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MRC SEA FOR HYDROPOWER ON THE MEKONG MAINSTREAM

ENERGY & POWER BASELINE ASSESSMENT WORKING PAPER

8 March 2010

The MRC SEA of Hydropower on the Mekong mainstream comprises 4 main phases: (i) scoping, (ii) baseline assessment, (iii) opportunities & risks assessment, and (iv) avoidance, enhancement and mitigation assessment.

The Baseline Assessment Report has two volumes:

VOLUME I: Summary Baseline Assessment Report

VOLUME II: Baseline Assessment Working Papers

This working paper is one of eight in Volume II of the baseline assessment report. The two volumes formally conclude the baseline assessment phase of the SEA and documents the outcomes of the baseline consultations and SEA team analysis.

CONTENT

ENERGY BASELINE ASSESSMENT

Theme: Energy and Power

Key Issues:

1. Electricity demand in the region
2. Buyer and seller motivations for cross-border power trade
3. Energy resource base and alternatives

1 BACKGROUND AND SUMMARY

1.1.1 Objective

The objective of this baseline paper is to provide relevant information on the status and trends on the power sectors of the Lower Mekong Basin (LMB) countries and on the historical, current and prospective development of LMB hydropower. This information will be used to assess tradeoffs and identify needs and options for the fair and sustainable development of LMB hydropower in subsequent stages of the SEA.

This broader objective is a key step in the formulation of policies endorsed by all LMB countries that would provide a much needed regulatory framework for IWRM. Such framework would be a primary tool for anticipating and resolving conflicts, enabling planners to incorporate the basin wide vision into their specific developments, and providing for a consistent set of objectives to guide the design and operating criteria of future hydropower projects.

1.1.2 Power sector focus

It is important to make it clear that this report is strictly focused on power sector aspects and, more specifically, on power generation aspects. It does not include any quantitative assessment of the cost of mitigation or compensation of social and environmental impacts of power generation nor does it include any evaluation of non-power benefits except export revenue from power generation and direct job creation in the generation industry.

Indeed, even though many studies of individual projects contain qualitative assessments of the cost of mitigation of social or environmental impacts and of the cost of facilities required to connect the project to the power grid, a special effort was made to eliminate up front any non-generation- costs from the analysis of generation projects, for the following reasons:

1. The analysis presented in this report is only one component of a much larger analysis that includes the assessment of non-power impacts, negative and positive. Thus, any quantitative assessment of non-power impacts would constitute a double-accounting in the larger picture that includes the evaluation of all aspects of the projects.

2. The transmission component of a grid-connected generation project or group of generation projects is only temporarily specific to that project. The transmission line and any required substations are, or should be eventually, assets of the interconnected power grid that serves all generation projects in the interconnected system. Thus, while the investment in transmission may be necessary to enable the project, it should not be allocated to its energy cost but rather to the cost of the grid and the grid should, eventually, pay back that investment to the project from the revenues collected for use of the grid (known as "wheeling fees").

3. The data on investment for all LMB projects considered in this analysis comes from budgets prepared by a large number of different entities, mostly engineering firms or engineering agencies of the different governments. These entities use different criteria in deciding what and how much to include in the budgets for social or environmental mitigation, for grid connection and even for interest during construction. Also, the budgets correspond to different points in time sometimes many years apart.

Therefore the analysis required a process to homogenize, as much as possible, the basis for determining the investment required by each project so that a meaningful comparison of different sets of projects could be undertaken. This was done as follows:

- First, the budgets were examined to identify any component corresponding to social or environmental mitigation, to high voltage transmission that would become part of the interconnected grid and to financial costs such as interest during construction. These components of the budgets were then eliminated

- Second, the interest during construction was recalculated applying a uniform assumption of the time-value of capital (discount rate) to the construction schedule reported for each project.

- Third, the adjusted budgets were brought to a uniform price level by applying indexes of escalation of construction costs from the time the budget were prepared to a common price level year.

1.1.3 Trends in electricity demand in the region

There are several factors driving electricity demand in the Greater Mekong Sub-Region (GMS) The rapid pace of export-led growth in the region comes on top of efforts to improve and expand electricity access in rural areas, amid trends to urbanization, diversification of regional economies and rapid population growth. As a result, electricity demand growth rates in many Mekong countries are among the highest in the world.

Currently, power consumption in the GMS is low by world standards (Figure 2.1), even when compared to developing countries. Average per capita power consumption in the GMS is only two thirds of the world average (ADB 2008). However, GDP growth and other demographic and economic indicators in the region (Figure 2.2) suggest rapid changes from 2005 intensity levels and these are reflected in the national projections of electricity demand.

In particular economic growth in the LMB is driven by rapid structural changes in the region's economies. Vietnam is currently undergoing rapid economic growth and, to a greater or lesser extent, all countries in the region are seeing their growth driven by expansion of the industrial sector. The energy-intensive manufacturing sector, in particular, has been a most important driver of this growth.

Rapid urbanization and electrification is a significant component of demand growth as it drives the fraction of population with access to more affordable on-grid electricity. Higher electricity consumption by the commercial and residential sectors is driven by higher income levels of consumers with preference for modern conveniences. A greater number of electrical appliances are thus widely used, for example, refrigerators, electric fans, rice cookers, televisions, light bulbs, including air-conditioners, computers, and so on.

Demand forecasts are always contested. Section 6 in this paper considered demand-side management as one aspect of that debate. The current status and official view of demand trends are indicated in Figure 1.1. This suggests that annual growth rates in electricity demand in the LMB will average up to 8.5 percent in 2015 and 6.5 percent by 2030, with the high rate of demand growth in Vietnam figuring prominently.

In both 2015 and 2025, energy demand (Gwh) in Vietnam and Thailand combined will represent 96 percent of LMB demand. The following puts in better perspective the trends in these two major markets for LMB hydropower:

- Thailand: the power demand will increase by a factor of 2.2 in the next 15 years, with an annual increase of peak demand of 2,600 MW per year in 2025 (equivalent to 3 new 800 MW gas-fired plants per year).

- Vietnam: will catch up with Thailand demand in 2014. The power demand will increase by a factor of 3.7 in the next 15 years, with an annual increase of 4,600 MW per year in 2025 (equivalent to 6 new gas-fired plants per year).

The significance of these projections can be better appreciated by considering that a single plant of that size requires an investment of approximately US$ 700 million.

Figure 1.1 Electricity Demand Forecast in LMB Countries

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

Source: ADB RETA 6440, December 2009 base on an update of GMS Power Development Plans

1.1.4 Drivers of cross-border power trade

Growing demand for electricity in the region is, unquestionably, a driver for any form of new power generating capacity. However, it cannot by itself be considered the direct driver of LMB hydropower development in general, or mainstream hydropower projects in particular. The drivers of LMB hydropower development are to be found in two broader and very distinct, economic and political phenomena.

Power System Planning

Power system planning determines which generation options fit within the framework of power supply policies set by governments. This essentially means a balance between power supply reliability and cost that denies the optimum expansion of generation capacity This aspect will be discussed in detail in Sections 2 to 5 which analyze the regional and national power sectors, however, a key aspect relevant to LMB hydropower is the strong interest of Thailand and Vietnam to diversify power supply sources for grid and off-grid power which include subsidies for RE generation and results in increased tolerance for power imports.

Volatility in international energy prices and concerns over climate change have all intensified the focus on developing the Mekong's indigenous renewable resources including solar, wind, biomass and hydropower to the optimal potential. The region as a whole imports about 22% of the energy for electricity generation (oil, coal and gas) and fossil fuel imports for power generation are set to rise. Governments are thus increasingly focused on achieving energy security at national and regional levels as part of the broader strategy of regional economic integration.

When generation capacity expansion plans, planners must combine a number of conflicting objectives, primarily:

1. to keep the cost of supplies as low as possible
2. to limit dependency on imported fuels
3. to limit dependency on power plants located beyond their borders.

Thailand is a perfect example of the conflict that planners face between objectives 2 and 3. On the one hand, thermal plants can be located near the load centers lowering transmission costs and losses and, more importantly, within the national territory and entirely within the national power grid. That adds a level of comfort to electric supply sovereignty even if fuel has to be imported, for two reasons: 1) as long as fuel can be stockpiled, the energy from those plants is relatively immune to events in the fuel supplier country and 2) having a maritime coast gives access to the world fuel markets so, worst comes to worst, fuel can be secured at world market spot fuel prices. On the other hand, while long term fuel supply contracts are common and quite secure, if prices skyrocket or there is an unfavorable political situation then even the most secure contract is at risk of default. Thus, Thailand planners have to choose the lesser of or rather, a combination of, two evils:

a) having sovereign capacity at the risk of skyrocketing variable costs or

b) relying on imported power from foreign hydropower plants that have more stable future cost

Export Income

Lao PDR and Cambodia, see the potential income from electricity export to the larger neighbouring economies of Thailand and Vietnam as a primary means for lowering national debt burdens, balancing trade, boosting growth and reducing poverty.

For countries with a low level of industrialization or with exports confined to raw materials, the export of electricity is an opportunity that is hard to pass, much more if it is produced by a renewable resource that will not be exhausted by such export. All over the world there are examples of similar situations where less economically developed countries in the upper and more mountainous reaches of river basins export hydropower to their downstream neighbours with flatter terrain that resulted in faster population and economic growth. To name a few: Nepal and Bhutan export hydropower to India; Kyrgyzstan and Tajikistan export hydropower to Uzbekistan; Peru has just signed a bilateral MOU for hydropower export to Brazil.

An important part of the arrangement is that the process not only generates income but it also provides for the development of the power sector infrastructure and know how of the exporting country.

1.1.5 Trends with multilateral, bilateral and project specific agreements

This broad picture is supported by the fact that all six governments of the Greater Mekong Sub-Region (the four MRC Member Countries plus Myanmar and China) signed an Intergovernmental Agreement on Power Interconnection and Trade in 2003. Subsequently, a 'road map' to implement the agreement was prepared. Regular updates are provided including a regional interconnection master plan and supporting institutional arrangements.

The regional road map builds on a series of bilateral MOUs and agreements developed by the Mekong governments over the past two decades to expand cross-border power trade between their respective countries. These bilateral MOUs authorize respective power entities in each country to negotiate a power purchase agreement for specific projects, which fit within the quantum of power under the bilateral MOU. The baseline trends show power import levels in the LMB is an evolving picture. So far, Thailand has signed bilateral agreements to buy up to 11,500 megawatts of electricity from its neighbors. It has signed memoranda of understanding with Laos to purchase 7,000 megawatts, with southern China for 3,000MW and with Burma for 1,500MW.

While bilateral MOUs are a definite step in the development of projects, their significance to the development status of any specific project should not be overstated. Bilateral MOUs are expressions of common interest in pursuing certain opportunities but they are not to be confused with firm commitments to accept or deliver power from specific projects, since they are entered before a detailed analysis of the projects.

Bilateral MOUs do however indicate the level of electricity import "tolerance" in the power system of the importing country and provide basis for further consideration of any project-specific agreements and eventually power purchase agreements (PPAs) between the utility in the importing country (EGAT in Thailand and EVN in the case of Vietnam, concerning LMB power projects in neighboring countries). In the AB RETA for GMS these import tolerances were estimate to be 15% of projected peak demand. Thailand and Vietnam have signed bilateral MOUs with Lao PDR. Cambodia has not signed any MOUs and proceeds with project specific arrangements only.

Project specific MOUs or Letters of Agreement are the equivalent to "temporary licenses" in open-entry wholesale electricity markets.[1] The objective is, for the importing party, to have authorization to start study a project (feasibility and EIA / SIA study) and exclusive right to pursue the project if the studies are favorable. For the host country, the objective is to have a plan of project development subject to the results of the studies. The project-specific MOUs are succeeded by Project Development Agreements,

[1] Lao PDR signs project-specific MOUs with developers issued by the Ministry of Energy; Cambodia signs Letters of Agreement and MOUs issued by the Ministry of Energy (and Mines?)

and eventually Concession and PPAs as outlined in Section 2. Ultimately whether a specific project proceeds or not depends on the ability of the proponent to secure financial closure, which means debt and equity financing for the project. Financial closure is not automatic and depends on the project developers ability to attract the necessary financing, which in the case of identified LMB projects can be anywhere between $US 9 to 64 billion (Figure 1.2)

Figure 1.2 - Identified LMB Projects by Level of Development

COUNTRY		PROJECT STATUS				
		IN OPERATION	UNDER CONSTRUCTION	UNDER LICENSE	PLANNED	TOTAL
LAOS	Projects	10	8	22	60	**100**
	Capacity (MW)	662	2,558	4,126	13,561	**20,907**
	Annual Energy (GWh)	3,356	11,390	20,308	59,502	**94,556**
	Investment (Million US$ 2008)	1,020	3,256	8,560	26,997	**39,832**
CAMBODIA	Projects	1	0	0	13	**14**
	Capacity (MW)	1	0	0	5,589	**5,590**
	Annual Energy (GWh)	3	0	0	27,125	**27,128**
	Investment (Million US$ 2008)	7	0	0	18,575	**18,582**
VIETNAM	Projects	7	5	1	1	**14**
	Capacity (MW)	1,204	1,016	250	49	**2,519**
	Annual Energy (GWh)	5,954	4,623	1,056	181	**11,815**
	Investment (Million US$ 2008)	1,435	1,312	381	97	**3,225**
THAILAND	Projects	7	0	0	0	**7**
	Capacity (MW)	745	0	0	0	**745**
	Annual Energy (GWh)	532	0	0	0	**532**
	Investment (Million US$ 2008)	1,940	0	0	0	**1,940**
ALL COUNTRIES	Projects	**25**	**13**	**23**	**74**	**135**
	Capacity (MW)	**2,612**	**3,574**	**4,376**	**19,199**	**29,760**
	Annual Energy (GWh)	**9,846**	**16,013**	**21,365**	**86,808**	**134,031**
	Investment (Million US$ 2008)	**4,402**	**4,568**	**8,941**	**45,669**	**63,580**

The LMB trend is for hydropower projects to be developed largely by the special project company or importing party, whether a private power producer (IPP), a utility or an agency in Thailand or Vietnam. The projects are then operated by said party or a designated operator for the duration of a concession period during which a fraction of the power produced is assigned to the host country (Laos or Cambodia) and the rest is used by the importing party.

For example:

- Theun Hinboun 1: 210 MW for export and 10 MW supply to Lao grid.
- Nam Theun 2: 1070 MW for export and 75 MW to Lao grid
- Theun Hinboun extension: 220 MW for export and 60 MW to Lao grid.

1.1.6 Alternative demand-supply option trends

During the scoping phase many stakeholders felt it important for the SEA to highlight the status and trends in alternatives to improve electricity access and services in power markets that LMB mainstream dams would target, in particular with (i) non-hydro indigenous, renewable energy sources (ii) further, or even accelerated hydropower development on LMB tributaries to replace or defer consideration of mainstream LMB hydropower until the full implications are better understood, and (iii) demand-side management in Thailand and Vietnam to reduce load growth.

Simply put, one set of views is alternatives do exist - and this fact needs to be brought to the attention of political decision-makers. If Thailand and Vietnam were to pursue these alternatives, in combination with exploiting the remaining hydrocarbon resources in the GMS region (e.g. primarily natural gas and coal) supplemented by imports from outside the GMS, the LMB mainstream dams would be unnecessary from a power demand-supply import perspective. A competing set of views was that all feasible supply options are needed to meet growing needs for electricity services, not only in Thailand and Viet Nam, but also in Cambodia and Lao PDR and that even aggressive demand-side management measures will only serve to moderate the rate of demand growth but would not diminish interest on LMB hydropower.

LMB Energy Resource Base

The GMS as whole has considerable hydrocarbon resources, which vary from country to country as discussed in Section 6.2 of the paper. The picture in the LMB countries is while countries do have proven hydrocarbons (i.e. coal, gas natural gas and oil in Vietnam, natural gas and limited coal Thailand and to a lesser extent, in many cases the reserves are not long term and there is competition for use of these resources in other economic sectors.

The total hydropower potential of the Mekong River Basin is estimated to be 53,000 MW, with about 30,000 MW technically available in the four lower Mekong countries of Cambodia, Lao PDR, Thailand and Viet Nam is well known.

The LMB countries possess large (non-hydro) renewable energy (RE) resources although the utilization with advanced conversion technologies to produce power is still comparatively low, and some of the traditional energy resources (i.e. wood fuels are under multiple pressures).

Thailand has estimated that its medium-term RE potential for conversion to power is some 14,300 MW (see table 6.6) including: biomass (7,000 MW); solar 5,000 MW; small hydropower (700 MW) and wind (1,600 MW). Although many stakeholders argue the RE potential for solar in stand-alone applications is much higher considering the potential for widely distributed solar applications that may be cost-effective. Other LMB have RE potential. In Viet Nam, the resources are similar to Thailand but perhaps with a greater potential for wind in off shore and coastal areas and in the longer term ocean.

There is additional potential for non-conventional sources including geothermal (limited), municipal solid wasted and perhaps a large untapped potential for co-generation link to industrial process heating and waste processing.

Alternative Supply Technologies

Two broader categories used in this paper to help clarify the status and trends in the LMB concerning these small and lager-scale RE options for power generation are (i) decentralized generation, and (ii) distributed generation. Decentralized generation means not connected to the national grid. It includes isolated or "mini-grids", as well as stand-alone systems for individual customers, especially rural, low-income households engaged in subsistence agriculture distant from the grid. The second broader category, distributed generation, which captures the family of RE conversion technologies (small hydro, wind, solar biomass, etc.) as well as conventional technologies (e.g. diesel generators) and non-conventional generation (e.g. industrial co-generation) used in a grid connected context.

Stand-Alone options provide a way to extend energy services to remote rural areas with no grid service, or limited prospects to be serviced by lo-voltage in the near term. These options are important to help meet the MDGs for electricity access in remote areas. The technologies include simple household lighting systems, solar (PV) home-systems, micro hydro and modified engines using bio-fuels coupled with generators, and potentially wind (electric or mechanical generators) depending on site specific conditions. Stand-alone applications for rural-based industry or enterprises that can afford energy conversion technologies at a larger scale include diesel generating sets, small steam or gas turbines, micro-hydro units, windmills coupled to generators, modified engines using bio-fuels coupled with generators, and wood residue or rice husks to raise steam and produce electricity locally.

Isolated grids service remote towns, settlements and local enterprise/industrial needs, which is the case in the 12 isolated grids in Cambodia. Medium-sized generation may be from a range of different sources including oil or diesel, natural gas, medium and small hydropower and the family other RE generators that depend on site specific RE resource availability. Assistance with RE technologies is one focus of attention in donor-supported programmes.

Drivers of RE: Each LMB country is evolving its RE policy, implementation of which is most advanced in Thailand. The Government of Thailand adopted a 15-year Alternative Energy Development Plan (AEDP) in January 2009, which aims to reach a target of 20% alternative / renewable energy in the total national energy mix by 2022, as well as advance the use of high-efficiency energy technologies. For the power sector, the target is to derive 11,216 MW from RE sources by 2022. The most significant policy trend is Thailand has advanced two programmes (1) the small power purchase (SPP) programme for RE generators up to 60 MW, and (ii) the very small power producer (VSPP) & Feed-in Tariff Programme. SPP applications for 6,682 MW had been received by mid-2008, of which 4,151 could be supplied to the grid. Installed capacity by mid-2008 had an installed capacity of 1,622 MW.

In Viet Nam, the updated Power Development Plan (PDP) prepared in 2009 anticipates that electric generation from RE sources may reach 2,400 MW by 2025, which would represent close to 3% of installed capacity by that time (see Table 6.7).

The challenges to address in RE promotion for decentralized and distributed uses in the LMB countries include the intermittent nature of energy availability of some technologies based on RE resources, high first costs hence the need for subsidy, the need for organization for their utilization, and to some extent foreign exchange implications. Each RE conversions technology also has its own complexity and institutional coordination requirements and environment and social implications.

Nuclear Power: Both Vietnam and Thailand included nuclear power in their latest Power Development Plans. Five to seven nuclear reactors are proposed by 2030 in the Latest Revision to Thailand PDP (January 2010, yet to go through public hearings). Vietnam more actively proposes to have 4,000 MW (in two complexes) by 2025, with the first unit possibly by 2020. It projects the nuclear power will eventually reach 20 percent of grid supply in Viet Nam., well beyond 2030. The Thai Government openly acknowledges the greatest challenge in proceeding with the nuclear power will be public acceptance.

Demand side-Management (DSM)

At the center of the critique of hydropower (certainly the LMB mainstream proposals) as well as other large-centralized power supply options is demand growth and demand side management. The government Power Development Plan (PDP) forecasts, for example, are contested on many grounds by non-government and academic energy research organizations, but primarily on the basis of overly optimistic economic growth forecasts and failure to invest in and recognize the full potential of demand-side management options.

There is ample evidence that LMB governments supported by donor partners increasingly recognize the value of energy efficiency in meeting environmental and development goals. DSM has gained support on number of grounds, particularly where cost-effective measures can be demonstrated to delay or offset the need for future power plants. DSM is also viewed as one of the most cost-effective ways to reduce greenhouse gases such as CO2.

Although all LMB Countries have made progress in the last decade with DSM there is a mixed picture as discussed in Section 6.2 of the paper. Focusing on the two main power markets for LMB mainstream dams; Thailand was on of the first countries in Asia to formally adopt a nationwide demand-side management master plan in 1997. Today Thailand maintains an active DSM program. As of June 2007, the DSM implementation reportedly reduced peak demand of 1,435.2 MW and energy demand of 8,148.3 GWh. As Thai Authorities note, the program also achieved CO2 Emission reduction of 5.63 million tons.

Viet Nam started its first DSM Programme in 1997 with a multi-phase and multi-year programme with targets for a 120 MW reduction in peak demand and 496 GWh in 2007. Independent review suggests achievements in DSM in Viet Nam to date are very difficult to monitor because of the growth rate in demand, load shedding and the lack of monitoring data. In 2006 the Viet Nam government launched a National Program on Energy Efficiency and Conservation with energy efficiency targets (or national aspiration goals) for a 5% reduction in overall energy consumption for 2006 to 2010, and 5 to 8% for 2011 to 2015 in all sectors. The most cogent analysis of DSM challenge in Vietnam was prepared by the APEC Energy Working Group Peer review of progress on DSM in the country. It confirms that while there is and urgent need to expand DSM activities there remains a major change in translating policy to practice.

The trend to higher electricity tariffs will gradually influence consumer behaviour in the medium to longer term, e.g. turning off lights and appliances when they are not needed and buying energy efficient bulbs and appliances. Except for the easier measures or low "hanging fruit" like energy efficient lighting and power factor (i.e. a measure of reactive energy demand which reduces supply efficiency) correction in industry, significant penetration of DSM is a longer-term prospect that requires structural change and well planned investment in replacement of the existing stock of inefficient appliances and electricity using equipment especially in the industrial and commercial sectors and a major initiative to introduce energy-efficient appliances in the manufacture and supply chain of appliances.

1.1.7 Other baseline trends

GHG emission reductions from LMB Hydropower

Applying national CO2 offset values to the annual energy produced by each hydroelectric project and targeted to each national power market the following values are obtained for the CO2 offset by each hydropower development scenario:

LMB projects in operation by 2010:	6.1 M.Ton/year
Tributary Projects that will be operational by 2015:	22.6 M.Ton/year
Tributary Projects that could be operational by 2030:	42.0 M.Ton/year
Mainstream projects that could be operational by 2030:	51.9 M.Ton/year
All Projects that could be operational by 2030:	93.9 M.Ton/year

It is important to recognize these are gross offsets. Discussion on net reduction accounting for potential reservoir emissions is noted in section 7, but a quantitative analysis of net offsets is beyond the focus of this report as it relates to non-power considerations.

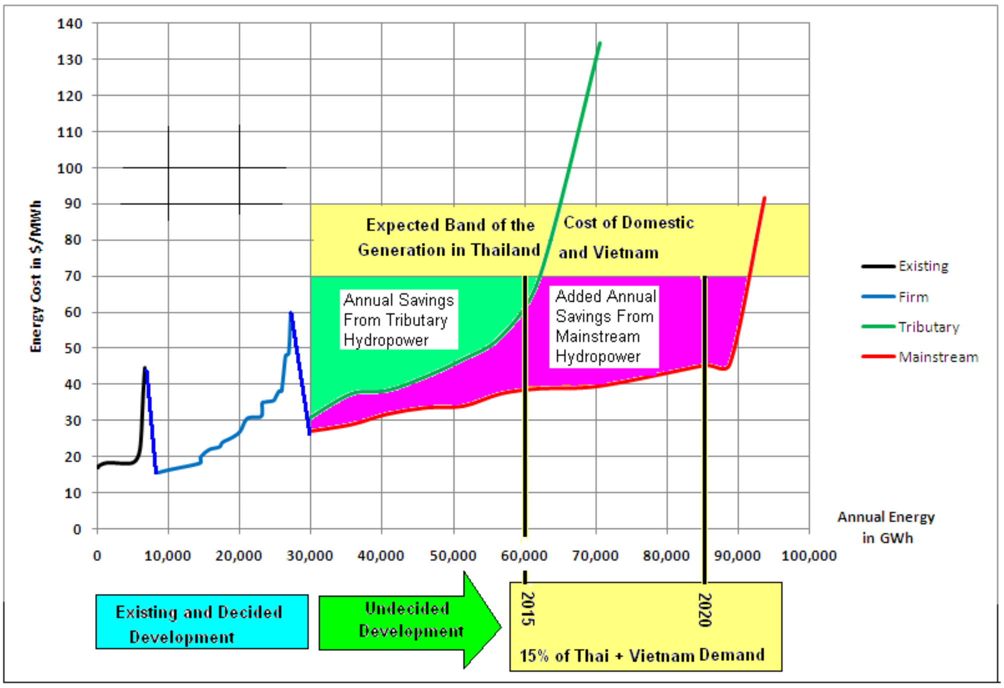
Investment Trends, Energy Costs and Competitiveness

As noted above hydropower is a highly capital intensive industry. A typical hydroelectric project today requires in the range of 1,500 to 3,000 $/kW (1.5 to 3 million US$ per installed MW) in construction budget and considerably more after accounting for the financing cost resulting from construction periods that can be as long as 7 years.

The 38 LMB hydroelectric projects in operation or under construction have an average installed capacity of around 170 MW and their unit cost is estimated at 1,250 $/kW. The remaining 97 projects identified in the LMB have an average installed capacity of 243 MW and estimated unit cost of around 2,320 $/kW.

However, installed capacity and energy potential are not directly proportional and there is a very wide range in the final cost of the energy produced by these projects. A good illustration of the quantity, cost and competitiveness of the energy from existing and future LMB projects by the supply curves in Figure 1.3. The development of these supply curves is explained in Section 6 of this report.

Figure 1.3 - LMB Hydro Supply Curve and Primary Market Thermal Alternative Costs



GMS and LMB Employment Trends

Because LMB projects are increasingly financed by GMS region private sector entities and there will be some GMS regional distribution of contracts for civil construction contracts and equipments, services and electrical and mechanical equipment. The trend is to increasingly produce hydropower equipment in China, and Thailand and Vietnam are major contractors and service providers.

GMS and LMB Employment Trends

Civil works, including roads, canals, dams, tunnels, etc., represent a very large portion of the budget of hydroelectric projects and these are labor intensive facilities that can use a considerable portion of local labor during their construction. The labor component of LMB projects identified for development during the next 20 years is estimated at 10.8 billion US$ and approximately 40 percent will almost certainly be local labor from Laos and Cambodia. The rest will be highly skilled labor mostly from equipment producing countries and it is likely that much of it would come from China, Thailand or Vietnam. Mainstream projects account for 55 percent of the estimated labor during construction.

By comparison, the labor cost during the operation of these projects is rather minor, even considering their long life. The net present value of operation and maintenance labor is 1.1 billion US$ and 55 percent of that is estimated to be local labor.

This analysis only includes direct labour creation in the hydropower industry and not the effects of hydropower trade upon the economies involved with the associated effect on job creation.

1.1.8 Summary baseline conclusions

On the status and trends in the power sector to 2015 and 2030 around key issues:

- Amid trends to urbanization, diversification of regional economies and rapid population growth electricity demand will continue to grow in the LMB. Current trends suggests that annual growth rates in electricity demand in the LMB will average up to 8.5 percent in 2015 and 6.5 percent by 2030, with the high rate of demand growth in Vietnam figuring prominently. In both 2015 and 2025, energy demand (GWh) in Vietnam and Thailand combined will represent 96 percent of LMB demand.
- From a strategic perspective current trends in supply side-efficiencies and demand side efficiency will lead to peak (MW) and energy (GWh) savings in LMB countries; however, the main role of DSM will be to slow the rate of demand growth. This recognizes that the full potential for DSM remains contested on (i) the amount of savings possible (peak reduction and energy reduction) and (ii) uncertainty on whether technical estimates of DSM are achievable and over what timeframe, and the extent to which they be depended upon in power supply planning .
- Hydrocarbon fuels are used for roughly 90 percent of power generation in LMB countries. Imports are 22 percent and set to rise as Thailand and Vietnam increasingly consider coal imports from outside the GMS for the power sector due to economics. The picture in the LMB countries is while countries do have proven hydrocarbons (i.e. coal, gas natural gas and oil in Vietnam, natural gas and limited coal Thailand and to a lesser extent, in many cases the reserves are not long term and there is competition for use of these resources in other economic sectors.
- Clean coal technologies will no doubt be of interest in LMB countries due to the high reliance on coal. However, these technologies imply higher investment and operating costs that those that have been assumed to determine the expected competitiveness of LMB hydropower in the region and therefore cannot be expected to displace hydropower solely on economic grounds.
- An analysis of supply curves of undecided LMB tributary and mainstream hydropower against a threshold energy price of 7 US Cents/kWh deemed to be competitive as an export price indicates a potential of 90,000 GWh per year of which 30 percent is in tributary projects and 70 percent is in mainstream projects.
- LMB countries have significant RE and non conventional energy resource base. Small-scale REs are important to pursue and central to the energy policies and the poverty reduction policies of LMB Counties. Strategically. the prospects for RE in the stand-alone, isolated mini grid and grid system context as well as DSM does not change the drivers of mainstream power export to Thailand and Vietnam and in the short to mid-term, which is more influenced by other consideration of levels of power import. Thailand has indeed signaled it would like to increase imports in its latest PDP Revision 2010
- Renewable off-grid power does not directly compete with, but complements grid power in extending power access and services to LMB Populations. In the longer term and with the trend established by Thailand with its feed-in tariff policies RE connected to the grid will expand. But in all

LMB countries subsidy is involved in the near term to make RE power compatible with consumer income.

