2008a).

Table 2: Energy resources and potential in GMS Countries

Country / Region	Coal	Natural Gas[a]	Crude Oil	Hydro (MW) P: Potential I: Installed	Renewable Energy[b]
Cambodia	Hard coal: 10 million tons	140 bcm	Reserves: 400–500 million barrels	P: 15,000 I: 13	Biomass: 16.04 GWh/y Wind: 1.73 GWh/y
PRC					
Guangxi	Hard coal: 1,055 million tons	-	-	-	N.A.
Yunnan	Hard coal: 27,123 million tons	Resource: 32 bcm Production: 6 mcm	136 million tonne	P: 90,000 I: 11,980	N.A.
Lao PDR	600 million tons	101.9 bcm	-	P: 18,000 I: 663	Biomass: 33,000 TJ/y Wind: 39,795 MW
Myanmar	Hard coal: 711 million tons	Resource: 569 bcm Production: 13,513 mcm	2.7 billion barrel	P: 100,000 I: 802	Wind: 365 TWh/y Solar power: 51,979 TWh/y
Thailand	1,240 million tons	Resource: 760 bcm Production: 20,023 mcm	0.2 billion barrel	P: 10,000 I: 3,422	Solar PV: 50,000 MW Biomass: 4,400 MW Biomass thermal: 7,400 ktoe Biogas: 190 MW Wind: 1,600 MW
Viet Nam[c]	45,000 million tons	Resource: 256 bcm Production: 5,892 mcm	3.2 billion barrel	P: 15,000 I: 4,155	Solar PV (off-grid household): 2 MW Biomass[d]: 250-400 MW Geothermal: 200-400 MW Wind: 110,000 MW

a bcm – billion cubic meters, mcm – million cubic meters

b Excluding the current operational potential.

c Hydro and renewable energy data was sourced from http://tel.archivesouvertes.fr/docs/00/59/35/73/PDF/PhDthesiswriting-20110510.pdf, except solar energy data.

d Biomass includes wood plantations, residues, rice husk, paddy straw, and bagasse.

Source: ADB (2008a), ADB (2008b), ADB (2008c), Beni Suryadi (2005), Shankar et.al (2005), Nguyen, T. Nhan (2011). Programming Sustainable Development in a Developing Country: A Social Optimization of the Vietnamese Power Sector. CIRED/CNRS archives, 2011. Available online at http://tel.archivesouvertes.fr/docs/00/59/35/73/PDF/PhDthesiswriting-20110510.pdf

2.2. Total Final Energy Consumption

Fossil fuels (coal, natural gas, crude oil) along with hydropower, biomass and other renewable sources constitute the energy consumption mix (Table 3), today and in the future. The values are provided for the base and terminal years of the analysis period, indicative of the growth that the region is set to witness.

The region will witness a more than doubling of its energy consumption over the fifteen year period. The modelling by IRM suggests that there will be drastic shift in the dependence away from solid fuels in Cambodia and Lao PDR as a result of increased electrification, which in turn is driven by exploitation of the hydroelectric potential. In contrast, Myanmar will continue to remain dependent on non-commercial fuel wood and shows an increasing trend through the forecast period.

In order to sustain the economic growth that the region has witnessed two specific aspects of energy consumption have to be addressed viz. electricity and transportation fuels.

Transportation Energy Demand in the GMS

Imported energy sources accounted for 21% of final energy consumption of the GMS in 2005. The region is poorly endowed when it comes to crude oil and imports upto 19%

Table 3: TFEC (in ktoe) in 2010 and 2025[a]

Country / Region	Coal		Gas		Oil		Electricity		Fuel wood and renewable energy		Total	
	2010	2025	2010	2025	2010	2025	2010	2025	2010	2025	2010	2025
Cambodia	93	24	19	490	607	3,191	103	406	3,377	2,408	4,199	6,518
PCR												
Guangxi	17,171	41,354	1,720	6,888	11,503	43,745	6,927	19,370	9,305	11,885	46,625	123,242
Yunnan	16,667	34,155	375	3,998	4,966	17,873	4,849	12,133	10,024	11,445	36,880	79,605
Lao PDR	227	681	256	380	642	1,722	153	566	1,013	762	2,291	4,111
Myanmar	564	2,455	265	638	1,963	3,466	542	1,975	12,210	19,831	15,544	28,365
Thailand	9,700	18,400	4,200	9,850	47,000	85,950	15,000	35,300	10,600	15,250	86,500	164,750
Viet Nam[b]	6,800	13,900	1,400	3,650	15,000	36,100	5,700	16,500	22,500	22,500	51,400	92,650

a For the purposes of analysis, a common base year was required and used the same source even for the year 2010 though these are projections for the 2008 data source.

b Viet Nam has the plans to introduce nuclear power and by 2025 it is expected to supply about 7,200 ktoe.

Source: ADB (2008b) for Cambodia, PRC, Lao PDR, and Myanmar; APERC (2006) for Thailand and Viet Nam.

Table 4: Transport energy demand in GMS in million liter

	2005	2010	2015	2020
Cambodia				
Gasoline	590	903	1,219	1,729
Diesel	1,375	2,235	3,307	4,396
PRC, Yunnan and Guangxi				
Gasoline	1,979	2,978	4,191	5,404
Diesel	3,898	4,970	6,744	8,518
Lao PDR				
Gasoline	129	208	336	540
Diesel	201	323	521	839
Myanmar				
Gasoline	434	590	1,001	1,656
Diesel	635	702	775	856
Thailand				
Gasoline	7,248	7,417	11,610	27,692
Diesel	19,594	18,480	26,314	64,049
Viet Nam				
Gasoline	3,554	5,095	7,185	10,132
Diesel	7,013	8,533	11,896	14,667

Source: ADB (2008b) for Cambodia; LBEDC (2008) for Lao PDR; EPPO (2011) for Thailand; PRC (2011) for Yunnan and Guangxi; Myanmar and Viet Nam - country data obtained from Ministry.

Table 5: Installed electricity generation capacity in GMS

Country / Region	Installed capacity (MW)
Cambodia (2008)	390
PRC	
Guangxi (2011)	26,257
Yunnan (2011)	37,437
Lao PDR (2011)	2,558
Myanmar (2011)	3,418
Thailand (2009)	29,212
Viet Nam (2011)	23,000
Total	**122,272**

Source: ADB (2008a), Sanhya.,S. (2011), EGAT (2010), EVN (2011), MEP (2011), EDC (2009), CSG (2011).

of its petroleum needs. In addition, the lack of refineries in the region implies that the reliance on refined products is to the tune of 33% (ADB, 2009a). It is also important for the GMS countries to diversify the transportation energy demand through introduction of alternative fuels, promotion of mass transport systems and increasing the efficiency of the same. Biofuels are being considered and produced within the GMS and there is an evolving policy framework to address the long term sustainability of biofuel usage for the region (Tharakan *et al,* 2011).

Table 4 shows the gasoline and diesel energy demand for transportation in GMS countries. Regression analysis was used to forecast the demand of gasoline and diesel consumption based on the current and historic consumption patterns. The gasoline demand from 2010 to 2020 is going to be somewhere in between 1.8 to 3.7 times the consumption level in 2010. Similarly the diesel consumption is going to be increased by 1.7 to 3.5 times the current consumption in 2010.

While biofuels provide an option to tide over the dependency on imports, biofuels development can be associated with numerous risks if deployed unsustainably. Risks may include food security, impacts on soil and water quality, and biodiversity, which in turn may have negative ramifications for human development (Tharakan *et al,* 2011). The analysis of its viability in the GMS context is outside the scope of the paper as one needs to pursue an economy wide analysis to ascertain the impact on agriculture, food sufficiency and long term sustainability of the approach.

Total Electricity Demand in the GMS

Table 5 lists out the installed electricity generation capacity in the GMS. The MESSAGE model forecasts that nearly 238 gigawatts (GW) of new electrical power generation capacity need to be added over the coming years in GMS i.e. more than three times to the current capacity generation is required by 2025. A substantial portion of the generation capacity required to sustain growth in the future is yet to be constructed.

2.3. Total Primary Energy Production in the GMS (Regional Supply)

Over the forecast period (2010 – 2025), given the doubling of the energy consumption (forecasted demand); it is inevitable that the supply side will also have to be scaled up proportionately to address the consumption needs. The role of biomass (as a proportion) in contributing to primary energy supply decreases over the forecast period whilst the role of renewables increased along with hydropower. However, there is also increased reliance on coal and other fossil fuel resources, refer to the Table 6.

Table 6: TPES (in ktoe) in 2010 and 2025[a]

Country / Region	Coal		Natural Gas		Crude Oil		Hydro		Biomass and renewables		Total	
	2010	2025	2010	2025	2010	2025	2010	2025	2010	2025	2010	2025
Cambodia	136	5	0	0	812	5,278	33	33	3,420	2,737	4,402	8,054
PRC												
Guangxi	37,957	88,929	0	0	12,874	57,801	1,564	2,049	10,502	16,619	62,898	165,398
Yunnan	29,185	66,230	208	490	5,302	17,484	2,491	8,149	11,603	15,267	48,789	107,619
Lao PDR	1,433	5,895	1,039	533	908	1,003	5,209	6,518	1,027	1,650	9,616	15,599
Myanmar	583	5,950	750	597	2,341	2,914	609	3,960	12,305	21,049	16,588	34,470
Thailand	15,500	48,800	35,100	61,100	51,500	90,850	1,000	850	11,000	18,150	114,100	219,750
Viet Nam[b]	11,300	27,100	6,800	13,750	15,000	37,650	2,800	5,350	23,200	25,550	59,100	109,400

a For the purposes of analysis, a common base year was required and used the same source even for the year 2010 though these are projections for the 2008 data source.

b Viet Nam has the plans to introduce nuclear power and by 2025 it is expected to supply about 7,200 ktoe.

Source: ADB (2008b) for Cambodia, PRC, Lao PDR, and Myanmar; APERC (2006) for Thailand and Viet Nam.

3. Background to Regional Power Trade Coordination Committee in GMS

3.1. Need for Regional Cooperation in Energy Sector

In order to evaluate the benefits of regional power trade and cooperation, one must look beyond the analysis presented above, which considers a base scenario, where there is no further trade and cooperation in the future than what exists at present. This could be compared against the reference scenario, which allows for cooperation and trading of energy between the GMS countries, which forecasts an additional requirement of 238 GW of electricity generation capacity, and provides an opportunity to save upto 19% in capital investment costs in power plants and other energy sources. The reference scenario, which optimises the energy consumption of the GMS as a whole indicates a savings of nearly 200 billion USD in energy costs (discounted to 2010). World market prices are much higher and hence all imports that happen are at world market prices in the base scenario. In contrast, the reference scenario assumes the possibility of providing reliable supply at a lower cost, with lesser transaction charges throughout the GMS by establishing an energy trading platform. The scenario also forecasts a much higher development of hydropower potential, in light of the opportunity to trade surpluses. This will further enhance the private sector investments for the power markets. Also, there is a scope for information sharing and knowledge exchange between countries in the GMS. There is already established power sharing through bilateral agreements between the countries in GMS, however, such cooperation needs to be expanded to the regional level. This approach will provide enduring benefits over those of bilateral agreements. In order to meet this demand, it is necessary to have dedicated institutions wherein each country of GMS has a role in fulfilling the regions demands as a whole.

3.2. The Existing Set Up and Co-operation Opportunities in the Near Term

Under the framework of GMS ECP, the Energy Power Forum (EPF) was set up in the year 1995. Over a period, this has evolved into two separate institutional structures (a) the Energy Sector Forum and (b) the Regional Power Trade Coordination Committee (RPTCC) a high level body, which coordinate implementation of Regional Power Trade (RPT) & represents the Countries. RPTCC consists of two subgroups i.e. the Focal Group and the Planning Working Group.

Since the establishment of EPF, there were three main achievements i.e. (i) Intergovernmental Agreement (IGA) for power trade within GMS, (ii) formulation of Regional Power Trade Operating Agreement (RPTOA), and (iii) developed Regional Indicative Master Plan on Power Interconnection (RIMPPI) (ADB, 2008a). Currently discussions are under progress for the establishment of GMS Regional Coordination Centre (RCC) to oversee power trade development and report to RPTCC.

