BUILDING A SUSTAINABLE ENERGY FUTURE

The Greater Mekong Subregion

ADB

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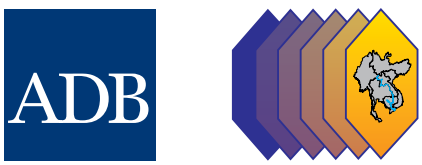

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Contents

	Abbreviations	**ix**
	Foreword	**xi**
	Acknowledgments	**xv**
	Executive Summary	**xvii**
1.	**Coming Together – The GMS**	1
	Growth, Poverty, and Human Development	3
	Energy, Environment, and Climate Change	10
2.	**Emerging Challenges in the GMS**	**15**
	Rapidly Rising Demand for Energy	15
	Energy Poverty	17
	High Degree of Energy Vulnerability	19
	Environmental and Social Issues	21
	Energy Productivity	22
	Institutions and Policy Regimes	23
3.	**Why Integrate the Energy Sector?**	**25**
	International Experience	27
	Advantages and Opportunities	29
	Costs and Threats	30
4.	**The Economics of Energy Integration**	**33**
	The Model	33
	The Reference Energy System	35
	Useful Energy	36
	GDP, Energy Demand, and Price Assumptions	38

Environmental and Social Impacts 40

Energy Supply Options 42

Technological Learning 43

Demand-Side Management and Energy Efficiency 43

The Four Scenarios 44

The Results: Looking Ahead 46

Other Scenarios 52

5. Energy Trade under the GMS Integrated Scenario 55

Electricity Trade under the GMS Integrated Scenario 56

Decentralized and Off-Grid Electricity 61

Natural Gas Trade under the GMS Integrated Scenario 61

Trade – Other Energy Sources 62

6. A Shared Energy Future: What Will It Take? 65

Improving the Overall Policy Environment 67

Electricity Sector: Policy and Institutional Environment 72

Natural Gas Sector 76

Energy Efficiency: Policy and Institutional Environment 78

Electricity for All: Closing the Gap 83

7. A Shared Energy Future: Acting Now 89

Endnotes 101

Appendixes

1 GMS and the Millennium Development Goals 105

2 Energy Balances for the GMS, 2001 and 2005 (PJ) 107

3	Status of Environmental Management in the GMS, 1992 vs. 2005	109
4	Simplified Reference Energy System	111
5	Environmental Impact Data and Estimated Costs	113
6	Energy Conversion and User Technologies	115
7	Scenario Results	125
8	Vientiane Plan of Action – Energy Sector	127
9	Summary of Private Stakeholder Survey Results	131
10	Developments in the GMS Energy Sector	137
11-1	Project Concept for a Regional Project Preparation Technical Assistance Facility	163
11-2	Project Concept for an Oil Refinery-Supporting Infrastructure and Guarantee Project in Cambodia	165
11-3	Project Concept for a Regional Energy Efficiency Program	169
11-4	Project Concept for a Regional Electricity Transmission Development Program	173
11-5	Project Concept for a Biomass Generation Project	177
11-6	Project Concept for a Coal Liquefaction and Carbon Neutrality Technical Assistance Project	179
11-7	Project Concept for a Small-Scale Clean Generation Fund	183
11-8	Project Concept for an Abated Clean-Coal Generation Facility in Viet Nam	189
	References	**193**
	Tables	
1	GMS Physical Indicators, 2005	1
2	GMS Human Development Index Values	5
3	Percentage Share of Biomass in Total Primary Energy Supply	6

4	Per Capita Electric Power Consumption, 2005	9
5	GMS Energy Resources	10
6	Environmental Pressures Facing the GMS	11
7	Forest Cover in the GMS	12
8	Carbon Intensity of Growth, 2005	13
9	Annual Per Capita Household Electricity Consumption in the GMS	18
10	Energy Productivity in the GMS, 1990 and 2005	22
11	Useful Energy Demand Sectors Used by the MESSAGE Model	37
12	GDP and Useful Energy Growth Assumptions	39
13	Estimates of the Costs of Environmental Damage ($/ton)	41
14	Estimated Costs of Damage from Hydropower $/MWh	42
15	Fuel Use and Import Dependence	50
16	Electricity Flows in the GMS	57
17	Energy Investments Required for Energy Integration in the GMS Over 2005–2025	69
18	Overall Economic Environment for Sustainable Growth in the GMS	70
19	Overall Electricity Sector Policy Environment in the GMS	74
20	The Natural Gas Sector Policy Environment in the GMS	77
21	Overall Policy and Investment Environment for Energy Efficiency in the GMS	82
22	Alternative Off-Grid Rural Energy System Technologies	83
23	Priority Actions Toward a Shared Energy Future for the GMS	95

Figures

1	Human Development Index and Global Per Capita Electricity Consumption, 2005	4
2	Share of Population Living Below the National Poverty Line (%)	5
3	Average Annual Growth in Energy Consumption and GDP, 1993–2005 (%)	8
4	GDP Growth in the GMS (CAGR %)	16
5	Growth in Transport Fuel Consumption in the GMS, 1990–2005 (%)	19
6	Percentage Share of Energy Imports in Total Energy Consumed in Thailand, 1988–2005	20
7	Intraregional Trade Shares (%)	26
8	Share of Exports in Total Lao PDR Electric Power Generation (%)	27
9	Total Useful Energy Demand in the GMS, 2000–2025	36
10	Energy Demand Under the Model's Low- and High-Growth Scenarios	39
11	Discounted Total Costs Under the Four Scenarios ($ billion)	47
12	Additions to Hydroelectric Generation Capacity (GW)	48
13	Discounted Environmental Costs Under the Four Scenarios ($ billion)	49
14	Percentage Share of Imports in Total Energy Consumption, 2005–2025	51
15	Projected Additional Electricity Generation Capacity in the GMS	58
16	Electricity Production and Exports within the GMS, 2005 and 2025 (GWh)	59
17	Projected Electricity Investments in the GMS, 2005-2025 ($ billion)	60
18	Retail Fuel Prices in the GMS (US cents per liter)	71

List of Boxes

1	Energy-Efficient Lighting	79
2	Electrification in the People's Republic of China	84
3	Renewables in Rural Electrification	86
4	Vientiane Plan of Action—Energy	90

Abbreviations

ADB	—	Asian Development Bank
ASEAN	—	Association of Southeast Asian Nations
CH_4	—	methane
CO_2	—	carbon dioxide
ESCO	—	Energy Service Company
GDP	—	gross domestic product
GHG	—	greenhouse gas emission
GMS	—	Greater Mekong Subregion
GWP	—	global warming potential
IGA	—	GMS Intergovernmental Agreement for Power Trade
IRM	—	Integriertes Ressourcen Management
Lao PDR	—	Lao People's Democratic Republic
MESSAGE	—	Model of Energy Supply Systems Alternatives and their General Environmental Impacts
MOU	—	memorandum of understanding
N_2O	—	nitrous oxide
NO_X	—	nitrogen oxide
OECD	—	Organisation for Economic Co-operation and Development
PRC	—	People's Republic of China
RES	—	Reference Energy System
SO_2	—	sulfur dioxide

Units of Measure

GW	-	gigawatt
GWh	-	gigawatt-hour
kW	-	kilowatt
kWh	-	kilowatt-hour
MW	-	megawatt
MWyr	-	megawatt-year
PJ	-	petajoules

Notes

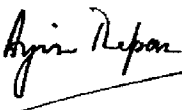
In this document, "$" refers to US dollars.
Guangxi refers to Guangxi Zhuang Autonomous Region, PRC.
Yunnan refers to Yunnan Province, PRC.

Foreword

The Greater Mekong Subregion (GMS) holds huge promise for Asia. Driven by a desire to benefit from smart strategies to cooperate and integrate, its governments recognize that access to energy services is critical in sustaining the pace of economic development achieved so far and in securing further prosperity. The multitude of challenges—from volatile global energy prices, increasing sustainability pressures, and widespread energy poverty in the GMS—requires a strategic approach in developing the subregion's energy sector. ADB has responded to the request from the GMS governments with a technical assistance grant to prepare a draft energy strategy for the subregion.

From the outset, this project has adopted an inclusive approach to involve as many stakeholders as possible to ensure that its output would be responsive to the particular needs of the GMS. A series of workshops, and other feedback received from a variety of stakeholders, have guided this process over the last two and half years.

The preparation of the draft energy strategy has received much valuable support and guidance from Rajat Nag, Managing Director General, ADB. Rita Nangia, Director, Special Projects, Southeast Asia Department led the work and prepared this publication, identifying concrete policy actions required to ensure a cleaner, brighter energy future for the GMS.



Arjun Thapan
Director General
Southeast Asia Department

Leo Schrattenholzer, one of the leading energy experts and Integriertes Ressourcen Management's (IRM) team leader for this project, suddenly and unexpectedly passed away on 23 April 2009. His contribution to this project as well as his work in the field of energy modeling will always be appreciated.

Acknowledgments

This volume contains three parts: a discussion draft energy strategy for the GMS, a technical paper that underpins the analytics, and a CD-Rom that contains the final reports of the consultants for the technical assistance and some important presentations from the consultation workshops. Many people have contributed to this long process spread over three and half years.

The preparation of the draft energy strategy and consultants' work was guided by the project team comprising of Rita Nangia, project manager from the Asian Development Bank (ADB) and country coordinators for the GMS: Victor Jona (Cambodia), Liu Deshun (PRC), Daovong Phonekeo (Lao PDR), Htin Aung (Myanmar), Cheerawan Rojcharoenchai (Thailand), and Vu Van Thai (Viet Nam).

Consultants from Integriertes Ressourcen Management, Austria (IRM) worked on energy modeling, and consultants from Castalia Strategic Advisors, New Zealand, did the policy analysis. Leo Schrattenholzer and Manfred Strubegger from IRM and David Ehrhardt and Anton Murashev from Castalia led the teams for this work.

The External Advisory Panel members, Johan Rockström, Akrasanee Narongchai, and Keobang Keola provided valuable insights. Special thanks are due to Mohan Munasinghe, Chair of the Experts' Panel, for keeping the project focused on key sustainability issues throughout the entire study process. Valuable feedback on the interim reports was provided by various stakeholders and experts, as well as team members from the Infrastructure Division, and Agriculture and Natural Resources Division of the Southeast Asia Department, ADB. We particularly acknowledge the overall support given by Pavit Ramachandran of the GMS Environment Operations Center.

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Executive Summary

Coming Together—The GMS

The Greater Mekong Subregion (GMS) Economic Cooperation Program (the Program) is the driving force in bringing together the six countries that share the Mekong River—Cambodia, the People's Republic of China (PRC), Lao People's Democratic Republic (Lao PDR), Myanmar, Thailand, and Viet Nam. Within the subregion, the PRC is represented by the Guangxi Zhuang Autonomous Region (Guangxi) and Yunnan Province (Yunnan). The GMS covers 2.6 million square kilometers, which is roughly an area the size of the Eurozone and is home to a total population of approximately 320 million. The subregion has significant potential for rapid and sustained economic growth, given its abundance of human and natural resources, as well as its strategic location that acts as a "land bridge" between South and East Asia. The GMS countries envision a subregion that is more integrated, prosperous, and equitable.

Energy services are crucial in achieving this vision of economic development and improving the quality of life. Although access to modern energy is not by itself a goal, it is a critical element in attaining virtually all of the Millennium Development Goals (MDGs). While the GMS has experienced high levels of economic growth over the last 15 years, over 45 million people are still living below national poverty lines and a larger community of energy poor—about 74 million people or over 20% of the region's population, do not have access to electricity.

During 1993–2005, the overall energy consumption growth in the GMS has averaged at 8% per annum. In spite of this high level of energy consumption growth during the last decade, the weighted average per capita use in the GMS region (i.e., 920 kilowatt-hours) remains at two-thirds of the world average for all developing countries, and is less than 10% of the average per capita consumption in the member countries of the Organisation for Economic Co-operation and Development (OECD).

In 2005, 21% of the total energy consumed by the subregion was imported. Thailand is the largest importer of energy and has to import nearly 40% of its energy in the form of electricity, natural gas, and oil products. Countries like Cambodia, Lao PDR, and Viet Nam import 100% of their transport and other petroleum-based fuels.

The subregion as a whole is well-endowed with the necessary energy resources, but these are distributed unevenly: Lao PDR, Myanmar, and Yunnan have large hydroelectric potential. Myanmar and Thailand have gas resources, whereas exploration activities have just begun for Cambodia's hydrocarbon resource assessments. Viet Nam and Yunnan also have large coal deposits.

Emerging Challenges in the GMS

Energy poverty remains widespread. A large share of the population in the GMS still depends heavily on traditional sources of energy and unless steps are taken, the total number of people relying on biomass will increase, adding to existing environmental pressures. Poor households often spend a large share of their income on fuelwood or charcoal. Despite proven benefits, enhancing access to modern energy in rural areas has so far remained a major challenge.

Energy vulnerability is high and rising. In the medium term, the subregion has to grapple with multiple concerns surrounding energy security. Myanmar and Viet Nam are net exporters of energy at present, but given rapid demand growth, the subregion is likely to remain heavily dependent on imported fossil fuels for the medium term. Poor production prospects, weak demand management, insignificant penetration rates for alternative energy sources, and high global oil prices make the region insecure and vulnerable.

Environment and social issues. The GMS is predominantly an agricultural economy with almost 70% of its population dependent on local resources. Its high economic growth has put increasing stress on important land and water systems in the subregion. The institutional and policy frameworks of member countries need to be enhanced to ensure that environmental and social costs in energy systems remain reasonable.

Improving energy productivity. The subregion has reported modest improvements in overall energy productivity, largely due to the shift from noncommercial to commercial energy sources. A number of barriers emanating from policy regimes, lack of information about energy efficiency practices, weak policy and institutions, and lack of human capacity hinder the region from realizing its potential for improving energy productivity.

Aligning institutions and policy regimes. The overall quality of energy supplies remains low and unpredictable in large parts of the GMS. Current financial incentives, lack of competitive pressures on energy suppliers, and weak policy regimes will need to change drastically to deal effectively with the energy challenges facing the subregion. Unless the institutional structures and policy regimes are aligned to enhance energy service delivery in an environmentally acceptable way, energy can easily be a barrier to medium-term economic growth and progress in the poverty reduction agenda.

Overcoming challenges and taking advantage of opportunities will require a consistent and comprehensive strategy for the sector. Regional integration is one of the most important opportunities.

Why Integrate the Energy Sector?

The global trend over the past several decades has been to move towards interconnected markets. In the power sector, interconnection goes almost always hand in hand with sector reforms and movement towards competitive markets. Potential gains from regional energy integration could be substantial, generally and in the context of the GMS. Overall, the subregion's resource base is quite diverse and exhibits significant complementarities. Trade and integration have the potential to enhance efficiency of the entire subregional energy system by exploiting the economies of scale and scope. Integrated energy approaches are also better at addressing environmental concerns, especially if these environmental and social costs spill beyond national boundaries. Regional integration can help expand choices for sustainable energy solutions that enhance energy security.

Integration saves money. The optimization exercise using the formal energy planning model of MESSAGE (Model of Energy Supply Systems Alternatives and their General Environmental Impacts) indicated that regional cooperation reduces overall energy costs:

the stream of discounted costs in the GMS Integrated scenario is over 19% lower than the Base case with business as usual. The model predicts that nearly 238 gigawatts (GW) of new capacity will have to be created in the power sector. Regional integration will also reduce overall energy dependence to the rest of the world by as much as 5.5% of total energy consumption. The subregion's emissions are expected to grow more slowly on the average than both gross domestic product (6.3% per year) and total useful-energy demand (6.0%).

Demand growth needs to be moderated. If the energy demand growth is not moderated with appropriate policy measures, the region will be in what is termed as a High Growth-High Risk scenario; implying a 38% higher overall energy consumption with increased import dependence on coal and crude oil, and much higher levels of emissions.

The sector needs high investments. The results of the optimization exercise undertaken as the part of the technical assistance make a strong economic and environmental case for integration of the GMS energy sector—saving the subregion 19% of total energy costs or nearly $200 billion over the next two decades. To benefit from the shared energy future, the region needs to invest $585 billion in power and other energy sectors to ensure that energy will not become a constraint to its rapid growth.

Integrating environmental costs improves overall outcomes. The results of the optimization exercise also indicated that integrating environmental and social costs improve overall outcomes in terms of 40% lower coal-based power generation capacity and greater reliance on renewable energy sources and other off-grid solutions by as much as 11 GW. By integrating environmental and social costs in planning, investment in decentralized photovoltaic technology are doubled as compared to that of the Base case; and smaller hydropower plants come up as least-cost options.

Integration increases regional energy security. By integrating the GMS energy sector, it is possible to reduce overall energy dependence vis-à-vis the rest of the world by as much as 5.5% of total energy consumption. In the case of individual fuels, the gains are much more substantial with the most significant impacts occurring in oil dependence.

Removing policy and institutional barriers yields high returns. In addition to physical infrastructure, regional energy trade faces

a number of barriers such as overall resource availability, energy policy asymmetries, widely varying levels, and speed of energy sector development across GMS economies, a complex regulatory environment arising from the lack of a consistent legal framework, limited human and institutional capacity, and market structure limitations. Concerted and sustained action on all these fronts will be needed to realize the projected benefits from integration of the energy sector.

Acting Now

Given the uncertain and volatile international energy prices, environmental sustainability pressures, geopolitical uncertainty in the oil-rich regions, interconnectedness of global energy markets, and widespread energy poverty in the subregion, the GMS governments felt the need for an integrated approach to deliver sustainable, secure, and competitive energy.

The high levels of investments alone will not fully address the energy challenges facing GMS. Simultaneous action will be needed in aligning the policy and institutional environments to ensure that the subregion is less vulnerable to global energy market fluctuations in the next two decades; that there is correct fuel diversification taking place; that the environmental and social considerations are integrated in the regional energy plans and project management processes; and that energy is used productively with lower overall global climate impacts. For this to happen, a balanced approach between creating and maintaining the existing physical infrastructure, and focusing on the policy and institutional agenda of energy integration is needed to achieve a sustainable future. The key to success will be in the ability to transform today's threats into tomorrow's opportunities. Seven priority actions are identified below:

Action 1. The political and technical leadership for cross-border trade and future energy integration needs to guide collective actions beyond the power sector into natural gas and refining.

As the overall demand for energy is expected to grow to over 238 GW by 2025, opportunities in the natural gas and refined petroleum products need to be explored. This includes formulating a regional master plan for natural gas—which takes into account

identifying resources and potential for trade within and outside the subregion, utilizing gas in other sectors, pricing and other related policies, and identifying projects and investment needs. Discovery of oil resources in the subregion is also an opportunity that needs to be examined to determine its viability and sustainability for utilization in the GMS.

Action 2. There is a small window of opportunity in which global support is available to enhance the energy productivity in the subregion. Investing in energy productivity now will help to increase energy security in the era of high and rising energy prices.

There are economically attractive opportunities to leapfrog to more efficient technologies, especially in sectors that are expected to experience higher levels of energy growth. As a substantial share of the energy-consuming assets in GMS has yet to be constructed, this is an opportunity to bring in and adopt higher productivity solutions in building and capital assets. Combined power plants, cogeneration, waste-to-energy possibilities, and mass transport services are alternatives that can help new energy systems be more efficient.

Action 3. Improvements in policy regimes and sector reforms are often easier to effect in a regional context and need to be pursued in a time-bound fashion.

The subregion is at varying levels of sector restructuring—moving from vertically integrated monopolistic structures to market-based energy entities. Sector liberalization, modernization of monopolistic utilities to competitive market structures, rationalization of the role of government, trade and regional harmonization of energy carriers will go a long way in improving sector efficiency and must be pursued through a coordinated set of actions over the next two decades.

Action 4. GMS has a very high dependency on oil imports from outside the subregion. Actions have to be taken to reduce oil consumption and review existing approaches to backstop technological options such as coal liquefaction and biofuels.

Exploring the options for the conversion of coal into liquid fuels such as gasoline or diesel by several different processes need to be continued, including the full implications of such backstop

technologies. The merits of biofuel programs within each economy should also be examined before regulations or targets are put in place—particularly vis-à-vis its impact on the food supply.

Action 5. Given the subregion's high oil dependence, growth in the transport sector poses a major threat and at current prices seem unsustainable, both in terms of its impact on overall oil demand and environmental implications. The long-term trends in transport modal-mix need to be reviewed.

National sector policies should be designed to move towards a sustainable transport future that is more energy-efficient. The region also needs to invest in capital intensive options that can ensure its global competitiveness particularly in the area of freight logistics.

Action 6. Given the large resource requirements, collective action is required to promote private sector participation and innovative solutions. The current policy environment needs to facilitate private investment.

The energy investments in the subregion are seen as attractive destinations for the private sector but a long-term and stable policy framework is essential to convince them to take greater risks. Investors are interested in clean and low-carbon technology, which the GMS governments can capitalize on through strong strategic alliances with the private sector.

Action 7. Finally, the subregion's energy sector is experiencing multiple levels of transition. Convergence to a sustainable path for the future will require financial and other resources, strategic planning at both the institution and energy system levels, ownership of the concept of sustainable and integrated energy future, and partnerships at various levels. Creating institutional capital and matching human capability will perhaps be the biggest challenge that needs to be met effectively for a cleaner, brighter energy future.

The policy and institutional development agenda will have to include detailed actions to moderate energy demand growth, provide adequate financial and other resources to meet the goal of energy for all, and to ensure that the future is sustainable. The numerous

national and subregional actions will need to be supplemented with global initiatives.

Considering the wide variation in the human and institutional capability across the countries, costs and benefits of energy integration should be shared in a fair and equitable manner. All the concerned stakeholders concerned, i.e., political leaders, business and corporate world, consumers, civil society, and multilateral agencies such as ADB need to facilitate the GMS transition to a cleaner and brighter energy future.

Seven Priority Actions Toward a Shared Energy Future for the GMS

Time Frame	GMS Initiatives	Country Initiatives	Initiatives by ADB and Other Development Partners
Action 1. Mobilize political will for cooperation in all energy sectors			
Short Term	• Adopt a resolution at the upcoming Energy Forum to prepare subregional plans for natural gas, energy efficiency, and energy for all		• Design a technical assistance for establishing a regional project preparation facility that supports GMS-wide energy integration (Appendix 11.1)
Medium Term	• Explore possibilities to expand GMS trade in natural gas; coordinate with other regional programs such as ASEAN	• Prepare national sector plans for natural gas (Cambodia, Myanmar, Viet Nam)	• Support preparation of a GMS natural gas master plan • Explore possibilities for innovative financing and further refine project concept to increase support to private refineries (Appendix 11.2)
Action 2. Improve energy efficiency			
Short Term	• Identify quick wins at the GMS level in terms of supporting energy efficiency programs, including initiatives for knowledge sharing	• Review existing levels of energy subsidies and prepare a time-bound program for using prices effectively to guide sustainable energy use (All countries)	• Support technical assistance for preparation of a GMS energy efficiency program (Appendix 11.3)

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Table continued

Time Frame	GMS Initiatives	Country Initiatives	Initiatives by ADB and Other Development Partners
Medium Term	• Prepare a GMS action plan to enhance energy productivity by improving efficiency on both the demand side and the energy supply side	• Prepare a strategic plan to remove barriers to increased energy productivity • Examine and formulate policy instruments for energy efficiency such as programs for the labeling of appliances and energy-consuming products, building construction standards, and promoting the use of energy audits and ESCOs • Review existing levels of energy subsidies and prepare a time- bound program for using prices effectively to guide sustainable energy use (All countries) • Promote education and energy conservation campaigns (All countries)	• Assist countries to prepare national action plans to enhance energy productivity. Prepare a GMS-wide program to enhance energy efficiency both from the perspective of energy users and energy suppliers. Assist in resource mobilization and knowledge-sharing. (Appendix 11.3) • Establish smart subsidies to promote sustainable energy use on a pilot basis; collaborate with other development partners in putting into place output-based subsidies on a pilot basis. • Prepare a project feasibility study and mobilize funding for developing a financing facility for packaging energy efficiency projects on a GMS-wide basis
Long Term	• Mobilize resources to implement an action plan that promotes investment and knowledge sharing; remove existing barriers to energy efficiency	• Establish time-bound targets to achieve energy efficiency both at the macroeconomic level, and by all major energy suppliers (All countries)	• Invest in energy efficiency projects across the subregion
Action 3. Pursue a time-bound program of sector reform on a GMS-wide basis			
Medium to Long Term	• Review experience of other regional energy integration initiatives for promoting sector reform and market competition.	• Prepare a time-bound program to introduce competition into the electricity and natural gas sectors (All countries)	• Assist countries in developing a financing facility for GMS-wide integration of transmission of electric power (Appendix 11.4)

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Table continued

Time Frame	GMS Initiatives	Country Initiatives	Initiatives by ADB and Other Development Partners
	• Prepare a GMS-wide plan to introduce competition into the power sector	• Reduce market power of state-owned utilities by unbundling the power sector • Strengthen the energy-sector legal and regulatory framework for promoting competition • Evaluate country-level barriers to cross-border trade in energy products and services and prepare a time-bound program to remove these	• Assist GMS efforts in preparing reform programs for the energy sector
Action 4. Reduce oil dependency			
Medium to Long Term	• Support regional integration of the entire energy sector to reduce oil dependence • Propose an emergency oil support system • Promote the use of renewable sources of energy	• Review oil price structure and remove subsidies • Explore local oil and natural gas resources (Cambodia, Myanmar, Thailand, Viet Nam)	• Formulate a technical assistance initiative to undertake a comprehensive review of the GMS alternative fuels program, including biofuels (Appendix 11.5) • Formulate a technical assistance initiative for coal liquefaction and carbon neutrality (Appendix 11.6) • Formulate a technical assistance initiative for a fund in support of small-scale clean electric power generation (Appendix 11.7) and clean coal power generation in Viet Nam (Appendix 11.8)

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Table continued

Time Frame	GMS Initiatives	Country Initiatives	Initiatives by ADB and Other Development Partners
Action 5. Review transport modal mix			
Medium to Long Term	• Generate collective support (financial and otherwise) to review the GMS' long-term logistics system for freight and passenger transport	• Review levels of diesel prices and road taxes • Explore possibilities for pipeline transportation of natural gas and petroleum products	• Assist the GMS' move toward a sustainable transport sector in which energy and environmental costs are minimized • Support a midterm review of the GMS transport strategy
Long Term		• Review plans to develop large and growing urban areas and promote the use of environmentally benign public transport modes (Cambodia, Guangxi, Viet Nam, Yunnan) • Review road tax structure and programs to finance road maintenance	• Support and promote knowledge sharing
Action 6. Promote regional private sector participation			
Short to Medium Term	• Prepare a subregional strategy to market the GMS as an attractive destination for private-sector investment in energy	• Identify country-level barriers to trade and private sector investment in the energy sector • Promote development of GMS natural gas resources and GMS trade in natural gas	• Mobilize financial resources to support an electricity transmission development program in partnership with the private sector

continued on next page

Table continued

Time Frame	GMS Initiatives	Country Initiatives	Initiatives by ADB and Other Development Partners
Action 7. Create institutional capital and human capability for a cleaner, brighter energy future			
Short to Medium Term	• Create an institutional base to integrate the GMS energy market • Generate political and technical-level ownership in promoting a sustainable energy future for the GMS	• Strengthen country-level energy planning capabilities (Cambodia, Lao PDR, Myanmar, Viet Nam)	• Determine the feasibility of creating a subregional institution to promote cooperation in the GMS energy sector, using similar initiatives of other regions as a model

ADB = Asian Development Bank, ASEAN = Association of Southeast Asian Nations, ESCO = energy service company, GMS = Greater Mekong Subregion, Lao PDR = Lao People's Democratic Republic.

1

Coming Together—The Greater Mekong Subregion

The Greater Mekong Subregion (GMS) Economic Cooperation Program (the Program) is the driving force in bringing together the six countries that share the Mekong River—Cambodia, People's Republic of China (PRC), Lao People's Democratic Republic (Lao PDR), Myanmar, Thailand, and Viet Nam. Within the subregion, the PRC is represented by the Guangxi Zhuang Autonomous Region (Guangxi) and Yunnan Province (Yunnan). The GMS covers 2.6 million square kilometers, which is roughly an area the size of the Eurozone, and is home to a total population of about 320 million (Table 1). The subregion has significant potential for rapid and sustained economic growth, given its abundance of human and natural resources and its strategic location that acts as a "land bridge" between South and East Asia.

Table 1. GMS Physical Indicators, 2005

Economy	Area	Population	
	(1,000 km^2)	Millions	Density
Cambodia	181.0	13.8	76.2
PRC			
Guangxi	236.7	49.3	208.1
Yunnan	396.8	44.5	112.2
Lao PDR	236.8	5.6	25.3
Myanmar	676.6	55.4	81.9
Thailand	513.1	64.8	126.1
Viet Nam	331.2	83.1	250.7

km^2 = square kilometer, GMS = Greater Mekong Subregion,
Lao PDR = Lao People's Democratic Republic, PRC = People's Republic of China.

Note: Density is defined as the number of persons per km^2.

Sources: ADB. 2007c. *Key Indicators*. Manila. and China Data Online 2008.

Despite the subregion's geographic advantage, rapid rate of economic growth, and abundance of natural resources, about 15 million GMS inhabitants are still poor, surviving on less than the equivalent of $1 a day, with nearly 60% of the population earning less than $2 a day. The GMS Program thus envisions a more integrated, prosperous, and equitable Mekong subregion, and its goal is to achieve this by complementing national efforts in promoting economic growth and reducing poverty. As a result, the Program focuses on expanding trade and investment among member economies, facilitating cross-border movement of people and goods, and addressing common resource and policy requirements. The Program underscores the importance of the "three Cs": greater Connectivity to enhance Competitiveness to help build a prosperous, cohesive Community.

The GMS Program is a results-oriented and pragmatic initiative guided by a set of general principles and institutional arrangements. Within this context, all member economies jointly plan and implement projects for their mutual benefit. Activities under the program focus on several strategic areas, and can be grouped into three major categories: (i) physical infrastructure (transport, power, and telecommunication facilities) to promote overall economic growth and greater trade, investment, and tourism flows; (ii) policy and institutional initiatives to maximize the benefits of physical infrastructure; and (iii) initiatives to address common concerns relating to social development and environmental sustainability.

In sum, the GMS Program helps realize the subregion's potential for economic growth and social development. It does this by (i) creating policies that promote growth, (ii) strengthening infrastructure linkages that facilitate economic cooperation, (iii) developing the subregion's human resources, and (iv) respecting the environment and the social interests of its member economies. The Program aims to ensure sustainable and equitable economic development.

At their first summit held at Phnom Penh, Cambodia in November 2002, the six GMS member economies formulated and endorsed a 10-year strategic framework that envisions an integrated and prosperous Mekong subregion free of poverty and committed to environmental protection. Its overall aim is to ensure that the economic benefits of regional cooperation and rapid growth are delivered within a context of rising income and continual improvement in the quality of life, and that both of these are shared as widely as possible.

Growth, Poverty, and Human Development

Energy is of crucial importance in fulfilling the Program's vision of economic development and continuous improvement in the quality of life. While access to modern energy is not by itself a goal, it is a critical element in attaining virtually all of the Millennium Development Goals (MDGs). A common recommendation of the 10 Task Forces of the United Nations (UN) Millennium Project was to improve access to energy services as a means of meeting each MDG. Appendix 1 describes GMS's progress in achieving these goals.

Some of the linkages between access to modern energy and achieving the MDGs are direct. For example, energy is a key input into industrial development, transport, and communications, all three of which are directly linked to economic development and poverty reduction. Effective health care service delivery requires access to modern energy sources. Media campaigns for spreading awareness of health threats from HIV/AIDS, malaria, and other communicable diseases are unlikely to succeed if the target population lacks access to electricity.

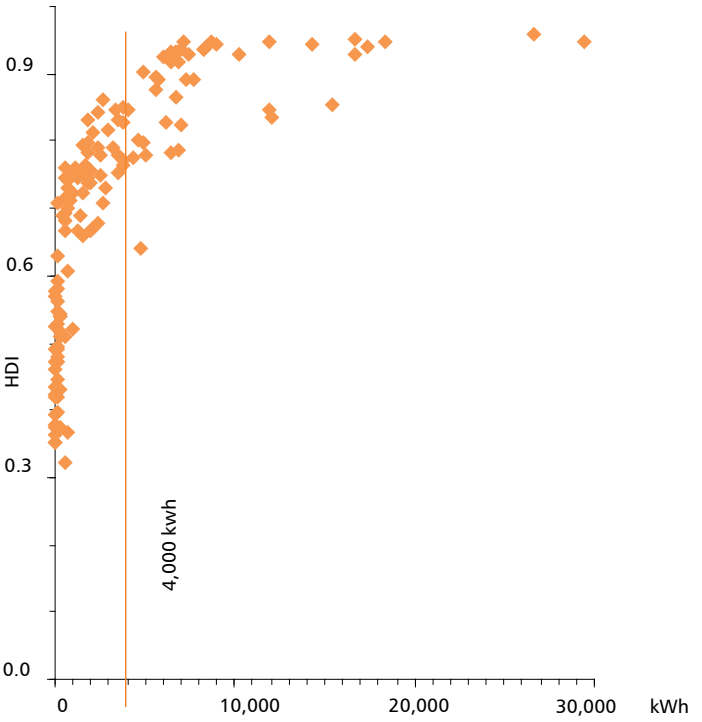
Indirect linkages between access to modern energy forms and success in achieving development-related goals also exist. Teachers and doctors are unlikely to serve in rural areas or isolated communities that lack access to modern energy sources. Electricity extends the working day for students, and access to modern cooking fuels saves time otherwise spent in collecting fuelwood. Similarly, unchecked use of traditional fuels leads to deforestation, soil erosion, and reduced soil fertility, and causes indoor pollution that leads to major health risks.

Access to energy is positively linked to fulfilling goals related to health and education. Several studies have established a link between the human development index (HDI) ranking of a country or province and access to modern energy sources. Figure 1 shows that most countries with high HDI rankings also have high levels of electricity consumption. In this regard, there is an important threshold level of annual per capita electricity consumption of 4,000 kilowatt-hours (kWh) that corresponds to an HDI value of 0.9.[1]

HDI rankings in the GMS vary widely. Thailand and Viet Nam are classified as members of the medium human development group

with 2007 rankings of 78 (Thailand) and 105 (Viet Nam), while Cambodia, Lao PDR, and Myanmar belong to the low human development group (Table 2). Provincial-level data for Guangxi and Yunnan are available in the 2005 National Report for the PRC, which is based on 2003 data. Based on these estimates, the HDI values for Guangxi (0.731) and Yunnan (0.657) are both lower than the PRC national average (0.746). Similarly, Guangxi ranked 22 and Yunnan 29 in an HDI ranking of 31 PRC provinces.

Figure 1. Human Development Index and Global Per Capita Electricity Consumption, 2005



kWh = kilowatt-hour.

Source: United Nations Development Programme (UNDP). 2007. *Human Development Report 2007/2008 Fighting climate change: Human solidarity in a divided world.*

Table 2. GMS Human Development Index Values

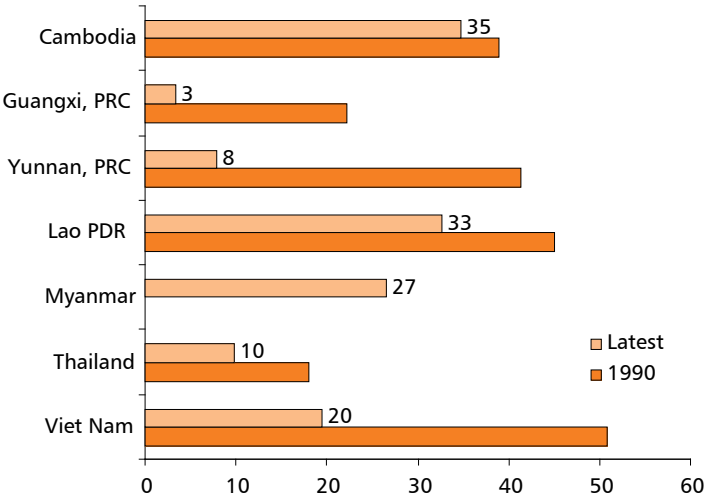
Economy	1990	2005
Cambodia	0.512	0.598
PRC	0.634	0.777
Guangxi	0.548	0.731*
Yunnan	0.496	0.657*
Lao PDR	0.478	0.601
Myanmar	0.385	0.583
Thailand	0.712	0.781
Viet Nam	0.620	0.733

* HDI values are based on 2003 data.

HDI= human development index.

Source: United Nations Development Programme (UNDP). *Human Development Report.* Various issues.

Figure 2. Share of Population Living Below the National Poverty Line (%)



Lao PDR = Lao People's Democratic Republic, PRC = People's Republic of China.

Sources: ADB. 2007a. *Asian Development Outlook 2007.* Manila; ADB. 2004. *Regional Cooperation Strategy and Program (2004–2008): Greater Mekong Subregion.* Manila.

Though the region has experienced rapid economic growth in recent decades, more than 45 million of its inhabitants still live below the national poverty line of the country in which they live (Figure 2). Income distribution is becoming more skewed, indicating that the

benefits of growth are not being shared equally. One major reason for this is lack of economic opportunity resulting from inequitable access to infrastructure services.

A large community of "energy poor" exists within GMS. Energy poverty is defined as the absence of sufficient choice in accessing adequate, affordable, reliable, high-quality, safe, and environmentally benign energy services to support economic and human development.[2] Of the total GMS population, 74 million people, or more than 20% have no access to electricity. The share of noncommercial energy in total energy use remains quite high, particularly in the rural areas (Table 3). Of the total number of households, 80% in Lao PDR, 83% in Cambodia, and more than 50% in Viet Nam use fuelwood and other traditional energy sources for cooking, and in Yunnan, nearly 41% of rural households are completely dependent on firewood for cooking food. The burden of collecting fuels and the negative impact of indoor air pollution from burning biomass falls largely on women and children. Studies have demonstrated that indoor air pollution in developing countries claims more lives than malaria or tuberculosis. Each day 4,000 such deaths are reported, with most of the victims being women and children—more than half of the latter being below the age of five.[3]

Table 3. Percentage Share of Biomass in Total Primary Energy Supply

Economy	1990	Latest
Cambodia	..	73.2
PRC	23.2	13.0
Guangxi	..	*46.7*
Yunnan	..	*14.4*
Lao PDR	93.0[a]	79.0
Myanmar	84.4	69.6
Thailand	33.4	16.5
Viet Nam	77.7	46.7

.. = data not available, Lao PDR = Lao People's Democratic Republic, PRC = People's Republic of China.

[a] 1995 data.

Note: Figures in italics represent the latest year available.

Sources: United Nations Development Programme (UNDP). 2007. *Human Development Report 2007/2008*; National Bureau of Statistics. 2006.

The overall demand for energy increases as economies modernize, due to several factors. First, income growth in all countries is associated with rising demand for modern energy sources as households switch to cleaner, more efficient fuels. For example, in the United States, the share of biomass in overall energy consumption declined from 99% at the beginning of the 1800s to 0.2% by 2000. This same pattern appeared on a global basis from 1860 to 2000, when improved energy infrastructure led to declines in the share of traditional fuel sources in overall energy consumption.

A second factor leading to increased demand for energy over time is structural change. As economies modernize, the industrial and service sectors, which are generally more energy intensive than agriculture, account for an increasing share of national income. A final factor is that income growth itself leads to increased demand for energy-intensive services such as personal transport and for space conditioning.[4]

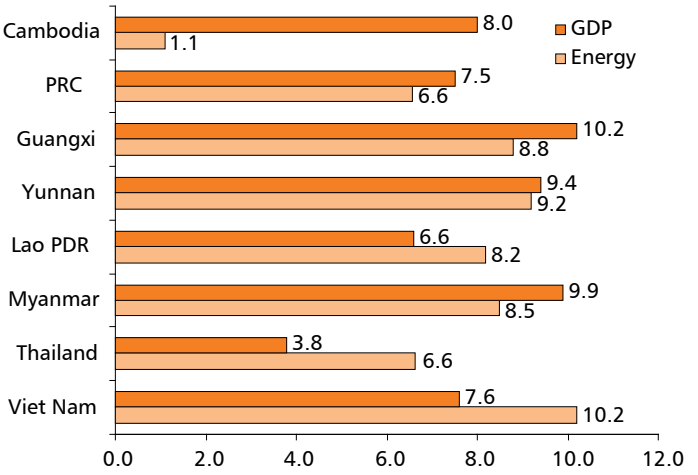
In terms of gross domestic product (GDP) and energy consumption, the GMS is dominated by Thailand, which accounts for approximately 50% of both GMS GDP and energy consumption. Viet Nam has the next highest shares in both variables, followed by Guangxi and Yunnan, each of which accounts for approximately 15% of both GMS GDP and energy consumption. Cambodia, Lao PDR, and Myanmar collectively account for the remaining 5% shares in the two variables.