- LMB has a significant potential for GHG reduction due to the high GHG content of the power it can be expected to displace up to 50 million tons of CO2 per year in the probable future scenario of the BDP (gross emission reductions at thermal plant replaced).

2 REGIONAL CONTEXT

2.1 ELECTRICITY DEMAND AND ITS DRIVERS

2.1.1 Economic Growth

Currently, power consumption in the GMS is low by world standards (Figure 2.1), even compared to developing countries average per capita power consumption in the GMS is only 2/3 of the world average (ADB 2008). However, GDP growth and other demographic and economic indicators in the region (Figure 2.2) suggest rapid changes from 2005 intensity levels that are reflected in the national projections of electricity demand.

In particular economic growth in the LMB is driven by rapid structural changes in the region's economies. To a greater or lesser extent all countries in the region are seeing their growth driven by expansion of the industrial sector. The energy-intensive manufacturing sector in particular has been the most important sector in driving this growth. This has been accompanied by rapid urbanization and increasing levels of household consumption, which also imply increases in power consumption as the portion of the population with access to on-grid electricity increases, and the level of household consumption increases.

As LMB economies expand particularly in Thailand and Vietnam this has resulted growing electricity consumption per connection by the commercial and residential sectors driven by higher income levels of consumers whose consumption characteristics have gradually shifted towards greater convenience and modernization. A greater number of electrical appliances are thus widely used, for example, refrigerators, electric fans, rice cookers, televisions, light bulbs, including air-conditioners, computers, and so on. As discussed in section 6.3.

Figure 2.1 - Per Capita Electricity Use (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.)

Figure 2.2: Changes in GDP/capita, household consumption expenditure and urban population in LMB 1998-2008 (constant 2000 USD)

Country	GDP/capita			Household consumption expenditure/capita			Total population (millions)		Urban population (%)	
	1998	2008	Change %	1998	2007	Change %	1998	2008	1998	2008
Cambodia	251	512	103.9	243	398	63.3	12.2	14.7***	15.82	21.56
Lao PDR	293	475	62.0	254*	285**	12.1	5.2	6.2	20.16	30.88
Thailand	1,827	2,645	44.8	1,022	1,396	36.7	61.4	67.4	30.78	33.32
Viet Nam	364	647	77.7	256	403	57.4	76.5	86.2	23.46	27.84

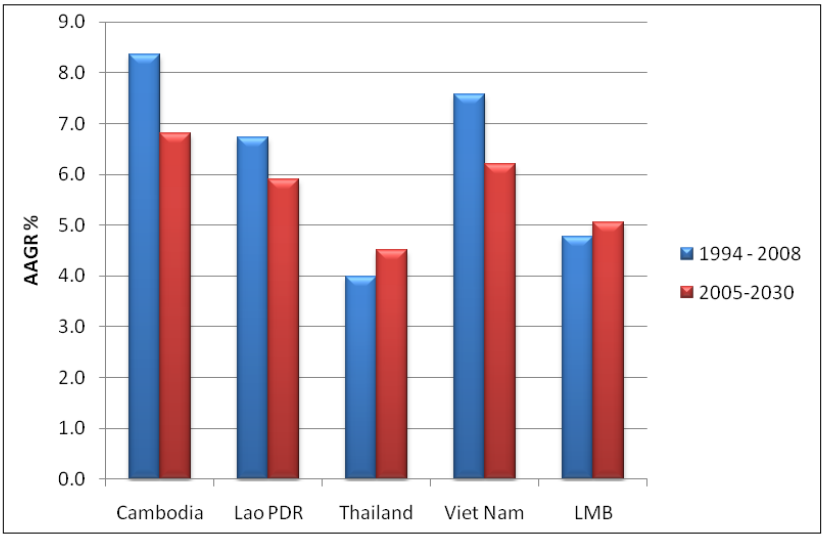
*2000, **2008, ***2007

Source: WDI, World Bank 2009

It may be too early to evaluate the prospects of economic growth beyond the recent global economic crisis since it is difficult to separate expectations, which could be politically motivated, from forecasts based on solid data. However, even in the Asian financial crisis, which affected the region much more severely than is expected in this current economic crisis, GMS growth rates did not deviate drastically from their long term trends (IRM-AG 2008). This is supported by the fact that Thailand and Vietnam showed significant economic growth in the third quarter of 2009 and Vietnam has returned to double digit power demand growth. Current projections by international agencies including the UN and IMF as well as national government forecasts suggest economic growth in the Asia region will resume to levels around 6.3 percent on average and the consensus seems to be that most countries will rapidly return to their long-term economic growth paths.

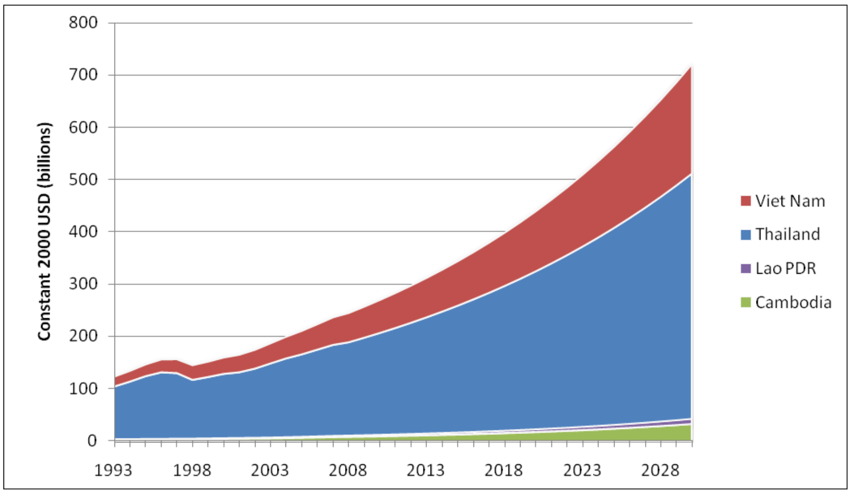
Figures 2.3 and 2.4 summarize the consequences of the projected growth rates in terms of economic size and relative economic performance of the LMB countries over the next two decades. Firstly, it is surprising that economic growth in Thailand is expected to remain so strong over the period to 2030. The relatively easy gains in productivity gains and correcting structural inefficiencies which characterize lower income countries are not likely to be available to Thailand. It will face increasingly tough competition both regionally and globally as it attempts to move up the global value chain. Secondly, Thailand will see its economic dominance eroded by more rapid growth in Vietnam, in particular, although it will remain the largest economy in the LMB by a significant margin. Thirdly, the phenomenal expected long term growth of the region in general stands out, with the region's economy expected to grow by over 240% between 2005 and 2030.

Figure 2.3: Real economic growth rates in LMB countries 1994-2030



Source: ADB/APERC 2009a

Figure 2.4: LMB countries economic growth 1993-2030



Source: Historical data from WDI, World Bank 2009, projections from ADB/APERC 2009a

2.1.2 Demand forecasts and trends

According to the Asian Development Bank (RETA 6440, December 2009) the peak demand in the LMB region will grow from 44,565 MW in 2010 to around 130,000 MW as shown in Figure 2.5. Energy demand is not directly proportional to peak demand as the load factors in Cambodia and Laos will grow a little in response to electrification and industrialization, but the picture that emerges is an overall growth of around 7% per year for the four countries, roughly a fourfold increase over the next 20 years.

Figure 2.5 Electricity Demand Forecasts and trends in LMB Countries

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

Source: ADB RETA 6440, December 2009

The forecast shown in Figure 2.5 is only one among several demand projections prepared by national and international agencies. It will only confuse the reader to report on the multitude of different projections but it should be noted that there are considerable differences, even between different forecasts by the same source. The government Power Development Plan (PDP) forecasts are contested on many grounds by non-government and academic energy research organizations, primarily on the basis of overly optimistic economic growth forecasts and failure to invest in and recognize the full potential of demand-side management options, as discussed in Section 6.3 of this paper. Regardless of which forecast is adopted, it is clear that projections in government planning are an additional 400,000 to 600,000 GWh of annual energy will be demanded in the next 20 years.

For reference, all 11 mainstream dams are expected to produce a combined total of 66,000 GWh, which equates to between 11% and 16.5% of the future demand.

It is also important to emphasize that the forecasts of demand, even peak demand, does not fully reflect the needs for installed capacity additions since older or less economic power stations, will be retired and their capacity will need to be replaced and also because some reserve capacity is needed to maintain adequate reliability of supply during maintenance or forced outage of some power stations.

Finally, in the context of discussing electricity demand as a driver of hydropower it is more convenient to refer to energy demand rather than peak demand and to pay little attention to installed capacity. The reason is that the energy production of hydroelectric plants is not directly proportional to their installed capacity. For example, a 100 MW hydroelectric plant designed for peaking operation may be expected to produce as little as 200 GWh per year, whereas another 100 MW plant designed for baseload (more continuous) operation may produce more than 800 GWh per year. Thus, while capacity is important in the context of operations, the value of hydroelectricity in the LMB comes primarily from its energy potential.

2.2 ELECTRICITY SUPPLY TRENDS

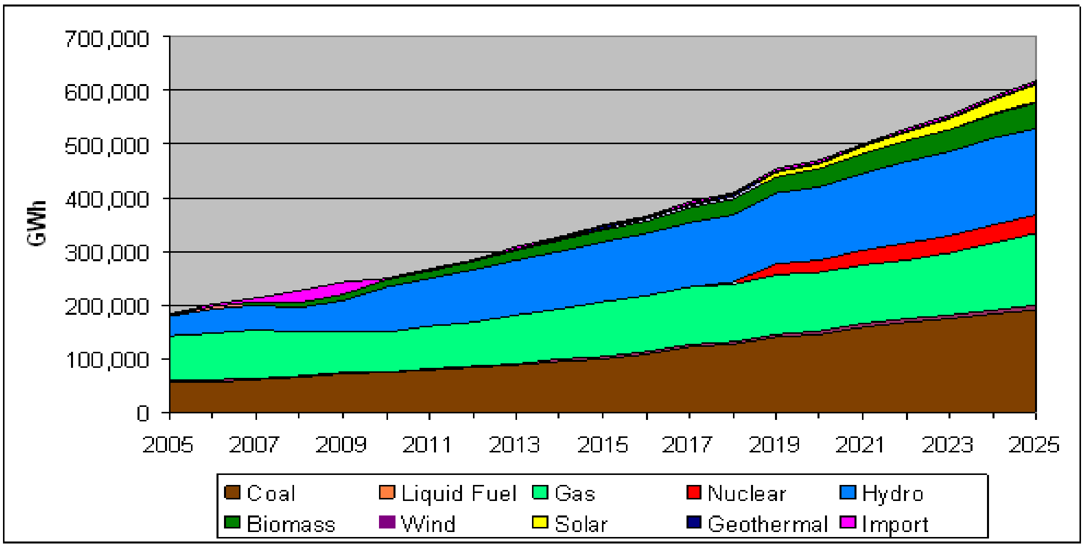
2.2.1 Regional perspective

Energy resources in the LMB are not uniformly distributed. Laos and Cambodia have abundant hydropower resources, while Thailand and Vietnam are rich in natural gas and coal respectively.

On a regional basis, natural gas supports the biggest share of power generation at 58% of the total. Coal fired plants and hydropower share equally another 30% of the supply and the remaining 12% is mostly oil fired generation, whether diesel or bunker. There are minor shares at present of biomass and wind.

As an illustration, Figure 2.6 shows the current and future (according to IRM-AG 2008 forecasts for ADB and the Greater Mekong Subregion) generation mix in the region in terms of the energy supplied by different technologies and fuels.

Figure 2.6: Generation Mix in the Region according to ADB Base Case Scenario[2]



Source: SEA own calculations based on IRM-AG 2008

[2] The percentage figures were taken for the whole GMS, including Myanmar and Yunnan.

This figure shows prominently the introduction of nuclear generation and a fast growing role of solar power. The figure also shows a sustained growth in coal based generation and a more modest growth in hydropower and biomass.

The hydropower proportion in this expected generation mix must be taken cautiously because much of it is based in policy and not on economic drivers and is, therefore, subject to change. For example, since the data on which this figure is based was released, Thailand announced a change of policy that would increase its imports of hydropower from 15% to 25% of demand (a revised PDP January 2010 yet to be subject to full Public Hearings). Indeed, the figure shows an increase in hydropower of approximately 50,000 GWh per year between 2010 and 2025. However, as will be discussed later, the potential for economically competitive hydro energy from the LMB is about twice as high and therefore the width of that hydropower band in the figure will depend on a range of issues but primarily on: a) power import policies in Thailand and Vietnam, b) hydropower development constraints in Laos or Cambodia and, quite possibly, c) regional and public attitudes about nuclear power development.

2.2.2 Regional power trade

So far, power trade is only happening on a bilateral basis through transfers between the grids of producer and consumer countries (Figure 2.7a). Power is sold under Power Purchase Agreements (PPAs) designed on a project-by-project basis.

These PPAs are not isolated events but rather part of a concerted effort. At the first GMS Summit in 2002, an Intergovernmental Agreement on Regional Power Trade was signed by the leaders of six countries (Cambodia, China, Laos, Myanmar, Thailand and Vietnam). In line with that agreement, a Regional Power Trade Coordination Committee (RPTCC) was set up.

As a result of the RPTCC rapid progress was achieved in the identification of new power trade opportunities and the intensity of the ongoing negotiations for power trade is illustrated by the following:[

- 3,800 MW exports from Lao PDR to Thailand are existing, or are committed (i.e. with commissioning date before 2015).
- A global MOU for a total of 7000 MW purchase of Lao power by Thailand by 2015 was signed in 2007. Under this MOU some 8,300 MW of capacity has been identified indicating that there is competition among projects to participate of the trading space opened by the global MOU.

[1] ADB, 2009, Greater Mekong Subregion Economic Cooperation Program, Road Map for Expanded Energy Cooperation in the Greater Mekong Subregion (GMS), 17 June 2009

http://www.adb.org/Documents/Events/2009/15th-GMS-Ministerial-Conference/Road-Map-for-Expanded-Energy-Cooperation.pdf

- A total of 6000 MW MOU on specific tributary hydro projects were signed, 2300 MW of which (tariff MOU) expired recently or negotiation has restarted.
- Additional MOUs exist for Hongsa lignite coal project in northern Lao (1,470 MW)
- Power from a LMB mainstream dam is inserted in the new Thai PDP of Jan 2010 even though no MOU has been officially reported

Figure 2.7a: Bilateral Power Trade Agreements

Source: Zhai, Y. 2008

Figure 2.7b shows data from projects currently under operation or construction and involved in power trade.

Figure 2.7b Active Projects involved in Power Trade

	Project	Purchased Power (MW)	Power purchased in 2008 (GWh)	Power-Transmitted Schedule
1	Signed and operational Projects			
1.1	Nam Theun – Hin Bun	190	1200	31 March1998
	Nam Ngum 1	30	200	?
1.2	Houay Ho	147	477	3 Sept 1999
2	Signed and under construction or committed Projects			
2.1	Nam Theun 2	920	5520	Dec 2009
2.2	Nam Ngum 2	597	1976	Jan 2011
2.3	Expansion of Theun – Hin Bun	220	1395	Mar 2012
2.4	Hongsa Lignite	1700		2015
	Total :	3804		

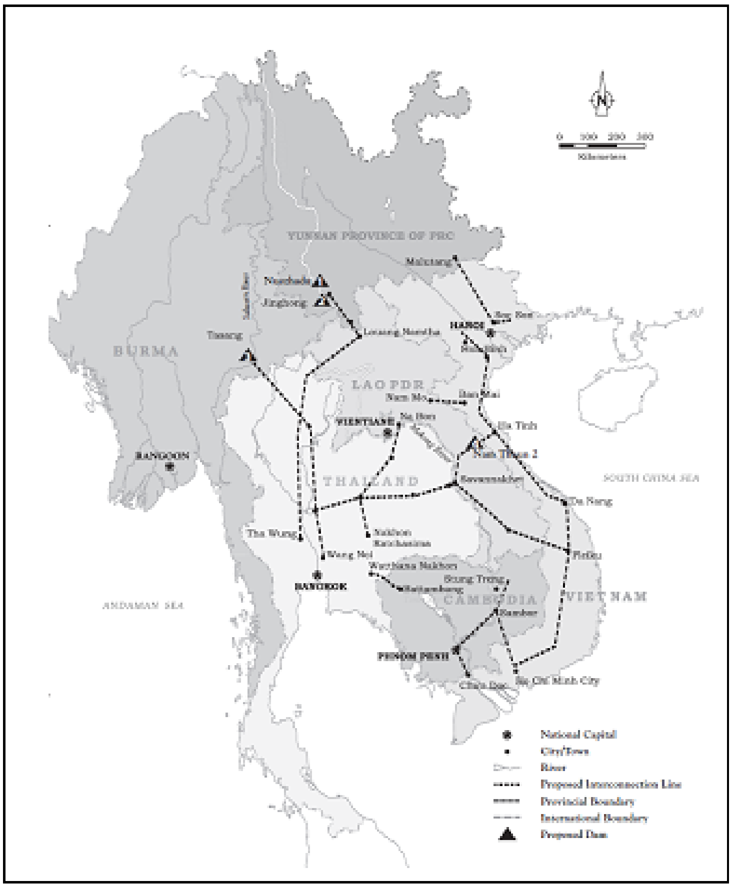
Table 5.4-1 : Export projects in Laos (in operation or under construction)

- The Governments of Thailand and Cambodia do not have a current MOU on power cooperation. However, current power exports from Thailand to Cambodia amount to 40 MW (10% of Cambodia peak demand), and will increase to 60 MW in 2012.
- According to a MOU between Vietnam MoIT and Laos Ministry of Energy and Mines signed in March 2008, Vietnam would invest in 31 projects with total installed capacity of 5,000 MW. A large part of the energy of those projects will be exported to Vietnam.
- In the last Vietnam PDP (MP VI), the total imports reach 5000 MW by 2020 (without indication about the origin of these imports) which is consistent with the MOU signed with Lao PDR.
- According to an electricity trading contract signed in May 2009 between EVN and Electricity of Cambodia (EDC), Vietnam will sell electricity to Cambodia at a capacity of 200MW from 2010.
- EVN will invest in Sesan 2 hydro project (420 MW) in Cambodia and will take half of the output (220 MW) by 2014.

Undoubtedly, a more efficient system would involve a regional power market with uniform pricing and regulatory procedures that could allow power trade in addition to, or even in the absence of, power purchase agreements. However, outside Western Europe and North America, broad regional arrangements for power trade are very rare. Even regions that include a majority of countries with well developed open-entry wholesale electricity markets at national level, such as the MERCOSUR countries of South America (involving, with different levels of membership, Brazil, Uruguay, Argentina, Paraguay, Bolivia, Chile, Peru, Colombia and Venezuela), have not been able to develop a uniform pricing system and rules and regional power exchanges, while plentiful, proceed along the lines of bilateral contracts or specific agreements for emergency support. Perhaps the most advanced among developing regions, in terms of regional integration of power systems, is the Central American region where SIEPAC, (Spanish acronym for Central American Electrical Interconnection System) promises to establish standard rules for exchanges among the power systems of Panama, Costa Rica, El Salvador, Nicaragua, Honduras and Guatemala.

The ADB is supporting work to develop and adopt a road map for implementing the Regional Power Trade (RPT) and to agree on a regional power interconnection master plan; (ii) help GMS countries develop strategic integrated environmental conservation programs; (iii) build on the results of this work and extend it to environmental planning and environmental monitoring of future power projects during their construction and operation. GMS energy road map to implement this is intimately linked and seeks to influence and help shape the national power development plan (PDPs). It is being revised with support from ADB and in conjunction with review, revision and preparation (i.e. in Lao PDR) of national power development plans through the same regional technical assistance package. Past and current drafts of the GMS energy road map do not refer to the mainstream Mekong project proposals. The plan for interconnecting the energy grid of the six countries is shown in figure 2.8.

Figure 2.8: Planned Transmission Network in the Greater Mekong Subregion



Source: IRN 2006

This regional-level process is divided into four sages:

1. Stage one reflects the current situation in the GMS. Bilateral trade exists - independent Power Producers (IPPs) can build power stations and sell the power under Power Purchase Agreements (PPAs). Developers often build power stations with BOT agreements in which the power station is transferred to the host country after some 20 to 25 years of operation.

2. Stage two envisages power trades between any two countries in the region using transmission lines of a third country. Transmission capacity at this stage is limited and power can be transferred only if excess capacity in the transmission line exists.

3. In stage three multiple countries have transmission facilities, some countries will have multiple seller-buyer competitive markets, while other countries will have integrated electricity systems.

4. In stage four, all countries have competitive power markets and transmission facilities that enable power trade between any of them and also by using transmission facilities of third countries.

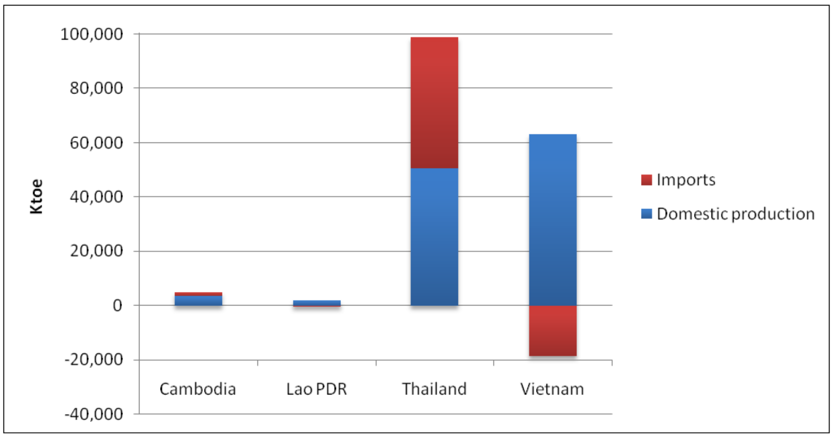
2.2.3 Energy import and fossil fuel dependency

The production and imports of primary energy the four LMB countries is shown in Figure 2.9. Thailand and Vietnam account for the lion's share of primary energy production in the LMB. Vietnam remains a net energy exporter (import dependency of -44.8%) due to oil and coal exports while Thailand imports a significant amount of energy (import dependency of 50%). Cambodia is also highly (and increasingly) dependent on energy imports (import dependency of 87%) due to the fact that its electricity generation system is almost entirely oil based. Despite its considerable hydropower exports Lao PDR remains dependent upon imports of oil and petroleum products (import dependency of 5.4%).

In general high energy import dependency in particular poses a strategic challenge to the four LMB countries, recent volatility in energy prices (as proxied below in the time series of oil price volatility in figure 2.10) brings this into relief. With the exception of Lao PDR all LMB countries are heavily dependent on fossil fuels for power generation (Figure 2.11). This dependency has increased as power generation and consumption has increased. While hydropower generation is significant and has increased by 75% since 1995, this has been far outstripped by expansion of thermal generation which has increased nearly 120% over the same period, in absolute terms thermal power generation has increased by 91,500 GWh/year, compared to an increase of 13,800 GWh/year for hydropower. The increase in hydropower generation over the same period has been concentrated in Vietnam which accounted for about 71% of the increase hydropower generation, compare to 18% in Lao PDR and 10% in Thailand (ADB/APERC 2009b).

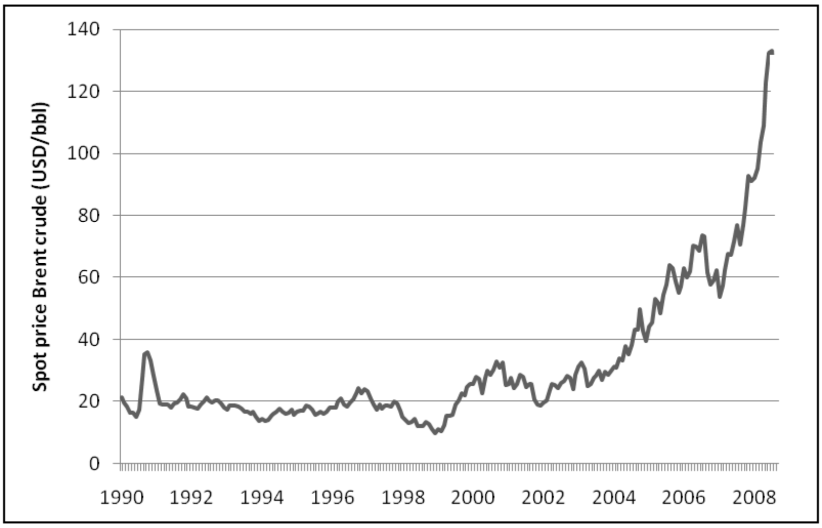
The balance of total primary energy production and use is not entirely representative of that of electricity supply and demand because a large share of primary energy is consumed in other sectors such as industry and transport. Nevertheless, on considering the composition of power generation in the LMB it is apparent why fossil fuel price is a key determinant in energy security.

Figure 2.9: Primary energy production and imports to the LMB 2006



Source: ADB/APERC 2009b

Figure 2.10: Oil price 1990-2009

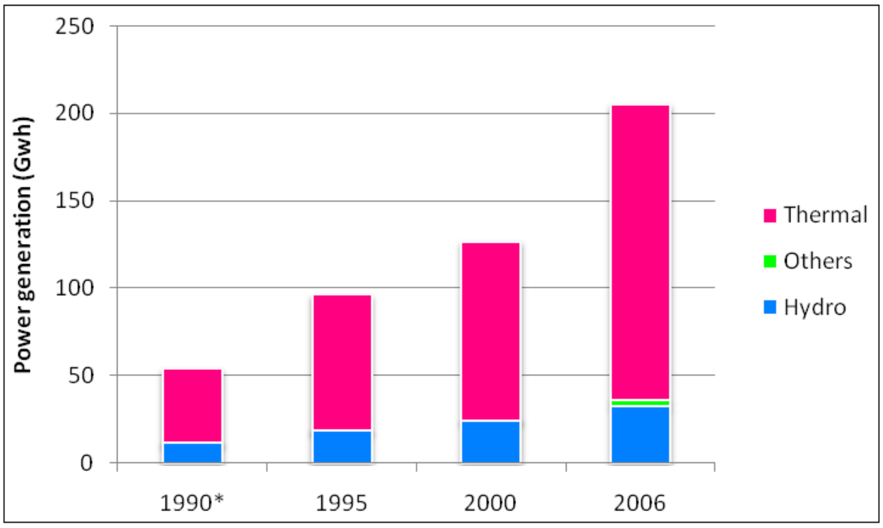


Source: IEA 2009

2.2.4 Mekong basin hydropower potential

The status of hydropower development in the Mekong river basin is summarized in Figure 2.12, which shows the number, power potential and estimated investment of projects by country and by level of development.

Figure 2.11: Power Generation Mix in LMB countries 1990-2006



* No figures available for Cambodia in 1990

Source: ADB/APERC 2009b

Figure 2.12 LMB Hydropower

COUNTRY		PROJECT STATUS				
		IN OPERATION	UNDER CONSTRUCTION	UNDER LICENSE	PLANNED	TOTAL
LAOS	Projects	10	8	22	60	**100**
	Capacity (MW)	662	2,558	4,126	13,561	**20,907**
	Annual Energy (GWh)	3,356	11,390	20,308	59,502	**94,556**
	Investment (Million US$ 2008)	1,020	3,256	8,560	26,997	**39,832**
CAMBODIA	Projects	1	0	0	13	**14**
	Capacity (MW)	1	0	0	5,589	**5,590**
	Annual Energy (GWh)	3	0	0	27,125	**27,128**
	Investment (Million US$ 2008)	7	0	0	18,575	**18,582**
VIETNAM	Projects	7	5	1	1	**14**
	Capacity (MW)	1,204	1,016	250	49	**2,519**
	Annual Energy (GWh)	5,954	4,623	1,056	181	**11,815**
	Investment (Million US$ 2008)	1,435	1,312	381	97	**3,225**
THAILAND	Projects	7	0	0	0	**7**
	Capacity (MW)	745	0	0	0	**745**
	Annual Energy (GWh)	532	0	0	0	**532**
	Investment (Million US$ 2008)	1,940	0	0	0	**1,940**
ALL COUNTRIES	Projects	**25**	**13**	**23**	**74**	**135**
	Capacity (MW)	**2,612**	**3,574**	**4,376**	**19,199**	**29,760**
	Annual Energy (GWh)	**9,846**	**16,013**	**21,365**	**86,808**	**134,031**
	Investment (Million US$ 2008)	**4,402**	**4,568**	**8,941**	**45,669**	**63,580**

2.2.5 Conclusions on the regional perspective

In this section several facts on status and trends have been established as follows:

- There is a high growth rate in the demand for energy in the LMB countries and the total need for additional energy in the next 20 years is three to four times the entire hydroelectric energy potential identified in the LMB.