When it comes to the power transmission lines, PRC, Thailand, and Viet Nam in the GMS have well established power grids with integrated 230 kilovolt (kV) and 500 kV lines forming the backbone. Cambodia has started developing its power grid and is in the process of establishing 69 kV, 115 kV, 132 kV, and 230 kV transmission lines. A similar scenario prevails in Lao PDR and Myanmar but with better progress (ADB, 2008a). The reference scenario, was estimated that about 238 GW of new electrical power generation capacity need to be added over the coming years in GMS, a larger proportion of this capacity will be added in Cambodia, Lao PDR and Myanmar. That means it provides an opportunity for these countries to develop low carbon energy technologies such as combined power plants, cogeneration, waste-to-energy options with a possibility to introduce new energy systems that are more efficient apart from hydropower (ADB, 2009a).

3.3. Regional Power Trade: A Starting Point

Globally, there have been a few successful regional energy trading regions, which provide a template for the GMS to adopt. European Network of Transmission System Operators for Electricity (ENTSO-E) formed in 2008 that combines the institutions established earlier in Europe. This is providing wider opportunity for power sector development and equitable role for countries in the European Union. South African Power Pool (SAPP) founded in 1995 links the power systems of Angola, Botswana, the Democratic Republic of the Congo, Lesotho, Malawi, Mozambique, Namibia, the Union of South Africa, Swaziland, Tanzania, Zambia, and Zimbabwe. There are other examples such as EAPP (connects 10 countries), WAPP (connects 14 countries), SIEPAC (connects 6 countries) for international regional trade in energy that has led to significant benefits, both financial and otherwise (ADB, 2009a). Certainly, such cooperation between the countries would help individual countries to achieve market competitiveness, electricity prices can be near the level of the marginal cost of power generation and improves the productivity of the power sector as whole.

Bilateral agreements for power purchase constitute a bulk of the regional power trade today. The most significant of these was the one signed between Lao PDR and Thailand for export hydropower to Thailand (ADB, 2008a). GMS ECP is one of the most successful regional cooperation programmes and is now help to diversify cooperation in the other economic sectors particularly power trade. The two factors that contribute to this success are strong political ownership and economic growth of the countries in the region.

3.4. Expected exchange of power within the region

A futuristic scenario of power trade and regional interconnection of power grid in GMS region was executed under MESSAGE model as GMS integrated scenario. It is expected that Cambodia, Lao PDR, and Myanmar would become the key electricity exporters in the GMS. By far, Thailand and Viet Nam are major importers. Figure 1 show the units of electricity exchanged between now and 2025 in an integrated scenario (ADB, 2009a).

4. Power Sector Development Plans and Policies in GMS Countries

Policies for power sector are developed with certain objectives. Some of those are (a) to meet the country's demand for electricity at the least cost, (b) to uphold the country's commitments under international conventions, (c) encourage private sector participation (d) efficient

Figure 1: Electricity production and exports within the GMS, 2005 and 2025 (GWh)

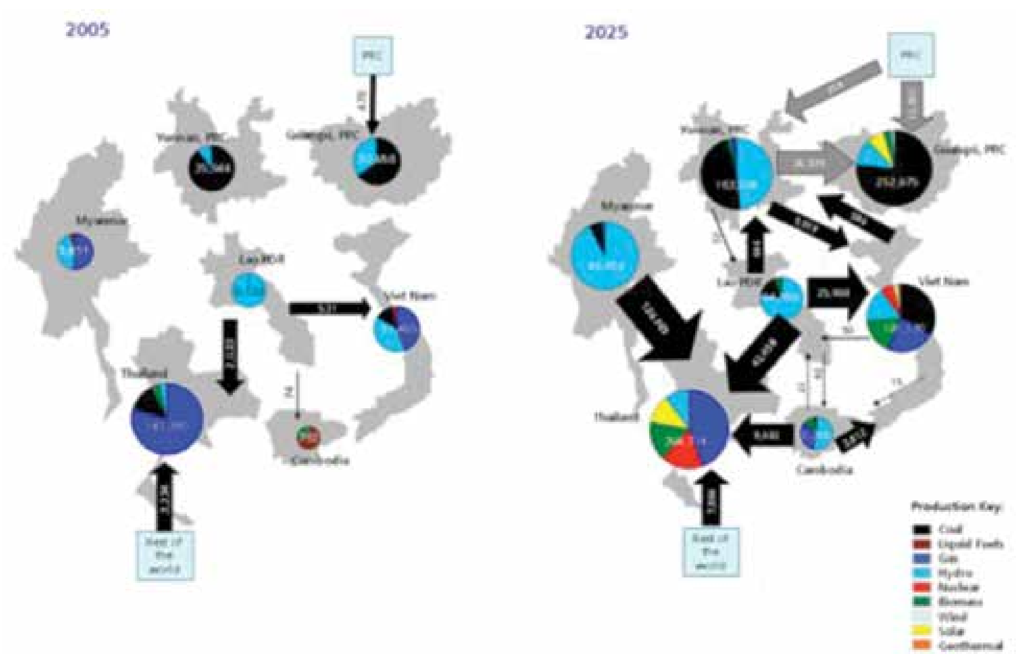

Table 7: Important policy parameters that guide the power sector environment in GMS

Parameter	Power development plans	Private participation in power generation	Private participation in power distribution	Target - 100% rural electrification by	Environmental Impact Assessment (EIA) process
Cambodia	Exist	Yes	Yes	2020	Weak
PRC					
Guangxi	Exist at the national level	N.A.	No	2010	N.A.
Yunnan	Exist at the national level	N.A.	No	N.A.	N.A.
Lao PDR	Exist	Yes	No	90% by 2020	Weak
Myanmar	No clarity	Yes	No	2020	Weak
Thailand	Exist	Yes	No	2010	Strong
Viet Nam	Exist	Yes	No	2020	Weak

Source: ADB (2008a).

use of available resources, keeping in mind the reserve depletion rate and ensuring a sustainable approach to the use renewable energy sources. The overall share of private sector investment in the energy sector remains low in the GMS due to a lack of favourable policies. Table 7 lists some of the important parameters that enable a clear understanding of the existing framework in the GMS countries.

4.1. Cambodia

As per the power development plan, Cambodia has an aggressive policy of total rural electrification by 2020. Nearly 70% of the rural households will have access to quality electricity supply by 2030. The total installed power generation capacity by 2020 is estimated to be 6,000 MW thereby covering the entire domestic demand of 3,500 MW (18,597 GWh) and leaving a surplus of more than 2,500 MW for export purposes (EDC, 2009).

4.2. Lao PDR

The Lao PDR government has a target to achieve rural electrification to the extent of 70% and 90% by year 2010 and 2020 respectively. Lao PDR earns substantial foreign exchange earnings through sale of power and attracts foreign direct investment to fund the projects, which in turn fuel the economy. The country has bilateral agreements with other GMS countries implementation of new projects will have to be accelerated to ensure that the commitments under intergovernmental agreements are honoured. A total of 68 projects with estimated installed capacity of 22 GW are currently under different stages of development (EDL, 2009; Sanhya.S., 2011).

4.3. Myanmar

There are two ministries focusing on power sector development in Myanmar - Ministry of Electric Power-I and Ministry of Electric Power-II with separated responsibilities, with overlap in some areas. Recognising the wide spread energy poverty, the Government has laid down policies to tap into the hydropower potential in the country. About 19 hydropower projects are planned to be constructed between 2010 and 2020. Local investors are allowed to participate in this through IPP agreements for hydropower projects and currently about 284.5 MW of hydro power capacity is under development. Modest targets of is 60% rural electrification by 2020 and 80% by 2025 has been set as per the policy (MEP, 2009).

4.4. Thailand

Thailand has a relatively well developed power development plan and provides a greater opportunity for private sector participation in electrical power generation through IPP, Small Power Producer (SPP) and Very Small Power Producer (VSPP) programmes. The power development plan is a step in low carbon development pathway and achieves emission reductions also through the promotion of energy efficiency and renewable energy development. The power capacity additions expected between 2010 and 2020 is about 21.6 GW (EGAT, 2010).

4.5. Viet Nam

The Electricity Law in Viet Nam took effect in 2005 (July) and provides a roadmap for regulatory reform in the power sector, assigns responsibilities for reform and was proposed with a view to promote investments in the power sector and liberalise the same. The nation has ambitious targets for power production to meet the domestic demand. Ground rules for setting of tariffs and for competitive markets to emerge have been laid out. The law further encourages energy savings and renewable energy development (IRG, 2006). Power Master Plan VII was recently approved and there is a strong emphasis on energy security, energy efficiency, renewable energy development and power market liberalisation. There is a change in the targets set for total power capacity additions from 121 GW (plan VI) to about 61 GW (VII) for the period 2016 to 2025 (Dao and Kevin, 2011).

4.6. Guangxi and Yunnan, PRC

PRC has power development plans at the national level, but Guangxi and Yunnan are given special attention due to the low development in these counties compared with other counties in the PRC. Having said this, regional cooperation with GMS provides an opportunity for Yunnan and Guangxi to work with other countries in the GMS to maximize the benefits through greater regional cooperation and integration with GMS. It is expected that in the future, Yunnan will make use of its resources (natural gas) and sources (hydro) for the promotion of relatively clean energy sources in GMS. Though Guangxi is endowed with coal resources, it is expected to largely contribute to the national goals than GMS. The use of high coal consumption in Guangxi has lead to severe environmental pollution and experienced acid rain in many cities of Guangxi (ADB, 2008b).

5. Other Opportunities for Sustainable Energy Sector Development in GMS

While promoting economic development and resource sharing are the focus of co-operation efforts, it is important that environmental and social costs associated with the exploitation of resources are internalised and accounted for. Given the large hydropower potential in the region, and the results from the scenarios, it is clear that a low carbon growth strategy will rely on the extensive tapping of the same. Hydropower projects have detrimental effects on the flora and fauna within the catchment area. The externalities must be accounted for by way of a Strategic Environment Assessment (SEA). The livelihoods of millions of people in the downstream nations of the Mekong depend on the ecosystems associated with the river. Any disturbance will also impact the poor adversely. Therefore, it is imperative that the GMS ECP provides special assistance to RPTCC with regard implementing social and environmental safeguards which are embedded in the SEA (MRC, 2010), while developing power projects. Significant capacity building is necessary at the country level as the existing environmental regulations in the GMS are weak.

As part of power sector development, there are other possible areas of intervention that could lead the GMS economies in low carbon development path without compromising economic growth. The GMS as a whole would be adding significant power generation capacity over the years and in their quest to reduce the carbon foot-print, they would inevitably pursue energy efficiency gains and renewable energy. The following section gives an overview of existing policies in these areas and discusses possible next steps in enhancing the current policies.

5.1. Energy efficiency

The GMS countries are in the varying stages of implementing policies directed at achieving energy efficiency. Thailand, for example, has in place several mandatory requirements with regard to energy standards and labelling and has even made available a fund to incentivise the adoption of energy efficient technologies. Sharing national experience in energy efficiency, renewable and clean coal technologies, establishing regional best practices and technical standards would greatly help the spread of energy efficiency as a policy paradigm. The prominent barriers for the promotion policies targeting energy efficiency are (a) fossil fuel subsidies (specifically towards diesel, gasoline and LPG) (b) lack of awareness, information and experience in implementation, (c) absence of incentives to end users and producers of energy to adopt efficiency measures (ADB, 2009a).

Table 8 summarises some of the energy efficiency policies prevailing in the GMS and implementation status. Among these, standards and labelling as well as energy conservation programmes are being implemented to an extent than other measures such as financial incentives, building energy standards, and introducing energy service companies (ESCOs) in GMS.

Cambodia is in the process of developing an energy efficiency master plan. There is also a possibility for the promotion of ESCOs as private sector could play a significant role in the power distribution in Cambodia. In Lao PDR there are no formal energy efficiency policies in place. However the country is encouraging voluntary energy audits in buildings and industry. Awareness raising events are being conducted for energy efficient lighting for various stakeholders with the support from ASEAN Centre for Energy. In Myanmar, Ministry of Energy developed an Energy Policy and Strategy, under which it is trying to promote energy conservation in industry (ADB, 2009a).