During 1993–2005, GMS energy consumption grew at an average annual rate of 8%, which is slightly higher than the average annual rate of economic growth for the period, thus indicating a small increase in energy intensity. Such growth in energy consumption would be expected, given the low level of per capita energy consumption (Figure 3) and limited access to energy across GMS countries at the beginning of the period, as well as the GMS's rapid rate of economic growth. Lao PDR, Thailand, and Viet Nam reported energy growth rates much higher than their respective GDP growth rates for the period, whereas in the rest of the GMS, growth in energy consumption lagged GDP growth.

Appendix 2, which reports consolidated energy balances for 2001 and 2005 for the GMS, indicates growth in overall energy consumption of 24% during this time frame. Most of this increase is due to the large rise in the demand for transport services (38%) that took place over the period. As would be expected, this was

accompanied by a decline in the share of biomass in total energy consumption (5%), and increases in the share of oil products (2%), and coal and electricity (slightly more than 1% each). The aforementioned increase in the demand for transport services is reflected in the large share of transport in total energy use (21%) and consumption of oil products (62%) for 2005. By way of comparison, the household and industrial sectors each accounted for 31% of total energy consumption in the same year. However, it should be remembered that in 2005, 75% of the energy used by households was sourced from biomass, indicating a high degree of energy and environmental vulnerability.

Figure 3. Average Annual Growth in Energy Consumption and GDP, 1993–2005 (%)



GDP = gross domestic product, Lao PDR = Lao People's Democratic Republic, PRC = People's Republic of China.

Sources: ADB. 2007. *Asian Development Outlook 2007.* Manila (for GDP); Energy Information Administration (EIA); China Data Online (for energy data).

Despite the GMS' rapid growth in energy consumption over the past decade, weighted average annual per capita electricity consumption for the entire subregion—estimated at 920 kWh—remains at two-thirds the world average for all developing countries, and less than 10% of average per capita consumption in the member countries of the Organisation for Economic Co-operation and Development (OECD) (Table 4). However, such weighted average data hide the wide

variation in electricity consumption across member economies. For example, per capita electricity use levels in Cambodia and Myanmar are less than 10% of the GMS average rate, this largely being due to their low electrification rates of 20% (Cambodia) and 11% (Myanmar).

Table 4. Per Capita Electric Power Consumption, 2005

Economy	Kilowatt-hour(kWh)
Cambodia	56
PRC	1,684
Guangxi	1,100
Yunnan	1,252
Lao PDR	187
Myanmar	78
Thailand	1,950
Viet Nam	573
World	2,701
Developing Countries	1,221
OECD	8,795
United States	14,240

Lao PDR = Lao People's Democratic Republic, OECD = Organisation for Economic Co-operation and Development, PRC = People's Republic of China.

Sources: United Nations Development Programme (UNDP). 2007. 2007. *Human Development Report 2007/2008*; National Bureau of Statistics. 2006. *China Energy Statistical Yearbook 2006* (Source of Guangxi and Yunnan data.)

In 2005, 21% of all energy consumed by the GMS was imported. Thailand was the largest GMS importer of energy, with imports (mainly electricity, natural gas, and oil products) accounting for nearly 40% of all energy consumed. Cambodia, Lao PDR, and Viet Nam import 100% of transport and other petroleum-based fuels. The whole subregion exports crude oil due to a lack of refining capacity, and net oil imports account for one-third of total oil consumption.

Overall, the GMS is well-endowed with energy resources (Table 5), but these are distributed unevenly. Hydroelectric potential is substantial in Lao PDR, Myanmar, and Yunnan, while Myanmar and Thailand have significant gas resources, and Viet Nam and Yunnan both have large coal deposits. In Cambodia, exploration of the country's hydrocarbon resources has just begun.

Table 5. GMS Energy Resources

Resource	Grade 1	Total
Coal (MTCE)	8,397	81,421
Lignite (MTCE)	10,699	11,475
Oil (MTOE)	450	1,198
Natural Gas (bcm)	245	1,645
Hydropower (MW/yr)	54,102	127,403

bcm= billion cubic meters, GMS = Greater Mekong Subregion, MTCE= million tons of coal equivalent, MTOE= million tons of oil equivalent,; MW/yr = megawatt year.
Source: IRM (2008).

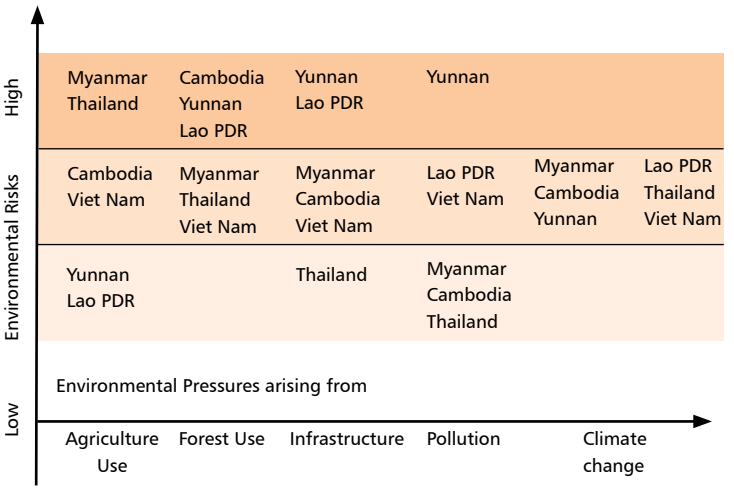
The data for GMS energy resources presented in Table 5 reflect uncertainties regarding both the estimated cost of extraction and the allocation of resources within various cost grades. Further, these data were collected from multiple sources including World Energy Surveys, national estimates, and published sources detailed in the main technical assistance report of *Integriertes Ressourcen Management* (IRM).

Energy, Environment, and Climate Change

The GMS remains predominantly an agricultural economy in which nearly 70% of the total population lives in rural areas and is dependent on local resources. This has important implications for the subregion's natural resource base and the state of its environment, which are critical elements in achieving sustainable economic development. For example, forests help maintain ecological balance and biodiversity, function as watersheds, and provide habitats for wildlife. Forest products, on the other hand, are vital for the welfare of rural communities. Because maintaining ecological balance is a critical factor in sustaining the GMS' impressive growth performance over the past two decades, a subregional environmental performance assessment was carried out under the GMS Core Environment Program. Table 6 summarizes the environmental pressures facing the subregion. These emanate from economic activity in the agriculture sector, depletion of forests, infrastructure development, pollution, and climate change. While in recent years, the GMS governments have focused on reforestation and protected area development, forest resource use still presents a

high level of environmental risk in Cambodia, Lao PDR, and Yunnan. Agricultural activities result in substantial environmental pressure in Myanmar and Thailand, and Yunnan appears to be vulnerable to environmental pressure in nearly all dimensions.

Table 6. Environmental Pressures Facing the GMS*



GMS = Greater Mekong Subregion, Lao PDR = Lao People's Democratic Republic, PRC = People's Republic of China.

* Guangxi Autonomous Region was not included in this assessment.

Source: ADB. 2008b. *Subregional Environment Performance Assessment (EPA) Report.* Manila: Greater Mekong Subregion–Enviroment Operations Center (GMS-–EOC).

All member economies face medium- to high-level environmental pressure from forest use, making it the single greatest environmental challenge to the GMS. This is true despite the rates of deforestation reported in Table 7, which do not at first glance appear to be particularly alarming. One recent study used comparative data for 1990 and 2000 to estimate the quantitative and qualitative loss of forest cover in the GMS. The data suggest that during 1990–2000, annual disinvestment in forest capital in the range of $27 billion–$54 billion occurred in the subregion—the absolute dollar value depending on the monetary value assigned to each hectare of forest.[5]

Table 7. Forest Cover in the GMS

Economy	% of Total Area	Annual Change (%)	
	2005	1990–2000	2000–2005
Cambodia	59.2	(1.1)	(2.0)
PRC			
Guangxi	41.4	..	..
Yunnan	40.8	..	..
Lao PDR	69.9	(0.5)	(0.5)
Myanmar	49.0	(1.3)	(1.4)
Thailand	28.4	(0.7)	(0.4)
Viet Nam	39.7	2.3	2.0

.. = data not available, ( ) = negative value, GMS = Greater Mekong Subregion, Lao PDR = Lao People's Democratic Republic, PRC = People's Republic of China.

Source: Food and Agriculture Organization of the United Nations. 2006. *Global Forest Resources Assessment.* Rome. p. 197.

Both the pattern of energy use and the manner in which it changes over time have a substantial impact on climate change. Though the subregion does not yet have a significant carbon footprint—GMS per capita carbon dioxide emissions are much lower than those for the entire world or for all of Asia—the subregion's rapid growth in energy consumption will invariably lead to increasing carbon intensity of the GMS economy (Table 8). The share of energy consumption in total greenhouse gas (GHG) emissions is high in Thailand and the PRC. In these countries, energy accounts for 59.4% (Thailand) and 72.5% (the PRC) of all GHGs, as compared to the world average of 68.8% and 42.1% for Viet Nam. The GMS' share of energy consumption in GHGs is likely to increase in the medium term, as growth in energy use accelerates due to improved access to modern energy sources. Thus, the future energy technology choices the GMS makes will have important implications for global climate change (Table 8) in the long term.

Table 8. Carbon Intensity of Growth, 2005

Economy	GDP	GDP (PPP)	Per Capita	% Change
	(kg of CO_2 per $)		(t of CO_2)	1990–2005
Cambodia	0.66	0.11	0.27	164.3
PRC	0.67	0.55	3.88	128.9
Lao PDR	*0.59*	*0.14*	*0.20*	..
Myanmar	0.73	0.15	0.22	177.8
Thailand	1.36	0.43	3.34	172.7
Viet Nam	1.80	0.35	0.97	374.0
World	0.75	0.50	4.22	29.1
Asia	1.31	0.37	1.25	102.7
OECD	0.45	0.45	11.0	16.4
United States	0.53	0.53	19.6	19.9

.. = no data available, CO_2 = carbon dioxide, GDP = gross domestic product, kg = kilogram, Lao PDR = Lao People's Democratic Republic, OECD = Organisation for Economic Co-operation and Development, PPP = purchasing power parity, PRC = People's Republic of China, t = ton.

Note: Figures in italics represent the latest year available.

Source: International Energy Agency (IEA). 2007. *Energy Statistics of Non-OECD Countries.* Paris: IEA.

2

Emerging Challenges in the Greater Mekong Subregion

The GMS economies are undergoing rapid transition in multiple dimensions. Some are transitioning from state-dominated to market-based economies. Others are shifting from subsistence agriculture to commercial agriculture, or from economies dominated by agriculture to those in which industry and services account for a significant share of GDP. Further, in many member economies, rural-to-urban migration is ongoing and rapid. Successfully managing such transitions poses major challenges to the leadership of the GMS economies. Regardless of the dimension in which they occur, all of the above transitions have a major impact on energy use patterns.

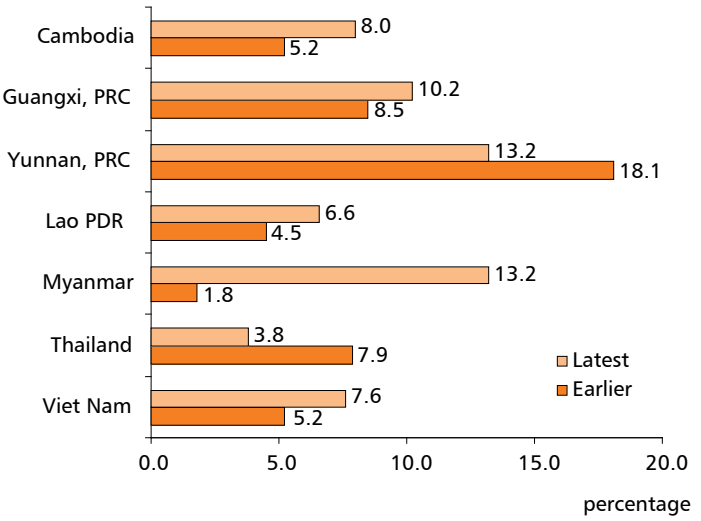
At present, the GMS energy sector remains dominated by large utilities directly or indirectly owned by governments. As a result, energy prices do not always reflect market conditions or the true scarcity value of energy to society. For the most part, growth in energy demand over the coming decades will be driven by two factors: (i) the transition from an agriculture- to an industry-based economy, and (ii) rural–urban migration. Many of the challenges facing the GMS are thus complex and require policy actions based on a well-formulated strategy. This section highlights important challenges facing the subregion.

Rapidly Rising Demand for Energy

The economic performance of the GMS over the past two decades has been impressive. Since 1992, the average annual GDP growth rate for all member economies taken together (except Thailand)

exceeded 6% (Figure 4). Further, the corresponding growth rate for each individual member economy (again excluding Thailand) was 4% or greater. What is equally impressive is that this rapid rate of growth occurred despite a number of internal and external shocks. These included the East Asian financial crisis, the slowdown in the global and regional economy in 2001, the onset of the severe acute respiratory syndrome (SARS) in 2003, the recent avian flu epidemic, and a persistent rise in oil prices over the past few years.

Figure 4. GDP Growth in the GMS (CAGR %)



CAGR = compound average growth rate, GDP = gross domestic product, GMS = Greater Mekong Subregion, Lao PDR = Lao People's Democratic Republic, PRC = People's Republic of China.

Note: "Latest" refers to the period 1993–2005 except for Myanmar, for which it refers to the period 2000–2005. "Earlier" refers to 1980–1992 except for Cambodia, Lao PDR, and Viet Nam, for which it refers to the period 1985–1992.

Sources: ADB database and China Data Online.

This rapid economic growth in the GMS has fuelled a significant expansion in energy demand. A major challenge facing the GMS economies is thus that of sustaining the rapid growth rates of both GDP and industrialization achieved over the past two decades, while maintaining international competitiveness by ensuring reliable energy supplies. Most member–economy growth forecasts in energy

demand foresee annual increases from 7% to 16%. Such rates significantly exceed the growth rate in economic activity forecast for the coming decade. The GMS medium-term energy strategy must therefore address the issue of ensuring reliable supplies of energy to member economies to prevent future economic growth from being constrained below its potential.

Energy Poverty

Access to modern energy is uneven across GMS economies, and between urban and rural areas. A large share of the GMS population thus still depends heavily on traditional sources of energy. Unless appropriate steps are taken, the absolute number of GMS inhabitants relying on biomass will increase over time, which would add greatly to existing environmental pressures.

Poor households often spend a large share of their income on fuelwood or charcoal. If not addressed, lack of access to modern energy sources could easily create a vicious cycle of decline in terms of the environment, and in the economic and social conditions of this population. Even for GMS households with access to electricity, electric power consumption is much lower than the average residential rate of use in other countries. For example, annual per capita household electricity consumption in the OECD countries varies from 1,500 kWh in Europe to 4,500 kWh in the United States. Thailand's annual household per capita consumption of electricity is only 409 kWh per year, despite the fact that nearly 100% of households have access to electricity (Table 9). As income increases, electricity consumption rises rapidly in the residential sector, especially in rural areas. The GMS medium- and long-term energy plans must therefore reflect structural changes in fuel usage and likely increases in household electricity use.

Despite the benefits of doing so, improving access to modern energy sources in rural areas presents a major challenge for several reasons. First, energy transport and distribution costs are higher in rural areas than in urban areas because of low density of use and infrastructural constraints. Second, programs that address energy poverty are often given low priority by governments due to (i) a lack of data on rural energy use, (ii) institutional weakness in the agencies responsible for addressing such concerns, (iii) fiscal constraints and lack of political will to support investments that would generate returns only in the long term, (iv) presence of large-

scale subsidies, and (v) the non-monetized nature of many aspects of the rural economy. Finally, rural electrification presents a special challenge, given its high cost of investment, low load factors, and significant transmission and distribution losses.

Table 9. Annual Per Capita Household Electricity Consumption in the GMS

Economy	Household ConsumptionPer Capita kWh	Share of Residential Sector in Total Electricity Consumption %
Cambodia	29	52.0
PRC	190	14.0
Guangxi	141	13.6
Yunnan	165	12.9
Lao PDR	95	53.0
Myanmar	29	40.0
Thailand	409	21.0
Viet Nam	242	42.0

GMS = Greater Mekong Subregion, kWh = kilowatt-hour, Lao PDR = Lao People's Democratic Republic, PRC = People's Republic of China.

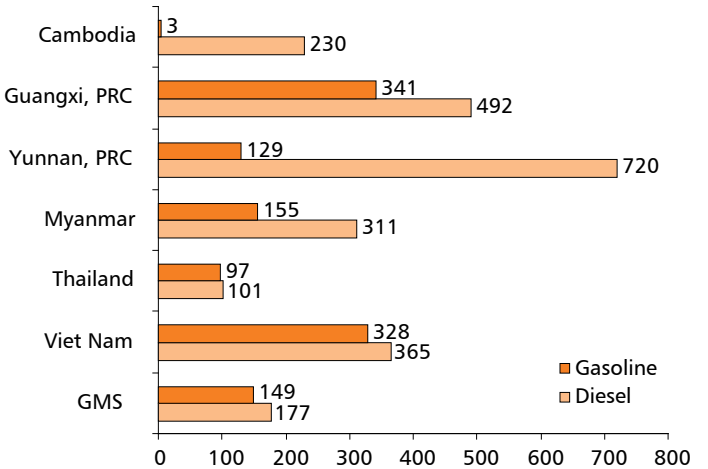
Source: ADB estimates.

Decentralized systems have a lot of promise for energy supply in rural areas. These are environmentally benign and can be tailored to suit local conditions efficiently. However, human and institutional capacity constraints are often significant barriers to the delivery of sustainable solutions. It is estimated that only 7% of world electric power production is sufficient to meet the basic energy requirements of the entire global population. However, despite the degree of modernization and technological advance achieved in the current age, this challenge remains unmet.[6] The fact that nearly one-fourth of the GMS population has no access to electricity presents a major development challenge. Modernization of the rural energy sector must be accelerated over the medium to long term to ensure inclusive growth and protection of the subregion's environment.

High Degree of Energy Vulnerability

Over the medium term, GMS leaders must address multiple concerns relating to energy security to place the subregion on a sustainable growth path. The rapid rate of economic growth achieved by the subregion over the past two decades has fuelled a staggering phase of motorization, resulting in a large vehicle boom. Thus, from 1990 to 2005, consumption of diesel increased by 177%, and petrol by 149% (Figure 5). To date, the GMS lacks sufficient refining capacity to meet its overall demand for petroleum products. It likewise remains a net importer of crude oil, with imports accounting for nearly 20% of all crude oil and 47% of all petroleum products consumed. In 2005, imports accounted for 21% of final energy consumption, with the import shares of crude oil amounting to 19%, and refined petroleum products, 33%.

Figure 5. Growth in Transport Fuel Consumption in the GMS, 1990–2005 (%)



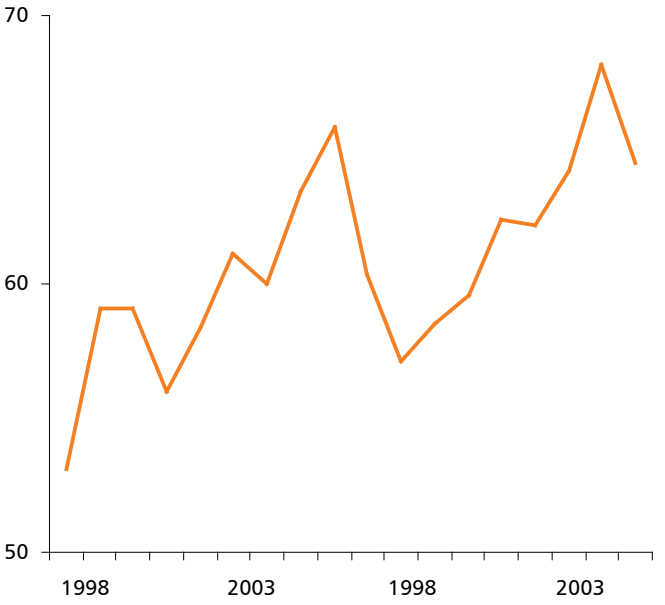
GMS = Greater Mekong Subregion, Lao PDR = Lao People's Democratic Republic, PRC = People's Republic of China.

Note: Cambodia's growth pertains to 1995–2005.

Sources: Organisation for Economic Co-operation and Development (OECD) (2007) and China Data Online.

Thailand, which is the subregion's largest economy, imported two-thirds of all crude oil, 20% of petroleum products, and 25% of all natural gas consumed in 2005. Compared with other GMS countries, Thailand imported more than 60% of its total primary energy requirement (Figure 6), whereas Cambodia and Lao PDR both imported 100% of all petroleum products consumed in 2005. As Viet Nam lacks petroleum refining facilities to date, it exported all of the crude oil it produced domestically, and imported 100% of its refined petroleum product requirement in 2005. While Myanmar and Viet Nam are currently net exporters of energy, rapid growth in energy demand in the GMS is likely to keep the subregion heavily dependent on imported fossil fuels over the medium term. At the individual economy level, Thailand, which is one of the largest energy consumers in the subregion, imports more than 50% of its domestic energy requirement, whereas Cambodia and Lao PDR import 100% of all commercial fuels used. Similarly, Guangxi and Yunnan import refined petroleum products from other areas of the PRC.

Figure 6. Percentage Share of Energy Imports in Total Energy Consumed in Thailand, 1988–2005 (%)



Source: Energy Policy and Planning Office, Thailand. 2008. Energy Statistics.

The subregion's oil dependence is expected to increase dramatically over the coming two decades. Poor production prospects, weak demand management, insignificant penetration rates for alternative energy sources, and high global oil prices make the subregion vulnerable with respect to energy security. The best means of reducing this vulnerability would be a GMS-wide program that diversifies the sources from which it imports crude oil from within and outside the subregion.

At present, the GMS lacks institutional mechanisms of any kind to address energy supply disruptions arising from emergencies or exogenous shocks. In addition to the issue of systems reliability relating to security of physical supply, affordability is an important aspect of energy security for the subregion. Given the GMS' low rates of access to energy and its importance in promoting growth and poverty reduction, energy security is a regional public good, and thus must be addressed comprehensively if sustainable growth is to be achieved for the subregion.

Environmental and Social Issues

The GMS has significant hydropower potential. Plans for developing this resource should thus integrate environmental and social costs. Such integration must include addressing cross-border externalities in the planning and design of large-scale power projects, as the experience of the Nam Theun 2 project has amply demonstrated. Resettlement is likewise an important concern in planning large-scale hydropower projects in the GMS. In this context, a technical assistance initiative that contributed to development of Lao PDR's power strategy in 2002 found that given the country's low level of population density, Lao PDR power projects compared favorably with other similar projects in terms of overall environment and social impact evaluation parameters. One reason for this is that Lao PDR power projects explicitly account for the number of persons required to be resettled for any given level of electricity output.[7]

Finally, integration of environmental and social costs into the design of proposed energy projects should be explicitly incorporated into the GMS institutional and policy framework (Appendix 3).

Energy Productivity

The expanding private sector participation in the GMS energy sector is an untapped area that can be used to mobilize resources in support of energy projects and increase the overall efficiency of energy use. Virtually all member economies have yet to acquire a large stock of appliances, and scores of investments in new energy capacity are yet to be made. This translates into an enormous opportunity for the subregion to further improve the productivity of each unit of energy it consumes. Such a move would be consistent with the improvements in energy productivity that the GMS has achieved thus far (Table 10), which are generally in line with global trends.

While a large part of this potential improvement would result from the GMS shifting from noncommercial to commercial energy sources, large and to some extent fragmented opportunities to improve energy productivity in the industry and transport sectors remain. Energy efficiency is low at present. For example,

Table 10. Energy Productivity in the GMS, 1990 and 2005

Economy	TPES/GDP toe per 1000 $		TPES/GDP (PPP) toe per 1000 $	
	1990	2005	1990	2005
Cambodia	*1.32*	0.86	0.22	0.14
PRC	1.94	0.91	0.47	0.22
Lao PDR	..	..	..	..
Myanmar	2.17	0.97	0.44	0.20
Thailand	0.55	0.64	0.17	0.20
Viet Nam	1.62	1.15	0.32	0.23
World	0.36	0.32	0.26	0.21
Asia	0.79	0.65	0.21	0.18
Non-OECD	1.00	0.72	0.22	0.18
OECD	0.23	0.20	0.22	0.18

.. = data not available, GDP = gross domestic product, Lao PDR = Lao People's Democratic Republic, OECD = Organisation for Economic Co-operation and Development, PPP = purchasing power parity, PRC = People's Republic of China, toe = ton of oil equivalent,
TPES = total primary energy supply.

Figures in italics represent 1995.

Sources: International Energy Agency (IEA). 2007. *World Energy Outlook*; IEA. 2007. *Energy Statistics of Non-OECD Countries.*

transmission and distribution losses in GMS electric power systems are high in some parts of the subregion.

Several existing policy regimes prove to be barriers to improving energy efficiency in the GMS. Examples include (i) implicit and explicit fuel subsidies in the transport and household sectors; (ii) an overall lack of financial incentives to improve energy efficiency for energy producers and large-scale, public sector energy users who often face non-binding budget constraints; (iii) lack of information concerning energy efficiency practices; (iv) weak policy and institutions responsible for addressing energy use inefficiencies; and (v) failure on the part of users to realize the potential benefits of improving efficiency of energy use. In Chapter 6, energy efficiency issues are discussed in greater detail, and specific areas that need to be addressed are identified.

Given the high level of dependence on fuelwood and biomass energy sources in the face of environmental pressure in some parts of the subregion, improving the efficiency of use of traditional fuel sources deserves the attention of policy makers. From the overall policy point of view for the GMS energy sector, it is important to partner with private sector and civil society groups to prepare a medium-term operational plan to improve energy productivity as it relates to these traditional fuels.

Institutions and Policy Regimes

Overall, the quality and reliability of energy supplies remain weak in many parts of the subregion. Such poor quality of energy infrastructure not only imposes additional costs on existing industrial production capacity, but also negatively affects the business investment environment. The existing market structures and relevant policy regimes in the energy sector are important challenges to the subregion. Weak and often inappropriate financial incentives, lack of competitive pressure facing suppliers of energy, and weak policy regimes should change drastically if current energy challenges facing the subregion are to be dealt with effectively.

The current global energy context is extremely complex, and includes uncertain energy prices, environmental sustainability pressures, geopolitical uncertainty in the oil-rich regions, interconnectedness of global energy markets, political and consumer pressures, and unprecedented scrutiny by civil society. Unless the GMS' existing

institutional structure and policy regimes are aligned to enhance energy service delivery in environmentally acceptable ways, the subregion's medium-term pace of economic growth and its poverty reduction agenda could easily be compromised.

In spite of the serious challenges the GMS faces, a number of opportunities are unique to the subregion. Overcoming these challenges and taking advantage of available opportunities will require a consistent and comprehensive strategy for the sector.

In terms of types of economic systems, the GMS is extremely diverse. Its economies are at widely differing stages of development, with average income (measured in terms of GDP per capita in current US dollars) varying by a factor of 10 between the highest and the lowest. Moreover, some member countries such as Cambodia, Lao PDR, and Viet Nam are undergoing transformation from a centrally planned economy to a market economy. However, these three countries are at different stages of transition. Thailand is an established market economy, but even there, the energy reform agenda remains unfinished. Sector reforms need to be deepened considerably to meet rising energy demand efficiently.

Overall, the GMS economies vary widely in terms of numerous parameters, including the degree to which the physical and human resource base has been developed, the structure of the economy itself, the degree of integration of the national economy into the global economy, the levels of income and poverty, the ease of access to infrastructure, and the pace of economic reform. Overall energy consumption levels vary dramatically across the GMS. Per capita electricity consumption in Thailand is approximately 40 times that of Cambodia, 10 times that of Lao PDR, and 4 times that of Viet Nam. Such variation in the degree of access to electricity reflects widely differing stages of economic advance and development of energy infrastructure. Within this context, the following section addresses the critical question as to whether energy integration presents the region with an opportunity or a challenge.

3

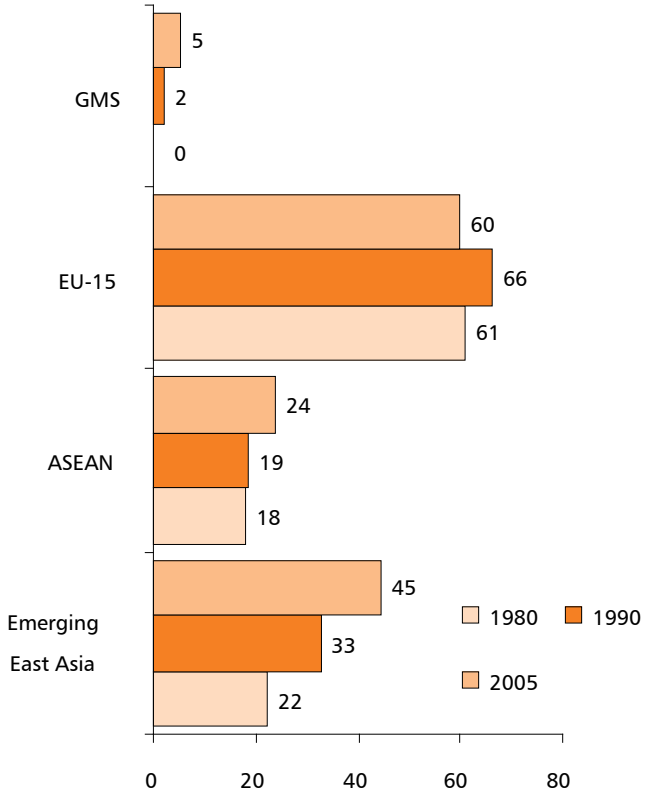
Why Integrate the Energy Sector?

Trade in goods and services in developing Asia has grown at an unprecedented rate over the past few decades, fueling rapid rates of economic growth and poverty reduction. With the expansion of production networks across Asia, intraregional trade has doubled in value since 1980, and now accounts for nearly 45% of total trade in emerging East Asia.[8] Likewise, the total value of GMS intraregional trade more than doubled from 1992 to 2002. During the latter period, GMS intraregional imports grew at a compound average rate of 23.6% and exports at 23.0%, which are well above the corresponding growth rates for the entire world of 15.4% and 16.7% for 1992–2005 (Figure 7).

Except for exports of electricity from Lao PDR and natural gas from Myanmar, GMS intraregional trade in energy remains limited. The share of exports in total Lao PDR electricity generation declined from 88% in 1979 to just little over 60% in 2005 (Figure 8). Likewise, at present, Myanmar natural gas exports meet about a quarter of the demand for gas in Thailand.

A number of cross-border energy projects that will boost intraregional energy trade have been planned. However, no significant move toward creating an Asian or a GMS energy community has been initiated due to several reasons. First, trade in energy, in particular electricity and natural gas, require dedicated infrastructure. Second, nearly all countries prefer self-sufficiency and national sovereignty over energy distribution networks. Third, externalities are inherent in such networks, since distribution lines remain natural monopolies and are therefore often publicly-owned in most GMS economies. The significant market power of such state-owned utilities would have to be reduced for an intraregional energy market to become a reality. Even Asia's other middle-income countries are still in the process of reforming their institutions and policies to reduce the

Figure 7. Intraregional Trade Shares (%)



ASEAN = Association of Southeast Asian Nations; EU-15 = Austria, Belgium, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Luxembourg, Netherlands, Portugal, Spain, Sweden, and United Kingdom; GMS = Greater Mekong Subregion.

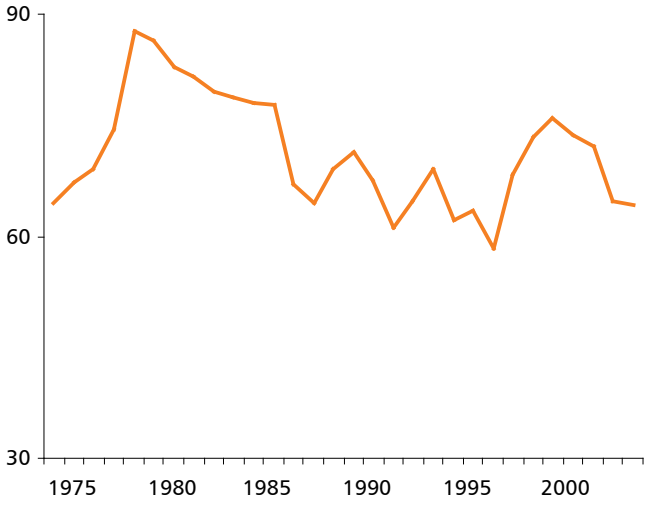
Note: Intraregional trade share is the percentage share of intraregional trade in the total dollar value of imports and exports.

GMS data are for 1992 and 2004–2006, and exclude the People's Republic of China.

Sources: ADB. 2007a. *Asian Development Outlook 2007*. Manila; ADB. 2007d. *The Mekong Region Trade Trends, Patterns and Policies.* Manila.

market power of state-owned electric utilities. Fourth, political or security problems arising from territorial disputes or riparian rights often tend to prevent energy trade between countries. Finally, countries often lack frameworks to share the benefits and costs arising from increased trade in energy. Thus, the barriers to GMS trade in energy remain significant.

Figure 8. Share of Exports in Total Lao PDR Electric Power Generation (%)



Lao PDR = Lao People's Democratic Republic.
Source: Electricité du Laos.

International Experience

The global trend over the past several decades has been moving toward interconnected markets for electricity, and a significant number of transnational gas pipelines already exist. Overall, developing interconnected markets in the power sector nearly always goes hand in hand with energy sector reform and a shift toward a more competitive market. The experience of major regional power networks is briefly outlined below.

UCTE. Founded in 1951, the Union for the Coordination of Transmission of Electricity (UCTE) is one of the oldest regional power networks. Its 33 transmission system operators manage 220,000 kilometers of high-voltage electric power networks in Europe. At the end of 2006, the network served about 450 million people with an installed capacity of 620 gigawatts (GW). Of the total consumption of 2,500 terawatt-hours (TWh) in 2006, about 10% (295 TWh) was exchanged internationally under UCTE rules.

UCTE's major tasks include compliance monitoring, coordinated system planning, and information exchange between members to promote reliable and efficient operation of the interconnected power systems based on commonly agreed standards.

Nordel. Founded in 1963, Nordel, or the Organisation for the Nordic Transmission System Operators, includes the interconnected networks of four Nordic countries (Denmark, Finland, Norway, and Sweden), as well as Iceland's isolated electric power system. Nordel also trades power with Germany, Poland, and the Russian Federation. Its mission is to promote the establishment of a seamless Nordic electricity market as an integrated part of the northwest European electricity market, and to maintain a high level of power system security. Nordel serves a total population of 25 million people with a total load of 61 GW. Of the total consumption of 405 TWh in 2006, 15% of all energy generated was traded between countries.

SAPP. Founded in 1995, the South African Power Pool (SAPP) 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. One of SAPP's aims is to help develop competitive electricity markets in southern Africa, in which the end-user has a choice of electricity suppliers. SAPP coordinates the planning and operation of the electric power system among member utilities and provides a forum for regional solutions to problems relating to all aspects of electricity generation and transmission. It operates a short-term energy market.

Latin America. Three distinct regional energy blocks exist in Latin America: the Andean Community, Central America, and the South American Common Market. All three of these regional energy markets are in their early stages of integration with bilateral contracts dominating power and gas exchanges. This is happening despite the existence of a number of institutions in the region such as the Regional Electrical Integration Commission, which was established in 1964, and the Latin American Organization for Energy Development, which was established in 1971 to serve all of South America. Several countries have achieved physical interconnection of energy distribution networks, but market integration has yet to occur.

ASEAN Power and Gas Grid. As part of promoting regional cooperation within the ASEAN region, the ASEAN Energy Center completed an interconnection master plan in 2003 that describes

the ASEAN Power Grid slated to achieve interconnection by 2020. The project identified 14 possible interconnection projects, and a number of these are being implemented. ASEAN has also formulated a Trans-ASEAN Gas Pipeline project that will create a gas grid for the region. Overall progress in this area remains slow, given the barriers to integration discussed above.

Globally, there are numerous examples of international trade in energy that have led to significant benefits, both financial and otherwise. Europe has an integrated energy market in electricity, and the United States and Canada have established an extensive electricity and gas trade. The same is true of the Southern Cone countries, the Andean Community, the countries of the Nile River Basin, and southern Africa. Nord Pool (the Nordic Power Exchange) has successfully curtailed national market power by integrating the electricity market in the Nordic countries. As a result, prices are near the level of the marginal cost of power generation, thus improving the productivity of the power sector. The United Nations estimates that electricity interconnection in Western Europe has helped the region save on investments in additional capacity by about 7% to 10%. Similarly, the United States saved $20 billion annually during the 1990s due to its energy trade with Canada. In the GMS, project-level energy exchange is already taking place, mainly in the electricity and gas sectors.

Advantages and Opportunities

The potential gains from regional energy integration could be substantial. This is true in a general sense, as well as in the context of the GMS region. Overall, the subregion's resource base is quite diverse, which gives rise to a significant number of complementarities. Lao PDR, Myanmar, and Yunnan have significant hydroelectric generation potential, whereas Viet Nam and Yunnan have substantial coal deposits. While the subregion's oil and gas resources have not yet been fully explored, Cambodia, Myanmar, and Viet Nam potentially have large natural gas resources. There is thus significant potential for reducing overall energy costs by building on such complementarities and comparative advantages arising from primary resource endowments.

Trade and economic integration can improve the efficiency of the entire subregional energy system. For resource-rich countries, exporters of energy are able to benefit from overall economies

of scale and scope, as well as from optimizing the fuel mix. For energy importers, regional energy supplies provide easier access and enhance energy security vis-à-vis the outside world. For the pure transit countries, energy transport rights provide additional sources of income and energy supply. Other benefits potentially accruing to the power sector from exploiting complementarities in national energy demand profiles include postponing investment in additional capacity, improving load factors and increasing load diversity, and coordinating maintenance schedules.

Further, integrated approaches to energy supply and distribution tend to be more efficient in addressing environmental concerns, especially in cases in which environmental and social costs transcend national boundaries. Expanding supply options thus can lead to environmental and social benefits in addition to increased economic efficiency from integration.

Finally, given the changes in the definition of energy security over time,[9] subregional energy integration has the potential to improve energy security in the GMS, provided that the development of market and institutional structures incorporate this objective into their design. Thus, subregional energy integration helps to expand the number of possible sustainable energy solutions.

Costs and Threats

Regional energy integration requires a considerable investment, not only for physical infrastructure, but also in social and political terms. This can at times increase risk by exposing the home country to a wide range of vulnerabilities that originate in neighboring countries.

Regionally integrated electricity and gas networks are quite complex, and thus require a high degree of technical compatibility and operational coordination. At times, technical or other faults originating from outside one member economy can result in cascading outages that bring down multiple systems. Minimizing the risk of voltage collapse, dynamic and transient instability, or disruption of supply requires careful system planning and operational coordination. Differences in organizational structures, levels of technical capability, and even cultural differences can be a major source of supply interruption. These factors all increase risks in the case of integrated networks.

Integrated networks may also limit discretionary national actions intended to fulfill national plans. Likewise, uneven bargaining power across integrating nations weakens the national position of the countries with the most limited capacities for negotiation.

To some extent, regional integration restricts domestic options for energy self-supply, independently setting tariffs, or offering subsidies. Similarly, in the absence of effective regional regulation, regional networks are prone to market power abuses.

Though regional networks help improve energy security vis-à-vis the global economy, they likewise increase interdependence within the region, and at times result in expanded energy trade flows, giving rise to a greater degree of regional import dependence.