- There are several power projects already involved in power trade, many more under negotiation or study with formal specific MOUs resulting from global bilateral MOUs with defined targets of power exchange and a large number of projects competing to fill the trading space defined by those global agreements.

- LMB hydroelectric projects currently produce about 7% of the identified potential. Another 12% is under active development and yet another 16% is under license covered by specific MOUs. That covers 25% of the power potential of the LMB, the remaining 75% will depend on policy decisions regarding mainstream development, on the policies of importing countries regarding the acceptable dependency on foreign power plants and on the economics of the individual projects relative to the alternative power supply options. These aspects will be discussed within the national perspectives in Sections 3, 4 and 5 of this report.

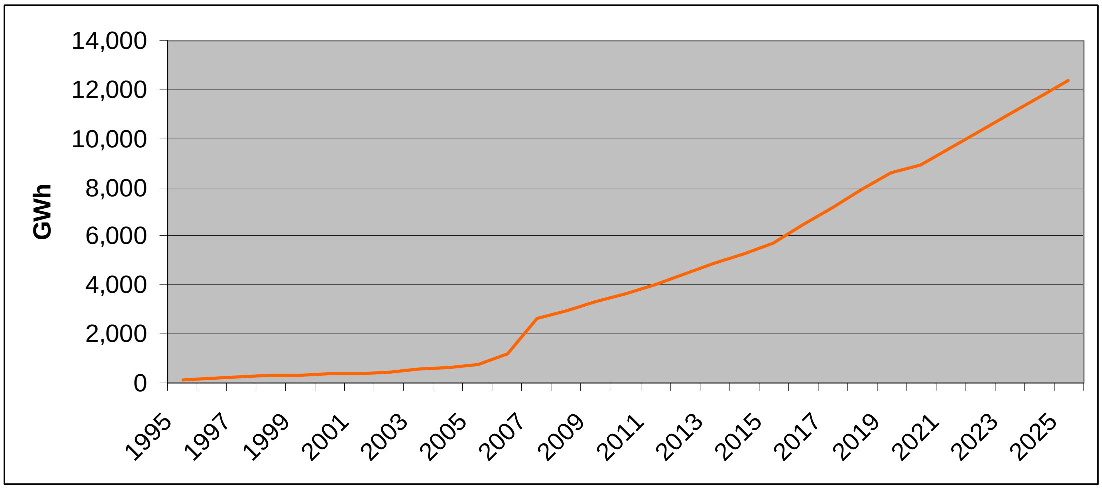
3 NATIONAL PERSPECTIVE - CAMBODIA

3.1 ELECTRICITY DEMAND

As was shown in Figure 2.5, Cambodia had a very high rate of growth in electricity demand in recent years which is explained by the fact that national electricity consumption was minimal before 2000. With increasing GDP and income, more households use electricity, but consumption is still low as most parts of Cambodia are not yet electrified.

The forecast is for a sustained growth in electricity demand consistent with plans for increased electrification of the country. However, average annual growth rate forecasts vary between 4.5% as shown in Figure 17 to the 9% and 10% shown in Figure 3.1. This spread is understandable since there is no historical basis for a more accurate forecast of electricity use, added to the uncertainties about the pace of electrification.

Figure 3.1: Past and Present Electricity Demand and Forecast, Cambodia



Source: ADB/APEC 2009, MIME 2006

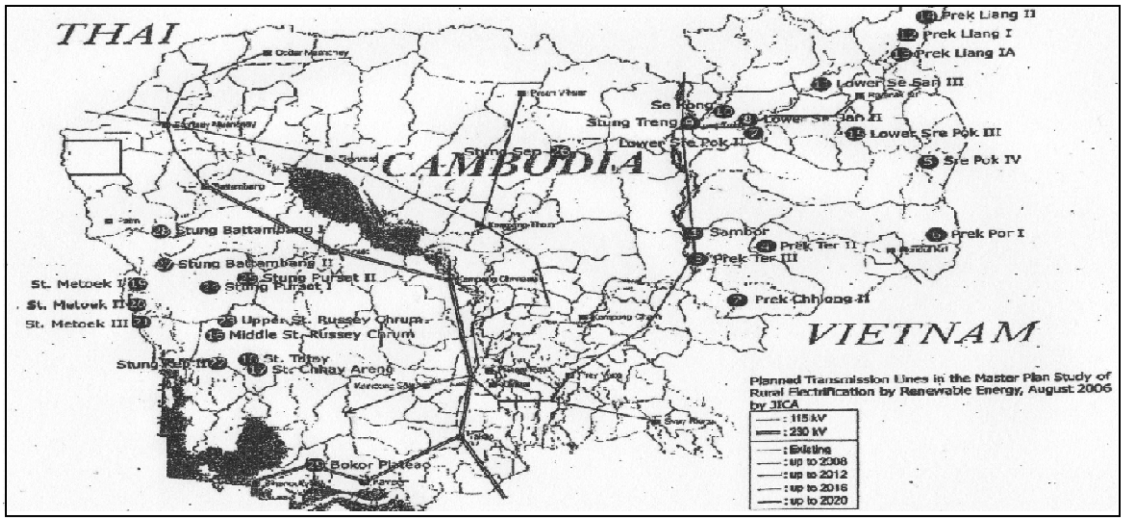
3.2 ELECTRIFICATION AND TARIFF ISSUES

Cambodia has a 220 kV power grid connecting to Vietnam and a 155 kV grid with connections to Laos and Thailand (Figure 3.2). These two networks supply only a fraction of the country, while the rest is supplied by 21 small isolated systems. There are ambitious plans for electrification of the country to interconnect most major load centers and increase the coverage of isolated systems.

Retail electricity rates in Cambodia are the highest in the region (ranging from around 17 to 27.2 US Cents/kWh). This is due primarily to the high cost of running isolated systems that must rely on small diesel fueled generation which are both, inefficient and also completely dependent on high-cost imported fuel. In addition, isolated systems operate at low voltage levels, which leads to high power losses that, in rural areas, reach around 25.34%. The very low per capita electricity consumption of Cambodia, (45 Kwh-year/person in 2005) also contributes to a heavy incidence in the tariff of the fixed cost of operation and administration of the system.

Decreasing electricity tariffs in Cambodia is a high priority. Lower tariffs attract investments in industry, make the existing industry more competitive and make it easier to connect more households to the electricity grid which in turn helps distribute fixed costs into a larger volume of energy sales.

Figure 3.2 - Existing and Planned Cambodia Power Grid

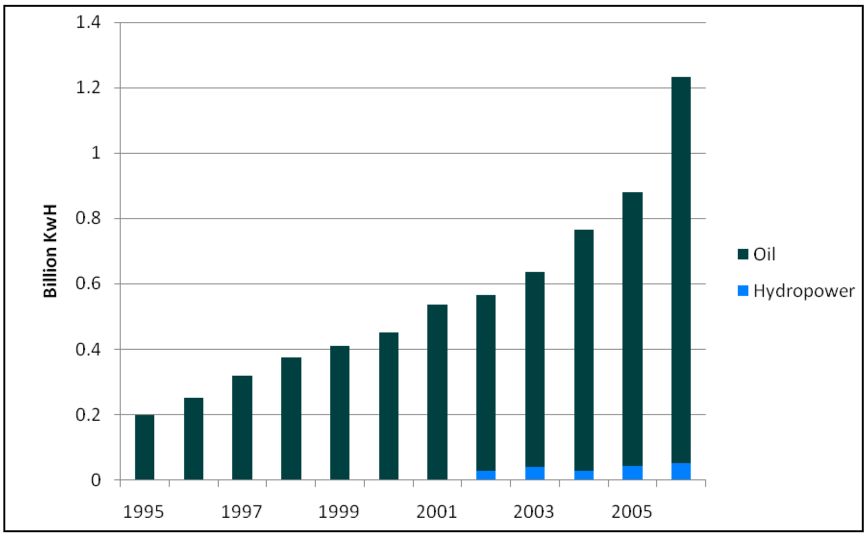


Source: Nikon Koei / JICA, Hydropower Master Plan 2007

3.3 POWER SUPPLY

Cambodia has an installed capacity of approximately 230 MW of which 90% corresponds to medium and high speed diesel generators. Approximately 95% of the electricity consumed in Cambodia is produced by imported diesel oil and the rest is domestic hydropower and small amounts of imports from Laos and Thailand.

Figure 3.3: Domestic electricity production Cambodia 1995 - 2006



Source: WDI, World Bank 2009

The Cambodian government formulated an energy sector development policy with the following objectives *(Source: ADB/APEC, 2009, pp. 228 – 229)*:

(i) to provide an adequate supply of energy throughout Cambodia at reasonable and affordable prices;

(ii) to ensure a reliable and secure supply of electricity at prices that facilitate investments in Cambodia and promote the development of the national economy;

(iii) to encourage the exploration and development of energy resources in an environmentally and socially acceptable manner; and

(iv) to encourage the efficient use of energy and minimize the detrimental environmental effects that result from energy supply and use.

The generation expansion plan associated with this policy is very ambitious and, perhaps, not entirely consistent with the policy statements. As shown in Figure 3.4, the plan to 2020 involves the addition of some 1,300 MW of coal fired capacity and more than 4,800 MW of hydropower capacity, dominated by the proposed 3,300 MW Sambor mainstream hydroelectric project. These numbers result in a 38.7% mean annual growth in installed capacity.

The annual hydropower energy alone, associated with this plan, is upwards of 20,700 GWh and the planed capacity of coal fired plans, (which to be economically attractive must operate some 7,000 hours per year) will add another 9,100 GWh. Thus, it appears that Cambodia plans to produce some 29,800 GWh of energy by 2020 to supply a demand of barely 9,000 GWh (Figure 3.1). Clearly a strong reliance on the export market would be needed to sustain such development.

Figure 3.4 - Cambodia Generation Expansion Plan to 2020

No.	Generation Expansion Plan	Type of Fuel	Power (MW)	Mean Annual Energy Generation (GWh)
1	Kirirom III Hydro power Plant *	Hydro	18	78
2	Kamchay Hydro Power Plant *	Hydro	193	498
3	200 MW Coal Power Plant (I) in Sihanouk Ville - Phase 1	Coal	100	---
4	Atay Hydro Power Plant *	Hydro	120	465
5	200 MW Coal Power Plant (I) in Sihanouk Ville - Phase 2	Coal	100	---
6	700 MW Coal Power Plant (II) in Sihanouk Ville -Phase 1	Coal	100	---
7	Lower Stung Rusey Chrum Hydro Power Plant *	Hydro	338	1020
8	Tatay Hydro Power Plant *	Hydro	246	858
9	700 MW Coal Power Plant (II) in Sihanouk Ville -Phase 2	Coal	100	---
10	700 MW Coal Power Plant (II) in Sihanouk Ville -Phase 3	Coal	100	---
11	700 MW Coal Power Plant (II) in Sihanouk Ville -Phase 4	Coal	100	---
12	Lower Sesan II + Lower Srepok II	Hydro	480	2,312
13	Stung Chhay Areng Hydro Power Plant *	Hydro	108	618
14	700 MW Coal Power Plant (II) in Sihanouk Ville -Phase 5	Coal	100	---
15	700 MW Coal Power Plant (II) in Sihanouk Ville -Phase 6	Coal	200	---
16	Sombor Hydro Power Plant	Hydro	3,300	14,870
17	Coal Power Plant (III) or Natural Gas Power Plant	Coal/Natural Gas	400	---
Total			6,103	

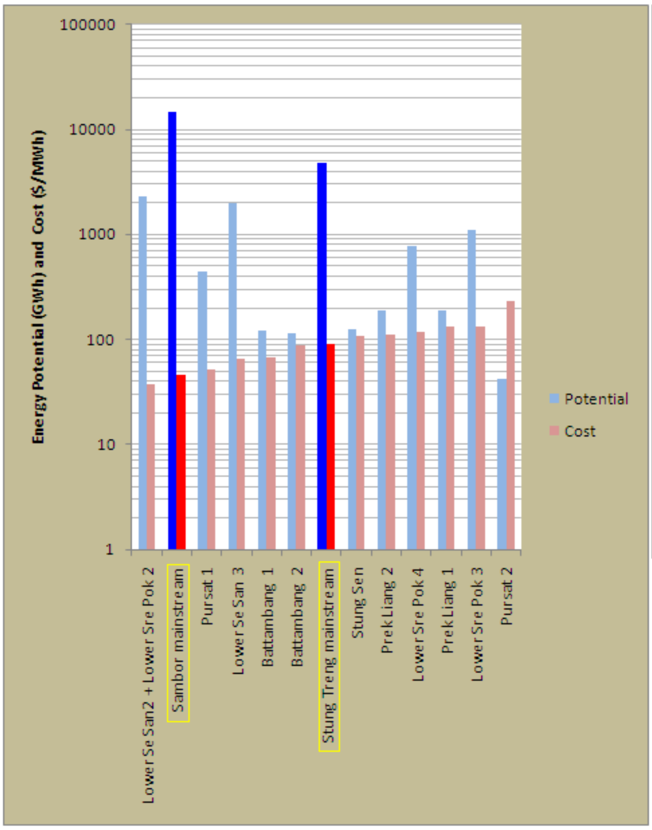
Source: Ministry of Energy and Mines of the Kingdom of Cambodia, 2008

3.4 KEY ISSUES RELEVANT TO MAINSTREAM MEKONG HYDROPOWER

It is clear from the preceding discussion that the development of hydropower and, in particular, mainstream Mekong hydropower is a cornerstone of Cambodia development plans, not just for its power sector but for its entire economy since so much export is planned. Figure 3.5 shows information provided by Cambodia to MRC on the existing and planned projects in the Cambodian portion of the LMB, including the planned markets for their energy.

The information on energy potential and cost of the LMB hydropower is shown in figure 3.5, the figure uses a logarithmic scale to accommodate the wide range of energy potential of different projects that are shown in order of increasing energy cost. This figure shows that the Sambor project is also one of the most economically attractive hydropower developments in Cambodia.

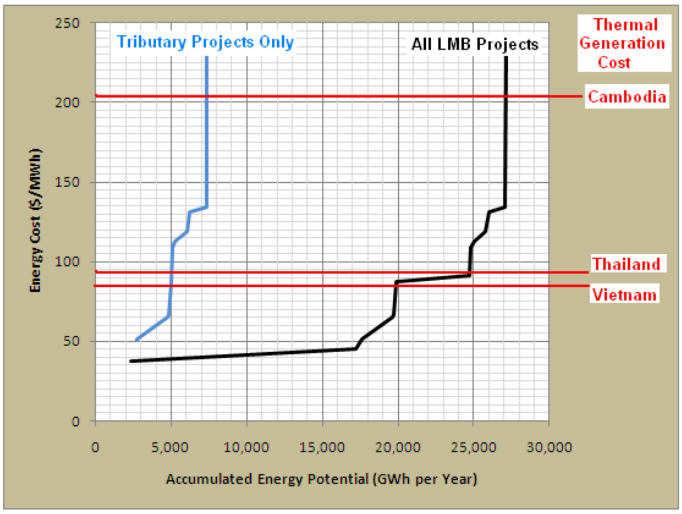
Figure 3.5 - Hydropower Potential of the Cambodia LMB



Source: MRC Hydropower Database based on Information Provided by Cambodia in 2008

The other mainstream project, Stung Treng, appears to be above the replacement cost of power in Thailand or Vietnam and therefore much less attractive. Yet, recent news items, indicate that there is interest from China in the development of Stung Treng and thus, it is unclear if strict economics are the principal driver or whether the project design has been reconsidered. The fact that projects not in the Cambodian PDP are the subject of current news on possible negotiations, suggests that the process for development of hydropower in Cambodia may be fluid. This is understandable. In many countries the realities of securing finance for large infrastructure projects must take precedence over a strict planning process so that, if a project that is farther in the plan can find an interested party willing to enable its development then the plan must accommodate rather than risk losing an option for implementation that may not remain indefinitely available.

Figure 3.6 - Supply Curve of Cambodia LMB Hydropower



The information in Figure 3.5 can be shown in the form of a "supply curve". This is a plot of accumulated energy potential against the incremental energy cost. This concept is useful to examine the relative potential and value of tributary and mainstream hydropower in the Cambodia LMB. It can be seen that tributary projects in the LMB could meet much of the 9,000 GWh domestic energy demand forecast by 2020 at costs that are attractive against Cambodia's expected thermal generation cost. However, only the mainstream Sambor project has the power potential and cost combination that could match Cambodia's ambitious export plans to Vietnam or Thailand.

Thus, the development or not of mainstream hydropower in Cambodia can make a critical difference in terms of future export revenue. At the same time, it is clear that, if Sambor is not an option, then Cambodia can only lower its tariffs and fuel dependency by either competing against Thailand for hydropower imports from Lao PDR or pursuing a very aggressive coal development plan possibly with a power export component.

4 LAO PDR

4.1 OVERVIEW

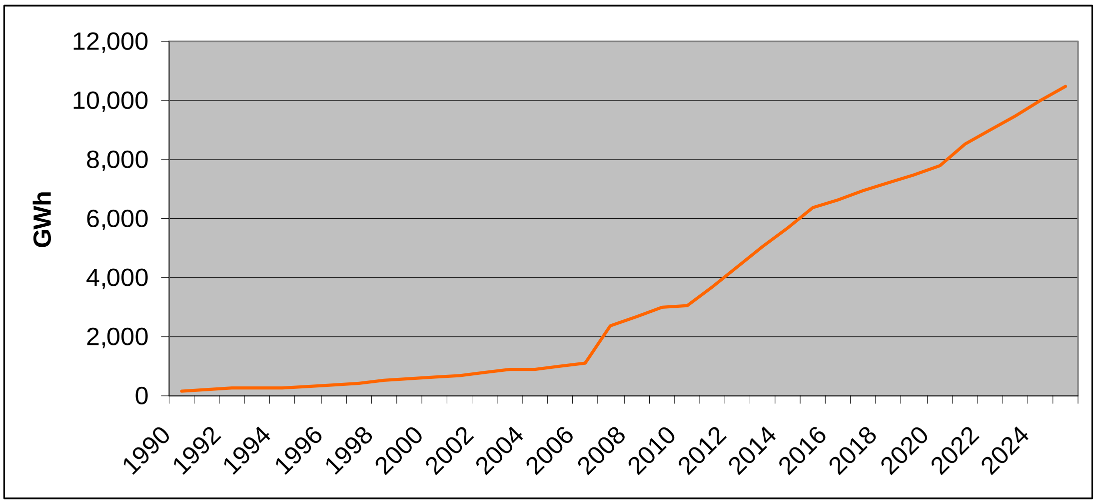
The power system of Laos is small, dispersed and not fully interconnected but, nonetheless, electrification has been rapidly achieved to now serve about 60% of the country and the plan is to electrify 90% of the country by 2020. Although Laos is a net exporter of power, the limitations of the transmission system result in still a significant amount of power imports from Thailand.

In terms of generation mix Laos is almost the exact opposite to Cambodia with 98% of power coming from hydro and only 2% from fossil fuel, mostly diesel units serving isolated areas.

4.2 NATIONAL ELECTRICITY DEMAND TRENDS

Increasing income through power exports and power generation for the Lao market are expected to result in increased GDP growth. However, growth will not be spread evenly between sectors (see macro-economic analysis – sorry where?). Energy intensive economic sectors are expected to develop most rapidly (e.g. mining and bauxite smelters). Overall, Lao PDR's power demand is expected to more than triple in the next 15 years, from around 3,000GWh in 2010, to over 10,000GWh in 2025.

Figure 4: Past and Present Electricity Demand and Forecast, Lao PDR



Source: ADB/APEC 2009, MEM/EdL 2008

4.3 POWER SECTOR POLICIES

The Lao Government's plans and policies for the power sector involve rapid and simultaneous development on several fronts with a view to:

- Expanding the generation, transmission, distribution and off-grid development to increase the domestic electrification ratio for the country from the current level of about 60% (in early 2008) to a target of above 90% by 2020;
- Increasing government revenues from Independent Power Plant (IPP) export investments and honoring power export commitments with neighboring countries by promoting private sector development in the power sector;

- Promoting the development of a 500kV regional grid within the Greater Mekong Sub-region (GMS) to integrate the power systems of Lao PDR and its neighbors (EPD, 2010)

- The development of power exports are a key socio-economic development objective for Laos, and are expected to generate significant revenues for the national government. Indeed, export revenues from hydropower are earmarked for social development spending (see social issues baseline paper). In 2007 electricity exports accounted for 11.6% of the country's total export revenues with an installed capacity of just below 700MW (Ministry of Energy and Mines, 2008).

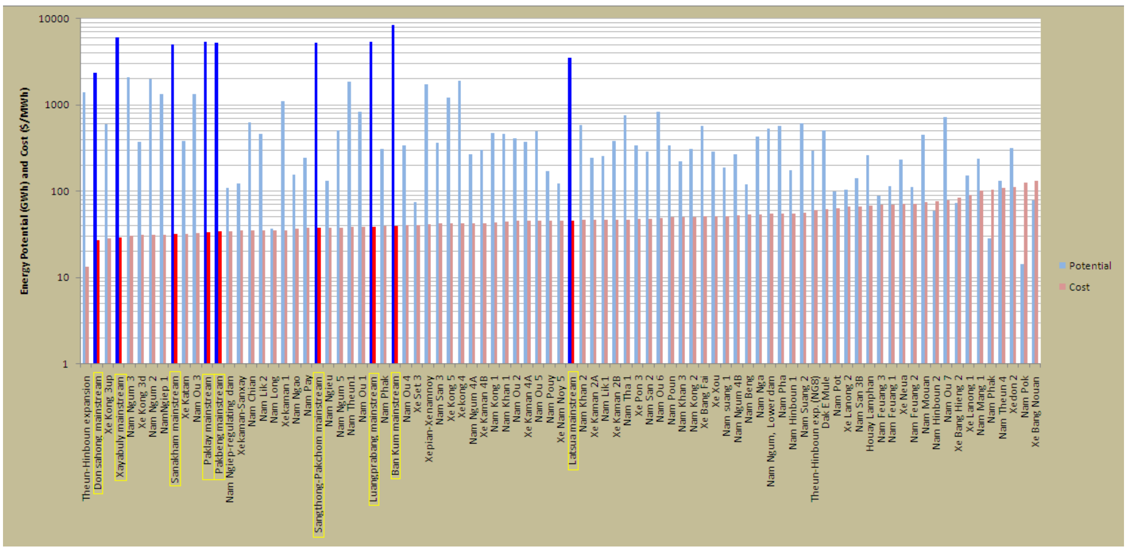
In order to understand the basis and likelihood of success of these policies it is essential to analyze in some detail the energy potential and cost of Lao LMB hydropower.

4.4 HYDROPOWER DEVELOPMENT

The mountainous topography and climate of Laos are ideal for hydropower and the power sector of the country has been relying in hydropower for the last four decades. While several hydroelectric projects in operation, it is estimated that only about 2% of the country's hydropower potential has been developed and agreements for future hydro-power exports are in place with Thailand, Vietnam and Cambodia. As was illustrated in Figure 2.14, there are 90 projects firmly identified in the Mekong basin alone, 30 of which are under active development.

The energy potential and cost of these projects is shown, in order of increasing energy cost, in Figure 4.2, where the mainstream projects are highlighted. As in the case of Figure 3.5 for Cambodia, this figure also uses a logarithmic scale to accommodate a wide range energy potential of the different projects.

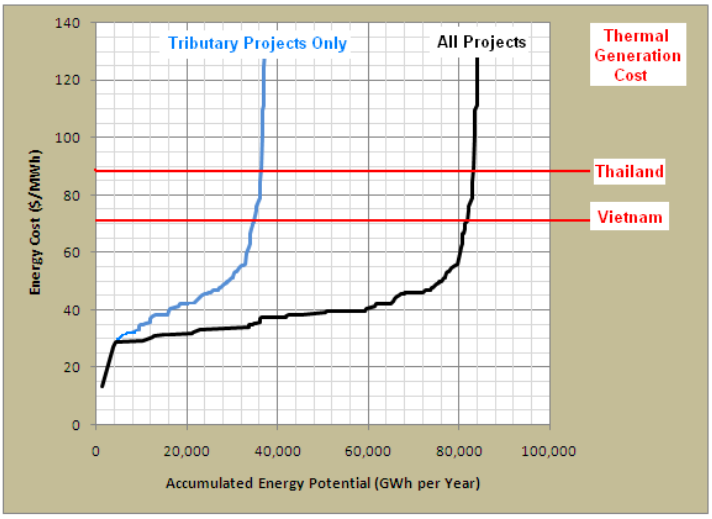
Figure 4.2 - Laos LMB Hydropower Potential and Cost



It is observed that several mainstream projects place among the projects with lowest energy cost and all mainstream projects are within the range of costs competitive against thermal generation in Thailand and Vietnam.

The supply curves of LMB hydropower for Laos are shown in Figure 4.3 together with the reference thermal generation costs expected in Thailand and Vietnam. These curves show that the energy potential of all export-viable LMB projects is enormous, roughly 80,000 GWh. The portion of this export-viable potential corresponding to tributary projects is also very large, about 50 percent larger than all the export-viable potential of Cambodia including Sambor.

Figure 4.4 - Supply Curve of Laos LMB Hydropower



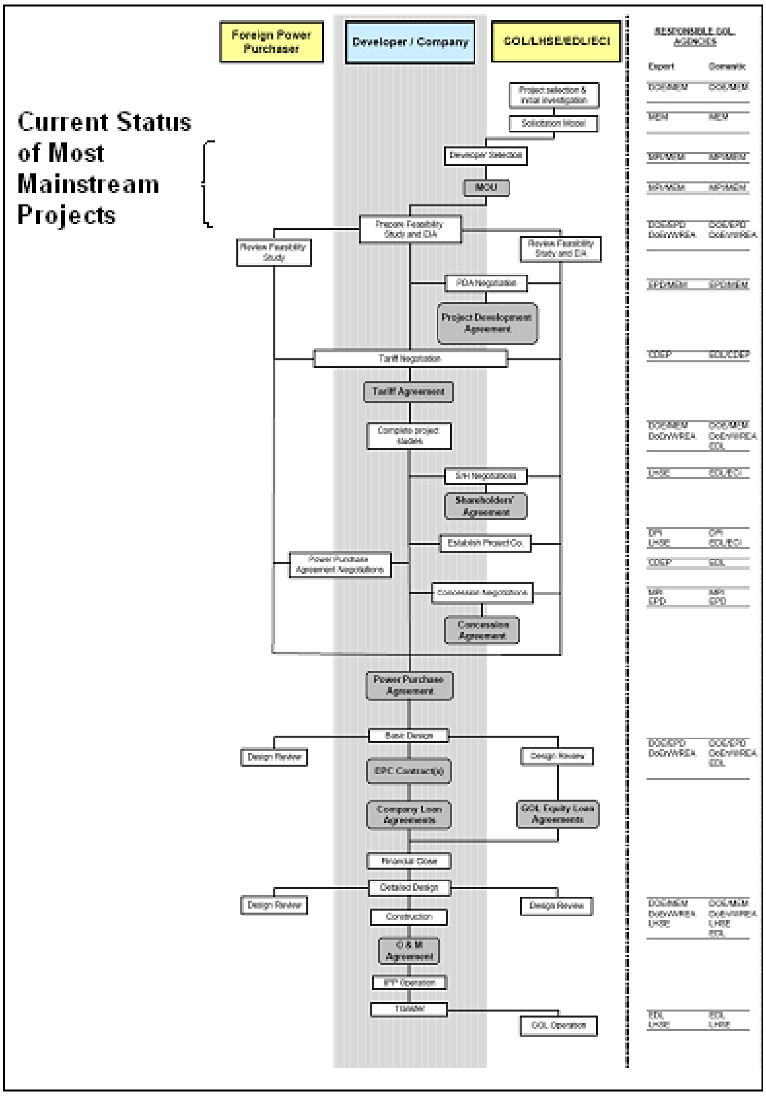
4.5 POWER SECTOR REGULATORY FRAMEWORK –GENERATION INVESTMENT

Lao PDR offers a well defined development path to parties interested in participating of its hydroelectric development programme (Figure 4.3). This path starts with a memorandum of understanding (MOU) between the interested parties and the GoL. The next step consists of feasibility studies leading to a project development agreement (PDA), tariff agreement, shareholders agreement and concession agreement. With these agreements in place the interested parties can proceed on the implementation phase which involves power purchase agreement (PPA) with the off-takers, loan agreements, engineer and construction agreements and operation and maintenance agreements.

This path is not a regulatory framework in the sense understood in open-entry generation markets where rules for licensing and pricing are uniform and quite permanent. Yet, it does guide the investor on the road to follow and has one considerable advantage relative to open-entry competitive wholesale markets. In Laos, many of the terms of development, including tariff, can be negotiated after the project costs become better understood. Thus, there is an opportunity for the GoL to meet investor's criteria, something that regulatory bodies in most competitive wholesale markets are unable to do as they are subject to strict and uniform pricing rules.

This same advantage is found in successful single-buyer markets (Mexico for example) where government invites independent power producers (IPPs) to bid for projects that match the national interest and therefore pricing is customized to project cost and investor criteria.