Thailand is implementing energy efficiency policies successfully. The energy conservation fund (ENCON) in Thailand provides low-interest loans to the designated

Table 8: Energy efficiency policies in the GMS

Policy measure	Energy conservation programmes	Standards and Labelling	Building energy standards	Energy Audit	Financial incentives	Private sector participation (ESCOs)
Cambodia	A few	Planned	Voluntary	Voluntary	N.A.	Yes
PRC Guangxi Yunnan	Yes	Yes	Mandatory	Mandatory for certain categories	Available	Yes
Lao PDR	A few	N.A.	Voluntary	Voluntary	N.A.	Yes
Myanmar	Yes	Planned	Voluntary	Voluntary	N.A.	Yes
Thailand	Yes	Partly mandatory	Partly mandatory	Partly mandatory	ENCON fund	Yes
Viet Nam	Yes	Planned	Mandatory for industries	Mandatory for industries	Available	Yes

Source: ADB (2009a).

factories, buildings, and ESCOs, under the specific criteria and conditions, to invest in energy efficiency projects. This fund is also called as revolving fund for energy conservation. Department of Alternative Energy Development and Efficiency (DEDE) is the lead agency responsible for its implementation (DEDE, 2008). Thailand is very successful in promoting ESCOs for energy conservation through performance based contracts. Apart from these, there is a Demand Side Management (DSM) program which integrates (a) energy standards and labelling program, (b) energy audit & load management, (c) incandescent lamps phase-out; and promotes energy efficiency in buildings (Oliver *et al.*, 2001; Nadel and Geller, 1996).

Viet Nam has a national programme for economical and efficient use of energy for 2006-2015. This programme aims to save about 5-8% of the total energy consumed during 2011-2015. Apart from awareness rising among stakeholder, it promotes industrial energy efficiency, efficient use of energy at household level, standards and labelling for certain household appliances and equipment, and energy efficiency in buildings (ADB, 2009a).

In the case of Yunnan and Guangxi, the national policies of PRC are applicable. PRC has a number of programmes for the promotion of energy efficiency at various levels. These would include renovation of boilers in existing power plants, waste heat recovery, energy efficiency in buildings, green lighting to name a few. Energy intensity is being monitored and reported at all levels (ADB, 2008c).

To summarise, three areas need immediate intervention to promote energy efficiency in GMS.

(a) Develop uniform energy standards and labelling for equipment and appliances across GMS. As exchange of goods and services is happening between the countries, such measures will benefit the end users and original equipment manufacturers across the region to compare the energy efficiency of different appliances and encourage promotion of efficient good and services.

(b) Promote the development of ESCOs and other private sector players that guarantee energy savings through performance based contracts.

(c) Promote information sharing and knowledge exchange between countries through dedicated institutions.

5.2. Promotion of Renewable Energy and Low-carbon Technologies

Apart from hydropower, there is a greater possibility for developing decentralised energy systems based on other renewable energy sources especially solar energy and biomass. Much of the GMS lies in the tropics and is blessed with ample hours of sunshine in a year and can be exploited through concentrated solar power (CSP) or solar-PV technology. Barring Yunnan and Guangxi regions of PRC, the wind energy potential in GMS is limited. Even in the face of available resource, reliable grid connectivity will be an issue, going forward, for wind energy development in the region. Viet Nam is the only country in the GMS that is significantly endowed with geothermal energy resources, estimated to be about 200 – 400 MW of power capacity (ADB, 2008c). The cost of exploiting this is fairly high given current technologies and will present an option for the future, with the right incentive structure.

As in other countries, the options for incentivising renewable energy investments are many and varied. Feed-in tariffs (FiT), Renewable Portfolio Standards (RPS), Tradable White Certificates (TWC)/Tradable Green Certificates (TGC) and financial incentives such as investment tax credits, production tax credits, fixed government investment subsidy/grant, low interest loans and credits form the gamut of options. Most of the countries in GMS have set renewable energy targets considering the fraction of the resource that is deemed exploitable. For instance, Thailand has enacted policy to increase its national share of alternative energy to 20% of total energy supply by 2022.

Renewable energy law in PRC makes it obligatory for the utilities to purchase energy generated from renewable sources, at a price as dictated by the FiT. The National Development and Reform Commission (NDRC) will be responsible for implementing the law. In Thailand, a mix of FIT and RPS is being practiced along with few other policies such as net metering. Thailand introduced net metering in May 2002, which is recognised as Very Small Power Producer (VSPP) scheme. This encourages small-scale renewable energy generators (up to 10 MW) to connect to the grid and guarantees a prescribed price for the electricity supplied to the grid. In addition, there is a subsidy available in the form of “adder” which is over and above the retail price for a given type of renewable energy source for a fixed number of years. The new law creates income opportunities for rural communities based on locally produced, clean and renewable energy and offers significant potential to reduce country’s dependence on imported oil and coal (Greacen et.al, 2003).

Cambodia has established the Rural Electricity Fund (REF) in 2005 as part of the Rural Electrification and Transmission project funded jointly by the World Bank and the ADB. Individual renewable energy projects are encouraged through the provision of a quarter of the total project investment cost in the form of an REF grant. In addition, there is a possibility to obtain concessional loans from private financing institutions, apart from being provided with an operating license from the Electricity Authority of Cambodia.

Table 9 summarises the existing policies for the promotion of renewable energy. Overall, FiTs seem to the more preferred and successful policy measure for promoting grid connected renewable energy projects. Providing subsidies does increase the number of project proponents in the initial stages, which is necessary to build a critical mass and to create a market for the clean energy. Once the market has matured, sustaining subsidies would not be viable and must be left to the market forces to decide the fate of new and existing investments. Therefore, the option of providing subsidies must be exercised with caution keeping in mind stage of development of the renewable energy sector.

6. Conclusions

Many of the riparian states of the GMS, despite being endowed with a rich natural resource base, are languishing in energy poverty. The GMS is at present composed of countries that are net importers and net exporters of certain forms of energy. This offers a unique opportunity for concerted effort in developing their respective resource bases in an integrated manner to ensure more equitable economic and social development prospects for all the states. The exploitation of resources must however be carried out keeping in mind the fragile nature of the environment and the dependence of the livelihoods of millions of people who depend on it.

The total energy demands of the GMS countries are expected to grow two fold, compared to current levels, by the year 2025. Despite the penetration of commercial energy sources, biomass and solid fuels will continue to play a significant role in meeting the energy demands of the rural population, throughout the analysis period. Myanmar shows increasing dependence on solid fuels, as the market for commercial fuels is not expected to penetrate, given the current policy framework. Electricity and oil (fuel in transportation) dominate the demand growth in the GMS, like in any developing area. Policies targeting the use and development of these resources are mandated for the countries in GMS. Natural gas provides an alternative to oil in the transportation sector, but much of the natural gas used in the region is also imported. It is then imperative that targeted policies be laid out for a low carbon, resilient growth pathways, to reduce the dependence on imported fuels.

It has been clearly established that there is immense potential for trading energy across borders, specifically electricity, provided there is a sustained effort to augment infrastructure that's aids in the transfer. A large portion of the energy resources that the region is bestowed with, namely hydroelectric and other renewable resources have been left untapped. The reasons for this vary from lack of adoption of suitable technologies to insufficient coordination in efforts and sharing national experience in developing them. Hydropower can play a vital role in strengthening regional integration by enabling a more interconnected and resilient power supply amongst the GMS countries. Lao PDR was an early mover in this regard and realised the benefits of trading surplus power with their energy starved neighbour, Thailand. Myanmar and Cambodia have charted out similar a strategy to exploit their hydropower potential. With the growing awareness of the threat of global climate change, GMS countries have now found another strong justification to promote cooperation in the energy sector as regional environmental benefits may also result due to a more efficient use of energy resources, reducing overall need for energy production and thereby potentially reducing carbon emissions, and land use impact from energy-related activities. It is estimated that 238 GW of additional capacity is required to sustain

Table 9: Renewable energy policies in the GMS

Policy measure	FIT	RPS	TWC/TGC	Tax credits	Fixed government investment subsidy/grant	Low interest loans and credits	Net metering
Cambodia	N.A.	N.A.	N.A.	N.A.	Yes	Yes	N.A.
PRC Guangxi Yunnan	Yes	N.A.	Voluntary	Partly (depends on technology)	Yes	Yes	Yes
Lao PDR	N.A.	N.A.	N.A.	N.A.	N.A.	Yes	N.A.
Myanmar	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.
Thailand	Yes	Yes	No	Yes	Yes	Yes	Yes
Viet Nam	Yes	N.A.	Voluntary	Yes	Yes	Yes	N.A.

Source: summarised from various sources including Romeo (2005). NA - Information not available.

the growth of the region over the next 15 years (as per the GMS Integrated Growth scenario). This scenario was created under the assumptions that optimal production, consumption and trade of energy within the GMS region would be enforced by a robust policy framework.

Addressing the transport energy demand in GMS is a more complicated affair. Given the thriving agricultural sector in the region, biofuels present a feasible alternative but assessing the economy wide implications of such a move is beyond the scope of this paper. Establishing seamless rail-network connectivity and improving road infrastructure in the region would result in more cost effective solutions and result in a significant reduction in the demand for oil as a transportation fuel.

There are other regional power trade examples that serve as success stories for the GMS to emulate. For a start, the countries of GMS have recognised and demonstrated their understanding of the importance of regional cooperation in the energy sector. The existing framework of GMS ECP provides enough space for successful implementation of power trading to happen. Regional upgradation of power-grids and construction of cross border high tension transmission lines is in progress in different countries and provides a measured sense of optimism that the benefits from power trading will be realised sooner than later. It is essential that private sector plays a key role in the power sector at country level. An environment conducive for the emergence of the private sector can be created through transparent policies and simplified procedures that lay stress on preserving and augmenting social and environmental capital. Targeted policies are also needed to incentivise energy efficiency within the economy and to promote low carbon and renewable energy technologies that are resilient to shocks associated with global energy supply chains.

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GREENHOUSE GAS MITIGATION BY HYDROPOWER TRADING FROM MYANMAR TO THAILAND

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Abstract

This paper analyzes the carbon dioxide (CO_2) reduction and economic effects of hydropower development in Myanmar and its power trade with Thailand. These two neighboring countries differ in their energy profiles, particularly in energy sources and requirements. The Myanmar Government's energy policy is to fully exploit enormous hydropower potential and export energy to Thailand in order to increase its foreign earnings while helping Thailand with its power requirements that are becoming an important issue.

To determine the optimal mix of generation planning to meet anticipated electricity demand while fulfilling specified constraints for Thailand, the Wien Automatic System Planning version IV (WASP-IV) was used. The results show how joint resource development is beneficial for both Myanmar and Thailand, financially and environmentally. The study recommends solutions for the attainment of energy security in Thailand and proposes the least-cost effective generation expansion planning to improve the outcomes of hydropower resources trading between Myanmar and Thailand—seen as a win-win solution for both countries.

1. Introduction

Globally, more than half of electricity production is from fossil fuel (natural gas, coal and oil). Nowadays, the emissions from power plants have become a matter of concern, especially carbon dioxide (CO_2) emissions, which are associated with global climate change.

Myanmar and Thailand are neighbors but their energy profiles are quite different. Myanmar relies more on renewable energy, especially mini hydropower plants with installed capacity 8.35 megawatts (MW), and has high hydropower potential (108,000 MW). In Thailand, the electricity sector is dominated by natural gas (70%) of which 77% is produced in Thailand and the rest is imported from Myanmar; the other 30% of Thailand's electricity is from lignite (20%), hydro power (7%), fuel oil (3%) and less than 1% biomass. In addition, according to the Greater Mekong Subregion (GMS) energy plan, the subregional power grid is to be fueled mainly by hydropower plants. There is concern in the GMS about the rapidly growing electricity demand in Thailand and that producing more electricity by fossil fuel should not be the sole solution. A CO_2 reduction program by power trading between Myanmar and Thailand is an attractive solution. In Myanmar, hydropower has huge potential, more than 108,000 MW. The proposed joint hydropower projects of Myanmar and Thailand can provide revenue for Myanmar and reduce CO_2 emission by Thailand. Moreover, construction of hydropower plants can provide many benefits for irrigation purposes and employment in Myanmar, which is an agricultural country. The outcome would be a win-win solution for both countries.

This paper investigates CO_2 reduction by power trading between Myanmar and Thailand for the planning horizon 2011–2025. Current CO_2 emissions from the various types of power plants in Thailand are calculated and the optimal mix of generation technologies for Thailand is evaluated in line with the country's demand and forecasted constraints.

Comparisons were made of projected CO_2 emissions by Thailand before and after trading power with Myanmar in terms of hydropower resources and the optimal mix of generation technologies using high and low fuel price scenarios.

The paper first discusses CO_2 and local air pollutant emissions of Thailand, then gives an overview of energy-economic indicators of Myanmar and Thailand, power trading, etc. Comparisons of different energy scenarios are next made from an economic and environmental view, followed by some conclusions and recommendations.