Any energy integration strategy must examine the costs and benefits associated with integrating the energy system in question. Since increase in overall economic efficiency is an important driver in integrating energy systems, the first step in formulating such a strategy for the GMS would be to rigorously analyze the impacts of energy integration in the subregion. This issue is addressed in the next chapter.

4

The Economics of Energy Integration

There are many ways to examine the economics of regional integration in any sector. The simplest way is to adopt a project-level approach in examining economic viability by integrating a cost–benefit analysis that goes beyond national boundaries. A sector-based approach to integration that follows the same methodology would require making an exhaustive inventory of candidate projects and then ranking these according to specific criteria, to create a list of possible projects that would fulfill regional integration objectives. In 1995, the GMS economies adopted a sector-based approach in identifying a set of feasible power projects that would lead to a greater level of cooperation. This approach is acceptable when the process of regional cooperation is initiated and energy trade is limited. It is not, however, feasible to analyze the implications of an interdependent integrated system without a formal model.

The Model

An appropriate model for this purpose would need to ensure transparency, comprehensiveness, consistency between subsectors, and replicability. As least-cost strategies are to be identified for each scenario considered, the model must be capable of optimization. It must also be equally suited to energy systems of varying sizes, and capable of integrating economy-level results. The latter requirement ensures that all relevant aspects of integration of energy subsystems into a larger system of collaborating countries and economies are addressed. The model must also take into account environmental considerations in identifying feasible choices.

Preparation of the strategy was based on MESSAGE (a Model of Energy Supply Systems Alternatives and their General Environmental

Impacts). This model was chosen because it offered the possibility of optimizing economy-level energy systems at the regional level, which allowed an assessment of the economics of regional integration. A summary of the basic features of the model and its underlying assumptions are described in the technical assistance report prepared by the consulting group *Integriertes Ressourcen Management* (IRM) of Austria. This report is entitled "*Economics of Energy Integration: Application of MESSAGE Model in the GMS*" (IRM 2008).

MESSAGE identifies the flow of energy from "primary-energy" resources to "useful-energy" demands that is feasible in both a mathematical and an engineering sense, and allows wise investment choices in feasible energy supply mixes to meet a given energy demand. Engineering feasibility is ensured by making energy flows consistent with model constraints on primary-energy availability and extraction, energy conversion and transportation, as well as on end-use technologies and limits on the environmental impact of energy conversion. Energy flows are further determined by constraints on the rate of new capacity installation (new capacity can be installed only gradually), substitutability among energy forms, the potential for adopting renewable-energy technologies, and other factors.

One important technical feature of MESSAGE is the "mixed-integer option". Expressed in less technical terms, this means that the model has the ability to consider fixed sizes of technologies. Out of many possible energy flows, MESSAGE selects the one that fulfills the exogenously given level of demand at the least cost. The optimization process chooses the most cost-effective investment choices from a pool of energy technologies that are characterized by differing levels of performance, cost, and environmental impacts under a given set of constraints. In the MESSAGE model, dynamic changes in the energy system are endogenous, i.e., the pace of enhanced energy conservation, technological learning (especially for new technologies), or structural changes in energy supply and conversion are determined by shifts in the set of energy conversion technologies selected for a given scenario. The model minimizes objective functions or total discounted system costs, which include investment costs (both fixed and variable), operation and maintenance costs, fuel costs, and any user-defined costs such as environmental or social costs.

In calculating total cost, MESSAGE can use assumptions relating to the specific costs of hundreds of individual technologies as they

develop over time. The actual number of technologies is determined by the degree of detail included in the Reference Energy System (RES), which is a formal description of energy supply and demand in a given economy, and is specified in the MESSAGE input files. The result of these two steps (establishing feasibility and then calculating the optimal supply path) is an optimal energy supply mix delivered by various energy supply technologies and energy carriers that satisfy the demands of given sectors.

The planning horizon for the modeling exercise is 2025, implying that most options for energy technology projects to be implemented within this time horizon are at least approximately known. Although this means that a fundamental restructuring of the GMS energy system is infeasible over this 20-year planning horizon, it is important to keep in mind the possibility of "leapfrogging", that is, that development does not necessarily have to follow the same technological path as other countries. Thus, the GMS could move to better technologies or adopt a steeper learning curve than the developed countries have.

The Reference Energy System

The results and usefulness of the formal modeling exercise depend on the questions that must be answered and the quality of data. The conceptual core of the MESSAGE model is the RES. In its most comprehensive form, RES represents a particular real-world energy system and includes resource extraction, imports and exports, all feasible conversion technologies, energy transport and distribution, and energy demand. A schematic illustration of a simplified RES appears in Appendix 4. The seven RES generated for, and used by the model are much more detailed, given the large number of technologies considered. The RES for the GMS was derived by aggregating the seven economy-level subsystems that comprise the larger GMS energy system.

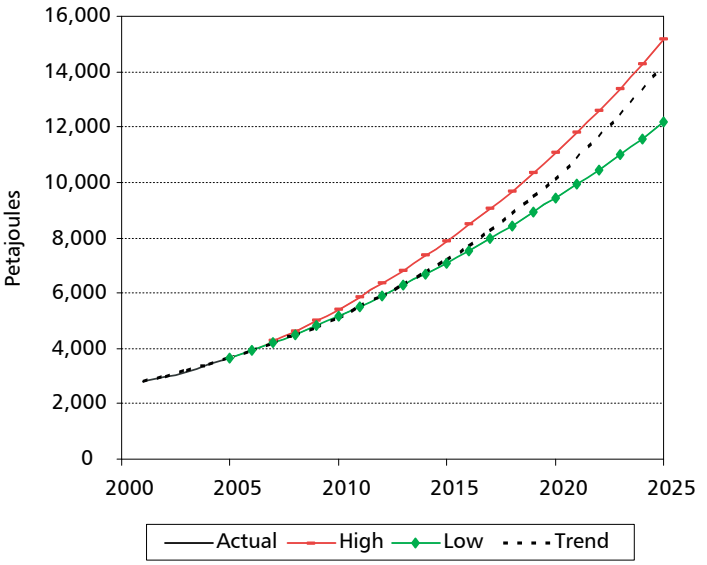
The degree of detail used in any given model application depends to a large extent on the data available for each economy. A first indicator of the degree of data availability is the completeness of an economy's energy balance, and a complete data table describing energy flows from primary-energy production to consumption of final energy by the various sectors during the base year. Sufficient historical data for such details should be available to allow trends to be identified. Fortunately, consistent energy balance data dating

back to the mid-1990s is available for all seven GMS economies. Though the actual data are not ideal, it was possible to supplement the information gathered on energy flows across sectors with some reasonable assumptions.

Useful Energy

Energy demand is modeled in terms of "useful energy",[10] rather than "final energy" for several reasons. First, useful energy (i.e., focusing on energy services rather than energy products) is particularly important when overall demand is being met from noncommercial energy sources. This approach is appropriate to the present modeling exercise since the share of noncommercial energy

Figure 9. Total Useful Energy Demand in the GMS, 2000–2025



GMS = Greater Mekong Subregion.

Note: Actual values (solid black line), low growth rate (green line) and high growth rate (red line) scenarios. For purposes of illustration, a trend line (exponential function with a compound growth rate of 6.8% per year, which corresponds to the average annual growth from 2001 and 2005, i.e., the dashed black line) is added to the graph.

Source: Integriertes Ressourcen Management (IRM). 2008. *Economics of Energy Integration: Application of MESSAGE Model in the GMS.* Austria.

in total GMS energy use in the seven member economies ranges from 20% to 70%. The potential for increasing energy efficiency and decreasing overall energy intensity can thus be better captured in the model if, for example, projected rural energy demand takes into account the demand for cooking energy (useful energy) instead of the demand for fuelwood (final energy). Figure 9 depicts total useful energy demand in the GMS as forecast by the MESSAGE model for the period up to 2025.

Second, it is possible to integrate improvement in energy efficiency at all stages of the energy cycle by modeling demand in terms of energy services rather than final energy. Third, since the seven GMS economy-level energy subsystems are in various transitional stages, disaggregated demand can better capture structural shifts. Finally, results presented in terms of useful energy demand provide much more information for policy analysis. For example, if rapid urbanization leads to greater demand for space conditioning, policy regimes that influence consumer behavior can be put in place.

The model incorporates 13 useful-energy demand levels and a non-energy feedstock (Table 11). Industry and service sector demands are disaggregated into electric and thermal uses, transportation

Table 11. Useful Energy Demand Sectors Used by the MESSAGE Model

Agriculture
Freight transportation
Industry, electric uses
Industry, thermal
Passenger transportation
Rural households, electric uses
Rural households, thermal uses
Service sector, electric uses
Service sector, thermal uses
Space conditioning, rural
Space conditioning, urban
Urban households, electric uses
Urban households, thermal uses
Non-energy use (Feedstocks)

Source: Integriertes Ressourcen Management (IRM). 2008. *Economics of Energy Integration: Application of MESSAGE Model in the GMS.* Austria.

demand into passenger and freight, and household demand into rural and urban, as well as into thermal and electric uses. Demand for space conditioning is specifically included because this energy segment is growing rapidly in the GMS, and because opportunities to improve efficiency of energy use in this application are many.

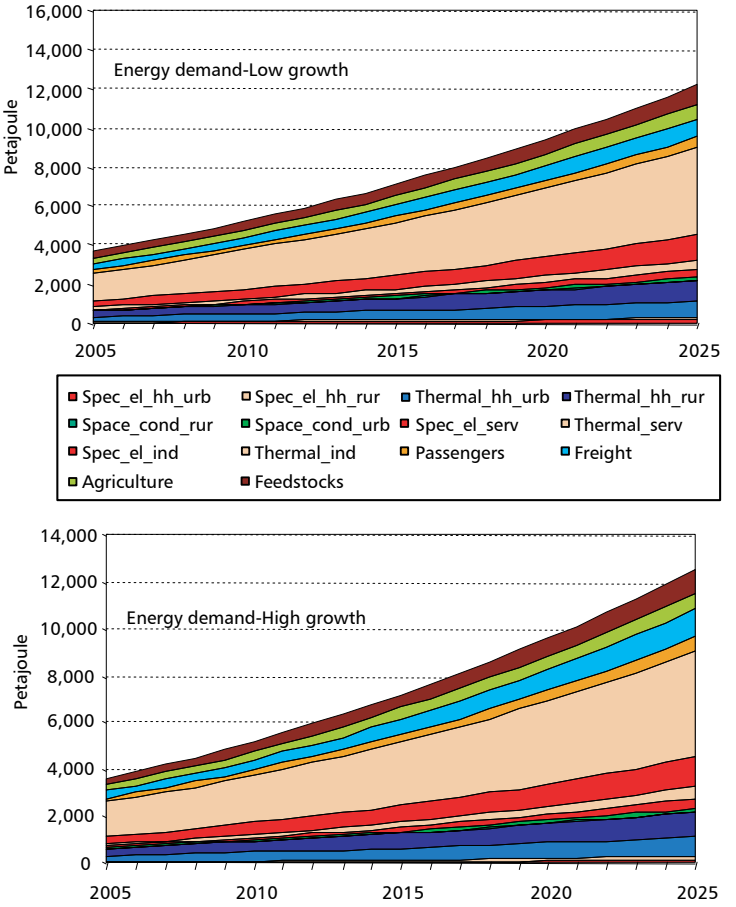
GDP, Energy Demand, and Price Assumptions

Energy demand forecasts for 2005–2025 are based on regional GDP projections using trends since 1992 (the average rate of economic growth in the GMS has been 7.1% per annum). The results of these projections are presented as two scenarios: high and low rates of economic growth. Estimates of future GDP growth for all GMS economies were used to derive future growth in energy demand. Higher economic growth rates imply an approximate 38% increase in total demand for useful energy (Figure 10 and Table 12).

The structure of demand does not vary drastically between the high- and low-growth scenarios. Analysis of the shares of the individual demand sectors in the low-growth case as compared to the high-growth case reveals that eight of the sectors increase their shares under the low-growth scenario, whereas the shares of six demand sectors decrease. These six demand sectors for which shares decrease are (i) electricity and space conditioning in urban households, (ii) electricity and space conditioning in rural households, (iii) electricity in industry, (iv) electricity in services, (v) thermal uses in services, and (vi) thermal uses in freight transport. These differences between the low-growth case as compared to the high-growth case reflect the increasing importance of electricity and the services sector. The high-growth scenario produces a somewhat different picture in that the electricity demand sectors increase their shares, as do thermal uses in urban and rural households. These differences may not be great, but they reflect the increased affluence of the high-growth scenario.

Initially, the energy demands used in the model were exogenously determined by the pace of economic growth. There were several reasons for adopting this approach. First, in the past, most GMS prices of final energy services did not reflect their true costs, given cross-subsidies and the dominance of the public sector in many member economies. Second, time-series data for the various

Figure 10. Energy Demand Under the Model's Low- and High-Growth Scenarios



Source: Integriertes Ressourcen Management (IRM). 2008. *Economics of Energy Integration: Application of MESSAGE Model in the GMS.* Austria.

Table 12. GDP and Useful Energy Growth Assumptions

Variable	Past Trend Rates	Low-Growth Scenario	High-Growth Scenario
UED	6.8%	6.0%	7.1%
GDP	7.8%	6.3%	7.6%
UED–GDP elasticity	0.87	0.95	0.93

GDP = gross domestic product, UED = useful energy demand.

Source: Integriertes Ressourcen Management (IRM). 2008. *Economics of Energy Integration: Application of MESSAGE Model in the GMS.* Austria.

useful energy sectors are not readily available for all member economies and sectors, and collecting this information would require a very large amount of additional financial resources. Even after completing such an exercise, it would still be difficult to predict prima facie whether the data would generate a meaningful relationship between price and energy use. Third, given the low level of energy consumption in many of the member economies, most energy service sectors in the GMS are undergoing structural transition that involves fuel switching. Finally, any energy-efficient technology that is viable would be selected automatically by the model. As there are numerous non-price barriers that are quite difficult to model but still need to be addressed, a decision was made to address these outside of the modeling exercise.

The model was nevertheless used to check the likely impact of prices on the overall optimal choices for energy consumption, investment, and environmental conditions. Several additional runs of the model were carried out that take full account of price responsiveness on the energy demand side. These are analyzed in detail in the accompanying technical assistance report.

Environmental and Social Impacts

The environmental impacts of an energy system are byproducts of energy conversion. The model thus integrates emission data as part of technology data. The model includes emissions of carbon dioxide (CO_2), methane (CH_4), nitrogen oxides (NO_x), sulfur dioxide (SO_2), and nitrous oxide (N_2O). The specific CO_2 emission factors used in the study are based on Intergovernmental Panel on Climate Change estimates and vary between 0.46 kilotons of carbon per megawatt-year (ktC/MWyr) for methanol and 0.87 ktC/MWyr.

Emissions other than CO_2 are technology-specific and are an integral part of the technology data used for optimization (details concerning how the non-CO_2 emissions were treated in the modeling exercise appear in Appendix 5). These pollutants were valued in terms of their potential damage. The methodology for doing this was taken from a detailed study undertaken by the Stockholm Environment Institute (SEI 2007) for this energy strategy study. Two sets of environmental damage values were estimated (Table 13) (the detailed methodology used is described in the IRM report and the SEI 2007 report). The damage costs for carbon-related pollutants were identical in both estimations given their global

impacts, whereas the impacts of NO_x and SO_2 varied, depending on local conditions within each member economy (Appendix 5).

Comparison of these two data sets reveals that the higher damage estimates per emitted ton of CO_2, CH_4, N_2O, and NO_x are larger by a factor of between 3 and 4 as compared to the lower damage estimates; for SO_2, by a factor of between 5 and 7.

Table 13. Estimates of the Costs of Environmental Damage ($/ton)

Economy	Low-Damage Case					High-Damage Case				
	CO_2	CH_4	N_2O	NO_x	SO_2	CO_2	CH_4	N_2O	NO_x	SO_2
Cambodia	7	150	1,924	1,027	403	25	568	7,311	3,628	2,616
PRC										
Guangxi	7	150	1,924	1,127	522	25	568	7,311	3,799	2,978
Yunnan	7	150	1,924	1,127	522	25	568	7,311	3,799	2,978
Lao PDR	7	150	1,924	1,005	342	25	568	7,311	3,523	2,200
Myanmar	7	150	1,924	1,021	397	25	568	7,311	3,619	2,602
Thailand	7	150	1,924	1,218	623	25	568	7,311	3,926	3,191
Viet Nam	7	150	1,924	1,083	604	25	568	7,311	3,963	4,025
GMS	7	150	1,924	1,064	466	25	568	7,311	3,728	2,930

CO_2 = carbon dioxide, CH_4 = methane, GMS = Greater Mekong Subregion, Lao PDR = Lao People's Democratic Republic, N_2O = nitrous oxide, NO_x = nitrogen oxides, PRC = People's Republic of China, SO_2 = sulfur dioxide.

Source: Stockholm Environment Institute (SEI) 2007. *Valuation of Some Environmental Costs within the GMS Energy Sector Strategy.*

In early runs of the model, separate scenarios were calculated for the high- and low-damage cost estimates. In the final report, only one set of environmental damage costs was used, this being under the Low Carbon scenario. The final damage costs were assumed to be as given for the low-damage values for NO_x and SO_2, and the high-damage values for CO_2, CH_4, and N_2O as shown in Table 13. In addition, a price sensitivity analysis was run for the Low Carbon case in which these environmental costs were included.

For hydropower, resettlement and environmental costs were estimated using project-level data. These estimates were derived from the 2002 master plan prepared under Asian Development Bank (ADB) technical assistance number 5920. The costs are normalized in terms of cost per unit of power (Table 14), these being of similar magnitude as in the case of large projects such as Nam Theun 2.

Table 14. Estimated Costs of Damage from Hydropower $/MWh

Economy	Type of Hydropower			
	Low Cost	Medium Cost	High Cost	Small
Cambodia	0.44	1.4	2.58	0.31
PRC				
Guangxi	0.54	1.4	2.58	0.31
Yunnan	0.54	1.4	2.58	0.31
Lao PDR	0.44	1.4	2.58	0.31
Myanmar	0.44	1.4	2.58	0.31
Thailand	0.54	1.4	2.58	0.31
Viet Nam	0.44	1.4	2.58	0.31

Lao PDR = Lao People's Democratic Republic, MWh = megawatt-hour, PRC = People's Republic of China.

Source: ADB. 2002. *Technical Assistance to Lao PDR on Power Sector Strategy Study.* Consultant's report. Manila (TA 3374-LAO).

Energy Supply Options

The energy supply options delivered by the MESSAGE model are expressed in terms of the various types of technologies. Since technology data are highly voluminous (more than 175 technologies for each member economy), a methodology for documenting the differences among them, that did not use economy-level data, was employed. While a number of technologies are generic (data for the generic groups appear in the IRM report), some technologies are specific to individual member economies (information concerning these technologies appears in Volume 2 of the IRM report).

All technologies incorporated into the model were grouped into four categories: (i) conversion from primary to secondary energy; (ii) technologies producing electricity and/or heat; (iii) transportation and distribution technologies; and (iv) end-use technologies (i.e., technologies satisfying useful-energy demand). Detailed parameter values and assumptions for the generic technologies are presented in Appendix 6.

Technological Learning

For many products and services, specific costs decrease due to increasing experience and adaptation. This process is usually referred to as a learning curve (also a progress curve, an experience curve, or learning by doing). In its most common formulation, unit costs decrease by a constant percentage, referred to as the learning rate, for each doubling of experience. Argote and Epple (1990) report a large number of such learning rates in the manufacturing sector, and McDonald and Schrattenholzer (2001) have published a survey of learning rates specific to energy conversion technologies.

The concept of learning rates is non-linear (costs are a non-linear function of cumulative capacity, even before they are multiplied by variables describing new installations). Thus, incorporating learning rates into the MESSAGE model would increase its overall size to a level that could no longer be run on today's computers. Since the concept is very important nonetheless, the "classical" form of technological learning was approximated for purposes of the study, which entailed defining cost reductions over time (instead of as a function of cumulative capacity). A value of 0.985 was uniformly used for all "learning" technologies as a cost reduction factor. More precisely, an annual reduction of specific (per-kW) cost of 1.5% was defined for technologies relating to biofuel production, biomass gasification, coal gasification, coal liquefaction, coal-based methanol, solar photovoltaic, and wind power. The repeated application over 20 years of the annual factor of 0.985 results in a end-value of 0.75, i.e., specific costs of these technologies are therefore 25% less in 2025 as compared to their costs in 2005.

Demand-Side Management and Energy Efficiency

Although not a supply option in the traditional sense, demand-side management must be included in all considerations of energy supply.[11] Energy efficiency as a supply option is integrated into the MESSAGE model in several ways. Most directly, it is included in the definition of energy conversion technologies, which includes a parameter that quantifies the amount of input energy needed to produce one unit of output. For a number of technologies, a decrease in this parameter over time reflects an improvement in energy productivity. Results from runs of the MESSAGE model thus

integrate energy efficiency improvements over time. The challenge for policy makers is to ensure that this actually occurs. Chapter 6 presents an analysis of price and non-price barriers to energy efficiency by country and suggests a project concept for delivering energy efficiency.

Indirectly, energy efficiency also enters into the MESSAGE model in the form of lower useful-energy demand. For example, lower demand for specific electricity in urban households means, *ceteris paribus,* that appliances such as refrigerators are more energy-efficient as compared to a situation of higher demand.[12]

The MESSAGE model optimizes the overall costs of meeting a given level of demand. The model's outputs (or results) provide basic information on how these demands are likely to be met, the final energy mix and primary energy shares, capacities and investments that need to be made to meet these demands over the planning period, and trade and environmental impacts. The best way to analyze the policy impacts of alternative courses of action is to build scenarios that explore future conditions under varying sets of assumptions. It should be emphasized that these are not forecasts, but scenarios,[13] which are detailed inquiries into an uncertain future under a given set of conditions. Energy planning studies have used scenarios to evaluate options and to select ways of dealing with the uncertainty of future challenges.

During the course of the study, many scenarios were constructed to understand the implications of the various policy issues facing the GMS. This paper focuses on four of the most useful scenarios, and the policy implications emerging from their analysis. These four scenarios are the Base scenario, the GMS Integrated scenario, the High Growth-High Risk scenario, and the Low Carbon scenario. The differences in the conditions and assumptions underlying these four scenarios are explained below.

The Four Scenarios

The Base Scenario. The Base scenario shows what will occur if energy sector cooperation among the GMS economies is limited to existing agreements and project investments. This scenario thus optimizes energy supply for each member economy separately. Consequently, indigenous resources are defined in the narrow

sense, and all imports into GMS economies are subject to world market conditions. The Base scenario thus presents results that relate to the case in which energy cooperation is not pursued as an important goal.

The GMS Integrated Scenario. This scenario assumes that the entire GMS is a single energy-economy system. This means that resources are shared in the sense that only their costs are considered and not their prices. It assumes that the economic cost of energy supply is equal to the production and delivery cost of energy rather than the world market price. Energy trade—especially in electricity and gas—requires infrastructure development; the costs of such investments are included as total systems costs.

The High Growth-High Risk Scenario. Based on higher-level demand forecasts, the High Growth-High Risk scenario assumes that overall GMS energy growth will be 7.1% as compared with the 6.0% assumed in all other cases. This scenario indicates that higher demand growth presents higher risks that translate into a greater degree of energy vulnerability and higher environmental costs for the GMS. This scenario provides interesting insights into the risk of higher-than-expected energy demand. Due to limits in the availability of natural resources and the environment's ability to absorb the harmful impacts of increased exploitation of natural resources, the results of this scenario provide quantitative information on multiple impacts of significantly higher energy demand and the risks associated with it. These risks include impacts on the local and global environment, a very high level of energy import dependence, a high level of use of coal, and the financial risks associated with meeting higher energy demand.

The Low Carbon Scenario. This scenario assesses the impacts of internalizing the external environmental and social costs of energy choices. Initial rounds of analysis included several scenarios that were ecologically driven, such as those relating to high and low levels of environmental and social costs, physical targets for renewables as set out in national policy statements, and absence of any large additions to hydropower generation capacity. Given the 20-year planning period of this study, the results indicated very small differences for these several scenarios. It was agreed in the workshops with stakeholders that these scenarios were not worth pursuing further, except for some interesting insights that are discussed below.

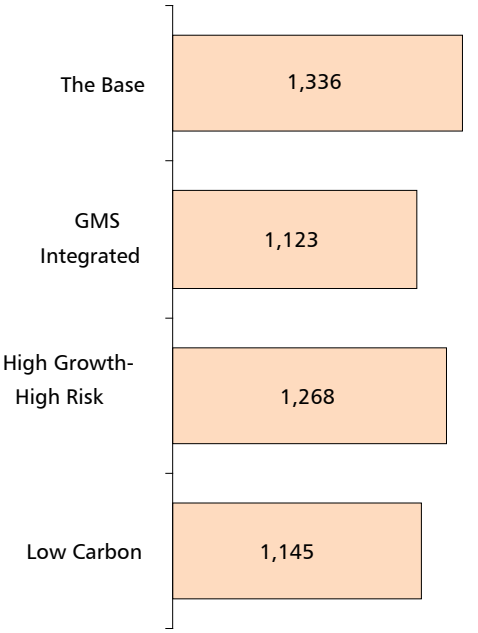
The Results: Looking Ahead

Highlights of the analysis of the four scenarios are summarized below. Detailed results for the GMS as a whole and for individual member economies appear in the main IRM report and the country-level appendix attached in the CD-Rom.[14]

Integration Saves Money. In any optimization study, the first point of interest remains the overall cost of the respective options (Appendix 7). The results from the various runs of the MESSAGE model indicate that regional cooperation reduces overall energy costs. In fact, the stream of discounted costs under the GMS Integrated scenario is more than 19% lower than under the Base scenario (Figure 11). In reality, these savings could be even greater for two reasons. First, overall capacity will probably be lower once bottom-up optimization is carried out to save on margins for reserves. Second, the current analysis is based on a constant 2005 oil price of $50 a barrel. Since the subregion is highly dependent on imported oil, any increase in the international price of oil makes regional integration even more attractive. This point becomes even clearer when the level of oil dependence associated with each of the four scenarios is analyzed. Even the High Growth-High Risk scenario is cheaper by 5% in monetary terms compared to the Base scenario that does not promote energy integration beyond existing levels. These results have important implications for global and subregional public policy in that the GMS will require significant additional resource mobilization if global public goods are to be conserved.

Large Increase in Capacity Required. The model suggests that nearly 238 GW of new generation capacity should be created in the power sector by 2025. Further, the required additional capacity under the GMS Integrated scenario exceeds that of the Base scenario by about 10% (Figure 12). This result is based on top-down optimization across the various energy sectors and does not include detailed power capacity planning, which would necessarily identify savings in peak capacity as well as in reserve margins. When these are taken into account using a bottom-up model, the required increase in overall power generation capacity is for the most part lower in the case of a GMS Integrated power grid than under the Base scenario. As for the overall power capacity requirement under the High Growth-High Risk scenario, it is nearly 30% larger than for the Base scenario.

Figure 11. Discounted Total Costs Under the Four Scenarios ($ billion)

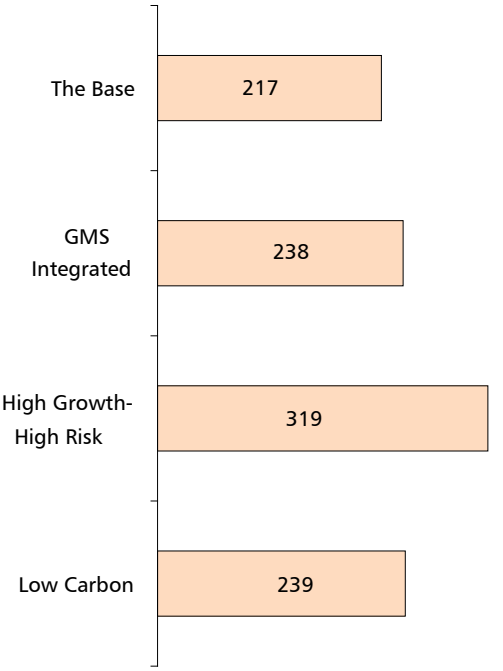


GMS = Greater Mekong Subregion.

Source: Integriertes Ressourcen Management (IRM). 2008. *Economics of Energy Integration: Application of MESSAGE Model in the GMS.* Austria.

Integrating Environmental Costs Improves Overall Outcomes. Though the overall cost of the Low Carbon scenario is somewhat higher than for the GMS Integrated scenario, the discounted environmental costs are lower for the Low Carbon case. Figure 13 shows that integrating the costs of environmental damage into energy choices via a carbon tax lowers the overall rate of consumption of natural capital. Though overall capacity levels for the GMS Integrated and Low Carbon scenarios are similar, the capacity mix is different in both cases when the environmental costs of emissions are internalized. Under the Low Carbon scenario, coal-based power generation is only half the level the GMS Integrated scenario recommends. Against a capacity of 61–71 GW, the Low Carbon scenario recommends only 37 GW of coal-based power capacity. Hydropower capacity is higher by about 11 GW, and gas-based capacity is higher by about 13 GW. Overall capacity

Figure 12. Additions to Hydroelectric Generation Capacity (GW)



GW = gigawatt, GMS = Greater Mekong Subregion.

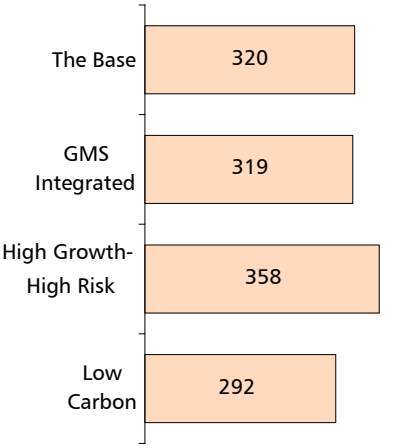
Source: Integriertes Ressourcen Management (IRM). 2008. *Economics of Energy Integration: Application of MESSAGE Model in the GMS.* Austria.

for renewable energy sources and other off-grid solutions is higher by 11 GW under the Low Carbon scenario. Finally, the Low Carbon scenario envisages nearly double the level of investment in decentralized photovoltaic technology as compared with the other scenarios. Even for hydropower plants, it has chosen smaller sizes.

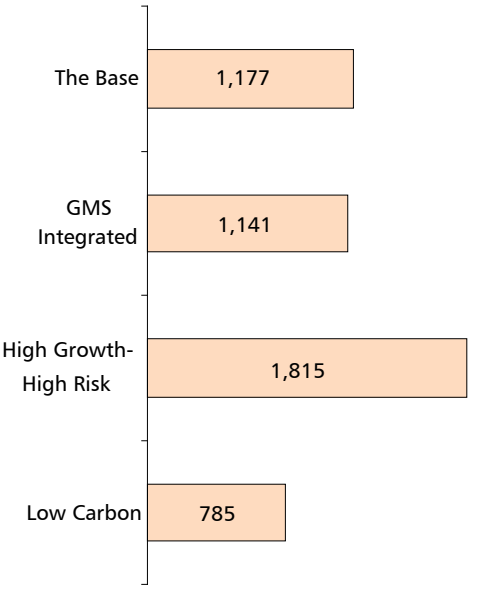
While the subregion's emissions are expected to increase, under all four scenarios the global warming potential (GWP) of GHG grows more slowly on average than GDP (6.3% per year) and total useful energy demand (6.0%). SO_2 emissions grow at an average annual rate even below that of GWP.

In the case of emissions, there are significant differences between the High Growth-High Risk and Low Carbon scenarios. The

Figure 13. Discounted Environmental Costs Under the Four Scenarios ($ billion)



Increase in Emissions (Mt of CO_2 equivalent)



CO_2 = carbon dioxide, GMS = Greater Mekong Subregion, Mt = million tons.
Source: Integriertes Ressourcen Management (IRM). 2008. *Economics of Energy Integration: Application of MESSAGE Model in the GMS.* Austria.

compound annual growth rate of emissions is 4.7% for the Low Carbon scenario and 7.8% under the High Growth-High Risk scenario (Figure 13). Thus, carbon emissions are nearly 45.0% lower under the Low Carbon scenario than under the High Growth-High Risk scenario. Similarly, carbon emissions under the High Growth–High Risk scenario are nearly two thirds higher than for the GMS Integrated scenario. The GMS Integrated energy scenario uses 11% more nonconventional sources of electric power capacity as compared to the Base scenario.

Integration Reduces Energy Vulnerability. By integrating the GMS energy sector, it is possible to reduce overall energy dependence vis-à-vis the rest of the world by as much as 5.5% of total energy consumption. In the case of individual fuels, the gains are much more substantial (Table 15), with the most significant impacts occurring in oil dependence. Against 56% import dependence under the Base scenario, the level of import dependence for the GMS Integrated scenario is only 44%. In fact, lower oil consumption under the GMS Integrated scenario is one of the major reasons for its lower overall cost as compared to the Base scenario. A second reason for its lower cost relates to regional refinery capacity. As Table 15 indicates, overall import dependence for light petroleum products is also lower in the case of cooperation. Figure 14 shows that while dependence on the rest of the world declines for most fuels, GMS imports rise over the period 2005–2025.

Table 15. Fuel Use and Import Dependence

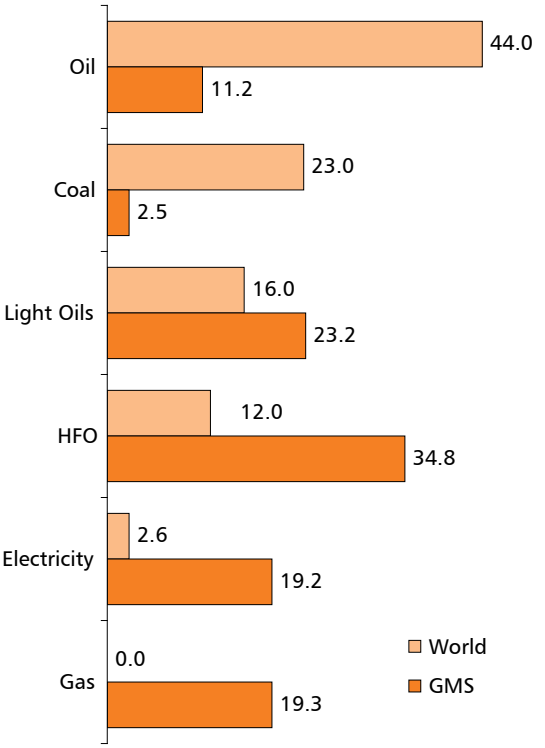
Fuel	Fuel Use (EJ)		Import Dependence[a]	
	Base	GMS Integrated	Base (%)	GMS Integrated (%)
Coal	129	126	26	23
Oil	124	118	56	44
Light oil products	85	80	28	16
Electricity	47	48	7	3
Gas	39	36	20	0
Heavy fuel oil	14	15	24	12

EJ = exajoule 10^{18}, GMS = Greater Mekong Subregion.

[a] Defined as % of total fuel use.

Source: Integriertes Ressourcen Management (IRM). 2008. *Economics of Energy Integration: Application of MESSAGE Model in the GMS.* Austria.

Figure 14. Percentage Share of Imports in Total Energy Consumption, 2005–2025



HFO = heavy fuel oil.

Source: Integriertes Ressourcen Management (IRM). 2008. *Economics of Energy Integration: Application of MESSAGE Model in the GMS.* Austria.

High Risks Associated with High Energy Demand Growth. Under the High Growth-High Risk scenario, overall energy consumption is greater by 38%, and as much as 51% for coal and 40% for crude oil, as compared with the Base case or the GMS Integrated scenario. Similarly, under the High Growth-High Risk scenario, the required addition to electricity generation capacity is greater by one third to one half (nearly 75 GW to 100 GW) as compared with the Base and GMS Integrated scenarios. Given the existing subregional resource base, reaching the 125 GW capacity required under the High Growth-High Risk scenario implies a doubling of coal-based power capacity and nuclear capacity of 16.8 GW. These levels for coal-based and nuclear power capacity are twice those projected to be required

under all other scenarios. The financial requirements for meeting such a level of energy development are at least 40% higher than for the Base and GMS Integrated scenarios, and result in approximately 60% more CO_2 emissions. SO_2 emissions are expected to increase to 260% of current levels if the demand conditions for the High Growth-High Risk scenario materialize.

Other Scenarios

At earlier stages of the study, additional scenarios were included in the analysis. One of these assumed that the GMS would move to coal as a major source of power generation. The assumption was that if large hydropower capacity was not available, or it was constrained for other reasons, the subregion would replace hydropower with coal on a one-to-one basis. As expected, this led to higher levels of emissions. In that sense, the analysis suggests that in energy use, there are trade-offs between local and global impacts.

Price Sensitivity. The manner in which price sensitivity analysis was carried out in runs of the MESSAGE model needs some explanation. Demand price–responsiveness means that at any point in time, the quantity of a given good or service that is demanded is determined by the per-unit price charged. Further, the degree to which the quantity demanded falls in response to a 1% rise in price is referred to as the "price elasticity of demand". Given the paucity of quality time-series data relating to useful energy services, calculating a value for the price elasticity of demand for useful energy services in the GMS was not attempted. Instead, an estimate based on an energy literature survey was used. After analyzing existing elasticity data, and considering that the logic of the MESSAGE model suggests the use of short-term elasticities, a value of –0.20 was assumed to correctly describe the price elasticity for all useful-energy demand sectors. Several cases were re-run during the price sensitivity analysis. In these cases, the values for demand under the GMS Integrated scenario were used as the point of departure. Runs of the MESSAGE model require that each demand sector, each time period, and each GMS member economy have a shadow price of energy attached to it. Thus, for each time period following 2009, a price elasticity of –0.20 was applied to each relevant shadow price to calculate future demand in all useful-energy demand sectors. Finally, the levels of demand were changed and the model re-run. Integrating price elasticity of demand into

the overall model confirmed that prices do matter in that higher prices result in lower overall energy costs. Since the source of marginal units of energy supplied is imports both under the Base and GMS Integrated scenarios, changes in price have little impact on useful-energy demand under the Low Demand scenario. Under the Low Carbon scenario, the overall impact was a bit more than 2% greater than the value produced by application of the elasticity in the Base scenario.

Targets for Renewables vs. Price. An Enhanced Share of Renewables scenario was modeled using specific national targets for renewables announced in various policy statements over the previous five years by the individual GMS member economies. Two of the results from the run of this scenario are notable in the context of the section below on policy analysis. First, introducing such targets implies additional costs. In particular, overall discounted costs were higher by 2.5% than in the case in which targets were not introduced. Second, when specific targets are introduced for a segment of the energy system, overall costs rise, but emissions of GWP do not necessarily fall. On the other hand, even when the lower-level estimates of the costs of environmental damage were used, the overall energy mix and its impact on the environment were more favorable.

Runs of the model suggest that penalizing CO_2 emissions cause the latter to fall by nearly 14% as compared to the case in which targets are introduced for renewables. In fact, overall coal usage was higher by nearly 20% when renewable targets were introduced, as compared to the case in which environmental damage costs were internalized by penalizing CO_2 emissions.

While wind power targets led to a higher level of wind-based electricity production, the overall share of solar and other environment-friendly technologies was much lower under the scenario in which targets were introduced as compared to the Low Carbon case. Finally, by internalizing environmental costs, overall final energy use was 5% lower, implying that the model chooses more efficient technologies. The relevant policy implication is that taxation and pricing are better instruments for curtailing emissions and improving overall energy choices than are specific renewable technology targets.

High Oil Prices. At the end of study, a number of government officials and other stakeholders requested that a run of the model be undertaken to assess the economic viability of subregional

integration under a scenario of elevated world oil prices. A price of $50 per barrel of oil equivalent (/boe) measured in constant 2000 dollars was used to calculate a simulated rise in the price of oil to $85/boe for 2006. As expected, the results from this run of the model suggest that the benefits of subregional integration are greater under the High Oil Price scenario.

5

Energy Trade under the GMS Integrated Scenario

The energy optimization model shows that promoting energy sector cooperation could result in a reduction of total discounted energy costs for the GMS of $200 billion, or 19% of total energy costs. These benefits are significant when compared to the current GDP of the GMS economies, which range from $3.4 billion for Lao PDR to $206 billion for Thailand. Such large gains are possible for three reasons: (i) the GMS is facing large increases in energy demand over the coming years; (ii) natural resource endowments across the subregion are diverse and thus complementary; and (iii) given the economies of scale relevant to the GMS, as the subregion develops its energy infrastructure, the least-cost means of meeting one member economy's energy demand will often be to import from a neighbor.