Figure 4.3 - Laos Hydropower Development Process



5 POWER IMPORTING COUNTRIES (NET)

5.1 GENERAL OBSERVATIONS

The importing countries of the LMB are Thailand and Vietnam. These countries have very large power sectors when compared with those currently in Cambodia and Laos and, therefore, their planning is considerably more complex.

All generation systems must be planned to meet target reliability at least cost. In small generation systems this process is relatively simple because they are mostly limited to technologies compatible with their scale. On the other hand, large generation systems are not constrained by the scale of technologies but rather by a complex matching of the characteristics of the expected demand to the technical and cost characteristics of all available generation options.

Because different generation options have different proportions of fixed and variable costs, planners look for the combination of technologies that, when used optimally to serve the demand (i.e. a process known as "economic load dispatch") will result in the lowest sum of all fixed and variable costs.

In the large systems of Thailand and Viet Nam, hydropower, imported or domestic, is one of those options and planners look at the cost and potential of available hydropower to combine it with the other options at their disposal into the least cost generation mix that will meet demand at reliability target level.

5.2 THAILAND

5.2.1 Thailand - power sector overview

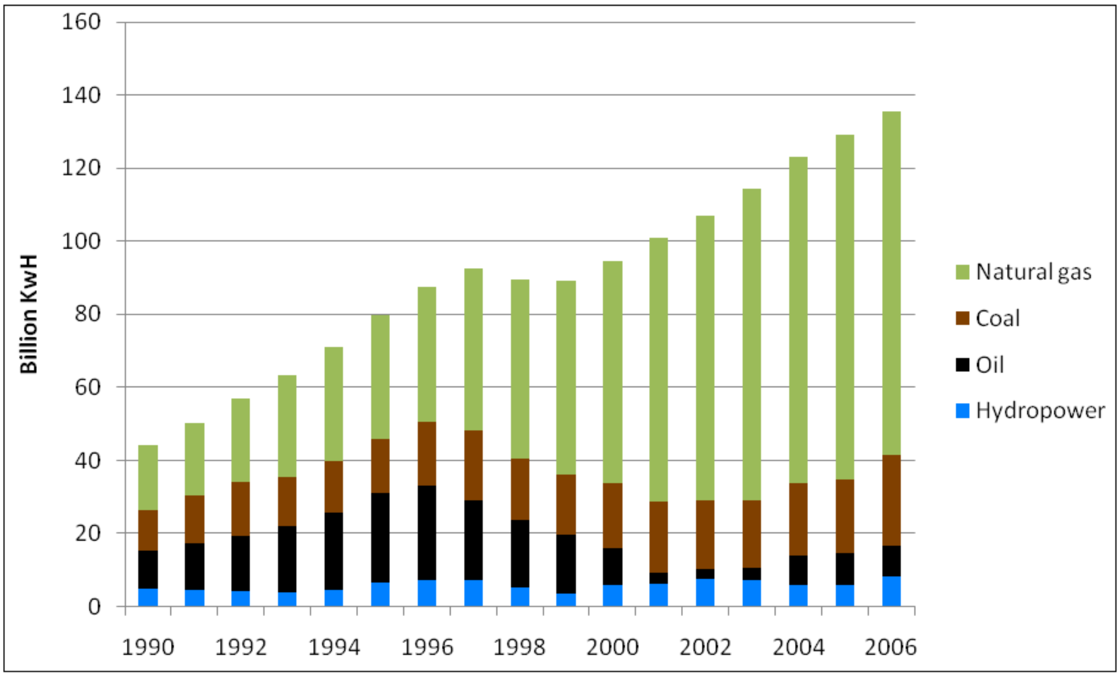
Thailand's power generation system has relied largely on natural gas (73%) (Figure 5.1), which makes it vulnerable to world market prices and dependent on other countries for energy imports. Although large quantities of gas used in domestic power stations is sourced from Thailand, gas prices are indexed to average oil prices.

Thailand has experienced natural gas supply disruptions in past that have reinforced concerns about the level of gas dependency in power generation. [3] As highlighted by the much publicized threats of the

[3] Source: Energy Policy and Planning Office, Ministry of Energy, Thailand: www.eppo.go.th. In 2008, natural gas supply disruption occurred twice -- in March and April. The first incident was caused by delayed supply to the system from Arthit and JDA gas fields; the second one by technical errors of the transmission pipeline from Yetagun field of Myanmar. Another three incidents occurred in August, September and October 2009. The August incident took place when the supply from Yadana field was tripped, coupled with the leakage of condensate pipeline from Bongkot field and the halt of supply from Arthit field which took place during the routine maintenance shutdowns of other gas supply sources. The second incident was due to the disruption of gas supply

Russian Federation to cut off gas supplies to Western Europe in recent years, dependency on foreign fuels is a risky business. Thailand's growing dependency on Myanmar for its gas supply is no less risky and therefore Thailand overall goal is to reduce its reliability on imported fossil fuels and become more energy independent.

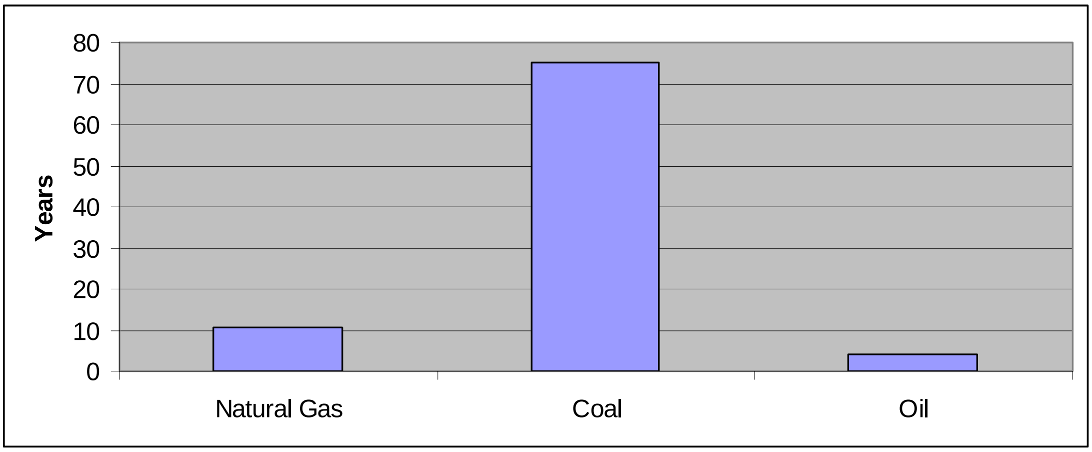
Figure 5.1 - Historical Generation Mix of Thailand



The reserve to production ratio suggests that at recent extraction rates natural gas reserves within the country will last just another ten years (Figure 5.2). By around 2020 Thailand is therefore likely to be 100% dependent on other countries for natural gas. Coal resources will last longer and the easier transportability of coal as opposed to gas ensures a larger choice of suppliers, but popular environmental concerns mean that constructing new coal fired power plants is politically difficult.

from JDA and Yetagun fields; and the third one was caused by the corrosion of a receiving gas pipeline from Bongkot field. Though these technical problems have rarely happened so far, they should be regarded as a warning signal related to natural gas supply via the pipeline system, i.e. although thorough control measures have been in place, such a system still faces certain risks which may cause simultaneous disconnection to the system of several power plants.

Figure 5.2: Reserve to Production Ratio, Thailand



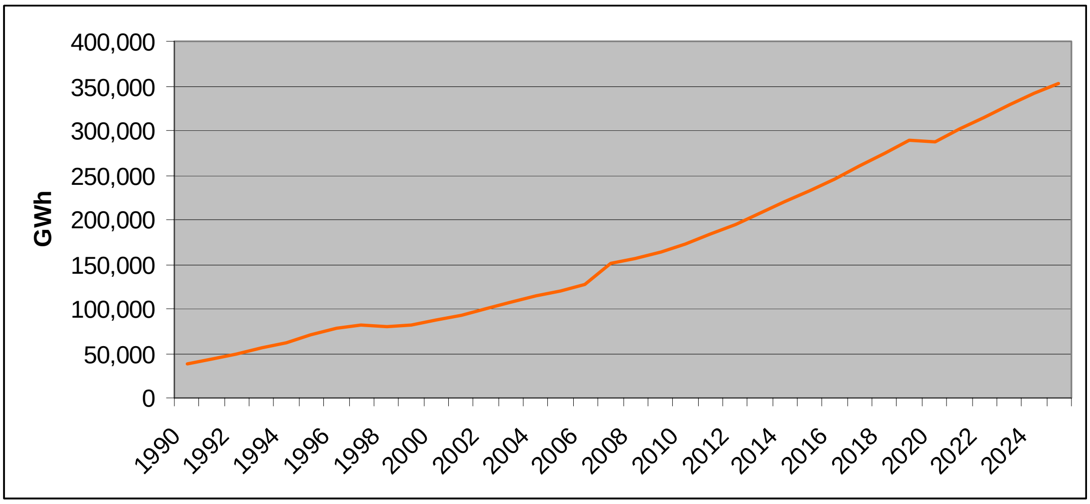
Source: BP, 2009

Hydropower generation contrasts markedly with this fossil fuel generation. Current Power Purchase Agreements (PPAs) for hydropower give the Electricity Generating Authority of Thailand (EGAT) control over power prices for around 25 years. In the future, Thailand is planning to import increasing amounts of power from Myanmar and Laos as both these countries still possess significant potential for low cost hydropower development.

5.2.2 Thailand - Electricity demand trends

Thailand's power demand is expected to maintain a high growth rate (Figure 5.3). Power demand fell slightly during the Asian financial crisis in 1997, although it quickly returned to trend. Similarly, while the current global financial crisis is likely to depress demand growth in the short term, as with the 1997 crisis, economic growth and power demand are expected to return to trend in the medium term. The main effect of this short term slowing in demand growth is likely to result in the postponement of some of the larger power projects. EGAT revised its power demand projections for 2021 down by more than 30,000 GWh, and targeted capacity down by a little less than 5 GW.

Figure 5.3: Past and Present Electricity Demand and Forecast, Thailand



Source: ADB/APEC 2009, EGAT 2009b

5.2.3 Thailand - Export and import policies

Thailand has a number of agreements (MOUs) with other LMB countries for cross-border power trade and power exchange. Lao PDR and Thailand signed a MOU on power exchange in 1993 and 1996 for 3,000 MW which has since been reportedly expanded to 7,000 MW. With current exports and proposed projects due to be completed by 2012 there are close to 3,600 MW of identified projects. The MOU provides the authorization and framework for specific negotiation for further export from Lao PDR to Thailand on power purchase agreements for individual projects which could potentially include the additional tributary developments as well as mainstream dam proposals.

Thailand has a policy to supply no more than 15% of power supply though imports. However, as overall demand grows, the absolute value of this portion of demand is set to increase substantially. Furthermore, in its most recent PDP Thailand proposes to increase the level of imports to 25%.

5.2.4 Thailand Agreements for cross-border power trade

Thailand also has a power exchange agreement with Cambodia, but no MOU for large scale imports. The status and trends in the Lao-Thailand power trade bilateral MOU, with Lao exporting to the north-east Thailand grid is illustrated in Figure 5.4.

Figure 5.4 – Trend in Power Trade Agreements between Thailand and Lao PDR

Time	Quantum of Power	Baseline and Trend Projections

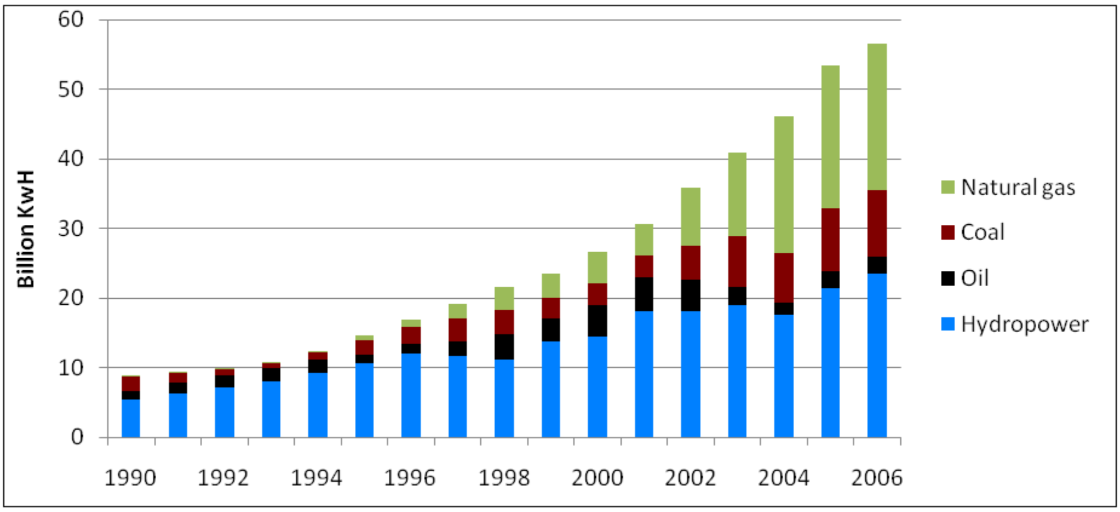
1990's	210 MW	First cross border export in 1990s Nam Ngum 1 (20 MW) Theun Hin Boun first IPP (210 MW export)
2003	3,000 MW	First MOU to accommodate Lao-Thai export from existing and potential new tributary projects including Theun Hinboun and Nam Ngum 1 above and Huay Ho (126 MW) and future projects
2005	5,000 MW	MOU raised to accommodate additional Lao exports, such as those anticipated from the Nam Ngum 2 (615 MW), Nam Theun 2 (920MW), Theun-Hinboun extension(220MW) and additional projects envisages
2007	7,000 MW	MOU raised to accommodate additional Lao exports, such as those anticipated from Hongsa lignite coal project in northern Lao (1,470 MW) as well as ongoing existing and proposed tributary projects e.g. Nam Ngum 3, (440MW), Nam Theun 1, Nam Ou, Nam Ngiep 1 and a proposed mainstream project Xayaburi (1200 MW).
2010-2030	Unspecified portion of Thai demand	With a revision of the Thailand PDP (January 2010- yet to go through public hearings) Thailand proposed to import up to 25% of its projected power needs to 2030 from Lao PDR, Myanmar and Southern China. The recent ADB RETA predicts Thai demand will rise to 60,000 MW by 2025 (25% would be 15,000 MW). The amount Thailand would import from Lao PDR beyond the current 7,000 MW was not specified.

5.3 VIETNAM

5.3.1 Vietnam - Power sector overview

Vietnam had a predominantly hydroelectric system until 2000 and only recently has it become a balanced hydro-thermal system (Figure 5.5) with a combination of coal and gas fired plants. Vietnam has developed most of its attractive hydropower sites. Of the 14 hydroelectric projects identified in the Vietnamese portion of the LMB, 7 are in operation and 5 are under construction.

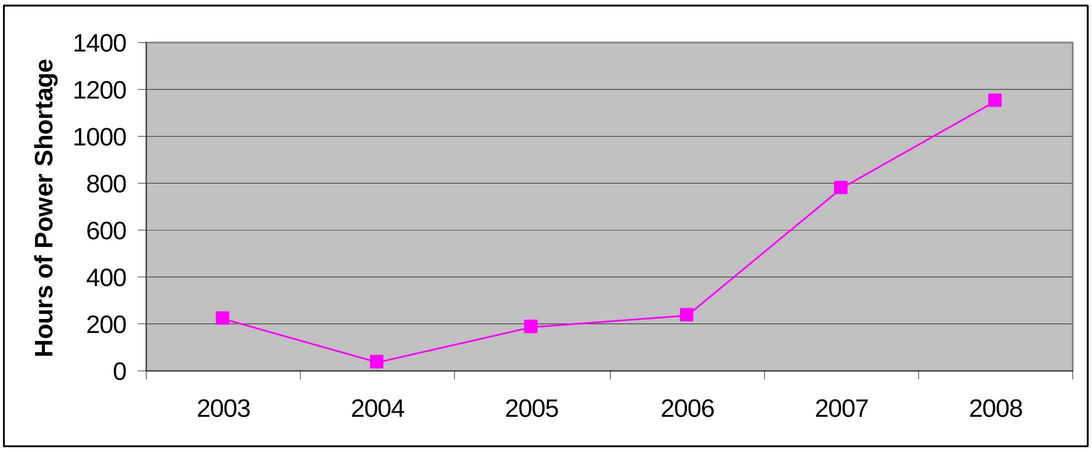
Figure 5.5: Vietnam domestic power production by source 1990-2006



Source: WDI, World Bank 2009

Over the last 5 years, power demand in Vietnam has exceeded supply at peak times and the hours of power shortage have grown considerably (Figure 5.5). This has resulted in a growing imperative for rapid power generation development.

Figure 5.5: Power Shortage in Vietnam 2003-2005

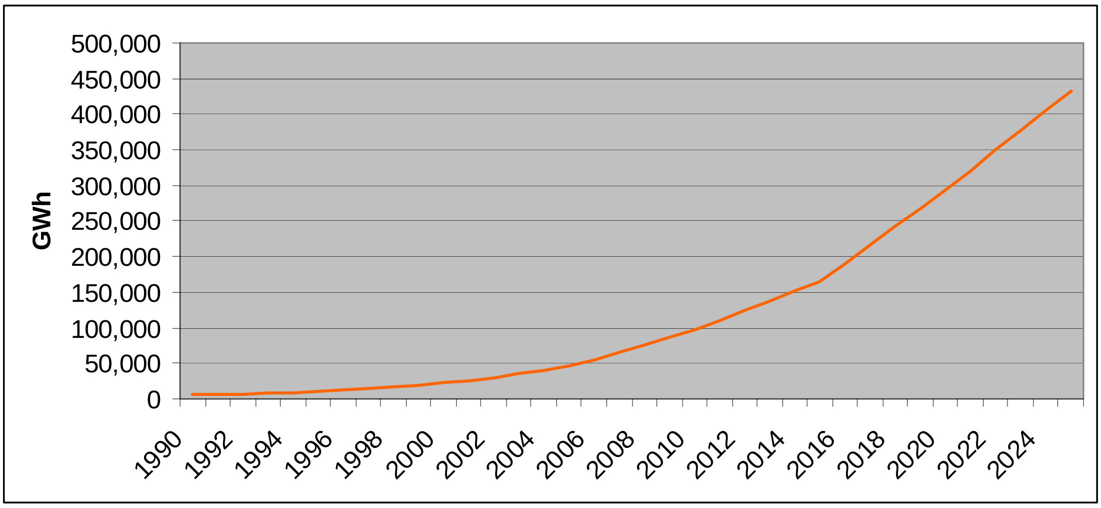


Source: Hanoi Technical University

5.3.2 Vietnam - Electricity demand trends

Vietnam's power demand is lower than Thailand's power demand at present despite a much larger population. However, with rapid economic growth, industrialization, increasing electrification and household consumption demand is expected to grow rapidly (see Figure 5.6). Even with reductions in transmission losses, increased efficiency and DSM policies, Vietnam's power demand is expected to increase rapidly. By 2020 Vietnam's demand for power is expected to overtake that of Thailand.

Figure 5.6: Past and Present Electricity Demand and Forecast, Vietnam



Source: ADB/APEC 2009, VUSTA 2007

5.3.3 Vietnam - Import and export policies

Vietnam has an agreement with Lao PDR for 3,000 MW and in 1996 this was subsequently increased to 5,000 MW. At present Lao exports to Vietnam are about 250 MW. As with Thailand Vietnam has a policy to supply no more than 15% of power supply though imports. However, as overall demand grows the absolute value of this portion of demand is set to increase substantially. Furthermore, there is also the possibility that this threshold may be revised upwards in the future.

Vietnam also has a power exchange agreement with Lao PDR and Cambodia.

5.4 THAILAND AND VIETNAM - COMMON DRIVERS

While quite different in the past, today Thailand and Vietnam are experiencing very similar circumstances regarding their power generation sectors. Their domestic hydropower has been fully developed, at least as far as energy costs that are competitive against expected medium term thermal options. Their domestic fuel reserves are being rapidly depleted and their planners are looking at hydropower imports or nuclear as their primary options for sustained supply of a fast growing electricity demand.

The supply curves shown in Figures 3.6 and 4.4 of LMB hydropower in Cambodia and Laos, relative to the expected cost of thermal power in Vietnam and Thailand illustrate very clearly that power supply economics is the driving force behind their interest. The only limits to these interests could come from a reluctance to become overly dependent on imported hydropower or a realization that the curves are in fact steeper than they look after the cost of mitigating social or environmental impacts is included in the energy cost.

6 ALTERNATIVE TRENDS

6.1 THE QUESTION OF ALTERNATIVES

The alternative question comes to the forefront in most strategic discussions about large dams, concerning the balance of development opportunities and risks.[4] The SEA of proposed LMB mainstream dams was no exception. As noted in the SEA background scoping paper, clarity on this issue is essential if overall the SEA is to have any credibility for many stakeholders.

6.1.1 General perspectives

During the scoping phase many stakeholders felt it important for the SEA to highlight the status and trends in alternatives to improve electricity access and services in power markets that LMB mainstream dams would target, in particular with (i) non-hydro indigenous, renewable energy sources (ii) further, or even accelerated hydropower development on LMB tributaries to replace or defer consideration of mainstream LMB hydropower until the full implications are better understood, and (iii) demand-side management in Thailand and Vietnam to reduce load growth.

Simply put, one set of views is alternatives do exist - this needs to be brought to the attention of political decision-makers. If Thailand and Vietnam were to pursue these alternatives, in combination with exploiting the remaining hydrocarbon resources in the GMS region (e.g. primarily natural gas and coal) supplemented by imports from outside the GMS, the LMB mainstream dams would be unnecessary from a power demand-supply import perspective. A competing set of views was that all feasible supply options are needed to meet growing needs for electricity services, in all LMB countries and that even aggressive demand-side management measures will only serve moderate the rate of demand growth.

The second view reflects national energy policies of LMB countries. Moreover, the policies suggest that a broader framework for considering alternatives is needed to strategically assess how the policy drivers behind consideration of LMB mainstream proposals link to national energy and macro development policies, of both power exporting and power importing countries. Also taking into account the rationale for expanding cross-border power trade as envisaged under the GMS agreement (2003) building on the bilateral MOUs. [5]

[4] This is shown in the World Commission on Dams (WCD) process and the report Dams and Development: A New Framework for Decision-Making (2000). Comprehensive options assessment was one of the seven strategic priorities of the WCD.

[5] The GMS Inter-Governmental Agreement on power interconnection and trade (2003) has the objectives to, "… continue with the development of (transmission) interconnections between the respective (electricity) networks and expand capacity and energy trade to provide further opportunities to: (i) enhance the reliability of supply, (ii) coordinate the installation and operation of (electricity) generation and transmission facilities, (iii) reduce

For example, from the perspective of the power exporting countries a broader view of alternatives must include consideration of alternative ways to earn the foreign exchange that mainstream developments would offer, and in the case of Lao PDR, on top of export earnings anticipated from tributary hydropower projects. [6] From the perspectives of power importing countries (i.e. Thailand and Viet Nam) the broader consideration of alternatives would look at other ways to reduce growing reliance on fossil fuel imports, reduce exposure to volatile international energy prices and satisfy energy security concerns.

The SEA does not attempt to reconcile competing views on the real prospects that each electicity demand-supply option offers in the LMB context. The issues are complex and not confined to power system planning and reliability alone, but embrace the range of social, environmental and political choices on competing views on how to develop LMB economies and improve the well-being of Mekong populations in a sustainable manner.

Rather this part of the baseline simply aims to provide a strategic context around the aleternative questions that have been raised by SEA stakeholders. And indeed, the other themes of the SEA will explore the wider range development opportunities and risks that maistream developments pose, including the distibution and social equity aspects.

Part 6.4.3 of this paper explores the tributary alternatives in more depth. This is due to the role that LMB tributary hydropower currently plays in power supply and the cross-border power trade trends in the LMB and n the definte future (2015) and probable future (2030) scenarios of the MRC's Basin Development Plan (BDP) now under preparation.

6.1.2 Different power markets and financing sources

In any discussion of electricity alternatives, it is important to first clarify the power markets and populations, or types of consumers to be served. Different demand-supply options apply. Similarly, the financing sources for capital investment in alternatives can be quit different.

Power Markets and Types of Consumers

Figure 6.1 offers a generic representation of five generic power markets in the LMB and the population, or type of customer served. These markets include (i) grid supply (ii) isolated load centers or "mini" grids (iii) household/ stand-alone systems (iv) dedicated supply to resource industries (and captive generation, or own-supply), and (v) export markets.

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investment and operating costs, and (iv) share in other benefits resulting from the interconnected operations of their systems".

[6] Which the case of Lao PDR may be lignite-coal plant or in the case of Cambodia importing quantities of coal for export-projects. This recognizes that a negotiated portion of the power from a mainstream hydropower project (or coal project) would be available for domestic use (significant in relation to the level of demand in Lao and Cambodia), and the full project would revert to the exporter at the end of the concession period. At that time the option may be to continue to export to earn revenue, or use the power domestically.

Figure 6.1: LMB Power Markets and Consumers

Power Market	Population served / Types of Consumers
Grid Supply	▪ All consumers connected to national grids, (e.g. - urban centers and provincial towns (for domestic, industry, commercial, public services, etc.) - rural electrification by grid supply
Isolated load centers or mini-grids	▪ All consumers connected to isolated load canters, e.g. - Provincial towns (also domestic, industry, commercial, public services, etc in the area) - rural electrification by grid supply served
Stand-alone household supply	▪ Individual customers and homes - Primarily in rural areas, where there is no grid service - More limited applications in town/urban areas with grid service
Dedicate Industry supply and captive generation	▪ Resource based-industries / enterprise with own generation or dedicated transmission supply (not from the national grid and wheeling arrangements in the case of IPPS or utility-to-utility agreements)
Export markets	▪ Sales to national grids of neighboring countries (either by dedicated transmission or connection between the two national grids)

While LMB Countries are rapidly urbanizing (2-3% a year), close to 70% of the 175 million people in LMB countries still live and work in rural areas. Thus, the extent to which the grid lines reach rural towns, communities and extend into the remote, low population density areas is important in considering the role of large generators and alternatives.

The situation varies considerably between LMB countries. In Thailand, for example, the grid reportedly reaches over 99% of Thai villages and electrification ratios are +95%. This means that large-scale grid supply options contribute to rural electrification needs in Thailand, as would electricity imports to the grid.

At the same time, it means that it is technically feasible for any community to connect their own renewable energy generators to grids (see section 6.4.2 on Thailand's Feed-in Tariff Programme for small power producers and very small power producers). Different views then come into play about the quantum and quality of the electricity supply that may realistically be provided by small-scale alternatives (e.g. the resource base, cost, intermittency, dependability, and suitability for peak / off-peak and the technical arrangements).

Similarly in Viet Nam, a large proportion of the rural population is now served by the national grid. The electrification ratio overall is over 85% presently, with targets to rise to +95% by 2020 (mainly, but not exclusively through grid extension).

In Cambodia and Lao the picture is different. The absence of a national grid in Cambodia has split the power system in the country into 22 isolated systems, or mini-grids, working separately on expensive small-scale power generation (diesel generators currently dominating). As discussed in Section 2, this has led Cambodia high electricity tariffs, with consequence not only for poverty alleviation but also for economic investment.[7] Most observers suggest the lack of efficient electricity supply in rural areas, home to about 93 percent of the poor in Cambodia, could impede on the government's policy towards effective poverty reduction. Lao PDR currently has four principal unconnected grids, each with a different supply and demand mix.

Figure 6-2 provides statistics to illustrate variations in electrification ratios and levels of demand in LMB countries. The high levels of electrification in Thailand and Vietnam indicate the extent of grid coverage in those countries to date.

Figure 6-2: Statistics on LMB Country Electrification

Country	Urbanization Ratio (2005-2008 data)	Per capita household consumption (KWh)	Share of household consumption in demand (%)	Electrification Ratio (%)
Cambodia	17%	29	52.0	Less than 20%
Lao PDR	21%	95	53.0	60% - 2008 Goal 90% -2020
Thailand	38%	409	21.0	+95%
Vietnam	27%	242	42.0	+85%

In the wider GMS region it is estimated that 20% of the population (or 74 million people) have no household access to electricity.[8]

Another consideration to prepare for the distribution analysis of power benefits in subsequent steps of the SEA is the type grid customers. This recognizes that from an equity perspective, poverty alleviation (including energy poverty) is a priority and improving electricity access is one of the Millennium Development goals.

In Thailand and Vietnam, the industrial sectors account for 46 percent and 42 percent of grid demand respectively. As shown in the table 6-2, household consumption represents 21 percent of electricity demand/use in Thailand. This share is more or less typical when diversification of the economy is higher, and commercial and industrial sectors represent a larger share of employment and GDP. In Lao PDR, where the economy is subsistence agriculture (dominated by rice cultivation in lowland areas)

[7] From a technical perspective, small-scale generation and the absence of interconnected system partly contribute to the high unit cost of power generation as the economy of scale of generation cannot be exploited.
[8] ADB, GMS Sustainable Energy Futures, 2009

agriculture accounts for about 40% of GDP and more than 70% of total employment, households are the largest consumption groups at present, accounting for slightly over 50% of electricity use. There is a similar picture to Cambodia as noted in table 6-2, though electrification rates are very low.

The markets served by large hydropower are national grids. Therefore, apart from supplying demand to urban and industrial centers, export projects serve rural areas to the extent the national grids feed rural electrification lines and distribution permits. In Lao PDR in 2006, where the electrification ratio is rapidly rising (proportion of population with electricity access), 93% of new rural household connections were derived from low voltage grid extensions.