2. CO_2 and Local Air Pollutant Emissions of Thailand

In Thailand, emissions of energy-related CO_2 are expected to grow at an annual rate of 4.1%, from 158 million tons (Mt) in 2000 to 676 Mt in 2035. During this period, about 93%

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of total CO_2 emissions will be from the power, industry, and transport sectors. By 2035, 43% of CO_2 emissions will be from coal and 40% from oil. Without mitigation actions, CO_2 emissions in Thailand will increase fourfold between 2000 and 2035. Also, emission of sulfur dioxide (SO_2) may rise from 899 thousand tons (kt) to 5,604 kt and that of nitrogen oxides (NO_x) from 926 kt to 3,413 kt during the same period. In Thailand, energy security is a top national agenda item. In 2000, half the total primary energy demand was imported and this proportion is projected to reach 77% by 2035.

3. Overview of Energy-Economic Indicators of Myanmar and Thailand

Agriculture makes up about 40% of GDP in Myanmar but only 11 % in Thailand, while the service sectors are the reverse, 45% of GDP in Thailand and 12% in Myanmar (Table 1). Thailand's GDP per capita and energy use per capita are far higher than those in Myanmar. GDP in Thailand grew by a factor of 1.45 during 1992–2002 and this was expected to increase to 1.84 during 2003–2016 (Table 2).

4. Power Trading

Power Trading is characterized as "purchase of electricity for resale thereof." It is a transaction where the price of power is changeable and options exist on trading partners and amounts. It concerns buying and selling electricity between various generators and the state electricity boards, or other large customers, directly through bilateral contracts, from a central pool, or through intermediaries.

Table 1: Energy-Economic Indicators, 2007

Indicators	Myanmar	Thailand
Population in millions	57.5	65.4
GDP per capita (ppp current US$)	462	4115
Structure of output (% of GDP)		
a) Agriculture	40.2	10.7
b) Services	11.7	44.7
Electricity use per capita (kWh)	110	1752
Energy use per capita (ktoe)	1084.46	1405.7

ktoe = thousand tons of oil equivalent, kWh = kilowatt hour, ppp = purchasing power parity.

Source: Data from the World Bank; Asian Development Bank; and Ministry of Agriculture and Irrigation. 2008. *Myanmar Agriculture at a Glance*. Myanmar.

The two main types of power trading are bilateral and pool contracts. A bilateral contract is a direct contract between parties, with optional balancing markets. Generators prepare to dispatch contracted loads. In a pool contract, generators sell electricity into a "pool" and suppliers buy from this pool. Market participants trade in the pool against a defined set of rules. Another type of trading is known as multilateral open market, in which power is traded among three or more parties, agencies, or national governments. Power trade between Thailand and Myanmar is on a bilateral basis, based on long-term power purchase agreements and has promoted hydropower development in Myanmar.

5. Power Generation Expansion Planning Overview

In power system development, power expansion planning is essential. Nevertheless, the optimal power generation planning is not easy and requires selecting which, where, and when new generation units can be built over a long-range planning horizon to meet the expected energy demand. Several problems arise that make the planning difficult. First is the uncertainty of input data, such as forecasts of demand for electricity, economic and technical characteristics of new evolving generating technologies, construction lead times, and government regulations. Second, there are conflicting objectives: equal attention must be given to reduction of the system's cost, reliability, and minimization of environmental impacts. Another planning issue is the high uncertainty in fossil fuel prices and their increasing tendency.

In 2003, more than 50% of the world's electricity production was from fossil fuel sources. The high levels of emissions to the atmosphere have contributed to the adverse greenhouse gas effect. In the United States and Europe, policies have been integrated to reduce the amount of fossil fuel used for generating electricity in accordance with the Kyoto Protocol.

Table 2: GDP and Power Demand of Thailand

Thailand	GDP Growth	Electricity Consumption on Growth	Ratio of GDP to Power Demand Growth
1992–2002	1.45 times	2.02 times	1.4
2003–2016	1.84 times	2.39 times	1.3

Source: EGAT's Power Development Plan 2003 and Electricity Demand Forecast Report, January 2004.

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Renewable energy (wind, hydropower, solar, and geothermal) is relatively costly and limited in accessibility. However, to mitigate the global environmental damage and the risk of depending on only a few sources of energy, increasing interest in renewable energy sources should be promoted. The option to produce more electricity from nuclear sources is also being re-evaluated by some decision makers.

6. Generation Mix

Electrical power utilities generate power from various sources, such as nuclear power plants, coal powered plants, gas turbines, hydrodynamic plants, and wind turbines. Each source of electrical power has unique power generation costs and capacity, as well as other benefits and disadvantages. These various sources of power are connected to a common power utility grid that distributes electrical power to a large geographic area of residential and commercial energy users. The demand for electrical power from all users on the power grid is used to determine a total power demand from all power sources. The generation of electricity depends on several factors, including economy, availability and accessibility of resources, availability of foreign investment, load duration curve, quality, security, reliability, and lately, public acceptance. According to country environmental analyses by the Asian Development Bank, countries should promote a hydro and thermal generation mixture in the ratio of 40:60.

7. WASP–IV Dynamic Programming

The methodology used in the study was the Wien Automatic System Planning version IV (WASP-IV), which is the latest version by the International Atomic Energy Agency (IAEA) for electricity system planning. The main characteristics of WASP-IV are planning that considers

a) constraints on environmental emissions, fuel usage, and energy generation;
b) representation of pumped storage plants;
c) fixed maintenance schedules;
d) environmental emission calculations; and
e) expanded dimensions.

WASP-IV is designed to find the optimal generation expansion policy for an electric utility system within user-specified constraints and which is also economically acceptable. It exploits probabilistic estimation of system production costs, unserved energy cost, and reliability, using (i) a linear programming technique for examining optimal dispatch policy that is sensitive to exogenous constraints on environmental emissions, fuel availability, and electricity generation by some plants; and (ii) a dynamic technique of optimization for comparing the costs of alternative system expansion policies. In the modular structure of WASP-IV, the user is allowed to monitor intermediate results, avoiding large amounts of computer time due to input data errors.

8. Generating System Cost

Whenever a power plant is constructed, calculation of power generation cost must take into account both economic and environmental points of view. There are two types of cost in power generation technology (Figure 2): power generation costs, based on fixed and variable costs; and capital investment costs, which comprise fixed investment based on depreciation, return on investment, other fixed charges, etc. These costs are based in turn on the technologies utilized in specific sectors. For example, fuel cost is a consideration for thermal power plants but for not for hydropower plants.

9. Methodology

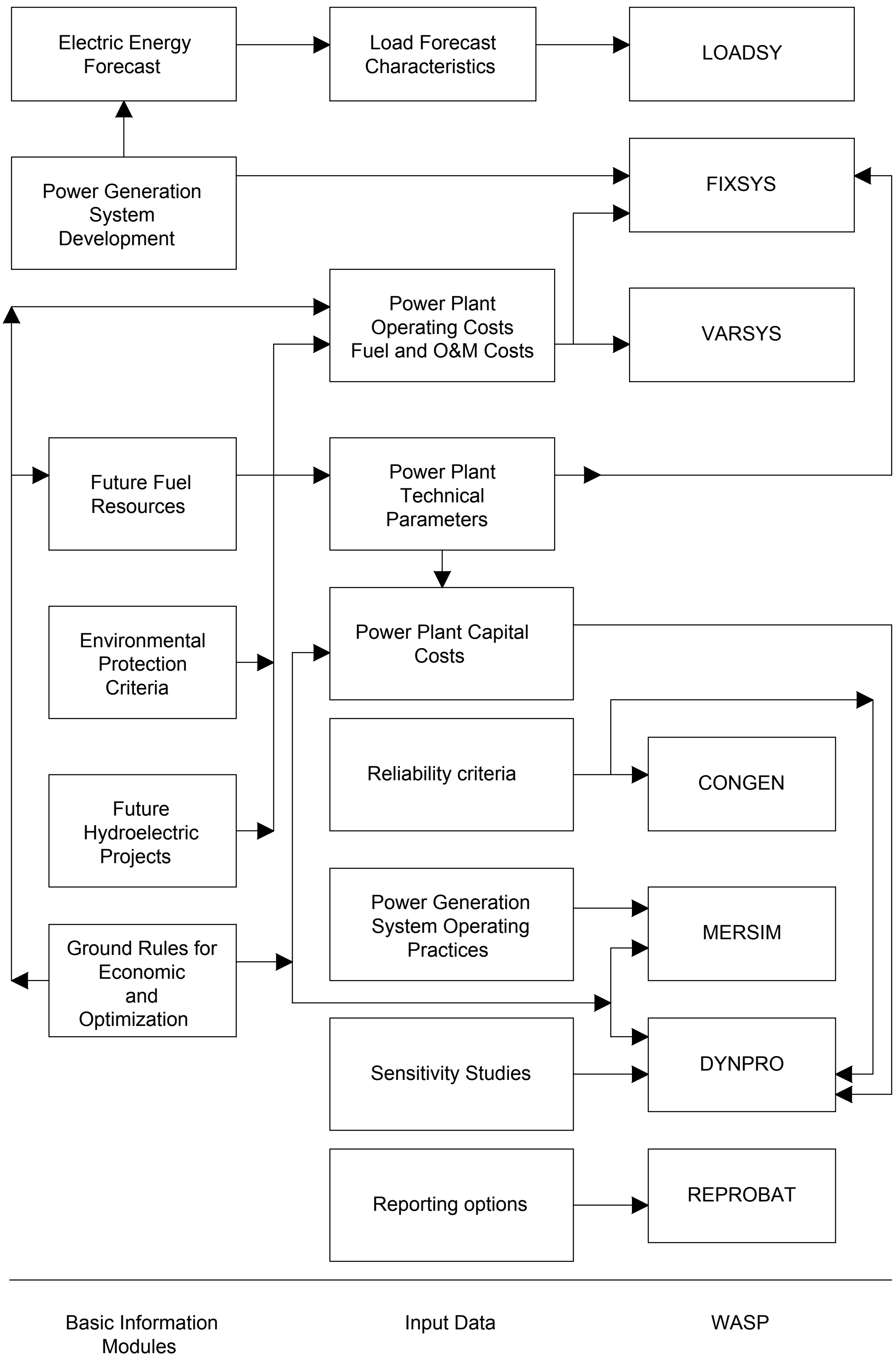
WASP-IV simulations were used to calculate production costs for a large number of potential future system configurations and to select the least-cost expansion plan. The planning period was 2011–2025. The detailed methodology is shown in Figure 3.

Objective functions are evaluated in terms of cost functions as in the following equation:
where:

$$Bj = \sum_{t=1}^{T} (\overline{I_{j,t}} - \overline{S_{j,t}} + \overline{F_{j,t}} + \overline{L_{j,t}} + \overline{M_{j,t}} + \overline{O_{j,t}})$$

Bj : the objective function attached to the expansion plan j,
t : the time in years (1, 2, ... , T),
T : length of the study period (total number of years), and
I : capital investment costs
S : salvage value of investment costs
F : fuel costs
L : fuel inventory costs
M : non-fuel operation and maintenance costs
O : cost of the energy not served.

Figure 1: WASP Dynamic Programming Overview



Source: International Atomic Energy Agency (IAEA). 2006. *A Computer Code for Power Generation Expansion Planning, Version WASP-IV*. Vienna.

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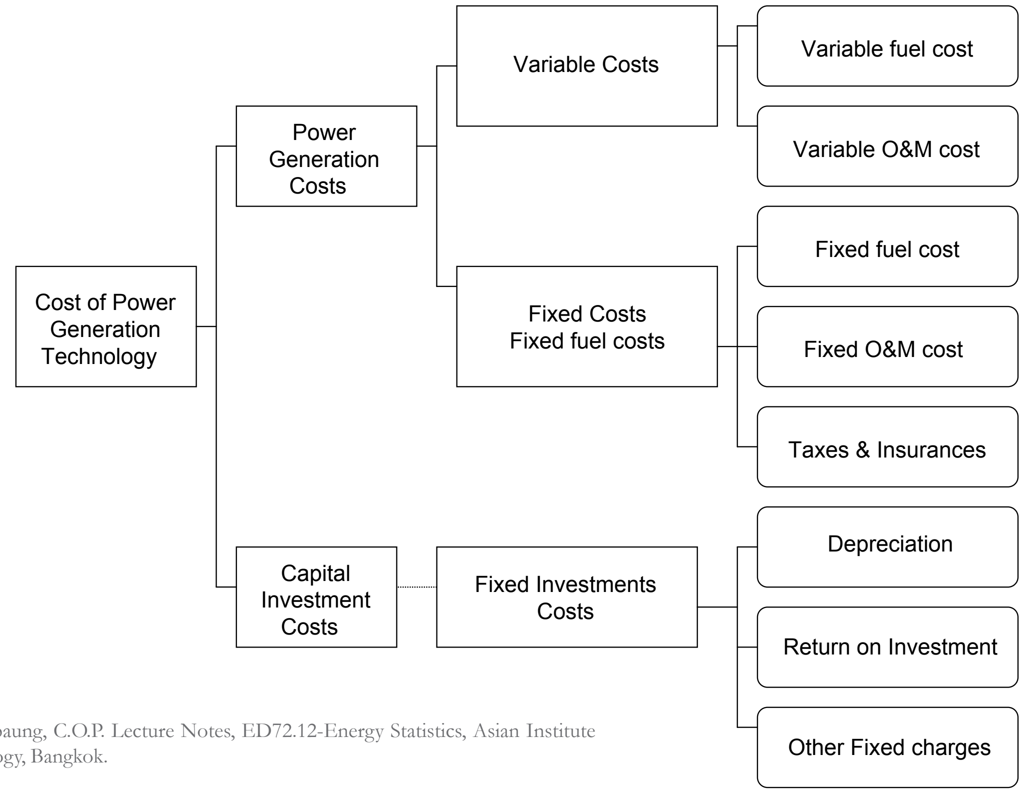
Figure 2: Cost of Power Generation



Source: Marpaung, C.O.P. Lecture Notes, ED72.12-Energy Statistics, Asian Institute of Technology, Bangkok.