Ensuring efficient trade flows and production of electricity is particularly important since under a scenario of cooperation, 19.2% of total GMS electricity consumption will be met from trade within the subregion. Similarly, almost the entire gas consumption requirement will be met from production within the GMS by 2025. Trade in coal and oil, on the other hand, will predominantly occur with non-GMS countries. However, the model indicates that a much higher level of refining activity will take place within the region. Thus, substantial flows of petroleum products are expected to occur across the GMS.

But how can the modeled benefits of cooperation be realized in practice? What does cooperation mean for the GMS at a practical level? Is it only the lack of physical infrastructure that inhibits realization of these substantial gains, or are concerted actions necessary to enhance energy integration?

Generally, efficient trade and production enabled through regional integration creates benefits for both producers and consumers. However, efficient trade and production are possible only if energy-sector entities, together with the governments of all GMS economies, are able to pursue value-creating opportunities in the absence of external barriers and restrictions. This implies that support of such efforts by existing institutions and policy regimes is a precondition to achieving the benefits potentially accruing from cooperation. This chapter analyzes policies and institutions that promote energy cooperation, to achieve a sustainable energy future for the GMS.

Except for Myanmar's small quantity of gas exports to the world market, the GMS will remain a net energy importer. At present, the GMS imports 17% of its total primary energy consumption, which is projected to grow to 25% of total consumption by 2025. The model suggests that by that year, electricity will account for 18.3% of total GMS energy consumption, having increased from 12.3% in 2005. Crude oil and petroleum products will continue for the most part to be imported from outside the subregion.

Electricity Trade under the GMS Integrated Scenario

Under the GMS Integrated scenario, trade in electricity increases across virtually all national borders in the subregion, with Cambodia, Lao PDR, and Myanmar becoming key power exporters. By far, the largest single projected increase is seen to take place in Myanmar's electricity exports to Thailand. Similarly, electricity exports from Lao PDR to Thailand and Viet Nam increase by as much as 26 times their 2005 levels. The model likewise sees substantial new electricity exports from Cambodia to Thailand (1,173 MWyr) and Viet Nam (436 MWyr) per year. Table 16 summarizes the direction of trade in cross-border flows of electricity within the GMS at present.

Overall, the GMS will need more than 190 GW of additional generating capacity from conventional sources, with the total capacity requirement reaching 228 GW over the model's time horizon. This suggests significant increases in nuclear and other nonconventional electricity generation sources such as municipal waste, biomass, solar, geothermal, and wind power (Figure 15). Once hydro and gas options have been exhausted, the subregion will have to adopt coal-based power generation.

Table 16. Electricity Flows in the GMS

Large-scale flows
From Cambodia to Thailand
From Cambodia to Viet Nam
From Myanmar to Thailand, and
Between Yunnan and Viet Nam (both directions)
From Lao PDR to Thailand
From Lao PDR to Viet Nam
Small-scale flows
Between Viet Nam and Guangxi
Between Viet Nam and Cambodia
Between Viet Nam and Lao PDR
Between Lao PDR and Cambodia
Between Lao PDR and Yunnan

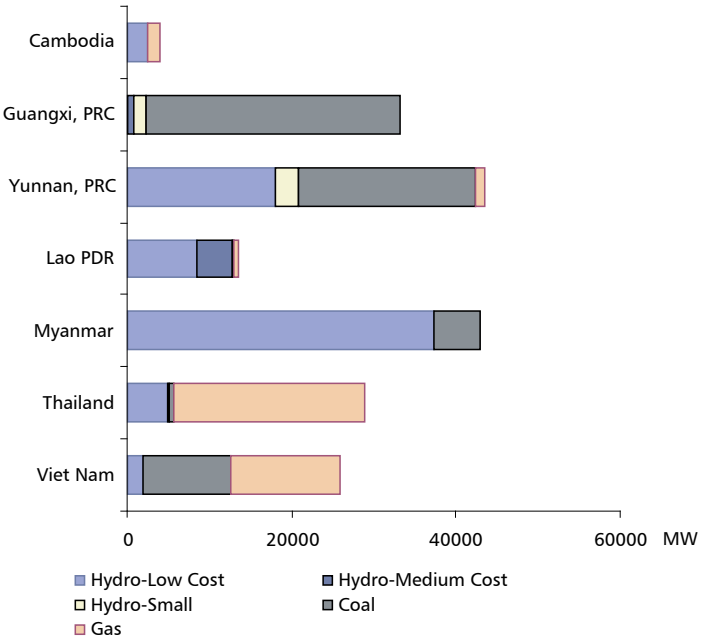
GMS = Greater Mekong Subregion, Lao PDR = Lao People's Democratic Republic.
Source: Castalia Strategic Advisers. 2008. *Promoting Greater Cooperation through Private Sector.* Wellington: Castalia.

The model also sees development of several limited cross-border flows, presumably to supply off-grid rural areas. Despite their small scale, some of these flows have been identified as priorities, simply because rural electrification is already an important subregional priority. However, for these flows to be realized, significant investment in electricity transmission facilities will be required. Under such a scenario, Guangxi, Thailand, and Viet Nam would be net importers of electricity, while Cambodia, Lao PDR, and Myanmar would be net exporters. However, realizing this objective requires that the latter three countries invest in generation capacity at levels well above that required to meet domestic demand.

Clean coal technology is not a least-cost option for the subregion, even under the Low Carbon scenario when it includes carbon and other damage costs. This has important global and regional public policy implications because use of clean coal technology in the GMS region would require global financial support (either directly or through clean-energy development funding mechanisms). Otherwise, such a large coal-based, business-as-usual approach would become a binding constraint on sustainable development.

Figure 16 illustrates the changes in electricity trade flows and production envisaged by the model to take place between

Figure 15. Projected Additional Electricity Generation Capacity in the GMS



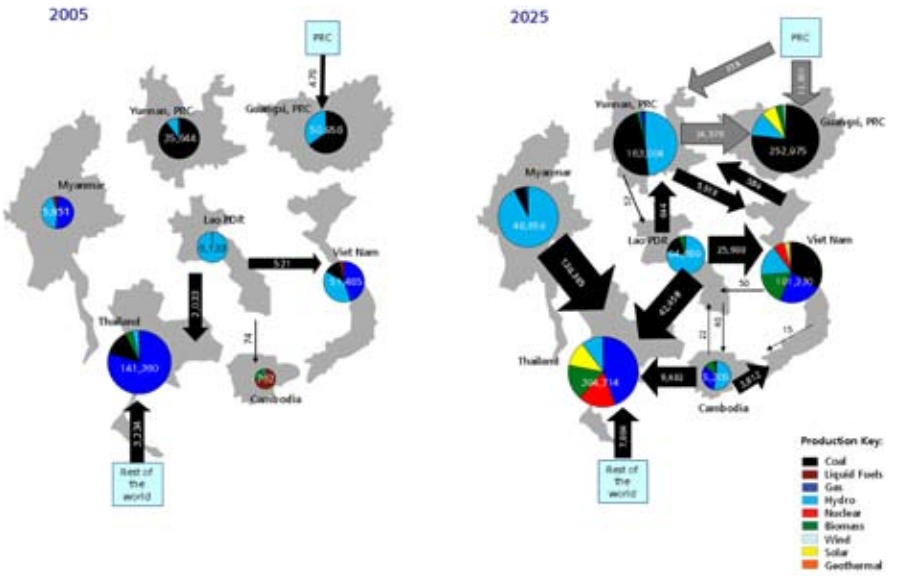
GMS = Greater Mekong Subregion, Lao PDR = Lao People's Democratic Republic, PRC = People's Republic of China.

Source: Integriertes Ressourcen Management (IRM). 2008. *Economics of Energy Integration: Application of MESSAGE Model in the GMS.* Austria.

2005 and 2025 under the GMS Integrated scenario. The arrows depict the trade flows, with the size of each arrow indicating the magnitude of the flow in question. The pie charts for the member economies represent electricity production, with the size of each pie depicting the level of internal electricity generation. The various colored segments of the pie charts represent the shares of each source of domestic power generation as envisaged by the model. The information for 2005 depicted by Figure 16 reflects the fact that currently the only electricity trade flows in the GMS are from Lao PDR to Thailand, with limited amounts of power flowing from Lao PDR to Cambodia and Viet Nam.

Under the GMS Integrated scenario, Thailand becomes the dominant importer of electricity in the subregion, with the bulk

Figure 16. Electricity Production and Exports within the GMS, 2005 and 2025 (GWh)



GWh = gigawatt-hour, GMS = Greater Mekong Subregion, Lao PDR = Lao People's Democratic Republic, PRC = People's Republic of China.

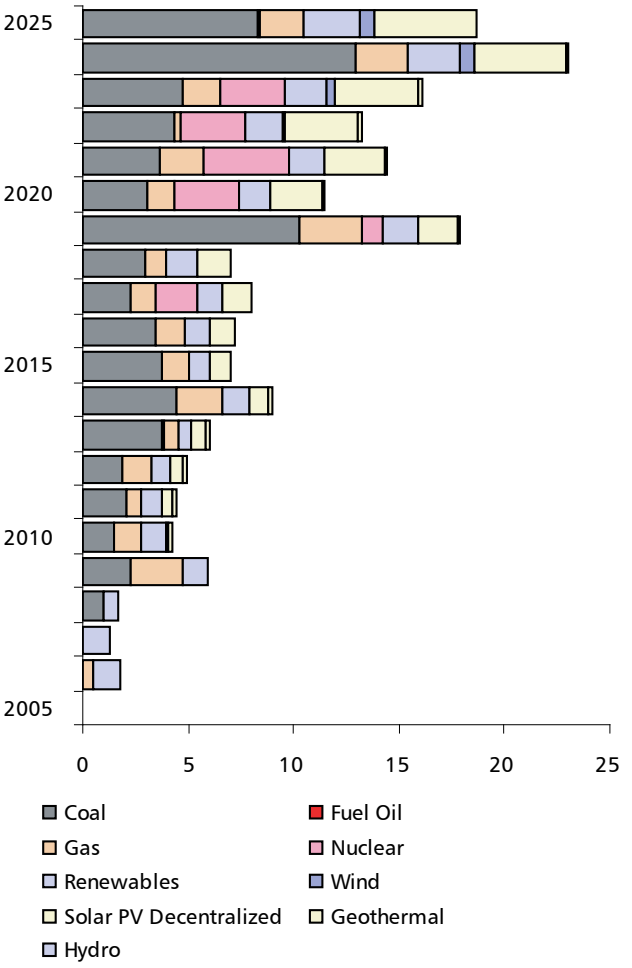
Source: Castalia Strategic Advisers based on Integriertes Ressourcen Management (IRM). 2008. *Economics of Energy Integration: Application of MESSAGE Model in the GMS.* Austria.

of its imports primarily coming from Myanmar, though Lao PDR and Yunnan likewise increase their exports to Thailand. Aside from Thailand, Guangxi and Viet Nam also become major importers. With the envisaged massive increase in electricity imports by Thailand, imports become the largest single contributor to total GMS electricity supply, reaching a 44% share in 2025.

It should be noted that the latter level of import dependence is lower than in earlier runs, mainly because of comments received from Palang Thai, a non-profit organization. In response to their comments, overall demand for electricity in 2025 in Thailand was assumed to be significantly lower than under earlier growth assumptions, with total demand amounting to 54 GW instead of 65 GW. Even under this more conservative assumption, the additional capacity required to produce the amount of electricity

indicated suggests investments by the subregion in the range of $240 billion over the period. Note also that in the case of electricity, trade flows require not only supply (generation) and demand, but also transmission links and other related infrastructure capable of efficiently moving large amounts of electricity from one GMS economy to another (Figure 17).

Figure 17. Projected Electricity Investments in the GMS, 2005–2025 ($ billion)



GMS = Greater Mekong Subregion, PV = photovoltaic.

Source: Integriertes Ressourcen Management (IRM). 2008. *Economics of Energy Integration: Application of MESSAGE Model in the GMS.* Austria.

Decentralized and Off-Grid Electricity

Under the GMS Integrated scenario, off-grid, decentralized power generation capacity could become cost effective. However, since the overall cost of decentralized capacity depends on location-specific factors, further studies would be required to determine feasibility in each particular case. Currently, at least two GMS economies actively support rural electrification through off-grid generation. Cambodia's national policy for rural electrification aims to achieve access to electricity for all villages in the country by 2020. Lao PDR has set a 90% electrification target, having identified rural electrification as integral to national development. Lao PDR has likewise established initiatives to promote off-grid generation to serve rural communities.

Commercial off-grid projects driven by small investor-owned businesses are also underway. Both Cambodia and Lao PDR have only recently begun to develop their abundant mini- and micro-hydropower generation potential. For example, in 2007, construction of two 175 kW hydroelectric power stations began in Cambodia's Mondulkiri province.[15] Mini- and micro-hydropower can also be combined with other electricity sources such as photovoltaic systems, wind, diesel, biodiesel, and biogas, as evidenced by the installation of a hybrid system under a public–private partnership in Lao PDR's Xiengkhouang province in April 2007. The system comprises 15 kW of hydro, 15 kW of diesel (the latter with the capability of running on biodiesel), and 1.84 kW of photovoltaic generation.[16]

Natural Gas Trade under the GMS Integrated Scenario

Natural gas is, and will continue to be a major source of electricity generation in the GMS, accounting for 15% of total electricity production by 2025. New natural gas generation capacity will most probably be almost exclusively in the form of combined-cycle gas power plants, due to their greater energy efficiency. GMS natural gas resources are spread fairly evenly across member economies. Since all GMS trade in natural gas occurs within the subregion, no imports originate from outside the grouping. At present, Myanmar is the only GMS exporter (given the current uncertainty surrounding Cambodia Gas). The model sees Thailand as dominating GMS

imports of natural gas by far, with Lao PDR importing small amounts of gas during most years that comprise the model's time horizon. If Cambodia Gas supplies come on stream, Thailand will import additional gas and lower its electricity imports by creating value within its domestic economy. Thus, additional value for Cambodia from its natural gas resources would be forthcoming only if the necessary infrastructure to allow export of power rather than gas is put into place during the planning period.

The present gas transportation infrastructure within the GMS is quite limited. However, there is large potential for expanding gas trade in the subregion. Individual projects for developing pipelines and other relevant infrastructure have been identified. In January 2007, China National Petroleum Corporation signed production contracts with Myanmar's Ministry of Energy to allow crude oil and natural gas exploration projects in three deep-water blocks off the western Myanmar coast. As a result, the PRC's three state-owned oil producers—China National Offshore Oil Corporation, China National Petroleum Corporation, and China Petroleum and Chemical Corporation—are all implementing oil and gas exploration projects in Myanmar coastal waters.[17] A feasibility study by China National Petroleum Corporation and Myanmar Oil and Gas for construction of a gas pipeline from Myanmar to Yunnan is also being prepared. Reportedly, the pipeline will be capable of transporting 170 bcm of natural gas per year in the next 30 years. While a timetable for completing the construction is not available in the public domain, the PRC reportedly plans to invest over $1 billion in the 2,380 km gas pipeline that will run from Myanmar to Kunming. The current approach to expansion of natural gas production and trade remains bilateral in that it is based on individual projects, in the absence of a regional strategic framework.

Trade—Other Energy Sources

Coal. The GMS has formal and informal trade links in place for all energy products that do not require dedicated infrastructure for such exchanges. Thus, coal, crude oil, and petroleum products are already traded throughout the GMS, and this trade is expected to grow during the model's time horizon. About a quarter of the coal used by the subregion will continue to be imported over the coming 20 years. While initially, the model sees Viet Nam as a net coal exporter, domestic consumption of coal in Myanmar and Viet Nam is seen to increase by 2025. As a result, Viet Nam will consume all

domestically produced coal internally, while exports from Myanmar will fall substantially. Imports of coal to Guangxi from the other PRC provinces will likewise increase substantially over the period. In the absence of cooperation, consumption and imports of coal increase slightly for Guangxi, Thailand, and Viet Nam, possibly to accommodate additional electric power generation by coal-fired power plants.

Crude Oil and Petroleum Products. Since the GMS lacks adequate refining capacity, crude oil is currently exported and refined products imported in the region. Under the GMS Integrated scenario, all imports of crude oil will come from the rest of the world by 2025. Large importers such as Guangxi, Thailand, and Viet Nam will import less crude oil for internal refining, but will import larger amounts of light oil products. Assuming cooperation, the largest shift in trade flows in 2025 will result from Cambodia's becoming a major exporter of light oil products; however, this presupposes investment in refining capacity sufficient to capitalize on recently identified oil reserves. In addition to Cambodia, Myanmar and Yunnan increase their export of light oil products over the model's planning horizon.

The implication of the above changes is that it is in the subregion's interest to invest in refining capacity. Overall investment in refining capacity is thus estimated to exceed $50 billion over the coming 20 years. Recognizing the need to invest in crude oil refining capacity, Viet Nam has begun construction on the country's first refinery (Dung Quat), which is scheduled to become operational in 2009. Plans to build two more refineries, which would result in a total capacity of 20 million tons per year are being accelerated, the objective being for Viet Nam to be 60% to 70% oil-self-sufficient by 2020. The Government of Viet Nam plans to lower crude oil exports to ensure sufficient supply of oil for domestic industry, and to reduce reliance on petroleum imports.

Others. The current volatile international prices of oil and natural gas have led to increased interest in clean coal technologies such as gasification, methanation, and liquefaction.[18] Gasification is an important option for future energy use, as the syngas[19] produced by the process can easily be cleaned, which translates into cleaner combustion as compared to direct burning of coal. Coal can also be converted into liquid fuels such as gasoline or diesel via several processes.

The Fischer–Tropsch (FT) process of indirect synthesis of liquid hydrocarbons has been used in Germany for many years and is today used by SASOL in South Africa. Given the use of the FT process, liquefaction plants in the United States become cost competitive when crude oil prices exceed $35 per barrel. Given the latter statistic, the model uses a coal liquefaction cost of $70 per barrel of oil, which takes into account the cost of transporting coal, the cost of importing technology from high-cost countries, and the cost of putting environmental safeguards into place. As this cost is above the current price of oil of $55 per barrel (at the time of writing of this report), coal liquefaction may not be a viable alternative to oil in the short term. However, if the future price of crude oil remains above $70 per barrel over an extended period, coal liquefaction could become cost effective over the long term. The model assumes a ceiling on the market penetration rates for synthetic fuels since the environmental implications for the technology still need to be fully understood.

6

A Shared Energy Future: What Will It Take?

The GMS is one of the world's most successful regional cooperation initiatives and is evolving as a major regional block. Much of its success is due to two factors: the robust economic rationale that underlies it, and the strong political ownership that is shared by the leadership of the GMS economies. As regards energy cooperation, the focus thus far has been to establish a sustainable and efficient GMS energy supply market.

The optimization exercise summarized in Chapter 4 makes a strong case for integrating the GMS energy sector from both the economic and the environmental perspective. The results from numerous interrelated runs of the MESSAGE model that formed the core of the optimization exercise suggest that reaping the full benefits of a shared energy future will require the subregion to invest $585 billion in power generation capacity and other initiatives for energy transformation and use over 2005–2025. This translates into an annual average investment of about $30 billion.

The reality is that there are multiple barriers to GMS energy integration, and that these have major impacts on the actual level of investment achieved, the pattern of energy use, and overall environmental parameters within the subregion and beyond. These barriers to energy integration occur in numerous dimensions and include (i) macroeconomic barriers, (ii) energy policy asymmetries, (iii) a widely varying level and pace of energy sector development, (iv) a difficult regulatory environment that arises from a lack of a consistent legal framework, (v) limited human and institutional capacity, and (vi) limitations on market structure.

This chapter, which examines some of these barriers in detail, focuses on identifying policy actions necessary to achieve a shared GMS energy future that is economically and environmentally sustainable.

Four specific areas relating to policy are analyzed: (i) electricity integration, (ii) natural gas integration, (iii) a regional approach to energy efficiency, and (iv) regional approaches to achieving access to electricity for all. The rationale underlying the topics chosen is that regional integration in these four areas would result in realizing maximum benefits for the subregion from energy integration. Two additional areas relate to development of regional petroleum refining capacity and removing barriers to trade in petroleum products.

There are many levels of regional cooperation in the energy sector. For commodities such as crude oil, petroleum products, and coal that do not require special mechanisms for transport over long distances, the benefits from international trade that accrue to producer and consumer economies alike provide a natural impetus that drives such exchanges. However, this presupposes absence of both tariff and non-tariff barriers. Thus, to ensure the full benefits that accrue from free trade in energy commodities across international boundaries within the GMS, the subregion's trade policy must focus on removing all barriers to trade in these commodities.[20] Less obvious in this regard are price distortions such as subsidies (as in the case of coal in Viet Nam) that form barriers to trade and thus need to be removed if the GMS is to achieve the full benefits of energy integration. It is possible to achieve regional energy integration through market forces for energy carriers that do not require special or dedicated networks once price and non-price barriers are removed. Once these barriers are removed, the private sector would be able to create value from trade opportunities in these energy commodities without further intervention from governments.

For energy carriers such as natural gas and electricity that do require dedicated transport and distribution networks, integration requires much more time and effort, as well as a greater degree of international cooperation.[21] Because network connectivity is a regional public good, market efforts will need to be supported and supplemented with appropriate government and policy actions. In the absence of the appropriate support, the optimum level of network connectivity will not occur. Electricity integration or gas grids require extensive interconnection of networks, harmonization of operational standards, system codes, institutional mechanisms, and human capacity to benefit from such exchanges.

Several levels of integration are possible and in use across the world for electricity and gas network integration. Bilateral exchanges across national boundaries occur provided there are opportunities for trade such as an energy surplus in one country and unmet

demand in the other, agreement on prices, and availability of appropriate physical infrastructure.

Such exchanges can be opportunistic or take place via long-term contracts. Currently, numerous bilateral exchanges of both types occur within the GMS. Natural gas is traded bilaterally across the subregion through long-term contracts, and numerous projects that will increase the aggregate volume of such exchanges are in various stages of implementation. However, the majority of these exchanges that currently take place occur in only one direction.[22]

The first phase of integration of the GMS market for electric power required (i) confirming that there are gains from trade in electricity that benefit the subregion, (ii) generating widespread ownership of electric power integration, and (iii) drafting a policy framework. All three steps were completed via a series of meetings at various levels. The result of all of these efforts was the signing of the GMS Intergovernmental Agreement for Power Trade (IGA) by all six economies in 2002. In November 2003, the IGA came into force with its ratification by three member countries. Ultimately, all GMS member economies ratified the IGA.

The second phase of integration of the GMS market for electric power involved identifying interconnection transmission projects. This occurred at the Leaders' Summit held in Vientiane in April 2008. The output of the summit was the Vientiane Plan of Action, which endorsed four strategic thrusts for Stage I of regional power trade development, and addressed the infrastructural and institutional arrangements necessary for supporting interconnection. A memorandum of understanding (MOU) regarding the concrete steps to be taken in implementing cross-border trade in electricity within the GMS was signed as part of the Vientiane Plan of Action for Energy (Appendix 8).

Improving the Overall Policy Environment

The GMS's ability to achieve a shared, sustainable energy future will largely be determined by the manner in which existing barriers to energy integration are addressed, and how well the market forces driving integration are enabled. This section analyzes these factors.

As important as appropriate national and international policies are in facilitating regional energy integration, an equally important factor that must not be overlooked is the macroeconomic environment in each member economy. In this regard, the following are of particular importance: (i) fiscal management and monetary conditions, since these influence the ability of government to finance required investments within and outside the energy sector; (ii) the business climate, which determines the level of attractiveness of the destination economy to internal and external investors; and (iii) the degree to which conditions are favorable for business activity, since this can either constrain or drive the integration process. In sum, an appropriate macroeconomic environment is essential to attract investment in energy projects and ensure smooth and efficient international trade in energy.

Results from multiple runs of the MESSAGE model indicate that 2% to 30% of current GDP is necessary to finance the investments necessary to achieve GMS energy integration, the actual level depending on the economy in question (Table 17). For Guangxi, Thailand, Viet Nam, and Yunnan, the level of investment required is equivalent to only a small share of GDP. However, in the case of Cambodia, Lao PDR, and Myanmar, the percentage of GDP required to undertake the level of investment required is much higher. Nevertheless, if GDP levels are adjusted for estimated growth rates, the share of GDP required to fund such investments is not particularly high. The only exception to this is Lao PDR, which required energy-sector investments that amount to more than 8% of GDP over the long term. Given that some member economies have large ongoing infrastructure expenditure programs, these levels of investment are not particularly excessive, provided that their current economic growth momentum continues.

The source of funds required for energy integration investments can be either the government or the private sector. In this regard, public investment requires as sound an economic environment as does private investment. This is so because if the necessary fiscal space is not available, governments cannot finance large-scale deficits for energy investments. A detailed economy-level analysis of the GMS policy environment is presented in a report prepared by a team of consultants from Castalia Strategic Advisers (Castalia) under Technical Assistance 6301 (Regional Analysis of the Policy Environment in the GMS). Castalia also surveyed perceptions of the GMS investment environment (Appendix 9). The analysis in this section draws from this report.[23]

Table 17. Energy Investments Required for Energy Integration in the GMS Over 2005–2025

Economy	Electricity	Total	As % of 2006 GDP (%)	As % of Long-Term GDP (%)
	$ million			
Cambodia	167	735	12.2	2.8
PRC				
Guangxi	2,271	2,995	4.9	0.9
Yunnan	1,793	2,732	5.5	1.0
Lao PDR	760	919	30.6	8.5
Myanmar	1,354	1,593	13.3	3.7
Thailand	3,129	3,705	2.2	0.6
Viet Nam	2,045	2,935	6.1	1.2

GMS = Greater Mekong Subregion, GDP = gross domestic product, Lao PDR = Lao People's Democratic Republic, PRC = People's Republic of China.

Sources: Integriertes Ressourcen Management (IRM). 2008. *Economics of Energy Integration: Application of MESSAGE Model in the GMS.* Austria; ADB estimates.

Most private investors surveyed by Castalia made it clear that their perception of an economy's overall economic environment was critical. If they perceived an economy as having a poor overall economic environment, then they would not consider it as an investment destination. Table 18 summarizes key indicators for three aspects of the overall economic environment in each of the GMS economies.

Since the inception of the GMS economic program, the subregion's GDP has grown at an average annual rate of 7.1% despite several adverse exogenous shocks, including a full-blown regional financial crisis, a devastating tsunami, and outbreaks of avian influenza and severe acute respiratory syndrome (SARS). After 2003, the overall rate of growth for the GMS rose above 8%. However, the subregion's laudable growth performance masks wide variations in national GDP levels that vary from $3.4 billion for Lao PDR to more than $200 billion for Thailand. While the GMS economy is dominated by Thailand, economic expansion in Guangxi, Viet Nam, and Yunnan is so rapid that these three economies are well on their way to becoming economies of substantial size. Although inflationary pressures in some member countries have increased because of a persistent rise in the international prices of crude oil and food, inflation rates remain at single-digit levels as national monetary policies have become more restrictive and the fiscal stance of the member economies has remained stable (with the exception of Myanmar). The subregion's degree of trade openness is both high and rising.

Table 18. Overall Economic Environment for Sustainable Growth in the GMS

Economic Aspect	Indicator	Cambodia	PRC		Lao PDR	Myanmar	Thailand	Viet Nam
			Guangxi	Yunnan				
Macroeconomic Environment								
Size of Economy (2006)	GDP$ billion	7.3	60.8	50.3	3.4	12	206	61.0
Economic Growth(2002–2006)	% per annum	9.7	11.9	10	6.6	*13.2*	5.6	7.8
Fiscal Space (2002–2006)	as % of GDP	(4.4)	*(8)*	*(12.8)*	(6.1)	*(5)*	(0.1)	(4.3)
Fiscal Space, Debt Service	External debt	83%	32%		486%	219%	39%	52%
Monetary Stability (2002–2006)	Annual inflation rate	3.8	..	..	10.1	24.4	2.9	6.1
Trade Openness	as % of GDP	107.8	9.4	10	49.1	..	115.6	121.4
Investment Environment								
FDI Level	$ million	475	379	174	650	*236*	7,978	2,315
FDI as % of GDP	as % of GDP	7.5%	0.7%	0.3%	26.0%	2.0%	4.8%	4.8%
Private Sector in Energy	Is it enabled?	Yes	Somewhat		Somewhat	Somewhat	Yes	Somewhat
Current PPP (2002–2006)	$ million	54	..	..	1,250	..	1,609	2,192
	No. of projects	2	..	..	1	..	..	3
Ability of Local Capital Markets		Low	High		Low	Low	High	Medium
Overall Attractiveness								
Doing Business Ranking	2007 ranking	145	*PRC 83*		164	..	15	91
TI Corruption Index Ranking	2007 ranking	162	*PRC 72*		168	179	84	123
Logistic Performance	2007 ranking	81	*PRC 30*		117	147	31	53

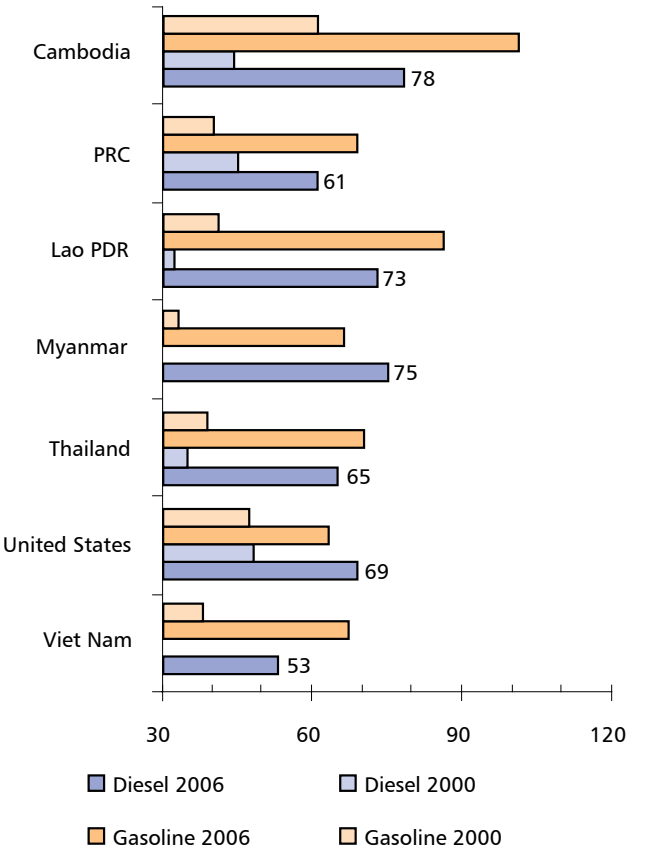
.. = data not available, ( ) = negative value, FDI = foreign direct investment, GMS = Greater Mekong Subregion, GDP = gross domestic product, Lao PDR = Lao People's Democratic Republic, PPP = public–private partnership, PRC = People's Republic of China, TI = Transparency International.

Note: Figures in italics represent the latest year available.

Source: Castalia Strategic Advisers. 2008. *Promoting Greater Cooperation through Private Sector.* Wellington: Castalia, for some indicators; ADB staff estimates for others; World Bank (2007), Myanmar data are up to 2005 only.

For the most part, the subregion's member-economy policy regimes for attracting foreign direct investment (FDI) are fairly open, and as a result, FDI flows are expanding. However, most private-sector FDI flows into the manufacturing sector. Private-sector FDI in energy is limited, except for large-scale initiatives such as the Nam Theun project. As a result, the public sector undertakes most energy-sector investment in GMS member economies. However, the ability

Figure 18. Retail Fuel Prices in the GMS (US cents per liter)



GMS = Greater Mekong Subregion, Lao PDR = Lao People's Democratic Republic, PRC = People's Republic of China, US = United States.

Source: German Technical Cooperation Agency (GTZ). 2008. *International Fuel Prices 2007 5th Edition.* Germany.

of member governments to continue financing growing energy infrastructure requirements is not limitless. Ultimately, it depends on the "fiscal space" available to each.

Fiscal space refers to the ability of a government to increase expenditure or borrowing as a means of funding investment. Two of the most commonly used indicators to measure fiscal space are the government's annual budget deficit or the debt-to-GDP ratio for the economy in question. For all member economies with the exception of Thailand, the fiscal space is somewhat limited as central government deficits remain above 3% of GDP. In this regard, Guangxi and Yunnan are somewhat different since available data at the provincial level are not strictly comparable with national statistics.[24] Energy subsidies both constrain fiscal space and in a strict economic sense, distort prices. Compared to 2000, overall cost recovery has improved, in part due to the high international price of oil over the past few years, since this is analogous to a decrease in the overall level of implicit subsidy within an economy. As for explicit energy subsidies, while most GMS economies do not subsidize gasoline, diesel is subsidized to some degree as a means of curtailing inflationary pressures (Figure 18). Significant subsidies exist for power and natural gas, and this no doubt influences the overall fiscal space available to finance additional investment in the GMS energy sector.

While the overall macroeconomic environment affects the investment climate in all economic sectors, energy-sector policy regimes influence choices relating to fuel consumption, production and technology, investments, and trade. In the next section, sector-specific policy and institutional barriers relating to integration of the GMS energy sector are discussed.

Electricity Sector: Policy and Institutional Environment

Integration of the GMS electricity sector began with the 1995 study on energy strategy and the potential for development of a regional grid. Both the GMS electricity grid and the rules for its long-term operation were originally outlined by GMS members in the 1998 Policy Statement on Regional Power Trade in the Greater Mekong Subregion ("the 1998 Policy Statement"), and were adopted at the Fifth Electric Power Forum Meeting. The 1998 Policy Statement was followed by the Inter-Governmental Agreement on Regional Power

Trade in the Greater Mekong Sub-Region (IGA), which was signed by all six GMS countries in 2002 and ratified in 2004.

The IGA formally endorsed the concept of a GMS electricity transmission grid to interconnect member economies. It also established the Regional Power Trade Coordination Committee (RPTCC) to coordinate the development of interregional trade in electricity. One of the major outputs of the RPTCC has been formulation of a regional power trade operating agreement (RPTOA). The RPTOA defines four key stages in developing trade in electricity within the subregion. These are (i) bilateral cross-border connections through power purchase agreements; (ii) grid-to-grid power trading between any pair of GMS countries, eventually using transmission facilities of a third regional economy; (iii) development of transmission links dedicated to cross-border trading, and (iv) a move to multiple seller-buyer regulatory frameworks by most GMS countries, to allow a competitive market for electricity to be developed throughout the subregion.

On 5 July 2005, the ministers of energy of the six GMS countries signed an MOU relating to the implementation of Stage 1 of the RPTOA (cross-border connection through power purchase agreements). The RPTCC is now working toward implementing Stage 1. As part of the Vientiane Action Plan and MOU, it is preparing a schedule, complete with timeline, for fully implementing Stage 1, and is preparing to implement Stage 2 over 2008–2012. Institutional arrangements for the first phase of power trading are expected to be completed by 2012. Ultimately, the overall impact of this initiative will depend on the level of performance of both the energy sector and the policy regimes that shape its performance.

Country-level information on the policy environment relating to integration of the GMS energy sector appears in Appendix 10. Related to this is Table 19, which summarizes country-level information regarding the most important drivers shaping the performance of the electricity sector. These include planning and preparing project pipelines, the environment for investment financing, the environment for electricity trading, and criteria relating to sustainability. The GMS economies have yet to restructure their electricity sectors to make them competitive. Thailand and Viet Nam have both adopted a phased approach to reform that indicates that a significant degree of structural change will take place within their respective electricity sectors over the next few years. Nevertheless, the sector remains dominated by government ownership and regulation. The overall share of private sector investment in energy thus remains low.

Table 19. Overall Electricity Sector Policy Environment in the GMS

Sector Detail	Indicator	Cambodia	PRC		Lao PDR	Myanmar	Thailand	Viet Nam
			Guangxi	Yunnan				
Planning and Project Pipeline								
National Power Plans	Least Cost	Yes	Yes (2004–2020)		2005	Yes	2007	2006
Regional Master Plans	Least Cost	– – – – – – – – – – – – – – – GMS Master Plan Preparation ongoing – – – – – – – – – – – – – – –						
Regional Projects Identified	Least Cost	– – – – – – – – – – – – – – – GMS Master Plan Preparation ongoing – – – – – – – – – – – – – – –						
Funding—Public Resources	Availability	Low	High	..	Low	Low	High	Medium
Investment Environment								
Independent Regulation		Yes	Not Yet	..	Not Yet	Not Yet	Yes	Not Yet
Market Structure		Mixed	Public	..	Mixed	Public	Mixed	Mixed
Utilities Ownership	Dominated by	Public	Public	..	Public	Public	Public	Public
Private Participation—Generation		Yes	..	..	Yes	Yes	Yes	Yes
Private Participation—Distribution		Yes	No	No	No	No	No	No
Cross-Subsidies		Present	Present	..	Present	Present	Present	Present
Trade-Enabled Environment								
Trade Permitted		Yes	Yes	..	Yes	Yes	Yes	Yes
Networks Connections		Border	Limited	..	Bilateral	Bilateral	Bilateral	Bilateral
Incentives to trade		X	X	..	X	X	✓	X
Sustainability								
Policy for Universal Access	Lifeline rates	Some areas	Yes	..	Yes	Yes	Yes	Yes
Rural Electrification	100% by	2020	2010	..	2020	2020	2010	2020
EIA Process and Monitoring		Weak	..	..	Weak	Weak	Strong	Weak

.. = data not available, EIA = environmental impact assessment, GMS = Greater Mekong Subregion, Lao PDR = Lao People's Democratic Republic, PRC = People's Republic of China.

Sources: Castalia Strategic Advisers. 2008. *Promoting Greater Cooperation through Private Sector.* Wellington: Castalia; ADB estimates.

Most GMS countries prepare national least-cost power plans and participate in the formulation of a regional power master plan. These plans generate a shelf of feasible projects based on economic efficiency criteria. However, funding for these projects remains an issue. Distribution of electricity still remains largely under government ownership, except for Cambodia where private distribution of power is gaining importance.

The overall financial condition of member-economy electricity utilities varies. In Cambodia, Lao PDR, Myanmar, and Viet Nam, cost recovery is low, with cross-sector subsidies influencing the financial performance of the utilities in these countries. The power plans of most member economies include targets to remove these subsidies over time, and adjust power tariffs with a view to ultimately achieving full cost recovery. Lifeline tariffs are common as well.

While most existing electricity linkages between GMS economies allow only one-way flows, power is being traded based on long-term contracts for large-scale projects with dedicated infrastructure that supports bilateral trade. Incentives to promote electricity trade are strongly linked to the degree of cost recovery in, and financial incentives for individual electric power utilities. Fuel subsidies (as in the case of coal in Viet Nam) tend to complicate integration of the GMS power trade.

Although nearly all GMS member economies have universal electrification targets that are to be achieved by 2020, financial support for achieving these targets is limited due to constraints on overall fiscal capacity. Similarly, while renewable energy sources and off-grid systems already contribute to achieving some electrification targets, the latter may not be met unless comprehensive financial plans to support electricity-for-all programs are implemented. All new electricity generation investments require an environmental impact assessment. However, the environmental aspects of implementation and monitoring of these projects require considerable strengthening if the sustainability aspect of integration of the subregion's energy sector is to be fulfilled. Although some electricity companies have established environmental and social divisions in an effort to mainstream environmental issues into the electricity sector, the human capacity of these divisions remains limited in many cases.

Natural Gas Sector

In the GMS, piped natural gas is used mainly to generate electricity. Thus, the only natural gas trade in the subregion at present involves exports from Myanmar to Thailand. Given the uncertainty surrounding the future of Cambodia Gas, a variant of several scenarios were run using the MESSAGE model that assumed these resources would come on stream during the later part of the planning horizon. Given that the latter possibility comes to pass, Cambodia would export nearly 14 billion cubic meters of gas per year, mainly to Thailand. Unfortunately, data relating to the GMS natural gas sector were limited at the time these runs of the model were undertaken.

The GMS does not currently have a coordinated policy framework to enable cooperation in the production and distribution of natural gas. However, the ongoing bilateral trade between Thailand and Myanmar is supported by Thailand's well-established framework for importing natural gas to fulfill its electricity generation requirements.