Financing and Power Markets

A second strategic aspect relating to consideration of power markets and electricity supply options is the funding source. With the exception of Thailand, LMB governments have until recently relied on concessionary financing for power generation projects of all scales (e.g. World Bank, ADB and donor partner grants and concessionary loans).

All LMB countries undertook some form of power market reform in the 2000's, at a minimum, the corporatization of national power utilities (I.e., EdC, EdL, EGAT, and EVN) and opened generation to private sector investment and independent power producers (IPPs). While IPPs were initially attracted to grid markets (and remain so) more recently LMB government policies have sought to streamline procedures to attract IPPs and private sector finance to grid-connected and isolated systems based on small-scale new and renewable energy (RE) sources. For example, since 2002 Thailand has been stimulating private investment in REs with its very small power producer (VSPP) and small power producer (SPP) Feed-in Tariff Programmes (see discussion in Section 5.4.2)

Financing for tributary projects in Lao developed for export markets (grids in Thailand and Viet Nam) as well as the proposed LMB mainstream dams in Cambodia and Lao PDR are now all based on private sector models. Because capital formation in Lao PDR and Cambodia is low, these are primarily Foreign Direct Investment (FDI) involving Asia region investors. With the exception of Thailand, most investments for generation for decentralized power markets and for stand-alone systems depend largely on financing from the traditional concessionary lenders.

Figure 6.3 is a simplified illustration of financing sources in different power markets.[9]

[9] Government policies seek to attract IPP and private investment to small-scale RE options. This is a challenge where the combination lower density, often geographically dispersed households and low consumption per connection makes it more expensive to provide electricity services. People in subsistence livelihoods also have difficulty affording high tariffs. Thus subsidy from government budgets or cross-subsidy by tariffs is generally involved as a catalyst. Nevertheless, because of the different risks (e.g. technical, market, project risks, etc.) and expectations for return on equity, the same investors attracted to grid-scale options (e.g. mainstream hydropower can not be redirected to investment in alternatives for other markets, such as rural electrification in Cambodia and Lao PDR.

Figure 6.3: Typical sources of financing alternative in different LMB power markets

Power Market	Typical Sources of Financing for power generation projects/ systems			
	Cambodia	**Lao PDR**	**Thailand**	**Vietnam**
Grid Supply	▪ NA- as the grid is not formed ▪ Imports to load centers (e.g. EdC purchase via PPAs Vietnam)	▪ IPP /FDI models ▪ Concessionary finance (IFIs, Donor Partners) ▪ Equity position often taken by EdL	▪ EGAT investment (tariff and capital market – i.e. bond issues) ▪ IPPs ▪ Imports (EGAT purchase via PPAs)	▪ IPP models ▪ Concessionary finance (IFIs, Donor Partners) ▪ Equity position may be taken by EVN ▪ EVN currently equitzing power companies under Power Market Reform
Isolated load centers or mini-grids	▪ IPP models ▪ Concessionary finance	▪ As above	▪ As above	▪ As above
Stand-alone household supply	▪ Concessionary finance (IFIs and Donor Partners)	▪ Concessionary finance (IFIs and Donor Partners)	▪ Mix of government , utility tariff based programs ▪ Local investment	▪ Concessionary finance (IFIs and Donor Partners)
Dedicate Industry supply and captive generation	▪ IPP /FDI models	▪ IPP /FDI models	▪ IPP Models	▪ IPP models
Export markets	▪ IPP /FDI models	▪ IPP /FDI models	▪ NA ▪ Export to Cambodia EGAT to EdC via PPAs	▪ NA ▪ Export to Cambodia EVN to EdC via PPAs

Baseline status and trend, concerning power markets:

- The trend to urbanization in all LMB countries (2-3% per year on average), combine with ongoing rural electrification dominated by grid extension means the proportion of the LMB population served by the grid will grow. By 2030 it may be anticipated that +95% of the LMB population is grid connected.
- Thailand and Vietnam are well advanced in electrification of rural areas, though the level of service is much higher in urban centers and towns. Lao is making rapid progress in connecting its population to the grid. Lao PDR increases household connections from 16 percent in 1995; to 44 percent in 2004; and to 60 percent in 2008. Policies are to achieve 90% household

connections by 2020 through a combination of expansion of grid and off-grid supply with local generation. And Lao PDR is moving toward interconnection of its 4 regional grids in the medium term.

- Cambodia has very low access to electricity and has the greatest challenges in the LMB in this regard. Cambodia is moving toward interconnection of its 12 isolated grids in the longer term. This will retire uneconomic generators (e.g. diesel generators and high cost RE generation unless there is a policy not to requiring subsidy).
- At present tributary dams in Lao PDR developed for export have a portion of output (selected generation units) dedicated for grid supply to EdL, illustrated by:
    - Theun Hinboun 1 first IPP (210 MW export) with domestic supply to Lao grid (10 MW to EdL) – about 5%.
    - Nam Theun 2 (1070 MW export) with domestic supply Lao grid (75 MW to EdL) – about 7%.
    - Theun Hinboun extension (220 MW for export) with domestic supply to Lao grid (60 MW to EdL) – about 27%.
- Continuing this trend, project-specific MOUs and feasibility studies for proposed LMB mainstream projects anticipate reserving a portion of output for domestic grids of the exporters, though the quantum of power (MW) and energy (GWh) are to be decided. Assumptions in the feasibility studies indicate this may be in the order of 5-10%.

Baseline status and trends, concerning financing sources:

- Power market reforms in LMB countries over the past decade invite private sector investment in electricity generation. In the case of Lao PDR and Cambodia all projects to date are IPP, some with a mix of FDI and concessionary finance.
- The proposed LMB projects are FDI, though as yet no clear indication is given whether investors will seek loans from Equator Principle banks in Asia, or elsewhere.[10]
- More recently, government policies have sought to attract IPPs finance to grid-connected and isolated systems based on new and renewable energy sources (RE) through preferential tariffs and streamlined PPA processes (see section 5.4.2)
- For the time frame of the baseline investment in stand-alone and decentralized power markets in Cambodia and Lao PDR are likely (i) to remain heavily dependent on government subsidy policy, and (ii) remain driven by concessionary finance.

6.1.3 Energy resource and fuel price trends

[10] http://www.equator-principles.com/

A second important consideration in the consideration of alternatives is the energy resource base. This section expands on the analysis in Section 2 on this aspect.

Hydrocarbon Resources

The GMS as whole has considerable hydrocarbon reserves, which vary from country to country. Table 6.4 illustrates the nature of hydrocarbon resources in the LMB. The picture is that while countries do have hydrocarbons, in many cases the reserves are not strategic or long term.

Figure 6.4 Overview of Hydrocarbon Resources in LMB Countries

Cambodia	***Natural Gas:*** Although it is possible that the country may have considerable offshore hydrocarbon reserves, such resources have yet to be proven. Some findings of Natural Gas have been reported but no figures have been published.
Lao PDR	***Lignite:*** anthracite and bituminous is available for about 2000 MW: possible as long term option depending on results of exploration ***Natural gas and Oil***: no significant reserve found yet. Exploration ongoing.
Thailand	***Natural Gas:*** Proven reserves of 11,198 bcm (probable 11, 676 bcm, and possible 6,843 bcm) for a total of 29,717 bcm including reserves in the Gulf of Thailand ***Coal***: sizeable resources of lignite, notably Mae Moh basin in the north of the country. Most of the domestically produced coal is of rather low quality, giving low calorific value. proven reserves of 1,372 million tons ***Oil:*** proven condensate of 265 MMbbl and a total 729 MMbbl; crude oil proven 176 MMbl and a total 430 MMbbl)
Vietnam	***Natural Gas***: Significant offshore NG reserve of 6.8 trillion cubic feet (Tcf). Most used for industrial and power use (allocations to the power sector are decreasing) ***Coal:*** In 2004, recoverable coal reserves of 165 million tons, mainly anthracite exported and used for power generation (annual coal production in 2004 was 18 million tons (rising since) indicating a limited life of Vietnam coal reserves. [11] ***Oil***: currently produces oil from nine offshore fields; 600 MMbbl proven oil reserves located offshore. Exploration is ongoing.

China (Yunnan Province) has the dominant reserves of coal (reportedly 26,000 million tones proven) and Myanmar has the significant and large gas resources, reportedly 283-368 BCF (10-13 tcf) and .18 billion barrels of oil.[12]

The overall hydrocarbon resource in the GMS regions is illustrated in Tables 6.5, 6.5b and 6.5c. What is notable is the amount of coal and that a large portion is below Grade 1 (lower quality in terms of energy

[11] http://www.eia.doe.gov/cabs/Vietnam/Full.html

[12] US DOE and http://www.eia.doe.gov/emeu/international/reserves.html

content, higher moisture content). This in part is driving the consideration of imports of higher quality thermal coal from outside the GMS region.[13]

Table 6-5: GMS Hydrocarbon Resources

	Energy Resource Classified as Grade 1	Energy Resource Classified as Less than Grade 1 (lower quality)	Total All Grades
Coal (MTCE)	8,397	73,024	81,421
Lignite (MTCE)	10,699	775	11,474
Oil (MTOE)	450	748	1,198
Natural Gas (bcm)	400	1,284	1,684
Notes: MTCE – million tones of coal equivalent; MTOE – million tones of oil equivalent; bcm – billions of cubic meters The figure for gas of 300 bcm is used insread of the 245 bcm in the IRM study to reflect current information on Myanmar gas reserves			
Sources: Adapted from ADB Sustainable Energy Futures (2009) – originally from IRM (2008).			

Table 6.5b illustrates the relative size of the different GMS hydrocarbon reserves in Peta Joules (PJ), a unit of energy measurement.

To gain a perspective on the relative amount of hydropower represented by these resources, in Table 6.5c the equivalent energy represented expressed in (PJ / year) in the 53,000 MW in the GMS region is shown as a ratio to the finite PJ reserve for each hydrocarbon resource. That is simply called the index ratio in Table 6.5b.

It is important to note this is theoretical, not only because of the conversion factors are assumed, but also because these resources in practice will be used in other sectors.

There are also competing claims to hydro carbon resources in the GMS and wider South Asia region. For example, Vietnam claims ownership of a portion of the potentially hydrocarbon rich Spratly Islands in the South China Sea, as do the Philippines, Malaysia, China, and Taiwan.

LMB Hydropower Resources

The total hydropower potential of the Mekong River Basin is estimated to be 53,000 MW, with about 30,000 MW technically available in the four lower Mekong countries of Cambodia, Lao PDR, Thailand and Viet Nam. Section 6.4.3 considers tributary and mainstream hydropower above 10 MW in more detail.

[13] Coal is in four types

Table 6-5b Energy Equivalent of GMS Hydrocarbon Resources (PJ)

	Grade 1 Energy Resources (PJ equivalence)	%	Less that Grade 1 Energy Resource (lower quality)	Total PJ	%
Coal	201,528	59.7%	1,402,061	1,603,589	88.6%
Lignite	101,641	30.1%	5,890	107,531	5.9%
Oil	18,900	5.6%	25,133	44,033	2.4%
Natural Gas	15,600	4.6%	40,061	55,661	3.1%
Total	337,669	100.0%	1,473,144	1,810,813	100.0%

Note: Assumptions on Conversions To PJ

Hydrocarbons		Grade 1 (PJ)	Other grades (PJ)	GMS Hydro Potential - MW to	
Coal	1 MTCE	24	19.2	53,000	MW
Lignite	1 MTCE	9.5	7.6	1,003	PJ / year
Oil	1MTOE	42	33.6	Assumed	
Gas	1bcm	39	31.2	Plant Factor 0.6	
Conversion of Grade 1 to Other Grades			0.8		

Sources: SEA calculations adapted from ADB Sustainable Energy Futures (2009) – originally from IRM (2008). Gas reserves increased to reflect current information

Table 6-5b Energy Equivalent of GMS Hydrocarbon Resources (PJ) and Index to compare to Hydropower Resource (PJ)"

	Grade 1 Energy Resources (PJ equivalence)	Index - Ratio to compare with average annual Hydropower (PJ)	Less that Grade 1 Energy Resource (lower quality)	Total PJ	Index - Ratio to compare with average annual Hydropower (PJ)
Coal	201,528	201	1,402,061	1,603,589	1,599
Lignite	101,641	101	5,890	107,531	107
Oil	18,900	19	25,133	44,033	44
Natural Gas	15,600	16	40,061	55,661	56
Total	337,669		1,473,144	1,810,813	

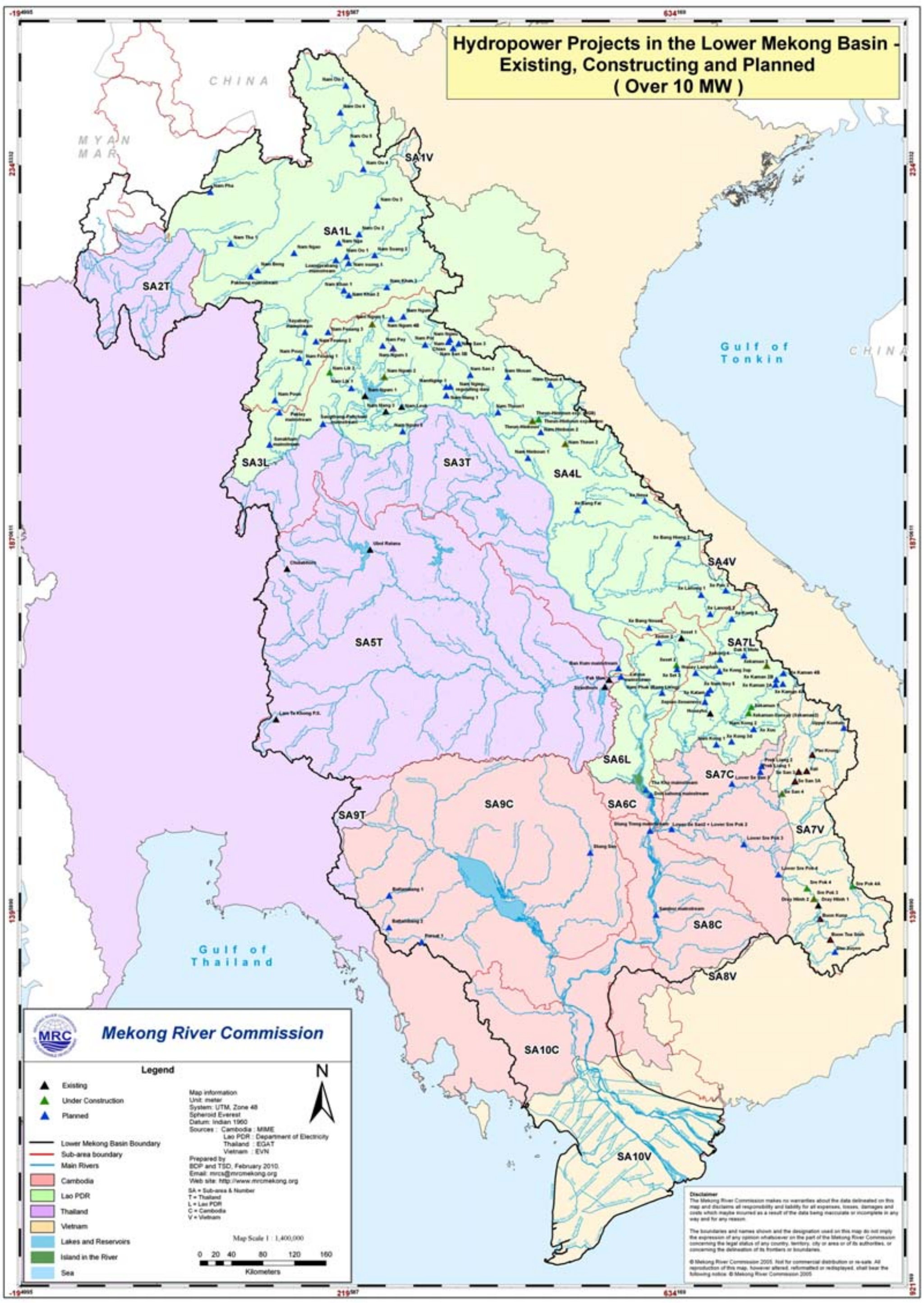
Note: Assumptions on Conversions To PJ

Hydrocarbons		Grade 1 (PJ)	Other grades (PJ)	GMS Hydro Potential - MW to	
Coal	1 MTCE	24	19.2	53,000	MW
Lignite	1 MTCE	9.5	7.6	1,003	PJ / year
Oil	1MTOE	42	33.6	Assumed	
Gas	1bcm	39	31.2	Plan Factor 0.6	
Conversion of Grade 1 to Other Grades			0.8		

Sources: SEA calculations adapted from ADB Sustainable Energy Futures (2009) – originally from IRM (2008). Gas reserves increased to reflect current information

Figure 6-6 shows the general location of the 135 existing and potential hydropower projects in the lower Basin, comprising close to 30,000 MW. As indicated, a large portion of this hydropower potential is in Lao PDR.

Figure 6.6: Hydropower Projects and Sites in the Lower Mekong Basin



Renewable and non-conventional resources

The LMB countries have large renewable energy (RE) resource base although the utilization with advanced conversion technologies is still comparatively low, and some of the traditional energy resources (i.e. wood fuel are under multiple pressures). The large biomass potential has been partially exploited for traditional household and farm energy use. In Cambodia, biomass (wood and charcoal mostly) still represent over 70 percent of the primary energy in the country.

More recently, Thailand has advanced its promotion of the more advanced RE conversion technologies for biogas, power generation, and bio-fuels. Activity with advanced RE conversion technology is more limited in the other LMB countries. There is a significant renewable energy resource base, to support non-hydro RE generation across the GMS countries from various biomass sources, solar and to a lesser extent wind on a highly site specific basis (and small hydro, when grouped with RE generators).

Thailand has estimated that its medium-term RE potential is some 14,300 MW (see table 6.6). Although some stakeholders argue the RE potential for solar in stand-alone applications is much higher considering the potential for widely distributed solar applications that may be cost-effective, such as solar water heating and advanced thermal-electric (solar towers). Solar water heating can realistically displace a portion of electricity use, in situations where electricity is currently or projected to be used for water heating.

One estimate of Thailand's RE potential is shown in the Figure 6.7.

Figure 6.7: Estimates of Thailand's RE Potential

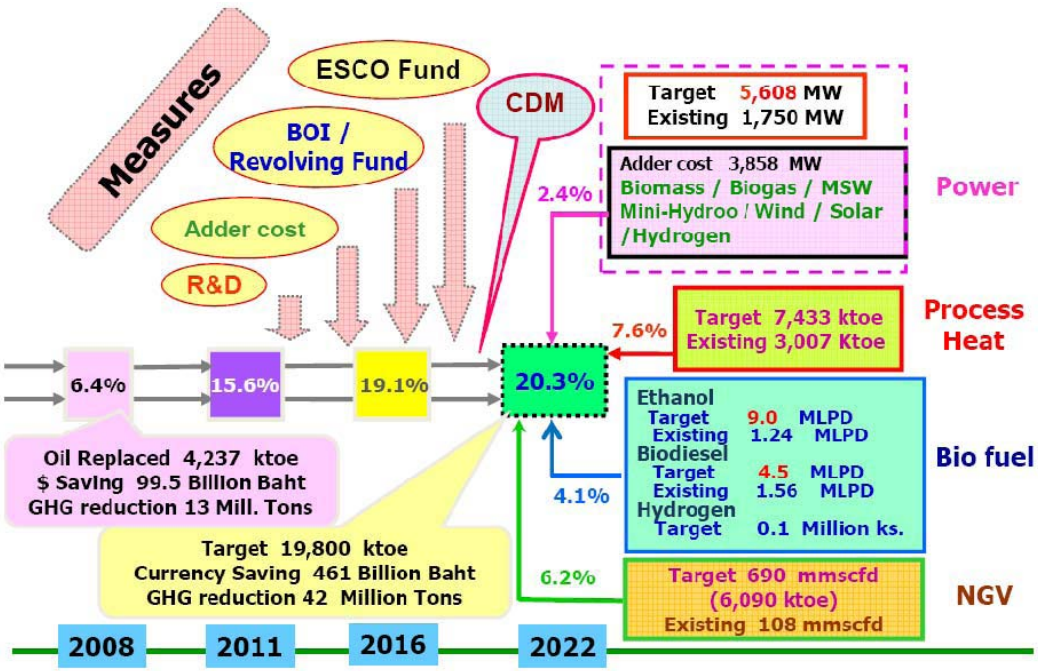
Renewable Energy	Energy Potential Approximation
Biomass	7,000 MW
Solar	>5,000 MW
Small hydropower	700 MW
Wind	1,600 MW

Source: Centre for Energy Environment Resources Development (CEERD), based on government estimates supporting the SPP and AEDP.

The Government of Thailand adopted a 15-year Alternative Energy Development Plan (AEDP) in January 2009, which aims to reach a target of 20% alternative / renewable energy in the total national energy mix by 2022, as well as advance the use of high-efficiency energy technologies. This 20% target includes the use of renewable energy in other sectors, such as bio-fuels for transportation. The AEDP is also designed to take advantage of any international carbon financing under the Clean Development Mechanism (CDM) for GHG emission reductions.

Thailand's targets in the three phases of the AEDP, ending respectively in (2011/2016/2022), are outlined in Figure 6.8. As noted in the upper right portion of this Figure, the power target is to derive 11,216 MW from RE sources by 2022. This compares to total installed capacity of about 56,000 MW projected in Thailand PDP (ADB RETA 2009 Revision) for 2022, which corresponds to 20% of installed capacity. The two main government programmes to raise public and private investment to reach these targets (the VSPP and SPP) are discussed in Section 6.2 .

Figure 6.8: Thailand Alternative Energy Development Strategies (2008-2022)



SOURCE: DEDE (JANUARY 2009); Reproduced from CEERD Report 2009

In Viet Nam, the updated Power Development Plan (PDP) prepared in 2009 anticipates that electric generation from RE sources may reach 2,400 MW by 2025, which would represent close to 3% of installed capacity by that time (see Figure 6.9).

Figure 6.9 Projected trend in non-hydro RE generation in Viet Nam

Viet Nam	2010	2015	2020	2025
Installed Capacity (MW)	21412	40619	56919	83619
Non-Hydro RE (MW)	86	300	1100	2400
RE as % Installed Capacity	0.40%	0.74%	1.93%	2.87%

Source: ADB RETA 6440 (update)

The focus in the discussion above was on the two primary power markets for the proposed LMB mainstream dams, where alternatives argument is raised (i.e. LMB mainstream dams can be deferred, or avoided, if feasible alternatives are pursued instead).

Full investigation of the scope for individual RE generators is beyond the scope of this SEA. But a broader picture of RE potential in the LMB countries is illustrated in the following Figure 6.10.

Figure 6.10: Quick profile of RE resources in LMB Countries:
(Note this table will be developed further for the final)

Cambodia	***Wind***: site specific, some costal with higher wind speeds ***Solar***: theoretical high ***Biomass***: Significant with agricultural residues: e.g. Agricultural residues - paddy husk sugar cane bagasse, wood residues, wood fuels, new plantations, ***Small hydro***: limited site specific potential ***Geothermal***: no known sources
Lao PDR	***Wind:*** limited potential (low average wind speed) ***Solar:*** theoretical high ***Biomass:*** Agricultural residues - paddy husk, wood residues, wood fuels, new plantations ***Small hydro***: various site-specific potential ***Geothermal***: no significant reserve known
Thailand	***Wind:*** site specific, some costal with higher wind speeds, possibly similar estimates to Vietnam suggesting <4,000 MW ***Solar:*** theoretical high ***Biomass***: Agricultural residues, sugar cane bagasse, wood residues, palm oil residues, wood fuels, new plantations, ***Small hydro:*** limited site specific potential (nine sites identified for small-scale development) ***Geothermal***: nine locations where developments started, full potential not known
Viet Nam	***Wind***: technical potential good. Academic research suggests that equivalents of 3,572 MW have current economic potential.[14]

[14] Wind energy in Vietnam: Resource assessment, development status and future implications. Khanh Q. Nguyen, Department of energy economics, Institute of Energy, Hanoi, Vietnam

	Solar: theoretical high ***Biomass***: Agricultural residues - paddy husk sugar cane bagasse, wood residues, wood fuels, new plantations, ***Small hydro***: various site-specific potential **Geothermal**: estimates in literature capacity may be up to 400MW; a 20 MW site was proposed in 1990's but not developed.

0ther LMB energy resources

Other RE and non-conventional resources have country specific, or longer term potential in LMB countries. Among these include ocean sources (e.g. tidal, wave and OTEC) and related technologies for LMB countries with significant coast lines. These advanced renewable energy conversion technologies may have application, for example, on coastal areas of Viet Nam and possibly Thailand, but likely only after commercial application of the technology is well demonstrated in other settings.

While there is some potential for geothermal in Thailand and Viet Nam, as shown by previous interest in geothermal pilot projects in these countries (e.g. a small geothermal system at San Kampaeng, Pai and nine other locations that have reportedly been under further investigation in Thailand; and in Viet Nam, a 20 MW project was reportedly proposed to EVN in the 1990's) there is as yet, no indication of a strategic or highly significant geothermal resource in the LMB than can be accessed with present-day technologies.

One example of a non-conventional energy resource of more immediate potential is municipal solid waste. Waste incineration is part of Thailand's RE programs.

Nuclear Power

Both Vietnam and Thailand included nuclear power in their latest Power Development Plans.

Thailand's goal, set out in the January 2010 revision of the Thailand PDP is to double energy output over the next decade. Five to seven nuclear reactors are proposed by 2030 (though the PDP is yet to have Public Hearings). The Thai Government openly acknowledges the greatest challenge in proceeding with the nuclear power will be public acceptance. A special study of nuclear power costs and risks will reportedly be done and submitted to the Cabinet in 2011.[15]

Viet Nam has moved ahead with plans for its first nuclear power units and proposed to have a 2,000 megawatt nuclear power plants built in the southern part of the country by 2020, or some time after that. There have been debates in the National Assembly about the costs.[16] By 2025, the government

[15] http://www1.voanews.com/english/news/science-technology/Thailand-Looks-at-Nuclear-Power-as-Part-of-Alternative-Energy-Plans-85040182.html

[16] http://www.earthtimes.org/articles/show/296061,vietnam-nuclear-plants-to-be-approved-despite-concerns.html

expects that 4.4% of the country's electricity would come from nuclear power. The long-range planning is for nuclear to represent 20% of the generation mix by 2040.

Vietnam reportedly has uranium resources. However under international arrangements it is expected the uranium will be imported. Russia, France and Japan all have cooperation arrangements and discussion with Viet Nam on participation in Viet Nam's nuclear power development program.

Baseline Trend

- Thailand had nuclear power in its 2007 PDP Revision (4 units); in the January 2010 PDP, 6 nuclear units are proposed by 2030;
- Vietnam more actively proposes to have 4,000 MW (in two complexes) by 2025, with the first unit possibly by 2020.

The strategic perspective is there will be a major challenge for public acceptance, especially in Thailand. The Thai Government sees the GHG reductions that nuclear would offer as key in the public debate. Otherwise, the nuclear power option has no impact on short or medium-term import tolerance levels in Thailand and Viet Nam. Any nuclear power development may impact on power import-export derived from hydro over the longer term; however from power system planning perspective hydro is less expensive.

Imported Fuel Quantity and Price Trends

Fuel prices directly impact the profitability and competitive advantage of RE generation in relation to hydrocarbon supply options as well the various interconnection projects between LMB countries that are based on hydropower. High or escalating fossil fuel prices will increase the attractiveness of all RE options (characteristically front-end capital intensive, and lower cost in terms of their "fuel" i.e. hydropower, wind and solar) as compared to thermal plant. Low fuel prices make RE projects and any exports derived from them, less profitable.

Roughly 90% of the LMB power generation today is based on hydrocarbons as discussed in previous sections. The general status and trends in LMB countries is given by the following, bringing together the discussions in previous sections. [17]

- ***Cambodia:*** Currently relies on oil imports (diesel generators for most of the countries generation in the 12 isolated grid centers. If mainstream hydropower is not pursued, Cambodia's power generation expansion would likely be based on expansion of the thermal mix, notably coal-fired generation based on imported coal from international markets.
- ***Thailand***: 15% of coal was imported in 2007, 23 % of NG was imported (from Myanmar in 2007), this ratio is likely to increase as domestic production falls and competition for use of gas in other sectors increases. More recently, the Energy Policy & Planning Office, Ministry of Energy, Thailand announced the policy to decrease gas dependency, by means which including higher coal imports.
- ***Vietnam***: Is currently a net coal exporter, Vietnam will become a net coal importer for domestic power generation by 2012,

Baseline Trend

The price trends in internationally traded hydrocarbons used by the ADB RETA 6440 to the update the GMS regional interconnection Master Plan follow the fuel price projections of the World Energy Outlook 2009 and the International Energy Outlook 2009. These are show below to illustrate the trend to higher import prices.

Figure 6.10b Trends in energy prices imported into the GMS region for power generation

Crude oil price projection :

$2008/barll	2010	2011	2012	2013	2014	2015	2020	2025	2030
	80	86	92	98	104	110	117	123	130

Oil derivatives price projection :

$2008/t	2010	2011	2012	2013	2014	2015	2020	2025	2030
HFO	399	429	459	489	518	548	582	615	648
DO	449	515	582	649	716	783	854	926	997

Natural Gas price projection :

NG Price	2010	2011	2012	2013	2014	2015	2020	2025	2030
$2008/MBTU	7.0	7.6	8.2	8.8	9.4	10.0	11.7	13.3	15.0

Coal price projection :

$2008/t	2010	2011	2012	2013	2014	2015	2020	2025	2030
Coal price	80	81	82	83	84	85	90	95	100

6.2 OPTIONS FOR ISOLATED GRIDS, STAND-ALONE AND DISTRIBUTED GENERATION

Two broader categories used in this paper to help clarify the status and trends in the LMB concerning these options are (i) decentralized generation, and (ii) distributed generation. This paper thus essentially adopts the grid and off-grid categorization.

