Mekong River Commission
P.O. Box 6101, Vientiane, Lao PDR.
Tel: (856) 21 263 263
Fax: (856) 21 263 264
Email: mrcs@mrcmekong.org

BASIN DEVELOPMENT PLAN PROGRAMME, PHASE 2

HYDROPOWER SECTOR REVIEW FOR THE JOINT BASIN PLANNING PROCESS

February 2009

Abbreviations, symbols and acronyms

$	United States Dollar
BCR	Benefit Cost Ratio
BDP	Basin Development Programme
BDP 2	Basin Development Programme - Phase 2
CTS	US Dollar Cents
GWH	Gigawatt-hour = 1000 MWH
IRR	Internal Rate of Return
IWRM	Integrated Water Resources Management
JICA	Japan International Cooperation Agency
KW	Kilowatt
KWH	Kilowatt-hour
LMB	Lower Mekong Basin
MCM	Million Cubic Meters
MRC	Mekong River Commission
MW	Megawatt = 1000 KW
MWh	Megawatt-hour = 1000 KWH
M$	Million US Dollars
PNPCA	Procedures for Notification and Prior Consultation
PPA	Power Purchase Agreement
RCT	Rule Curve Tool
TWH	Terawatt-hour = 1000 GWH
UN	United Nations
URF	Upper Rule Factor

EXECUTIVE SUMMARY

Introduction

The Basin Development Plan Phase 2 (BDP2) is designed to provide an integrated basin perspective through the participatory development of a rolling Integrated Water Resources Management (IWRM) based Basin Development Plan. The plan comprises:

- ***Basin-wide Development Scenarios***, which will provide the information that Governments and other stakeholders need to develop a common understanding of the most acceptable balance between resource development and resource protection in the various parts of the LMB. The results will guide the formulation of the IWRM-based Basin Strategy.

- ***An IWRM-based Basin Development Strategy***, which provides a shared vision and strategy of how the water and related resources in the LMB could be developed in a sustainable manner for economic growth and poverty reduction, and a coherent and consistent IWRM planning framework that brings basin perspectives into the national planning. The results will guide the formulation of the Project Portfolio.

- ***A Project Portfolio*** of significant water resources development projects and supporting non-structural projects that would require either promotion or strengthened governance, as envisioned in the 1995 Mekong Agreement.

The preparation of the Plan will bring all existing, planned and potential water and related resources development projects in a joint basin planning process, through a combination of sub-basin and sector activities, and a basin-wide integrated assessment framework. This offers an integrative platform for the Mekong River Commission (MRC) to engage in transboundary assessment and multi-stakeholder consultation to facilitate a broad and informed dialogue on sustainable water resources development and management.

As an input to the hydropower aspects of the IWRM-based Basin Development Plan, several activities were carried out by a team comprising staff of the Mekong River Commission Secretariat (MRCS), National Mekong Committees (NMCs), national sector specialists in Lao PDR, Cambodia, Vietnam and Thailand, and one international hydropower expert. The activities and key results are described in the report.

Hydropower Database

A database was prepared to organize data on existing, planned and potential hydropower projects in the Mekong River Basin portion of Lao PDR, Cambodia, Vietnam and Thailand. The information on projects is of two types. The first type consists of some 60 major data items organized into the following headings: General Data, Operation Data, Characteristics Data, Hydrology Data, Cost & Market Data, and Impacts. These data are available for 135 projects currently in the database.

The second type corresponds to more detailed data, including specific reservoir characteristics, generation equipment characteristics, hydraulic characteristics, and flow records. A template for organization of this data is included in the database, but this has not yet been populated for all projects.

In addition, the database contains key data on the likely replacement cost of power in the power sectors of the four countries. This "value of power" is used in combination with project data on power production, cost, and target market to automatically calculate power benefits and a benefit/cost ratio for each project. Thus the database can be used for a cursory analysis of the economic performance of the projects from a regional economic perspective.

A comprehensive manual was prepared as a reference for the future maintenance and expansion of the database. The manual provides definitions and guidelines for every data item and offers a short course on hydropower evaluation.

Reservoir Rule Curve Tool

The formulation and assessment of basin-wide development scenarios requires information on the likely operation of hydropower reservoirs. This information consists of monthly maximum and minimum limits to the reservoir elevation and there is a provision for such data in the database. However, very often this information is not available in the feasibility reports of the projects. Moreover, such operational guidelines are bound to change as upstream projects modify the flow regime. In addition, in the assessment of scenarios it is important to estimate the likely operation of hydropower reservoirs on the Lancang in China, which are not included in the database.

To assist the modeling of reservoirs, a tool was developed to generate reservoir guidelines in those cases where such information is not available from the project. The tool was used to develop reservoir operation guidelines for the existing and planned dams on the Lancang in China.

Comparative Analysis of Hydroelectric Projects

The large sample of projects in the database offers the opportunity to examine the statistical characteristics of different cost indicators, such as the cost per unit of capacity and the cost per unit of mean annual energy. The results are compared against certain cost drivers, such as the scale of the project and the capacity factor of the projects.

It was observed that for projects under 100 MW (Megawatt) the unit capacity cost is between 2 M$/MW (million US dollars per Megawatt) and 3.5 M$/MW, while most projects above 100 MW have unit costs around 1,5 M$/MW. The majority of projects have capacity factors in the 0.40 to 0.60 range, resulting in energy costs of 50 to 60 $/MWh (US dollars per Megawatt-hour) for projects under 100 MW and 40 $/MWh for projects over 100 MW.

The national hydro development plans correlate reasonably well with the calculated energy costs. The average energy cost of projects not yet under operation or construction is 55 $/MWh. Most projects before 2015 showing lower than average cost and most projects beyond 2015 showing higher than average cost.

Mekong Hydropower in the Regional Power Context

The economic value of hydropower is very different between the producing countries (Lao PDR and Cambodia) and the large power systems of Vietnam and Thailand. These large systems have several large-scale thermal generation options, including coal fired steam technology, gas fired combined cycle technology, and nuclear power. These large-scale thermal generation options can offer, on average, thermal energy costs of the order of 70 $/MWh. Large-scale thermal options are not practical or economic for the scale of demands in Lao PDR and Cambodia which, in the absence of hydropower, would depend on oil fired thermal technologies that have costs in the order of 200 to 300 $/MWh.

The economic benefit of projects is therefore very sensitive to where the power is targeted. The economic benefit is much lower for predominantly export projects than for predominantly domestic consumption projects. However, since this differential value of power is poorly represented by tariffs, having high economic performance does not mean that a project is easier to finance. Indeed, it is likely that the easiest projects to finance are those with high exports and hence low regional economic value. It is therefore relevant to explore how critical hydropower from the Mekong Basin is to the export markets of Vietnam and Thailand.

It is of course difficult to anticipate the impact of the current global financial crisis on the long term regional economic growth. If this impact can be ignored in the longer term, then by 2020 the electricity demand of Vietnam and Thailand will dwarf the hydropower potential of the Lower Mekong Basin. The annual energy potential of all the hydropower projects in the Lower Mekong Basin that are not yet under operation or under construction will probably not exceed 12% of the combined electricity demand of Vietnam and Thailand in 2020. With an average energy cost of new Mekong hydro power of 55 $/MWh, and average replacement value of that power in these markets of 70 $/MWh, the margin is only 15 $/MWh. That means about 21% potential cost savings on 12% of the power supply, or only a 2.6% overall saving in power supply cost.

Of course, on a case by case basis many projects will be more attractive than depicted by these average numbers. But the point is that the regional economics of hydropower development does not suggest a forecast of hydropower development of all sites. The prospect of delays, or environmental mitigation costs in controversial projects, could easily postpone the development of many projects until the value of alternative power is significantly higher than today.

As a final point, a reflection is made on the extent of hydropower export revenue that would effectively impact the economies of Lao PDR and Cambodia. It would appear that large export projects will largely be financed by exports. Furthermore, the export price that the importer (Thai and Vietnamese markets) can bear will be, on average, only marginally higher than the hydropower energy cost. It is therefore expected that only a small part of export revenue will actually impact the exporting country economy. The benefit for the exporting country will mostly be derived from the portion of the project energy that is targeted for domestic consumption.

It is nevertheless recognized that in South East Asia, as in other parts of the world, large export oriented projects offer feasibility of hydropower development that may not exist for smaller projects targeted solely for domestic consumption.

1 INTRODUCTION

1.1 Basin Development Planning

While millions of poor people exploit the natural resources of the Mekong Basin for their food security and livelihoods, water infrastructure development is limited compared with most other large river basins in the world. The most downstream part of the Mekong Basin, the Vietnamese Delta, is by far the largest water-using area in the Basin.

Currently, water resources development is being accelerated, in particular for the generation of hydro-electric power, driven by markets and the private sector. A range of factors is driving this development:

- ***At the global level***, high oil and natural gas prices make hydropower development financially more attractive, and rises in food prices make irrigation more profitable. In addition, global climate changes may affect water demand and availability in the Mekong basin.

- ***At the basin level,*** increases in the population, the economy and trade are resulting in greater demands for energy and water related commodities and services. Also, the financial attractiveness of run-of-river dams in the mainstream in the LMB is further enhanced by the large storage dams that are being constructed in the Upper Mekong Basin.

- ***At the national level***, the Governments increasingly recognize that developing some of the economic potential of the water resources in the Mekong Basin for hydropower, navigation, irrigation, and flood management can contribute to increasing economic growth, alleviating poverty, improving livelihoods, and meeting the UN Millennium Development Goals.

Given the above described situation, there has been an increasing pressure from the basin countries and project developers for provision of an integrated basin perspective against which national plans and proposed projects can be assessed to ensure an optimal balance between economic, environmental, and social outcomes in the Lower Mekong Basin (LMB), and mutual benefits to the LMB countries.

The development of such a basin perspective is beyond the responsibility of any individual country or project developer. For example, a developer of a particular mainstream dam in the LMB cannot assess the impact of the dam on the basin’s capture fisheries, since the impact typically depends on other possible developments, such as a downstream dam.

MRC’s Basin Development Plan Phase 2 (BDP2) is designed to provide such an integrated basin perspective through the participatory development of a rolling Integrated Water Resources Management (IWRM) based Basin Development Plan. The plan comprises:

- ***Basin-wide Water Resources Development Scenarios***, which will provide the information that Governments and other stakeholders need to develop a common understanding of the most acceptable balance between resource development and resource protection in the various parts of the LMB. Each considered scenario represents a specific balance (trade-off) between economic, social and environmental objectives. The results will guide the formulation of the IWRM-based Basin Strategy.

- ***An IWRM-based Basin Strategy***, which provides a shared vision and strategy of how the water and related resources in the LMB could be developed in a sustainable manner for economic growth and poverty reduction, and a coherent and consistent IWRM planning framework that brings basin perspectives into the national planning process, and vice versa, amongst others through MRC's sector programmes and BDP2's sub-area activities. The results will guide the formulation of the Project Portfolio.

- ***A Project Portfolio*** of significant water resources development projects and supporting non-structural projects that would require either promotion or strengthened governance, as envisioned in the 1995 Mekong Agreement.

The preparation of the Plan will bring all existing and planned water and related resources development projects in a joint basin planning process, through a combination of participatory sub-basin and sector activities and a basin-wide integrated assessment framework. The formulation of the Plan will employ appropriate knowledge and tools that will ensure the plan achieves benefits for all countries and the projects comply with sound environmental and socioeconomic principles.

This offers an integrative platform for the MRC to engage in transboundary assessment and multi-stakeholder consultation to facilitate a broad and informed dialogue on sustainable water resources development and management.

1.2 Scope of Hydropower Sector Review

A large knowledge base on the basin's water and related resources is available at regional, national and local level in the Mekong Basin. The BDP1 (2001-2006) has defined nine water related sectors (see text box) and ten sub-areas in the LMB, and it established a participatory planning process and prepared sector reviews and sub-area studies. The BDP2 built on these achievements to address the remaining gaps in the sector knowledge base for basin planning.

The BDP2 has engaged the MRC sector programmes to address the identified knowledge gaps. For example, the FP in collaboration with World Fish modeled the barrier effect of dams on migratory fish production. The EP improved its information regarding the wetlands in the Mekong Basin, and revitalized its Social Impact Monitoring (SIM) and Vulnerability Assessment (VA) activities. The FMMP prepares flood risk reduction strategies for the BDP sub-areas and identifies significant flood management projects.

Since the MRC did not have operational programmes in the hydropower and irrigation sectors during the last several years, its knowledge gap was relatively large in these two sectors. Therefore, the BDP2 has been working with national sector specialists since the beginning of 2008 to improve existing hydropower and irrigation databases and produce the required sector information for basin planning[1].

The hydropower sector database consolidates data and information of almost 150 significant existing, planned and potential hydropower projects. The data include the project's characteristics, operation data, cost data and power market data.

The database has been used to support the formulation and assessment of basin-wide development scenarios, in particular the development of reservoir operation rule curves, the economic screening of all mainstream and tributary hydropower projects, and a regional assessment of the potential and constraints of hydropower development.

BDP Development Sectors

- Irrigated agriculture
- Watershed management
- Fisheries
- Hydropower
- Navigation, transport, river works
- Tourism and recreation (water-related)
- Water supplies (domestic and industrial uses)
- Flood control and flood management
- Environment, including water demand of ecosystems

Currently, the database is being used to support the implementation of the various activities under the new MRC Sustainable Hydropower Initiative. The database and associated applications will also support the improved implementation of the water utilization procedures, in particular the Procedures for Notification, Prior Consultation and Agreement (PNPCA) and the MRC Internal procedures for implementation of the PNPCA (November 2005).

1.3 Review Team

The Hydropower Sector Review project is under the direction of the following team from MRC Secretariat:

- Ms Pham Thanh Hang - BDP Programme Coordinator
- Mr Ton Lennaerts - BDP Chief Technical Advisor
- Dr Thanapon Piman - BDP Senior Modeling Specialist

This team directed and supervised the activities of the following consultant team:

- Mr Carlos Yermoli - International Hydropower Consultant.
- Dr Narith Bun - National Consultant – Cambodia.
- Mr Chansaveng Buongnong - National Consultant – Lao PDR.
- Mr Nguyen Huy Hoach - National Consultant – Vietnam.
- Ms Kanikan Patomnuphong - National Consultant – Thailand.

1.4 Key Activities Completed

Several activities have been completed by MRC towards this goal including:

- A hydropower database and associated user manual.
- A tool for predicting the likely operation of hydropower reservoirs.
- An analysis of the relative economic performance of existing and planned projects.
- A review of the electricity sector of the LMB countries.

2 HYDROPOWER DATABASE

2.1 Objective of the Database

The Hydropower Database has three primary objectives:

1) To provide input for the formulation and assessment of basin-wide scenarios for the IWRM-based Basin Development Plan

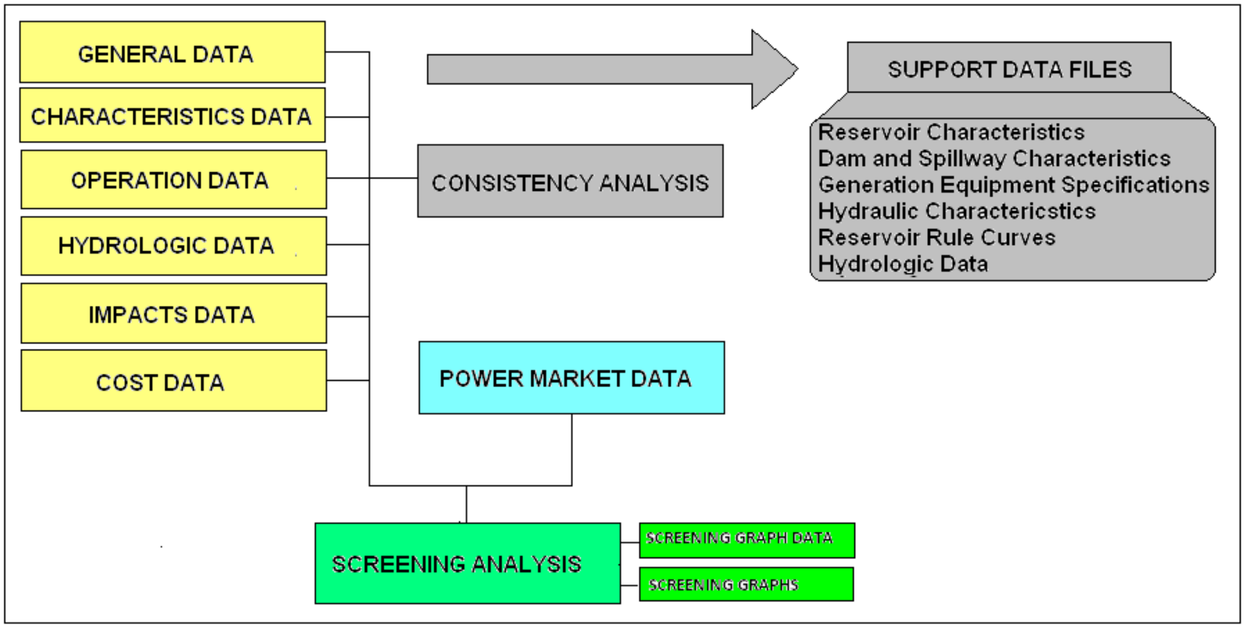
2) To facilitate the Procedures for notification, prior consultation and agreement (PNPCA) and the MRC Internal procedures for implementation of the PNPCA (November 2005)

3) To support the MRC Hydropower initiative with a view to promote the most sustainable options for water resources development in the LMB

2.2 Structure

The database consists of a file in Excel workbook format and an associated manual for its use. The structure of the Excel file is illustrated in Figure 2.1.

Figure 2.1 - Database Structure



The workbook contains several sheets as follows:

- 6 Project Data sheets.
- 1 Power Market Data sheet.
- 3 Screening Analysis sheets.
- 1 Consistency Analysis sheet.
- 1 Support Data Template sheet.

2.3 Project Data

The Project Data sheets contain project specific information arranged in one line per project. There are some 60 data items for each project and each sheet corresponds to a category of data as illustrated in Figure 2.2

Each data item is defined and discussed in the User Manual, units of measurement are specified and codes are established for certain data items. For example there are several codes for Condition, Purpose, Dam Type and Spillway Type.

The last of these Project Data sheets, the Impact Scorecard is a little different in character. Only one item in this sheet refers to actual data, the number of people that need to be resettled on account of the project. The rest are qualitative statements of the level of different impacts from a simple scale of -3 to +3; -3 being a very negative impact, 0 being neutral and +3 being a very positive impact.

The purpose of this sheet is to attempt a rough assessment of the relative social and environmental impact of projects but this is certainly not to be construed as a complete or even basic understanding of these impacts. That would require a completely different type of approach probably with its own specific database for each type of impact. Nevertheless, the Impact Scorecard will be used in the preparation of the Project Portfolio as a preliminary basis for establishing areas that need more detailed evaluation in coordination with all sectors for which impacts are being noted.

Figure 2.2 - Project Data Sheets

GENERAL DATA	OPERATION DATA	CHARACTERISTICS DATA
Project Identification Code	Rated Head	Dam / Type
Project Name	Plant Design Discharge	Dam / Length
Location / River	Installed Capacity	Dam / Height
Location / Province & District	Peaking Capability	Spillway / Sill Elevation
Location / Latitude & Longitude	mean Annual Energy	Spillway / Design Head
Commissioning Year	Firm Annual Energy	Spillway / Design Discharge
Condition	Full SupplyLevel	Spillway / Type
Purpose	Low Supply level	Bottom Outlet / Invert Elevation
National Priority Ranking	Live Storage	Bottom Outlet / Design Discharge
Availability of Layout Plans		
Identification of Data Sources		

HYDROLOGY DATA	COST & MARKET DATA	IMPACT SCORECARD
Catchment Area	Construction Period	Re-regulation Storage
Flow Record Period	Reference Year for Budget	Number of Persons Resettled
Mean Flow	reference Project Budget	Hourly Flow Regime Disruption
Ecological Flow / base	Grid Expansion Cost	Seasonal Flow Regime Disruption
Ecological Flow / By-Pass	Taxes	Ecosystem Disruption
Project Design Flood / Criterion	Interest During Construction	Micro Climate Modification
Project Design Flood / Peak Flow	Social & Environmental Mitigation	Resettlement Impact
Annual Sediment Load	Development Cost	Tourism Potential
	Destination of Power	Flood Control Potential
		Navigation Impact
		Job Creation Impact
		Water Supply

2.4 Economic & Power Market Data

One immediate application of the database was a comparison of the relative economic performance of projects, a subject that will be discussed in more detail later in this report. The economic performance of a project is a function of both, the project and the market where the project will deliver its power output. The Power Market Data sheet contains both data and calculations resulting in the value of power in each market.