Potential future gas projects are currently being discussed by the countries involved. Discussions of the Association of Southeast Asian Nations (ASEAN) relating to natural gas pipelines have mainly focused on links with countries outside the GMS, and plans for the trans-ASEAN pipeline exclude new links within the GMS. However, as the use of natural gas in the GMS increases over the long term, a more coordinated regional approach to policy and interconnection may be warranted. Table 20 summarizes the current natural gas–sector policy environment in the GMS that would provide the basis for such an approach.

Pricing will be a key issue in increasing the supply of gas within the subregion. At present, gas is subsidized to keep electricity prices low (as in the case of Viet Nam). The price of gas needs to be set at a level that reflects its true scarcity value so as to mobilize the financial resources necessary to set up GMS gas grids.

Table 20. The Natural Gas Sector Policy Environment in the GMS

Sector Detail	Indicator	Cambodia	Yunnan, PRC	Myanmar	Thailand	Viet Nam
Gas Sector						
Resources	bcm	140	32	569	760	256
Production	mcm	..	6	13,513	20,023	5,892
Domestic Gas Infrastructure		not yet	Limited	Limited	Limited	Limited
Pipelines	km	..	..	3,707	4,381	510
Trade	mcm	..	0	1,186 MMcfd	5,605	0
Power	%	..	Negligible	11%	95%	87%
Planning and Projects						
Sector Planning	Least Cost	not yet	..	not yet	..	..
Projects Identified	Basis	Bilateral	Bilateral	Bilateral	Bilateral	Bilateral
Regional Master Plans	Availability	– – – – – – – – – – – – – – – – No GMS Gas Master Plan as yet – – – – – – – – – – – – – – – –				
Domestic Gas Master Plan	Availability	..	Unclear	Unclear	2007	2006
Funding—Public Resources	Availability	Low	High	High	High	Medium
Investment Environment						
Independent Gas Regulation		No	No	No	Yes	Not Yet
Market Structure Domestic	Dominated by	Public	Public	Public	Public	Public
Gas Price Controls		..	Yes	Yes	Yes	Yes
Cross-Subsidies		..	Large	Large	Medium	Large
Trade-Enabled Environment						
Trade Permitted		Yes	Yes	Yes	Yes	Yes
Network Connections		not yet	Bilateral	Bilateral	Bilateral	Bilateral

.. = data not available, bcm = billion cubic meters, GMS = Greater Mekong Subregion, MMcfd = million cubic feet per day, mcm = million cubic meters, PRC = People's Republic of China.

Sources: ADB estimates; Central Intelligence Agency (CIA). 2008. The World Factbook for pipeline information; Integriertes Ressourcen Management (IRM). 2008. *Economics of Energy Integration: Application of MESSAGE Model in the GMS.* Austria.

At present, the GMS natural gas industry is completely electric power-centric: nearly all gas traded across the subregion is used to generate electricity. Thus, appropriate policies for efficient subregional trade in gas have yet to be evolved. For natural gas, at this stage, even a vision for a regional market for the electricity sector is yet to be developed. Given the GMS' substantial gas resources, natural gas holds the promise of becoming an important clean transition fuel for the entire subregion during the period up to 2025. Taking full advantage of the subregion's endowment of natural gas will require a coordinated action plan by all GMS members. More importantly, it will require support and ownership by the political leaders, policy makers, and technocrats involved in the natural gas sector.

Energy Efficiency: Policy and Institutional Environment

Thus far, integration of the GMS energy sector has focused on infrastructure linkages and capacity-building as these relate to trade in electricity. But integration would deliver significant benefits in other important areas as well. Improving GMS energy efficiency and productivity is one such area. Collective action in promoting energy efficiency and productivity is capable not only of moderating demand growth, but also of improving GMS energy security and reducing emissions. However, this would require making energy efficiency and productivity priorities in the context of integrated energy planning. This is so because improvements in energy efficiency and productivity impact future investment and infrastructure requirements.

In the OECD countries, efforts to promote energy efficiency have resulted in significant savings in overall energy use. On average, overall world energy intensity has declined by 1.5% per year since 1980. Mainstreaming energy efficiency into the strategy requires attention to energy efficiency issues at various levels: sector planning, project selection, pricing and other regulatory policies, and institutional structures. Box 1 depicts the energy savings that can be achieved by simply replacing incandescent bulbs as a source of lighting with compact fluorescent bulbs.

Box 1. Energy-Efficient Lighting

It is possible to reduce end-use energy demand through the use of efficient lighting. A comparison of the technical and economic parameters of incandescent light bulbs (ILBs) and compact fluorescent light (CFL) bulbs that provide the same level of end-use service indicates that CFL bulbs reduce energy intensity. Even when the higher initial cost of CFL bulbs is taken into account, there is an overwhelming case for adopting energy efficient lighting. From the perspective of runs of the MESSAGE model, CFL light bulbs comprise a least-cost technology and thus should have already completely replaced the old ILB technology. However, numerous barriers must be addressed if such energy efficiency measures are to be properly promoted.

Efficiency Comparison of ILB and CFL Technologies

	ILB	CFL
Power (W)	60	15
Lumens per watt (lm)	20	100
Output in terms of lumens (lm)	1,200	1,500
Utilization (hours per day)	5	5
Service life (hours)	1,000	8,000
Cost of one bulb ($)	0.5	2.75
Time horizon	8,000	8,000
Units for total time	8	1
Electricity use (MWh)	0.48	0.12
Energy Costs in $/MWh	60	60
Total costs of acquisition ($)	3.18	2.75
Total energy costs ($)	22.86	5.72
Total discounted costs[a]	26.04	8.47

CFL = compact fluorescent light bulb, ILB = incandescent light bulb, MESSAGE = Model of Energy Supply Systems Alternatives and their General Environmental Impacts, MWh = megawatt-hour, W = watt.

[a] 10% discount rate.

Source: Integriertes Ressourcen Management (IRM). 2008. *Economics of Energy Integration: Application of MESSAGE Model in the GMS.* Austria.

Energy efficiency covers many diverse and distinct market segments, both on the supply side and the user side: supply-side efficiency in generation, transmission and distribution; grid-connected and off-grid renewable energy; industrial energy productivity, including changes in production technology; building end-use efficiency; municipal infrastructure (street lighting, water, waste and sewerage); transport efficiency, including urban mass transit; biofuel use to substitute for fossil fuels; irrigation (such as efficient pumps, foot valves and piping); equipment and/or appliance standards; and household energy use improvements, especially for noncommercial sources. The latter segment could lead to significant improvements in indoor air pollution and long-term sustainability of forest resources.

Four distinct sets of barriers influence energy productivity improvements: (i) managerial and organizational capacity constraints, (ii) technical and information barriers, (iii) financial and economic feasibility, and (iv) policy- and market-related constraints. GMS countries are still in the early stages of promoting energy efficiency, although most have begun the process of formulating targets and programs. In pursuing energy efficiency, all of the above types of barriers apply to the various facets of the potential to improve energy efficiency discussed previously, though not equally.

This section highlights a few of the barriers referred to above, and describes the approaches to energy integration that are most likely to succeed in the GMS context. Energy efficiency is one area in which it is easy for the GMS economies to "leapfrog". This is particularly true in light of the wide variety of successful investment models relating to the industrial, commercial, and government sectors that already exist.

For example, public buildings and facilities have become important clients of energy service companies (ESCOs), which are companies that specialize in reducing their clients' energy consumption. ESCO services include (i) energy audits; (ii) developing and implementing packages of energy-saving measures; (iii) arranging financing for such measures; (iv) staff training; and (v) measuring, verifying, and guaranteeing energy savings. ESCOs often do their work under an energy performance contract or a shared savings agreement.

Despite the potential gains from adopting energy efficiency measures, market forces alone are not likely to drive energy efficiency initiatives on a significant scale in the GMS. This is so

because energy prices are often set below cost-recovery levels in member economies, the result being that the financial benefits of energy efficiency are underestimated. Thus, initiatives to achieve greater energy efficiency are market segment–specific, and therefore must be crafted accordingly. Ultimately, this is likely to require a combination of public investment, commercial investment, and use of aid funds. Table 21 summarizes the current overall policy and investment environment for energy efficiency in the GMS.

Within the GMS, PRC, Thailand, and Viet Nam have well-tailored energy conservation programs. The PRC program incorporates targets to reduce energy intensity that are monitored regularly via an elaborate reporting system. The program targets both the supply side and the demand side, and includes renovating coal-fired power generation plants as well as promoting energy-efficient buildings and green lighting. Viet Nam's targets are time-bound and aim for a savings of 3%–5% of total energy consumed nationwide over 2006–2010. The corresponding target for 2011–2015 is 5%–8%. Cambodia, Lao PDR, and Myanmar are in the process of formulating their own energy conservation programs, but at present face capacity constraints at present. Lao PDR's Ministry of Industry and Handicrafts has performed energy audits and has implemented several energy efficiency improvement initiatives. Similarly, Myanmar's Ministry of Energy has developed an Energy Policy and Strategy for using an optimum amount of energy that is efficient, and that conserves nonrenewable energy resources.

By building on national synergies and preparing a robust program to improve regional energy productivity, it is possible to take advantage of the economies of scale that naturally arise from the subregion's diverse natural resource base.

Some policy-level measures such as moving energy prices toward full-cost recovery have strong political dimensions. Implementing such measures will thus be somewhat easier if they are part of a shared vision and strategic thrust to enhance energy security in the GMS. There are also synergies possible in regional energy efficiency standards and labelling regulations for appliances. Education and advocacy programs on energy efficiency and development of regional ESCOs could all go a long way in improving regional energy security and would form an important step toward sustainable development over the medium term.

Table 21. Overall Policy and Investment Environment for Energy Efficiency in the GMS

Measures	Cambodia	PRC	Lao PDR	Myanmar	Thailand	Viet Nam
Strategic Vision	Being prepared	Yes	..	Yes	Yes	Yes
Energy Policy Thrust	No	Yes	No	Yes	Yes	Yes
Energy Conservation Program	A few	Yes	A few	Yes	Yes	Yes
Equipment and Appliance Labeling	Planned	Yes	..	Planned	Partly Mandatory	Planning
Energy Intensity Targets	No	Yes	No	No	Yes	Yes
Building Standards	Voluntary	Mandatory	Voluntary	Voluntary	Partly Mandatory	Mandatory for Industries
Energy Audits	Voluntary	Voluntary	Voluntary	Voluntary	Voluntary	Voluntary
Financial Incentives / Disincentives	..	..	..	..	ENCON Fund	Available
Private Sector Participation (ESCOs)	Yes	Yes	Yes	Yes	Yes (8)	Yes (4)
Energy Price Subsidies	Yes	Yes	Yes	Yes	Some	Yes
Campaign Programs	Few	..	Few	Few	Many	Few

.. = data not available, ENCON = Energy Conservation Promotion Fund, ESCO = energy service company, Lao PDR = Lao People's Democratic Republic, PRC = People's Republic of China.

Sources: ADB estimates; Castalia Strategic Advisers. 2008. *Promoting Greater Cooperation through Private Sector.* Wellington: Castalia.

Electricity for All: Closing the Gap

Electricity for all is an important goal for the GMS economies. Cambodia, Lao PDR, and Viet Nam have targeted 100% electrification by 2020. However, given the GMS' current low rate of electrification overall, as well as its high rate of dependency on noncommercial sources of energy, the subregion must find innovative ways of reaching this goal. The market for rural electrification is large. Thus, several approaches to close the current electricity availability gap are available. Off-grid technologies offer promising solutions, particularly in the subregion's more remote areas (Table 22).

Table 22. Alternative Off-Grid Rural Energy System Technologies

Project Detail	Range	Biomass	Hydro	Solar PV
Installed Capacity	High	1MW	1kW	85W
	Low	2 MW	1MW	85W
Investment Cost, ($/kW)	High	6,000	6,000	9,000
	Low	4,000	2,000	4,500
O & M Cost, ($/kW/yr)	High	300	300	225.0
	Low	120	60	67.5
Service Life, years	High	15	20	5
	Low	25	40	10
Plant Factor, % (hours/year)	High	22.8% (2,000)	22.8% (2,000)	20.5% (1,800)
	Low	50.0% (4,380)	80.0% (7,000)	22.8% (2,000)
Fuel Cost, $/MWh-ouput	High	36.00	0.00	0.00
	Low	13.50	0.00	0.00
Electricity Costs, $/MWh	High	475.03	390.73	1,279.87
	Low	105.69	25.19	325.14

kW = kilowatt, MW = megawatt, MWh = megawatt-hour, O&M = operations and maintenance, PV = photovoltaic, W = watt.

Source: Integriertes Ressourcen Management (IRM). 2008. *Economics of Energy Integration: Application of MESSAGE Model in the GMS.* Austria.

The first approach is to direct a percentage of profits from regional trade to rural electrification. This approach has enabled Lao PDR to significantly increase its electrification rates. Second, several successful projects at the decentralized level in Cambodia, Lao PDR, Yunnan, and other remote areas have tapped hydropower potential at the micro level. Third, integration can help increase the supply of modern energy to remote areas that are located near national borders. Finally, important lessons can be gained from the PRC's remarkable success in implementing its electrification program within a short time period (Box 2).

Currently, 74 million GMS inhabitants lack access to electricity. However, the task of providing electricity to this population is only about 10% of what the PRC achieved in the previous two decades. However, given the low level of income in the countries concerned and the early stage of development of these economies, resource mobilization and sustainability of effort could become binding constraints on achieving this goal. The cost of meeting the goal of electricity for all can be large, and can vary from $150 to $2,000 per household depending on the location, the size of the community, and the type of fuel and technology used. This translates into an aggregate cost of $400 million to $5 billion. Only a few economy-

Box 2. Electrification in the People's Republic of China

The People's Republic of China (PRC) secured access to electricity for 700 million inhabitants in less than two decades. A number of favorable factors allowed this to occur. These include (i) abundant domestic coal resources, (ii) the ability of the central government to mobilize local resources, and (iii) very low domestic production costs for equipment and materials. All of these factors contributed to lowering the cost of the PRC's electrification program as compared to other countries. Strong political support backed by subsidies and low-interest-rate loans also enabled households to switch to modern fuels. A remarkable degree of payment discipline also contributed to the success of the program. If bills were not paid on time, connections were promptly cut off. Most remarkably, all of this was accomplished against a backdrop of relatively low international energy prices.

Source: International Energy Agency. 2002. *World Energy Outlook*. Paris: IEA.

specific cost estimates for electricity for all exist. Lao PDR's power development plan has allocated $165 million to connect nearly 281,000 households. This translates into an average per household cost of $600. However, this figure excludes connection costs and does not capture the cost of increased generation capacity or strengthening of the grid infrastructure to accommodate additional connections. Viet Nam has also included resources for rural electrification to meet their target of universal electrification by 2020.

Financial resources are not the only major constraints to achieving electricity for all. Most countries need to develop a policy framework that attracts innovation and encourages extensive use of renewable energy sources as a means of contributing to achieving this goal (Box 3). Thailand seems to be the only GMS economy with an advanced program for electricity generation from renewable energy sources. The Thai program includes physical targets, incentives such as tax credits and subsidies, and research and development support relating to sectors with significant potential to achieve greater use of renewable energy sources.

Appropriate institutional models for sustainable rural electricity delivery are needed. A number of important lessons from alternative institutional structures exist. A single public sector utility subsidized by the state seems to have worked in the PRC, whereas in India, this model has failed. In the Philippines, diverse cooperatives operating under performance-related contracts seems to have worked well, whereas in Thailand, a dedicated government office and sufficient funds to oversee the rural electrification program has delivered a greater than 90% electrification rate. An important lesson emerging from the various successful rural electrification programs is that there is no standard recipe for success. Thus in each case, an appropriate model that takes account of the local context and the state of development of the electricity sector must be designed. In addition, a successful system must be flexible and focus on service delivery.

Two important innovations in rural electrification that the GMS can embrace are engaging private sector participation and the use of smart subsidies. According to interviews conducted with private investors as a part of this study, there is substantial private sector interest in pursuing these alternatives. For example, one company stated that it would like to invest more in renewable energy in the GMS. There is a growing interest in greenfield renewable energy projects, and solar and waste-to-energy projects appear to hold significant profit potential. Another company is considering investing in wind- and solar-generated (grid-connected) power, and is particularly interested in thermal energy.

Box 3. Renewables in Rural Electrification

In most countries, diesel generation is the preferred technology for off-grid generation. In some cases however, generation using renewable energy sources is cheaper—and it is always more environment-friendly. For this reason, governments may wish to ensure that at a minimum they are not biasing developers in favor of diesel generation, and could also consider going further to actively promote the use of off-grid renewable energy sources. Possible biases against the use of renewable energy sources include diesel subsidies, and approval processes for renewables that are more extensive or difficult than the processes required for installing diesel generators. Another source of bias may be a government-owned electricity company investing in rural electrification, but choosing to use thermal generation without fully considering all relevant alternatives. This bias can be avoided. Instead of a government company developing rural electricity schemes, private suppliers can be invited to compete for electricity supply contracts for particular areas, perhaps with the contract being awarded to the firm that requires the least subsidy. When this was done in the Philippines, private firms were considerably more likely than the state-owned power company to choose renewable energy sources for rural electrification purposes.

Given the environmental and energy security benefits of renewable energy sources, governments may also choose to offer a subsidy for rural electrification from renewable energy sources in order to bias technology choices away from diesel and toward renewables. This could be done, for example, through a bounty payment for each household connected to a renewable energy source. Or if the government decides to seek bids from private firms for rural electrification, those firms proposing generation from renewable sources could be given a margin of preference in the bidding process.

The Government of Lao PDR has recognized this. Article 20 of the Electricity Law stipulates that small-scale hydro generators with a capacity of under 2 megawatts (MW), and thermal electricity generators under 500 kilowatts (kW), are exempt from filing concession applications. Since the majority of rural electrification projects are likely to have capacities under 2 MW (or under 500 kW in the case of diesel generators), concessions for such projects are generally not required. Other countries such as Cambodia should clarify the regulatory context for the solicited and unsolicited establishment of private mini-grids for facilitating development of off-grid generation.

Source: Castalia Strategic Advisers. 2008. *Promoting Greater Cooperation through the Private Sector.* Wellington: Castalia.

Since the scale of some projects in these areas can be quite small, bundling similar projects together and financing them via an investment fund structure may increase their attractiveness to the private sector. In addition, it is possible to structure the financing of projects in a manner that makes them viable under local conditions, particularly if such financing is supplemented with subsidies available from global programs to promote clean energy. Above all, it is necessary to design project finance structures in a way that includes guarantees and support from incentives that focus on performance and service delivery. A significant hurdle to overcome in this regard is maintaining tariffs at levels sufficient to cover the required level of investment when designing electricity generation projects that use renewable energy sources. "Smart subsidies" are of particular help in this regard. These subsidies are directed toward beneficiaries and are monitored through accountability monitoring systems such as regulation, performance contracts, and community participation schemes.

For grid-connected generation such as small hydro or methane generation, feed-in tariffs tend to promote the efficient use of renewable energy sources. Feed-in tariffs are standing offers from the grid utility to purchase power generated from renewable energy sources at a stable and pre-specified tariff. The tariff should at least reflect the cost of generation avoided, and in addition should include any incentive the government considers necessary to promote the use of renewable energy sources for energy security or environmental sustainability.

A straightforward and transparent regulatory environment relating to decentralized electricity generation is key in promoting local ownership. In cases in which rural electrification is best achieved through small isolated systems, governments should ensure that investors can easily obtain permits and that they do not encounter excessive bureaucratic, legal, or regulatory hurdles. Cambodia has already made significant progress in this regard by establishing its Rural Electricity Fund (REF) in 2005 (which is a component of the Rural Electrification and Transmission project funded by ADB and World Bank). Successful proposals receive an REF grant, which is expected to contribute about one quarter of the total investment required for the project concerned. Together with an operating license from the Electricity Authority of Cambodia, an REF grant helps the project proponent obtain the remaining required funding from a private financial institution. Similarly, the Electricity Generation Authority of Thailand encourages private investment through programs for small-scale power producers and via a

targeted subsidy from the Energy Conservation Promotion Fund. Though currently a small contributor to overall energy requirements, small-scale power producers have spurred significant growth in the use of renewable energy sources in Thailand. The subsidies used achieve two separate objectives: promoting the use of renewable energy sources and participation by the private sector.

Overall, GMS member governments should ensure that policies relating to off-grid generation allow for private sector operation, and that they encourage adoption of least-cost technologies, given that the full environmental costs and benefits of the various technological options are taken into account. Similarly, regulatory transparency helps encourage off-grid generation either via investment in particular projects, or else through investor-owned utilities where commercially feasible. Some member economies currently lack a transparent policy statement to the effect that private firms are legally allowed to sell off-grid electricity. This deficiency—which is so simple and obvious that it is often overlooked by policy makers and regulators—can be corrected easily, quickly, and at low cost. However, if not addressed, it can present a formidable barrier to realizing the potential for commercially viable off-grid generation.

7

A Shared Energy Future: Acting Now

Since the inception of the GMS Economic Cooperation Program, several institutional arrangements have been put into place for cooperation within the power sector. In addition, there is a robust program of investment, power trading, and interconnection of transmission networks that is coordinated through the Regional Power Trading Coordination Committee and supported by partnerships with ADB. GMS energy sector investments by ADB and other development partners have thus far totaled $2 billion. At the Vientiane Summit held on 30–31 March 2008, an MOU regarding the strategy for implementing GMS cross-border power trading was signed by the member governments. The Vientiane Action Plan has four strategic thrusts for the energy sector and lists 32 projects to be undertaken during 2008–2012 to complete the first stage of regional power interconnection (Box 4). To a large extent, the shared energy future of the GMS will be shaped by the degree to which delivery of these projects is successful (Appendixes 11-1 through 11-8).

Given uncertain and high international energy prices, environmental sustainability pressures, geopolitical uncertainty in the world's oil-rich regions, the interconnectedness of global energy markets, political and consumer pressures, civil society scrutiny, and widespread energy poverty in the GMS, member governments felt the need for an integrated approach to delivering sustainable, secure, and competitively priced energy to the subregion. The results of the optimization exercise undertaken as part of the technical assistance and described in Chapter 4 make a strong economic and environmental case for integration of the energy sector: doing so would save the GMS discounted costs of $220 billion or 19% of total costs over the coming two decades. To benefit from a shared energy future, the GMS must invest $585 billion in power and other energy subsectors to prevent lack of energy from constraining the

remarkable economic growth momentum that the GMS has built up over the previous two decades. In addition, up to $15 billion would be required to meet the electricity-for-all targets, which translates into annual investments of nearly $30 billion during each of the coming 20 years. However, such levels of investment alone will not fully address the energy challenges facing the GMS. Simultaneous action will be required in aligning the policy and institutional environments of the various member economies in a way that (i) makes the subregion less vulnerable to exogenous shocks that may occur in global energy markets; (ii) ensures that appropriate fuel diversification takes place; (iii) ensures that environmental and social considerations are properly integrated into GMS energy plans and processes; and (iv) ensures that energy is used productively, and in a manner that minimizes adverse impacts on regional and global environments. For this to occur, an approach is required that creates and maintains the existing physical infrastructure, and focuses on the energy integration policy and institutional agenda in a manner that achieves a sustainable future. The key to success in this regard is using the ability to transform today's threats into tomorrow's opportunities.

Box 4. Vientiane Plan of Action—Energy

Strategic Thrust I: Broadening GMS Energy cooperation through enhanced efficiency and security, and sustainable development of energy resources

Strategic Thrust II: Regional power trade development: Building capacity for power trade cooperation, coordination, and grid interconnection

Strategic Thrust III: Regional power trade development: Implementing key GMS interconnection projects for Stage I power trading

Strategic Thrust IV: Regional power trade development: Developing generation projects for power exports under Stage I.

GMS = Greater Mekong Subregion.
Source: ADB. 2008. *Asian Development Outlook*. Manila.

Sustainable energy development in the GMS must first address the issue of accessibility, given the widespread nature of energy poverty in the subregion. In a context of volatile international oil prices, the poor are particularly vulnerable to the adverse impacts of energy poverty and bear a disproportionate share of the cost of energy supply constraints that are transmitted through formal and informal markets. It is the intent of the policy actions outlined below to meet the goal of achieving access to energy for the entire GMS population. Appendixes 11-1 through 11-8 develop some of these actions further in terms of project concepts that strengthen the infrastructure for regional integration. Implementation of these programs and projects will help develop a detailed strategy for regional integration over the long term.

Action 1. The political and technical leadership for cross-border trade and future energy integration needs to guide collective actions beyond the power sector.

The overall demand for energy is expected to grow, leading to a large demand for power. By 2025, power capacity will need to rise by more than 228 GW. However, as the optimization exercise indicates, important opportunities in two other sectors need to be explored further: natural gas and refined petroleum products. A master plan for natural gas needs to be prepared to identify resources, examine the trade potential within and outside the subregion, review the possibility of utilizing gas in other sectors, review pricing and other policies, and identify projects and investment requirements relevant to the next two decades. While the natural gas resources of the region have not been fully explored, the level of existing resources indicates that significant potential exists for scaling-up current production levels.

Opportunities likewise exist in the petroleum refining sector, especially if additional oil resources are discovered within the subregion. It is possible to retain the economic rent inherent within the subregion if crude oil is refined rather than subjected to the system of double trade that currently occurs. The viability of establishing pipelines to transport gas sustainably also needs to be explored.

Action 2. There is a small window of opportunity in which global support is available to enhance energy productivity in

the subregion. Investing in energy productivity now will help increase energy security in an era of volatile energy prices.

There are economically attractive opportunities to leapfrog to more efficient technologies, especially in sectors that are expected to experience high levels of energy demand growth. The fact that a substantial share of the subregion's energy-consuming assets has yet to be constructed implies that it is much more cost-effective to adopt higher productivity solutions in buildings and capital assets now, even within the energy sector. Combined power plants, cogeneration, waste-to-energy technologies or environment-friendly mass transport services are all alternatives that can help the new energy systems to be more efficient.

Prices based on costs are important market signals and need to be tailored to enhance energy efficiency. The action plan needs to address policy and institutional barriers to adopting energy productivity improvements in passenger and freight transport, residential and commercial building construction, and the industry sector overall. Available technology opportunities must be turned into business opportunities, particularly since some of these technologies have internal rates of return in excess of 100%.

Feasible options in the field of improving energy productivity in the use of traditional biomass fuels also need to be explored further. The region can seize opportunities available in this field, given the current high level of global attention to climate change issues.

Action 3. Improvements in policy regimes and sector reforms are often easier to effect in a regional context, and need to be pursued in a time-bound fashion.

Unlike the previous energy crisis, the current global energy environment is expected to remain uncertain over the medium to long term. Sector liberalization, changing monopolistic utilities into competitive market structures, rationalizing the role of government, and trade and regional harmonization of energy carriers will all go a long way in improving sector efficiency. All of these goals need to be pursued through a coordinated set of actions over the next two decades.

The subregion is at varying levels of sector restructuring, i.e., moving from vertically integrated monopolistic structures to market-based energy entities. This process of change requires simultaneous action in putting into place effective regulation, streamlining the

role of government, and ensuring that governance structures are accountable.

Action 4. The subregion has a very high dependency on oil imports from outside the subregion. Oil consumption must be reduced and existing approaches to backstop technological options, such as coal liquefaction and biofuels, reviewed.

Coal can be converted into liquid fuels such as gasoline or diesel by different processes. There are many unknowns at this stage that surround not only the price of oil, but also the environmental implications of its use in terms of net carbon impacts. The PRC is exploring the option of coal conversion, and there seems to be some merit in exploring the full implications of such backstop technologies.

Thailand has set up a National Biofuels Committee and private investor interest seems to be robust in this program. The merit of biofuel programs within each economy needs to be examined before regulation or targets are put in place. In the current situation of high food prices, these options need to be examined comprehensively before any large-scale diversion of productive land takes place to address the concerns of high energy dependence.

Action 5. Given the subregion's high level of oil dependence, growth in the transport sector poses a major threat and its current rate of growth seems unsustainable, in terms of both its impact on overall oil demand and the environment. There is a case for reviewing long-term trends in the transport modal–mix.

The transport sector's passenger and freight growth is occurring at an alarming rate. Domestic diesel prices should be reviewed to moderate growth, whereas urban transportation needs to move toward more energy-efficient modes. National sector policies need to be designed to move member economies toward a sustainable transport future. In particular, freight logistics can be examined to ensure that the region's global competitiveness is not affected. The region needs to invest today in some of these capital-intensive options for a better tomorrow. Global financial and other support are needed in this effort.

Action 6. Given the large resource requirements relevant to the subregion, collective action is required to promote private sector participation and innovative solutions. The current policy environment needs to facilitate private investment.

The private sector is at the forefront of these efforts. A long-term and stable policy framework is essential, but to take best advantage of this opportunity, private investors need to take greater risks. A large number of economically attractive opportunities are waiting to be explored. Investors are interested in clean and Low Carbon technology. This will require strong strategic alliances with the private sector and a long-term view.

The GMS energy sector is seen as an attractive investment destination, and the required changes will be crucial in dealing with the GMS energy challenge.

Action 7. Finally, the subregion's energy sector is experiencing multiple levels of transition. Convergence to a common path for the future will require financial and other resources, strategic planning at both the institution and energy system levels, ownership of the concept of a sustainable and integrated energy future, and partnerships at various levels. Creating institutional capital and matching human capability will perhaps be the largest challenge that needs to be met effectively for a cleaner, brighter energy future.

As the analyses indicate, the subregion's current energy challenges present a complex set of realities: a small increase in the pace of demand growth can place the subregion on to the High Growth-High Risk path. The policy and institutional development agenda must include detailed actions that moderate energy demand growth, provide adequate financial and other resources to meet the goal of energy for all, and ensure that the future is sustainable. The numerous national and subregional actions will need to be supplemented with initiatives at the global level. Important benchmarks and models can be followed and improved upon to ensure that GMS integration keeps the subregion on a sustainable growth path.

Table 23 elaborates in some detail what the above actions mean for individual economies and the subregion as a whole. Attempts are

Table 23. Priority Actions Toward a Shared Energy Future for the GMS

Time Frame	GMS Initiatives	Country Initiatives	Initiatives by ADB and Other Development Partners
	Action 1. Mobilize political will for cooperation in all energy sectors		
Short Term	• Adopt a resolution at the upcoming Energy Forum to prepare subregional plans for natural gas, energy efficiency, and energy for all		• Design a technical assistance for establishing a regional project preparation facility that supports GMS-wide energy integration (Appendix 11.1)
Medium Term	• Explore possibilities to expand GMS trade in natural gas; coordinate with other regional programs such as ASEAN	• Prepare national sector plans for natural gas (Cambodia, Myanmar, Viet Nam)	• Support preparation of a GMS natural gas master plan • Explore possibilities for innovative financing and further refine project concept to increase support to private refineries (Appendix 11.2)
	Action 2. Improve energy efficiency		
Short Term	• Identify quick wins at the GMS level in terms of supporting energy efficiency programs, including initiatives for knowledge sharing	• Review existing levels of energy subsidies and prepare a time-bound program for using prices effectively to guide sustainable energy use (All countries)	• Support technical assistance for preparation of a GMS energy efficiency program (Appendix 11.3)
Medium Term	• Prepare a GMS action plan to enhance energy productivity by improving efficiency on both the demand side and the energy supply side	• Prepare a strategic plan to remove barriers to increased energy productivity	• Assist countries to prepare national action plans for enhancing energy productivity. Prepare a GMS-wide program to enhance energy efficiency both from the perspective of energy users and energy suppliers. Assist in resource mobilization and knowledge-sharing. (Appendix 11.3)

continued on next page

Table 23:continued

Time Frame	GMS Initiatives	Country Initiatives	Initiatives by ADB and Other Development Partners
		• Examine and formulate policy instruments for energy efficiency such as programs for the labeling of appliances and energy-consuming products, building construction standards, and promoting the use of energy audits and ESCOs • Review existing levels of energy subsidies and prepare a time- bound program for using prices effectively to guide sustainable energy use (All countries) • Promote education and energy conservation campaigns (All countries)	• Establish smart subsidies to promote sustainable energy use on a pilot basis; promote collaboration with other development partners in putting into place output-based subsidies on a pilot basis. • Prepare a project feasibility study and mobilize funding for developing a financing facility for packaging energy efficiency projects on a GMS-wide basis
Long Term	• Mobilize resources to implement an action plan that promotes investment and knowledge sharing; remove existing barriers to energy efficiency	• Establish time-bound targets to achieve energy efficiency both at the macroeconomic level, and by all major energy suppliers (All countries)	• Invest in energy efficiency projects across the subregion
Action 3. Pursue a time-bound program of sector reform on a GMS-wide basis			
Medium to Long Term	• Review experience of other regional energy integration initiatives for promoting sector reform and market competition • Prepare a GMS-wide plan to introduce competition into the power sector	• Prepare a time-bound program for introducing competition into the electricity and natural gas sectors (All countries) • Reduce market power of state-owned utilities by unbundling the power sector • Strengthen the energy-sector legal and regulatory framework for promoting competition	• Assist countries in developing a financing facility for GMS-wide integration of transmission of electric power (Appendix 11.4) • Assist GMS efforts in preparing reform programs for the energy sector

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Table 23: continued

Time Frame	GMS Initiatives	Country Initiatives	Initiatives by ADB and Other Development Partners
		• Evaluate country-level barriers to cross-border trade in energy products and services and prepare a time-bound program for removing these	
		Action 4. Reduce oil dependency	
Medium to Long Term	• Support regional integration of the entire energy sector to reduce oil dependence • Propose an emergency oil support system • Promote the use of renewable sources of energy	• Review oil price structure and remove subsidies • Explore local oil and natural gas resources (Cambodia, Myanmar, Thailand, Viet Nam)	• Formulate a technical assistance initiative to undertake a comprehensive review of the GMS alternative fuels program, including biofuels (Appendix 11.5) • Formulate a technical assistance initiative for coal liquefaction and carbon neutrality (Appendix 11.6) • Formulate a technical assistance initiative for a fund in support of small-scale clean electric power generation (Appendix 11.7) and clean coal power generation in Viet Nam (Appendix 11.8)
		Action 5. Review transport modal mix	
Medium to Long Term	• Generate collective support (financial and otherwise) to review the GMS' long-term logistics system for freight and passenger transport	• Review levels of diesel prices and road taxes • Explore possibilities for pipeline transportation of natural gas and petroleum products	• Assist the GMS' move toward a sustainable transport sector in which energy and environmental costs are minimized • Support a midterm review of the GMS transport strategy

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Table 23:continued

Time Frame	GMS Initiatives	Country Initiatives	Initiatives by ADB and Other Development Partners
Long Term		• Review plans to develop large and growing urban areas and promote the use of environmentally benign public transport modes (Cambodia, Guangxi, Viet Nam, Yunnan) • Review road tax structure and programs to finance road maintenance	• Support and promote knowledge sharing
	Action 6. Promote regional private sector participation		
	• Prepare a subregional strategy to market the GMS as an attractive destination for private-sector investment in energy	• Identify country-level barriers to trade and private sector investment in the energy sector • Promote development of GMS natural gas resources and GMS trade in natural gas	• Mobilize financial resources to support an electricity transmission development program in partnership with the private sector
	Action 7. Create institutional capital and human capability for a cleaner, brighter energy future		
	• Create an institutional base to integrate the GMS energy market • Generate political and technical-level ownership in promoting a sustainable energy future for the GMS	• Strengthen country-level energy planning capabilities (Cambodia, Lao PDR, Myanmar, Viet Nam)	• Determine the feasibility of creating a subregional institution to promote cooperation in the GMS energy sector, using similar initiatives of other regions as a model

ADB = Asian Development Bank, ASEAN = Association of Southeast Asian Nations, ESCO = energy service company, GMS = Greater Mekong Subregion, Lao PDR = Lao People's Democratic Republic.

also made to present steps that are required to realize the goal of integrating the subregion's energy markets by 2025.

The international experience of regional integration shows clearly that the process of regional integration is long term and requires focus and attention on many interrelated aspects. Essentially, the GMS program thus far has benefited from opportunistic bilateral exchanges in the power sector. The region will have to go through a long process of sector reform and institution building to realize the enormous potential that exists for saving energy and decreasing environmental costs. Actions will be required on three fronts: infrastructure integration, regulatory integration, and commercial integration.

Given the wide variation in human and institutional capability across countries, there is a need to ensure that costs and benefits of energy integration are shared in a fair and equitable manner. All the concerned stakeholders, i.e., political leaders, business and corporate world, consumers, civil society, and multilateral agencies such as ADB need to facilitate the GMS transition to cleaner and brighter energy future.

Endnotes

1 ADB. 2007b. *Energy For All*. Manila p. 38.

2 United Nations Economic Commission for Africa (UNECA). 2003. Reports on selected themes in natural resources development in Africa: Renewable energy technologies (RETs) for poverty alleviation. Paper presented at the Third Meeting of the Committee on Sustainable Development, Addis Ababa, 7–10 October. page i.

3 UNDP. 2007. *Human Development Report 2007/2008 Fighting climate change: Human solidarity in a divided world*. p. 45. hdr.undp.org/en/media/hdr_20072008_en_complete.pdf

4 Space conditioning refers to controlling the temperature of a given space using air conditioning (hot or cold).

5 Mir, Javed Hussain, and C. Chandrasekharan. 2006. Forest Capital Disinvestments and Sustainable Development in the Greater Mekong Subregion: Making Visible the Invisible. *Journal of Greater Mekong Subregion Development Studies* 3 (2). p. 23.

6 Food and Agriculture Organization of the United Nations (FAO) and World Energy Council (WEC). 1999. *The challenge of rural energy poverty in developing countries*. London: WEC. p. 7.

7 ADB. 2002a. Technical Assistance to Lao PDR on Power Sector Strategy Study. Consultant's final report, Vol. 1, p. 239. Manila (TA 3374-LAO). TA 3374.

8 Emerging East Asia includes newly industrialized economies and the members of the Association of Southeast Asian Nations. Source: Kuroda, Haruhiko, Masahiro Kawai, and Rita Nangia. 2007. Infrastructure and Regional Cooperation. In Bourguignon, François, and Boris Pleskovic, eds. *Annual World Bank Conference on Development Economics 2007, Global: Rethinking Infrastructure for Development*. Washington, DC: World Bank.

9 The new concept of energy security is concerned with not only securing energy supplies for an economy or region, but also with the process of ensuring adequate supplies at reasonable cost in a sustainable manner. Environmental considerations are an integral part of energy security.

10 Useful energy is the formal term for energy services such as cooking, illumination, space conditioning, refrigerated

storage, transport, industrial production processes, and the like.

[11] Amory Lovins has coined the suggestive term "negawatts" to make this point. Source: Integriertes Ressourcen Management (IRM). 2008. *Economics of Energy Integration: Application of MESSAGE Model in the GMS.* Austria.

[12] At the First Planning and Consultation Workshop on the GMS Energy Sector Strategy (held on 31 July 2006 in Bangkok, Thailand), it was suggested that such aggregate treatment of energy efficiency is not sufficient because it does not lend itself directly to actual projects with a positive effect on energy demand that can be implemented. The strategy includes a specific project concept for energy efficiency in the GMS since energy productivity improvement is a strategic priority. This is discussed later in the paper.

[13] A description of how a situation might develop based on a particular set of assumptions and factors, which is used to evaluate available options and select ways of addressing uncertainty; a history of the future of an economy as it would be, given assumptions about how it operates. The assumptions concerning, for example, government tax and spending policies, can be varied to produce alternative scenarios. The construction of alternative scenarios is common when considering the effects of policy changes in models too complicated to be capable of analytical solutions.

[14] This paper presents the results of refined model runs carried out following discussions at the final regional consultation workshop on the GMS Energy Strategy in June 2008.

[15] Lu, An, 2007. Cambodia to construct 2 hydroelectric power stations. *The China View*. Xinhua. 8 Aug. news.xinhuanet.com/english/2007–08/08/content_6493570.htm

[16] Promotion of the Efficient Use of Renewable Energies in Developing Countries (REEPRO). 2007. *Operation of Hybrid Village Grid Technology Data Sheet*. www.reepro.info/fileadmin/files/REEPRO/Lao_projects/PV_Operation_of_Hybrid_Village_Grid_2007_Laos_ENGL.pdf

[17] Ni, Chun Chun. 2007. *China's Natural Gas Industry and Gas to Power Generation.* Tokyo, Japan: The Institute of Energy Economics.