Decentralized generation means not connected to the national grid. It includes isolated or "mini-grids", as well as stand-alone systems for individual customers. In the LMB context, stand-alone applications divide further into (i) rural / remote household stand-alone systems, and (ii) those serving larger consumers or enterprises.

The second broader category, **distributed generation**, captures the family of RE conversion technologies (small hydro, wind, solar biomass, etc.) as well as conventional technologies (e.g. diesel generators) and non-conventional generation (e.g. industrial co-generation) used in a grid connected context. Small generators may produce power in any location (rural or urban). While some regard distributed

- **Lao PD**: The role of thermal generation is expected to be marginal. The expansion of the generation mix being based on hydropower.

generation as long-term, there is interesting progress in the LMB with Thailand's very small power producer (VSPP) & Feed-in Tariff Programme and the small power producer programme (SPP), recently extended from 60 MW to 90 MW. In developed countries, decentralized generation is largely promoted to change the present generation mix on the grid (even if there is little or no load growth) so as to reduce reliance on fossil generation. That is increasingly a motivation factor in the LMB context, as seen in the policy for the recent Thailand PDP, dubbed by some as the "green" PDP, designed to increase the percentage of renewable energy in the supply mix by 2022 and reduce GHG emissions by 20-30% per/ kwh.[18]

To some extent decentralized and distributed generation rely on the same RE generators - but in different situations. Plus there are dynamic trends over the longer term. For example, high-cost, or low-power stand-alone systems that serve immediate needs when there is no grid, are frequently retired when mini-grids or main grids eventually reach rural households. Similarly, some options that supply mini-grids are retired when the isolated grid is eventually connect to the central grid (like expensive diesel generators in Cambodia). In that case RE generators that support mini-grids, such as small hydro are integrated into local supply and otherwise become distributed grid-feeding applications. It depends on the characteristics of the generation, as well as government policy on what RE generation to retain if the power economics are not attractive.

For example, grid electrification and community micro-hydroelectric plants ranging in size from 10 to 40 kW have been built in 59 remote villages in Thailand's mountainous Northern provinces. The national grid was far away when these projects were developed, but now that the grid has reached these villages, at least 30 of the micro-hydro systems have been abandoned, in part because of the local requirements to manage them were high.[19]

6.2.1 Stand-alone rural household systems

These options provide simple and flexible ways to extend energy services to remote rural areas where there is no grid service. They include simple household lighting systems, solar (PV) home-systems, micro hydro, biomass and potentially wind (electric or mechanical generators) depending on site specific conditions. These conversion technologies can be used for on-farm needs like crop processing or water pumping, with a range of financing mechanisms to recover capital and operating expenses.

There is much in the literature about stand-alone household systems. Rapid improvements in technology and practical learning have made RE systems increasingly attractive. For example, in 2003 in Vietnam micro-hydropower systems were estimated to generate a total of 30 to 75 megawatts, consumed by about 100,000 off-grid, remote households and small community groups on village-scale network. Potentially, they could provide a total capacity of 90 to 150 megawatts for over 200,000 households.

[18] The January 2010 Thai PDP has yet to go through Public Hearings.
[19] www.gwenvironment.com/gwe/pdf/thailand/Thai%20power.pdf

Photovoltaic (solar homes) was also estimated to be a viable power option for around 5,000 households (UNDP 2003). The cost of providing these generation units to remote communities is estimated to be similar to connection to the national grid, though the quantum of power is low and local maintenance capacity is needed. Cambodia has plans to introduce 10,000 (PV) home systems in its 10-year Renewable Energy Action Plan (REAP).[20]

These projects are usually wholly funded through public sector or donor funds. Financing facilities such as the CDM and GEF have also been important in supporting these initiatives. And again the locations the serve must be carefully planned so the economic life is not cut short by grid extension (grid feeding is not generally a technical option for these type of stand-alone solar (PV) systems).

Stand-alone urban systems / industry scale

Stand-alone applications in urban areas and industry applications similarly include solar, biomass conversion technologies and wind electric generators. For industry or enterprise scale they are larger and typically include diesel generating sets, small steam or gas turbines, micro-hydro units, windmills coupled to generators, modified engines using bio-fuels coupled with generators, and wood residue or rice husks to raise steam and produce electricity locally.

They have the advantages of potential reliance on local renewable energy sources, quick implementation, portability and modularity, little or no fuel costs (for solar, hydro and wind) and decreasing costs with technological advancement.[21]

6.2.2 Isolated Mini Grids

Medium-sized, isolated generation options are designed to service remote towns, settlements and local enterprise/industrial needs. LMB country examples include the 12 medium sized urban areas not connected to the grid in Cambodia. Medium-sized generation may be from a range of different sources including oil or diesel, natural gas, medium and small hydropower and other RE generators.

In Cambodia there are losses, especially in the smaller isolated grids and RE systems and high risk premiums in small IPP contracts because they operate on short contracts with limited or no government guarantees. There is also limited access to capital for investments to improve efficiency or capture economies of scale. The heavy reliance on diesel generation (and the high tariff implications as well as

[20] http://www.recambodia.org/reap.htm

[21] Solar photovoltaic modules, especially for household applications, have seen a phenomenal growth in the 1990s, with a cumulative production of about 800MWp in 1998. Several private and multilateral initiatives to promote PV development are also in place even as system prices are as low as $8/Wp and expected to drop further to about $1-2/Wp by 2020, with a projected market growth rate of about 25% for the next several years. Harnessing energy from biomass using advanced technology such as gasifiers is especially attractive in rural areas for community power, with the additional bonus of providing process heat for industrial applications. Biomass energy is greenhouse gas neutral and has potential for generating rural employment, but its widespread application may be restricted by land-use limitations, in particular, competition with food production.

the petroleum product import burden) has stimulated policy to address the barriers to attract IPP investment to a wider range of RE generators.

Further discussion on RE technologies for mini-grid and central grid markets is provided in Section 6.4 including the policy drivers.

6.2.3 Distributed energy systems

Distributed systems are small-scale power generation technologies (typically in the range of 3 kW to 10,000 kW) used to provide an alternative to, or an enhancement of the traditional electric power grid system. Any generation in excess to electricity needed on site (for a particular time of day) can be sold back to the grid (with technical and regulatory arrangements in place, such as in Thailand).

The conversion technologies include all the generators noted in previous sections. They also include roof top solar installations and co-generation systems based on utilizing steam from industrial processes or burning waste (from agro processing, municipal waste, industrial waste) where the industry or enterprise generate power on-site for self-needs, and “feed” the rest back into the grid. It draws from the grid when more power is needed on-site then they can self-generate. Where natural gas is available (and government policy permits) distributed cogeneration sources can also use natural gas-fired micro-turbines or reciprocating engines to turn generators.

Distributed generation reduces the amount of energy lost in transmitting electricity because the electricity is generated very near where it is used, perhaps even in the same building or factory. In sufficient numbers, distributed generation has potential in the longer term to reduce the size and number of local power lines that must be constructed.

6.2.4 Challenges and baseline trend

The challenges to address in RE promotion for decentralized and distributed uses in the LMB countries include the intermittent nature of energy availability of some technologies based on renewables, high first costs, the need for organization for their utilization, and to some extent foreign exchange implications. Solar for example, has a low duty cycle producing peak power at local noon each day. Average duty cycle is typically 20%.

Each RE conversions technology also has its own complexity and institutional coordination requirements and environment and social implications. For example, biomass is a more complex fuel source, as compared to fossil fuels, or other renewable sources such as solar or hydropower. Often biomass is associated with forests and it takes time to educate people that biomass, including forests, can be managed sustainably, while providing a continuous supply of biomass fuel from crop, or forest residue or even plantations.

Distributed energy systems can be technically complex. The appropriate legal, technical and human resource requirements need to be in place. The experience in Thailand with its feed-in tariff program will be important to demonstrate what can be achieved in the Mekong setting and what is needed to successfully transfer experience. For example, among the challenges reportedly faced in Lao PDR are key barriers to creating conditions supportive of increased use of non-hydro renewable energy include: (i) insufficient small-scale RE planning capacity to prepare integrated projects (with both on- and off-grid components) that would provide most cost-effective delivery to households and productive electricity applications; (ii) insufficient availability of concessionary financing to achieve RE targets; and (iii) lack of private sector capacity for scaling-up implementation of RE.[22]

The usual problem with distributed generators though is their relative high costs. Innovative financing and organizational arrangements, training in the servicing and use of new technologies, and the application of hybrid systems based on a mix of renewable sources and diesel, where appropriate, have been important ways of overcoming these barriers in many field situations.

Baseline Trend

The main trend to 2015 – 2030

- In the 2000's a number of donor-supported projects, often as part of rural electrification programs in Cambodia, Lao PDR and Vietnam have started to promote stand-alone and isolate RE technologies as well as financing and institutional arrangements. There is more rapid advancement of the policy environment in Thailand for all RE generators, and more recently in Vietnam.
- From 2004, in Cambodia the REAP funded by the World Bank's Energy Sector Management Assistance Program (ESMAP) to encourage the generation of electricity from renewable energy sources (from 2004). The REAP envisions an active partnership between public and private sectors to create a favorable environment for investment opportunities in renewable electricity, in particular in hydroelectricity, and to a lesser extent in solar installations. The underlying targets for the coming decade include: 6 MW of electrical supply capacity from Renewable Energy sources; 500,000 households served; 10,000 solar (PV) home systems; and creation of profitable, demand-driven renewable electricity markets.[23] Lao is progressing with grid extensions based on large hydro, but at the same time is stepping up activities to develop small-scale RE targets and for scaling-up implementation of RE.
- Funds are being established in LMB countries for RE promotion. For example, in Cambodia the pilot Rural Electrification Fund (REF) component to implement an innovative mini and off-grid electrification program funded by concessionary finance (the ADB and World Bank, plus donors). These are based on mini-grids based on generation from diesel, solar or hydropower generation. And Thailand is establishing and RE promotion fund to deal with the subsidy requirements, where it is expected that existing generators will contribute (see discussion in 6.4.2)

Strategic perspective:

[22] Lao PDR Rural Electrification Project Appraisal, 2006, World Bank
[23] Cambodia http://www.recambodia.org/reap.htm

From a strategic perspective in consideration of alternatives:

- Small-scale REs are important to pursue and central to the energy policies and the poverty reduction policies of LMB Counties.
- Grid power does not directly compete with, but complements the RE activities.

6.3 ROLE OF DEMAND-SIDE MANAGEMENT

In LMB countries as elsewhere, power sector reform is leading to the removal of government subsidies in the power sector and consequently higher consumer prices for electricity. This provides a better environment for adopting demand-side management (DSM) and wider conservation and energy efficiency measures in the power sector. For instance, reform in distribution requires the removal of subsidies, effective billing and collection procedures and innovative arrangements to make bulk sales to co-operatives, time-of-day pricing to smooth peak demand, etc.

There is ample evidence that LMB governments supported by donor partners increasingly recognise the value of demand-side management (DMS) and energy efficiency (EE) potential in supply, transmission and end-use in meeting environmental and power development goals. DSM has gained support on number of grounds, particularly where cost-effective measures can be demonstrated to delay or offset the need for future power plants. DSM is also viewed as one of the most cost-effective ways to reduce greenhouse gases such as CO2.

At the same time, the need for serious and aggressive demand side management is at the centre of many CSO and NGO critiques of PDPs in the LMB and also the consideration of external financing for export projects. For example, there were competing assessments of DSM/EE in Thailand when the World Bank assessed its support for the Nam Theun 2 project in Lao to export to Thailand's north-east grid. A total of 912 MW in DSM was estimated in the project appraisal whereas other researchers suggested that an additional 1,225 MW of possible savings - as consequence the project was not needed. [24] These assessments generally follow the fault lines in the ongoing global large dam debate (as noted in the WCD-2000).

Although all LMB Countries have made progress in the last decade with DSM there is a mixed picture. Focusing on the two main power markets for LMB mainstream dams:

Thailand reportedly became the first country in Asia to formally adopt a nationwide demand-side management master plan in 1997 and today maintains an active DSM program. The literature notes that DSM implementation strategies adopted by EGAT to date can largely be classified into four categories: (a) Market Transformation through Voluntary Agreement; (b) Energy Efficiency Labeling; (c) Customer-Oriented Program Design; and (d) Public-Private Sector Partnerships. There are specific initiatives that have attracted public attention including the High Efficiency Lighting T5 Retrofit

[24] http://siteresources.worldbank.org/INTLAOPRD/Resources/ResponseWitoonPermpongsacharoen.pdf

Program.[25] As of June 2007, the DSM implementation reportedly educed peak demand of 1,435.2 MW and reduced energy demand of 8,148.3 GWh. As Thai Authorities note, the program also achieved CO2 Emission reduction of 5.63 million tons.

Viet Nam: started its first DSM Programme in 1997 with a multi-phase and multi-year programme. The first phase focused on implementing EVN's DSM business plan, developed in Phase 1 that included:

- Expanded time-of-use (TOU) metering by procuring and installing TOU meters;
- Pilot direct load control (DLC) Program introduced by using ripple control systems;
- Compact fluorescent lamp (CFL) promotion;
- Fluorescent tube lamp (FTL) market transformation;
- Supporting programs and technical assistance for DSM efforts.

The second stage approved in 2003 was longer (2003-2010) effort to support DSM and EE programmes to achieve reductions in energy consumption and peak power demand.[26] The program would, in the course of 3-4 phases, test, develop and seek to scale-up successful and sustainable business models to promote DSM/EE and facilitate investments. Programme targets that evolved were to produce a 120 MW reduction in peak demand and save some 496 GWh in 2007. However, independent review suggests it was very difficult to monitor because of the 13-16% growth rate in demand, load shedding and the lack of monitoring data.

Preliminary results of Phase II have reportedly included:

- transformation of the CFL market in Viet Nam from less than 1 million lamps a year in 2004 to more than 10 million by 2007;
- Independent evaluation of EVN's programs reported almost 500 GWh in annual energy
- savings and 91 MW in peak load reduction to date;
- Approval and implementation of 100 commercial energy efficiency projects with expected energy savings of 34 GWh/year and
- training of service providers

Options for a third phase investment program in 2011 are reportedly under consideration.

As the part of its overall energy efficiency improvement strategy, the government of Viet Nam in 2006 launched the Viet Nam National Energy Efficiency Program (VNEEP). The VNEEP set out sector-by-sector energy efficiency programs up to 2015, including a range of initiatives from solar water heating to investing in manufacturing plant for energy efficient lighting, and industry energy audits for power factor correction. A peer review of the DSM/EE progress and measures was provided by the APEC Energy Working group in 2007. This recommended a series of much stronger measures to identify and implement DSM /EE in all sectors of the economy. [27]

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[25] Thailand http://www.egat.co.th/en/index.php/egat-dsm-programs
[26] Vietnam Demand-Side Management and Energy Efficiency Project, World Bank Appraisal, 2003
[27] Peer Review On Energy Efficiency In Viet Nam http://www.ieej.or.jp/aperc/PREE/PREE_Vietnam.pdf

The APEC peer review addressed progress implementing the government's 2006 Decision on Approval of the National program on Energy Efficiency and Conservation. The energy efficiency targets (or national aspiration goals) for a 5% reduction in energy consumption for 2006 to 2010, and 5 to 8% for 2011 to 2015) including measures to:

- Strengthen the legislative framework;
- Increase public awareness through outreach campaigns and the education system;
- Develop energy efficiency standards and labels for appliances and equipment;
- Establish energy efficiency programs for industry;
- Implement energy efficiency in the design and operation of buildings; and
- Reduce fuel consumption and emissions in the transportation industry.

The APEC team recommended various strengthening measures including a stronger energy efficiency program with supply-side and demand-side efficiency measures to. among other activities (i) improve load research activities to identify proper DSM measures (ii) improve power plant efficiency (iii) reduce T&D losses, and (iv) investigate a sustainable funding mechanism for DSM implementation, e.g. setting a DSM fund with contribution from electricity tariff or placing a levy on the revenue of electricity distribution companies to be used to fund energy efficiency programs.

The DSM Challenge

The challenge for DSM in Vietnam is illustrated by the following text extract from the APEC Energy Working Group Peer review of progress on DSM in the country, focusing on appliances. [28] The situation describes in Viet Nam generally applies to Cambodia and Lao PD as regard to future directions and challenges in DSM and Thailand perhaps to a lesser degree.

"Vietnam is currently in the phase of rapid economic growth. To follow suit the rapid economic development is the strong growing demand and uses of appliances and equipment – ranging from refrigerators and air conditioners in homes, to photocopiers and lighting equipment in office buildings – which will drive more demand for energy, i.e. electricity. In meeting the growing power demand and managing the power load efficiently will be a great challenge to the government. In this regard, improving the energy-efficiency of appliances and equipments by standards and labelling will be the most cost-effective types of policy to address the surging power demand and managing power loads efficiently. Energy-efficiency standards and labelling have the potential to effect complete market transformations for different classes of energy saving products, at a cost far below the cost of providing new energy supply.

A lack of standards can result in inefficient appliances and equipments entering the market and locking consumers into years of additional costs and sub-standard performances. Mandatory energy standards such as Minimum Energy Performance Standards (MEPS) will provide efficient and effective solutions in improving energy efficiency of appliances and equipments. At the same time, labelling, especially

[28] APEC, Peer Review On Energy Efficiency In Viet Nam, Final Report, 2006, http://www.ieej.or.jp/aperc/PREE/PREE_Vietnam.pdf

Mandatory Energy Performance Labelling (MEPL) will enhance the implementation of MEPS. MEPL is also could improve market penetration of energy-efficient products by creating a well informed society. The PREE team identified that Vietnam has recently issued MEPS for a few products; however, they have yet to begin enforcement. Furthermore, Viet Nam has also designed both a comparative and endorsement energy label, but a clear road map for implementation and mechanism for applying them have not been yet developed.

Integrated institutional approach for MEPS and labelling program planning and implementation is important because the roles and responsibilities for energy efficiency are vested with various agencies. However, the PREE team found this important link in the appliances and equipments energy efficiency improvement efforts is missing. Currently, the implementation of MEPS and labeling has been on ad hoc basis and without a clear strategy. MEPS and labeling programs should be developed in a holistic manner with a clear strategy and well-defined roles and responsibilities of the agencies involved.

Generally, the most energy-efficient model in a group of product class is more expensive than that of others but over the long run the energy-efficient one will provide more savings and cost benefit. However, the lower initial investment cost element on inefficient product will always outweigh the long run savings and benefits element. The PREE team therefore believed that for better penetration of the most energy-efficient appliances and equipments into the market, and to establish a niche, requires strong support from the government. The support could be provided as fiscal or financial incentives to manufactures, importers or buyers of the most energy-efficient appliances and equipments in the market.

The PREE team realized that Viet Nam has limited local knowledge of the technical basis and terms for carrying out a benefit-cost analysis for energy labeling and MEPS requirements. This limitation impeded Viet Nam to promote the use of MEPS and MEPL on a wider scope vigorously. Furthermore, technical barriers such as limited number of energy efficiency testing laboratories or no accredited laboratories are also a huge barrier for Viet Nam in implementing MEPS and labeling effectively and efficiently."

One major hurdle in accelerating and exploiting the full potential of DSM in the long-term is the long replacement cycle of motors. Electric motor loads (in industries, buildings and homes - e.g. fans, refrigerators and AC units in homes) account for between 45%-80% of total electricity use in all societies, and represent the largest single barrier to more efficient use of electricity.

Baseline Trend

- DSM started in all LMB countries in the 2000's or late 1990's.
- Thailand is the most advanced in DSM and has achieved 1,435.2 MW by 2007; Vietnam's has achieved 120 MW in 2007,
- Ongoing DSM/EE programs would be expected to continue and be strengthened (2015-2030). Awareness is growing of the role of DSM in power demand-supply balances.

- Donor Partners are highly active in DSM in Vietnam in particular, where significant scope for DSM exists. Tariffs are increasing which will further motivate interest in DSM among the many different consumer groups.
- In terms of kwh/yr/per person the region as a whole remains below developing country averages.

Strategic perspective:

- Supply side-efficiencies and demand side efficiency will lead to peak (MW) and energy (GWh) savings in LMB countries; however, with current trends it is clear the main role of DSM will be to slow the rate of demand growth and increase the load factor (i.e. the ratio between mean demand and peak demand) and, therefore, delay new capacity additions in the medium to longer term.
- Higher tariffs will gradually influence consumer behavior, e.g. turning off lights and appliances when they are not needed and buying energy efficient bulbs and appliances. Except for the easier measures or low “hanging fruit” like energy efficient lighting and power factor (i.e. a measure of reactive energy demand which reduces supply efficiency) correction in industry, significant penetration of DSM is a longer-term prospect that will involve structural change and replacement of the existing stock of inefficient appliances and electricity using equipment.
- The full potential for DSM remains contested on (i) the amount of savings possible (peak reduction and energy reduction) and (ii) whether technical estimates of DSM are achievable and over what timeframe, and whether can be depended upon in power supply planning and with what degree of certainty an risk.
- Prospects for DSM (i.e., peak shaving and energy savings) do not change the drivers of mainstream power export in the short to mid-term.

6.4 SUPPLY OPTIONS FOR GRID CONNECTED SUPPLY

Around the world, numerous energy conversion technologies are considered for grid-connected power generation from hydrocarbon, renewable and non-conventional energy sources.

6.4.1 All potential options in a supply mix

Figure 6.11 provides a generic illustration of the range of supply options for power grids. The columns in the table indicate the energy resources, typical MW range and the typical service, or role in the generator plays in electric supply (e.g. peak, mid-range, base load, variable or intermittent supply) and a general indication of the LMB potential.

Figure 6.11: General Options for Grid Supply and LMB Application Potential [29]

Supply Option / Technology	Energy Sources	Decade Commercial (International)	MW Range	Typical Duty on the Grid	LMB Grid Potential
Thermal					
Oil Based – Steam Generation	Oil	1900s	50-600	Base and Mid Load	Current use
Coal Based – Conventional Steam Generation	Coal	1900s	50-800	Base Load	Current use
Supercritical-(higher efficiencies)		2000's	50-800	Base Load	Important
Ultra-Critical (highest efficiencies)			50-800	Base Load	Important
Diesel Generation	Oil	1940s	0.1-45		Current use
Gas Based – Steam Generation	Gas	1950s	50-600	Base and Mid Load	Current use
Combustion Turbine Generation	Gas/Oil	1960s	20-250	Peak Load and Standby	Current use
Combined Cycle Generation	Gas/Oil	1980s	50-750	Base and Mid Load	Current use
LNG Technologies (Combustion)	Gas	1980s	20-250 50-750	As Above	Potential
Fluidized Bed Generation Technologies	Various fuels, and wastes	1980-90s	100-300	Base Load	Potential
Other Thermal/Steam					
Co-Generation	Waste heat	1940s-CIS	variable	Usually Base Load or Feed in supply	Current use and high potential
CHIP (Combined Heating & Power)	Fossil fuel	1960s-in CIS	50-300		Potential
Nuclear Generation					
Light Water (LWR/PWR) and Heavy Water Uranium Fuelled	Various Fissile material	1950-60s	600-1400	Base Load	Potential Policy driven and public acceptance
Pebble Bed		Prototype Near Commercial		Base Load	
Fast Breeder _ U-238 and Plutonium		Prototype		Base Load	Horizon
Other Advanced Nuclear)		Prototype Near Commercial		Base Load	Horizon
Hydro-Electric Generation					
Simple Run of River	Tributaries	1900s	0.1-1000	Base Load; variable	Current use
Small Hydro	Tributaries/	1900s	0.1-10	Peak to Base Load,	Current use

[29] Adapted from the World Commission on Dams (2000), Electricity Supply and Demand Management Options Thematic Paper.

Supply Option / Technology	Energy Sources	Decade Commercial (International)	MW Range	Typical Duty on the Grid	LMB Grid Potential
	Streams			Variable	
Mini and Micro Hydro	Streams	1900s	0.001-0.1	Peak to Base Load	Current use
Run-of-River Diversion Dams	Main Stem Rivers or Tributaries	1920s	0.1-1000	Peak to Base Load	Current use
Reservoir Storage Dams	Main Stem Rivers or Tributaries	1920-30s	0.1-18000	Peak to Base Load	Current use
Pumped Storage	Various	1980s-90s	100-3000	Peak Load	potential
Other Renewable					
Bio fuelled – Steam Generation	Biomass Waste or grown	1900s	2-50	Base and Mid Range Load	Initial pilots and potential
Bio fuelled Combined Heat and Power	Biomass waste or plantation	1940s-60s	2-50	Base Load	Initial pilots and potential
Geothermal Generation	Geothermal	1950s	5-100	Base Load	Initial pilots and some potential
Wind Energy Generation	Solar	1990s	0.1-5	Variable and intermittent	Initial pilots and potential
Solar Electric (PV)	Solar	Near commercialisation	0.0001-10	Variable and intermittent	Limited Current use and potential
Solar Thermal-Electric (solar towers)	Solar		100-500	Base to Mid Load Variable and intermittent	Pilot proposals and potential
Ocean Energy Systems					Horizon
Tidal Energy Systems	Estuaries	Prototype only	?	Variable	Horizon
Wave Energy Systems	Coastal		0.1-10	Variable	Horizon
Advanced Systems					
Ocean Thermal Energy Conversion Systems (OTEC)	Ocean	Prototype only	10-1000	Base Load	Horizon
Fuel Cells	Water	Near commercialisation	0.01-10	Peak to Base Load	Horizon
Hydrogen Systems	Hydrogen	Horizon	?	Peak to Base Load	Horizon
Distributed (RE) Systems	RE sources	Various	3 kW to 5 MW (RE systems only)	Intermittent feed in supply	Current and potential

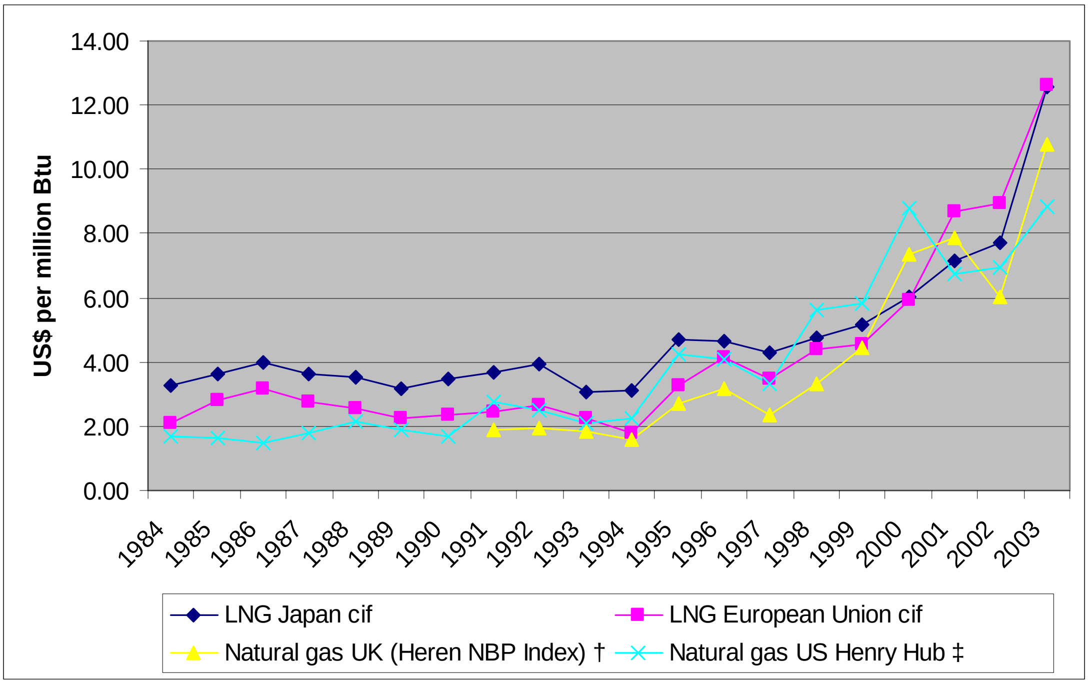
The selection of the mix of grid-connected generators for a particular grid system is based on a number of power system planning and reliability considerations, the resource base and overall power sector development and sustainability policies of the utility, the regulator and government, as discussed in the following sections.

6.4.2 Power system planning considerations – and new technology

The 21st century is moving towards an era of higher efficiency power systems and renewable energy find alternatives to reduce dependence on finite fossil fuels and to mitigate climate change – arguments today are generally more about the pace than the direction and specific projects.

BP's Statistical Review of World Energy from June 2009 shows that the global reserve to production ratio is 60.4 years for natural gas, 122 years for coal and 42 years for oil at present production rates. Figure 6.12 shows that trend in natural gas prices, 1984-2003 as a result of growing demand. The analysis in section 2 of this paper shows that time periods in the LMB countries are dramatically shorter (e.g. at current rates of proven natural gas reserves in Thailand are 12 years).

Figure 6.12: Natural Gas Prices, 1984-2003



Source: BP, 2009

Consideration of Hydropower relative to other grid-options

Hydropower generation is subject to seasonal and multi-year variation in rainfall and climate. As the climate change predications indicate more rainfall is expected in the Mekong region in the longer term future, by as much as 20-30 percent (see the SEA background paper on climate change).