Figure 3: General Framework of the Research

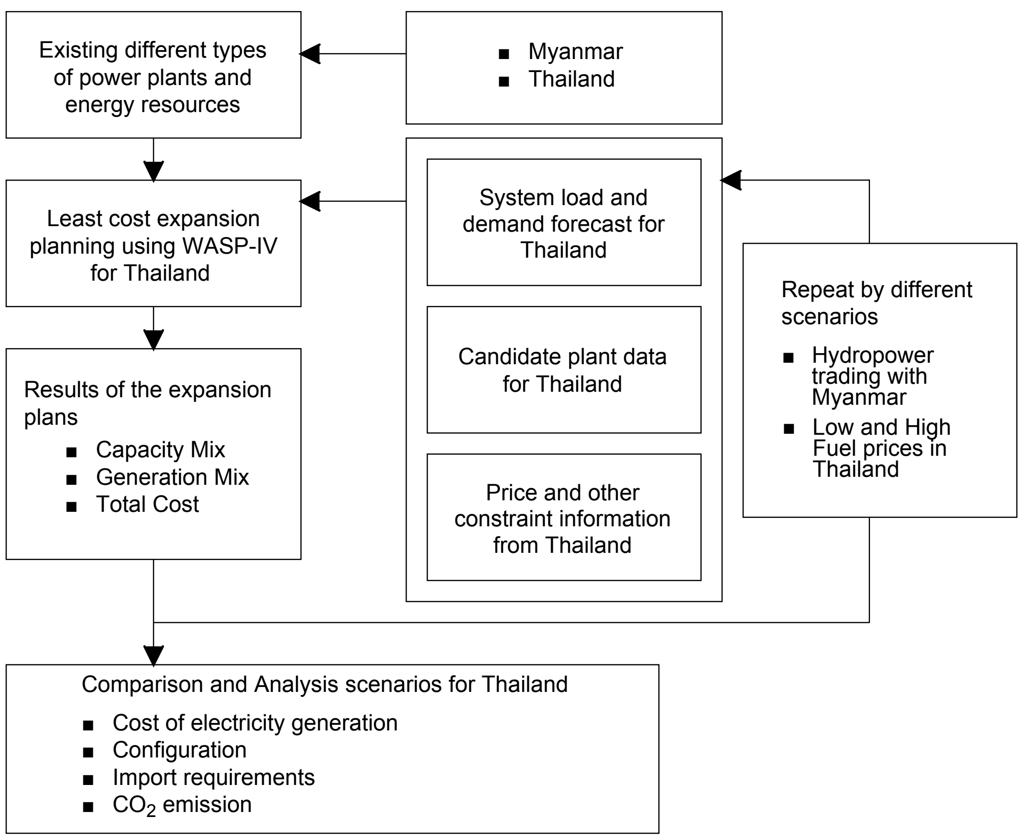
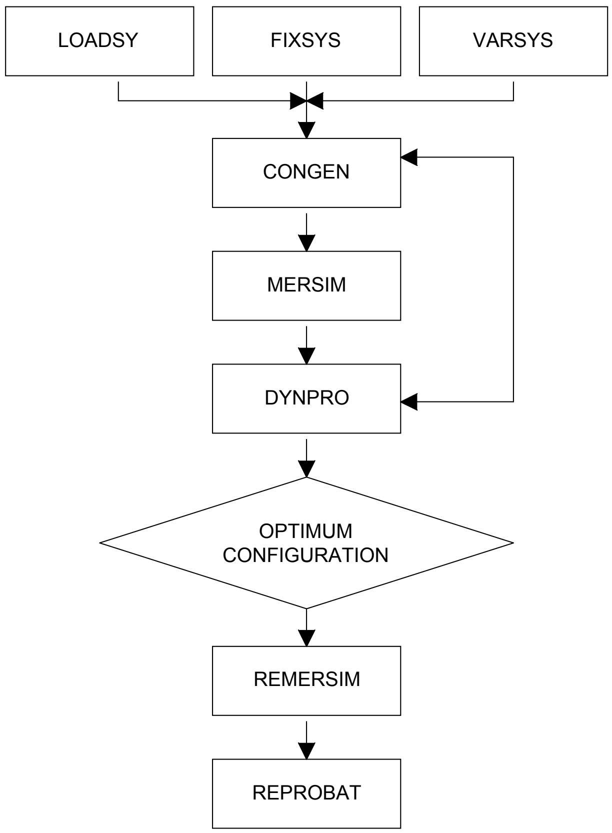


Figure 4: WASP Model General Flow Chart



Source: International Atomic Energy Agency (IAEA). 2006. *A Computer Code for Power Generation Expansion Planning, Version WASP-IV*. Vienna.

To derive the most practical solution for optimizing the power system, limitations on emission and fuel price were used in order to get reasonable outputs. Future demand was calculated based on the population growth rate and economic activities. Different types of fuel resources and other relevant economic issues were employed to select candidate plants.

9.1 Organization of WASP Modules

Figure 4 describes a WASP-IV basic flow chart, which exemplifies the information flow among the various WASP-IV modules, namely LOADSY (Load System Description), FIXSYS (Fixed System Description), VARSYS (Variable System Description), CONGEN (Configuration Generator), MERSIM (Merge and Simulate), DYNPRO(Dynamic Programming Optimization), and REPROBAT (Report Writer of WASP in a Batched Environment).

Module 1: especially used for peak loads annually and periodically, and load duration curves during the study period.

Module 2: processes information about existing systems by considering additions and retirements of power plants during the study period and associated environmental emissions, availability of fuel, and electricity generation capacity. The inputs required for this module are the name, maximum capacity, minimum capacity, fuel type used in specific power plants, heat rates, maintenance days, forced outage rates, and fixed and variable operation and maintenance (O&M) costs.

Module 3: describes the characteristics of the various candidate power generating plants for future power systems.

Module 4: calculates, on a year-to-year basis, possible combinations of expansion candidate additions through iteration to get the best solution. Essential inputs are reserve margin, maximum LOLP and final combined output from FIXYS, LOADSY, and VARSYS.

Module 5: uses the results from the above four modules to merge the existing system with candidate plants that were established and then makes suitable stimulations.

Module 6: evaluates the results according to resultant operating costs. The inputs needed are the capital investment costs of candidate power plants, how much should be assigned as escalation rate and the cost of energy not served, and the discount and interest rate during construction. Probabilistic simulation of the system is used to estimate the associated production. The final outcome provides the best combination of plants to supplement the existing generation system.

Module 7: gives the final result that best meets the objectives.

9.2 Planning Horizon and Candidate Power Plants

CO_2 emission and uncertainties in fuel cost (high/low fuel price) were considered for 2011-2025 to get the most feasible, optimal energy solution for Thailand. For the VARSYS WASP- IV module, the candidate power plants were characterized (Table 3). In the list of the candidate power plants, no additional hydro projects are included because they generate public opposition in Thailand.

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Table 3: Characteristics of Candidate Power Plants for Future Expansion

WASP Name	V-CC	V-TH	V-GT	VIGC	VNUC
Fuel	Natural Gas	Imported Coal	Diesel Oil	Imported Coal	Imported Uranium
Capacity (MW)	700	700	220	500	1,000
Heat Rate (BTU/KWh)	7,000	9,260	10,995	7,346	9,208
Maintenance (days/year)	28	42	14	28	42
Fixed O&M cost (US$/KW-month)	1.49	2.12	0.87	1.27	2.5
Variable O&M (US$/MWh)	0.6	1.04	0.4	0.73	0.5
Capital Cost (US$/MWh)	545.6	941.9	545.6	1,420	1,020

BTU = British thermal unit, KW = kilowatt, KWh = kilowatt hour, MW = megawatt, O&M = operation and maintenance, V-CC = Combined cycle, V-TH = Thermal, V-GT = Gas Turbine, VIGC = Integrated Gasification Combined Cycle, VNUC = Nuclear.

Source: Electricity Generating Authority of Thailand (EGAT). 2007. *Thailand Power Development Plan*. Bangkok.

Table 4: Electricity Demand Forecast

Year	2011	2013	2015	2017	2019	2021	2023	2025
Peak Demand (MW)	28,124	31,569	35,467	39,816	44,336	49,213	54,565	60,2500

MW = megawatt.

Source: Thailand Load Forecast Sub-Committee (2007) and authors' assumptions.

9.3 Input Data for LOADSY Module in WASP-IV

The Thailand Load Forecast Sub-Committee (TLFS) has projected the demand for Thailand up to 2012. Demand is expected to increase continuously up to 2025.

10. Hydropower Trading with Myanmar

The governments of Myanmar and Thailand have a Memorandum of Understanding for a power purchasing program. For hydropower trading, there are two main projects: Hutgyi hydropower project with capacity (for trading) of 1,360 MW which will be connected to Thailand at Tha Song Yang district, Tak Province; and Tasang hydropower project, which is expected to connect to Thailand at Mae Eye district, Chieng Mai Province. As the Tasang project has not yet started, this simulation provides the least-cost generation expansion planning for Thailand in terms of hydropower trading based on the Hutgyi project, which will begin operation in 2014. (The total capacity of the Hutgyi project is 3,000 MW of which 1,360 MW would be exported to Thailand).

11. Changes in Fuel Price

Fuel costs play an important role in creating uncertainty. Thus, both low and high fuel prices were used for sensitivity studies. Table 5 summarizes possible fuel price conditions to reflect the situation in the international fuel market.

12. Results

12.1 The Base Case

Thailand's mainly fossil-fuel based power system was taken as the base case. Other sources—nuclear power plants, gas-fired combined cycle power plants, coal-fired power plants, and diesel-based gas turbine power plants—were then considered in order to determine the optimal mix for generation planning in Thailand. Hydropower trading with Myanmar was not considered. Based on configurations and capacities of the various sources, the capacity and energy mix for an expansion plan were then calculated as shown in Figure 5 and Table 6. Hydropower capacity is constant because no more local hydropower

Table 5: Assumptions of Fuel Prices (constant 2011 price)

Fuel Type	Baseline Price (US$/ million BTU)	Low Price (US$/million BTU)	High Price (US$/million BTU)
Natural Gas (Domestic)	6.63	5.42	8.30
Natural Gas (Foreign)(Import)	6.63	5.42	8.30
Lignite	1.55	1.55	1.55
Imported Coal	2.41	2.41	2.41
Fuel Oil	8.82	7.22	11.73
Diesel Oil	16.63	13.61	22.01
Nuclear	0.74	0.74	0.74

Source: Electricity Generating Authority of Thailand data and author's estimates.

projects are planned during the period. Hydropower trading with Lao People's Democratic Republic (Lao PDR) with a capacity of 1,857 MW, storage capacity of 17,894 gigawatt hours (GWh), and inflow energy of 16,267 GWh was included. Starting in 2011, hydropower trading with Lao PDR was considered to be the most feasible optimum solution for power generation expansion for Thailand. In view of the need to minimize greenhouse gas emissions, it is recommended that the load curve providing least CO_2 emission in the country be used in evaluating the optimal mix of power generation.

12.2 Alternative Case

For the case of hydropower trading from Myanmar to Thailand, the proposed 1,360 MW capacity from the Hutgyi Hydropower project from the beginning of its operation in 2014 was used in the model. The capacity and energy mix for an expansion plan were then calculated. Results are shown in Figure 6 and Table 7.