[18] Coal gasification breaks down coal into its components, usually by subjecting it to high temperature and pressure and using steam and measured amounts of oxygen. This leads to the production of syngas, a mixture consisting mainly of carbon monoxide (CO) and hydrogen (H_2).

[19] Syngas (from synthesis gas) mainly consists of CO and H_2.

[20] At present, energy is treated as special commodity for international trade purposes and is thus often exempted from free trade agreements. There are a few bilateral agreements governing joint resource exploration in disputed areas.

[21] Regional integration of networks is defined here as the interconnection of isolated and national systems of countries and coordination of their operations.

[22] The major subregional cross-border flows of electricity at present are as follows: PRC to Viet Nam, Lao PDR to Cambodia, Lao PDR to Thailand, Thailand to Cambodia, Viet Nam to Cambodia, and Viet Nam to Lao PDR.

[23] Details of the survey, the methodology used, the questionnaire itself, and the responses to it appear in Castalia Strategic Advisers. 2008. *Promoting Greater Cooperation through Private Sector.* Wellington: Castalia.

[24] The data reflect a fiscal deficit, which is defined as the excess of total provincial government expenditure over revenue. It is not clear how federal transfers are addressed in PRC government finance statistics.

Appendix 1

Greater Mekong Subregion and the Millennium Development Goals

	Cambodia	Lao PDR	Myanmar	PRC	Thailand	Viet Nam
Goal 1: Eradicate extreme poverty and hunger						
$1/day poverty	No data	No progress/ regressing	No data	Early achiever	Early achiever	No data
Underweight children	No progress/ regressing	Slow	Slow	Early achiever	No data	Early achiever
Goal 2: Achieve universal primary education						
Primary enrollment	Early achiever	On track	No progress/ regressing	No data	On track	No progress/ regressing
Reaching grade 5	Slow	Slow	On track	No data	No data	On track
Primary completion rate	Early achiever	Slow	On track	No data	No data	No progress/ regressing
Goal 3: Promote gender equality and empower women						
Gender primary	On track	On track	Early achiever	Early achiever	Early achiever	Slow
Gender secondary	Slow	Slow	Early achiever	Early achiever	Early achiever	Early achiever
Gender tertiary	Slow	On track	No data	On track	Early achiever	No progress/ regressing
Goal 4: Reduce child mortality						
Under–5 mortality	No progress/ regressing	On track	Slow	Early achiever	Early achiever	Early achiever
Infant mortality	No progress/ regressing	On track	Slow	On track	Early achiever	Early achiever
Goal 5: Improve maternal health						
Maternal health	No data	No data	No data	No data	No data	No data

Key:	Early achiever	On track	Slow	No progress/ regressing	No data

continued on next page

Appendix 1: continued

	Cambodia	Lao PDR	Myanmar	PRC	Thailand	Viet Nam
Goal 6: Combat HIV/AIDS, malaria, and other diseases						
HIV prevalence rate	Early achiever	On track	Early achiever	On track	On track	On track
TB prevalence rate	Early achiever	Early achiever	Early achiever	Early achiever	Early achiever	Early achiever
TB death rate	Early achiever	Early achiever	Early achiever	Early achiever	Early achiever	Early achiever
Goal 7: Ensure environmental sustainability						
Forest cover	No progress/ regressing	No progress/ regressing	No progress/ regressing	Early achiever	No progress/ regressing	Early achiever
Protected areas	Early achiever	Early achiever	Early achiever	Early achiever	Early achiever	Early achiever
CO_2 emissions	Early achiever	No progress/ regressing	No progress/ regressing	No progress/ regressing	No progress/ regressing	No progress/ regressing
CFC consumption	Early achiever	No progress/ regressing	Early achiever	Early achiever	Early achiever	Early achiever
Water, urban	No data	No data	No progress/ regressing	No progress/ regressing	Early achiever	Early achiever
Water, rural	No data	No data	Early achiever	Slow	Early achiever	Early achiever
Sanitation, urban	No data	No data	Early achiever	Slow	Early achiever	Early achiever
Sanitation, rural	No data	No data	Early achiever	Slow	Early achiever	On track

Key:	Early achiever	On track	Slow	No progress/ regressing	No data

AIDS = acquired immune deficiency syndrome, CO_2 = carbon dioxide, CFC = chlorofluorocarbons, GMS = Greater Mekong Subregion, HIV = human immunodeficiency virus, Lao PDR = Lao People's Democratic Republic, PRC = People's Republic of China, TB = tuberculosis.

Source: United Nations Economic and Social Commission for Asia and the Pacific (UNESCAP), Asian Development Bank, and United Nations Development Programme. 2007. *The Millennium Goals: Progress in Asia and the Pacific 2007,* Bangkok: UNESCAP.

Appendix 2

Energy Balances for the Greater Mekong Subregion, 2001 and 2005 (PJ)

	2001								
GMS 2001	**Coal**	**Crude oil**	**Oil products**	**Natural gas**	**Hydro**	**Other renewables**	**Electricity**	**Biomass**	**Total**
Production	1,133	1,043	..	905	184	0	..	2,538	5,803
Imports	1,082	1,616	762	125	..	..	23	..	3,609
Exports	(256)	(712)	(278)	(176)	..	..	(7)	..	(1,430)
Primary consumption	1,959	1,947	484	854	184	0	16	2,538	7,982
Petroleum refineries	..	(1,972)	1,671	..	..	..	..	..	(301)
Power plants	(863)	..	(94)	(778)	(184)	0	745	(28)	(1,202)
Others	0	..	..	..	..	..	..	..	0
Final consumption	1,096	(25)	2,062	76	0	0	761	2,510	6,479
Agriculture	34	..	140	..	..	..	10	257	441
Households	89	..	92	0	..	..	198	1,725	2,104
Industry	824	..	301	61	..	..	312	465	1,963
Services	15	..	53	1	..	..	100	..	169
Transport	5	..	1,214	1	..	..	..	..	1,220
Non-energy uses	75	..	56	3	..	..	9	..	143
Losses	54	(25)	205	9	0	0	132	63	438

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Appendix 2: continued

	2005								
GMS 2005	**Coal**	**Crude oil**	**Oil products**	**Natural gas**	**Hydro**	**Other renewables**	**Electricity**	**Biomass**	**Total**
Production	2,226	1,744	..	1,233	203	22	..	2,772	8,199
Imports	793	1,450	1,111	207	..	..	35	..	3,596
Exports	(394)	(1,033)	(234)	(207)	..	..	(9)	..	(1,876)
Primary consumption	2,625	2,162	877	1,233	203	22	26	2,772	9,919
Petroleum refineries	..	(2,162)	1,847	..	..	..	..	..	(314)
Power plants	(1,181)	..	(34)	(1,109)	(203)	0	1,019	(65)	(1,573)
Others	0	..	..	..	..	..	..	..	0
Final consumption	1,444	1	2,691	124	0	21	1,045	2,707	8,032
Agriculture	38	..	191	..	..	..	11	276	516
Households	171	..	113	22	..	14	271	1,902	2,493
Industry	1,096	..	375	81	..	..	448	488	2,489
Services	26	..	54	11	..	..	133	7	231
Transport	9	..	1,683	1	..	..	..	..	1,693
Non-energy uses	101	..	65	5	..	..	13	..	184
Losses	2	1	209	3	0	7	169	34	425

( ) = negative value, GMS = Greater Mekong Subregion, PJ - petajoule (10^{15} joule).

Source: Integriertes Ressourcen Management (IRM). 2008. *Economics of Energy Integration: Application of MESSAGE Model in the GMS.* Austria.

Appendix 3

Status of Environmental Management in the Greater Mekong Subregion, 1992 vs 2005

Economy	Energy Department		Environmental Authority				
	Existing	Environment Section	Existing	EIA Process	Quality Standards		Standards Monitored
					Air	Water	
1992							
Cambodia	Yes	No	Yes	No[a]	No	Yes	No
PRC							
Guangxi	..	..	..	..	..	..	..
Yunnan	Yes	No	Yes	Yes	Yes	Yes	Informal[c]
Lao PDR	Yes	No	Yes	No[a]	No	Yes	No[d]
Myanmar	Yes	No	Yes	No[a]	No	Yes	No
Thailand	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Viet Nam	Yes	No	Yes	Informal[b]	Yes	Yes	Informal[e]
2005							
Cambodia	Yes	No	Yes	Yes	No	Yes	No
PRC							
Guangxi	Yes	..	..	..	..	..	..
Yunnan	Yes	No	Yes	Yes	Yes	Yes	Informal[c]
Lao PDR	Yes	No	Yes	Yes	No	Yes	No[d]
Myanmar	Yes	No	Yes	No[b]	No	Yes	No
Thailand	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Viet Nam	Yes	No	Yes	Yes	Yes	Yes	Informal[e]

.. = data not available, EIA = environmental impact assessment, Lao PDR = Lao People's Democratic Republic, PRC = People's Republic of China.

[a] EIA process is being established in these countries.

[b] EIA may be carried out, but on an informal (or ad hoc in 2005) basis.

[c] Standards may be monitored as necessary.

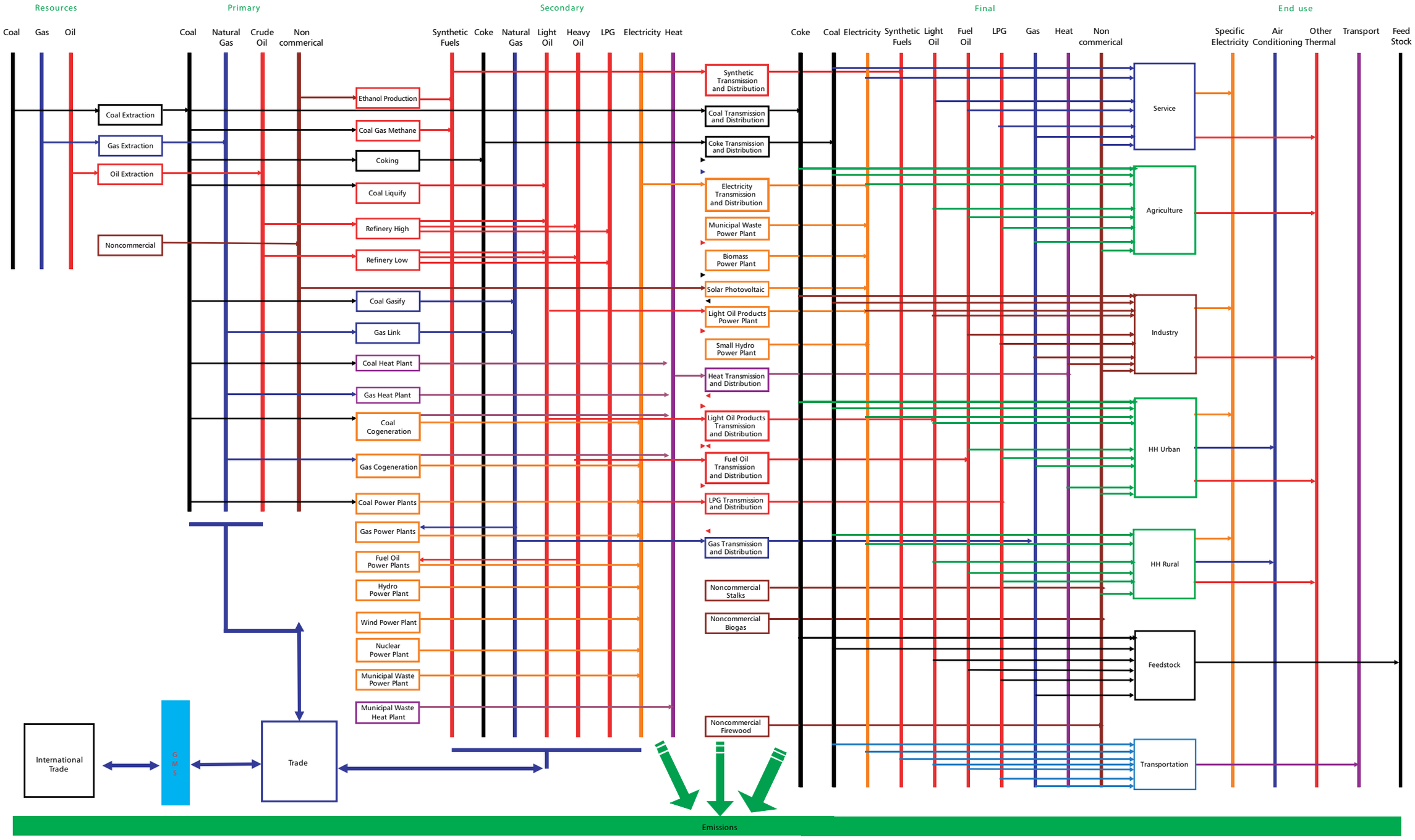
[d] Mekong Secretariat conducts water samples as required for its purposes.

[e] Water samples taken for Mekong Secretariat, and may be monitored as required.

Sources: For 1992, Asian Development Bank. 1995. *Subregional Energy Sector Study for the Greater Mekong Subregion.* Manila; For 2005, Interviews with Greater Mekong Subregion's government officials, 2007–2008.

Appendix 4

Simplified Reference Energy System



GMS = Greater Mekong Subregion, HH = household, LPG =liquefied petroleum gas.

Appendix 5

Environmental Impact Data and Estimated Costs

Technology Details

Environmental Impact Data: Pollutant Emissions of End-use Technologies (kg/MWyr)

End-use Technology	CH_4	N_2O	NO_X	SO_2
Thermal use of coal in industry	0.27	0.037	5.82	17.75
Thermal use of fuel oil in industry	0.54	0.012	5.36	37.72
Thermal use of light oil in industry	0	0	2.42	5.72
Thermal use of gas in industry	0.13	0.002	0	0.156
Thermal use of biomass in industry	0.8	0.1	4.1	1.98
Coal use in the service sector	0.27	0.037	5.82	17.75
Light oil use in the service sector	0	0	2.42	5.72
Fuel oil use in the service sector	0.54	0.012	5.36	37.72
LPG use in the service sector	0	0	2.42	5.72
Gas use in the service sector	0	0	0	0.16
Use of noncommercial fuel in the service sector	0.80	0.1	4.10	1.98
Coal heating in the residential/commercial sector	4.04	0.037	2.29	20.23
Fuel-oil heating in residential/commercial sector	0.26	0.009	5.05	42.39
Light-oil heating in residential/commercial sector	0	0	1.85	2.56
Gas heating in the residential/commercial sector	0.03	0	1.58	0.279
Heating with biomass in the residential/commercial sector	8.09	0.1	1.58	2.20

CH_4 = methane, kg = kilogram, LPG =liquefied petroleum gas, MWyr = megawatt-year, N_2O = nitrous oxide, NO_X = nitrogen oxides, SO_2 = sulfur dioxide.

Source: Estimates based on International Institute for Applied System Analysis. Greenhouse Gas Initiative Scenario Database (IIASA–GGI).

Estimated Cost of Environmental Damage, Low Impacts, $/ton

Economy	CH_4	CO_2	N_2O	NO_x	SO_2
Cambodia	150	7	1,924	1,027	403
Lao PDR	150	7	1,924	1,005	342
Myanmar	150	7	1,924	1,021	397
Thailand	150	7	1,924	1,218	623
Yunnan, PRC	150	7	1,924	1,127	522
Viet Nam	150	7	1,924	1,083	604
GMS	150	7	1,924	1,064	466

CH_4 = methane, CO_2 = carbon dioxide, GMS = Greater Mekong Subregion, Lao PDR = Lao People's Democratic Republic, N_2O = nitrous oxide, NO_x = nitrogen oxides, PRC = People's Republic of China, SO_2 = sulfur dioxide, $ = US dollar.

Source: Stockholm Environment Institute (SEI). 2007. Valuation of Some Environmental Costs within the GMS Energy Sector Strategy. Paper presented at the Second Regional Consultation Workshop, Bangkok, 28–29 May.

Estimated Cost of Environmental Damage, High Impacts, US$/ton

Economy	CH_4	CO_2	N_2O	NO_x	SO_2
Cambodia	568	25	7,311	3,628	2,616
Lao PDR	568	25	7,311	3,523	2,200
Myanmar	568	25	7,311	3,619	2,602
Thailand	568	25	7,311	3,926	3,191
Yunnan, PRC	568	25	7,311	3,799	2,978
Viet Nam	568	25	7,311	3,963	4,025
GMS	568	25	7,311	3,728	2,930

CH_4 = methane, CO_2 = carbon dioxide, GMS = Greater Mekong Subregion, Lao PDR = Lao People's Democratic Republic, N_2O = nitrous oxide, NO_x = nitrogen oxides, PRC = People's Republic of China, SO_2 = sulfur dioxide.

Source: Stockholm Environment Institute (SEI). 2007. Valuation of Some Environmental Costs within the GMS Energy Sector Strategy. Paper presented at the Second Regional Consultation Workshop, Bangkok, 28–29 May.

Appendix 6

Energy Conversion and User Technologies

Part A. Energy Conversion Technology

Cost of Converting Primary into Secondary Energy Using Alternative Technologies

Technology	Investment cost ($ '00/kW)	Fixed O&M cost ($/kW/yr)	Variable O&M cost ($/kW/yr)	Conversion efficiency (%)	Availability factor (%)
Biofuels Production	1,580	83	8	56	90
Charcoal Production	–	–	0	60	100
Coal Gasification	850	37	25	76	80
Coal Liquefaction	1,500	50	35	51	85
Coal-based Methanol	1,350	56	22	65	90
Coking	100	2	2	71	80
Gas Compressor Station	350	350	8	95	90
Gas pipelines	–	–	100	95	100
Gasworks	50	5	10	94	95
Oil Transportation	66	8	0	100	100
Refinery High Light Oil Products	2,000	50	11	10	90
Refinery Low Light Oil Products	400	15	3	27	90

– = not applicable, kW = kilowatt, O&M = operation and maintenance, yr = year, $ = US dollar.

Source: Integriertes Ressourcen Management (IRM). 2008. *Economics of Energy Integration: Application of MESSAGE Model in the GMS.* Austria.

Cost of Producing Electricity and/or Heat Using Alternative Technologies

Technology	Investment cost ($ '00/kW)	Fixed O&M cost ($/kW/yr)	Variable O&M cost ($/kW/yr)	Conversion efficiency (%)	Availability factor (%)
Advanced Coal Power Plant	1,650	65.0	30.0	43.0	85
Biomass Power Plant	1,100	30.0	31.0	30.0	75
Coal Cogeneration, CHP mode	1,500	40.0	14.3	70.0	40
Coal Cogeneration, electricity only	1,500	40.0	11.5	38.0	40
Coal Heat Plant	275	12.0	12.5	90.0	90
Coal Power Plant (no abatement)	1,000	17.0	15.0	22.0	65
Coal Power Plant (with abatement)	1,300	30.0	21.0	38.0	75
Fuel Oil Power Plant	730	21.0	15.4	29.0	75
Gas Cogeneration, CHP mode	910	30.0	11.4	80.0	40
Gas Cogeneration, electricity only	910	30.0	8.6	40.0	40
Gas-Combined Cycle Plant	730	23.0	12.3	50.0	85
Gas Heat Plant	95	6.0	7.5	70.0	40
Gas Power Plant	710	23.0	12.3	34.0	80
High-Cost Hydro Power Plant	2,000	42.0	16.0	38.5	50
Light Oil Products Power Plant	600	18.0	15.4	29.0	35
Low-Cost Hydro Power Plant	500	7.5	8.0	100.0	75
Medium-Cost Hydro Power Plant	1,200	25.0	9.0	38.5	55
Municipal Waste Heat Plant	400	22.0	150.0	45.0	40
Municipal Waste Power Plant	2,000	43.0	46.0	28.7	75
Nuclear Power Plant[a]	1,700	60.0	35.0	100.0	75
Small Hydro Power Plant	1,000	8.0	4.0	38.5	40
Solar Photovoltaic Plant	4,500	80.0	85.7	100.0	30
Solar Photovoltaic Rural	4,000	80.0	80.0	–	30
Wind Power Plant	1,200	40.0	50.0	38.5	24
Wood Cogeneration,[b] CHP mode	1,500	33.0	25.7	70.0	70
Wood Cogeneration,[b] electricity only	1,500	33.0	21.4	27.0	70

– = not applicable, CHP = combined heat and power, kW = kilowatt, O&M = operation and maintenance, yr = year, $ = US dollar.

[a] Nuclear only in Thailand and Viet Nam.

[b] Wood cogeneration only in Thailand.

Source: Integriertes Ressourcen Management (IRM). 2008. *Economics of Energy Integration: Application of MESSAGE Model in the GMS.* Austria.

Cost of Transportation and Distribution Using Alternative Technologies

Technology	Investment cost ($ '00/kW)	Fixed O&M cost ($/kW/yr)	Variable O&M cost ($/kW/yr)	Conversion efficiency (%)	Availability factor (%)
CNG T/D	–	–	10	100	100
Coal T/D	–	–	20	100	100
Coke T/D	–	–	20	93	100
Electricity T/D, Rural	900	35	20	84	100
Electricity T/D, Urban	800	33	18	84	100
Electricity T/D, Industry	800	33	18	84	100
Electricity T/D, Service Sector	800	33	18	84	100
Ethanol T/D	–	–	10	100	100
Fuel Oil T/D	–	–	15	100	100
Gas T/D	200	14	3	100	90
Heat T/D	400	20	4	95	52
Light Oil Products T/D	–	–	10	100	100
LPG T/D	–	–	10	100	100
Methanol T/D	–	–	10	100	100

– = not applicable, CNG = compressed natural gas, kW = kilowatt, LPG =liquefied petroleum gas, O&M = operation and maintenance, T/D = transmission and distribution, yr = year, $ = US dollar.

Source: Integriertes Ressourcen Management (IRM). 2008. *Economics of Energy Integration: Application of MESSAGE Model in the GMS.* Austria.

Cost of Delivering Off-grid (On-site) Electricity Using Alternative Technologies

Technology	Investment cost ($' 00/kW)	Fixed O&M cost ($/kW/yr)	Variable O&M cost ($/kW/yr)	Conversion efficiency (%)	Availability factor (%)
Diesel generators	600	18	15	29	35
Industry on-site solar photovoltaic	4,000	85	60	–	30
Small hydro	1,000	8	4	39	40
Solar photovoltaic rural	4,000	80	80	–	30

– = not applicable, kW = kilowatt, O&M = operation and maintenance, yr = year, $ = US dollar.

Source: Integriertes Ressourcen Management (IRM). 2008. *Economics of Energy Integration: Application of MESSAGE Model in the GMS.* Austria.

Cost of Alternative Technologies for Delivering Industrial Heat

Technology	Investment cost ($ '00/kW)	Fixed O&M cost ($/kW/yr)	Variable O&M cost ($/kW/yr)	Conversion efficiency (%)	Availability factor (%)
Industry—Charcoal	–	–	15	70	100
Industry—Coal	–	–	0	80	100
Industry—Coke	–	–	15	80	100
Industry—Crude	–	–	15	80	100
Industry—Electricity (thermal uses)	–	–	0	80	100
Industry—Ethanol (biofuels)	–	–	0	75	100
Industry—Fuel Oil	–	–	0	80	100
Industry—Gas	–	–	0	80	100
Industry—Heat	–	–	15	80	100
Industry—Light Oil Products	–	–	0	80	100
Industry—LPG	–	–	0	80	100
Industry—Methanol	–	–	0	75	100
Industry—Noncommercial	–	–	15	20	100
Industry—Other	–	–	25	100	100
Industry—Solar (thermal)	70	5	25	100	50

– = not applicable, kW = kilowatt, LPG =liquefied petroleum gas, O&M = operation and maintenance, yr = year, $ = US dollar.

Source: Integriertes Ressourcen Management (IRM). 2008. *Economics of Energy Integration: Application of MESSAGE Model in the GMS.* Austria.

Cost of Alternative Technologies for Delivering Heat to Rural Households

Technology	Investment cost ($'00/kW)	Fixed O&M cost ($/kW/yr)	Variable O&M cost ($/kW/yr)	Conversion efficiency (%)	Availability factor (%)
Rural—Thermal Use—Biofuels	–	–	0	60	100
Rural—Thermal Use—Coal	–	–	0	30	100
Rural—Thermal Use—Electricity	–	–	0	90	100
Rural—Thermal Use—Fuel Oil	–	–	0	50	100
Rural—Thermal Use—Kerosene	–	–	0	60	100
Rural—Thermal Use—LPG	–	–	0	60	100
Rural—Thermal Use—Methanol	–	–	0	60	100
Rural—Thermal Use—Noncommercial	–	–	0	20	100
Rural—Thermal Use—Solar	70	5	25	100	50

– = not applicable, kW = kilowatt, LPG =liquefied petroleum gas, O&M = operation and maintenance, yr = year, $ = US dollar.

Source: Integriertes Ressourcen Management (IRM). 2008. *Economics of Energy Integration: Application of MESSAGE Model in the GMS*. Austria.

Cost of Alternative Technologies for Delivering Heat to the Service Sector

Technology	Investment cost ($' 00/kW)	Fixed O&M cost ($/kW/yr)	Variable O&M cost ($/kW/yr)	Conversion efficiency (%)	Availability factor (%)
Service Sector—Biofuels	–	–	0	75	100
Service Sector—Coal	–	–	0	80	100
Service Sector—Electricity	–	–	0	100	100
Service Sector—Fuel Oil	–	–	0	70	100
Service Sector—Gas	–	–	0	90	100
Service Sector—Light Oil Products	–	–	0	80	100
Service Sector—LPG	–	–	0	80	100
Service Sector—Methanol	–	–	0	75	100
Service Sector—Noncommercial	–	–	0	20	100
Service Sector—Solar (thermal)	70	5	25	100	50

– = not applicable, kW = kilowatt, LPG =liquefied petroleum gas, O&M = operation and maintenance, yr = year, $ = US dollar.

Source: Integriertes Ressourcen Management (IRM). 2008. *Economics of Energy Integration: Application of MESSAGE Model in the GMS*. Austria.

Cost of Alternative Technologies for Delivering Heat to Urban Households

Technology	Investment cost ($ '00/kW)	Fixed O&M cost ($/kW/yr)	Variable O&M cost ($/kW/yr)	Conversion efficiency (%)	Availability factor (%)
Urban—Thermal Use—Biofuels	–	–	0	60	100
Urban—Thermal Use—Coal	–	–	0	40	100
Urban—Thermal Use—Coke	–	–	10	40	100
Urban—Thermal Use—Electricity	–	–	0	90	100
Urban—Thermal Use—Fuel Oil	–	–	0	55	100
Urban—Thermal Use—Gas	–	–	0	60	100
Urban—Thermal Use—Heat	–	–	10	90	100
Urban—Thermal Use—Kerosene	–	–	0	65	100
Urban—Thermal Use—LPG	–	–	0	65	100
Urban—Thermal Use—Methanol	–	–	0	60	100
Urban—Thermal Use—Noncommercial	–	–	0	20	100
Urban—Thermal Use—Solar	70	5	25	100	50

– = not applicable, kW = kilowatt, LPG =liquefied petroleum gas, O&M = operation and maintenance, yr = year, $ = US dollar.

Source: Integriertes Ressourcen Management (IRM). 2008. *Economics of Energy Integration: Application of MESSAGE Model in the GMS.* Austria.

Part B. User Technology

Technologies (Supply Options) for Delivering Useful Energy to Agriculture

Technology	Conversion efficiency (%)
Agriculture—Coal	80
Agriculture—Charcoal	100
Agriculture—Light Oil Products	100
Agriculture—Fuel Oil	80
Agriculture—Methanol	75
Agriculture—Biofuels	75
Agriculture—LPG	80
Agriculture—Electricity	100
Agriculture—Noncommercial	20

LPG =liquefied petroleum gas.

Source: Integriertes Ressourcen Management (IRM). 2008. *Economics of Energy Integration: Application of MESSAGE Model in the GMS.* Austria.

Technologies (Supply Options) for Delivering Useful Energy to Freight Transport

Technology	Million tkm/MWyr
Trucks fueled by methanol	760
Diesel trucks	704
Trucks fueled by LPG	640
Freight trains fueled by biofuels	691
Freight trains fueled by methanol	691
Diesel freight trains	641
Freight trains fueled by coal	795
Fuel oil freight trains	795
Electric freight trains	2,346
Freight barges fueled by coal	2,678
Freight barges fueled by diesel	2,705
Freight barges fueled by fuel oil	2,946

LPG =liquefied petroleum gas, MW = megawatt, tkm = ton–kilometer, yr = year.

Source: Integriertes Ressourcen Management (IRM). 2008. *Economics of Energy Integration: Application of MESSAGE Model in the GMS.* Austria.

Technologies (Supply Options) for Delivering Useful Energy to Passenger Transport

Transport mode	Persons per vehicle
Motorcycles	1.55
Passenger Cars	2.58
Buses	30.90
Passenger Train	206.00

Source: Integriertes Ressourcen Management (IRM). 2008. *Economics of Energy Integration: Application of MESSAGE Model in the GMS.* Austria.

Energy source for transport	1,000 vehicle-km per kWyr
Gasoline for Motorcycles	36.800
Ethanol (biofuels) for Cars	7.950
Methanol for Cars	7.950
Gasoline for Cars	7.370
LPG for Cars	6.700
Ethanol (biofuels) for Buses	1.224
Methanol for Buses	1.224
Diesel for Buses	1.134
LPG for Buses	1.032
CNG for Buses	0.860
Biofuels for Passenger Trains	0.069
Methanol for Passenger Trains	0.069
Diesel for Passenger Trains	0.063
Coal for Passenger Trains	0.070
Fuel oil for Passenger Trains	0.055
Electricity for Passenger Trains	0.196
Coal for Passenger Boats	0.086
Diesel for Passenger Boats	0.078
Fuel oil for Passenger Boats	0.070

CNG = compressed natural gas, km = kilometer, kW = kilowatt, LPG = liquefied petroleum gas, yr = year.

Source: Integriertes Ressourcen Management (IRM). 2008. *Economics of Energy Integration: Application of MESSAGE Model in the GMS.* Austria.

Appendix 7

Scenario Results

Four Scenarios—Discounted Costs and Other Details

Scenario	Discounted Costs	Total Investment Undiscounted	New Capacity	Coal-Based	Hydro Power	Nuclear	Gas	Others	Environmental Impacts Increase in		
									GWP	SO_2	NO_X
	$ Billion	$ Billion	MW	MW	MW	MW	MW	MW			
Base	1,336	497	217,091	60,666	62,274	9,600	43,133	41,419	224	173	181
GMS Integrated	1,123	520	238,467	71,768	82,527	9,600	39,934	34,637	219	180	182
High Growth-High Risk	1,268	746	319,321	125,630	85,307	16,800	44,930	46,654	346	260	242
Low Carbon	1,437	464	239,261	37,092	93,941	9,600	53,083	45,545	155	158	179

GMS = Greater Mekong Subregion, GWP = global warming potential, MW = megawatt, NO_X = nitrogen oxides, SO_2 = sulfur dioxide.

Source: Integriertes Ressourcen Management (IRM). 2008. *Economics of Energy Integration: Application of MESSAGE Model in the GMS.* Austria.

Price Responsive Scenarios

Scenario	Discounted Costs	Total Investment Undiscounted	New Capacity	Coal-Based	Hydro Power	Nuclear	Gas	Others	Environmental Impacts Increase in		
									GWP	SO_2	NO_X
	$ Billion	$ Billion	MW	MW	MW	MW	MW	MW			
Base	1,336	497	217,091	60,666	62,274	9,600	43,133	41,419	224	173	181
Base, Price-Responsive	1,297	481	218,508	69,262	59,375	9,600	40,265	40,006	226	174	182
Low Carbon	1,437	464	239,261	37,092	93,941	9,600	53,083	45,545	155	158	179
Low Carbon, Price-Responsive	1,417	463	237,694	35,441	94,949	9,600	50,909	46,796	139	131	173

GWP = global warming potential, MW = megawatt, NO_X = nitrogen oxides, SO_2 = sulfur dioxide.

Source: Integriertes Ressourcen Management (IRM). 2008. *Economics of Energy Integration: Application of MESSAGE Model in the GMS.* Austria.

Scenarios with Gas from Cambodia

Scenario	Discounted Costs	Total Investment Undiscounted	New Capacity	Coal Based	Hydro Power	Nuclear	Gas	Others	Environmental Impacts Increase in		
									GWP	SO_2	NO_X
	$ Billion	$ Billion	MW	MW	MW	MW	MW	MW			
Base	1,336	497	217,091	60,666	62,274	9,600	43,133	41,419	224	173	181
Base with Gas	1,297	489	219,806	71,355	60,355	9,600	40,203	38,292	231	172	182
GMS Integrated	1,123	520	238,467	71,768	82,527	9,600	39,934	34,637	219	180	182
GMS Integrated with Gas	1,123	536	237,431	65,102	82,484	9,600	47,197	33,047	225	176	181
Low Carbon with Gas	1,417	463	234,945	27,743	93,271	9,600	57,606	46,726	136	130	173

GMS = Greater Mekong Subregion, GWP = global warming potential, MW = megawatt, NO_X = nitrogen oxides, SO_2 = sulfur dioxide.

Source: Integriertes Ressourcen Management (IRM). 2008. *Economics of Energy Integration: Application of MESSAGE Model in the GMS.* Austria.

Appendix 8

Vientiane Plan of Action—Energy Sector

	Priority Projects/Activities	Indicative Timeline	Countries Involved	Estimated Total Cost ($ million)	Financing ($ million)	Remarks
ENERGY						
Strategic Thrust I: **Broadening GMS energy cooperation through enhanced efficiency and security, and sustainable development of energy resources**						
Strategic Thrust II: **Regional power trade development: Building capacity for power trade operation, coordination, and grid interconnection**						
Strategic Thrust III: **Regional power trade development: Implementing key GMS interconnection projects for Stage 1 power trading**						
Strategic Thrust IV: **Regional power trade development: Developing generation projects for power exports under Stage 1**						
Group 1: Ongoing projects or projects for immediate implementation with identified financing						
	Strategic Thrust I					
1.	Developing the GMS Energy Strategy	Completing in 2008	All GMS countries	1.15	1.15	Financed by ADB
2.	Subregional Strategy for Cooperation in Renewable Energy	2008–	All GMS countries	0.60	0.60	
3.	Promoting Greater Interaction Between the Subregional Energy Forum/Regional Power Trade Coordination Committee and the Working Group on Environment/Environment Operations Center	2008–2012	All GMS countries	0.05	0.05	Included in the work program of the GMS Environment Operations Center (EOC)

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Appendix 8: continued

	Priority Projects/Activities	Indicative Timeline	Countries Involved	Estimated Total Cost ($ million)	Financing ($ million)	Remarks
	Strategic Thrust II					
4.	GMS: Regional Power Trade Coordination and Development	Completing in 2008	All GMS countries	1.30	1.30	Ongoing
5.	Establishment of Regional Power Database and Website	2007–2010	All GMS countries	0.10	0.10	Included in the work program of the Regional Power Trade Coordination Committee
6.	Facilitating Sustainable Environment—Friendly Regional Power Trading	2008–2010	All GMS countries	5.00	5.00	Financed by the Swedish International Development Cooperation Agency (Sida)
	Strategic Thrust III					
7.	GMS Nabong–Udon Thani Power Transmission and Interconnection	2008–2012	Lao PDR, Thailand	84.00	84.00	To be financed by ADB (loan to Lao PDR of $74 million included in ADB indicative 2008 pipeline) and Lao Government ($10 million)
8.	GMS Northern Power Transmission	2008–2010	Lao PDR	35.00	35.00	To be financed by ADB (loan to Lao PDR of $20 million included in ADB indicative 2009 pipeline); Lao Government ($5 million); and cofinancing ($10 million)
9.	Viet Nam–PRC (Yunnan) 500 kV Power Interconnection	2008–2011	PRC, Viet Nam	400.00	400.00	Potential funding source: World Bank for the section in Viet Nam
10.	Cambodia: GMS Power Trade Project	2007–2011	Cambodia	18.50	18.50	Financed by World Bank (International Development Association)
11.	Transmission Line: 220 kV link between Kampot and Sihanoukville	2009–2010	Cambodia	35.00	35.00	Potential funding source: World Bank, Nordic Development Fund, German Development Lending Agency (KfW)
12.	Lao PDR: GMS Power Trade Project	2007–2013	Lao PDR	15.00	15.00	Financed by World Bank (International Development Association)
13.	Study on PRC–Lao PDR–Cambodia Power Interconnection and Transmission Improvement	2008–2010	Cambodia, PRC, Lao PDR	2.00	2.00	Potential funding source: ADB-administered PRC Fund for Regional Cooperation and Poverty Reduction

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Appendix 8: continued

	Priority Projects/Activities	Indicative Timeline	Countries Involved	Estimated Total Cost ($ million)	Financing ($ million)	Remarks
	Strategic Thrust IV					
14.	Xe Kaman 1 (Lao PDR) 290 MW Hydropower Project	2008–2011	Lao PDR, Viet Nam	440.00	440.00	To be financed by the private sector and Electricity of Viet Nam
15.	Nam Ngum 3 (Lao PDR) 440 MW Hydropower Project	2008–2013	Lao PDR, Thailand	600.00	600.00	To be financed by public–private partnership; ADB (loan to Lao PDR of $47 million included in ADB indicative 2008 pipeline); and Lao Government ($5 million)
16.	Xe Kaman 3 (Lao PDR) 250 MW Hydropower Project	2006–2009	Lao PDR, Viet Nam	340.00	340.00	Financed by the private sector and Electricity of Viet Nam
17.	Jinghong (PRC) Hydropower Project	Completing in 2009	PRC	1,200.00	1,200.00	Ongoing, financed by the PRC
Group 2: Projects for implementation later within the plan period and/or projects requiring financing						
	Strategic Thrust I					
18.	Facilitating Sustainable Environment–Friendly Regional Power Trading Phase 2	2010–2012	All GMS countries	2.00	2.00	To be financed by ADB (included in the ADB indicative 2008 pipeline)
	Strategic Thrust II					
19.	Developing the Regional Transmission and Regulatory Authority	2010–2012	All GMS countries	1.00	1.00	Included in the ADB indicative 2010 pipeline, to be financed by French technical assistance
	Strategic Thrust IV					
20.	Xe Pian–Xenamnoy (Lao PDR) 390 MW Hydropower Project	2008–2010	Lao PDR, Viet Nam	400.00	TBD	
21.	Lower Se San 1 (Cambodia) 90 MW Hydropwer Project	2008–2012	Cambodia, Viet Nam	TBD	TBD	Priority project under the Cambodia Power Plan

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Appendix 8: continued

	Priority Projects/Activities	Indicative Timeline	Countries Involved	Estimated Total Cost ($ million)	Financing ($ million)	Remarks
Group 3: Projects with no definite timeline and/or cost estimate and financing						
	Strategic Thrust III					
22.	Shweli 1–Yunnan Interconnection	2008–2011	Myanmar, PRC	24.50	TBD	
23.	PRC–Thailand Power Transmission through Lao PDR	2009–2013	PRC, Lao PDR, Thailand	620.00	TBD	Pending agreement on pricing
24.	Nam Mo–Ban Mai Interconnection Project (including Possible Extension)	2010–2013	Lao PDR, Viet Nam	14.10	TBD	
	Strategic Thrust IV					
25.	Xe Kong 4 (Lao PDR) 600 MW Hydropower Project	2009–2012	Lao PDR, Viet Nam	TBD	TBD	Potential funding source: public–private partnership
26.	Lower Se San 2 (Cambodia) 420 MW Hydropower Project	2010–2014	Cambodia, Viet Nam	400.00	TBD	
27.	Nam Kong 1 (Lao PDR) 200 MW Hydropower Project	2009–2012	Lao PDR, Viet Nam	250.00	TBD	Potential funding source: public–private partnership
28.	Xe Kong 5 (Lao PDR) 400 MW Hydropwer Project	2010–2013	Lao PDR, Viet Nam	TBD	TBD	Potential funding source: public–private partnership
29.	Nam Mo (Lao PDR) 105 MW Hydropower Project	2010–2013	Lao PDR, Viet Nam	TBD	TBD	Potential funding source: central government financing
30.	Nam Theun1 (Lao PDR) 523 MW Hydropower Project	2010–2013	Lao PDR, Thailand	TBD	TBD	
31.	Nam Ngiep1 (Lao PDR) 261 MW Hydropower Project	2011–2014	Lao PDR, Thailand	380.00	TBD	
32.	Theun–Hinboun Expansion (Lao PDR) 210 MW Hydropower Project	2011–2014	Lao PDR, Thailand	TBD	TBD	

ADB = Asian Development Bank, GMS = Greater Mekong Subregion, kV = kilovolt, Lao PDR = Lao People's Democratic Republic, MW = megawatt, PRC = People's Republic of China, TBD = to be determined.