Most other renewable energy sources, such as wind and solar power can generate power only under the right conditions (i.e. with adequate wind and sun). Electricity has a value based not just on the power produced, but on when it is available. Often, back-up power stations are needed to guarantee energy security. In effect, if wind is developed off-shore of Vietnam to meet electricity demand growth, then a back-up generator (e.g. fossil fuel or hydro) is needed to meet electricity when the wind is not available. Thi s requires capital for two systems.

Most large-scale renewable sources (non hydro) that are grid-connected thus operate in a fuel saving mode on the grid, that is, to reduce the burning of fuel at existing thermal stations generation, where power can be available on demand. Where wind power is intended to meet new load, an equivalent thermal or other storage power plant is required when the wind is not available. This is the situation with wind power in Europe today. The back-up generation in the case of wind power in Germany is mainly coal-fired plant. In Denmark, back-up generation is primarily imports of hydropower from Norway and Sweden.

Because of regional grid interconnections, when wind is not available in Denmark, other suppliers provide a ready source to step in and ship the necessary megawatt-hours. [30]

Distributed power offers another avenue to significantly enhance the contribution of RE to the grid. As noted later in this section, Thailand by mid-2008 had 1,622 of MW of RE through the very small power producer feed-in tariff program and SPP applications for 6,682 MW, of which 4,151 could be supplied to the grid (though the latter includes some non-RE generation).

Figure 6.13 illustrates that RE technologies of different scales can play a role in grid-supply, though these must be seen as complementary, rather than competing opportunities, tempered by realistic potential of each option.

Figure 6.13 RE Generation in LMB Grid Context – Complementary rather than Competing

Large-Scale Renewable (RE) Grid-Connected	Distributed RE Generation Local generation and Grid Feedback
▪ Hydro (current use) ▪ Wind, Solar (back up required) ▪ Biomass (supply requirements) ▪ other Each limited by resource potential. Wind and solar only at early stages of market entry.	▪ RE Generators (all types, solar, wind biomass, micro-hydro, etc) - Intermittent supply (own use and conditions - Requires grid to install other capacity to deal with intermittent supply Limitations in scale relative to total grid demand.

If a very large-scale commitment is envisaged to renewable energy in the LMB power sector over the longer term (such as to meet 2050 Global GHG reduction aspiration), hydropower, particularly in Lao PDR will play a major complementary role dealing with the intermittency problem of other renewable options, like in Europe. Hydropower can be stored in a reservoir project (if sites are available) and stored water can be released to follow load patterns on a daily or seasonal basis depending on the

[30] Statement of the Royal Academy of Swedish Scientists
http://www.kva.se/Documents/Vetenskap_samhallet/Energi/Utskottet/uttalande_energi_vind_eng_2010.pdf

amount of storage. The grid Interconnection also becomes a consideration but, typically, even lengthy transmission lines, rarely account for more than 15% of the construction cost of a large hydroelectric project.

Power System Considerations

In historic trends, during the period from late 1970's to early 1990's, hydropower development in most of the developing world slowed due to combination of two circumstances: First, the rapid escalation of fuel prices predicted during the 1960's did not materialize, and thermal generation remained a more economic alternative, particularly after the introduction of a new technology known as "combined cycle", that drastically reduced investment cost while increasing the efficiency of thermal power generation using natural gas or diesel oil. Second, most power sectors at the time were entirely in state hands and the majority of these sectors in developing countries were chronically budget deficient, complicating the finance of large capital projects like hydro, even by development banks. Public attitudes about the adverse impacts of hydropower and large dams more generally were an important factor (World Commission on Dams (2000)).

The rapid escalation and volatility in the price of fossil fuels after 1995, the increased concern over greenhouse gas (GHG) emissions, and the creation of a worldwide private power industry (resulting from the restructuring and privatization of power sectors around the world in the 1990's), revived the interest in hydroelectric power at the beginning of the 2000 Millennium.

The LMB countries at that time did not undergo major structural changes to their power sectors, but share the concern for increased fuel prices and GHG emissions prevalent in the rest of the world. There are other factors driving the increased interest in hydropower in the Mekong region.

Thailand and Vietnam are among the fastest growing economies in the world with rapidly expanding power demand. This rapid increase in electricity demand and a diminishing availability of domestic fuel awoke a strong interest in these countries for hydropower from the Mekong River basin inside or outside their borders. At the same time, Lao PDR and Cambodia, with a lower level of economic development than their neighbors, saw this interest as an opportunity to develop their own power generation infrastructure while also generating large amounts of export income contributing to consistent revenues for poverty reduction and growth in the long term.

Without embarking on a treatise on power generation planning, the reasons generally why hydropower has advanced more rapidly than other renewable options are found in one or more of the following characteristics:

- Hydropower’s proven technology and resource availability
- Lack of other primary resource for other options (geothermal, and to some extent wind)
- Lack of suitable sites (tidal)
- Lack of proven technology (wave power)
- Low and/or intermittent quality of the resource in terms of hours per year (solar, wind, tidal)
- High technology, cost and political constraints (nuclear)

- Only recent advancement of other large-scale RE technologies
- Benefit-cost ratio (all)
- Important but still limited RE generation capacity and market penetration in relation to demand levels and demand growth
- Significant long lead times for DSM penetration into the market

From a power system planning/reliability perspective, hydropower also offers unique, dynamic benefits (also called ancillary services) to the power system operation which gives it a comparative advantage over other conversion technologies (RE and hydrocarbon based generation) and lowers supply cast from the system overall (from all generators).

Among these are:

- rapid load following capability
- frequency and voltage control
- VAR control
- coping with sudden major load increase and decrease (steep ramp rates)
- synchronous condenser operation
- system black start
- smoother operation and lifetime extension of thermal plant.

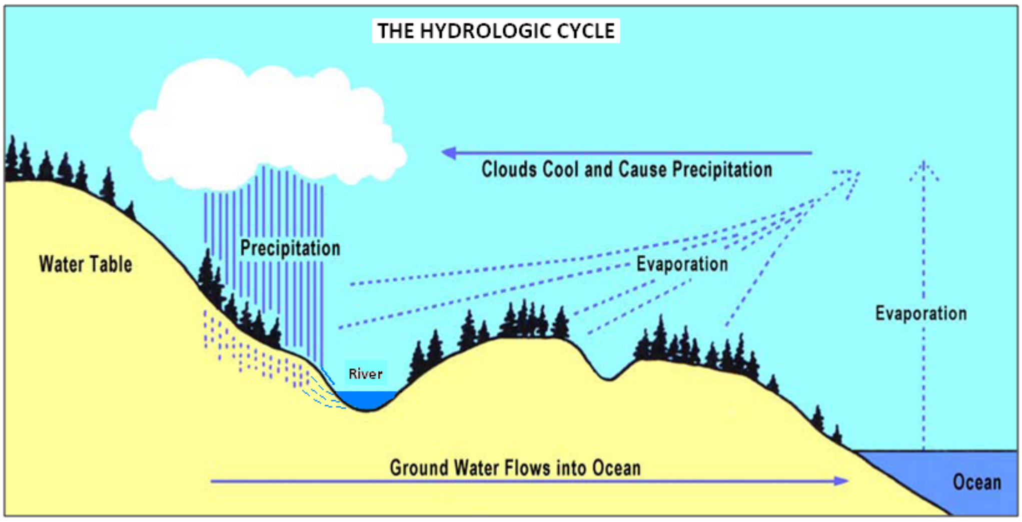
While hydropower, as a general concept, offers significant advantages as part of the generation mix and thermal/hydro system integration and operation, its development comes at a cost to other sectors, to local communities, to natural systems and in the form of trade offs for national and local development. The full costs and benefits need to be fully understood by LMB governments before long term and permanent commitments are made.

Hydropower Characteristics

Hydropower is driven by the hydrologic cycle of evaporation and precipitation (Figure 6.14) and is, therefore, a highly concentrated form of solar energy.

Since most rivers have a predictable, non-zero, minimum flow and since water, unlike wind or sunlight, can be stored prior to its conversion into electricity, hydropower is a reliable means of renewable power generation. Indeed, hydropower was the first source of commercial scale supply in the history of electricity and the United States, Western Europe and other regions of early industrial growth developed most available sites for hydropower many decades ago. These projects continue providing a considerable share of the electricity supply of those regions.

Figure 6.14 - The Hydrologic Cycle



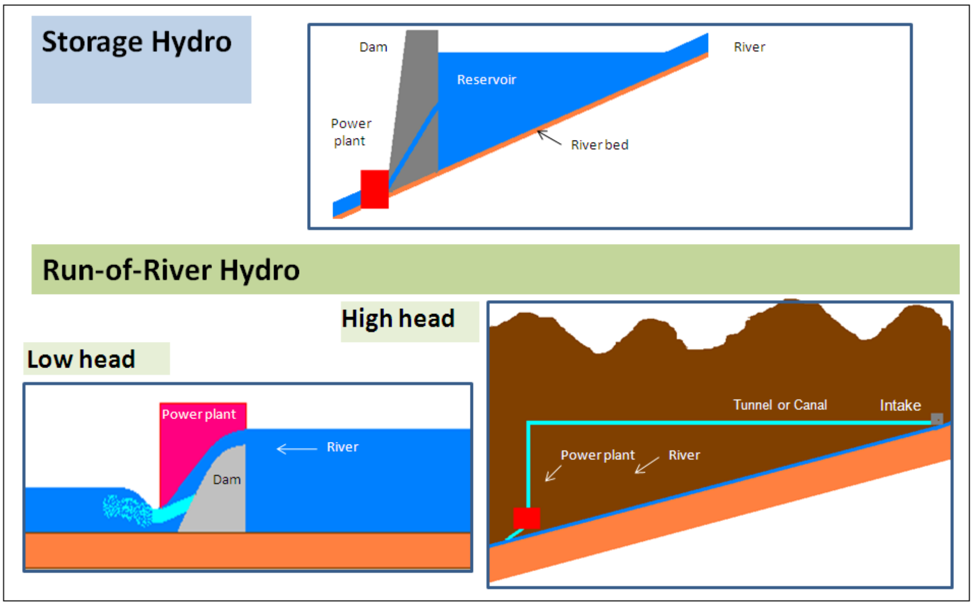
Hydropower projects come in a large variety of types (Figure 6.15). Some have large dams and reservoirs to store water at the same time that they create a difference of elevation; others divert water through a canal or tunnel to gain a difference of elevation without any significant storage of water; and yet another type have only low dams that while creating some differential elevation, are not capable of water storage. Each project demands a unique arrangement and design of several components that must be specifically suited to the topographic, geologic and hydrologic conditions of the site.

In addition, and also unlike other generation technologies, hydropower projects often serve more than one purpose. Because the ability to control river flows has many practical applications, it is common for hydropower projects to be developed with multiple uses in view such as irrigation, water supply, flood control, navigation and, even, recreation.

It is not surprising then that hydropower is both, the oldest, and one of the most controversial generation technologies. It makes use of one of the most important natural resources on earth, it can combine a variety of important benefits to mankind, it has the potential for severe impacts, and each project is different and admits many alternative designs. The challenge then is to recognize these differences in benefit and impact among different projects and develop criteria to sort out and design the projects that offer the highest overall value.

The important aspect in today's policy in today's context is that hydropower must be seen in terms of comparative advantages over conventional thermal options, and complementary with the wider portfolio of RE generation to the maximum potential from local to grid-scales.

Figure 6.15 - Types of Hydropower Projects



LMB Policy Trends supporting RE Technologies

As discussed in previous sections, RE technologies (apart from hydropower) have an important role to play in decentralized energy systems (today), distributed energy systems (limited now but increasingly in the future) and in conventional grid-connected applications (increasingly in the future). Perhaps the most significant policy trend is Thailand's two programmes (1) the small power purchase (SPP) programme for RE generators up to 60 MW, and (ii) the very small power producer (VSPP) & Feed-in Tariff Programme. [31]

Thailand's Small Power Producer (SPP): Under the SPP programme EGAT must purchase power generated by small power producers (SPPs) using renewable energy for projects up to 60 MW. SPPS can also sell to private customers (captive generation). With a PPA form EGAT the qualified SPPs are better able to secure commercial bank financing. There is also a government tariff subsidy on SPP selling price. Various media reports indicate the programme will reportedly allow SPPs to increase to 90 MW and the government has allocated US$ 661 million to the programme including the subsidy component.

Figure 6.16 shows that SPP applications for 6,682 MW had been received by mid-2008, of which 4,151 could be supplied to the grid.

[31] Thailand abandoned the previous minimum portfolio standard approach in 2007 when it expanded these two programmes.

Figure 6.16: Status of Thailand Small Power Producer Programme SPP (as of June 2008)

Fuel	Power to Grid			Received Notification of Acceptance		
	No.of Project	Installed Capacity (MW)	Sale to Egat (MW)	No.of Project	Installed Capacity (MW)	Max.Capacity to Grid (MW)
Non-conventional Energy	30	609.15	378.32	40	951.65	543.82
Commercial Energy	26	2,721.71	1,670.20	46	5,225.10	3,374.20
Mixed Fuel	4	476.0	233.0	4	476.0	233.0
Total	60	3,806.86	2,281.52	90	6,652.75	4,151.02

Source: reproduced from Thailand Country Profile prepared by the Centre for Energy Environment Resources Development (CEERD)

Thailand's Very Small Power Producer (VSPP) & Feed-in Tariff Programme: The Thai Cabinet originally approved the VSPP regulations in 2002. That was to allow customers with renewable energy generators (solar, wind, micro-hydro, biomass, biogas, etc.) to connect their generators to the grid and offset their consumption. If a net surplus is generated, Thai distribution utilities must purchase this electricity at the same tariff that they purchase electricity from EGAT (bulk power). In 2006, the National Energy Policy Council (NEPC) upgraded and streamlined the VSPP regulations. The aim was to include larger size generators and also efficient fossil-fuel fired combined heat and power (CHP) generation and co-generation.

Figure 6.17 indicates installed capacity by mid-2008 had an installed capacity of 1,622 MW. The larger co-generation projects would appear in latter years after the 2006 revisions have and impact on proposals preparation.

Figure 6.17: Status of Thailand Tariff Feed in Programme VSPP (as of June 2008)

TABLE 5x VSPP STATUS (as of June 2008)	Power to Grid					Received Notification of Acceptance
	No.of Project	Installed Capacity (MW)	Max.Capacity to Grid (MW)	No.of Projects	Installed Capacity (MW)	Max.Capacity to Grid (MW)
MEA	31	1.33	1.08	51	11.47	8.01
PEA	67	537.9	212.51	245	1,611.17	1,046.30
Total	98	539.23	213.60	296	1,622.63	1,054.31

Source: reproduced from Thailand Country Profile prepared by the Centre for Energy Environment Resources Development (CEERD)

Thailand's Electricity Regulatory Commission (ERC), says investors have already shown interest in solar and wind power, especially solar power towers.

Solar Power Tower, The solar power tower (also known as 'Central Tower' power plants or 'Heliostat' power plants or power towers) is a type of solar furnace using a tower to receive the focused sunlight. It uses an array of flat, movable mirrors (called heliostats) to focus the sun's rays upon a collector tower (the target). Early designs used these focused rays to heat water, and used the resulting steam to power a turbine. However, designs using liquid sodium in place of water have been demonstrated; this is a metal with high heat capacity, which can be used to store the energy before using it to boil water to drive turbines. These designs allow power to be generated when the sun is not shining.

ERC has also indicated one new channel for implementing the subsidy for RE generators is a Power Development Fund, currently under establishment, which aims to raise capital from power generators. The reported objectives of the fund are to: 1) support the extension of electricity service provision to localities so as to decentralize operations; 2) develop local communities affected by the operation of a power plant; 3) promote the use of renewable energy and technologies in the electricity industry which conserve natural resources and have less impact on the environment; and 4) create fairness for power consumers.

High efficiency Coal Power Stations

Utility scale conventional thermal generation is well proven technology (gas- and oil-fired gas turbines and combined cycle plant; coal-, gas- and oil-fired steam plant; and diesel plant). Broadly speaking gas turbines and combined cycle plant are preferred by utilities on account of their low capital cost, short lead-time and high efficiency. When no gas is available, and only thermal options are presented, the next choice is typically a coal-fired plant for base load and oil-fired gas turbines for peaking and standby.

At present natural gas generators in the LMB (i.e. combustion turbines (CTs) and combined cycle systems (CC)) are relatively efficient, as these technologies are inherently efficient. Though there are opportunities in gas re-powering projects to improve efficiencies.

Given the level of coal-fired generation in the LMB, one trend of primary interest is the new high-efficiency coal conversion technology called "super-critical" and "ultra-critical" clean coal.

These super-critical and more recently ultra-critical systems use pulverised coal combustion – utilising supercritical and ultra-supercritical boiler technology to operate at increasingly higher temperatures and pressures. They therefore achieve higher efficiencies than conventional coal units and significant CO_2 reductions. Supercritical steam cycle technology has been used for decades and is becoming the system of choice for new commercial coal-fired plants in many countries.[32]

[32] http://www.worldcoal.org/coal-the-environment/coal-use-the-environment/improving-efficiencies/

Globally the overall thermal efficiency of some older, smaller units burning, possibly, poor quality coals can be as low as 25% (the global average efficiency's is about 28% taking into account coal power stations of all ages). A commonly used assumption for the average efficiency of larger existing plants with sub-critical steam burning somewhat higher quality coals is in the region of 35-36%. The new generation of plants, however, with ultra-critical steam boilers can now achieve overall thermal efficiencies in the 43-45% range.

This is significant for power planning as well as GHG reduction. A one percentage point improvement in the efficiency of a conventional pulverised coal combustion plant results in a 2-3% reduction in CO2 emissions. Therefore, highly efficient modern coal plants emit almost 40% less CO2 than the average coal plant currently installed.

The new technologies come at a capital cost premium. As with all technical options, there is a trade-off between the costs involved (both capital and operating), the risk element in the decision and the amount of additional energy recovered.[33]

Lignite coal represented 15% of generation in Thailand in 2003. [34] Coal used in power generation remained almost 16,000 tonnes from 2003 to 2008. [35] In the Thailand PDP 2007 Revision 2, it was projected that 4 coal-fired power plant with total capacity of 2,800 MW will be operated each year from 2016 to 2017. The PDP 2010 indicates further imports of coal may be considered. Expectations are now any new plant will be based on the latest pulverized coal fired, steam-electric generation with nominal output of 700 – 1,000 MW and the boilers will be super or ultra critical.

In Vietnam, coal represents the majority of the thermal generation. In the last several years, Vietnam has started to promote the construction of new coal-fired power plants to diversify energy sources and utilize domestic supplies. EVN has outlined plans to build 17 new coal-fired power stations by 2020. At present, coal accounts for about 14 percent of Vietnam's electricity generation, although some projections are this figure will rise to 25 percent in the future.

Lao PDR is proposing to build the lignite-plant for export to Thailand (MOU in place) and Cambodia would likely base future power development around imported coal if hydropower options (i.e., Stung Treng and Sambor) are not pursued.

6.4.3 Hydropower on LMB tributaries

One question that came up frequently in stakeholder discussion on the SEA was the merits of pursuing LMB tributary alternatives versus mainstream hydropower options.

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[33] http://www.iea-coal.org.uk/site/ieacoal_old/databases/ccts/pulverized-coal-combustion-pcc?

[34] Coal Demand/Supply Outlook in Thailand, Viroj Sivavong, Chief of Fuel Development and Planning Department, EGAT http://pr.egat.co.th/prweb/new/generation.htm

[35] http://www.egcfe.ewg.apec.org/publications/proceedings/CFE/Korea_2009/(Session3-B)Coal%20Demand-Supply%20Outlook%20in%20Thailand.pdf

Relevant Project Groups

In order to understand the drivers and the trade-offs involved in the development of mainstream or tributary projects in the LMB from a power planning perspective it is useful to examine sets of data corresponding to four groups of projects:

1. Existing tributary projects
2. Firm tributary projects (committed or under construction)
3. Undecided tributary projects
4. Mainstream projects

Key Project Indicators

Because hydroelectric projects are limited by water availability, the best indicator of the contribution of a hydroelectric project to any electricity system is its mean annual energy and not its installed capacity.

The mean annual energy is the annual energy that the project will produce, on average, during its life, taking into account the variation in hydrology from year to year. Energy is usually measured in GWh or thousands of megawatt-hours (MWh). Thus, for example, a typical 1 MW project operating every hour of the year produces 8,760 MWh or 8.76 GWh.

Most hydroelectric projects are not designed to run all the time at their full capacity. This is because much of the capacity cannot be used during the dry season for lack of water but must be available during the wet season to try and use as much as possible of the available water. Thus the mean annual energy production of a hydroelectric project is the product of its installed capacity times 8,760 hours and times a design parameter, called capacity factor that is less than one and measures the level of utilization of the installed capacity. Example: a 1 MW project with a capacity factor of 0.60 produces, on average, 5,256 MWh per year.

Just as energy is the best indicator of the power potential of a hydroelectric project, the most important indicator of its economic performance is the lifetime cost of the energy it produces or is expected to produce. Since hydroelectric projects have negligible variable costs, the cost of energy is essentially the amortization of the investment and the cost of operation and maintenance. The sum of the annual amortization and the annual operation and maintenance costs, divided by the annual energy results in the average energy cost. This value is usually expressed in $/MWh or, when translated into actual electricity tariffs, in Cents/KWh, the conversion is: 1 Cent/kWh = 10 $/MWh

Project Population

Tables 6.18 to 6.21 show the values of the key indicators for projects in each of the four groups discussed above. It is observed in the first two tables that all the projects already in operation or under development are in Laos and Vietnam. There are several projects in operation in Thailand too, but these are old projects and data on the cost of their energy is not reliable.

Table 6.21 shows the extensive list of projects under study, most of them are in Laos, only two in Vietnam and Cambodia has several but their energy cost is among the most expensive. The existing tributary projects and those under development (first two tables) correspond to the BDP definite future scenario that forms the baseline.

The undecided projects (table 6.21) correspond to additional projects that are in the probable future scenario plus all the remaining sites in the MRCS hydropower data base. It is important to note again also that the costs used for this analysis have unverified environment and social mitigation costs. The costs include resettlement costs as calculated in the feasibility studies prepared by project proponents and are before EIA /SIA reviews in many cases.

Table 6.18 – Existing LMB Tributary Projects

EXISTING TRIBUTARY PROJECTS			
Country	Project	Annual Energy GWh	Energy Cost $/MWh
Laos	Nam Ngum 1	1,006	22.1
Laos	Nam Dong	5	17.4
Laos	Xelabam	24	17.0
Laos	Theun-Hinboun	1,327	18.4
Laos	Houayho	487	38.6
Laos	Nam Leuk	207	44.6
Vietnam	Yali	3,659	18.4

Table 6.19 – LMB Tributary Projects under Development

FIRM TRIBUTARY PROJECTS			
Country	Project	Annual Energy GWh	Energy Cost $/MWh
Laos	Nam Mang 3	138	48.0
Laos	Nam Theun 2	5,936	18.2
Laos	Xekaman 3	983	30.6
Laos	Xeset 2	309	36.2
Laos	Nam Ngum 2	1,976	31.1
Laos	Nam Lik 2	460	35.1
Laos	Nam Ngum 5	507	38.1
Laos	Xekaman 1	1,096	35.4
Laos	Xekaman-Sanxay	123	34.7
Laos	Theun-Hinboun expansion	1,395	13.2
Laos	Theun-Hinboun exp. (NG8)	294	59.7
Vietnam	Plei Krong	417	48.5
Vietnam	Se San 3	1,225	21.9
Vietnam	Se San 3A	475	24.0
Vietnam	Se San 4	1,420	25.4
Vietnam	Buon Tua Srah	359	38.1
Vietnam	Buon Kuop	1,455	22.7
Vietnam	Dray Hlinh 2	85	19.8
Vietnam	Sre Pok 3	1,060	27.0
Vietnam	Sre Pok 4	329	15.5
Vietnam	Sre Pok 4A	302	46.0

Table 6.20 – Undecided LMB Tributary Projects

UNDECIDED TRIBUTARY PROJECTS			
Country	Project	Annual Energy GWh	Energy Cost $/MWh
Laos	Nam Ngum 3	2,077	30.4
Laos	Nam Theun1	1,840	38.3
Laos	NamNgiep 1	1,327	31.2
Laos	Nam Ngiep-regulating dam	108	34.5
Laos	Nam Tha 1	759	47.0
Laos	Nam Long	37	35.1
Laos	Xepian-Xenamnoy	1,748	41.1
Laos	Xe Katam	380	32.1
Laos	Xekong 4	1,901	42.1
Laos	Nam Kong 1	469	43.8
Laos	Xe Kong 3up	599	28.6
Laos	Xe Kong 3d	376	31.0
Laos	Xe Kong 5	1,201	42.0
Laos	Nam Ou 1	829	38.3
Laos	Nam Ou 2	413	45.3
Laos	Nam Ou 3	1,337	33.0
Laos	Nam Ou 4	337	40.3
Laos	Nam Ou 5	496	45.4
Laos	Nam Ou 6	840	49.2
Laos	Nam Ou 7	725	79.2
Laos	Nam Lik 1	255	46.7
Laos	Nam San 3	366	42.0
Laos	Nam Pha	577	55.3
Laos	Nam suang 1	187	51.4
Laos	Nam Suang 2	618	55.9
Laos	Nam Nga	434	53.3
Laos	Nam Beng	120	53.3
Laos	Nam Feuang 1	113	69.9
Laos	Nam Feuang 2	111	70.9
Laos	Nam Feuang 3	89	69.7
Laos	Xe Pon 3	339	47.6
Laos	Xe Kaman 2A	242	46.2
Laos	Xe Kaman 2B	381	47.0
Laos	Xe Kaman 4A	375	45.4
Laos	Xe Kaman 4B	301	42.8
Laos	Dak E Mule	506	62.0
Laos	Nam Khan 1	459	44.7
Laos	Nam Khan 2	579	46.1
Laos	Nam Khan 3	222	49.8
Laos	Nam Ngum 4A	268	42.6
Laos	Nam Ngum 4B	267	52.7
Laos	Nam Ngum, Lower dam	526	54.5

UNDECIDED TRIBUTARY PROJECTS			
Country	Project	Annual Energy GWh	Energy Cost $/MWh
Laos	Nam Pay	243	37.4
Laos	Nam Mang 1	235	101.3
Laos	Nam Pouy	172	45.7
Laos	Nam Poun	342	49.6
Laos	Nam Ngao	155	36.8
Laos	Nam Chian	627	34.8
Laos	Nam Ngieu	132	37.6
Laos	Nam Pot	100	63.2
Laos	Nam San 3B	141	66.8
Laos	Nam San 2	291	47.6
Laos	Nam Pok	14	124.7
Laos	Nam Phak	28	104.6
Laos	Nam Hinboun 1	173	55.6
Laos	Nam Hinboun 2	58	76.3
Laos	Xe Bang Fai	564	51.0
Laos	Xe Neua	230	70.6
Laos	Nam Theun 4	131	109.5
Laos	Nam Mouan	452	74.8
Laos	Xe Bang Hieng 2	74	84.6
Laos	Xedon 2	319	111.4
Laos	Xe Set 3	74	40.5
Laos	Xe Bang Nouan	79	130.6
Laos	Xe Lanong 1	153	89.3
Laos	Xe Lanong 2	104	66.7
Laos	Nam Phak	307	39.4
Laos	Xe Nam Noy 5	124	45.8
Laos	Houay Lamphan	264	68.5
Laos	Nam Kong 2	310	50.0
Laos	Xe Xou	286	51.1
Cambodia	L. Se San2 + L. Sre Pok 2	2,312	37.5
Cambodia	Battambang 1	123	66.4
Cambodia	Battambang 2	114	87.8
Cambodia	Pursat 1	443	51.3
Cambodia	Pursat 2	42	230.9
Cambodia	Lower Se San 3	1,977	65.0
Cambodia	Prek Liang 1	189	130.9
Cambodia	Prek Liang 2	186	112.8
Cambodia	Lower Sre Pok 3	1,102	134.6
Cambodia	Lower Sre Pok 4	772	119.1
Cambodia	Stung Sen	124	109.2
Vietnam	Upper Kontum	1,056	31.8
Vietnam	Duc Xuyen	181	47.4

Figure 6.21 – Proposed LMB Mainstream Projects

MAINSTREAM PROJECTS			
Country	Project	Annual Energy GWh	Energy Cost $/MWh
Laos	Don sahong mainstream	2,375	27.1
Laos	Pakbeng mainstream	5,268	34.1
Laos	Luangprabang mainstream	5,437	38.9
Laos	Xayabuly mainstream	6,035	29.0
Laos	Paklay mainstream	5,421	33.6
Laos	Sanakham mainstream	5,015	31.9
Laos	Sangthong-Pakchom mains	5,318	37.5
Laos	Ban Kum mainstream	8,434	39.6
Laos	Latsua mainstream	3,504	45.8
Cambodia	Sambor mainstream	14,870	45.4
Cambodia	Stung Treng mainstream	4,870	91.6

Note: The above figures do not have verified social and environment management costs. These factors will be considered in the next Phase of the SEA

Supply Curves

A useful tool for analyzing these data is called “supply curve”. This curve is constructed by first organizing projects in order of increasing energy cost and then plotting the energy cost as a function of the accumulated energy. The resulting curve gives an indication of how much energy is available below a given cost level.