The structure of this sheet is illustrated in Figure 2.3 and consists of three sections of data and calculations. The first section refers to data that is common to all markets. The second section refers to data that is specific to each market and used for the calculation of fixed and variable costs of alternative generation. The third section, not shown in Figure 2.3, uses these fixed and variable costs to define the reference value of capacity and energy.

Common Economic Data

These data items are parameters that will be used in the economic analysis but are not specific to any country, including:

- Current Year. The year used as a reference price level for all costs and benefits.
- Discount Rate. The cost of capital to be used in the calculation of capital recover factor and the interest during construction and reflects the time value of money.
- Construction Cost Inflation. The annual rate of inflation to be applied to construction cost estimates expressed in US$ dollars.
- Development Cost. Percent of the costs incurred in developing the project other than for engineering, procurement and construction. These include negotiation, permitting, contract preparation, investor due diligence, lender due diligence and financial analysis.
- Reference Power Trade Price. Reference regional average power trade value. This should be a weighted average of the terms in all international Power Purchase Agreements (PPA) but a reasonable proxy is the avoided cost of power at the load factor of importing countries.
- Reference Peak Period Duration. The weekly number of hours of peak power demand is a key parameter to define the value of hydropower to system reliability. This is truly a system specific value but it can be approximated by a regional value.

Power Market Data

This section contains data to first define the thermal reference which is the thermal generation technology that will most likely be used if hydropower is not available and then calculate its fixed and variable costs. This involves a fair amount of information, including:

- Construction cost and duration and economic life of each thermal reference.
- Fixed operation and maintenance costs.
- Type, price and energy content of fuel.
- Fuel consumption.

Variable operation and maintenance costs are shown in Figure 2.3

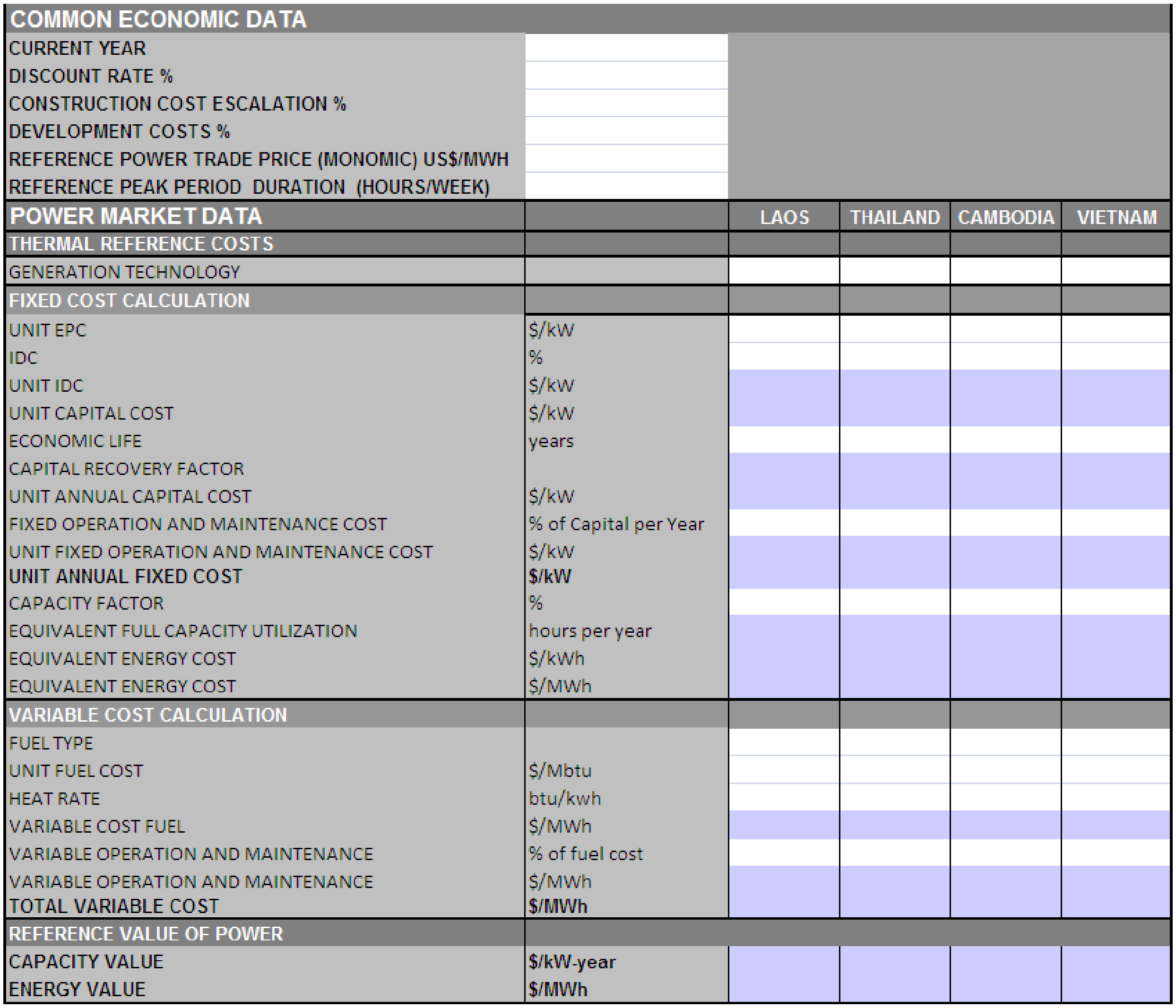
Power Value

The third section uses the fixed and variable costs of the thermal reference to calculate the value of capacity and energy in each market. Since separate values for capacity and energy make it more difficult to compare the value of power, a table is also provided in the datasheet (not shown in Figure 2.3) indicating the monomic (i.e. one-part) value of power for different load factors.

The load factor is a characteristic of electricity demand consisting of the ratio between average load (representative of energy demand) and peak load (representative of capacity demand). Therefore the load factor can be used to "spread" the value of capacity over the energy demand. This spread value of capacity added to the value of energy results in the monomic value of power.

Using the load factors of the importing countries (Thailand and Vietnam) the average value of power for these countries is used as a proxy to determine the Reference Power Trade Price discussed above. The use of this parameter will be discussed in the last chapters of this report.

Figure 2.3 - Economic & Power Market Data



COMMON ECONOMIC DATA					
CURRENT YEAR					
DISCOUNT RATE %					
CONSTRUCTION COST ESCALATION %					
DEVELOPMENT COSTS %					
REFERENCE POWER TRADE PRICE (MONOMIC) US$/MWH					
REFERENCE PEAK PERIOD DURATION (HOURS/WEEK)					
POWER MARKET DATA		LAOS	THAILAND	CAMBODIA	VIETNAM
THERMAL REFERENCE COSTS					
GENERATION TECHNOLOGY					
FIXED COST CALCULATION					
UNIT EPC	$/kW				
IDC	%				
UNIT IDC	$/kW				
UNIT CAPITAL COST	$/kW				
ECONOMIC LIFE	years				
CAPITAL RECOVERY FACTOR					
UNIT ANNUAL CAPITAL COST	$/kW				
FIXED OPERATION AND MAINTENANCE COST	% of Capital per Year				
UNIT FIXED OPERATION AND MAINTENANCE COST	$/kW				
UNIT ANNUAL FIXED COST	**$/kW**				
CAPACITY FACTOR	%				
EQUIVALENT FULL CAPACITY UTILIZATION	hours per year				
EQUIVALENT ENERGY COST	$/kWh				
EQUIVALENT ENERGY COST	$/MWh				
VARIABLE COST CALCULATION					
FUEL TYPE					
UNIT FUEL COST	$/Mbtu				
HEAT RATE	btu/kwh				
VARIABLE COST FUEL	$/MWh				
VARIABLE OPERATION AND MAINTENANCE	% of fuel cost				
VARIABLE OPERATION AND MAINTENANCE	$/MWh				
TOTAL VARIABLE COST	**$/MWh**				
REFERENCE VALUE OF POWER					
CAPACITY VALUE	**$/kW-year**				
ENERGY VALUE	**$/MWh**				

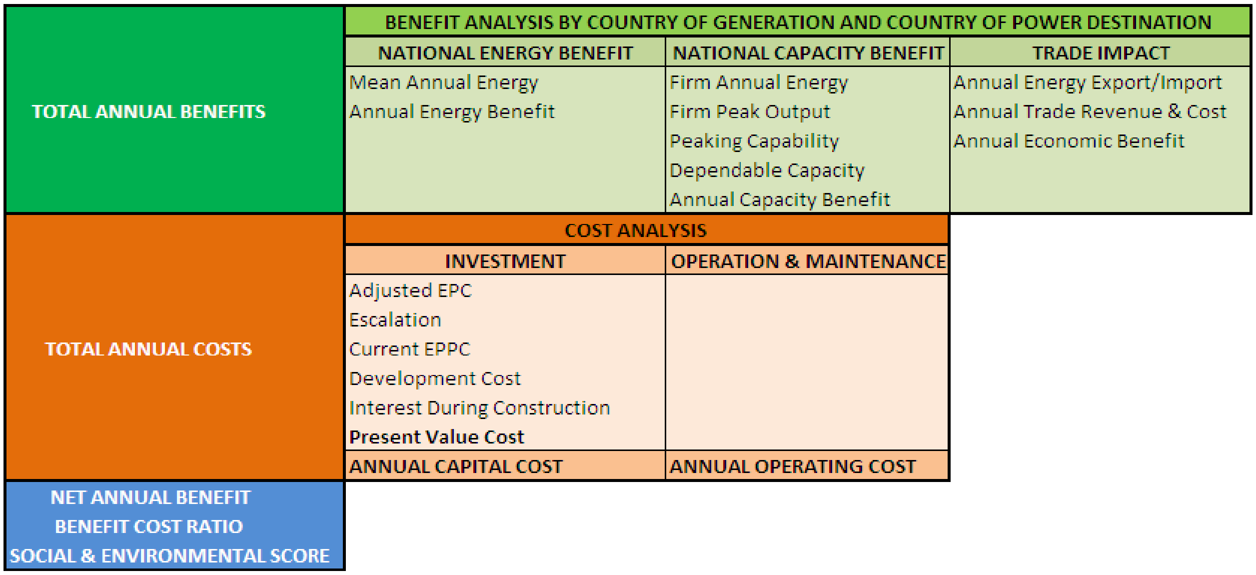
2.5 Screening Analysis

Economic Performance and Other Impacts

The database has a built-in application to evaluate the relative economic performance of the hydropower projects in what is called a Screening Analysis. The intent of this analysis is that the economic merits of the projects not yet developed or under advanced development should serve as an indicator of the order in which they should be developed from a regional perspective. As will be shown and discussed later this differs from the national perspective because the first is based on economics and the second on commercial considerations.

The analysis carried out in this sheet is illustrated in Figure 2.4 and consists of three components that will be described in detail in Chapter 4 together with the results obtained for the projects in the database below.

Figure 2.4 - Screening Analysis



	BENEFIT ANALYSIS BY COUNTRY OF GENERATION AND COUNTRY OF POWER DESTINATION		
	NATIONAL ENERGY BENEFIT	**NATIONAL CAPACITY BENEFIT**	**TRADE IMPACT**
TOTAL ANNUAL BENEFITS	Mean Annual Energy Annual Energy Benefit	Firm Annual Energy Firm Peak Output Peaking Capability Dependable Capacity Annual Capacity Benefit	Annual Energy Export/Import Annual Trade Revenue & Cost Annual Economic Benefit
	COST ANALYSIS		
	INVESTMENT	**OPERATION & MAINTENANCE**	
TOTAL ANNUAL COSTS	Adjusted EPC Escalation Current EPPC Development Cost Interest During Construction **Present Value Cost**		
	ANNUAL CAPITAL COST	**ANNUAL OPERATING COST**	
NET ANNUAL BENEFIT **BENEFIT COST RATIO** **SOCIAL & ENVIRONMENTAL SCORE**			

The primary indicator is the Benefit Cost Ratio which is the ratio of total annual benefits to total annual costs. This is shown side by side with the consolidated score of the social and environmental scorecard discussed in section 2.3 above.

Graphic Presentation of Results

Built into the screening analysis are also several graphs to show relevant information such as the following:

- Relative merits of the projects
- Correlation between project scale, capacity cost, energy cost and economic performance
- Correlation between capacity factor and project performance

2.6 Data Quality and Consistency Analysis

The quality of data in any database is without doubt a major concern. The data in the hydropower database is extracted from many different sources and the primary responsibility for quality has been with the national teams in charge of collecting it. A complete validation of all data would require a verification against values contained in the latest studies prepared for each project. Just the six project sheets of the database, without the detailed support data sheet, contain some 9,000 individual pieces of data. Therefore, even if all reports for such studies were available in a central location and all data was easily found in the reports, it would take several months of effort if the international consultant had to verify each item.

It was necessary to rely on each national team for the acquisition of data from such reports and, for much of the data, there is no way to guarantee its accuracy. However, for critical power production data used to calculate economic benefits there is a way to test internal consistency and a Consistency Analysis sheet has been included for this purpose.

The sheet draws data from the Operation Data and Hydrology Data sheets to perform a number of simple tests assigning a score of 0 (consistent) or 1 (suspected inconsistent). The scores of all tests are then added to indicate the number of possible inconsistencies that need to be resolved. The goal is to achieve a score of zero indicating that all inconsistencies have been resolved. The tests include:

- Plant Efficiency Test. This test calculates the plant efficiency that is implied by the data on design flow, rated head and installed capacity. If that efficiency exceeds a reasonable value the test fails.

- Mean Energy Test. It is not possible to independently validate mean energy production because a great many different variables intervene in its calculation. However, there is a theoretical limit which is the energy that would be produced if all the water available could be utilized as if the plant had infinite storage capacity. If the mean energy reported is greater than this value the test fails.

- Capacity Factor Test. The capacity factor is simply the ratio between mean output and installed capacity and therefore measures the extent of utilization of available installed capacity. The test fails if this utilization is higher than 100 percent.

- Peaking Capability Test. The peaking capability of the plant is the maximum instantaneous output that the plant can guarantee with the minimum head expected at the time of maximum system demand. The test fails if this value is greater than the installed capacity.

- Firm Energy Test. The test fails if the firm energy reported is greater than the mean energy of the project.

2.7 Support Data Template

The database has been designed as a repository of key data for a large number of hydroelectric projects in a way that can be rapidly accessed, compared and analyzed for all of them. However, the detailed analysis of any individual hydroelectric project involves far more detailed information that cannot be placed in the simple format of one line per project as in the Project Data sheets. This information is usually found in the feasibility studies of each project and includes series of monthly or daily flows at the site, details of turbine efficiency at different combinations of head, reservoir storage tables, tailwater tables, head loss tables and reservoir rule curves.

As a guideline for a more extended effort than is possible within the initial time allocated for development of the database, a template is provided in the database so that all these support data can be collected and organized in a uniform way for all projects. This template is shown in Figure 2.6.

2.8 Database User Manual

A comprehensive User Manual for the database has been prepared. The main purpose of the manual is to eliminate, in the data gathering process, differences of interpretation which are not unusual even among experts in the field. The manual contains illustrations, formulas, calculation procedures and any other material that can assist the user in placing the correct value for each data item.

The manual also provides a step by step description of the screening analysis process which, together with the detailed explanation of the Power Market Data sheet, can be construed as a short course on hydroelectric project economic evaluation.

3 RESERVOIR RULE CURVE TOOL

3.1 Objective of the Tool

In section 2.7 of this report a Support Data Template Sheet was described as part of the hydropower database. That template, illustrated in Figure 2.7 has provisions for information on the elevation-storage-area relationship for the reservoir and also for "rule curve" information. As it will be described in more detail below such rule curves provide information about the way in which a reservoir will be operated.

However, unless a projects is in operation or the final stages of development it is unusual to find rule curve information in the studies. This is mostly the case even if such rules had been developed as part of the power production analysis for the project.

For the purposes of assessing the impact of hydroelectric reservoir it is important to know how they are or will be operated and therefore a tool was developed to prepare reasonable rule curves with only a minimum of information from each project. The tool was put to use in the forecast of the operation of a cascade of reservoirs in the Lancang river in China.

3.2 Fundamentals of Hydroelectric Reservoir Operation

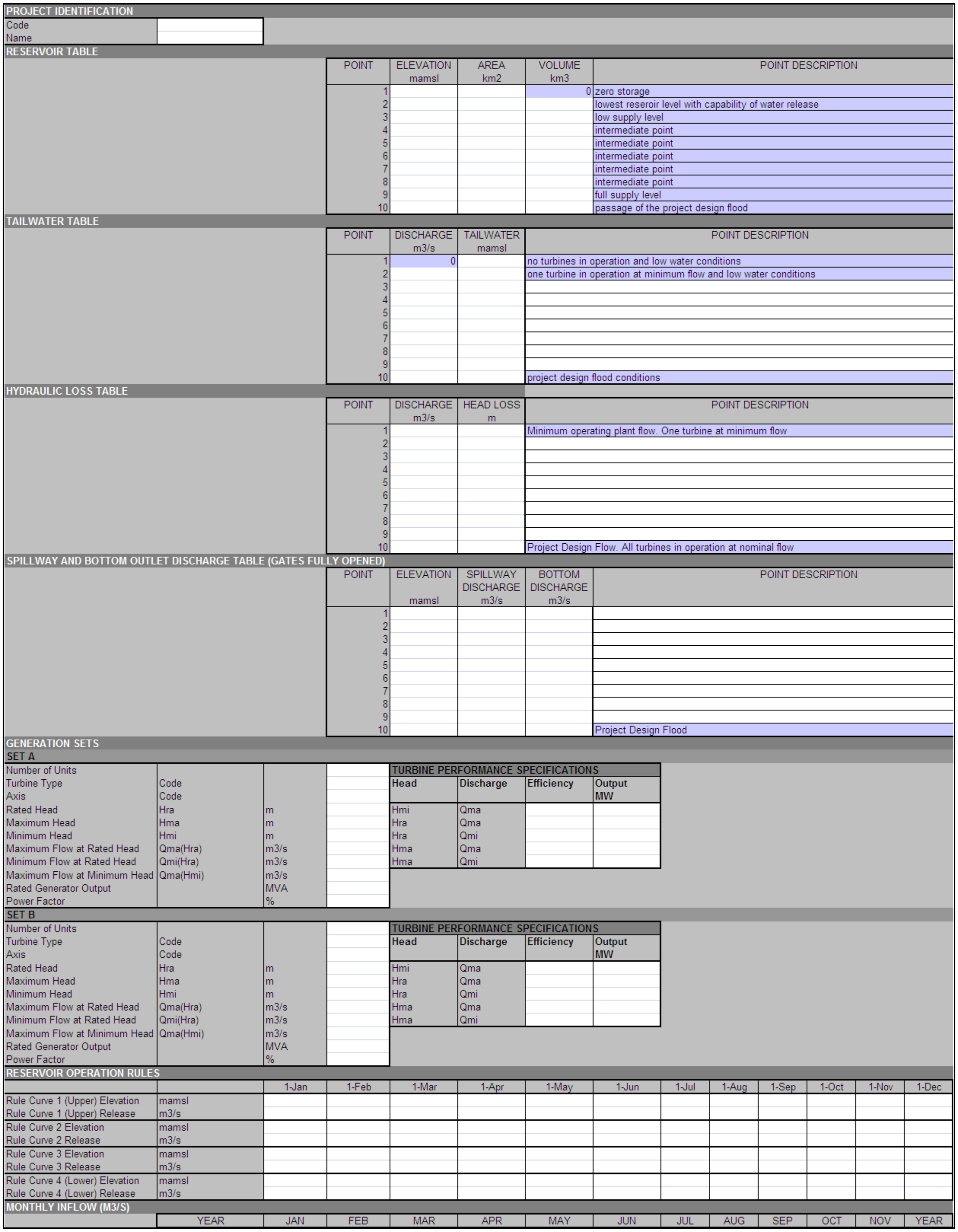
Reservoir Operation Objectives

The operation of a large hydroelectric reservoir is very often subject to a number of non-power constraints derived from the use of the reservoir for irrigation, flood control and other purposes. However, even if used solely for power the operational rules can be fairly complex since they must strike a compromise among the following conflicting objectives:

1) Maintain the reservoir as high as possible to maximize the energy produced by the water released through the turbines.
2) Avoid running the reservoir dry before the end of the dry season.
3) Minimize the risk of spill due to reservoir being full before the end of the wet season.
4) Minimize evaporation from the reservoir surface.