Source: Vientiane Plan of Action for GMS Development, 2008–2012 (2008).

Appendix 9

Summary of Private Stakeholder Survey Results

Background

This survey was conducted as a part of the process of development of a strategy for the energy sector in the Greater Mekong Subregion (GMS). The aim of the survey was to develop a better understanding of the attitudes and perceptions of business executives whose companies are currently investing, or considering investing in energy sector projects in the GMS. Key objectives included the following:

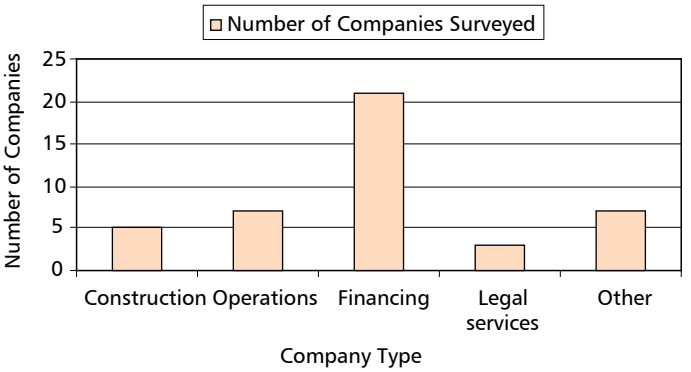
- Assessing the overall perceptions of investment opportunities and environments across the GMS, and across each of its constituent countries,
- Identifying the key motivations, barriers, and trends in energy-sector investment across each GMS economy, and
- Identifying the views on subregional cooperation in the GMS and the key roles the Asian Development Bank (ADB) should play in the GMS energy sector.

This survey represents only the views of operators in the private sector. By assessing these opinions, policies and strategies can be formulated on a country-wide basis that will facilitate expansion of investment in each of the GMS economies, and on a subregional basis as a means of expanding cooperation across the GMS as a whole.

Methodology

Surveys were completed with executives from 29 private-sector companies involved in energy or infrastructure development in Asia. Twenty-five surveys were completed online as a means of gathering overall perspectives. In-person interviews were likewise conducted with 26 representatives from 19 companies to further discuss topics raised in the survey. These interviews were conducted both over the telephone and in person with organizations based in Singapore and Hong Kong, China. The interviewees were assured both anonymity and confidentiality regarding dissemination of the results. Figure A9.1 shows the composition of the companies interviewed by the type of business in which they engage.

Figure A9.1 Composition of Survey Respondents



Source: Castalia Strategic Advisers. 2008. *Promoting Greater Cooperation through Private Sector.* Wellington: Castalia.

Key Findings

On average, private-sector stakeholders viewed the investment climate in the GMS positively. However, respondents emphasized the differences in macroeconomic conditions across the subregion. Similarly, perceptions of the investment climate varied from one economy to another. The key findings are as follows:

- Thailand and Viet Nam were viewed most positively, with investors being most excited about the prospects there. While Cambodia, Lao PDR, Guangxi, and Yunnan generated less

interest, potential investors were nevertheless positive. The idea of investing in Myanmar almost universally received a cool response.

- The key conclusion was that national utilities need to be financially sound and energy fairly priced. The general approach used by investors to assess potential opportunities is to look at three factors: sovereign payment, deal structure, and comfort (e.g., recourse to government).
- In general, policies for promoting sustainable energy were perceived to be lacking. There is a perception of there being no clear policy regarding renewable energy sources, thus making competition with fossil-based energy production difficult. There was interest in the biodiesel sector.
- Many respondents supported the idea of freer energy trade within the subregion. However, there was concern about the feasibility of integration. The general consensus seemed to be that integration would be driven by local demand and supply considerations first, and that it would have to be preceded by harmonization of rules and legal systems.
- Investors overwhelmingly wanted assistance from multilateral development organizations in mitigating political risk and executing transparent transaction processes. There was disagreement on the degree of direct financing needed for the private versus the public sector in the subregion.

Overall Regional Prospects and Regional Cooperation

Many interviewees pointed to the fact that some of the GMS countries have highly regulated energy markets, while others have deregulated the energy sector to a large extent. There seemed to be a consensus that regional integration will be driven by matching needs with excess resources. This could open up markets in sectors in which there is insufficient demand locally. Further, the GMS countries will need to create similar market infrastructures and trading laws if integration is to proceed unimpeded. In general, integration was thought to promote greater market transparency and a set of common rules, as well as increasing sector efficiency and more rapid growth.

One respondent said that regional integration, while a good thing, adds to the cost of investment, because the risk is higher when operating across borders. A central regulating authority would need to be in place to set objectives and align incentives across the subregion. Another added to this point, stating that from a power load/network efficiency point of view, integration would be positive, but that it does not necessarily make investment more attractive, given increased exposure to political risk.

Views were mixed regarding the potential impact of the types of investments that might result from integration. One company stated that the western model of large power stations and wheeling power needs to be challenged with a distributed power generation model. Another thought the GMS should consider ways in which to integrate such infrastructure in terms of scale, stability, and diversity.

ADB Involvement

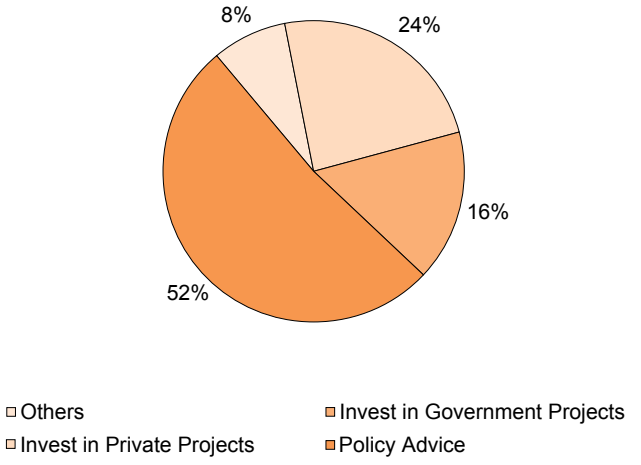
On ADB involvement and views on how it can best help develop the energy sector in the GMS, respondents emphasized that if the private sector can make money developing power in an open competitive market, then power will be developed. If the private sector cannot make money, "then you have one long road ahead". Adequate returns were necessary for private-sector interest in regional integration.

One respondent wrote:

"The ADB has significant advantage in terms of its experience of the various countries and its access to upper levels of the governments. Leveraging these advantages for the benefit of the projects can only be beneficial for the development of the projects and the country as a whole. Assisting governments [to] set policy and cascade this policy through the various levels of government to the implementers of projects would be beneficial. Some investment in projects as guarantor for example would remove the political/sovereign risk that is often perceived for the countries in the GMS."

The quote above neatly summarizes many views of how ADB can assist as shown in Figure A9.2.

Figure A9.2: How Can ADB Help?



ADB = Asian Development Bank.

Source: Castalia Strategic Advisers. 2008. *Promoting Greater Cooperation through Private Sector.* Wellington: Castalia.

Appendix 10

Developments in the Greater Mekong Subregion's Energy Sector

Cambodia

A. Overall Economic Environment

- Macroeconomic environment:
  - Size of the economy as measured by gross domestic product (GDP) is $7.3 billion (2006)
  - Economic growth rate for 2002–2006 is 9.7%
  - Fiscal space as a percentage of GDP for the period 2002–2006 is -4.4%
  - Debt service as a percentage of GDP is 83.0%
  - Inflation rate for the period 2002–2006 is 3.8% per annum
  - Trade openness as a percentage of GDP is 107.8%

- Investment environment:
  - Foreign direct investment (FDI) is $475 million
  - FDI as a percentage of GDP is 7.5%
  - Private sector participation in energy sector is enabled
  - Current public-private partnerships (PPP) for the years 2002–2006 total $54 million with 2 projects
  - Ability of local capital markets is low
- Government seeks to create the conditions to attract private sector investment in the power sector so as to:
  - Speed up rehabilitation of the power sector
  - Mobilize capital that may not be available from multilateral lending agencies
  - Reduce pubic sector debt, and
  - Increase the efficiency of existing power utilities through increased competition and transfer of technology and skill
- The Law on Concession, promulgated in October 2007, promotes and facilitates implementation of privately financed infrastructure projects that are in the public interest and fulfill social and national economic needs.

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Appendix 10: continued

- The Working Group on Energy, Infrastructure and Transport has been created as part of the Government-Private Sector Forum and is a mechanism for encouraging private sector participation in Cambodia's development. The private sector identifies issues and recommends solutions which are discussed in formal meetings with the Government.
- Country attractiveness as measured by:
  - Doing Business (2007 ranking): 145
  - Transparency International Corruption Index (2007 ranking): 162
  - Logistic Performance (2007 ranking): 81

B. Electricity

- Planning and project pipeline:
  - National power master plan updated in 2004
  - GMS regional master plan preparation currently ongoing
  - Low availability of public resource funding
- The Electricity Law of 2001 established the Ministry of Industry, Mines and Energy as the body responsible for formulating and administering policies, strategies and plans related to the energy sector. It also supports commercial development and competition in the power sector and has established an independent electricity regulator.

- Investment environment: –
  - Independent regulation: Yes
  - Market structure: Mixed
  - Utilities ownership dominated by: Public sector
  - Private sector participation in generation: Yes
  - Private sector participation in distribution: Yes
  - Cross-subsidies: Present
- The Electricity Authority of Cambodia (EAC) was created in 2001 as an independent power regulatory body to (i) oversee both public and private suppliers of electricity; (ii) determine and review tariffs as well as other charges to ensure reasonable costs for consumers and adequate returns for investors; (iii) issue licenses to electrical utilities for generation, transmission and distribution; and (iv) create favorable conditions for capital investment in, and the commercial operation of, the electric power industry.
- Electricité du Cambodge (EDC) is a wholly state-owned limited liability company responsible for the generation, transmission, and distribution of electric power throughout Cambodia.
- EDC is in negotiation with private investors regarding development of various projects including a coal-fired plant, transmission lines, and hydroelectric plants. It has cross-border projects with Viet Nam and power cooperation agreements with Lao PDR, Thailand, and Viet Nam.

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Appendix 10: continued

- Trade-enabled environment:
  - Trade permitted: Yes
  - Network connections: Border

- Sustainability:
  - Policy for universal access: Life-line rates in some areas
  - Rural electrification: 100% by 2020
  - Environmental impact assessment (EIA) process and monitoring: Weak

- A Rural Electrification Fund (REF) was set up in December 2004. The REF provides grant assistance for rural electricity enterprises for new connections, for firms that supply rural solar home systems, and for development of micro-hydro (average of 50 kW), mini-hydro (average of 0.75 to 5 MW), and other renewable energy technology power plants with a total capacity of 6,850kW.
- A Rural Electrification and Transmission (RE&T) project is being undertaken with the following objectives:
  - To improve power sector efficiency and reliability and reduce electricity supply costs;
  - To improve standards of living and foster economic growth in rural areas by expanding rural electricity supply; and
  - To strengthen electricity institutions, the regulatory framework, and the enabling environment for commercialization and privatization of the electric power sector.
- There is no national grid, except for a 115 kV single-circuit transmission line of 120 km from Kirirom mini-hydropower station to Phnom Penh that was rehabilitated under a build-operate-and-transfer (BOT) arrangement by the China Electric Power Technology Import and Export Corporation (CETIC). This line was put into operation in late May 2002.
- Power supply is available through small isolated systems using diesel generators with medium- to low-voltage distribution systems. The country is served by 24 small isolated power systems.
- Preparation of a 20-year Master Plan for Hydropower Development is underway. The Plan gives priority to 10 hydropower projects based on environmental, technical, and economic assessments.
- The draft Renewable Electricity Action Plan (REAP) incorporates incentives such as subsidies, and tax and duty exemptions on imported capital equipment as a means of creating a favorable environment for market development and private sector participation.
- REAP's 5-year action plan includes the following goals: (i) 5% of all new installed capacity, or about 6MW of mini hydro and 850 kW of village hydro, will be supplied by renewable electricity technologies and delivered to rural households or businesses; (ii) 50 000 new households will be connected by off-grid extension via rural electricity enterprises; (iii) 12,000 households will be served by solar photovoltaic generation systems.
- A policy on renewable energy is being proposed.

continued on next page

Appendix 10: continued

C. Natural Gas

- Gas sector:
  - Resources: 140 billion cubic meters (bcm)
  - Production: None
  - Domestic gas infrastructure: None yet
- Planning and projects:
  - Sector planning: No least-cost plan yet
  - Projects identified: Bilaterally
  - No GMS regional gas master plan yet
  - Domestic gas master plan is available
  - Low availability of public resource funding
- Created in 1998, the Cambodian National Petroleum Authority (CNPA) is responsible for developing and managing both the downstream and upstream activities of the petroleum industry as well as the gas sector. It is in charge of policy making, regulation, and commercial operations including joint venture agreements with the private sector.
- The petroleum industry is in its early stages of development.
- Major oil and gas exploration is being undertaken with the private sector.

- Investment environment:
  - Independent gas regulator: None yet
  - Domestic market structure dominated by: Public sector

- Trade-enabled environment:
  - Trade permitted: Yes
  - Network connections: Not yet

D. Energy Efficiency

- Measures:
  - Strategic vision: Under preparation
  - Energy policy thrust: None
  - Energy conservation programs: Few
  - Equipment and appliance labeling: Planned
  - Energy intensity targets: None
  - Building standards: Voluntary
  - Energy audits: Voluntary
  - Private sector participation (energy service companies [ESCOs]): Yes
  - Energy price subsidies: Yes
  - Campaign programs: Few

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Appendix 10: continued

Lao People's Democratic Republic

A. Overall Economic Environment

- Macroeconomic environment:
  - Size of the economy as measured by GDP is $3.4 billion (2006)
  - Economic growth rate for 2002–2006 is 6.6%
  - Fiscal space as a percentage of GDP for the period 2002–2006 is -6.1%
  - Debt service as a percentage of GDP is 486.0%
  - Inflation rate for the period of 2002–2006 is 10.1% per annum
  - Trade openness as a percentage of GDP is 49.1%

- Investment environment:
  - FDI is $650 million
  - FDI as a percentage of GDP is 26.0%
  - Private sector participation in energy is somewhat enabled
  - Current PPP for the years 2002–2006 totals $1,250 million with 1 project
  - Ability of local capital markets is low
- Promulgation of key legislation includes: (i) the Law on the Promotion of Investment of October 2004; (ii) the National Policy on Environmental and Social Sustainability of the Hydropower Sector of June 2005; and (iii) the Enterprise Law of April 2006. These laws are aimed at enhancing development of the power sector.

- Country attractiveness as measured by:
  - Doing Business (2007 ranking): 164
  - Transparency International Corruption Index (2007 ranking): 168
  - Logistic Performance (2007 ranking): 117
- The Power Sector Policy Statement issued in March 2001 sets out the following policy goals:
  - Maintain and expand an affordable, reliable, and sustainable electricity supply;
  - Promote power generation for export to provide revenue to the Government;
  - Develop and enhance the legal and regulatory framework to effectively direct and facilitate power sector development;
  - Strengthen institutions and their structures by clarifying responsibilities, supporting their commercial functions, and streamlining their administration.

B. Electricity

- Planning and project pipeline:
  - The Power System Development Plan for Lao PDR was completed in 2004. It outlines a development path for the sector covering the period 2005 to 2020.

continued on next page

  - GMS regional master plan preparation is currently ongoing
  - Low availability of public resource funding
- The Ministry of Energy and Mines is responsible for formulating plans, policies, and projects for the energy sector. It is also responsible for reviewing and recommending action on electricity tariffs, as well as for drafting laws, decrees and regulations for approval or action by the appropriate government bodies.

- Investment environment:
  - Independent regulation: None yet
  - Market structure: Mixed
  - Utilities ownership dominated by: Public sector
  - Private sector participation in generation: Yes
  - Private sector participation in distribution: No
  - Cross-subsidies: Present
- Electricité du Laos (EdL), a state-owned corporation under the Ministry for Energy and Mines, develops, owns, and operates the country's major generation, transmission, and distribution assets, and manages electricity imports to its grids and exports from its stations.
- Although it was corporatized in 1997, EdL remains wholly owned by the Government with substantial receivables due from government customers.
- In terms of regulation, the review authority ultimately resides in the Prime Minister's Office.
- Despite recent adjustments, electricity tariffs are very low in Lao PDR when compared with other ASEAN countries, and are below full-cost recovery levels. The average tariff is 17% below the cost-recovery level with substantial distortions existing across consumer categories.
- The Lao power sector is divided into four principal unconnected supply areas and a number of smaller supply areas. Off-grid village and household systems provide electricity to remote and isolated communities.
- A system for licensing enterprises wishing to provide off-grid services has been introduced.
- Establishment of a National Grid Company to implement a high-voltage transmission network has also been studied.
- The Lao National Committee for Energy (LNCE) manages the development and marketing of electricity across the country. It also negotiates and oversees investments in power projects, regional grid interconnection and electricity exports.

- Trade enabled environment:
  - Trade permitted: Yes
  - Network connections: Bilateral
- Electricity trading between Lao PDR and its neighbors is carried out at several levels:
  - Committed exports under project-specific power purchase agreements (PPAs) with strict conditions governing delivery of capacity and energy;

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  - Under a blanket PPA such as that between EdL and the Electricity Generating Authority of Thailand (EGAT), EdL can freely export surplus energy without committing to either quantity or timing;
  - Opportunistic power trading with Lao PDR's neighbors for least-cost supply to border areas.
- There are existing inter-governmental memorandums of understanding (MOUs) and agreements with Cambodia, PRC, Thailand, and Viet Nam regarding power.
- In response to renewed investor interest, the Government has initiated a review of existing, inactive mandates with a view to transferring previously attributed sites to reputable developers.
- In support of the objective of promoting power generation for export, the Government has prioritized the development of procedures for independent power producer (IPP) project selection and implementation.
- Development of hydro resources for export of power to neighboring countries has been promoted by seeking private sector participation in joint-venture IPP projects, subject to equity participation by the Government.

- Sustainability:
  - Policy for universal access: Life-line rates available
  - Rural electrification: 100% by 2020
  - EIA process and monitoring: Weak
- Key components of the Government's strategy for meeting its 2020 electrification target are:
  - An off-grid household electrification program. The program will employ off-grid technologies including solar, micro-hydro and diesel mini-grids. It is targeting 150,000 household installations by 2020;
  - Grid extension programs involving sub-transmission and distribution development. These programs will be scoped to achieve the 90% target after taking into account the contribution of off-grid household electrification
- Establishment of a Rural Electrification Fund is being proposed to coordinate and channel contributions from development partners, private sector, and government sources. Drafting of a rural electrification master plan is also being proposed.

C. Natural Gas

- Gas sector:
  - Resources: none
- No GMS regional gas master plan as of yet

continued on next page

Appendix 10: continued

D. Energy Efficiency

- Measures:
  - Energy policy thrust: None
  - Energy conservation programs: Few
  - Energy intensity targets: None
  - Building standards: Voluntary
  - Energy audits: Voluntary
  - Private sector participation (ESCOs): Yes
  - Energy price subsidies: Yes
  - Campaign programs: Few
- ESCOs have been established for the installation and servicing of off-grid units. Five provincial ESCOs, with a network of village electricity managers, are now registered and in operation. About 5,300 households participate in this scheme.

Myanmar

A. Overall Economic Environment

- Macroeconomic environment:
  - Size of the economy as measured by GDP is $12 billion (2006)
  - Economic growth rate for 2002–2006 is 13.2%
  - Fiscal space as a percentage of GDP for 2002–2006 is -5.0%
  - Debt service as a percentage of GDP is 219.0%
  - Inflation rate for the period of 2002–2006 is 24.4% per annum

- Investment environment:
  - FDI is $236 million
  - FDI as a percentage of GDP is 2.0%
  - Private sector participation in energy is somewhat enabled
  - Ability of local capital markets is low
- Foreign investment requires case-by-case approvals by the Myanmar Foreign Investment Commission. Oil, gas, and mining companies have recently applied for permits to extract Myanmar's mineral resources only for sale abroad, rather than for satisfying low domestic demand.

- Country attractiveness:
  - Doing Business (2007 ranking): Not available
  - Transparency International Corruption Index (2007 ranking): 179
  - Logistic Performance (2007 ranking): 147

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Appendix 10: continued

B. Electricity

- Planning and project pipeline:
  - Least-cost Master Plan covering the period 2002–2030 is available
  - GMS regional master plan preparation is currently ongoing
  - Low availability of public resource funding
- The Energy Planning Department has overall responsibility for energy policy formulation within the Ministry of Energy, and for coordination, discussion, and negotiation of the Energy Development Programme.
- The Ministry of Electric Power was reorganized in May 2006 to form two separate ministries to handle (i) generation of electricity and hydroelectric power implementation; and (ii) transmission and distribution of electricity throughout the country.
- Policy guidelines for the energy sector include:
  - Maintain the current status of energy independence,
  - Employ hydroelectric power as a vital source of energy self-sufficiency,
  - Save nonrenewable energy for the nation's future energy self-sufficiency,
  - Promote efficient utilization of energy and energy conservation,
  - Generate and distribute more electricity for economic development and
  - Prevent deforestation caused by excess use of fuel wood and charcoal.
- The Government gives priority to development of hydro power projects to increase the installed capacity of the country by utilizing its hydro resources as much as possible, since this energy source is clean and renewable.
- Continued development of medium- and large-scale hydropower projects along the borders with Bangladesh, India, and Thailand in support of regional development.
- Upgrading of transmission system to accommodate larger power capacities from additional hydropower plants has begun with the undertaking of a feasibility study and basic design for a 500 kV transmission system backbone to link the upper and lower parts of the country. Construction is targeted to begin by the second 5-year plan.

- Investment environment:
  - Independent regulation: None yet
  - Market structure: Pubic sector
  - Utilities ownership dominated by: Public sector
  - Private sector participation in generation: Yes
  - Private sector participation in distribution: No
  - Cross-subsidies: Present

- Trade enabled environment:
  - Trade permitted: Yes
  - Network connections: Bilateral

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- Sustainability:
  - Policy for universal access: Life-line rates available
  - Rural electrification: 100% by 2020
  - EIA process and monitoring: Weak
- As a measure for reducing the cutting of fuel wood, efficient cook stoves, substitute fuel sticks and briquettes utilizing coal and petroleum coke and biodigesters are being promoted in most parts of the country. The Government is targeting a 46% decrease in dependence on fuelwood over the next 30 years.
- The Ministry of Energy is also promoting utilization of liquefied petroleum gas (LPG) as a household fuel. LPG production is presently about 16,000 metric tons per year, of which 45% is utilized as household fuel.
- A measure to control environmental pollution caused by greenhouse gas (GHG) emissions from plants under the supervision of the Ministry of Energy is being implemented in cooperation with the Government and the Japanese private sector.

C. Natural Gas

- Gas sector:
  - Resources: 569 billion cubic meters (bcm)
  - Production: 13,513 million cubic meters (mcm)
  - Domestic gas infrastructure: Limited
  - Pipelines: 3,707 km
  - Trade: 1,186 million cubic feet per day (mmcfd)
  - Power: 11%
- Planning and projects:
  - Sector planning: No least-cost plan yet
  - Projects identified: Bilaterally
  - No GMS regional gas master plan yet
  - Availability of a domestic gas master plan is unclear
  - High availability of public resource funding
- The Myanmar Oil and Gas Enterprise (MOGE) is responsible for the upstream petroleum subsector, while the Myanmar Petrochemical Enterprise is responsible for the downstream subsector. The Myanmar Petroleum Products Enterprise (MPPE) is responsible for retail and wholesale distribution of petroleum products. All three of these entities are state-owned enterprises.

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- The Government seeks to utilize the full capacity of all gas turbine power plants in the national grid system to maintain a stable power supply, particularly for large cities and industrial areas which are at some distance from hydro plants, and also to supplement generation capacity during the dry season.

- A compressed natural gas/natural gas for vehicles (CNG/NGV) Program was reactivated in August 2004. As of March 2007, there were 26 CNG refueling stations in the country with additional stations slated for future installation along the existing domestic pipeline route.

- Investment environment:
  - Independent gas regulator: None yet
  - Domestic market structure dominated by public sector
  - Gas price controls: Yes
  - Cross-subsidies: Large

- Trade-enabled environment:
  - Trade permitted: Yes
  - Network connections: Bilateral
- For the oil and gas sector, the government currently has a total of 30 contracts with various foreign companies for onshore and offshore development.

D. Energy Efficiency

- Measures:
  - Strategic vision: Yes
  - Energy policy thrust: Yes
  - Energy conservation program: Yes
  - Equipment and appliance labeling: Planned
  - Energy intensity targets: None
  - Building standards: Voluntary
  - Energy audits: Voluntary
  - Private sector participation (ESCOs): Yes
  - Energy price subsidies: Yes
  - Campaign programs: Few

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Appendix 10: continued

Thailand

A. Overall Economic Environment

- Macroeconomic environment:
  - Size of the economy as measured by GDP is $206 billion (2006)
  - Economic growth for 2002–2006 is 5.6%
  - Fiscal space as a percentage of GDP for the period 2002–2006 is -0.1%
  - Debt service as a percentage of GDP is 39.0%
  - Inflation rate for the period of 2002–2006 is 2.9% per annum
  - Trade openness as a percentage of GDP is 115.6%

- Investment environment -
  - FDI is $7.9 billion
  - FDI as a percentage of GDP is 4.80%
  - Private sector participation in energy is enabled
  - Current PPP for the years 2002–2006 is $1.6 billion
  - Ability of local capital markets is high

- Country attractiveness -
  - Doing Business (2007 ranking): 15
  - Transparency International Corruption Index (2007 ranking): 84
  - Logistic Performance (2007 ranking): 31

B. Electricity

- Planning and project pipeline -
  - Power Development Plan 2007–2021 was completed and used as a framework for the development of Electricity Generating Authority of Thailand's (EGAT's) new power plants, solicitation of new independent power producers (IPPs), small power producers (SPPs), and power purchase from neighboring countries.
  - GMS regional master plan preparation currently ongoing
  - High availability of public resource funding
- The Ministry of Energy oversees the planning, policy formulation, regulation, procurement and development of the energy sector. The Energy Policy and Planning Office (EPPO) is the implementing arm of the ministry and is in charge of developing energy policies and regulations.

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- Investment environment:
  - Independent regulation: Yes
  - Market structure: Mixed
  - Utilities ownership dominated by: Public sector
  - Private sector participation in generation: Yes
  - Private sector participation in distribution: No
  - Cross-subsidies: Present
- The Energy Industry Act of 2007 established a new regulatory regime for electricity and natural gas to prevent abusive use of monopoly power and to protect energy consumers and those adversely affected by operation of the energy industry. The Act also restructures management of the energy industry by separating policy making, regulatory, and operating functions.
- Functions of the newly established Energy Regulatory Commission include (i) regulating operation of the energy industry; (ii) granting, amending, suspending and terminating licenses for energy industry operators; (iii) determining measures for promoting competition and preventing abusive use of monopoly power; (iv) proposing power development plans, investment plans for the electricity supply industry, natural gas procurement plans and energy network system expansion plans; (v) establishing technical and safety standards for operation of the energy industry.
- The Electricity Supply Industry Reform Model, also known as the Enhanced Single Buyer (ESB) model, was approved by the Cabinet on 9 December 2003. This model maintains EGAT as the sole buyer of electricity.
- Privatization of EGAT began in June 2005 with the initial public offering (IPO) scheduled for November 2005. However, the IPO was suspended by the Administrative Court following complaints filed by various interest groups. In March 2006, the Supreme Administrative Court of Thailand ruled that privatization of EGAT, the national power utility, was carried out illegally. As a result, EGAT was forced to delist its shares from Thailand's stock exchange.
- Two other state-owned power utilities, the Metropolitan Electricity Authority and the Provincial Electricity Authority are also being prepared for privatization.
- The National Energy Policy Council approved an energy tax to be paid by all power plants, old and new. The rates vary, depending on the amount of pollution emitted and the fuels used.

- Trade enabled environment:
  - Trade permitted: Yes
  - Networks connections: Bilateral

- Sustainability:
  - Policy for universal access: Life-line rates available
  - Rural electrification: 100% by 2010
  - EIA process and monitoring: Strong

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- The Renewable Portfolio Standard (RPS) is a regulatory policy that requires increased production of renewable energy sources such as wind, solar, and biomass.
- While it was introduced in the workshop on Energy Strategies in 2003, RPS was also applied to the preparation of the Power Development Plan. The RPS mechanism initially applied only to EGAT, which was obliged to develop renewable energy sources totaling not less than 5% of new generating capacity for the period 2008–2010. The total capacity of EGAT's renewable energy plants required by the RPS is 140.7 MW

C. Natural Gas

- Gas sector:
  - Resources: 760 bcm
  - Production: 20,023 mcm
  - Domestic gas infrastructure: Limited
  - Pipelines: 4,381 km
  - Trade: 5,605 mcm
  - Power: 95%

- Planning and projects:
  - Projects identified: Bilaterally
  - No GMS regional gas master plan yet
  - Domestic gas master plan: Available (2007)
  - High availability of public resource funding
- In response to increased demand for natural gas, a review of the Third Gas Pipeline Master Plan was carried out in 2005. The Master Plan proposed construction of a national natural gas pipeline and includes investments in several natural gas pipeline projects during the period 2001–2011.

- Investment environment:
  - Independent gas regulator: Yes
  - Domestic market structure dominated by public sector
  - Gas price controls: Yes
  - Cross-subsidies: Medium

- PTT Public Company Limited (PTT) (formerly the Petroleum Authority of Thailand) dominates the oil and gas industry. This national oil company was partially privatized in 2001, with 32% of its equity sold through the Bangkok Stock Exchange.

continued on next page

- PTT's engagement in the oil sector includes exploration, development, refining, retail distribution, international trading, and international downstream operations. In the gas sector, it is engaged in gas exploration, development, transmission, and trading.
- PTT has established a subsidiary, PTTLNG, to study the feasibility of building a liquefied natural gas (LNG) import and storage terminal. Construction of the LNG Receiving Terminal Project has commenced with a projected capacity of 5 million tons per year. It is scheduled for completion in June 2011.
- The natural gas transmission infrastructure is in a more advanced state than the oil pipeline infrastructure. PTT Natural Gas Distribution (PTTNGD) has more than 3,700 km of natural gas transmission pipelines throughout the country.

- Trade enabled environment:
  - Trade permitted: Yes
  - Network connections: Bilateral
- The oil sector is open to foreign investment, although foreign companies work in joint venture with PTT Exploration and Production (PTTEP), PTT's upstream subsidiary. PTT also has a considerable presence in Thailand's downstream subsidiaries, Thai Oil Company (Thaioil) and the Thai Petroleum Pipeline Company (Thappline).
- Oil price stabilizing measures were introduced in 2004 in reaction to rising international oil prices. These included (i) fixing gasoline prices for 9 months prior to their being allowed to float again; (ii) adopting a semi-flotation mechanism for diesel prices after total subsidies reached $2 billion; (iii) issuing a 5-year fuel subsidy bond to raise money to replenish the Government's oil fund.

D. Biofuels

- A Biodiesel Promotion Program was approved in 2001 and includes such measures as a waiver of excise fuel tax and exemption applied on levies for the Oil Fund and the Energy Conservation Fund Contribution. A budget of $32 million for the period of 2005–2012 was allocated for biodiesel development and promotion.
- A National Biofuels Committee was established and will be responsible for policy, strategy planning, and implementation of biofuels development. A two-phase biofuel program has been formulated by the Ministry of Energy. In Phase 1 (2004–2006), three ethanol plants came on-stream (in addition to three existing plants); in Phase 2 (2007–2012), licenses are being awarded to 18 biofuel plants to bring the total installed capacity to 3 million liters per day by 2012. Of the 18 plants to come on stream during Phase 2, 14 will use molasses as feedstock and the rest will use cassava.

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Appendix 10: continued

- In 2005, 53 SPPs were granted subsidies to help cover the cost of biomass power generation, the total capacity of which was about 1,090 MW. The Government has also been actively involved in improving public acceptance by demonstrating good practices, as well as showing the financial benefits local communities can secure from operating biomass power plants.
- The Government has also supported and promoted the production and use of ethanol and gasohol by: (i) approving in principle an excise tax exemption for ex-plant ethanol and ethanol mixed with gasoline; (ii) deducting the contribution rates for gasohol to the Oil Fund and the Energy Conservation Promotion Fund; (iii) setting a lower price for gasohol vis-à-vis Octane 95, within a range not exceeding 3.50 baht per liter.
- The Government is also promoting use of alternative fuels for transportation such as natural gas for vehicles (NGV), gasohol, and biodiesel.
- A 10% target has been set to increase the use of NGV as opposed to gasoline and diesel by 2008. Retail prices of NGV are set much lower than traditional transport fuels: initial prices were 50% of the price for diesel and adjusted to 55% of the price for octane gasoline by 2007.
- A Gasohol Roadmap has been developed with a target of distributing gasohol 95 across the country as a replacement for 95 octane gasoline starting January 2007. Setting the price of gasohol below that of gasoline will provide an incentive for users to substitute gasohol 95 for 95 octane gasoline.

E. Energy Efficiency

- Measures:
  - Strategic vision: Yes
  - Energy policy thrust: Yes
  - Energy conservation program: Yes
  - Equipment and appliance labeling: Partly mandatory
  - Energy intensity targets: Yes
  - Building standards: Partly mandatory
  - Energy audits: Voluntary
  - Financial incentives: Energy Conservation (ENCON) fund
  - Private sector participation (ESCOs): Yes (8)
  - Energy price subsidies: Some
  - Campaign programs: Many
- A Energy Strategy for Competitiveness Workshop held in 2003 produced four energy strategies which the Government is now pursuing:
  - The Strategic Plan for Energy Efficiency (target: to reduce the country's energy elasticity from the current level of 1.4:1 to 1:1 by the year 2007);

continued on next page

  - The Strategic Plan for Renewable Energy Development: New Options for Thailand (target: to increase the share of renewable energy from 0.5% of commercial primary energy, or 265 thousand tons of crude oil equivalent (ktoe) in 2002 to 8% of commercial primary energy, or 6,540 ktoe by 2011);
  - The Strategic Plan for Energy Security Enhancement;
  - The Strategic Plan for Thailand to be the Regional Energy Center (target: to enhance the country's capacity by restructuring relevant factors and shifting the role from being an energy buyer to an energy trader).
- The Energy Conservation Programme (ENCON) Phase 3, which is currently being implemented, has three main subprograms as follows (i) renewable energy development; (ii) energy efficiency improvement; and (iii) strategic management. This program also manages the Energy Conservation Promotion Fund (ENCON Fund), which provides financial support to government agencies, state enterprises, non-government organizations, and individuals and businesses that are prepared to implement conservation measures.

Viet Nam

A. Overall Economic Environment

- Macroeconomic environment:
  - Size of the economy as measured by GDP is $61 billion (2006)
  - Economic growth rate for 2002–2006 is 7.8%
  - Fiscal space as a percentage of GDP for the period 2002–2006 is -4.3%
  - Debt service as a percentage of GDP is 52.0%
  - Inflation rate for the period 2002–2006 is 6.1% per annum
  - Trade openness as a percentage of GDP is 121.4%

- Investment environment:
  - FDI is $2.3 billion
  - FDI as a percentage of GDP is 4.8%
  - Private sector participation in energy is somewhat enabled
  - Current PPP for the years 2002–2006 totals $2.1 billion with 3 projects
  - Ability of local capital markets is medium

- Country attractiveness:
  - Doing Business (2007 ranking): 91
  - Transparency International Corruption Index (2007 ranking): 123
  - Logistic Performance (2007 ranking): 53

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Appendix 10: continued

B. Electricity

- Planning and project pipeline:
  - The Sixth Power Master Plan (2006–2015) has been completed. The Ministry of Industry prepares 10-year national master plans while the various provincial People's Committees prepare 5-year provincial development plans.
  - GMS regional master plan preparation is currently ongoing
  - Availability of public resource funding: medium
- The Ministry of Industry has principal oversight and policy-making responsibilities for the energy sector. It supervises state-owned companies operating in the various energy subsectors such as oil, gas, coal, and electricity. It likewise oversees implementation of government policy, prepares the master plans and major investment projects, and provides advice on necessary policy reforms.
- The Electricity Law, which came into effect in July 2005, governs all entities involved in electricity sector activities including planning and investment in electricity development, generation, transmission, distribution, wholesale and retail electricity sales, and monitoring and regulation of the electricity market.
- The Law aims to stimulate development of the sector by diversifying the various forms of investment in the sector, as well as by encouraging economical use of electricity. It also seeks to protect the country's electricity infrastructure and to develop a competitive electricity market.
- The Law also sets out a policy framework with regard to electricity pricing. This includes implementation, gradual reduction, and elimination of a reasonable price cross-subsidy regime. Electricity generation and wholesale tariffs, fees for electricity transmission and distribution, and auxiliary services are proposed by the entities involved in the relevant electricity sector activity. These proposals are then evaluated by the Electricity Regulator and approved by the Minister of Industry.

- Investment environment:
  - Independent regulation: Yes
  - Market structure: Mixed
  - Utilities ownership dominated by: Public sector
  - Private sector participation in generation: Yes
  - Private sector participation in distribution: No
  - Cross-subsidies: Present
- The Competition Law of 2004 allows the Government to continue its control of state-owned enterprises operating in sectors it has declared to be state monopoly sectors, and that are significant for socioeconomic or national defense and security reasons. In March 2007, the Government announced that it will retain full control of companies that operate energy projects.
- Investment in the electricity sector must comply with the approved electricity master plans. This includes the issuance of licenses for electricity generation, transmission, and distribution. Investment projects not within the scope of the approved master plans must secure consent from the Prime Minister or the Minister of Industry, depending on the type of investment and its proposed location.

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Appendix 10: continued

- The Electricity Regulatory Authority of Viet Nam (ERAV) was created in November 2005 in accordance with the Electricity Law. Among its functions are to:
  - prepare national power master plans;
  - develop a framework for operation of a competitive power market;
  - issue, amend, and revoke licenses for electricity sector undertakings;
  - assess and promulgate tariffs for electricity generation and wholesale distribution, as well as the level of fees for transmission and distribution;
  - monitor implementation of investment plans and projects relating to development of electricity sources, electricity transmission and distribution grids, with a view to ensuring compliance with the master plans; and to
  - settle complaints and disputes that arise in the electricity market
- The state-owned Electricite' de Vietnam (EVN) has been restructured, and by 2006 it had privatized 21 subsidiaries and converted others to limited liability companies. EVN oversees operation of the electricity sector and acts as a holding company for various companies involved in electric power generation, transmission, and distribution.
- EVN has established the Vietnam Electricity Group as a holding company to utilize the overall strength of its member companies and to facilitate their participation in domestic and foreign undertakings in electricity generation and management.
- A competitive electricity market will be developed in stages over a period of about 20 years. The development of the power market can be described as follows: Period 1 - internal market with EVN as a state corporation which manages power production, transmission and distribution; Period 2 - establishment and development of a competitive power generation market; Period 3 - establishment and development of a competitive power trading market; and Period 4 - establishment of a power retail market.

- Trade-enabled environment:
  - Trade permitted: Yes
  - Network connections: Bilateral

- Sustainability:
  - Policy for universal access: Life-line rates available
  - Rural electrification: 100% by 2020
  - EIA process and monitoring: Weak
- Electricity access was approximately 90% in 2005; the Government’s target is 95% coverage by 2010.