Table 6: Base Case: Expected Generation by Plant Type (GWh)

Year	2011	2013	2015	2017	2019	2021	2023	2025
Thermal	133,510	154,634	178,536	205,204	232,920	262,825	295,643	332,035
Hydro	36,911	36,911	36,911	36,911	36,911	36,911	36,911	36,911
Other	2,032	2,032	2,032	2,032	2,032	2,032	2,032	2,032
Total Energy	**172,452**	**193,577**	**217,479**	**244,146**	**271,862**	**301,768**	**334,585**	**370,978**

Table 7: Alternative Case: Expected Generation by Plant Type (GWh)

Year	2011	2013	2015	2017	2019	2021	2023	2025
Thermal	133,510	154,634	169,004	195,672	223,388	253,293	286,111	322,504
Hydro	36,910	36,910	46,442	46,442	46,442	46,442	46,442	46,442
Other	2,032	2,032	2,032	2,032	2,032	2,032	2,032	2,032
Total Energy	**172,453**	**193,577**	**217,479**	**244,147**	**271,863**	**301,768**	**334,586**	**370,980**

Figure 5: Base Case: Capacity Mix (MW) for the Study Period
(89 % thermal, 10% hydro and less than 1 % from other resources)

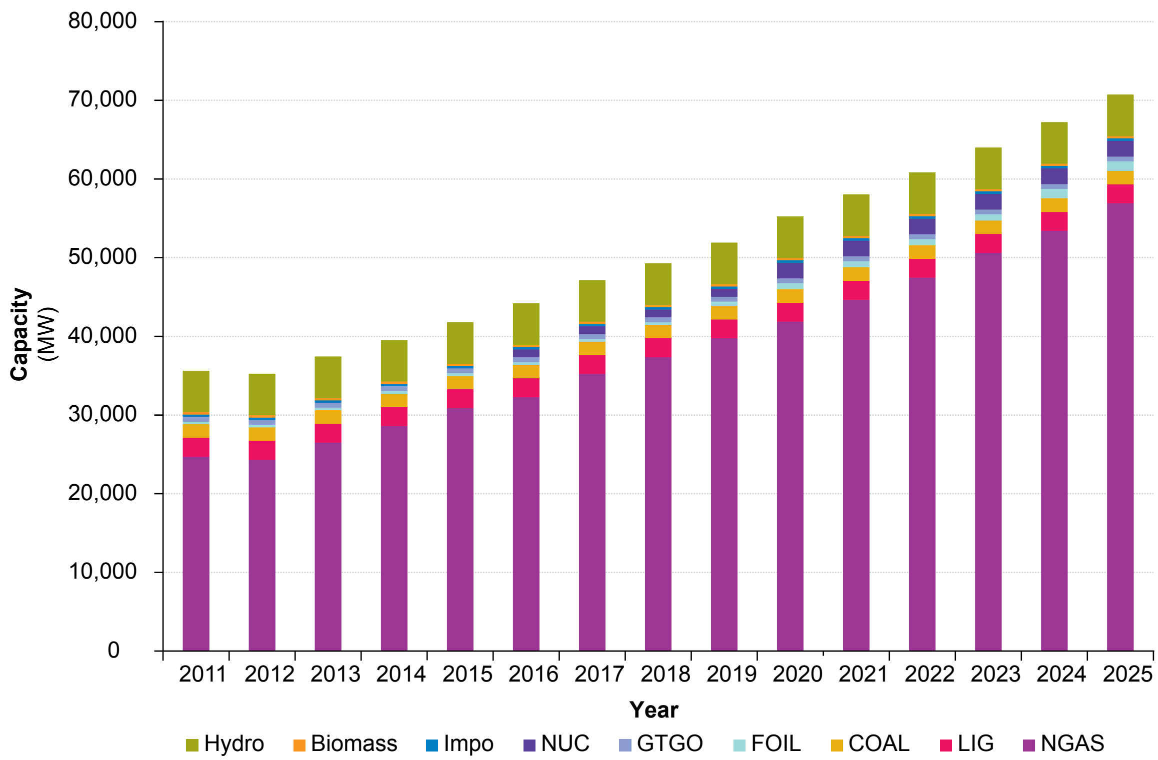
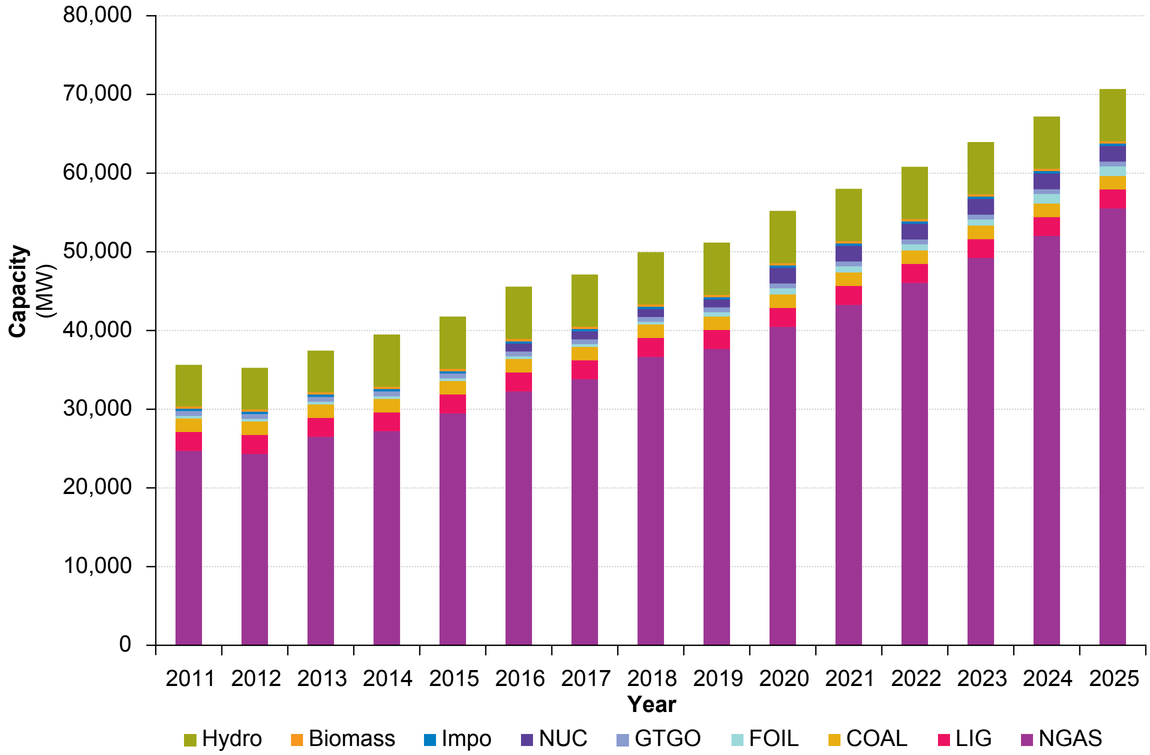


Figure 6: Alternative Case: Capacity Mix (MW) for the Study Period

(87 % thermal, 12.55% hydro and less than 1 % from other resources)



According to the capacity and energy mix of the base and hydropower trading case, it is concluded that natural gas will remain the main source of electricity generation in Thailand during the planning period.

12.3 Simulation Results

In line with the results of the REPROBAT module of WASP-IV, the schedule for addition of new capacities with least-cost generation for Thailand was determined. More than 500 configurations for capacity were considered in covering the study time horizon (2011–2025). The reserve margin used for the planning horizon was between 15% and 25%.

The simulation results suggest that by 2025, without hydropower trading with Myanmar, the optimal mix of these new capacities for Thailand would comprise

- 59 x 700 MW gas-fired combine cycle plants,
- 4 x 220 MW diesel based gas turbine power plants, and
- 2 x 1,000 MW nuclear power plants.

When hydropower trading is included, the optimal mix would comprise

- 57 x 700 MW gas-fired combine cycle plants,
- 4 x 220 MW diesel based gas turbine power plants, and
- 2 x 1000 MW nuclear power plants.

The lowest greenhouse gas emissions and the least-cost generation expansions resulted from the scenarios in which power generation is highly dominated by natural gas. Continued reliance on natural gas for power supply makes the supply mix non-diversified and forces the country to face risks, while a diversification to other fossils fuels would entail an additional environmental burden.

Thailand will not undertake further local hydropower construction due to public opposition although other renewable energy sources could provide cleaner solutions for power sectors. Presently, some of Thailand's electricity capacity is based on renewable energy through its Small Producers Programme. However, this study only considers supply security and environmental impact of bulk electricity supply. It does not consider production of power from these other types of renewable resources. The study concludes that the most viable way for Thailand to reduce CO_2 emissions is to use more hydropower through trading with other countries.

13. Comparative Scenarios of Environmental and Economic Benefits to Thailand and Myanmar

13.1 Environmental Benefits to Thailand

CO_2 emission from the Thailand power sector would be reduced by adopting hydropower trading with Myanmar in 2014. For the base case, total CO_2 emission for the whole study period is 692 million tons and for the alternative case 671 million tons. CO_2 emission reduction and cost saving between base and alternative case during the period are shown in tables 8 and 9, respectively, and the costs and savings using alternative low and high fuel prices are shown in tables 10 and 11, respectively.

All values are discounted to the 2011 base year. The results show total savings for Thailand by hydropower trading with Myanmar for the whole planning period of US$1.02 billion in both the normal and low fuel price scenarios and US$1.13 billion in the high fuel price scenario. The opportunity cost of CO_2 is very attractive from the economical point of view but barriers exist for hydropower projects, such as high capital investment cost. In the following section, the economic and environmental benefits for the two countries are considered.

13.2 Economic Benefits to Thailand

The cost function in WASP-IV shows how various constraints can be met by each possible sequence of power units that are added to the existing system. Costs of fuel, operation and maintenance costs, capital cost, and salvage value costs are taken into consideration in this cost minimization function. All economic and technological benefits shown in tables 9-11 of each alternative generation expansion in WASP-IV are balanced and weighted against present costs.

13.3 Environmental Benefits to Myanmar

The potential benefits for Myanmar from an environmental perspective are:

- Water supply and flood control can be manipulated in the region.
- The water from the dams can be used for irrigation.
- Job opportunities are created in rural areas, improving rural development in those areas.
- Hydro-electricity does not emit greenhouse gases or other atmospheric pollutant, unlike most other types of power plants.
- Hydropower is produced by water, which is a clean fuel source.

Table 8: Comparison of Annual CO_2 Emission during the Planning Period (million ton of CO_2)

Year	2011	2015	2020	2025	Total
Base Case	30.344	38.679	50.177	65.802	692.667
Alternative Case	30.344	36.915	48.412	64.037	671.533
Difference	0	1.765	1.765	1.765	21.135

Table 9: Cost Comparison between Base case and Alternative Case (million US$)

Year	2011	2015	2020	2025	Total
Base Case	7,598.92	3,302.41	2,070.50	633.32	34,837.25
Alternative Case	7,598.91	3,298.43	1,875.12	631.78	33,810.51
Saving	0	3.972	195.38	1.53	1,026.74

Table 10: Cost Comparison between Base case and Alternative Case (Low Fuel Price, million US$)

Year	2011	2015	2020	2025	Total
Base Case	5,053.80	3,302.41	2,108.91	657.17	34,620.79
Alternative Case	5,053.80	3,298.43	1,900.53	655.64	33,600.03
Saving	0	3.97	195.38	1.53	1,020.76

Table 11: Cost Comparison between Base case and Alternative Case (High Fuel Price, million US$)

Year	2011	2015	2020	2025	Total
Base Case	6,765.81	3,302.41	2,108.91	657.17	36,332.86
Alternative Case	6,667.19	3,298.43	1,913.53	655.64	35,200.49
Saving	98.62	3.97	195.38	1.53	1,132.37

According the speech of the Energy Minister in Thailand on 15 February 2010 (National News Bureau of Thailand), the Hutgyi Project has been subjected to environmental impact assessment (EIA) and implementation of recommendations in the EIA would remedy possible construction impacts on the local residents and any violations of human rights.

13.4 Economic Benefits to Myanmar

According to the contract between the Thailand and Myanmar governments, the economic benefits for Myanmar are:

1) Free energy for Myanmar
   7.5 % (first 5 years)
   12.5% (during the following 25 years)
2) Tax exemption for first 5 years
3) Withholding tax exemption during the contribution period
4) Internal rate of return (IRR) on projects of 10.04%
5) IRR on equity, 14%

The equivalent results in monetary value (US$ million) are:

• Free energy	1,206
• Commercial tax	622
• Withholding tax on contracts	0
• Withholding tax on interest	106
• Income tax (project)	81
• Income tax (salaries)	20
• Value of free shareholder	189
• Profit sharing	407

The total benefit to Myanmar over the period is US$2.67 billion. Thus, both countries could get enormous financial benefits from this hydropower project.