These objectives are the most immediate and are meant to maximize the total annual energy produced by the plant. There can be other more complex objective functions to maximize such as maximizing the total value of the hydroelectric project which involves considerations of firm energy or peaking capability but these cannot be analyzed without referring to specific contractual terms between the hydroelectric plant and its client. Without knowledge of specific terms it is reasonable to assume that the hydroelectric reservoir will be operated to maximize energy production.

Figure 2.6 - Support Data Template



PROJECT IDENTIFICATION

Code	
Name	

RESERVOIR TABLE

POINT	ELEVATION mamsl	AREA km2	VOLUME km3	POINT DESCRIPTION
1			0	zero storage
2				lowest reseroir level with capability of water release
3				low supply level
4				intermediate point
5				intermediate point
6				intermediate point
7				intermediate point
8				intermediate point
9				full supply level
10				passage of the project design flood

TAILWATER TABLE

POINT	DISCHARGE m3/s	TAILWATER mamsl	POINT DESCRIPTION
1	0		no turbines in operation and low water conditions
2			one turbine in operation at minimum flow and low water conditions
3			
4			
5			
6			
7			
8			
9			
10			project design flood conditions

HYDRAULIC LOSS TABLE

POINT	DISCHARGE m3/s	HEAD LOSS m	POINT DESCRIPTION
1			Minimum operating plant flow. One turbine at minimum flow
2			
3			
4			
5			
6			
7			
8			
9			
10			Project Design Flow. All turbines in operation at nominal flow

SPILLWAY AND BOTTOM OUTLET DISCHARGE TABLE (GATES FULLY OPENED)

POINT	ELEVATION mamsl	SPILLWAY DISCHARGE m3/s	BOTTOM DISCHARGE m3/s	POINT DESCRIPTION
1				
2				
3				
4				
5				
6				
7				
8				
9				
10				Project Design Flood

GENERATION SETS

SET A

Number of Units			
Turbine Type	Code		
Axis	Code		
Rated Head	Hra	m	
Maximum Head	Hma	m	
Minimum Head	Hmi	m	
Maximum Flow at Rated Head	Qma(Hra)	m3/s	
Minimum Flow at Rated Head	Qmi(Hra)	m3/s	
Maximum Flow at Minimum Head	Qma(Hmi)	m3/s	
Rated Generator Output		MVA	
Power Factor		%	

TURBINE PERFORMANCE SPECIFICATIONS

Head	Discharge	Efficiency	Output MW
Hmi	Qma		
Hra	Qma		
Hra	Qmi		
Hma	Qma		
Hma	Qmi		

SET B

Number of Units			
Turbine Type	Code		
Axis	Code		
Rated Head	Hra	m	
Maximum Head	Hma	m	
Minimum Head	Hmi	m	
Maximum Flow at Rated Head	Qma(Hra)	m3/s	
Minimum Flow at Rated Head	Qmi(Hra)	m3/s	
Maximum Flow at Minimum Head	Qma(Hmi)	m3/s	
Rated Generator Output		MVA	
Power Factor		%	

TURBINE PERFORMANCE SPECIFICATIONS

Head	Discharge	Efficiency	Output MW
Hmi	Qma		
Hra	Qma		
Hra	Qmi		
Hma	Qma		
Hma	Qmi		

RESERVOIR OPERATION RULES

		1-Jan	1-Feb	1-Mar	1-Apr	1-May	1-Jun	1-Jul	1-Aug	1-Sep	1-Oct	1-Nov	1-Dec
Rule Curve 1 (Upper) Elevation	mamsl												
Rule Curve 1 (Upper) Release	m3/s												
Rule Curve 2 Elevation	mamsl												
Rule Curve 2 Release	m3/s												
Rule Curve 3 Elevation	mamsl												
Rule Curve 3 Release	m3/s												
Rule Curve 4 (Lower) Elevation	mamsl												
Rule Curve 4 (Lower) Release	m3/s												

MONTHLY INFLOW (M3/S)

	YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	YEAR

Reservoir Rule Curves

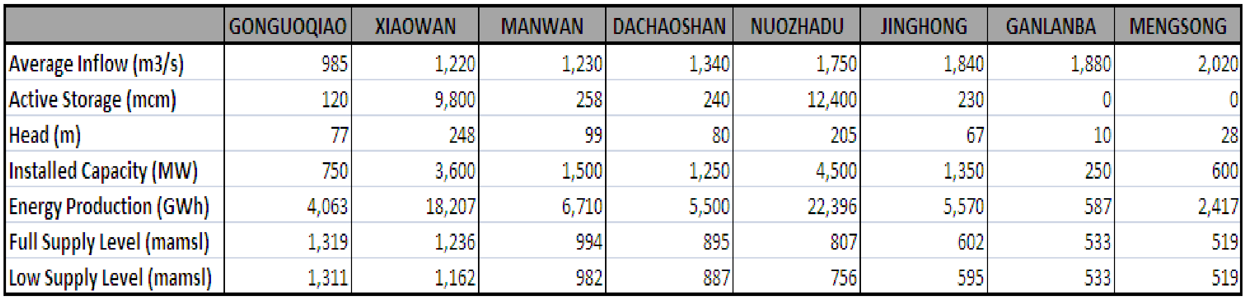
In order to maximize the energy production of a hydroelectric plant a rule is developed after the analysis of the hydrologic record of inflows. The rule essentially consists of target elevations of the reservoir during the year. If the reservoir is above target releases must be increased, if below target they must be reduced. The trajectory of target levels is called reservoir rule curve.

A single rule curve is sufficient but it is more convenient to have a set of rules, each associated with a specific level of release so that the operators and dispatch authorities have a more clear guideline and the operation proceeds smoothly.

3.3 Available Data on the Lancang Cascade

The Lancang hydropower cascade consists of eight plants and the available information relevant to the analysis of their operation is listed in Figure 3.1. In addition, MRC has sufficient hydrologic information to determine a reasonable series of monthly flows for each of the sites over the period 1986-2000.

Figure 3.1 - Relevant Data on Lancang Cascade Projects



	GONGUOQIAO	XIAOWAN	MANWAN	DACHAOSHAN	NUOZHADU	JINGHONG	GANLANBA	MENGSONG
Average Inflow (m3/s)	985	1,220	1,230	1,340	1,750	1,840	1,880	2,020
Active Storage (mcm)	120	9,800	258	240	12,400	230	0	0
Head (m)	77	248	99	80	205	67	10	28
Installed Capacity (MW)	750	3,600	1,500	1,250	4,500	1,350	250	600
Energy Production (GWh)	4,063	18,207	6,710	5,500	22,396	5,570	587	2,417
Full Supply Level (mamsl)	1,319	1,236	994	895	807	602	533	519
Low Supply Level (mamsl)	1,311	1,162	982	887	756	595	533	519

Source: Department of Strategy Planning, State Power Corporation of China

3.4 Development of Elevation-Storage-Area Relationships

The first step in the path to forecasting the operation of these reservoirs was to prepare relationships between the storage volume and the elevation so that any change in storage could be related to a consisting change in head. This information is, no doubt, available somewhere but since it was not immediately available it had to be inferred.

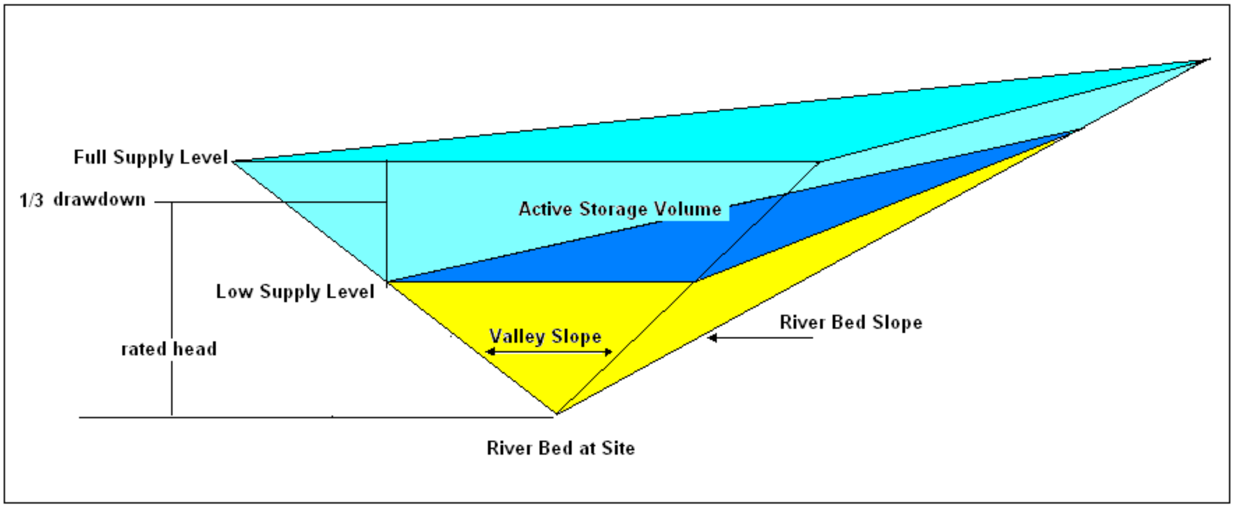
River Bed Elevation

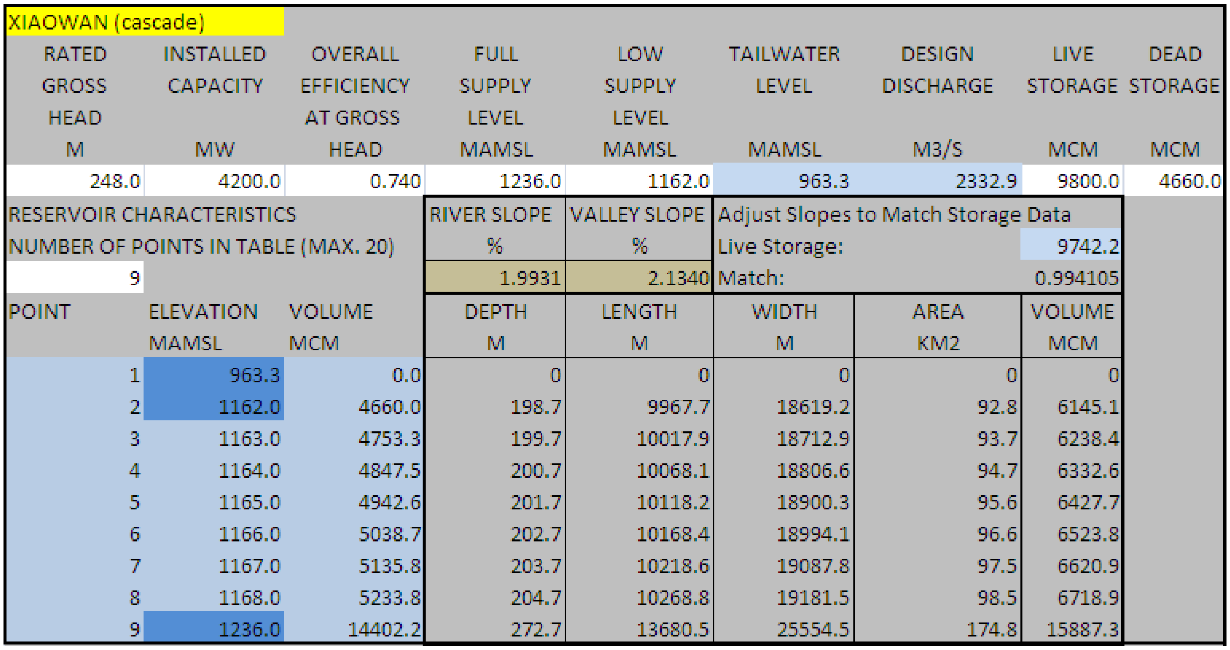
The reservoirs are not so closely linked that one can infer the elevation of the river bed at one site from the full supply level of the site immediately downstream. However, in hydroelectric planning practice it is a fair assumption that the rated head of a hydroelectric plant roughly corresponds to the elevation of the reservoir at one third normal drawdown because. This elevation can be obtained from the full and low supply levels and by subtracting from that result the rated head it is possible to infer the approximate elevation of the river bed at the dam site. This is illustrated in Figure 3.2.

River Slope and Valley Slope

Having fixed the river bed elevation and knowing the maximum and minimum operating levels (Full Supply Level) the relationship between storage and elevations can be approximated by assuming different slopes for the river bed and the valley until the active storage between the two operating levels is that provided as data.

Figure 3.2 - Approximation to Reservoir Storage-Elevation Relationship




XIAOWAN (cascade)

RATED GROSS HEAD M	INSTALLED CAPACITY MW	OVERALL EFFICIENCY AT GROSS HEAD	FULL SUPPLY LEVEL MAMSL	LOW SUPPLY LEVEL MAMSL	TAILWATER LEVEL MAMSL	DESIGN DISCHARGE M3/S	LIVE STORAGE MCM	DEAD STORAGE MCM
248.0	4200.0	0.740	1236.0	1162.0	963.3	2332.9	9800.0	4660.0

RESERVOIR CHARACTERISTICS

NUMBER OF POINTS IN TABLE (MAX. 20): 9

RIVER SLOPE %	VALLEY SLOPE %
1.9931	2.1340

Adjust Slopes to Match Storage Data

Live Storage: 9742.2

Match: 0.994105

POINT	ELEVATION MAMSL	VOLUME MCM	DEPTH M	LENGTH M	WIDTH M	AREA KM2	VOLUME MCM
1	963.3	0.0	0	0	0	0	0
2	1162.0	4660.0	198.7	9967.7	18619.2	92.8	6145.1
3	1163.0	4753.3	199.7	10017.9	18712.9	93.7	6238.4
4	1164.0	4847.5	200.7	10068.1	18806.6	94.7	6332.6
5	1165.0	4942.6	201.7	10118.2	18900.3	95.6	6427.7
6	1166.0	5038.7	202.7	10168.4	18994.1	96.6	6523.8
7	1167.0	5135.8	203.7	10218.6	19087.8	97.5	6620.9
8	1168.0	5233.8	204.7	10268.8	19181.5	98.5	6718.9
9	1236.0	14402.2	272.7	13680.5	25554.5	174.8	15887.3

Rule Curve Tool

The Rule Curve Tool (RCT) is a program that allows the user to rapidly estimate three rule curves that will define the operation of the reservoir under the assumption that such operation is planned to maximize energy production.

Lower Rule Curve

The Lower Rule Curve is the trajectory of reservoir elevations during the year that defines the following:

- The Maximum Firm Flow. This is the flow that can be maintained through the dry season under the lowest hydrologic condition so that the reservoir reaches its minimum operating level exactly by the end of the dry season and can be filled up to its maximum operating level during the wet season.

- The Minimum Reservoir Elevations. These are the minimum elevations that the reservoir should maintain in order to guarantee the above.

Upper Rule Curve

The Upper Rule Curve is the trajectory of reservoir elevations during the year that defines the following:

- The minimum spill. This is the volume that, on average will not be captured for power production as it will exceed the regulating capacity of the reservoir combined with the discharge capacity of the power plant.

- The maximum reservoir elevations. These are the maximum elevations that the reservoir should maintain in order to guarantee the above.

Operating Regime

The Lower and Upper Rules Curves only define a range of elevations within which the reservoir surface must be at the end of each month. However, if the reservoir is allowed to get too close to the upper rule curve it is possible that a very wet month could cause it to go over the curve. Conversely, if the reservoir is allowed to get too close to the lower rule curve it is possible that in a very dry month the firm flow cannot be maintained in order to stay above the curve.

In order to refine the analysis into a proper operating regime the RCT allows the user to simulate the operation of the reservoir to obtain the optimum value of a parameter called the Upper Rule Factor (URF). The URF will the be used every day to define an intermediate level between the Upper and Lower curves. When the reservoir is above this Intermediate Level the turbines are allowed their maximum discharge, when the reservoir is below the Intermediate Level then the discharge is reduced in proportion to the distance to the Lower Curve. The smaller the distance the closer the turbine discharge approaches the Firm flow.

The process of rule curve definition and selection of URF is illustrated in Figure 3.3.

3.5 Xiaowan Reservoir Example

Some results obtained for the Xiaowan reservoir are presented as an illustration of the use of the Rule Curve Tool.

This particular analysis determined that the optimum Upper Rule Factor (URF) was 0.69 and this results in the reservoir elevation trajectories shown in Figure 3.4 for every year of the period of record utilized. It can be observed from the figure that the reservoir never approaches the Lower rule curve but it several times exceeds the Upper rule curve.

This operation yields the maximum average energy production. If the operation would keep the reservoir lower there would be less spill than 240 MCM but the lower average head would result in less energy production. Conversely, if the operation would keep the reservoir higher the average head would be more but more water would be spilled also resulting in less energy production.

The average results of the operation using these rule curves are shown in Figure 3.5. It is observed by comparison with the table in Figure 3.1, that the energy production under this simulation is 18,456 GWH, less than 1.5% different from that provided as data. This validates the quality of the simulated operation and the assumption that the objective is to maximize energy production.