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Appendix 10: continued

C. Natural Gas

- Gas sector:
  - Resources: 256 bcm
  - Production: 5,892 mcm
  - Domestic gas infrastructure: Limited
  - Pipelines: 510 km
  - Power: 87%

- Planning and projects:
  - Projects identified: Bilaterally
  - No GMS regional gas master plan yet
  - Domestic gas master plan: 2006 plan available
  - Medium availability of public resource funding
- The state-owned Vietnam Oil and Gas Corporation (Petrovietnam) dominates the natural gas sector and has joint ventures with foreign partners. Most natural gas produced is processed and then sent directly to industrial and power-sector end-users.
- The Oil and Gas State Management Body is responsible for organizing the bidding process, technical regulation, and advising the Government on strategies, policies, and plans for the sector.

- Investment environment:
  - Independent gas regulation: None yet
  - Domestic market structure dominated by: Public sector
  - Gas price controls: Yes
  - Cross subsidies: Large

- Trade enabled environment:
  - Trade permitted: Yes
  - Network connections: Bilateral

D. Oil

- Petrovietnam also dominates the oil sector. It is responsible for developing and adding value to the country's oil and gas resources. Its business activities cover all operations from oil and gas exploration and production to storage, processing, transportation, distribution, and oil- and gas-related services.

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- All oil production is carried out by Petrovietnam or through production sharing contracts and joint ventures in which the national oil company has an equity stake. Petrovietnam controls the country's downstream oil sector through various subsidiaries such as Petechim and Petrovietnam Oil Processing and Distribution Company. The largest oil-producing company is Vietsovpetro (VSP), a joint venture between Petrovietnam and Zarubezhneft of the Russian Federation. Petrovietnam has also formed partnerships with other international oil companies and national oil companies.
- The above notwithstanding, the Government began to privatize the national oil company's non-oil related business units in 2006.
- Viet Nam is in the process of developing its first refinery which is the planned $2.5 billion 140,000 bbl/day facility at Dung Quat. After several years of delay as a result of problems in securing financing for the project, construction began in November 2005.
- Petrovietnam is developing into a conglomerate operating in various fields such as finance, trade, services and industry. In the service sector, it will maintain oil and gas operations, and technical and logistic services. Oil exploration and exploitation abroad will be expanded. In the trade sector, it will not limit its business to crude oil export, but will join the world oil and petroleum products trading market. In the finance sector, the company is looking to establish a bank and join the world financial market. To shift to a conglomerate, Petrovietnam will equitize a number of subsidiaries and turn several others into limited liability companies. Over the next two years, seven subsidiaries will be equitized in which Petrovietnam will hold a minimum stake of 50%. The company will maintain control of eight other subsidiaries. In the long term, Petrovietnam expects to list on stock exchanges abroad to raise funds for its operations.
- Amendments to the Petroleum Law in 2000 paved the way for a more open and transparent licensing scheme through which exploration and production projects would be offered to international investors.

E. Coal

- The state-owned Viet Nam National Coal Corporation (VINACOAL) was transformed to the Viet Nam National Coal and Mineral Industry Group (VINACOMIN) in August 2005 through a directive from the Prime Minster's Office. The new group will operate as a holding company. It will be the first state-owned enterprise with diversified business interests including coal, energy engineering, mining, shipbuilding, automobile production, and mineral exploitation and processing.
- The Government has begun promoting construction of new coal-fired power plants to diversify energy sources and utilize domestic energy sources. EVN has outlined plans to build 17 new coal-fired power stations by 2020.

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Appendix 10: continued

F. Energy Efficiency

- Measures:
  - Strategic vision: Yes
  - Energy policy thrust: Yes
  - Energy conservation program: Yes
  - Equipment and appliance labeling: Planned
  - Energy intensity targets: Yes
  - Building standards: Mandatory for industries
  - Energy audits: Voluntary
  - Financial incentives: Available
  - Private sector participation (ESCOs): Yes (4)
  - Energy price subsidies: Yes
  - Campaign programs: Few
- A legal and institutional framework for energy saving and efficient use of energy was established in September 2003 under Government Decree 102/2003/ND-CP. This decree regulates energy conservation and efficiency in production, building and equipment, power-intensive machines, and residential use. It also includes measures to reduce the level of import tax on a range of energy efficiency equipment.
- The July 2004 Circular (No. 01/2004/TT-BCN) from the Ministry of Industry contains guidelines on energy efficiency for industrial facilities. It requests large industrial customers to use energy more efficiently, report their energy consumption levels, and undertake energy audits.
- The Government is aiming to reduce Viet Nam's energy elasticity from an average of 1.46 to 1.0 by 2015, to 0.9 in 2020, and to finally reduce this to 0.8 in the years following 2020.

People's Republic of China (PRC)

A. Overall Economic Environment

- Macroeconomic environment:
  - Size of the economy as measured by GDP is $60.8 billion for Guangxi and $50.3 billion for Yunnan (2006)
  - The economic growth rate for 2002–2006 is 11.9% for Guangxi and 10.0% for Yunnan
  - Fiscal space as a percentage of GDP for the period 2002–2006 is -8.0% for Guangxi and -12.8% for Yunnan
  - Debt service as a percentage of GDP is 32.0% for Guangxi
  - Trade openness as a percentage of GDP is 9.4% for Guangxi and 10.0% for Yunnan

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Appendix 10: continued

- Investment environment:
  - FDI is $379 million for Guangxi and $174 million for Yunnan
  - FDI as a percentage of GDP is 0.7% for Guangxi and 0.3% for Yunnan
  - Private sector participation in energy is somewhat enabled
  - Ability of local capital markets is high

- Country attractiveness:
  - Doing Business (2007 ranking): PRC, 83
  - Transparency International Corruption Index (2007 ranking): PRC, 72
  - Logistic Performance (2007 ranking): PRC, 30

B. Electricity

- Planning and project pipeline:
  - National power master plan available for the period 2004–2020
  - GMS regional master plan preparation currently ongoing
  - High availability of public resource funding

- An interministerial National Energy Leading Group was established in 2005 to consider strategic issues relating to sustainable energy sector development and to guide energy corporations, planning agencies both at the central and provincial levels, and investors.
- The Bureau of Energy is responsible for (i) studying energy development and utilization locally and abroad; (ii) putting forward energy development strategies and major policies; (iii) formulating development plans for the energy sector, and making recommendations relating to system reform in the sector; (iv) administering oil, natural gas, coal, power and other parts of the energy sector as well as the national oil reserve; and (v) formulating policy measures for energy conservation and renewable energy development.
- Oversight for the energy sector principally lies with the National Development and Reform Commission (NDRC), the State-owned Assets Supervision and Administration Commission, the Ministry of Science and Technology, and the State Electricity Regulatory Commission. NDRC is the policy and planning body for national economic and social development.

- Investment environment:
  - Independent regulation: None yet for Guangxi
  - Market structure: Public sector for Guangxi
  - Utilities ownership dominated by: Public sector for Guangxi
  - Private sector participation in distribution: No for Guangxi and Yunnan
  - Cross-subsidies: Present for Guangxi

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- The State Electricity Regulatory Commission was established in March 2003 and is the national regulatory body in charge of the electricity sector. Its responsibilities include (i) monitoring electricity market operations, ensuring orderly and fair competition, and regulating transmission, distribution and generation of power; (ii) establishing and enforcing safety and technical standards; (iii) proposing tariffs, charges and other fees; (iv) resolving disputes and investigating possible violations by market participants; and (v) implementing sector reform programs.
- In 2002, the State Power Corporation was restructured into separate generation, transmission, and service companies. The Southern Power Grid Corporation owns the power grid in Guangxi and Yunnan, as well as the rest of south and southwestern PRC.

- Trade enabled environment:
  - Trade permitted: Yes for Guangxi
  - Network connections: Limited for Guangxi

- Sustainability:
  - Policy for universal access: Lifeline rates available for Guangxi
  - Rural electrification: 100% by 2010 for Guangxi
- The Renewable Energy Law covers priority policies for electricity from renewable energy sources and its priority connection to grids, preferential pricing, and public sharing of costs. The Government has also earmarked special funds for renewable energy development.
- A Medium- and Long-term Program for Renewable Energy Development has been released, with the goal of increasing renewable energy consumption to 10% of total energy consumption by 2010 and 15% by 2020.
- The Government is supporting development of clean coal technology, as well as research and development of advanced technologies such as coal gasification, processing and conversion, and integrated gasification (combined cycle).
- Restructuring of the coal sector began in 2005 with the purpose of consolidating the fragmented industry into a few giant conglomerates and encouraging foreign investment as a means of modernizing large-scale mines and introducing new technologies.

C. Natural Gas

- Gas sector (Yunnan only):
  - Resources: 32 bcm
  - Production: 6 mcm
  - Domestic gas infrastructure: Limited
  - Pipelines: Data unavailable
  - Power: Negligible

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- Planning and projects (Yunnan only):
  - Projects identified: Bilaterally
  - No GMS regional gas master plan yet
  - Domestic gas master plan: Availability is unclear
  - High availability of public resource funding
- The PRC's oil and gas industry is dominated by three state-owned holding companies: China National Petroleum Corporation (CNPC), China Petroleum and Chemical Corporation (SINOPEC), and China National Offshore Oil Corporation (CNOOC). Each company operates a number of local subsidiaries. CNPC and SINOPEC are engaged in both upstream and downstream activities, while CNOOC operates offshore activities.
- In 2007, CNPC signed a framework agreement on strategic cooperation with the Yunnan Provincial Government for the development of major energy projects in the oil and natural gas marketing network, as well as development of biomass energy.
- In 2007, PetroChina began building an oil refinery in Guangxi with a projected capacity of 10 million tons per year. The refinery is designed to mainly process crude oil from CNPC's overseas oil projects. Upon completion, the plant is expected to provide 7.6 million tons per year of refined oil products, liquefied petroleum gas (LPG), and polypropylene and other petrochemicals to the southwest PRC market.

- Investment environment (Yunnan only):
  - Independent gas regulator: None yet
  - Domestic market structure dominated by: Public sector
  - Gas price controls: Yes
  - Cross-subsidies: Large

- Trade enabled environment (Yunnan only):
  - Trade permitted: Yes
  - Network connections: Bilateral

D. Energy Efficiency

- Measures (PRC as a whole):
  - Strategic vision: Yes
  - Energy policy thrust: Yes
  - Energy conservation program: Yes
  - Equipment and appliance labeling: Yes
  - Energy intensity targets: Yes
  - Building standards: Mandatory

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Appendix 10: continued

  - Energy audits: Voluntary
  - Private sector participation (ESCOs): Yes
  - Energy price subsidies: Yes
- The energy priorities under the 11th Five-Year Plan include the following: develop the coal industry in an orderly manner; speed up exploitation and development of oil and gas; positively develop hydropower; and optimize development of thermal power.
- To promote energy conservation, the Government has made conservation of resources a basic state policy, and has issued the Decision of the State Council on Strengthening Energy Conservation Work.
- The Government has also promulgated and implemented the Medium- and Long-term Special Plan for Energy Conservation. The Plan sets the target for energy consumption reduction during the 11th Five-Year Planning period (2006–2010), and assigns specific tasks and responsibilities to the various provinces, autonomous regions, and municipalities directly under the central government, as well as to key enterprises.
- To promote all-around energy conservation, the PRC is taking the following measures:
  - Promoting structural adjustment to ensure that economic development is low-input, low-consumption, low-emission, and high-efficiency.
  - Improving energy conservation in industry.
  - Launching energy-saving projects such as petroleum substitution, simultaneous generation of heat and power, surplus heat utilization, and construction of energy-saving buildings.
  - Strengthening the administration of energy conservation. In this regard the Government has established a system of compulsory procurement of energy-saving products by government agencies.
  - Advocating energy conservation in society.
- The 11th Five-Year Plan includes a target of reducing energy consumption per unit of GDP by 20% by the year 2010 for the PRC as a whole.

Appendix 11-1

Project Concept for a Regional Project Preparation Technical Assistance Facility

The regional energy integration projects outlined previously have significant benefits but they are complex, usually involving cross-border projects and private sector participation. Adequate specialized resources are therefore needed to ensure high-quality project preparation that can facilitate the desired results.

This project preparation technical assistance facility (PPTAF) will fund preparation of the project concepts outlined earlier. The expected budget for the program is on the order of $20 million. The scope of work to be funded includes

- **Regional Electricity Transmission Development Program:** refining the project concept, developing governance structure, and financing development of specific transmission link projects.
- **Regional Energy Efficiency Program:** developing details of the project types to be supported, developing governance structure, and financing consultant input for preparation of specific investment applications under the program.
- **Small-Scale Clean Generation Fund:** developing the fund concept and documentation, and funding of studies and technical assistance required to clear the way for pilot projects in a series of replicable small investments.

- **Advanced Clean-Coal Generation Projects:** for each country concerned, the PPTAF could finance (i) the process of reaching a consensus with the government regarding project structuring, location, and technology; (ii) advisory services for policy changes required for success, such as changes in national power procurement approaches and environmental conditions; and (iii) preparation of tender documents for selection of private sector partners who will build and operate the facility.
- **Oil Refinery Supporting Infrastructure and Guarantee Project:** refining the economics of the project, determining a suitable location, assessing key risks to be covered and basic infrastructure to be provided, developing project documentation (especially the guarantee component), and assisting government in selecting a suitable private sector partner for refinery development.
- **Biomass Generation Project:** identification of sites, development of investment-specific feasibilities and documentation, and formulation of an action plan to address social and environmental issues; and assistance in the selection of private sector and community partners for development of specific investment opportunities.

Technical and Economic Viability

This PPTAF is necessary to ensure proper preparation of projects that could have a total investment cost of $4 billion. Substantial additional benefits will flow from subsequent projects made possible by demonstration effects, policy, and regulatory and contractual developments financed by the project. The program can be financed by grants from participating multilateral development agencies.

Critical Success Factors

Selection of high-quality consultants for project preparation.

Appendix 11-2

Project Concept for an Oil Refinery-Supporting Infrastructure and Guarantee Project in Cambodia

The MESSAGE modeling results indicate that it would make good economic sense for the GMS to invest in facilities for refining oil within the subregion rather than simply importing refined products and exporting crude oil. Viet Nam is already constructing its first oil refinery. Given the recent discovery of oil reserves (estimated to be approximately 700 million barrels),[1] Cambodia is a possible location for a second refinery in the GMS.

Refineries are generally financed, built, and operated on a purely private basis, with no need for government or development agency involvement. Any refinery in Cambodia would ideally be developed privately. However, the reality of the subregion is that any private sector investor is likely to seek an agreement from government for developing the project. Investors worry about political risk, and would expect government assistance with basic supporting infrastructure, including road and perhaps port facilities. This creates an opportunity for multilateral development agencies to play a catalytic role in helping to structure a deal with the Government that could then be backstopped with a partial risk guarantee from a multilateral development agency, as well as loan support for the development of basic supporting infrastructure.

The project will consist of an initial study to help determine a suitable location for a refinery, followed by

- technical assistance for development of a comprehensive legal and contractual framework to allow and protect private sector investment in a refinery,
- assistance in selecting a suitable refinery development partner,
- a partial risk guarantee for government commitments available to the refinery partner to help remove fears that government action could reduce the value of the investment, and
- a loan to finance development of basic supporting infrastructure such as transport links to and from the refinery.

Technical and Economic Viability

The MESSAGE model results indicate that Cambodia could economically invest $5 billion in refining capacity by 2015. The perceived level of risk by investors could be reduced through a guarantee from a multilateral development agency that would facilitate realization of the project. Reducing risk also reduces the cost of the project's capital by helping ensure that risks are allocated to the party that can best manage them.

Financial Viability and Structuring

The refinery itself would be privately financed, owned, and operated. A multilateral development agency could help the Government of Cambodia create a comprehensive investment support and protection framework. Basic supporting infrastructure would be financed by a standard loan from the multilateral development agency to the host government. The project loan could also include a guarantee that would indemnify the investor against loss caused by a failure to honor this framework.

Critical Success Factors

- Interest and engagement by the Government of Cambodia.
- Development of a simple, but secure investment facilitation and protection framework in law or contract.
- Selection of a suitable private sector firm to finance and develop the refinery.

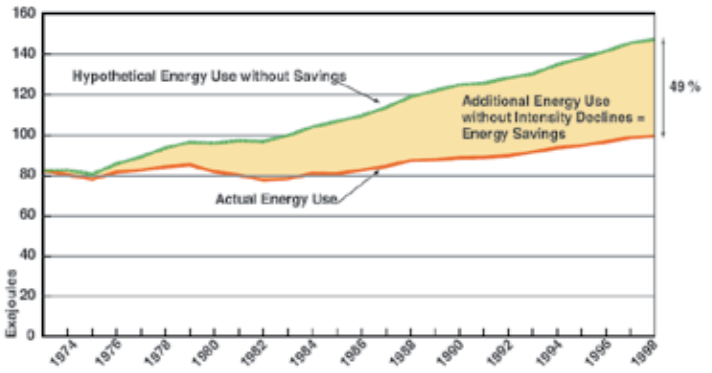
[1] Crispin, Shawn W. 2007. Cambodia's coming energy bonanza. *Asia Times Online*. 26 January. www.atimes.com/atimes/Southeast_Asia/IA26Ae01.html

Appendix 11-3

Project Concept for a Regional Energy Efficiency Program

Promoting energy efficiency (EE) in the GMS makes sense due to the success of EE initiatives in other countries. As the figure below shows, member countries of the Organisation for Economic Co-operation and Development (OECD) have been able to reduce their energy use substantially with the help of EE initiatives. Acting now will ensure that new capital stock being created in the GMS in the form of new buildings, factory equipment, and domestic appliances will embody efficient technology. Failure to act now means that inefficiencies will be locked in during the life of the assets, or will require expensive retrofitting. A regional program approach is justified because the problems and opportunities are

Gains from Energy Efficiency in the OECD countries, 1973–1998



OECD = Organisation for Economic Co-operation and Development.
Source: ADB. 2006. *Report on the Energy Efficiency Initiative.* 29 March.

similar across the GMS. In addition, EE needs to be addressed in a coordinated manner across a number of fronts, and usually only requires a small investment for individual projects.

The Regional Energy Efficiency Program will include a number of windows that can be deployed across the region. Examples of these are:

- **Power plant efficiency:** improving fuel conversion rates in existing power plants through refurbishment and improved operating procedures.
- **Industrial sector efficiency:** energy audits for large industrial enterprises that identify EE improvement opportunities and measures for taking advantage of those opportunities.
- **Commercial-sector building efficiency:** improvements in air conditioning and lighting systems achieved through replacing chillers and ballast, lighting retrofits, and using voltage regulators. Energy audit reports and EE studies conducted by various institutions and cited by the Dutch Cooperation Fund for Promotion of Renewable Energy and Energy Efficiency (PREGA) indicate that improving air conditioning systems can potentially reduce building energy consumption by up to 30%. The potential savings under this window in Thailand alone are between 127 and 522 GWh per year.[1] Governments could help catalyze market forces in this regard by entering into public–private partnerships for improving the energy efficiency of government-owned buildings. This approach has been successfully used in Singapore.
- **Support for development of Energy Services Companies (ESCOs):** this window will promote development of ESCOs, which are private companies that specialize in reducing their clients' levels of energy consumption. ESCO services include energy audits; developing packages for energy-saving measures; installing and operating EE measures; and arranging financing, staff capacity-building, and measuring, verifying, and guaranteeing energy savings. This window would complement the commercial-sector building efficiency window described above.
- **Energy-efficient light bulbs for households:** promoting energy-efficient light bulb use for reducing household electricity consumption.
- **Energy efficiency standards and labeling for appliances:** a consistent approach used throughout the subregion would produce the greatest level of benefits from this initiative.

- **Regulation and policy advocacy:** promoting incentives for energy efficiency by pricing energy in a manner that reflects its true scarcity cost to society.

Technical and Economic Viability

Technical viability of this program would be assured by use of technologies and approaches that have been proven internationally. Similarly, the economic viability of similar projects has already been established. For example, pre-feasibility studies by PREGA have shown that the economic internal rate of return for commercial-building efficiency projects can be as high as 30%.[2] Also, a proposed project for promoting energy-efficient lighting for households in Indonesia was recently deemed to be economically viable, with an economic internal rate of return of more than 250%.[3] ADB also recently estimated that cost-effective EE initiatives in the industrial sectors of developing member countries have the technical and economic potential to reduce total energy use by 40%.[4]

Financial Viability and Structuring

Energy efficiency initiatives have been proven to be financially viable in developing countries outside the GMS, with pre-feasibility studies by PREGA showing that the financial internal rate of return for building efficiency projects can be as high as 28%.[5] The proposed ADB project for promoting energy-efficient lighting for households in Indonesia was estimated to have a financial internal rate of return of 304%.[6] The proposed program could be undertaken within the scope of the ongoing EE initiatives being undertaken by multilateral development agencies, including ADB.

Critical Success Factors

- Gaining agreement between GMS governments on a subregional rather than a national basis on a unified approach to EE standards and labeling.
- Aligning GMS energy tariff levels with the full cost of production and distribution.
- Creating an environment that enables and encourages privately-owned ESCOs.

[1] Asian Development Bank (ADB). 2006. *Report of the Energy Efficiency Initiative*. Manila (29 March).
[2] PREGA. 2005 *Improvement of Air-Conditioning System in the Building Sector: Case of Cardiac Center Hospital*. Harapan Kita, Jakarta (October).
[3] ADB. 2007f. *Report and Recommendation of the President to the Board of Directors on a Proposed Loan to the Republic of Indonesia for Energy Efficiency in Power Distribution and End Use*. Manila (April).
[4] Footnote 1.
[5] Footnote 2.
[6] Footnote 3.

Appendix 11-4

Project Concept for a Regional Electricity Transmission Development Program

Regional cooperation in electricity is estimated to have the potential to unlock net benefits of $450 million to $910 million across the GMS.[1] To realize these benefits, an electricity transmission infrastructure is needed to facilitate power distribution within and across GMS member countries. The Long-Term Indicative Master Plan for the GMS Region estimates that from 2010 to 2035, approximately 41,000 megawatts (MW) of transmission capacity will have to be installed, with a total cost over the period of $8.5 billion.[2] In addition, specific institutional and regulatory reforms need to be in place to make the grid inter-operable.

A regional electricity transmission development program could be developed as a multi-country, multi-investor initiative since the electricity grid needs to be developed as an integrated system involving a large investment of capital. To ensure the effectiveness of this program, a long-term planning horizon should be used, keeping in mind that decisions and changes made in one area will have ripple effects on optimal investment elsewhere. Multilateral development agencies may want to finance a significant portion of the required investment, including technical assistance for institutional and regulatory reforms as well as management and accountability systems.

Program Governance and Structure

This multi-stakeholder program needs a well-defined governance structure to ensure that the GMS governments, multilateral development organizations, private sector investors, and other stakeholders are involved in key stages of program development and implementation. Some ideas that can be considered are

- The program would be governed by a board consisting of representatives of the investors that have contributed to the program. These investors would include multilateral development agencies and governments of GMS countries that chose to invest in the program. In a later stage, ways could be found to open the program to private investment at the program level as well. The Regional Power Trade Coordination Committee (RPTCC) would be either represented on the board or would serve as an advisor to the board.
- The participating multilateral development agencies would provide a secretariat to manage the program.
- Regional transmission plans would be periodically refined by external consultants, who are engaged by, and report to the board. The consultants would be asked to develop specific project concepts that are consistent with the least-cost plan.
- Once the board is satisfied with the plan, national governments would be invited to take up particular programs included in the plan that fall under their respective jurisdictions.
- All projects accepted by national governments that are located in the countries of their respective jurisdictions would be financed by the fund, unless:
    - The failure of another country to support one of the recommended links meant that the plan had to be modified, or
    - Funds were insufficient; in which case projects would be ranked according to the economic benefits delivered per dollar of expenditure, and the top-ranked projects would be financed first.

Technical and Economic Viability

The transmission development program would use well proven technologies, consisting of 220-kilovolt (kV) AC, 500 kV AC, and

3,000 MW DC transmission lines. Actual transmission line routes and designs would be determined by consulting engineers who are experts in the field to ensure technical viability.

The program is economically viable, with net benefits estimated at $450 million to $910 million. In addition, individual projects within the program would be assessed against criteria that demonstrate that each project: (i) is part of the least-cost plan, (ii) produces a level of benefits that exceeds project costs, and (iii) has a design that uses a least-cost approach to creating particular links.

Financial Viability and Structuring

Financial structuring and charging arrangements would be worked out as part of the development of the RPTCC plan and might differ, depending on the location of the link in question. Structuring options include (i) on-lending to national utilities, which would then repay the loans from revenues received from transmission charges; and (2) build-own-operate-and-transfer (BOOT) projects, with some of the debt provided from the fund; in this case private project companies would most likely be paid an annual availability payment by the national transmission companies, which would in turn recover the costs through revenues produced from their transmission charges.

Critical Success Factors

- An effective governance structure that leads to agreement between governments on which links are to be built, and
- Coordination with investment in generation facilities to take advantage of the trade opportunities created by the transmission grid.

[1] Asian Development Bank and Norconsult. 2002. *Regional Indicative Master Plan on Power Interconnection in the GMS: Final Report*. Manila. June.

[2] Mercados EMI and Soluziona. 2007. Long Term Indicative Master Plan for the GMS Region. Draft Final Report, October. Manila (TA 6304-REG).

Appendix 11-5

Project Concept for a Biomass Generation Project

The MESSAGE model predicts that the least-cost expansion of electricity generation in the GMS will involve installing 19,400 megawatts (MW) of biomass-fired generation in the subregion from 2005 to 2025, with 7,600 MW of biomass-fired generation needed by 2015. The model also estimates that by 2015, biomass-fired generation will supply 25 terawatt hours (TWh) of electricity per annum.[1]

GMS countries have two abundant renewable sources of biomass—sugar cane *bagasse* and rice husk. Coffee husk and coconut residues are also potential sources of biomass. For example, it is estimated that Viet Nam alone has 2.5 million tons of rice husk available that could be used for energy generation.[2] Biomass-fired generation is attractive because it can use waste to help satisfy the demand for electricity and heat. The objective of the project would be to introduce, promote, and expand the application of biomass-fired generation technologies in the GMS.

A multilateral development agency could finance several private or community-owned biomass-fired power plants that would be connected to the local grid. Plant capacities would be from 500 kilowatts (kW) to 5 MW. The location, configuration, and fuel-type of the plants would be determined following a review of the pre-feasibility work undertaken by the Dutch Cooperation Fund for Promotion of Renewable Energy and Energy Efficiency (PREGA). The plants would most likely be located in the PRC, Lao PDR, or Viet Nam.

Technical and Economic Viability

The technical viability of biomass generation units has been proven internationally. Commonly used technologies include direct combustion, gasification, anaerobic digestion, pyrolysis, briquetting, and liquefaction. At present, the most common technologies are direct combustion and gasification from rice husk to produce electricity.

The project is economically viable, given model results that show growing substantial investment in biomass-fired generation. Integriertes Ressourcen Management (IRM) estimates the levelized cost of energy from a biomass-fired power plant to be 2.9 US cents per kilowatt-hour—well below the average shadow prices estimated for each of the GMS countries. Pre-feasibility studies by PREGA also estimate that biomass-fired power plants of this type in Viet Nam can be economically viable, with an economic internal rate of return from 11.9% to 25.1%. PREGA also estimates that a 500 kW rice-husk fired power plant in Viet Nam could reduce CO_2 emissions by 20,194 tons during the project's lifetime.

Financial Viability and Structuring

Loans to private or community-owned organizations could be provided by a multilateral development agency. Pre-feasibility analyses carried out by PREGA for similar projects in Viet Nam indicate that projects of this type can be financially viable, with a financial internal rate of return of from 9.7% to 17.0%.

Critical Success Factors

- Selection of appropriate project location, technology, and fuel.
- Ability to sell the plant's output not only to the community, but also to the national electricity company through a feed-in tariff.

[1] IRM. 2008. *Economics of Energy Integration: Application of MESSAGE Model in the GMS*. Austria.

[2] PREGA. 2004. *Demonstration of Rice Husks-fired Power Plant in An Giang Province*. Viet Nam. May. www.adb.org/Clean-Energy/documents/VIE-PFS-Rice-Power-Plant.pdf

Appendix 11-6

Project Concept for a Coal Liquefaction and Carbon Neutrality Technical Assistance Project

The results of the MESSAGE model indicate that development of $29 billion in coal-to-liquid plants is likely to be economically justified over the period 2005–2025. Although this investment level may seem high, it is in fact based on relatively conservative assumptions, with the total cost of coal liquefaction at $70 per barrel of oil equivalent, including the cost of both transporting the coal and importing technology from high-cost countries. This compares favorably with liquefaction plants in the United States that can profitably supply synthetic fuels at $41–$56 per barrel.[1] The GMS economies—particularly Viet Nam and Yunnan—have considerable coal resources, which raises the prospect of increasing their levels of energy security and lowering their production costs through coal liquefaction technology.

Some key issues that need to be studied in undertaking a coal liquefaction and carbon neutrality project are as follows:

- The technology is relatively new and untested. While the processes involved date back to World War I and World War II Germany, the viability of the technology at the time was dictated by the need for energy self-sufficiency. Likewise, during South Africa's trade isolation under apartheid, coal liquefaction was used to produce synthetic fuel.
- The viability of the project depends critically on the international price of oil. At an estimated production cost of $70 per barrel

or less, the project appears viable at recent oil prices, which were for some time above $90 per barrel. Nevertheless, oil prices have been volatile historically, and were below $30 per barrel only 5 years ago. Indeed, widespread adoption of coal liquefaction technology, as well as increased use of other alternative oil technologies such as biofuels and extraction of oil from tar sands, could be among the factors driving oil prices down in the future. If oil prices drop below the levelized cost of production of oil from coal for any sustained period, the investment in coal liquefaction would be wasted

- Coal liquefaction releases carbon dioxide in quantities that can exceed by up to 50% those released in the extraction of petroleum and its refinement.[2] Carbon sequestration is currently being explored as a means of offsetting these excess greenhouse gas emissions and making coal liquefaction carbon-neutral in the sense that it causes no more emissions than conventional oil production. However, the high cost of sequestration reduces the financial viability of carbon-neutral liquefaction.

This project will be a study that will

- assess the current state of technological development of coal-to-liquid conversion processes, and advise on the processes and technologies that have most potential for the GMS;
- identify technical options for making coal liquefaction carbon neutral, including the state of readiness of these options in contexts in which they have been used before, and advise on the carbon-neutrality options likely to be promising for the GMS;
- calculate the probable capital and operating costs of coal liquefaction, and hence the likely all-in levelized production cost;
- estimate the increment to the all-in levelized production cost that would result from making the coal-to-liquid conversion process carbon neutral;
- assess alternative scenarios for the evolution of oil prices, and hence the expected economic benefits of coal liquefaction, as well as the value of its contribution to diversifying oil price risk and increasing energy security; and
- identify suitable locations for coal liquefaction plants in the GMS, and formulate detailed project concepts for plants, if the foregoing work indicates that they are likely to be technically feasible and economically and environmentally justified.

Critical Success Factors

- Engagement of quality consultants.
- Active participation of the country governments being advised.

[1] Miller, C.L. 2007. Coal Conversion—Pathway to Alternate Fuels. Presentation to 2007 EIA Energy Outlook Modeling and Data Conference, 28 March, Washington, DC. United States Department of Energy.

[2] Department of Trade and Industry of the United Kingdom. 1999. *Cleaner Coal Technology Programme, Technology Status Report 010, Coal Liquefaction*. London.

Appendix 11-7

Project Concept for a Small-Scale Clean Generation Fund

According to the results of the MESSAGE model, investments in small-scale renewable and clean energy can be made on the order of $2.6 billion for small hydro and $3.7 billion for decentralized solar generation by 2015. The investments can be used to support a number of small projects of a similar type that can be implemented by private developers (e.g., grid-connected mini-hydro generation systems) and communities. The conventional loan process is deemed inappropriate for this purpose since it would be too costly and inflexible to manage. As an alternative, a small-scale clean generation fund can be set up for this purpose. Under this approach, a private firm can manage the fund and invest in a number of project types depending on their size, technology to be used, and economic viability.

Multilateral development agencies can contribute toward the financing portion of the required investment for the fund. The program can support a wide range of small-scale clean generation technologies within the GMS using fund windows with pre-defined investment criteria such as those described below.

Possible Small-Scale Clean Generation Fund Windows

Community-based clean electricity generation

Project counterparts	Villages, local governments, cooperatives, and nongovernment organizations serving communities of less than 5,000 people
Technologies	Mini- and micro-hydro generation Biomass generation Mini- and micro-grids to distribute power to community members Connections to utility transmission or distribution grids for back-up power or sale of surplus energy
Project size	No individual project to exceed 5 megawatts (MW) capacity or $5 million
Structuring	Loans to the counterpart agency, or to an electricity service entity owned by the counterpart agency. Loan secured by the assets financed, as well as by other cashflows of the borrowing entity. Personal guarantees from community members may also be considered (as in microfinance)
Economic and financial viability	Standard multilateral development agency economic criteria Financial criterion is proof of ability to service loan May lend up to 80% of project cost

Policy advice and technical assistance to government

Project counterparts	GMS governments
Technologies	Targeted advice to assist governments in removing specific barriers to development of one or more types of projects within the fund's mandate
Project size	No individual contract to exceed $50,000
Structuring	Grant finance window for this targeted technical assistance
Economic and financial viability	Demonstration of a clear link between the assistance to be provided and the likely implementation of a number of small-scale clean-energy projects

Small-scale private clean power generation

Project counterparts	Private firms, incorporated under private law, with at least 50% private ultimate beneficial ownership
Technologies	Mini- and micro-hydro generation Wind generation Biomass generation Connections to utility transmission or distribution grids for sale of energy Mini- and micro-grids to distribute power in off-grid areas
Project size	No individual project to exceed 20 MW or $20 million
Structuring	May provide equity investment and debt investment. Equity investment would generally be at the project company level, and would be limited to 30% of total equity. Debt would also generally be at the project company level, and would be limited to 80% of total debt.
Economic and financial viability	Standard multilateral development agency economic criteria. Financial criteria for equity investment are that expected financial returns exceed a commercial hurdle rate (e.g., 8% real post-tax return), and that investing development partners receive treatment equal to that offered other equity investors. Financial criterion for debt is demonstrated ability to service, as measured by debt service coverage ratios. The interest rate on the debt should be consistent with commercial lending rates in the country in which the project is located.

Isolated system energy efficiency

Project counterparts	Private, community, or local-government entities that operate existing off-grid systems serving communities of less than 20,000 people.
Technologies	Distribution-efficiency programs to reduce system losses to economic levels. Rehabilitation and improved maintenance and management of existing diesel systems as a means of reducing pollution and emission levels. Replacement by, or supplementing existing diesel generation facilities with renewable generation facilities.
Project size	No individual project to exceed 20 MW or $20 million
Structuring	May lend to existing entities that invest in assets for improving energy efficiency; in this case may lend up to 80% of project cost, with the debt secured by assets and cash flows. May also support new management teams that take over existing assets, provided that the new team has a credible plan and requisite experience in introducing new management systems for reducing emissions and increasing efficiency. In this case, may invest both equity and debt in the acquiring vehicle. Equity investment limited to 30% of total equity, and debt limited to 80% of total debt.
Economic and financial viability	Economic viability as assessed against standard multilateral development agency criteria. Emissions reduction per dollar of investment must exceed a specified level. Financial criteria for equity investment are that expected financial returns exceed a commercial hurdle rate (e.g. 8% real post-tax return), and that investing development partners receive treatment equal to that offered other equity investors. Financial criterion for debt is demonstrated ability to service, as measured by debt service coverage ratios. The interest rate on the debt should be consistent with commercial lending rates in the country in which the project is located.

Program Governance and Structure

A private firm would be competitively selected as the fund manager by the group of multilateral development organizations and other fund investors. A board of directors can also be appointed by the fund investors to oversee the performance of the fund manager. The fund manager will seek out and evaluate investment opportunities under a performance-based remuneration arrangement, while the board will have oversight powers to ensure compliance with stated investment criteria.

To further expand the small-scale clean generation fund, private investors could also be invited to join at a later stage, primarily to fund the more commercial types of fund windows.

Critical Success Factors

- Selection of a competent, motivated fund manager with the ability to establish strong links with communities and small-scale entrepreneurs in the subregion.

Appendix 11-8

Project Concept for an Abated Clean-Coal Generation Facility in Viet Nam

The MESSAGE model identifies 11,000 megawatts (MW) of abated coal power plants in Viet Nam in the subregional least-cost expansion scenario, with 3,000 MW needed by 2015. Investing in this capacity will supply approximately 17 terawatt hours (TWh) of electricity annually.[1] Carbon abatement can be achieved in a number of ways, although there is debate among energy-sector stakeholders as to which technology or combination of technologies is best. Some examples of carbon abatement technologies include:

- plant efficiency improvements,
- co-firing with carbon-neutral biomass,
- feedwater heating, and
- carbon dioxide capture and storage.

By supporting clean-coal technology with carbon abatement, multilateral development agencies would allow the subregion to continue to benefit from the use of a local and relatively low-cost energy resource, while mitigating the negative environmental impacts that would arise from the use of conventional coal technologies. In addition to the direct benefits from the increment in generation capacity, supporting introduction of such technology in Viet Nam would assist diffusion of advanced technology throughout the GMS by providing demonstration and learning-by-doing benefits.

Multilateral development agencies could propose financing a clean-coal power plant that uses abatement technology. The location and configuration of the plant would be determined following a review and update of Viet Nam's least-cost expansion plan, as well as the subregional expansion plan. A technical assistance component could be included to help investigate the various abatement technologies and analyze which technologies are best suited to local conditions in Viet Nam.

Technical and Economic Viability

The levelized delivered cost of electricity from an abated coal power plant is estimated to be around 4.4 US cents/kilowatt-hour (kWh).[2] In comparison, the model estimates the average final consumption shadow price of electricity in Viet Nam from 2010 to 2015 at approximately 16.7 US cents/kWh. Since the levelized production cost is less than the economic value of the output (as proxied by the shadow price), the project is economically viable.

Technical viability of this project has been proven in power plants in non-GMS countries, and would be assured through engagement of engineers, construction companies, and operators with experience in this technology in other locales.

Financial Viability and Structuring

The project could be structured so as to support an independent power producer (IPP). The IPP company to be supported should be competitively selected, with proven experience in advanced clean-coal generation technology as a requirement. A multilateral development agency could provide a loan to the IPP through its private sector window or through a loan to the Government of Viet Nam for on-lending to the IPP through the country's national development bank. The multilateral agency could consider offering a partial risk guarantee to backstop the national power company's Electricite de Vietnam (EVN) obligations under the power purchase agreement.

Financial viability would be achieved for the project via EVN's agreeing to pay the costs of power, as established through a competitive bidding process. As of 2005, Viet Nam's electricity tariffs

(which are used to recover the cost of generation, transmission and distribution) ranged from 2.7 to 7.6 US cents/kWh for residential customers and 2.6 to 13.1 US cents/kWh for industrial customers. Once the cost of transmission and distribution is taken into account, it is unlikely that EVN would be able to recover the full costs of energy production and distribution from the proposed IPP power plant through current tariff levels. The Government would therefore need to either provide an explicit subsidy to EVN, to increase electricity tariffs, or to continue to supply coal to the power sector at prices below world-market levels. However, the issue of financial viability of new generation facilities must be addressed, regardless of the type of technology and financing sources chosen. This issue is not specific to an abated clean-coal IPP.

Critical Success Factors

- Selection of an appropriate project location and design.
- Selection of experienced firm as IPP.
- Ability to structure lending from the multilateral development agencies involved to the IPP special purpose vehicle.
- Ability to protect the financial viability of EVN under the arrangements specified.

[1] Using the MESSAGE Model's availability factor of 65%.
[2] Using IRM's levelized cost estimate of $279,900 per MWyr, adjusted for a transmission and distribution margin of 100%.

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Building A Sustainable Energy Future: The Greater Mekong Subregion

An integrated, prosperous, and equitable Mekong subregion is the vision of the Greater Mekong Subregion (GMS) Economic Cooperation Program. Developing the energy sector is critical to realizing this vision. The results of the formal energy modeling exercise make a strong case for pursuing an integrated regional energy strategy. Targeted and sustained policy actions, including reforms, are necessary for a viable GMS energy strategy. Private sector participation is also key in accomplishing this goal. This book synthesizes the output of the consultative process undertaken by the Asian Development Bank's technical assistance to develop a GMS energy strategy, and proposes concrete actions for a cleaner, brighter energy future for the subregion.

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