14. Conclusions

The study has examined, for present and candidate power plants in Thailand, various scenarios for an optimum power expansion plan. For the base case, during the study period, the optimum energy capacity mix would be 89% thermal MW, 10% hydropower MW, and less than 1% from other resources; while for the alternative case, it would be 87%, 13%, and less than 1%, respectively. In the base case, hydropower capacity remains unchanged, while for the alternative case, hydropower capacity increases in 2014, when hydropower trading with Myanmar would begin. As a result, thermal capacity decreases from 89% to 87%. This 2% saving in thermal energy is very attractive for the world at present in view of global warming.

In value terms, the US$1.02 billion–$1.13 billion, depending on the future price of fossil fuels, that could be saved by Thailand through power hydropower trading with Myanmar is also very attractive, both in satisfying the country's energy demand and in keeping the environment cleaner—21 million tons of greenhouse gas CO_2 would be saved. In Thailand, the government views access to hydropower as an important issue because use of fossil fuels has been opposed due to environmental concerns; it is necessary to diversity the fuels used in power generation; and while nuclear power projects are within Thai national plans, their use still faces some constraints.

In Myanmar, insufficient power supply is the main problem in development. This situation can be overcome by developing hydropower and selling part of the capacity to Thailand.

This kind of study could be extended to other GMS countries, especially Yunnan Province of People's Republic of China, Lao PDR, and Cambodia, which are rich in potential hydropower, to determine the economic and environmental implications for Thailand and those countries. Moreover, comparison of those cases with hydropower trading between Myanmar and Thailand would reveal the hydropower trading scenario that would provide optimal regional environmental and economic solutions. Those results could lead to the evaluation of win-win solutions among all the countries in terms of energy security, economics, and environmental protection, by using the high potential for hydropower trading in the GMS. This could lead in turn to new investments in hydropower projects in those countries.

The largest hydropower resources in the GMS are in Myanmar, Lao PDR, and also in Viet Nam. Thailand has limited mineral and hydropower resources. Cambodia has diverse resources including hydropower and natural gas but is yet to fully exploit them. Hydropower resources are among the best energy options for the GMS power market. The power market should therefore promote hydropower development in the GMS to help optimize investments in power reserves to meet peak demand, reduce greenhouse gas emission and pollutants, and increase consumer access to the cheapest power sources available.

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Panel discussion – Day 1

Scaling economic development and environmental challenges

Facilitator: Dr Nessim Ahmad, ADB

PANEL DISCUSSION – DAY 1 SCALING ECONOMIC DEVELOPMENT AND ENVIRONMENTAL CHALLENGES

Facilitator: *Dr Nessim Ahmad, ADB*

Panelists
H.E. Dr Parisak, H.E. Mr Ros Seilava, Dr Daovong Phonekeo, Mr Tang Shengyao, Mr Arjun Thapan, Dr Jeff McNeely, Dr Duong Duc Ung, Dr Kyoko Kusabe, Dr Mark Rosegrant

Nessim Ahmad: Good morning Ladies and Gentlemen. We are now ready to have our panel discussion on scaling economic development and environmental challenges. I guess that could be reconciling economic development and environmental challenges. The purpose of this panel is to look at the last decade of growth in the GMS and take stock of lessons learned. We are particularly interested to reflect on how we can, indeed, reconcile future growth with environmental sustainability in the context of the food-water-energy nexus. This topic is, of course, important in implementing the GMS Strategic Framework to 2022. But, as mentioned by Vice President Groff this morning, it is a topic that preoccupies the entire world, particularly as we move toward the United Nations Conference on Sustainable Development or Rio+20, which will be taking place in June this year.

This morning we have been fortunate to benefit from a broad spectrum of excellent presentations from internationally renowned speakers on environment, water, food, energy. We have heard that the GMS has seen substantial gains and growth, poverty reduction, and human development over the last decade and whether these gains could be under threat and how future growth needs to be much more environmentally sustainable and inclusive. Jeff McNeely gave us a compelling overview of the ecosystems and biodiversity resources that have underpinned development in the GMS, how these have suffered over the last decade, and how to ensure that ecosystem services, natural capital or natural infrastructure as he calls it, are properly factored into the economic growth equation. Arjun Thapan provided a thoughtful, thought-provoking look at water resource management and the inevitable difficulties that will be faced moving forward; he emphasized the need for rational allocation of water resources, true value pricing, technology adoption, and tough legal and administrative frameworks. Peter Warr shared with us his analysis of growth and poverty reduction in the GMS and his view on how poverty reduction may increase in the coming decade as a result of structural changes away from agriculture and industry to the service sectors. Mark Rosegrant presented an outlook on water and food security in the GMS to 2030/50, which suggests the need for proactive policies and investments in the face of climate change, higher energy prices, and growing water scarcity. Peter Rogers shared his views on the role of urbanization in the GMS and how this will influence the water and energy demands, with a need to search for greater efficiencies in water and energy use. We have been reminded by Kyoko Kusakabe how gender issues need to be better integrated in development strategies and specifically in the context of cross-border transport development. And finally we had an excellent keynote address on the dynamics of economic growth in the GMS, both retrospective and prospective, delivered by Ms Ladawan Kumpa.

So I think we have a rich basis to reflect on what are some of the key pointers for the next few days of discussion and, of course, for this panel. Now before opening the floor for questions or comments or suggestions to the panelists, I would like to give the opportunity to the country representatives to provide a couple of reactions to what they have heard in the context of their own country's experience, and essentially ground-truthing some of what has been said earlier today.

Ros Seilava, Cambodia: Thank you very much Mr Chair. First, let me thank ADB for the invitation to this very important event. Although I am from the Ministry of Economy and Finance, I find it very useful because I think the way forward for development is a comprehensive not a fragmented, sectoral approach. So that is why I am attending this event. Let me briefly give my feedback on this morning's session. I find the message from all the speakers quite positive, although they highlight the key challenges that we need to deal with properly. We have heard clearly that our success over the past decade with consistently high growth has put a lot of pressure on the natural resources and the environment. The next decade is our challenge; how to address the issues properly. However, quite a number of ideas have been offered to us today; we not only have to fight these challenges head-on but as I put it, it is in the nature of human society going through a crisis that there will be adjustments resulting from the very complex interaction between human development and nature.

In terms of economic growth, I think there is intraregional development going on. Here, in the subregion, we see an important trend in terms of integration; we have the ASEAN connectivity and the GMS economic corridors. These can be seen as second-generation efforts in terms of integration or the evolving development of a production network. What is the implication on future development in the region? Definitely, we need to take care of the environment carefully but in terms of development, I think, there will be a shift from heavy use of resource-based production and industry to broader-based economic growth. Referring to the projections by Peter Warr, the service sector share of the GDP is going to increase, which will take pressure from natural resources.

Let me just briefly talk about the challenges. Cambodia takes the issue of food, water, and energy very seriously. We are one of the rice exporting countries and rice consumes a lot of water. Recently, we issued the Rice Policy, which expects to export 1 million tons by 2015. We have a very ambitious target. My message here is that the Government of Cambodia takes climate change or environmental impacts very seriously. We are now implementing a policy that moves towards rice commercialization but with climate resilience. The study is on-going with discussions and dialogue. On urbanization, key important issues that Cambodia has been experiencing are with regard to the development of the garment industry. We started with a very small industry, which has now grown huge; this has a big impact on urbanization. Over the next decade, Cambodia will move toward industrialization and urban planning will be one of the challenges that will need serious attention. I am sure that we also need to take care of gender issues; we have to think about how to get the community engaged so that we can address the issues more effectively than just to rely on experts. I would like to close by saying that this is a very important agenda, not only for the region but globally; the G20 is taking this issue very seriously and they have commissioned a study and discussion on how to stabilize commodity prices and address food security and energy issues. Thank you very much.

Tang Shengyao, People's Republic of China (PRC): Let me first thank ADB for the invitation to this Conference. I find this event important and very informative. Personally, I have learned a lot from the presentations, in particular, about the connection between food, water, and energy. This food-water-energy nexus has been the concern of many people and also the governments around the world. It is also the case for the Chinese government. You may understand the Chinese experience has been a successful and good story. But, we do have experience and lessons in terms of agricultural production; we have successfully solved the problem of food security with our own effort using less than 9% of the world's arable land to feed about 21% of the world's population. For eight consecutive years, Chinese agricultural production has had good harvests, increasing year on year. For more than six years, grain production has surpassed 500 million tons; that is almost one quarter of the world's cereal production.

Although it has been successful, personally speaking, the PRC does have some lessons. For example, we face resource constraints: land and water. In terms of water availability, the freshwater availability per capita is only one quarter of the world's average; and the land availability per capita is just one mu (one fifth of a hectare). You can imagine with that land, we have to feed 1.34 billion people now. It is a very, very difficult challenge. We also have problem of land degradation due to frequent and heavy use of fertilizers and chemicals. Every year we have millions of hectares of land lost to non-farm use, for example industrial and other uses. And recently, we have more frequent natural disasters. I don't know if it is due to climate change or not; but it seems we face more every year. Many years ago, the Chinese Government realized the importance of sustainable development; and five years ago, adopted a policy of harmonious development of human beings and nature. I think the core is a sustainable environment. Now we say we have to change the development modality; and five years ago, we stressed development and protection and the importance of economic growth. Now we say, economic development but with quantity and quality. We want to improve the structure of economy, education, health care, rural infrastructure for farmers, and the countryside. I think the GMS 2020 Conference is in line with what the Chinese government is doing. Thank you ADB again for this opportunity and all presenters who have done a wonderful job for us. Thank you very much.

Daovong Phonekeo, Lao PDR: Thank you very much for giving me this opportunity to say a few words about this Conference. As the previous panelist mentioned, this Conference is very important and informative and for our country, it is relevant. The Lao PDR is in a unique position that it can export electricity to neighboring countries. As you know, there is high demand for electricity; so for us, the development of hydropower is crucial and we have started with this policy for some time now to earn revenue and sustain the economy. In terms of development, hydropower is the main attraction for foreign direct investment (FDI) in the Lao PDR so far. With the assistance of ADB, we could realize the very first successful IPP[1] project, the Theun Hinboun Project, which is a good platform to show the international community that the IPP in Lao PDR is viable.

The Government's policy is to reduce poverty by 2020; this means we have to increase investments in poverty reduction and these investments could benefit from hydropower development, as we have seen with the Nam Theun 2 hydropower development with the assistance of the World Bank, ADB, and the private sector. So the next step for us is the continuation of the development of hydropower. In order to do that, we need good governance and natural resources. For good governance, from our standpoint, we would need capital, good knowledge, and increased capacity building for our country. I believe that in order to maximize the value of natural resources, especially water, we can put in improved technology like re-using the water through cascade hydropower plants, whereby the same water can be used several times and produces more value. It is in our interest to conserve water by sustainable water management as water is our life. Thank you very much.

Duong Duc Ung, Viet Nam: I would like to thank all presenters and speakers for the interesting and comprehensive presentations in this Conference on "Balancing Growth and Environmental Sustainability." I would like to share my views on the Vietnamese case. As with other countries in the GMS, Viet Nam has in the past decade made big socioeconomic progress. But at the same time, Viet Nam is facing a number of challenges; one of them is the consequence of climate change. If there is a rise in sea level by 1 meter, 105 of the population will be affected; we will Lose 10% of GDP; and we will lose land (territory). It will not happen in the immediate future but may happen by 2100; however, we are already feeling some of its effects now. That is why Viet Nam is very interested in quality and quantity of water of the international river.

My message is: I would like to see the countries of the GMS move to a legal framework for the utilization of water, to ensure quality and quantity for countries located downstream. This is particularly important for Viet Nam, as the country is agricultural and 70% of its population is living in rural areas and poverty is concentrated in this area. A large portion of the population depends on agricultural production. Viet Nam has already ensured food security for its people and we also contribute to the food security of the world. Last year, we exported 7 million tons of rice.

The Government adopted a National Target Program for Climate Change and we are integrating this program into the process of restructuring our economy, including market system, public investments, and services. We are moving to a modern economy based on human resources with less capital intensity. We believe that in framework of the GMS economic cooperation and the Mekong Committee, all the subregional countries could share benefits of utilization and exploitation of the rivers in the common interest of the subregion and development of the countries. Thank you.

Nessim Ahmad: We will now open the floor for any comments and suggestions. If you have questions, please direct them specifically to the panelists.