Figure 3.3 - Flow Diagram

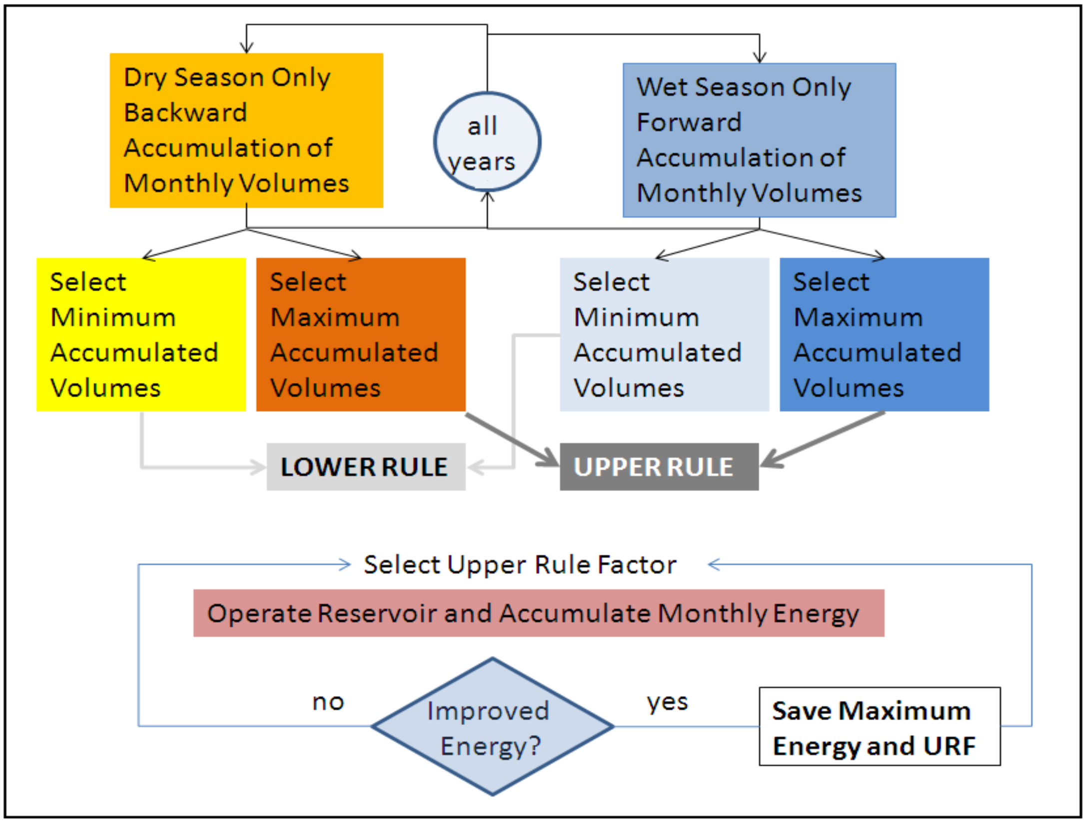


Figure 3.4 - Simulated Reservoir Trajectories

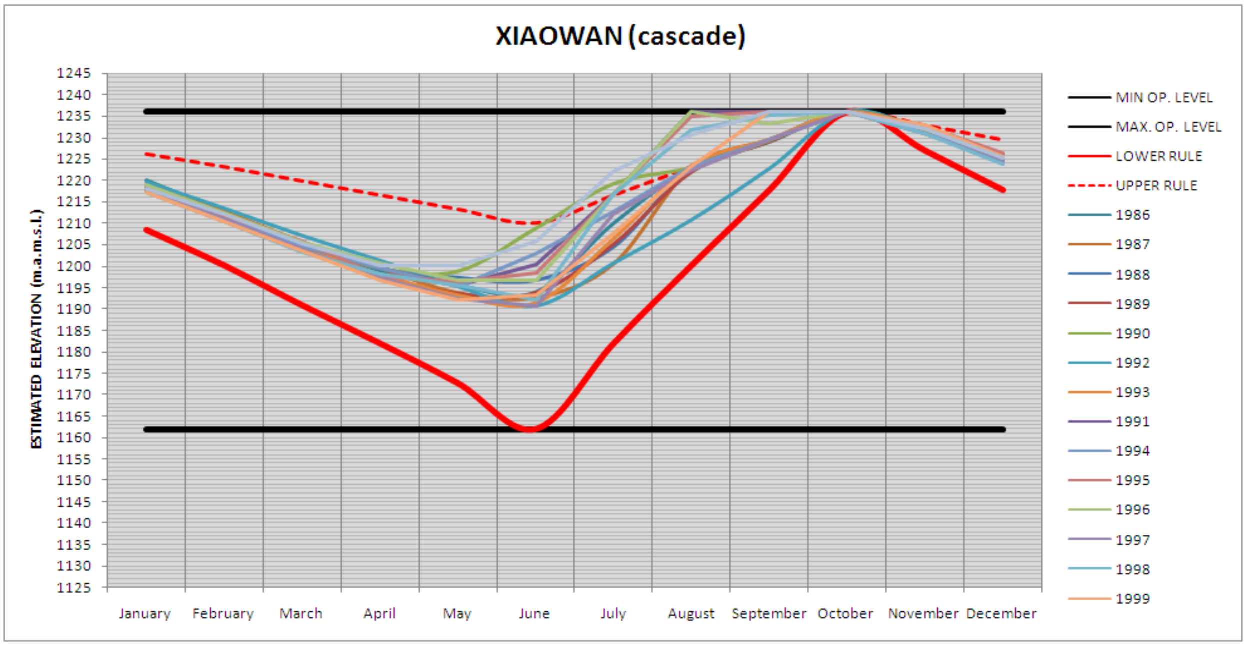
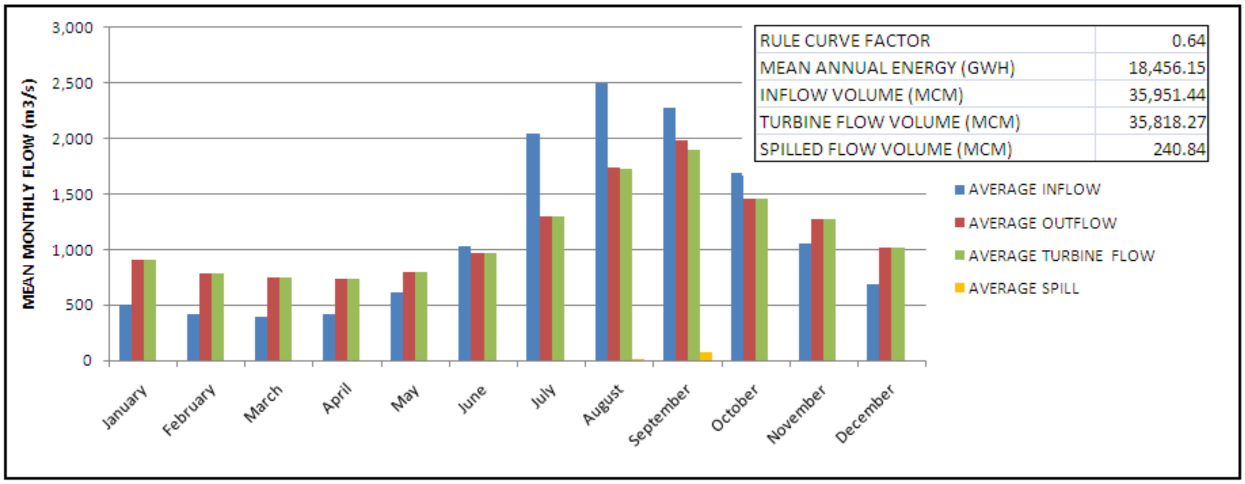


Figure 3.5 Average Operating Results for Xiaowan



RULE CURVE FACTOR	0.64
MEAN ANNUAL ENERGY (GWH)	18,456.15
INFLOW VOLUME (MCM)	35,951.44
TURBINE FLOW VOLUME (MCM)	35,818.27
SPILLED FLOW VOLUME (MCM)	240.84

4 COMPARATIVE ANALYSIS OF HYDROELECTRIC PROJECTS

4.1 Objective of the Analysis

The primary objective of the analysis of economic performance of the hydroelectric projects in the database is to establish the likely order in which they may be developed. However, anytime a sample of considerable size is analyzed there is always the benefit of useful insights on trends and correlations that offer a better understanding the general behavior of its population. In this case, several interesting aspects of hydroelectric projects in the region are also learned through his comparative analysis.

4.2 Projects in the Database

There are 135 hydroelectric projects identified in the hydropower database for the Mekong basin so far. Their location, key characteristics and the final results of their economic analysis are shown in Annex A. The distribution of projects by country and by level of development is shown in Figure 4.1.

These projects have an aggregated annual energy potential of 134 TWH which, to put it in perspective is approximately 85% of the current power demand in Thailand. Only about 7% of that potential is in operation, another 12% is under construction and the rest in various stages of development.

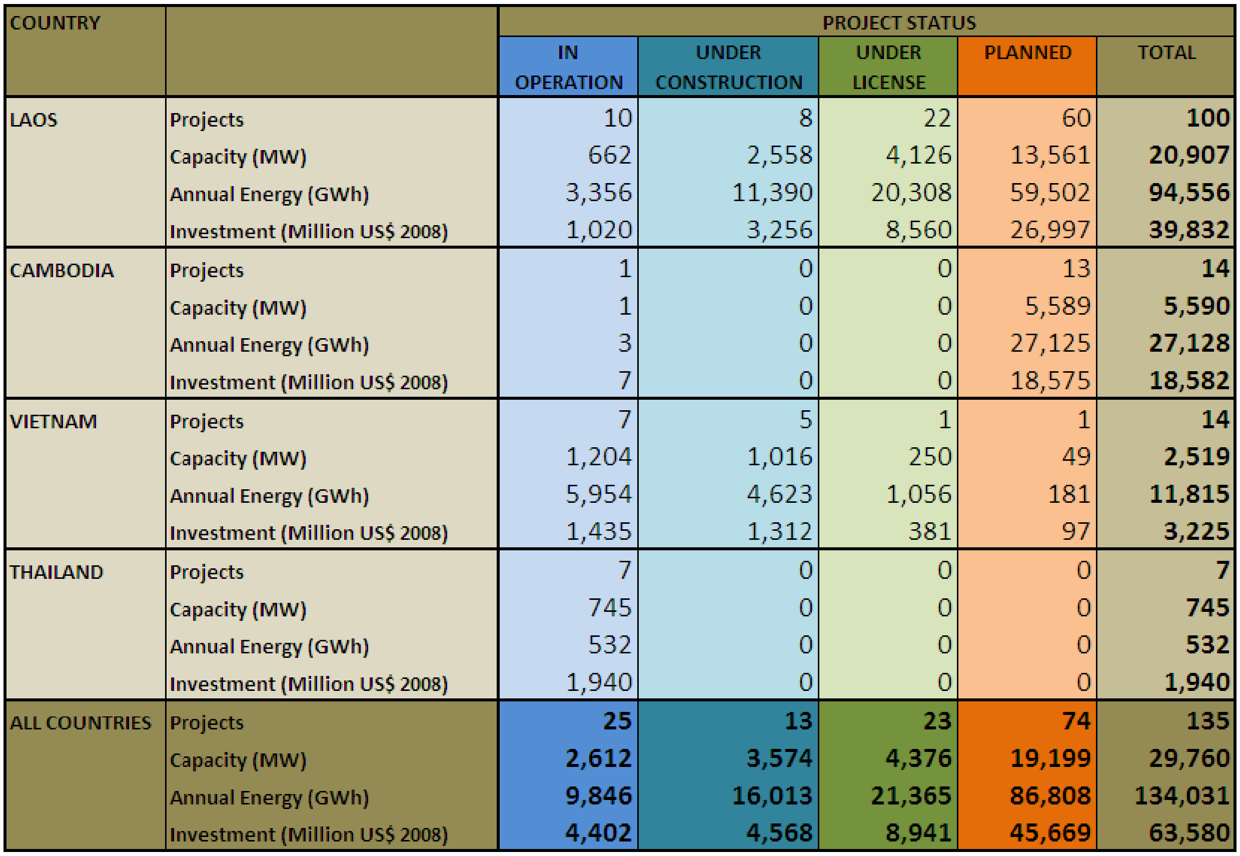
The distribution by country is very uneven. Of the projects in operation 95% of the production is in Vietnam and Lao PDR, 5% in Thailand and it is negligible in Cambodia. Of the energy potential from projects not yet in operation 73% is in Lao PDR, 22% in Cambodia and 5% in Vietnam. It also seems that the reported distribution of future potential is a poor indicator of hydropower development activity because despite the large share reported by Cambodia none of it is under construction or even under license. In contrast, 37% of the share reported by Lao PDR and nearly all the potential in Vietnam corresponds to projects under construction or under license.

4.3 Development of Project Costs

The cost of hydroelectric projects is obtained from the cost estimate information disclosed in the studies. There is always some uncertainty in cost estimating which depends to a large extent on the level of study of each project. Typically cost estimates at pre-feasibility level are only accurate to within +/- 25% , at feasibility level that margin is reduced to +/- 15% and at final design level one can expect accuracy within +/- 8%. This cannot be avoided, however, in addition to this intrinsic inaccuracy there are many aspects that can make cost estimates not comparable among projects. Some estimates may be recent and some may be quite old so they are in different price levels. Some may include taxes and interest during construction and others not.

These and other differences can distort cost perceptions very considerably. The information reported in the database (Project Data Sheet "Cost Data") is designed to eliminate as much as possible differences in price level and content to developed an adjusted cost suitable for economic (not financial) assessment. Financial assessment would require information on equity structure and debt terms that is not possible to anticipate for planned projects.

Figure 4.1 - Database Projects



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**

Adjusted EPC Cost

The cost estimate is based on the Engineering, Procurement and Construction (EPC) cost of the project that is captured from the Cost Data sheet but it is adjusted as follows:

- Any transmission cost representing an expansion of the national grid not exclusively serving the project is eliminated.
- Any tax included as a specific item in the EPC cost is eliminated.
- Any development cost included as a specific item in the EPC cost is eliminated.
- Any interest during construction included as a specific item in the EPC cost is eliminated.

Thus the EPC cost reported in the Cost Data sheet is sanitized to eliminate costs that are either not applicable to the economic analysis or that will be later added to all projects in a consistent manner.

Current EPC Cost

The EPC cost is deemed to correspond to the price levels of the reference year reported in the Cost Data sheet and these will be different for each project. These costs will be brought to price levels of the current year by applying the construction cost escalation rate also defined in the Power Market Data sheet.

Development Cost

Development costs are costs incurred in developing the project other than for engineering, procurement and construction. These costs apply when projects are privately or jointly (private-government) developed and include primarily legal and consulting fees involved in negotiation, permitting, contract preparation, investor due diligence and lender due diligence. If any of these costs were explicitly included in the EPC these would have been eliminated in the adjustment above and will now be added uniformly to all projects as a percent of their adjusted and current EPC.

IDC Cost

The interest during construction represents the opportunity cost of capital disbursed during construction up to the time when the project starts operating. This cost is a function of the duration of construction (captured from the Cost Data sheet), of the discount rate (captured from the Screening Data sheet) and also of the schedule of disbursements during construction.

To simplify the analysis it is assumed that IDC can be approximated by the following formula:

$$\text{IDC} = EPC * 0.25 * (1 + i)^{P}$$

where:

IDC: interest during construction in Million $

EPC: current adjusted EPC in Million $

i: discount rate

P: construction period in years

This formula is developed on the basis of actual cost disbursements for projects around the world and takes into account the fact that in most projects the heaviest expenditures take place during the middle years of construction.

PV Cost

The sum of the current adjusted EPC, the development costs and the IDC Cost gives the present value of the investment at the time of commissioning of the project

Annual Project Cost

The annual project cost is the sum of the annual capital cost and the annual operating cost. In hydroelectric projects operation and maintenance costs are typically around 0.5% to 1% of the total investment. For this analysis 1% was used.

Annual Capital Cost

In some aspects of cost analysis it is more practical to express cost as an annual value rather than its total value. For example, this is a useful representation of cost when calculating cost per unit of energy production.

The annual capital cost is the result of applying to the PV Cost the capital recovery factor corresponding to the expected economic life of the project. The capital recovery factor is a standard financial operator given by the formula:

$$\text{CRF} = \frac{[(1+i)^L]*i}{[(1+i)^L]-1}$$

where:

CRF: Capital Recovery Factor

i: discount rate

L: economic life in years

In this analysis the economic life is assumed to be 50 years, the normal life expectancy of a hydroelectric project before a major rehabilitation. The discount rate used was 11%.

4.4 Project Cost Analysis

Unit Cost of Capacity

The most common way to refer, generically, to the cost of a hydroelectric project is by expressing it as cost per unit of installed capacity. This is obtained by dividing the PV Cost by the installed capacity and is expressed in million dollars per MW (M$/MW) [1]

Despite its popularity this is not a very good indicator because it does not capture the difference in storage among projects and its value to energy production. Nevertheless, in very general and worldwide terms it can be said that very good sites show unit costs of around 1 M$/KW while poor sites tend to be well upwards of 3 M$/MW. The cost per unit of capacity is also sensitive to project scale and it is quite difficult to find projects under 30 MW below 2 M$/MW.

The projects in the database show reasonable consistency with these general international guidelines as shown in Figure 4.2. Most projects are in the range of 1 to 3 M$/KW and there is a noticeable sensitivity to project scale.

Unit Cost of Energy

A much better generic cost indicator for hydroelectric projects is the cost per unit of mean annual energy production since this not only captures more aspects of the power production of the project clearly but also offers a very direct contrast to wholesale electricity prices in the market where that power will be injected. This indicator is obtained by dividing the Annual Project Cost by the mean annual energy of the project and is usually expressed in $/MWH.[2] Worldwide values of the cost of hydroelectric energy cost range from 10 to 70 $/MWH and this cost tends to be quite sensitive to project scale. Figure 4.3 shows the sensitivity of energy cost to project scale and it is interesting to observe that projects in the database, while generally within the range, appear to be in the higher part of the range, between 40 and 70 $/MWH and many are above the range.

---

[1] It is also common to use $/KW. One M$/MW = 1,000 $/KW

[2] When comparing to tariffs it is more common to use in Cts/KWH. This dual practice can be confusing so it is useful to remember that 1 $/MWH equals 0.1 Cts/KWH.