Figure 6.22 – Supply Curves for Existing and Firm Projects

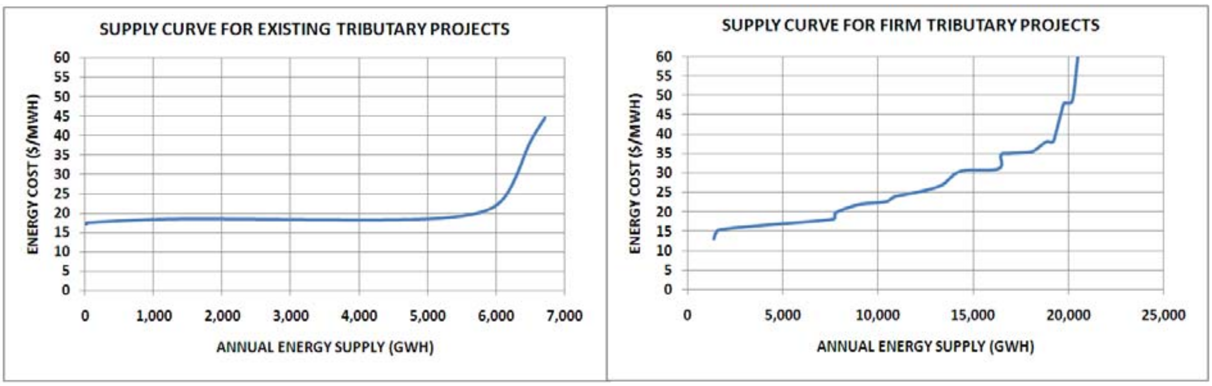


Figure 6.22 compares the curves for existing projects and projects under development. It is observed that most of the energy of existing projects is below 20 $/MWh and their supply is under 7,000 GWh per year. For projects under development the supply reaches more than 20,000 GWh and the curve shows a regular increase in the cost of energy as opposed to a relatively flat curve. It is interesting to note that there are approximately 7,000 GWh under development for less than 20 $/MWh, about the same as those already in operation. Most of the remaining energy is in the range of 20 to 40 $/MWh.

Figure 6.23 – Supply Curve for Undecided Projects

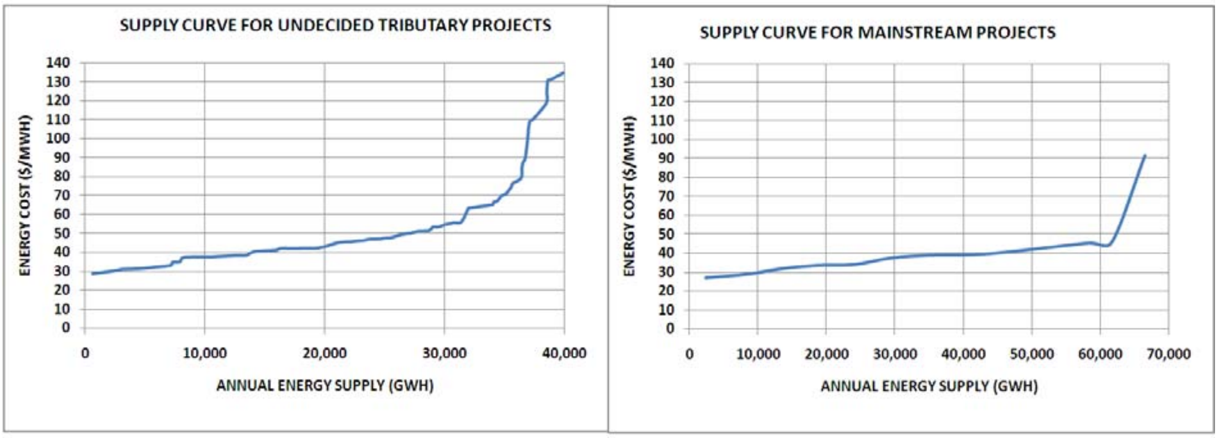


Figure 6.23 compares the supply curves of undecided projects in tributary rivers and the mainstream Mekong. The tributary projects have a potential of 40,000 GWh per year and reach energy costs of more than 130 $/MWh with about 30,000 MWh below 50 $/MWh. The mainstream projects reach almost 65,000 GWh per year and most of that is below 50 $/MWh.

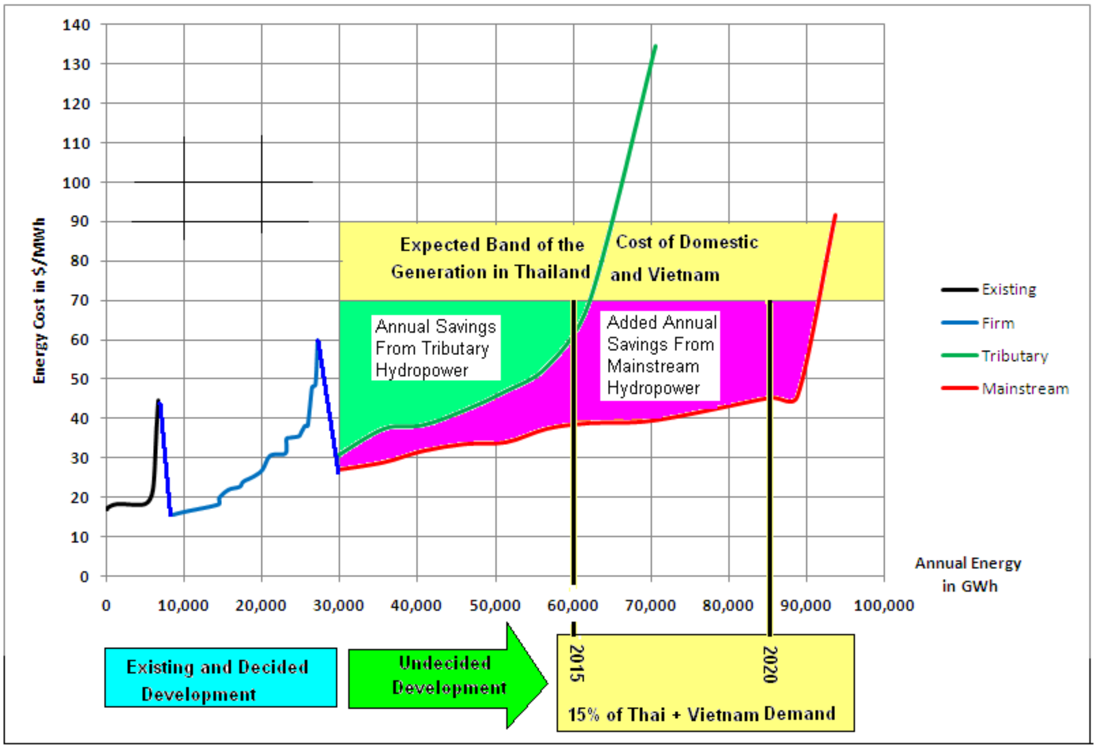
Consolidated Information

The information discussed above can be all consolidated in one single graph that illustrates the relationships between domestic cost of generation in importing countries, demand for hydropower imports and the supply curves for the four groups of projects discussed above. This is achieved in Figure 6.24.

Figure 6.24 combines the four supply curves in one graph. The supply curves are unique up to 30,000 GWh, the annual energy produced by all projects already in operation or under firm development. After 30,000 GWh the curves split into two paths, the supply curve for tributary projects and the supply curve for mainstream projects.

The first path is good up to a supply of some 70,000 GWh, however, the likely marginal cost of generation in Thailand and Vietnam probably will justify importing only up to the 60,000 GWh level. Interestingly, that level of 60,000 GWh is also the level at which Thailand and Vietnam would be importing 15% of their 2015 energy demand. The second path is good for up to 95,000 GWh of which 90,000 GWh will be attractive to import. That level will correspond to 15% of the demand of Thailand and Vietnam in about 2023.

Figure 6.24 - Consolidated Supply Curves



There are of course many other paths that would combine tributary and mainstream projects. For example, the red line can be shifted to start at the 60,000 GWh level, after all economically attractive source of imports of tributary hydropower have been tapped. However, the point of this Figure is to show that even if only 15 percent of the Thai and Vietnamese demand targets imported hydro, that is still a very large demand compared to the available supply below the energy cost level of 70 to 80 $/MWh.

Indeed, it is almost inconceivable that hydropower can be built at such a pace in Laos or Cambodia so as to satisfy 15 percent of the Thai and Vietnamese demand because most of the projects not yet decided particularly mainstream projects, require lengthy construction times and are very unlikely to be operational before 2020.

Other comparisons LMB mainstream versus tributary (MDM)

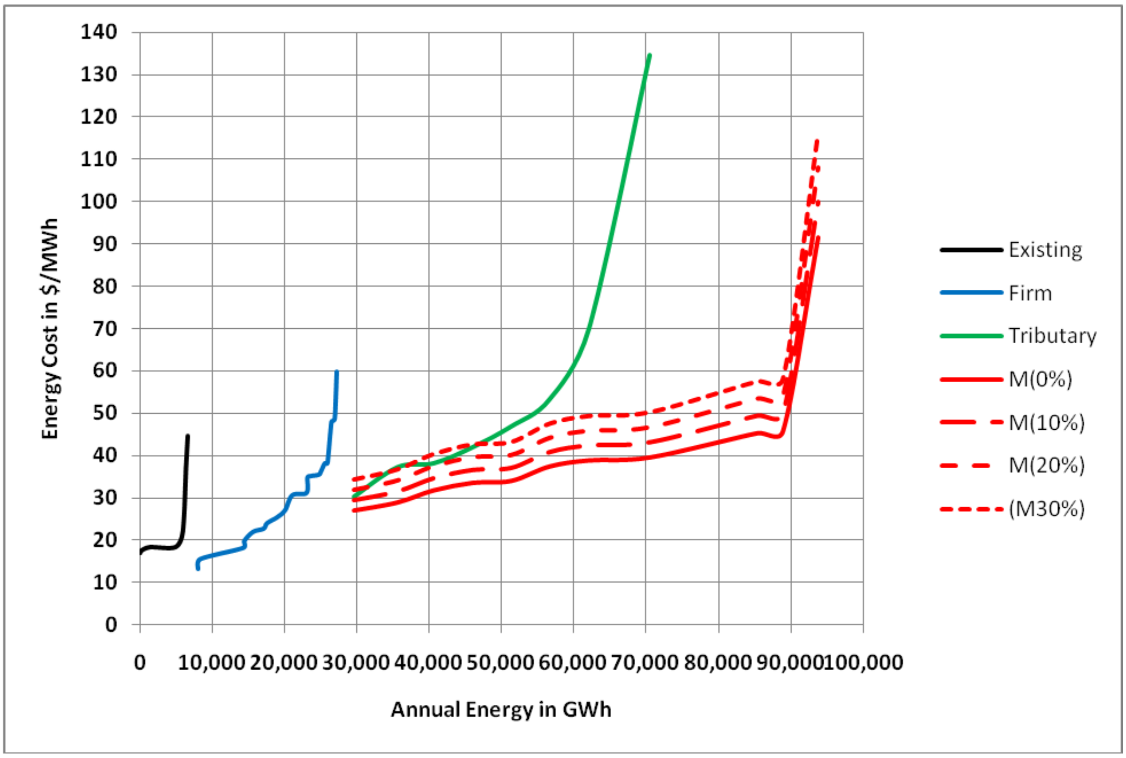
As explained in section 1.2 of the paper, this analysis is focused on power and does not attempt to quantify non-power impacts. It is however unquestionable that the potential for negative social and environmental impacts of a transboundary nature is greater in mainstream dams than in tributary projects. Therefore it is useful, even in a purely power sector focus, to offer an opinion of how would the supply curves look if such differential impacts between tributary and mainstream dams were quantitatively assessed.

Approximately 90 percent of the annual cost of energy of hydroelectric projects is capital cost (amortization of debt and return on equity). Let us define a concept, the **Mainstream Differential Mitigation (MDM)** factor, as the percent increase in capital cost that it would take for mainstream projects to mitigate their social and environmental impacts to levels comparable to tributary projects.

In Figure 6.25 the supply curves are plotted with different MCDF for mainstream projects. It is observed that propose LMB mainstream projects retain their advantage over tributary projects up to a MCDF of 20%. Above 20% they are comparable to tributary projects for the first 20,000 GWh of supply (beyond firm or already decided projects).

It can be seen that it would take very high MDM factors for the supply from mainstream dams beyond the first 20,000 GWh to be as expensive as that of tributary projects which, in any case is far more limited than that of mainstream projects. This gives an indication of the immense investment that can be afforded on social and environmental mitigation if the policy would be to make the impacts of mainstream dams comparable to that of and tributary projects

Figure 6.26 – Baseline Mainstream Differential Mitigation (MDM) factor



7 OTHER BASELINE TRENDS FOR IMPACT ASSSEMENT

7.1 IMPACTS OF HYDROPOWER

The scope of impacts both positive and negative, of the development of hydropower is very large, perhaps larger than that of any other generation technology and only comparable to open pit coal mining in terms of land disturbance. In this section the objective is to indicate trends for impacts strictly related to the power supply aspects and therefore it will focus on GHG emission offsets, investment levels, job creation directly linked to construction and operation of hydropower and the distribution of net power benefits.

7.2 GHG EMMISSION OFFSET TRENDS

7.2.1 Background

Global production and burning of fossil fuels today is estimated to account for nearly two-thirds of total anthropogenic GHG emissions. Thermal power generation based on coal, oil and gas alone accounts for up to one third. Current forecasts are the power sector GHG emissions under a business as usual scenario, could reach 40% of total human emissions by 2030.

Over the past decade major advances were made to reduce the emission of SO_2, NO_x and PM_{10}. For large coal-fired plant, for example, the state of the art desulfurization eliminates over 95% of the SO_2 emissions. DeNOx equipment removes over 90% of the NO_x. Modern electrostatic filters capture over 99.9% of the dust (PM_{10}). The removal of these components from the power plant emissions reduces the overall plant efficiency and increases the capital cost of the plant.

More problematic is the emission of green house gases, particularly CO_2. Coal is the most polluting in terms of CO2. Currently the only way to address this is by increasing the efficiency of the plant and by switching to gas-fired generation (for example one kWh produced with a coal plant produces 1 kg of CO_2, but one kWh produced with a gas-fired combined cycle produces 0.4 kg of CO_2). There are currently no practical techniques to extract the CO_2 from the emissions and store or deposit the end-product. Studies have been done to inject the emissions in disused natural gas fields or in the deep-sea ocean, but this would be prohibitively expensive compared with other measures to reduce green house gas emissions.

Nuclear power does not emit CO_2, SO_2, NO_x and $PM_{10 \text{ during}}$ operation. Though based on LCC Analysis all generation technologies have during construction, mining, decommissioning stages). If more emphasis is placed on climate change mitigation, nuclear power may enter into the arena again. However the problem of storing high level nuclear waste and decommissioning, public attitudes and the competitiveness are unresolved matters.

7.2.2 Gross emission reductions from LMB hydropower

For the purpose of this analysis, gross emission reductions are defined as thermal emission offset – meaning the gross emissions that would be produced if the energy produced by hydroelectric projects were instead produced by the combination of thermal plants most likely to be used in each country where the hydropower energy is being targeted.

In the LMB as a whole much of the current power generation is from fossil fuels based on coal, gas or oil sources. The ADB RETA N0.6440 offers the following guidelines to estimate the level of CO2 emissions from different types of thermal power plants:

Coal Fired Steam Plant:	0.97 Ton/MWh
Oil Fired Steam	0.75 Ton/MWh
Gas Fired Combined Cycle	0.43 Ton/MWh

Using the thermal generation mix likely to be used in each country in the absence of hydroelectric power the following values are obtained to estimate displaced CO2 emissions by hydropower:

Lao PDR	0.86 Ton/MWh
Thailand	0.65 Ton/Mwh
Cambodia	0.86 Ton/MWh
Vietnam	0.97 Ton/MWh

Applying these national CO2 offset values to the annual energy produced by each hydroelectric project and targeted to each national power market the following values are obtained for the CO2 offset by each hydropower development scenario:

LMB projects in operation by 2010:	6.1 M.Ton/year
Tributary Projects that will be operational by 2015:	22.6 M.Ton/year
Tributary Projects that could be operational by 2030:	42.0 M.Ton/year
Mainstream projects that could be operational by 2030:	51.9 M.Ton/year
All Projects that could be operational by 2030:	93.9 M.Ton/year

7.2.3 Net emission reductions from LMB hydropower

The net emissions offset by hydropower are the gross emissions discussed above less those that are deemed to be generated by the presence of a reservoir. This aspect is a subject of much debate both because of the technical complexity to estimate emissions from hydroelectric projects and also because of the diversity among hydroelectric projects.

As such, all that can be said is that net emissions offset would certainly be less than gross emissions offset but the extent of that reduction can only be estimated with any confidence by a detailed analysis of each individual project knowing the characteristics of the land prior to flooding, the watershed characteristics and carbon flux and the reservoir characteristics (e.g. volume, depth potential for thermal stratification, etc.).

7.3 LMB HYDROPOWER INVESTMENT TRENDS

The present value in 2010 of the investment associated with each of the scenarios identified above is shown in Figure 7.1

Figure 7.1 - Present Value of Investments in LMB Hydropower

	Laos	Cambodia	Vietnam	Total
2015-DF	2,330	4	1,324	3,658
2030-20Y	11,344	4,501	1,473	17,317
2030-20Y- W/O MD	5,442	491	1,473	7,405

It is observed that mainstream projects account for roughly 40 percent of the investment that could be made in hydropower over the next 20 years. Some of this investment, while directed towards the generation of electricity will add to other aspects of the national infrastructure.

In particular, mainstream dams will create bridges over the Mekong River but it is uncertain if such bridges will be of public or restricted use. Other portions of the investment will contribute to the extension of the power grid and also to new roads or the improvement of existing roads as necessary to access the projects.

An quantitative analysis of the impact of these infrastructure additions to the overall economy of the LMB countries is beyond the scope of this report as it involves many sectors of the economy including transport, commerce and industry that are outside the power sector focus. However, the direct effect of these investments in the creation of power sector specific employment will be analyzed in the next section.

7.4 GMS AND LOCAL EMPLOYMENT TRENDS RELATED TO HYDROPOWER

Because LMB projects are increasingly financed by private sector entities and banks from the GMS region, there will be GMS regional benefits related to contracts for civil construction, services and electrical and mechanical equipment. The trend is to increasingly manufacture hydropower equipment in China, and Thailand and Vietnam are major construction contractors. While the proposed LMB schemes represent over $US 24 billion, the distribution among GMS countries is difficult to estimate to the extent that international competitive bidding (ICB) may be used.

Otherwise the construction of and operation of a hydroelectric projects is labour intensive.
Approximately one half of the construction budget is in civil works of which 80% would be spent in local

labour. The other half of the budget corresponds to electrical and mechanical equipment of which there could be a small component of local labour during the installation phase. During the operation phase, approximately 85% of the budget will be labour and 70% should consist of local labour.

Figure 7.2 shows an estimate of the present value of wages during the lifetime of the project for each scenario being contemplated by MRC Basin Development Plan. These scenarios are as follows:

- 2015-DF refers to the Definite Future scenario including projects to be operational by 2015
- 2030-20Y refers to a scenario that includes projects that may be operational by 2030 and has several variations including:
  - w/o MD excludes all mainstream dams
  - w/o LMD excludes all mainstream dams except those in northern Lao PDR
  - w/o TMD excludes mainstream dams in the border between Lao and Thailand
  - w/o CMD excludes mainstream dams in Cambodia

Local labour corresponds to labour in the country where the project is located. Foreign labour may come from inside or outside the LMB countries but this distribution cannot be estimated with any degree of confidence.

Figure 7.2 – Present Value of Wages during Construction and Operation of Projects

SCENARIO	Code	LABOR DURING CONSTRUCTION (M$)				LABOR DURING OPERATION (M$)				TOTAL PROJECT LIFETIME (M$)			
		Local Laos	Local Cambodia	Local Vietnam	Foreign	Local Laos	Local Cambodia	Local Vietnam	Foreign	Local Laos	Local Cambodia	Local Vietnam	Foreign
2015-DF	3	647	1	367	1,374	132	0	75	44	780	1	442	1,418
2030-20Y	4	3,125	1,068	409	6,226	638	218	83	201	3,763	1,286	492	6,428
2030-20Y-w/o MD	5	1,517	133	409	2,786	310	27	83	90	1,827	161	492	2,876
2030-20Y-w/o LMD	6.1	2,584	133	409	4,230	527	27	83	137	3,111	161	492	4,366
2030-20Y-w/o TMD	6.2	2,611	1,068	409	5,531	533	218	83	179	3,144	1,286	492	5,710
2030-20Y-w/o CMD	6.3	3,125	133	409	4,962	638	27	83	160	3,763	161	492	5,122

In addition to direct employment there is of course the effect of low electricity tariffs and export revenue in the economy with the resulting creation of employment but this effect has not been quantified.

7.5 DISTRIBUTION OF POWER BENEFITS

7.5.1 Drivers of power benefit distribution

The regional distribution of power benefits will be considered in the next stage of the SEA. For the baseline assessment the distribution of power benefits of LMB hydropower to Thailand, Cambodia, Vietnam and Laos is based on two key assumptions that may differ considerably from project to project and could have a significant impact on how economic benefits get distributed among countries.

The first assumption is that the host country, that is, the country where the project is located, will be the project owner and therefore will have all the burden of cost including equity, debt and operating expense. The second assumption is that the importing country will pay a price equal to 85% of its domestic cost of thermal generation.

The objective of this section is to describe the different consequences of departure from the two assumptions since the viability of many projects may require very different cost sharing structures and pricing agreements between the countries interested in their development.

7.5.2 Alternative cost structures

In addition to the base case assumption it would seem reasonable that many projects may be structured as a cost sharing between the host and the importer and, very likely, this sharing will be in proportion to the quantities of energy expected to be taken by each party.

7.5.3 Alternative trade prices

The price at which export-import will take place will probably be different for each project because it depends on very specific conditions. First, it will depend on the actual cost of alternative power of the buyer which may or may not be well represented by the system wide replacement cost forecasted for Thailand or Vietnam. Second, it will depend on the actual cost of energy from the project which is, of course, different in each case. Finally, it will depend on the requirements of the lender which may ask for a specific debt coverage ratio and therefore influence the terms of any power purchase agreement.

7.5.4 Sensitivity analysis

The full sensitivity analysis will be done during the next stage of the SEA. For baseline purposes only, the effect of different cost sharing and trade price conditions upon the distribution of net economic benefits from power is illustrated in Figure 7.3. The figure shows the net economic benefit accruing to each country under different conditions of cost sharing and trade price for projects in the 20 year development scenario ending in 2030. The benefits are shown separately for tributary and mainstream projects.

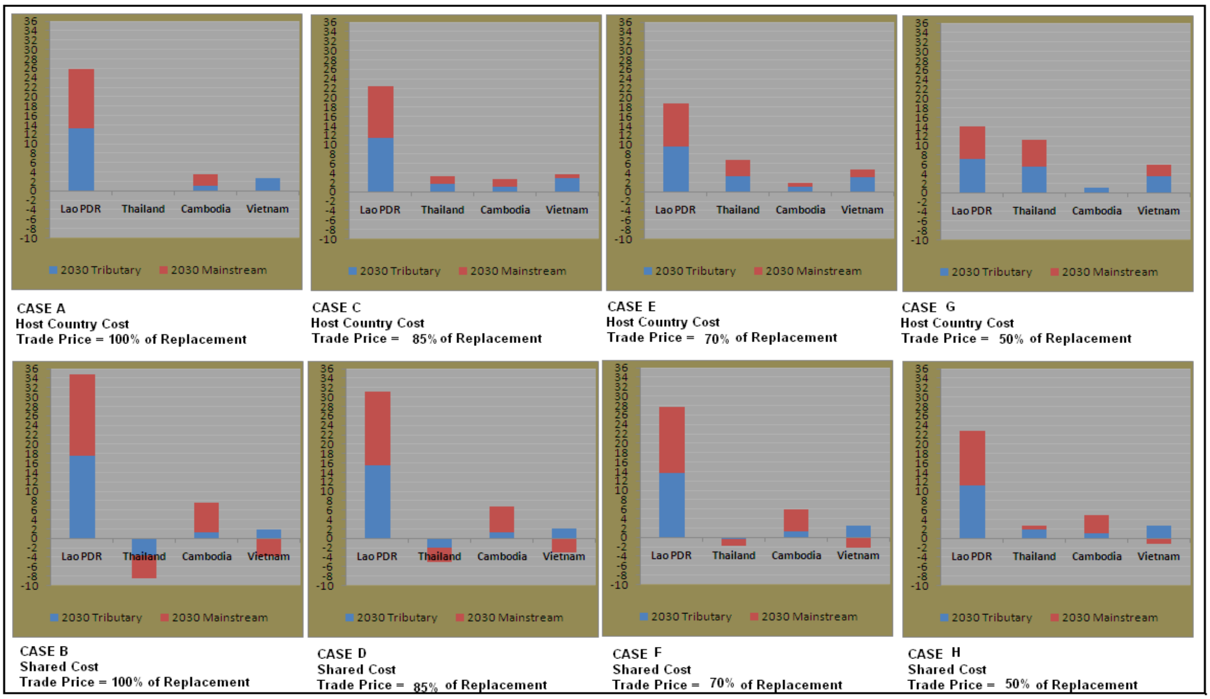
The following observations are made with reference to Figure 7.3.

Cases A and B: Very High Trade Price

Cases A and B show an extreme situation in which the trade price would be equal to the replacement cost of the importing country. Case A corresponds to the case when the host country assumes all the cost.

In Case A Thailand gets zero benefit because it does not own any portion of any project and it merely buys energy at the same cost of its thermal replacement. Vietnam will own those projects located in its territory and therefore will get the benefit of the difference between the cost of energy from such projects and the replacement cost of power. The net benefit to Laos is 26 billion US$, evenly divided between tributary and mainstream projects and the net benefit to Cambodia is 8 billion US$.

Figure 7.3 - Net Economic Benefits (in billion US$) for Different Cost Sharing and Trade Conditions



Case B shows the situation if the cost of the projects is shared. This is a hypothetical case, only shown for illustration, because neither Thailand nor Vietnam would benefit if they have to pay for producing their portion of energy and, in addition, have to pay a high price for importing it. Clearly, the exporting countries will have extremely high, albeit, not realistic, benefits.

Cases C and D: Base Case Trade Price

Case C corresponds to the base case assumptions used in Chapter 4. The host country assumes all costs and exports power at 85% of the importing country replacement cost.

It is interesting to observe Case D which shows that a trade price of 85% of domestic generation cost is too high to be attractive to Thailand or Vietnam if they have to pay for their share of the project cost.

Cases E and F: Lower Trade Price

Cases E and F are based on the assumption of a trade price equal to 70% of replacement cost. At this trade price, Cambodia finds very little benefit unless the cost is shared with the importing country but neither Thailand or Vietnam derive any benefit from importing if they have to share the cost.

Cases G and H: Very Low Trade Price

These cases correspond to the assumption of a trade price equal to half the replacement cost of power in Thailand and Vietnam. At this low price Thailand would derive benefit even if it had to pay for its share of the cost but not so Vietnam, probably due to the higher costs of the projects in which it is named as importer.

References

1. ADB, 2009, Building a Sustainable Energy Future, The Greater Mekong Subregion
2. ADB/APEC, October 2009a, Energy Outlook for Asia and the Pacific
3. ADB/APEC, October 2009b, Energy Statistics in Asia and the Pacific (1990 – 2006)
4. BP, 2009, Statistical Review of World Energy 2009, http://www.bp.com/statisticalreview, accessed January 2010
5. CIA, World Factbook, www.cia.gov/library/publications/the-world-factbook
6. Department of Energy Promotion and Development (EPD), 2010, www.poweringprogress.org/index.php?option=com_content&view=article&id=49&Itemid=53, accessed January 2010
7. Electricity Authority of Cambodia (EAC), 2008, Report on the Power Sector of The Kingdom of Cambodia for the Year 2007
8. Electricity Generation Authority of Thailand (EGAT), 2009a, Annual Report 2008
9. Electricity Generation Authority of Thailand (EGAT), May 2009b, Thailand Power Development Plan 2008 – 2021 (PDP 2007: Revision 2)
10. Energy Information Administration (EIA), tonto.eia.doe.gov/country/index.cfm
11. Integriertes Ressourcen Management (IRM-AG), February 2008, Economics of Energy Integration: Application of MESSAGE Model in the GMS
12. International Energy Agency (IEA), www.iea.org/country/index.asp
13. International Rivers Network (IRN), September 2006, Trading Away the Future, The Mekong Power Grid
14. Ministry of Energy and Mines (MEM), Electricite du Laos (EdL), March 2008, Power Development Plan (2007-2016)
15. Ministry of Energy and Mines, September 2008, Regional Consultation on MRC's Hydropower Programme, Lao PDR Powering Progress
16. Ministry of Industry, Mines and Energy (MIME), Kingdom of Cambodia, December 2006, Rural Electrification and Transmission Project & Great Mekong Subregion Power Project
17. Vietnam Union of Science and Technology Associations (VUSTA), 2007, Assessment of Vietnam Power Development Plan
18. World Bank 2009, Macroeconomic Key Indicators, East Asia Pacific Update, siteresources.worldbank.org/INTEAPHALFYEARLYUPDATE/Resources/550192-1207007015255/EAPUpdate_keyindicators.pdf
19. Zhai, Y, ADB, September 2008, GMS Regional Electricity Market and Hydropower Development, Regional Consultation on MRC Hydropower Programme