Geoffrey Blate, WWF: I would like to thank all presenters for their excellent presentations, which will help frame the discussion and challenges over the next couple of days. I would like to make a couple of comments to support some of the points that were made so far. The main point is that the GMS truly is at a crossroads, as the presenters this morning conveyed to us. I think there is a sense of urgency in terms of the water challenges, energy challenges, and the biodiversity challenges that we face.

Firstly, the GMS is still, despite all the degradation, one of the most biologically diverse regions on the planet, a truly biologically diverse hotspot. That biodiversity underscores or contributes to the subregion's incredible productivity. Especially in a climate change future, maintaining that diversity is an important risk management strategy; and one that leads to increasing resilience and increasing competitiveness compared to the rest of the region, where we have seen an incredible degradation of the natural environment. And, therefore, productivity is extremely challenging in those other places. I would also like to say that Rio+20 presents an incredible opportunity for this subregion to shift from the current 'business as usual' development pathway to really a 'green growth', green economy transition. All of the countries in this subregion have either already adopted green growth, green economy policies or national plans or they are in the process of doing so. Moreover, there is hardly any other region in the world that has an economic cooperation program integrated across all of the important economic sectors, with a commitment to actually mainstream environmental considerations across those. Hardly any other region in the world has anything like that. So there is quite a lot to be proud of and to showcase at Rio. All that is necessary is for countries represented in this room, with the support

[1] Independent Power Producer

of development partners, ADB, and others, to articulate a clear, green economy vision and a roadmap to actually achieve that vision. There will be a platform in Rio to secure investments to achieve that vision.

WWF is supportive of this idea. Back in December 2011, the Government of Viet Nam hosted a regional workshop on green economy and natural capital. The key point is that moving to green economy hinges on maintaining natural capital; we can do that collectively by improving the management of the shared resources, enhancing our competitiveness. The delegates at the Viet Nam workshop underscored the importance of a green economy vision and that a roadmap be prepared before Rio. I will be very keen to hear if any of the panelists have any comments about that or any practical suggestions on how we could actually achieve that.

John Kessels, IEA Clean Coal Center: My question is addressed to Mr Thapan. You mentioned in your presentation about the possibility of the flow of water in the Mekong being reduced to a trickle. I have been told about an agreement that the flow will be maintained. So I would like to have your comment on whether the flows will remain the same, or will turn into a trickle, or somewhere in-between?

Archie Beaton, Chlorine-Free Products Association: One of the questions we are trying to deal with today; is water a human right? How do governments balance out private use of water versus the right to water? Or is it a commodity, like coal or gas? Could the countries tell us how they perceive it?

Peter Warr, Australian National University: There is one input into that production story of food-water-energy nexus that we haven't heard mentioned; and that input is knowledge. Around Asia in the countries that I have studied, there has been an alarming decline in commitment to agricultural research. I understand that the People's Republic of China is an exception to that story. But if we are going to produce more food with the same amount of land, with less pressure on the natural resources and environment, we need to expand the supply of knowledge that it takes to do that. And that means research, and research takes investment. I will direct my question to Mark Rosegrant to comment on this please.

Nessim Ahmad: On green growth and the potential to make a difference at Rio+20; there is a zero draft, still work in progress, Probably a Conference like this can provide meaningful insights that find a way into the process and discussions. On this question, Jeff McNeely may wish to say a few words on the potential for biodiversity ecosystems management to find its way into a meaningful outcome at Rio+20.

Jeff McNeely: The best way to approach this is to think of biodiversity as knowledge. The diversity we see in genes, species, and ecosystems is a result of a few billion years of evolution. And that is learning, that is, either you survive or you die. The species we see today are the ones that survived, the ones who had the knowledge within their genes on how to adapt to changing conditions. What we have heard from all of the speakers is that we are going to see continuing changing conditions, surprises in the coming few years, and the way we are going to adapt to those surprises is to capture the knowledge that is contained in living nature. It will not happen just by some miraculous transformation; we have to actually study, get people to look into these issues. And there is actually quite a lot going on but there needs to be more. We need to apply it to practical challenges. The number one challenge is what we might call decoupling—reducing the amount of resources that are required—water, energy, minerals and so forth, per unit of GNP growth. We have to become much more efficient in the way we use our resources, including our living resources. The capacity to do that is available in the region. What we really need to do is mobilize that capacity and make it happen on the ground. We have a structure within the GMS to make that happen.

Arjun Thapan: The statement I made in my address comes from two sources; one is an internal ADB exercise done in 2005, the other is The Economics of Climate Change in Southeast Asia: A Regional Review (the mini Stern Report) of 2009. Both seem to suggest that flows in the Mekong will increase during the dry season and decrease in the wet season up to a point, and the reverse will be true for the larger part of the year. Over the next 75 years, the expectation is that Mekong flows will decline in overall terms by about 25%. Much, of course, will depend on how the climate change scenarios pan out over the next 60-70 years. And much will also depend on the volume of abstraction that occurs as a result of growth in demand by the various sectors, including, principally, agriculture. But why don't I throw this back to the audience, particularly Jeremy Bird, who has been monitoring this in his previous incarnation in the MRC. Would you like to make a comment on this Jeremy?

Jeremy Bird: Thanks Arjun for putting me on the spot. I like the differentiation between the changes expected through climate change, of which the 25% reduction in Mekong flows may be one extreme value, and the reductions in per capita availability of water due to population increases, etc. The other part of the question is related to what is happening as a result of increasing storage in the basin due to hydropower and nonconsumptive uses, not irrigation storage. We are seeing two different sides balancing out; the modeling that was done for the MRC showed that once storage was completed in PRC, for example, flows at the border with Thailand would increase during the dry season and decrease in the wet season quite considerably. Now there is a benefit there but you also have the downside on the issues of sediment and nutrient storage upstream. A lot of modeling work has been done by MRC, which has been corroborated by work done by institutes in PRC as well. All that information is available in the scenario assessments carried out by the Basin Development Plan of the MRC.

Mark Rosegrant: Peter Warr made a great point there; to meet the kinds of needs we have been seeing for productive and efficient growth that also saves natural resources, the countries in the region will have to very significantly increase their agricultural research. There needs to be not only yield enhancing but sophisticated research, in particular of the new stresses that climate change will make on water resources, scarcity of water, nitrogen use efficiency, drought tolerance, heat tolerance, and greater resistance to insects and disease, as all the models are showing that these stresses will increase due to climate change. There has to be a combination of fairly high-tech research and knowledge generation with greater effort and investment in getting those technologies out to farmers, There has also been a near collapse in some of the countries of their extension systems; we need to build in back-ups to transfer technologies with a combination of, probably, public sector extension services and tap into NGOs and relevant private sector to get those technologies out to farmers. That is another essential piece of the pie.

Kyoko Kusabe: I want to raise for discussion the issue of land, as in many countries of the GMS, private land titling is being promoted. But the process is very slow and has been taken advantage of by some people with negative effects on forest resources. By putting community titling to land would actually solve a lot of problems; the advantage is that there would be large amount of land being managed by one entity, which will allow it to enjoy water rights for the community. It will also allow us to have more flexibility in terms of the use of land as well as creating visibility so that the community is able to negotiate with other contesting users of forest resources. Of course, there are a lot of challenges in empowering local communities as well as issues of governance. But this kind of community ownership is what we can explore.

Tira Foran, CSIRO, Australia: This question is addressed to Mark Rosegrant: I was surprised by your point presented on child malnutrition rates that in 2005, child malnutrition rate in Thailand was 20%. According to your model, the same is the case in Myanmar; you project, based on food price increases and climate change, that the situation gets much better in Thailand but does not improve in Cambodia and the Lao PDR. I am wondering about the reliability of the results and whether you have had a chance to compare with other sources of data and statistics? Where is child malnutrition concentrated: is it in rural or urban areas? In the conclusion of your paper you call for subsidy regimes to be removed, for example for biofuels; you regard these as economically inefficient. I am just wondering whether your modeling also allows you to estimate the impacts on malnutrition if subsidies are removed?

Mark Rosegrant: The 2005 numbers are actual data, they are not from the models; these are figures estimated by UN agencies. If they are wrong, they are wrong; I have no means of checking the UN figures. The development of food prices is the basis for the projections; we have also estimated long-term investments in female education, clean water, and a measurement of women's status in the household. It could be that we are underestimating progress on those factors for the future. We could look into our estimates on those factors as well. But the key thing is that the higher food prices we project do dampen consumption. I was also surprised at the numbers, given the rapid rate of growth. The key thing will be to double-check our assumptions on those non-food items.

Dr. Parisak: From my understanding and listening to all the excellent papers and discussions, I think as far as achievements are concerned in the last ten years, there are two sides we have to look into. First, it is clear from the papers we have listened to this morning that all countries in the subregion, as part of ASEAN, ASEAN plus 3, or GMS, whatever groupings, have been instrumental in helping the subregion, especially the less advanced countries in the region (called CLMV)[2], to realize high growth. It is all in the statistics, we have seen that. This is thanks to increased

[2] Cambodia, Lao PDR, Myanmar, and Viet Nam

connectivity, mobility, and foreign direct investments (FDI) in the region. We have received tremendous investment in cross-border value chains, especially in the agriculture sector, the natural resource sector; this has helped to facilitate cross-border trade. There have been tremendous investments in energy and the mining sector; there has been a transfer in innovation and technology ensuring better complementarity among the countries in the subregion. This has been helpful, especially for the less advanced GMS countries, Lao PDR being one. We have also seen increase of human resource development within the region. Most countries have benefited from this, especially the less advanced countries in the region.

At the same time, what we need to look into is that development in the GMS is uneven and unbalanced. A lot of investments have been detrimental and harmful to the environment. We knew that this would happen but we still allowed it. For example, as far as cross-border value chain is concerned, e.g., maize production in Lao PDR, in the north it has increased by 10-fold or more in less than 10 years. That goes along with increased use of pesticide and machinery in the hilly areas, which has destroyed the top soil. So in the long term it is not helping at all. A lot of investors as well as development partners are involved in this.

Secondly, we were unprepared in terms of capacity. The capacity was not there to manage quality FDIs; we don't even know what that is. So there was an eagerness attract FDI but we were not prepared to get the most out of it in terms of quality performance. We were faced with new challenges, like increased disease breakout; that have created a lot of problems; we still don't know how to manage those challenges. Food safety standards for example are something new; the farmers don't know about that. We have produced a lot of maize; it was sent to the Chinese border and everybody is asking for SPS[3]; the farmers don't understand what SPS is. We understand what SPS means but we don't have the means to help the farmers. So the capacity was not there.

Thirdly, a lot of development assistance has been uncoordinated. Everybody is talking about sectoral development versus inter-sectoral development. We know about this but we are still promoting sectoral development both from the development partner as well as the Lao side. I think Jeff has mentioned Nam Theun 2, which is the fruit of a collective effort among dozens of ministries, with involvement of CSOs, NGOs, and private sector. This is a good example but it took too long. I hope we do not have to take 15 years for every development program. Another good example is the Nam Ngum River Basin with ADB. We have brought together the Ministry of Energy and now the Ministry of Environment to work together. We need to promote more of those inter-sectoral programs. Hopefully, ADB will pay more attention to inter-sectoral, collaborative efforts.

Fourthly, development has not been inclusive. Even if we put the term in whatever contractual arrangement, development has been exclusive. There have been efforts to involve the communities but they were not prepared. Investors, development partners, and the Lao side see transfer of ownership to communities as a slow process, as we have to build capacity and this takes time. That goes against the interest of FDI. So we have to balance this; how do we look for an optimal formula?

Last but not least, we need to continue the subregional dialogue. As Viet Nam was saying, and others have pointed out, we need to ensure sustainable subregional development. All countries have to work together to design and align to the same rules of engagement. In our respective countries, we have to try to address our deficiencies, which should have no bearing on the development of other countries. We need to agree on some rules and adhere to a more collective effort of proper resource management in the region. So it is not the rule of country A or B but a regional rule. If not, then we cannot agree on anything at the end of the day. As Kofi Annan said, to move forward in order to engage in collective effort, all sides have to compromise. We need to sacrifice to some extent our interests. We can't continue with business as usual.

The strategy is clear; we have been hearing about this green economy, green agriculture, and other buzzwords. At Rio+20, I don't think there will be something new; they will come up with new buzzwords but they boil down to the same thing—better inter-sectoral work; we need to do it both on the Lao PDR side and the development partner and private sector sides. We have to compromise on all sides (development partners, government, private sector). Thank you.

[3] Sanitary-Phyto-Sanitary