Figure 4.2 - Cost per Unit of Installed Capacity

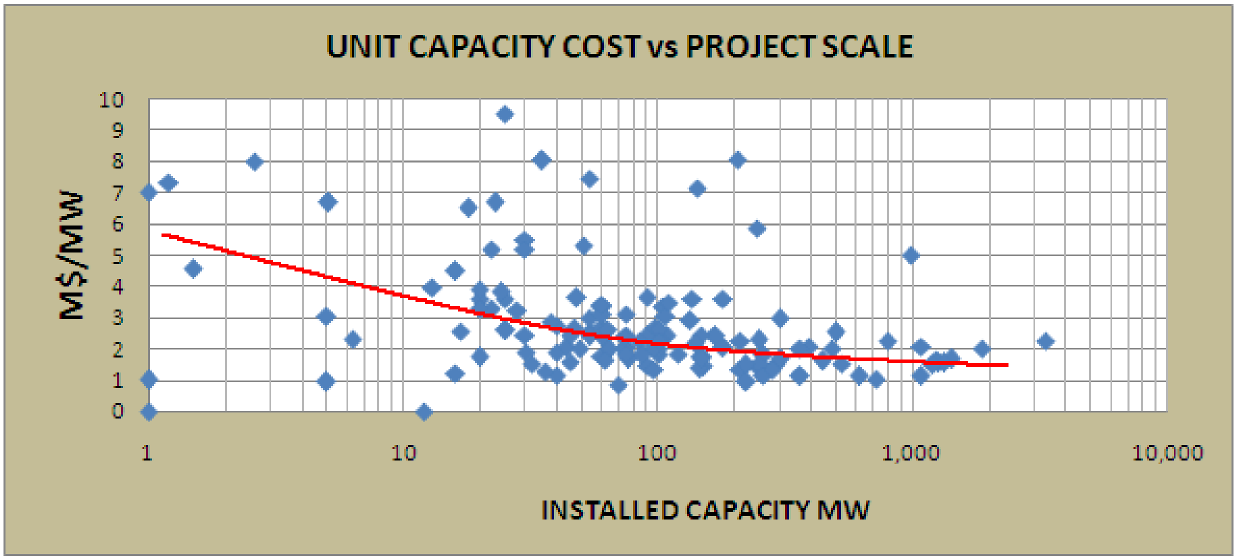
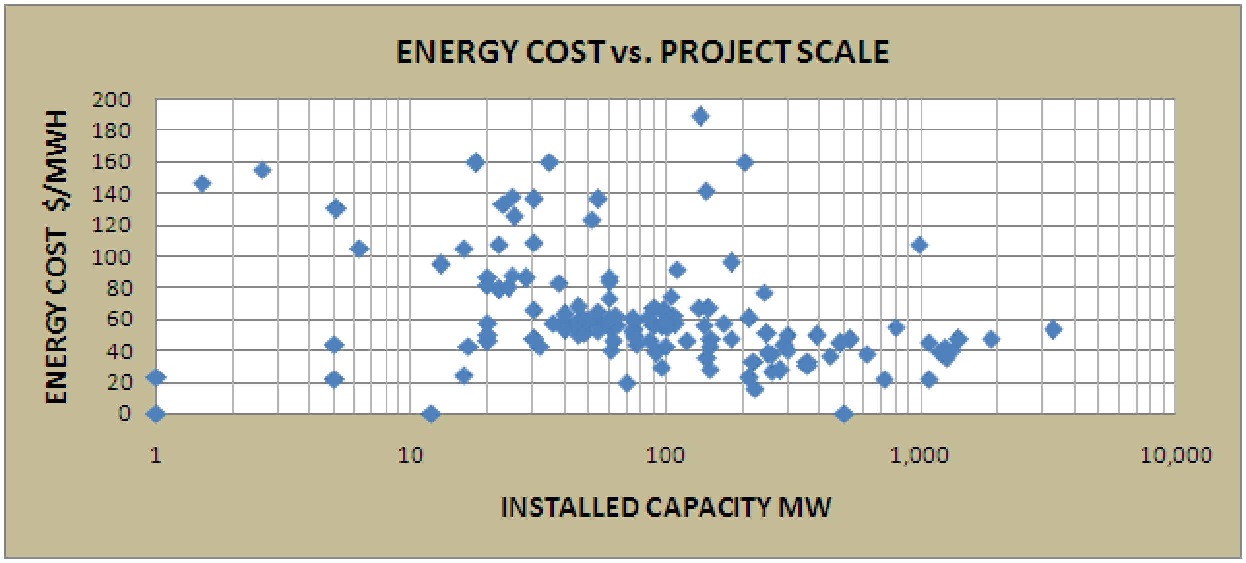


Figure 4.3 - Sensitivity of Energy Cost to Project Scale

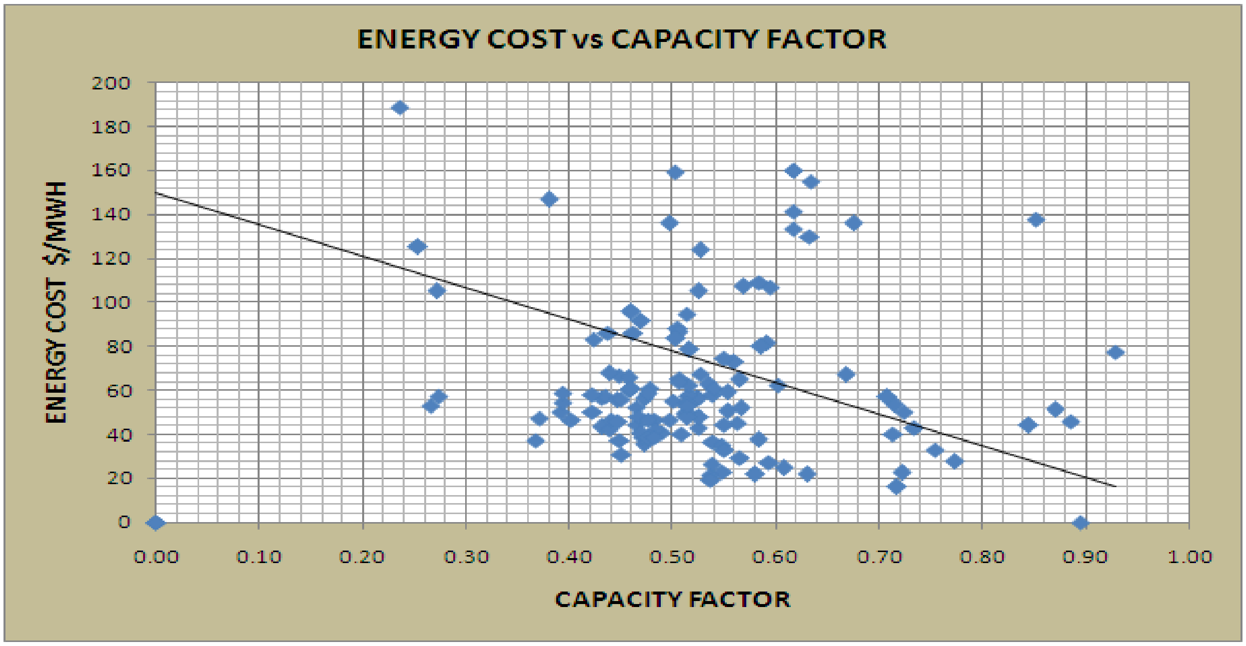


Capacity Factor

If the mean annual energy is expressed in MWH and is divided by the number of hours in a year (8,760) the result is mean output in MW. This value when divided by the installed capacity is the capacity factor and is quite simply a measure of how much of the installed capacity is actually used on average.

The sensitivity of energy cost to capacity factor is shown in Figure 4.4. Most of the projects in the database have capacity factors between 0.4 and 0.6 which is not unreasonable but on the low side since, at least in the most competitive hydro markets of the world, projects with capacity factors under 0.70 prove difficult to finance unless the systems offer high prices for capacity.

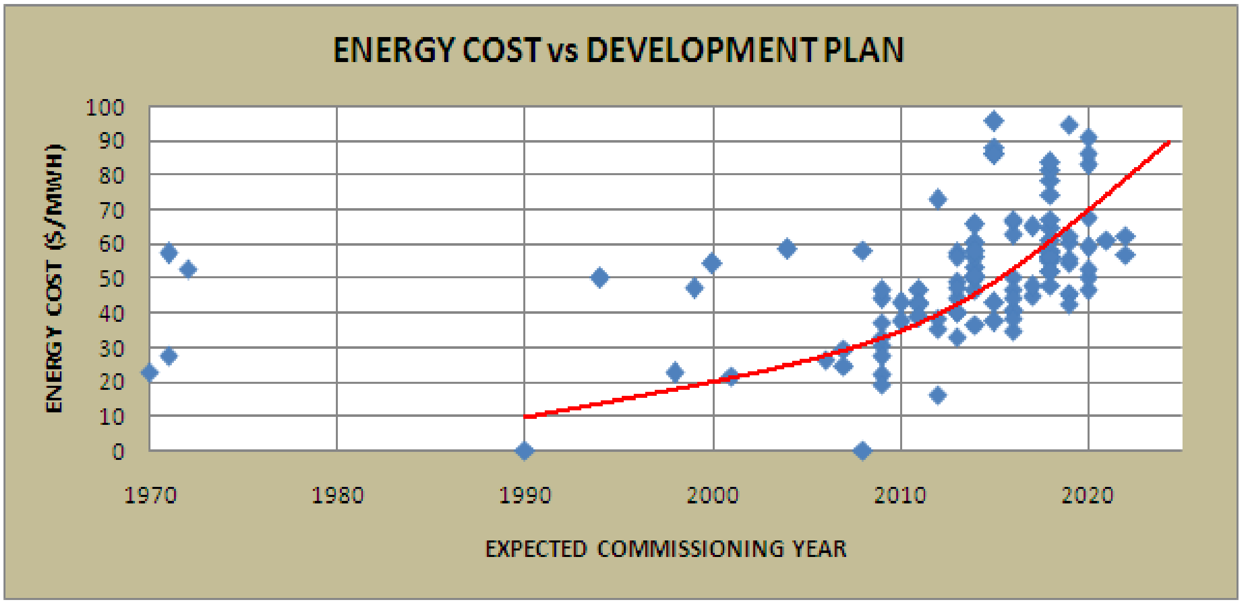
Figure 4.4 Capacity Factor



Energy Cost and Development Plans

Based on the objectives presented in section 4.1 it is interesting to test whether energy cost is a good indicator of likely development. Figure 4.5 shows a plot of the energy cost against the expected (and actual for existing projects) commissioning date. It is clear that the national development plans follow a trend of increasing energy costs which of course is quite logical and does provide some level of confidence in the cost data reported into the database.

Figure 4.5 - Correlation between Unit Energy Cost and Development Plans



4.5 Development of Project Economic Benefits

Annual Power Benefits

While it is possible to express benefits as a present value over the life of the project it is far more practical to express them in terms of annual values. Obviously the actual annual benefits will vary from year to year depending on hydrology but a good approximation to the average annual benefits can be obtained assuming mean annual energy production.

The analysis of benefits involves both the production of the project and the market where its power is delivered. Therefore this analysis is carried out separately for the country where the project is located and for any countries where power from the project may be delivered.

In each of these countries there are two types of economic impacts from the power delivered by the hydroelectric project.. One is the impact on the national generation system in terms of value of energy and capacity from the project. The other is the impact on the national economy of the export and import of power.

Energy Benefit

The value of energy in each market was discussed in section 2.4 of this report and is the variable cost of the thermal alternative more likely to be used if hydroelectric power is not available.

This benefit is simple to calculate as it is the quantity of mean annual energy that is allocated to each country at the value of energy determined for that country.

Capacity Benefit

The capacity benefit of a project in each market is more difficult to assess because it is a measure of the contribution of hydroelectric capacity to the reliability of the particular power system. The analysis involves several steps.

The first step is to estimate the firm energy of the project. Firm annual energy is a value reported in the Operation Data sheet and is defined in the database manual as annual energy that can be expected to be produced by the project with a confidence of 95%. This is illustrated in Figure 4.6. In the screening analysis it is assumed that firm energy is allocated to each country in the same proportion established for mean energy in the Cost Data sheet.

The second step is to estimate what is the contribution of the allocated firm energy to displacing thermal capacity in each system. A detailed analysis would involve hourly dispatch of the firm energy of the plant over an entire year but this is clearly not practical for a screening analysis. The adopted procedure is to calculate the reduction in peak demand if all the firm energy was dispatched during the peak hours. This reduction, illustrated in Figure 4.7 is called Firm Peak Output but is not yet the amount of thermal capacity that can be displaced.

Third step. Before accepting this value it must be compared against the peaking capability reported in the Operation Data sheet and the lowest value must be adopted. The Peaking Capability is the instantaneous output that the plant is capable of producing at the time of peak demand and it does not depend on water availability but on hydraulic head. Therefore in a storage hydroelectric plant the peaking capability is calculated as the maximum output at the lowest head (i.e. reservoir elevation less tailwater elevation) that can be expected at the time of the peak annual load.

Figure 4.6 - Mean Energy and Firm Energy

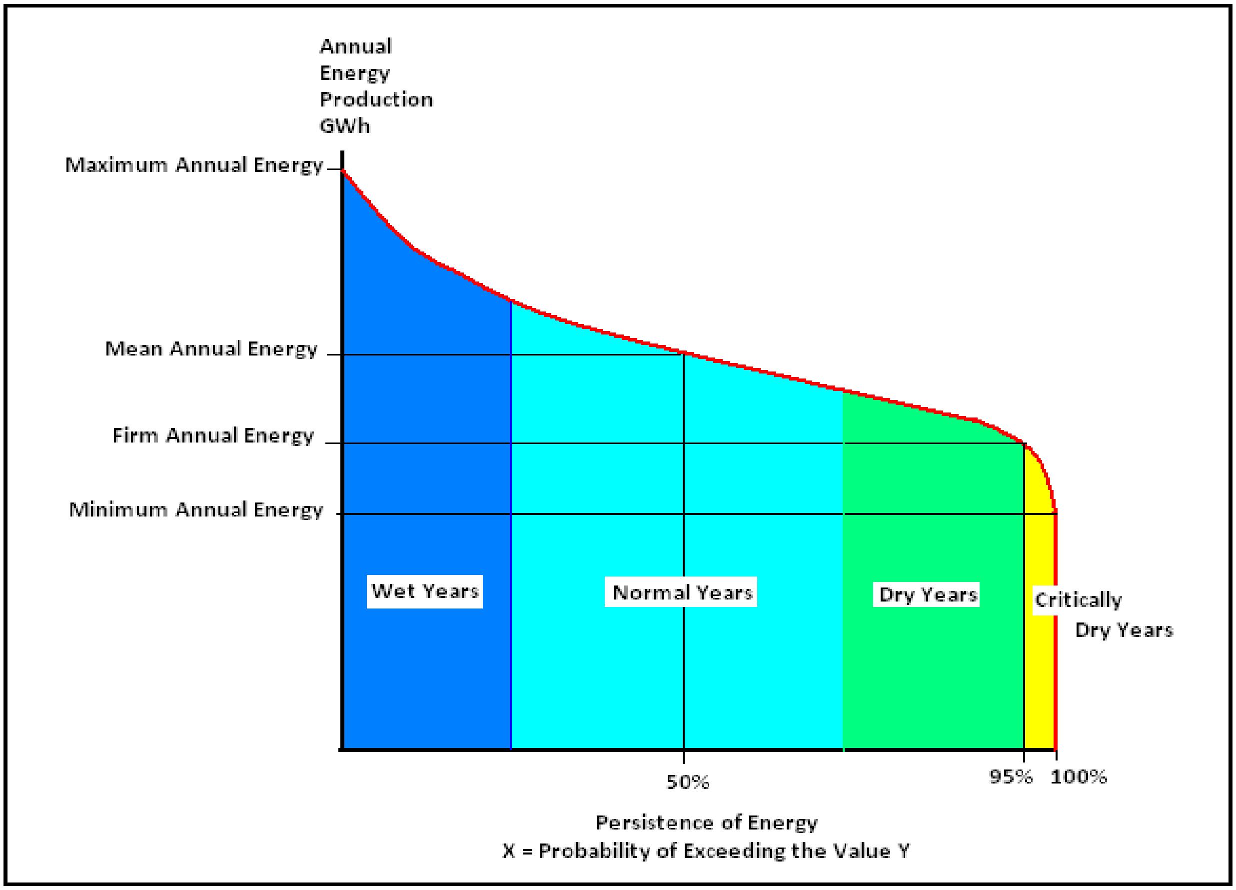
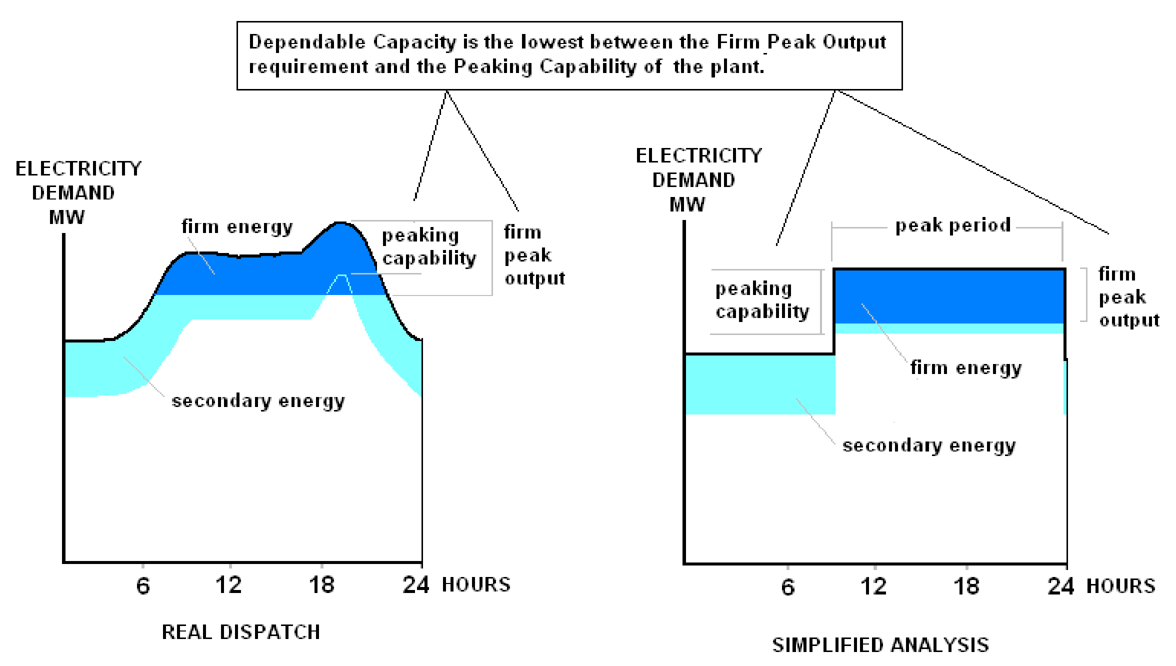


Figure 4.7 - Estimating Dependable Hydroelectric Capacity



The fourth step involves comparing the mean peak output to the peaking capability and selecting the smaller of the two. This value is called Dependable Capacity and is the true measure of the contribution of the capacity of a hydroelectric project to the reliability of the power system.

The capacity benefit is calculated as the product of dependable capacity by the capacity value in the market. The capacity value was also described in section 2.4 as the fixed cost (capital and operation) of the thermal plant most likely to be used if hydroelectric power is not available.

Export-Import Benefits

From a national perspective the total benefits of a hydroelectric project are the energy and capacity benefits discussed above plus (or minus) the export (import) revenue (cost) of the international exchange of hydroelectric power. This last component is the trade impact.

For the exporting country the trade impact is positive because it is simply the revenue from exports. For the importing country annual benefits it is negative as it is the cost of import. These two values (revenue and cost) are calculated at the Reference Trade Price described in section 2.4 and assumed as the average of the monomic cost of power computed at the load factors of Vietnam and Thailand.

Summary of Project Benefits

The national annual benefits of the project in each country is then the sum of the energy benefit, the capacity benefit and the trade impact (with positive or negative sign). The total annual benefit is the sum of the national benefits of all countries involved.

It must be emphasized that the trade impact is only relevant from the national perspective of each country and not from a regional perspective. From a regional perspective the trade impact cancels out since all export revenues must equal or import costs.

4.6 Benefit Cost Analysis

Benefit Cost Ratio

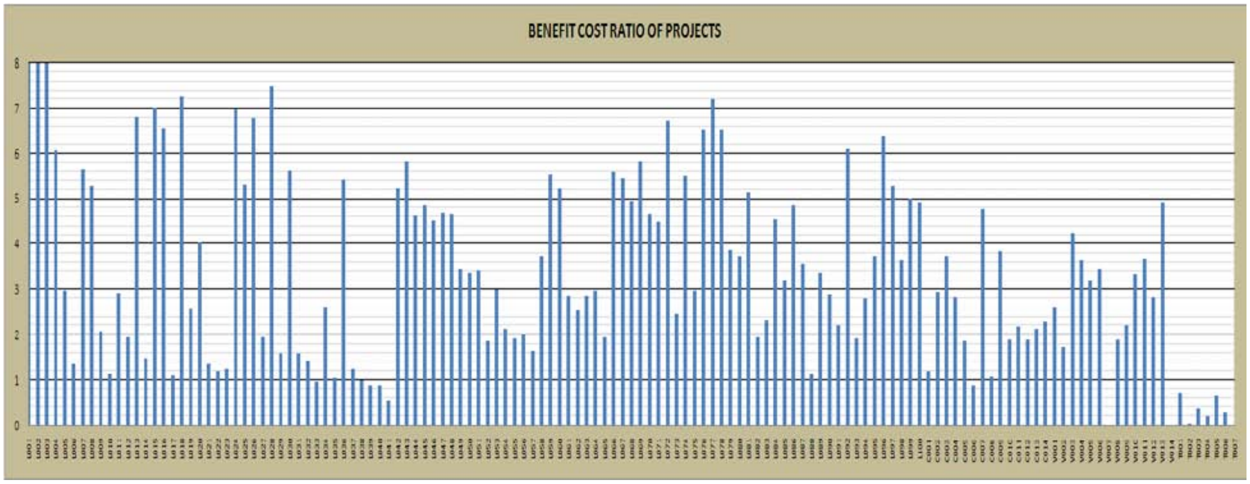
The Benefit Cost Ratio (BCR) of the projects is calculated by dividing total annual benefits by total annual costs. The result is shown in Figure 4.8. The BCR runs from nearly zero to upwards of 8 with an average of 3.5. The benefit cost ratio was calculated assuming a discount rate of 11% and it represents an economic internal rate of return (Economic IRR) of around 38% on average. This is not to be construed as expected return on investment of the projects and even less the return on equity since that will depend on debt equity structure, loan terms, taxes, PPA agreements and many other financial and commercial arrangements. However, it does reflect the potential for a very attractive financial outlook and hence the dynamic activity now underway in hydropower development in the region.

Several projects show very low and even negative BCR and it is interesting that many of them are existing projects including all the projects in Thailand. There are two reasons for this:

1) These projects projects were developed several decades ago and their budgets are being escalated from their original values. This may or may not reflect the actual cost of developing these projects today as opposed to recent or planned projects for which their budgets are relatively current.

2) the benefits of these projects may have been very different when they were built as they may have been displacing more expensive thermal generation than that now used to compute their energy and capacity benefits

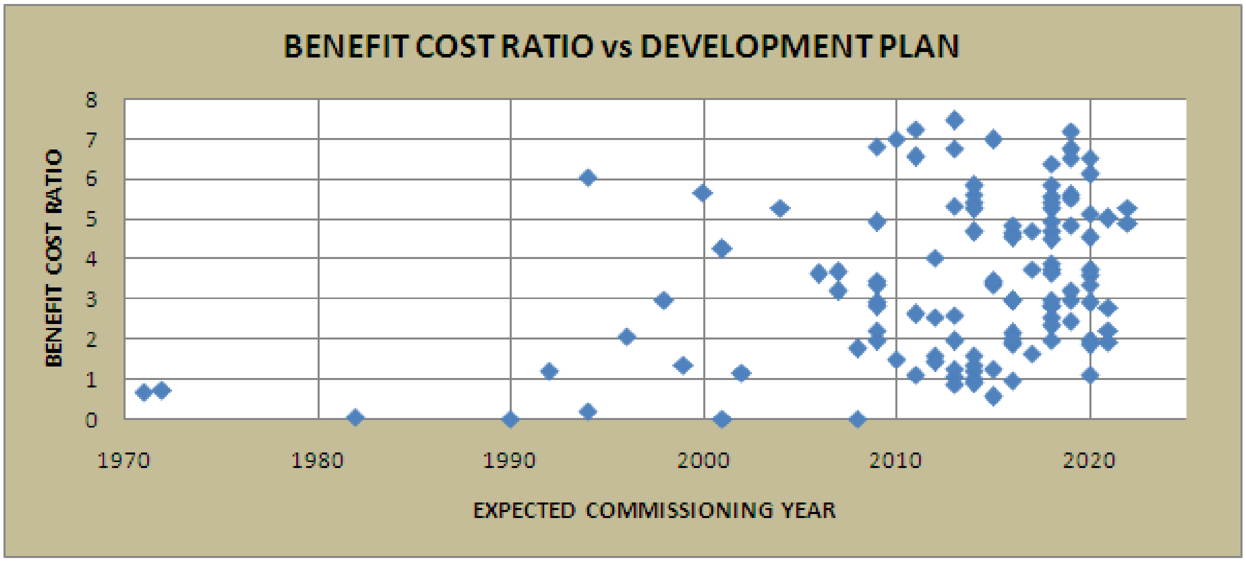
Figure 4.8 Benefit Cost Ratio of Projects



BCR and Development Plans

Figure 4.9 shows a plot of the BCR of the projects against the reported expected (or actual for existing projects) commissioning year. It can be observed that there is no discernible relation between good BCR and early development, at least for planned projects between 2010 and 2020.

Figure 4.9 - Disconnect between Development Plan and Project Performance



This disconnect between economic performance, as calculated in the database, and actual or expected development will be further explored in Chapter 5 and refers to the major difference in relative project value that exists when viewing projects from a national or a regional perspective.

5 MEKONG HYDROPOWER IN THE REGIONAL POWER CONTEXT

5.1 Objective

The previous chapters focused on the projects in the database and their relative characteristics and merits both from purely cost considerations and from a perspective of regional economic net benefit. This chapter seeks to analyze the reasons and implications of the results reported in Chapter 4 in the context of the relevance of Mekong hydropower to the economies of Lao PDR, Cambodia, Vietnam and Thailand.

5.2 Regional vs. National Perspective

In Figures 5.1a and 5.1b are reproduced, side by side, the Figures 4.5 and 4.9 of Chapter 4 to illustrate the contracts between regional and national perception of value. Figure 5.1a attempts, unsuccessfully, to find a correspondence between national priority and economic value where both costs and benefits of the projects are weighted. Figure 5.1b illustrates how national priorities are aligned with the objectives of an exporting country for which costs are the only consideration.

Figure 5.1a - Regional Perspective

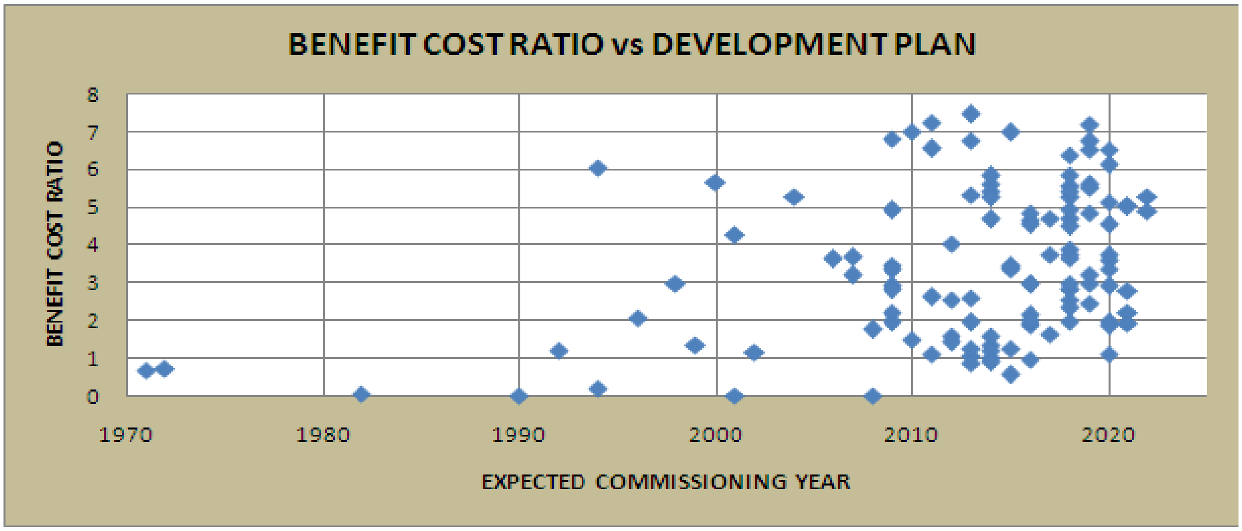
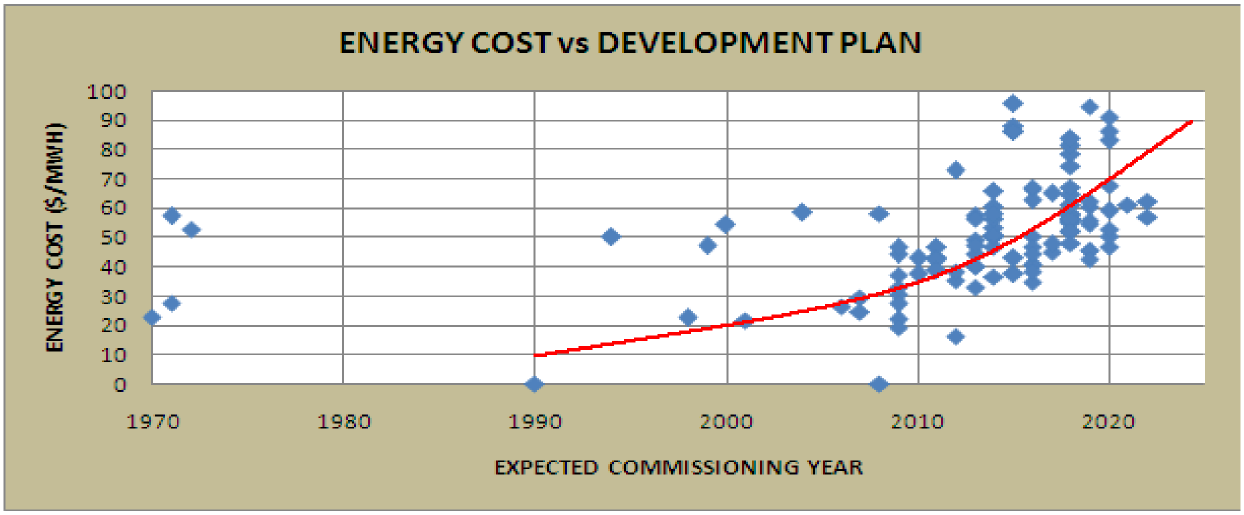


Figure 5.1b - National Perspective

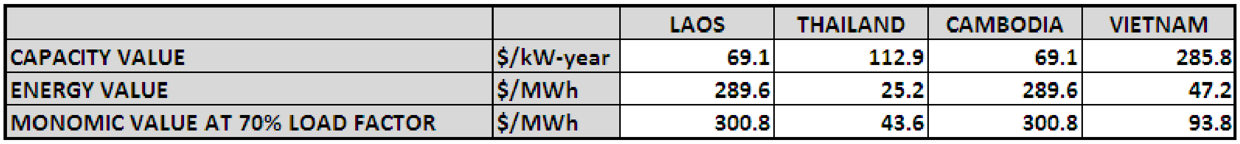


The point of this is not to suggest that national priorities must be aligned with regional economic value, that would be illogical. The point is that it could be worthwhile to explore why the two perspectives are so different and what does that mean for future hydropower development in the Mekong.

The answer to the first question lies in the different value of power in different markets and the fact that international exchanges are the primary driver for hydropower development in the Mekong. Regardless of actual electricity tariffs and when analyzed in terms of their respective alternative generation options the value of power is very different in the region.

Figure 5.2 shows the value of power in terms of its capacity value and energy value as described in detail in Chapter 4. These two values are combined into the monomic or one-part value also shown in the table.

Figure 5.2 - Regional Value of Power



		LAOS	THAILAND	CAMBODIA	VIETNAM
CAPACITY VALUE	$/kW-year	69.1	112.9	69.1	285.8
ENERGY VALUE	$/MWh	289.6	25.2	289.6	47.2
MONOMIC VALUE AT 70% LOAD FACTOR	$/MWh	300.8	43.6	300.8	93.8

There are many reasons for these large differences. It has to do with the relative scales of the power systems, the extent of interconnection and the cost and availability of fuel compatible with the generation technologies appropriate for each system scale.

In Annex B there are details of the calculations and assumptions used in obtaining the values in Figure 5.2. The analysis is, admittedly, very crude and it would require a very thorough study of the real cost of generation options in each country to refine it. However, it appears quite clearly that one unit of hydropower energy, if needed to meet the demand in Lao PDR or Cambodia, would be worth a lot more domestically than what it is worth in Thailand or Vietnam.

These differences would not be very relevant if national planning in Lao PDR and Cambodia were focused on meeting national demand but the issue is that a the majority of planned Mekong hydropower in Lao PDR and the most ambitious projects in Cambodia are not needed there and therefore their economic value is much discounted as a function of where the power is going to be used.

Before further exploring the implications of this finding it is useful to examine the characteristics of planned demand and supply of electricity in each country

5.3 Power Generation Balance

This part of the report is prepared with a limited amount of information and the key references for this are as follows:

Thailand: Draft Mekong River Basin Hydropower Sector Review in Thailand,
Thai National Mekong Committee, January 2009

Vietnam: Hydropower Sector Review in Vietnam, Nguyen Huy Hoach, November 2008

Lao PDR: Power Demand Forecast, JICA January 2009
Hydropower Expansion Progress, Chansaveng Boungnong, August 2008

Cambodia: Hydropower Sector Review in Cambodia, Dr. Narith Bun, November 2008

Some aspects are likely to be a little different under more research on these sectors and also the effects of the current global economic crisis are likely to have some impact on the plans and forecasts used to prepare those reports. Nevertheless, the general picture that emerges is clear and illustrated in Figure 5.3 that shows an estimate of the contribution of each type of primary energy resource to the regional demand for power generation.

Distribution of Power Generation Demand

The contributions of Lao PDR and Cambodia to the regional demand cannot be seen directly in Figure 5.3 as it is the difference between expected production (+) and expected surplus exported (-). It is however, very small, 1% of the regional energy demand in each case. This relationship to regional demand is unlikely to change much by 2020.

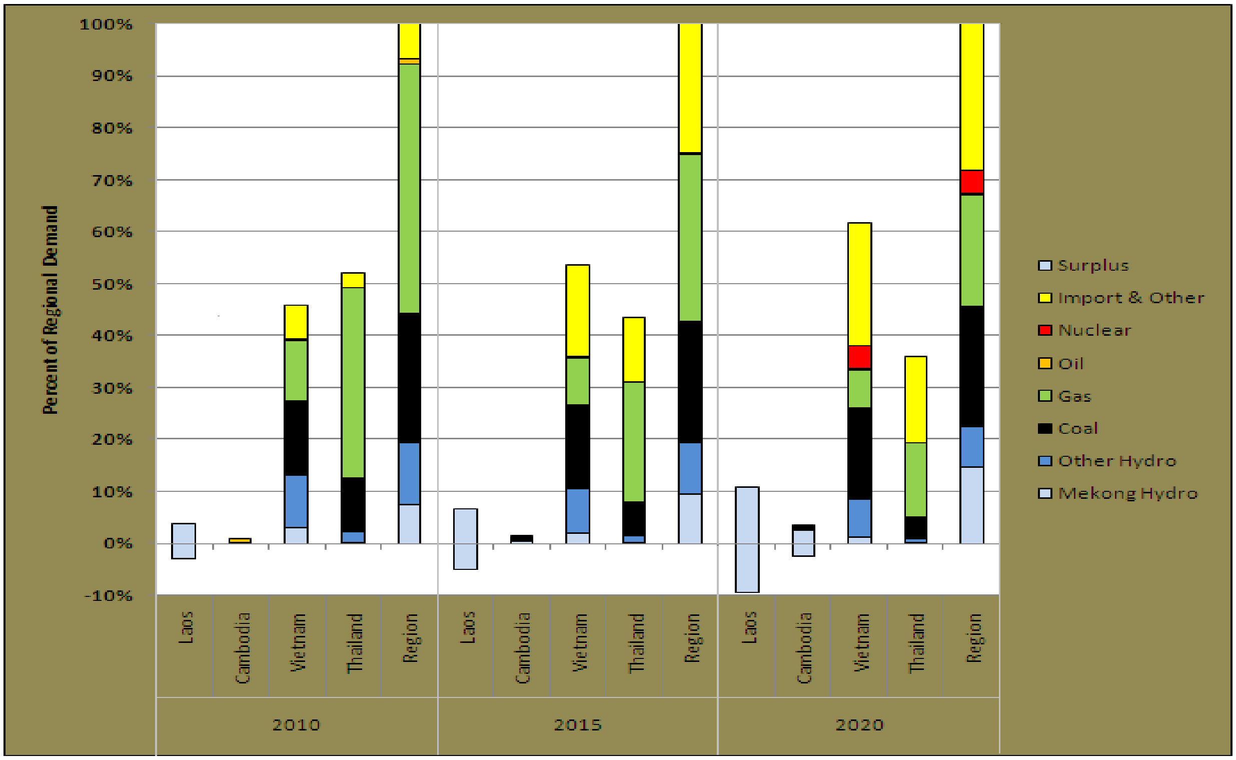
The contributions of Vietnam and Thailand to the regional demand are of course the sum of the individual contributions of each resource including a segment that represents imports of hydropower from Lao PDR and Cambodia and other, yet unknown, generation sources.

Expected Changes in the Generation Matrix

The power generation structure of Lao PDR will not change and will continue to be predominantly hydro. Indeed the only reason for Lao PDR to use any other generation technology but hydropower is the cost of expanding and maintaining the transmission grid to reach every load.

Thailand will move towards reducing its dependency on gas and coal with as much hydro as it can competitively import. Natural gas is a fuel that can be used advantageously in several sectors including industrial heat, residential cooking and transport and therefore its use for power generation may not be the most efficient from an overall national energy planning perspective.

Figure 5.3 - Regional Power Generation Matrix



The Cambodia power sector is expected to change radically from its current almost complete oil dependency to a mix of hydro and coal with substantial hydro export. The export aspect however is almost entirely dependent on the Sambor mainstream hydropower project, an immense undertaking almost three times the average size of other mainstream projects. Without Sambor the Cambodia system could be essentially equal parts of domestic hydro and coal generation unless it can compete against Vietnam or Thailand for imported hydro from Lao PDR.

Given Cambodia plans for coal, a point could be made that the value of power in Cambodia should use a coal reference rather than diesel making it of course comparable to that of Vietnam. However, there are no coal plants yet in Cambodia so the viability of that type of generation at the scale of Cambodia is not clear and the immediate value the remains that of displacing diesel generation.

The biggest unknown in the long term is Vietnam. The rapid growth of the Vietnamese demand means that it will probably double that of Thailand by 2020. There are ambitious plans for new coal and nuclear capacity totaling some 20,000 MW by 2020 but that capacity and the expected capacity of new domestic hydro still leaves a large gap against expected demand. That gap will likely be filled by imports from Lao PDR, more aggressive coal or nuclear development or, more likely, a combination of all three.

5.4 Relevance of New Energy from the Mekong

The impact of the expected changes in the Vietnamese and Thai power sectors on their national portion of the Mekong Basin is minimal since there will be hardly any new hydroelectric development in these areas after 2010. However, the reported hydro and thermal expansion plan still leaves open a very large portion of the demand and that could mean more pressure for imports of hydropower from Lao PDR or Cambodia. It is therefore relevant to evaluate how critical are these possible imports to the Thai and Vietnamese economies.

Assuming that the current global crisis does not have a devastating long term effect the power demand of Vietnam and Thailand by 2020 could reach 840 TWH (terawatt hours = millions of MWH). Current generation and the supply plans reviewed for this study account for 490 TWH. The rest, approximately 350 TWH will be filled in part by hydro energy imports from Lao PDR and Cambodia. The total energy potential of Mekong hydro projects not yet in operation or under construction is 108 TWH and nearly all of it will be available for export from Lao PDR and Cambodia to Vietnam and Thailand.

That means that the exportable hydro not yet under development accounts for 12% of the total energy demand of Vietnam and Thailand in 2020 and for 30% of the demand not yet under specific plans of supply. This is not overwhelming but very significant in terms of quantity. Now the question is how significant it is in terms of cost of electricity supply in those countries?

Let us assume that all of that hydro energy available for export is developed at its average energy cost (see Figure 5.1b) of 55 $/MWH. This is rather expensive for hydropower and presumably, this is the minimum that any importer should pay. That hydro energy will displace, on average, thermal energy that would cost 70 $/MWH to produce so the savings relative to thermal power are, at best, 15 $/MWH or about 21%.

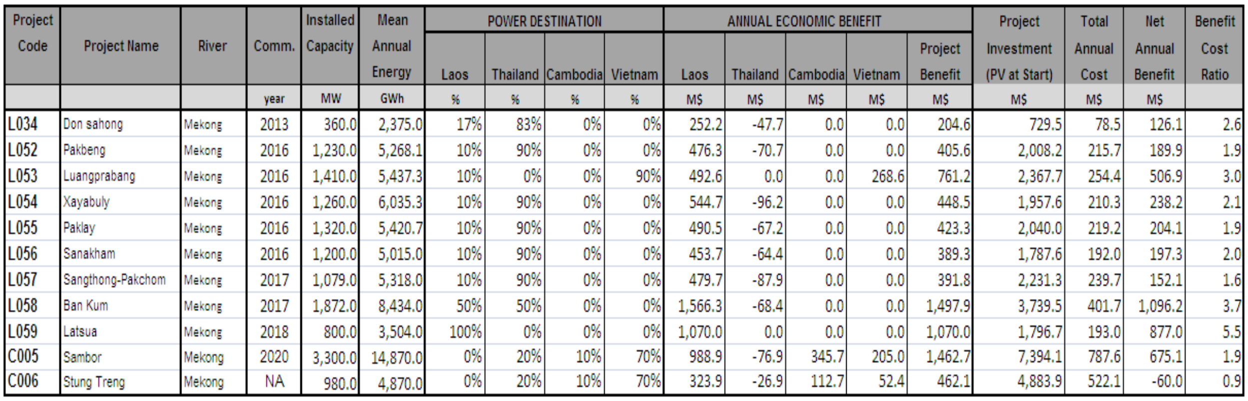
Therefore, all the hydro export potential not yet under construction or operation from Lao PDR and Cambodia represents a saving of 21% of 30% or 6% of the cost of energy supplies not yet defined by those countries. In terms of the total cost of supply it represents 21% of 12% or a mere 2.5% of the cost of electric power. In other words, Mekong hydropower is not a critical economic input for those countries.

5.5 Mainstream Projects

The term "mainstream project" refers to hydropower project sites in the Mekong River itself, as opposed to projects located in tributary rivers. The analysis of basin-wide development scenarios by the BDP programme includes prominently the assessment of the impacts of mainstream projects relative to other hydropower development as these projects have specific issues and risks, particularly with regards to the barrier effect on fish migration and sediment transport and its attendant socio-economic and environmental consequences. As an extension to the comparative analysis of database projects presented in Chapter 4 and to complement the discussion of national versus regional economic perspective earlier in this Chapter 5 it is now useful to look at these specific projects in terms of their relevance and merits within the sample of 96 projects in the database reported as not currently in operation or under construction.

There are 11 mainstream projects, 2 in Cambodia and the rest in Lao PDR and their key characteristics as reported and analyzed in the database are shown in the table of Figure 5.4.

Figure 5.4 - Key Data and Results for Mainstream Projects



Project Code	Project Name	River	Comm.	Installed Capacity	Mean Annual Energy	POWER DESTINATION				ANNUAL ECONOMIC BENEFIT					Project Investment (PV at Start)	Total Annual Cost	Net Annual Benefit	Benefit Cost Ratio
						Laos	Thailand	Cambodia	Vietnam	Laos	Thailand	Cambodia	Vietnam	Project Benefit				
			year	MW	GWh	%	%	%	%	M$	M$	M$	M$	M$	M$	M$	M$	
L034	Don sahong	Mekong	2013	360.0	2,375.0	17%	83%	0%	0%	252.2	-47.7	0.0	0.0	204.6	729.5	78.5	126.1	2.6
L052	Pakbeng	Mekong	2016	1,230.0	5,268.1	10%	90%	0%	0%	476.3	-70.7	0.0	0.0	405.6	2,008.2	215.7	189.9	1.9
L053	Luangprabang	Mekong	2016	1,410.0	5,437.3	10%	0%	0%	90%	492.6	0.0	0.0	268.6	761.2	2,367.7	254.4	506.9	3.0
L054	Xayabuly	Mekong	2016	1,260.0	6,035.3	10%	90%	0%	0%	544.7	-96.2	0.0	0.0	448.5	1,957.6	210.3	238.2	2.1
L055	Paklay	Mekong	2016	1,320.0	5,420.7	10%	90%	0%	0%	490.5	-67.2	0.0	0.0	423.3	2,040.0	219.2	204.1	1.9
L056	Sanakham	Mekong	2016	1,200.0	5,015.0	10%	90%	0%	0%	453.7	-64.4	0.0	0.0	389.3	1,787.6	192.0	197.3	2.0
L057	Sangthong-Pakchom	Mekong	2017	1,079.0	5,318.0	10%	90%	0%	0%	479.7	-87.9	0.0	0.0	391.8	2,231.3	239.7	152.1	1.6
L058	Ban Kum	Mekong	2017	1,872.0	8,434.0	50%	50%	0%	0%	1,566.3	-68.4	0.0	0.0	1,497.9	3,739.5	401.7	1,096.2	3.7
L059	Latsua	Mekong	2018	800.0	3,504.0	100%	0%	0%	0%	1,070.0	0.0	0.0	0.0	1,070.0	1,796.7	193.0	877.0	5.5
C005	Sambor	Mekong	2020	3,300.0	14,870.0	0%	20%	10%	70%	988.9	-76.9	345.7	205.0	1,462.7	7,394.1	787.6	675.1	1.9
C006	Stung Treng	Mekong	NA	980.0	4,870.0	0%	20%	10%	70%	323.9	-26.9	112.7	52.4	462.1	4,883.9	522.1	-60.0	0.9

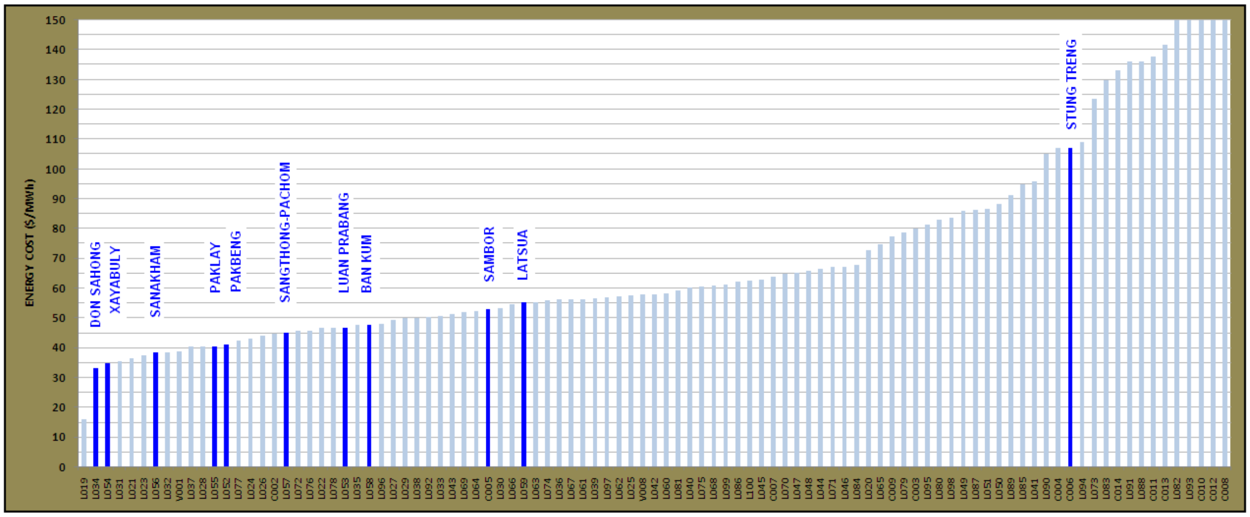
Figure 5.5 shows the ranking of all projects not under operation or construction purely in terms of their energy cost. In this ranking mainstream projects look generally attractive with the exception of Stung Treng in Cambodia. This project is indeed very expensive at nearly 5 M$/MW but this could be in error as some inconsistencies in the data were being investigated by the national consultant at the time this report was prepared.

All the other mainstream projects are under 55 $/MWH which should be competitive in Vietnam and also in Thailand as natural gas generation becomes less available.

These are large projects. Their average capacity is 1,350 MW against the average of 230 MW for the entire sample of future projects. The load growth in Lao PDR or Cambodia is under 100 MW per year so it is clear that these projects cannot be economically absorbed in their systems alone. Therefore, the value of these projects cannot be measured against the high replacement cost of power in Lao PDR or Cambodia but against a combination of domestic and export value of power. This means that the BCR discussed in Chapter 4 which captures both domestic and export value is a better indicator of the likely development merits of these projects.

Figure 5.6 shows two frequency distributions. One shows the distribution of the benefit cost ratio (BCR) of the projects measured as percent of the BCR of the most attractive project. The other shows the cumulative contribution to the energy potential of the entire sample.

Figure 5.5 - Energy Cost of Projects not Under Operation or Construction

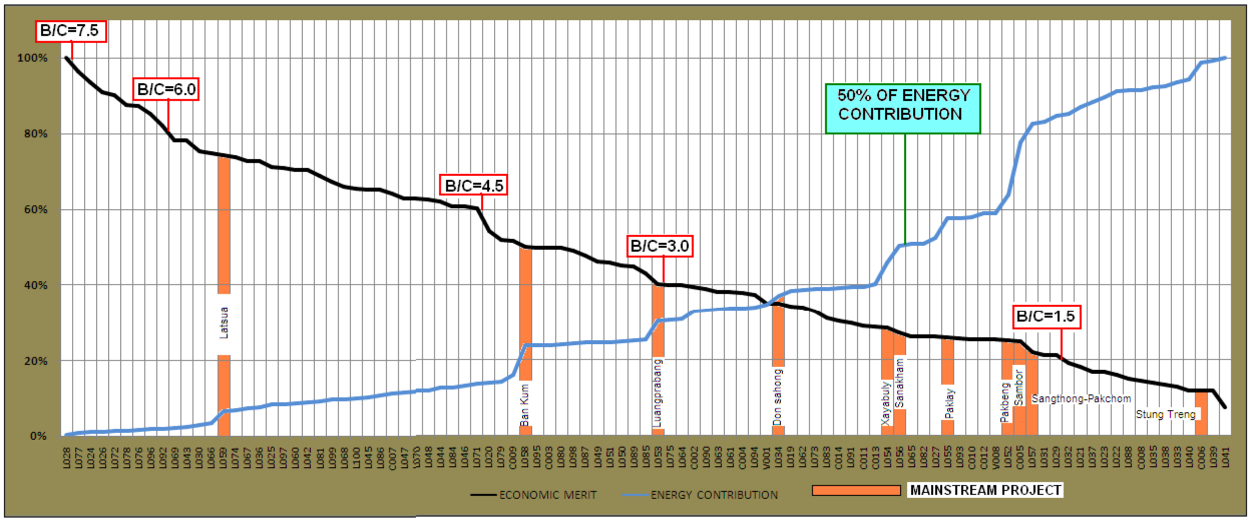


This figure shows a very different picture of economic merit of mainstream projects. Only 2 of the 11 mainstream projects have BCR above 3 which is the sample average.

More detailed examination of the data reveals that these two projects, Latsua and Ban Kum, do not have any significant cost advantage. The reason of their better outlook is that they are the only mainstream projects that are reported to target less than 50% of their production to Thailand. In other words, a higher proportion of the power from these projects is directed to domestic markets and therefore it is valued at the replacement cost of diesel generation which is much higher that the export value.

The reported targeting is of course subject to question. Latsua, being rather small for a mainstream project could be marginally viable for domestic consumption but not so Ban Kum. It is therefore quite likely that the mainstream projects in Figure 5.6 will become less attractive once the destination of their output is clearly established.

Figure 5.6 - Mainstream Dams in a Regional Hydropower Planning Context



5.6 Reflections on the Economic Value of Hydro Exports

It was discussed in Chapter 4 that the regional economic benefits used to determine BCR only reflects a regional perspective and that trade impact on individual economies cancels out between exporter and importer/s. For the exporter country however, the only thing of consequence is its own economy and therefore even a project with low BCR is attractive solely on account of the potential export revenue.

It is beyond the scope of this analysis to evaluate the impact of export revenue to the economies of Lao PDR and Cambodia but it could be useful to reflect on the realities of hydroelectric project finance to estimate how much of that export revenue will actually remain in the economy of the exporting country.

While the economic value of power in Lao PDR and Cambodia is high due to the high cost of alternative energy, the ability of electricity customers to pay cost recovery tariffs is, at best, questionable. It is therefore unlikely that such high economic value will be reflected in the average wholesale price of power anytime soon.

With domestic tariffs below cost recovery level the domestic portion of a large export oriented hydropower project will not contribute very much to its financing. Indeed, it may well burden its financing rather than help it. Most of the financing will probably depend on the export portion, that portion with the lowest economic value but the most "bankability" as is often called the ability to secure debt.

Thus, the importing country, through a power utility, has to secure much of the debt and is also likely that the utility or an international investor has to put much of the project equity. These things are certainly going to be recovered by an export price that leaves very little margin to the exporting country except of course the agreed domestic portion of energy from the project.

It does not really matter how this is done, the export country may levy royalties on exports and use that revenue to pay all or part of the debt or it could be done through any number of financial arrangements. The net result is that as long as the debt remains export revenues and returns on equity are not likely to flow significantly into the exporter economy.

Thus, it would appear that the main appeal to Lao PDR or Cambodia of large hydro with lots of export potential against a smaller one with a majority of energy for domestic consumption is that the second would be more difficult or impossible to finance. This is the reason why several countries not just in South East Asia but other parts of the world look to large export oriented projects for solution to their energy needs.

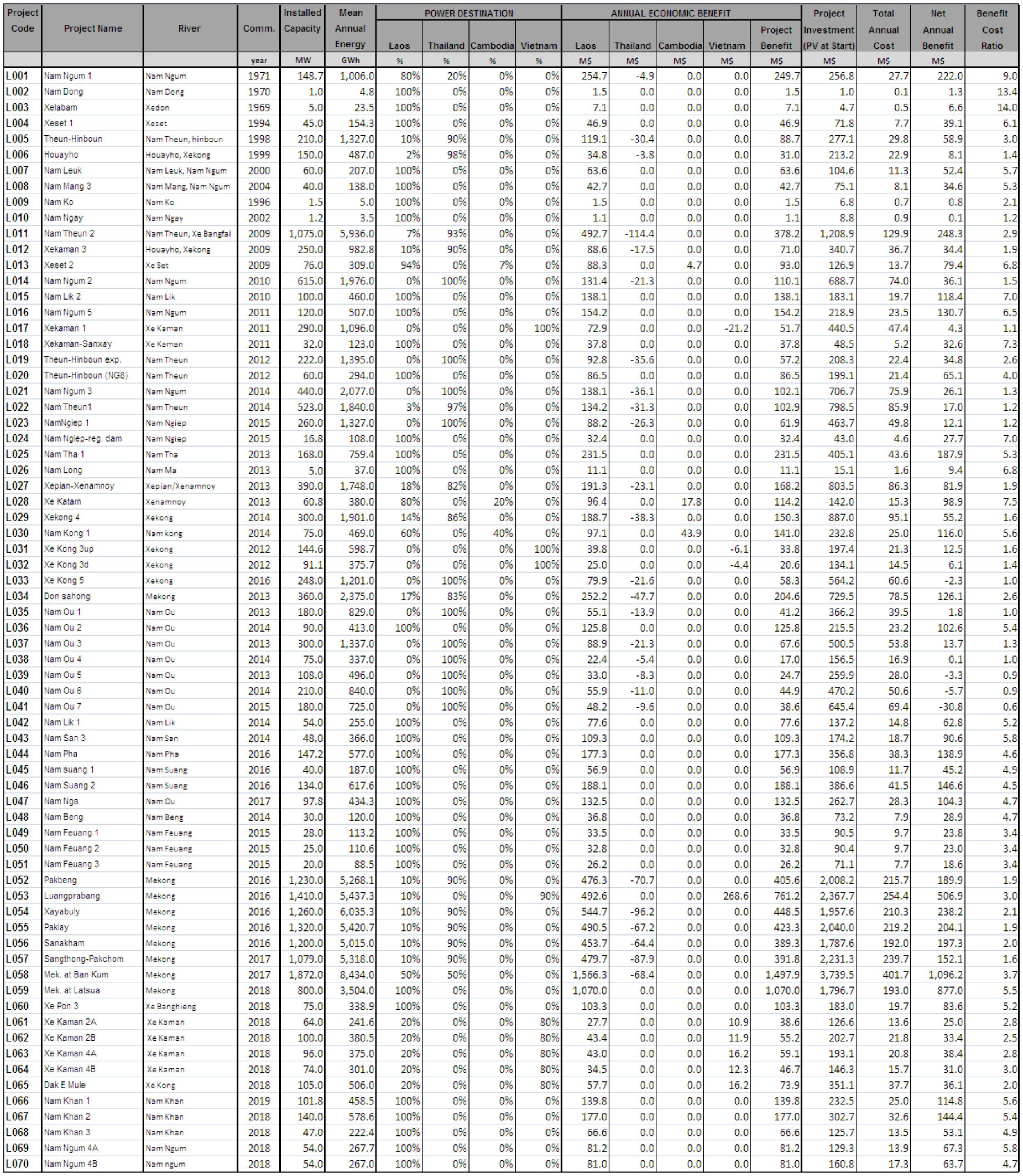
5.7 Conclusions of the Regional Analysis of Mekong Hydropower

While the quantity of potential new Mekong hydropower is not insignificant (12%), in relation to the demand of Vietnam and Thailand by 2020, it is not overwhelming and, more importantly, the impact of its availability on the economies of these markets driving its development is decidedly small. Even considering the entire inventory of identified projects not yet under operation or construction, including all mainstream projects, that hydropower could save not much more than 3% of the cost of power supply.

The cost of energy from Mekong basin hydro projects not yet committed is not particularly low by hydroelectric standards and only about 20% lower than alternative thermal generation options in Vietnam and Thailand. These cost and value realities mean that most projects cannot tolerate long delays or expensive social or environmental mitigation costs and still remain viable. The limited profit margin for these projects cannot be risked in sites that are likely to stir controversy and delay their schedule.

Mainstream projects are relatively more attractive than average in terms of their unit cost of energy but their regional economic benefit is generally less because export value is lower than domestic value in terms of replacement cost. Furthermore, the viability of these projects is highly dependent on their export potential to the extent that the financial and equity structures necessary to develop these projects make it unlikely that the exporting countries will derive much more economic benefit than the off-take of inexpensive energy.

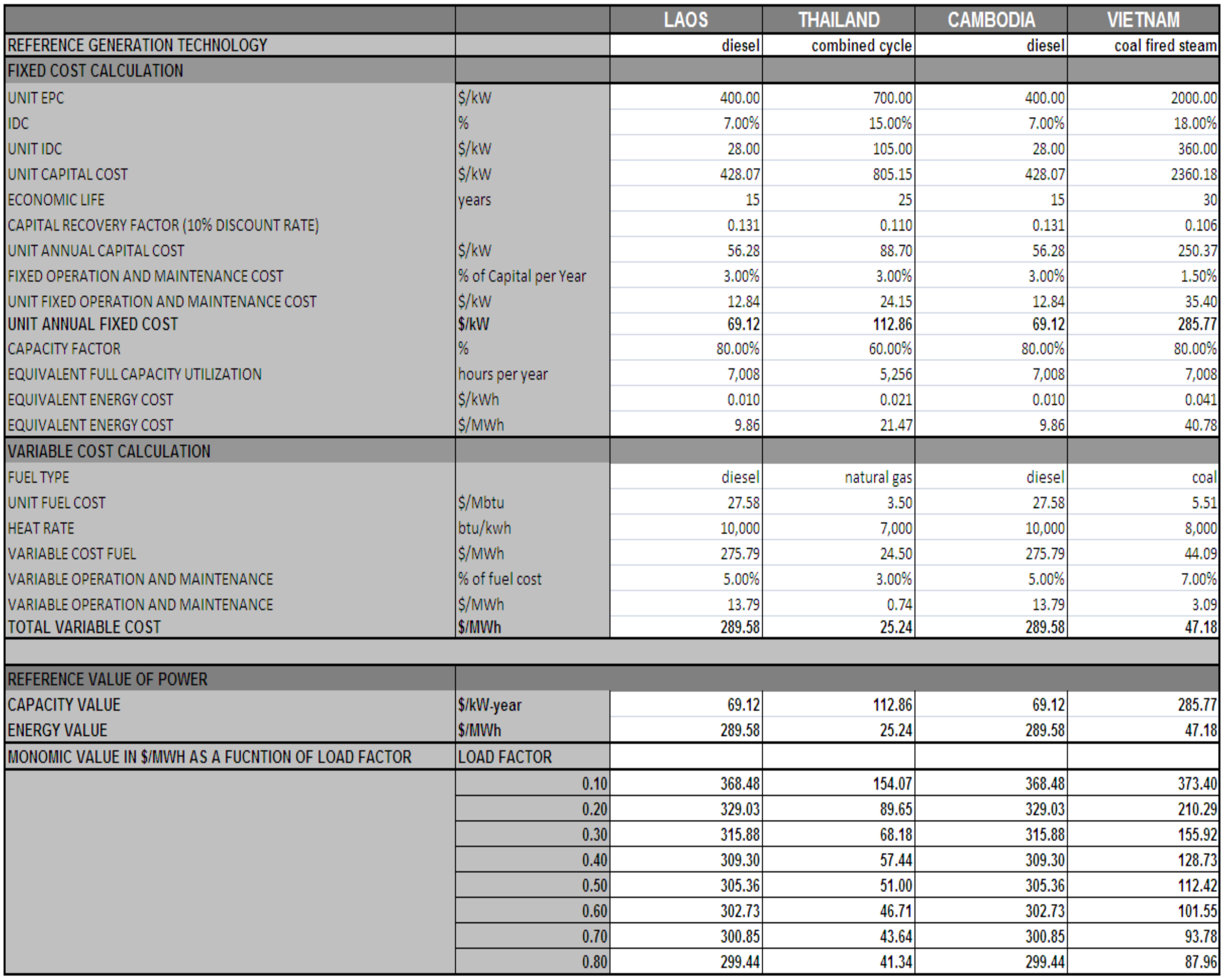
ANNEX A - SUMMARY OF KEY PROJECT DATA AND RESULTS



Project Code	Project Name	River	Comm.	Installed Capacity	Mean Annual Energy	POWER DESTINATION				ANNUAL ECONOMIC BENEFIT					Project Investment (PV at Start)	Total Annual Cost	Net Annual Benefit	Benefit Cost Ratio
						Laos	Thailand	Cambodia	Vietnam	Laos	Thailand	Cambodia	Vietnam	Project Benefit				
			year	MW	GWh	%	%	%	%	M$	M$	M$	M$	M$	M$	M$	M$	
L001	Nam Ngum 1	Nam Ngum	1971	148.7	1,006.0	80%	20%	0%	0%	254.7	-4.9	0.0	0.0	249.7	256.8	27.7	222.0	9.0
L002	Nam Dong	Nam Dong	1970	1.0	4.8	100%	0%	0%	0%	1.5	0.0	0.0	0.0	1.5	1.0	0.1	1.3	13.4
L003	Xelabam	Xedon	1969	5.0	23.5	100%	0%	0%	0%	7.1	0.0	0.0	0.0	7.1	4.7	0.5	6.6	14.0
L004	Xeset 1	Xeset	1994	45.0	154.3	100%	0%	0%	0%	46.9	0.0	0.0	0.0	46.9	71.8	7.7	39.1	6.1
L005	Theun-Hinboun	Nam Theun, hinboun	1998	210.0	1,327.0	10%	90%	0%	0%	119.1	-30.4	0.0	0.0	88.7	277.1	29.8	58.9	3.0
L006	Houayho	Houayho, Xekong	1999	150.0	487.0	2%	98%	0%	0%	34.8	-3.8	0.0	0.0	31.0	213.2	22.9	8.1	1.4
L007	Nam Leuk	Nam Leuk, Nam Ngum	2000	60.0	207.0	100%	0%	0%	0%	63.6	0.0	0.0	0.0	63.6	104.6	11.3	52.4	5.7
L008	Nam Mang 3	Nam Mang, Nam Ngum	2004	40.0	138.0	100%	0%	0%	0%	42.7	0.0	0.0	0.0	42.7	75.1	8.1	34.6	5.3
L009	Nam Ko	Nam Ko	1996	1.5	5.0	100%	0%	0%	0%	1.5	0.0	0.0	0.0	1.5	6.8	0.7	0.8	2.1
L010	Nam Ngay	Nam Ngay	2002	1.2	3.5	100%	0%	0%	0%	1.1	0.0	0.0	0.0	1.1	8.8	0.9	0.1	1.2
L011	Nam Theun 2	Nam Theun, Xe Bangfai	2009	1,075.0	5,936.0	7%	93%	0%	0%	492.7	-114.4	0.0	0.0	378.2	1,208.9	129.9	248.3	2.9
L012	Xekaman 3	Houayho, Xekong	2009	250.0	982.8	10%	90%	0%	0%	88.6	-17.5	0.0	0.0	71.0	340.7	36.7	34.4	1.9
L013	Xeset 2	Xe Set	2009	76.0	309.0	94%	0%	7%	0%	88.3	0.0	4.7	0.0	93.0	126.9	13.7	79.4	6.8
L014	Nam Ngum 2	Nam Ngum	2010	615.0	1,976.0	0%	100%	0%	0%	131.4	-21.3	0.0	0.0	110.1	688.7	74.0	36.1	1.5
L015	Nam Lik 2	Nam Lik	2010	100.0	460.0	100%	0%	0%	0%	138.1	0.0	0.0	0.0	138.1	183.1	19.7	118.4	7.0
L016	Nam Ngum 5	Nam Ngum	2011	120.0	507.0	100%	0%	0%	0%	154.2	0.0	0.0	0.0	154.2	218.9	23.5	130.7	6.5
L017	Xekaman 1	Xe Kaman	2011	290.0	1,096.0	0%	0%	0%	100%	72.9	0.0	0.0	-21.2	51.7	440.5	47.4	4.3	1.1
L018	Xekaman-Sanxay	Xe Kaman	2011	32.0	123.0	100%	0%	0%	0%	37.8	0.0	0.0	0.0	37.8	48.5	5.2	32.6	7.3
L019	Theun-Hinboun exp.	Nam Theun	2012	222.0	1,395.0	0%	100%	0%	0%	92.8	-35.6	0.0	0.0	57.2	208.3	22.4	34.8	2.6
L020	Theun-Hinboun (NG8)	Nam Theun	2012	60.0	294.0	100%	0%	0%	0%	86.5	0.0	0.0	0.0	86.5	199.1	21.4	65.1	4.0
L021	Nam Ngum 3	Nam Ngum	2014	440.0	2,077.0	0%	100%	0%	0%	138.1	-36.1	0.0	0.0	102.1	706.7	75.9	26.1	1.3
L022	Nam Theun1	Nam Theun	2014	523.0	1,840.0	3%	97%	0%	0%	134.2	-31.3	0.0	0.0	102.9	798.5	85.9	17.0	1.2
L023	NamNgiep 1	Nam Ngiep	2015	260.0	1,327.0	0%	100%	0%	0%	88.2	-26.3	0.0	0.0	61.9	463.7	49.8	12.1	1.2
L024	Nam Ngiep-reg. dam	Nam Ngiep	2015	16.8	108.0	100%	0%	0%	0%	32.4	0.0	0.0	0.0	32.4	43.0	4.6	27.7	7.0
L025	Nam Tha 1	Nam Tha	2013	168.0	759.4	100%	0%	0%	0%	231.5	0.0	0.0	0.0	231.5	405.1	43.6	187.9	5.3
L026	Nam Long	Nam Ma	2013	5.0	37.0	100%	0%	0%	0%	11.1	0.0	0.0	0.0	11.1	15.1	1.6	9.4	6.8
L027	Xepian-Xenamnoy	Xepian/Xenamnoy	2013	390.0	1,748.0	18%	82%	0%	0%	191.3	-23.1	0.0	0.0	168.2	803.5	86.3	81.9	1.9
L028	Xe Katam	Xenamnoy	2013	60.8	380.0	80%	0%	20%	0%	96.4	0.0	17.8	0.0	114.2	142.0	15.3	98.9	7.5
L029	Xekong 4	Xekong	2014	300.0	1,901.0	14%	86%	0%	0%	188.7	-38.3	0.0	0.0	150.3	887.0	95.1	55.2	1.6
L030	Nam Kong 1	Nam kong	2014	75.0	469.0	60%	0%	40%	0%	97.1	0.0	43.9	0.0	141.0	232.8	25.0	116.0	5.6
L031	Xe Kong 3up	Xekong	2012	144.6	598.7	0%	0%	0%	100%	39.8	0.0	0.0	-6.1	33.8	197.4	21.3	12.5	1.6
L032	Xe Kong 3d	Xekong	2012	91.1	375.7	0%	0%	0%	100%	25.0	0.0	0.0	-4.4	20.6	134.1	14.5	6.1	1.4
L033	Xe Kong 5	Xekong	2016	248.0	1,201.0	0%	100%	0%	0%	79.9	-21.6	0.0	0.0	58.3	564.2	60.6	-2.3	1.0
L034	Don sahong	Mekong	2013	360.0	2,375.0	17%	83%	0%	0%	252.2	-47.7	0.0	0.0	204.6	729.5	78.5	126.1	2.6
L035	Nam Ou 1	Nam Ou	2013	180.0	829.0	0%	100%	0%	0%	55.1	-13.9	0.0	0.0	41.2	366.2	39.5	1.8	1.0
L036	Nam Ou 2	Nam Ou	2014	90.0	413.0	100%	0%	0%	0%	125.8	0.0	0.0	0.0	125.8	215.5	23.2	102.6	5.4
L037	Nam Ou 3	Nam Ou	2013	300.0	1,337.0	0%	100%	0%	0%	88.9	-21.3	0.0	0.0	67.6	500.5	53.8	13.7	1.3
L038	Nam Ou 4	Nam Ou	2014	75.0	337.0	0%	100%	0%	0%	22.4	-5.4	0.0	0.0	17.0	156.5	16.9	0.1	1.0
L039	Nam Ou 5	Nam Ou	2013	108.0	496.0	0%	100%	0%	0%	33.0	-8.3	0.0	0.0	24.7	259.9	28.0	-3.3	0.9
L040	Nam Ou 6	Nam Ou	2014	210.0	840.0	0%	100%	0%	0%	55.9	-11.0	0.0	0.0	44.9	470.2	50.6	-5.7	0.9
L041	Nam Ou 7	Nam Ou	2015	180.0	725.0	0%	100%	0%	0%	48.2	-9.6	0.0	0.0	38.6	645.4	69.4	-30.8	0.6
L042	Nam Lik 1	Nam Lik	2014	54.0	255.0	100%	0%	0%	0%	77.6	0.0	0.0	0.0	77.6	137.2	14.8	62.8	5.2
L043	Nam San 3	Nam San	2014	48.0	366.0	100%	0%	0%	0%	109.3	0.0	0.0	0.0	109.3	174.2	18.7	90.6	5.8
L044	Nam Pha	Nam Pha	2016	147.2	577.0	100%	0%	0%	0%	177.3	0.0	0.0	0.0	177.3	356.8	38.3	138.9	4.6
L045	Nam suang 1	Nam Suang	2016	40.0	187.0	100%	0%	0%	0%	56.9	0.0	0.0	0.0	56.9	108.9	11.7	45.2	4.9
L046	Nam Suang 2	Nam Suang	2016	134.0	617.6	100%	0%	0%	0%	188.1	0.0	0.0	0.0	188.1	386.6	41.5	146.6	4.5
L047	Nam Nga	Nam Ou	2017	97.8	434.3	100%	0%	0%	0%	132.5	0.0	0.0	0.0	132.5	262.7	28.3	104.3	4.7
L048	Nam Beng	Nam Beng	2014	30.0	120.0	100%	0%	0%	0%	36.8	0.0	0.0	0.0	36.8	73.2	7.9	28.9	4.7
L049	Nam Feuang 1	Nam Feuang	2015	28.0	113.2	100%	0%	0%	0%	33.5	0.0	0.0	0.0	33.5	90.5	9.7	23.8	3.4
L050	Nam Feuang 2	Nam Feuang	2015	25.0	110.6	100%	0%	0%	0%	32.8	0.0	0.0	0.0	32.8	90.4	9.7	23.0	3.4
L051	Nam Feuang 3	Nam Feuang	2015	20.0	88.5	100%	0%	0%	0%	26.2	0.0	0.0	0.0	26.2	71.1	7.7	18.6	3.4
L052	Pakbeng	Mekong	2016	1,230.0	5,268.1	10%	90%	0%	0%	476.3	-70.7	0.0	0.0	405.6	2,008.2	215.7	189.9	1.9
L053	Luangprabang	Mekong	2016	1,410.0	5,437.3	10%	0%	0%	90%	492.6	0.0	0.0	268.6	761.2	2,367.7	254.4	506.9	3.0
L054	Xayabuly	Mekong	2016	1,260.0	6,035.3	10%	90%	0%	0%	544.7	-96.2	0.0	0.0	448.5	1,957.6	210.3	238.2	2.1
L055	Paklay	Mekong	2016	1,320.0	5,420.7	10%	90%	0%	0%	490.5	-67.2	0.0	0.0	423.3	2,040.0	219.2	204.1	1.9
L056	Sanakham	Mekong	2016	1,200.0	5,015.0	10%	90%	0%	0%	453.7	-64.4	0.0	0.0	389.3	1,787.6	192.0	197.3	2.0
L057	Sangthong-Pakchom	Mekong	2017	1,079.0	5,318.0	10%	90%	0%	0%	479.7	-87.9	0.0	0.0	391.8	2,231.3	239.7	152.1	1.6
L058	Mek. at Ban Kum	Mekong	2017	1,872.0	8,434.0	50%	50%	0%	0%	1,566.3	-68.4	0.0	0.0	1,497.9	3,739.5	401.7	1,096.2	3.7
L059	Mek. at Latsua	Mekong	2018	800.0	3,504.0	100%	0%	0%	0%	1,070.0	0.0	0.0	0.0	1,070.0	1,796.7	193.0	877.0	5.5
L060	Xe Pon 3	Xe Banghieng	2018	75.0	338.9	100%	0%	0%	0%	103.3	0.0	0.0	0.0	103.3	183.0	19.7	83.6	5.2
L061	Xe Kaman 2A	Xe Kaman	2018	64.0	241.6	20%	0%	0%	80%	27.7	0.0	0.0	10.9	38.6	126.6	13.6	25.0	2.8
L062	Xe Kaman 2B	Xe Kaman	2018	100.0	380.5	20%	0%	0%	80%	43.4	0.0	0.0	11.9	55.2	202.7	21.8	33.4	2.5
L063	Xe Kaman 4A	Xe Kaman	2018	96.0	375.0	20%	0%	0%	80%	43.0	0.0	0.0	16.2	59.1	193.1	20.8	38.4	2.8
L064	Xe Kaman 4B	Xe Kaman	2018	74.0	301.0	20%	0%	0%	80%	34.5	0.0	0.0	12.3	46.7	146.3	15.7	31.0	3.0
L065	Dak E Mule	Xe Kong	2018	105.0	506.0	20%	0%	0%	80%	57.7	0.0	0.0	16.2	73.9	351.1	37.7	36.1	2.0
L066	Nam Khan 1	Nam Khan	2019	101.8	458.5	100%	0%	0%	0%	139.8	0.0	0.0	0.0	139.8	232.5	25.0	114.8	5.6
L067	Nam Khan 2	Nam Khan	2018	140.0	578.6	100%	0%	0%	0%	177.0	0.0	0.0	0.0	177.0	302.7	32.6	144.4	5.4
L068	Nam Khan 3	Nam Khan	2018	47.0	222.4	100%	0%	0%	0%	66.6	0.0	0.0	0.0	66.6	125.7	13.5	53.1	4.9
L069	Nam Ngum 4A	Nam Ngum	2018	54.0	267.7	100%	0%	0%	0%	81.2	0.0	0.0	0.0	81.2	129.3	13.9	67.3	5.8
L070	Nam Ngum 4B	Nam ngum	2018	54.0	267.0	100%	0%	0%	0%	81.0	0.0	0.0	0.0	81.0	160.8	17.3	63.7	4.7

Project Code	Project Name	River	Comm.	Installed Capacity	Mean Annual Energy	POWER DESTINATION				ANNUAL ECONOMIC BENEFIT					Project Investment (PV at Start)	Total Annual Cost	Net Annual Benefit	Benefit Cost Ratio
						Laos	Thailand	Cambodia	Vietnam	Laos	Thailand	Cambodia	Vietnam	Project Benefit				
			year	MW	GWh	%	%	%	%	M$	M$	M$	M$	M$	M$	M$	M$	
L071	Nam Ngum, Lwr. dam	Nam ngum	2018	90.0	526.0	100%	0%	0%	0%	158.5	0.0	0.0	0.0	158.5	327.9	35.3	123.2	4.5
L072	Nam Pay	Nam ngum	2019	62.0	242.6	100%	0%	0%	0%	74.5	0.0	0.0	0.0	74.5	102.8	11.1	63.5	6.7
L073	Nam Mang 1	Nam Mang	2019	51.0	235.3	100%	0%	0%	0%	71.7	0.0	0.0	0.0	71.7	270.4	29.1	42.6	2.5
L074	Nam Pouy	Nam Pouy	2019	43.7	172.0	100%	0%	0%	0%	52.8	0.0	0.0	0.0	52.8	89.2	9.6	43.2	5.5
L075	Nam Poun	Nam Poun	2019	84.9	342.0	50%	50%	0%	0%	63.8	-2.3	0.0	0.0	61.6	192.4	20.7	40.9	3.0
L076	Nam Ngao	Nam Ou	2019	20.0	155.0	100%	0%	0%	0%	46.3	0.0	0.0	0.0	46.3	65.8	7.1	39.2	6.5
L077	Nam Chian	Nam Ngiep	2019	148.0	627.2	100%	0%	0%	0%	191.9	0.0	0.0	0.0	191.9	247.6	26.6	165.2	7.2
L078	Nam Ngieu	Nam Ngiep	2020	30.4	132.3	100%	0%	0%	0%	40.4	0.0	0.0	0.0	40.4	57.4	6.2	34.2	6.5
L079	Nam Pot	Nam Ngiep	2018	22.0	99.5	100%	0%	0%	0%	30.3	0.0	0.0	0.0	30.3	72.5	7.8	22.5	3.9
L080	Nam San 3B	Nam San	2020	38.0	141.0	100%	0%	0%	0%	43.5	0.0	0.0	0.0	43.5	108.6	11.7	31.8	3.7
L081	Nam San 2	Nam San	2020	60.0	290.7	100%	0%	0%	0%	88.3	0.0	0.0	0.0	88.3	159.6	17.2	71.1	5.1
L082	Nam Pok	Nam Ou	2020	2.6	14.4	100%	0%	0%	0%	4.4	0.0	0.0	0.0	4.4	20.7	2.2	2.1	1.9
L083	Nam Phak	Nam Ou	2018	5.1	28.3	100%	0%	0%	0%	8.5	0.0	0.0	0.0	8.5	34.1	3.7	4.9	2.3
L084	Nam Hinboun 1	Nam Hinboun	2020	45.0	173.0	100%	0%	0%	0%	53.2	0.0	0.0	0.0	53.2	109.1	11.7	41.5	4.5
L085	Nam Hinboun 2	Nam Hinboun	2019	13.0	58.5	100%	0%	0%	0%	17.8	0.0	0.0	0.0	17.8	51.4	5.5	12.3	3.2
L086	Xe Bang Fai	Xe Bang Fai	2019	107.0	564.2	100%	0%	0%	0%	170.6	0.0	0.0	0.0	170.6	326.4	35.1	135.4	4.9
L087	Xe Neua	Xe Bang Fai	2020	60.0	230.0	100%	0%	0%	0%	70.7	0.0	0.0	0.0	70.7	184.3	19.8	50.9	3.6
L088	Nam Theun 4	Nam Theun	2020	30.0	130.5	20%	0%	0%	80%	14.9	0.0	0.0	4.8	19.8	164.7	17.7	2.0	1.1
L089	Nam Mouan	Nam Theun	2020	110.0	452.2	100%	0%	0%	0%	138.4	0.0	0.0	0.0	138.4	383.8	41.3	97.1	3.4
L090	Xe Bang Hieng 2	Xe Bang Hieng	2020	16.0	73.5	100%	0%	0%	0%	22.4	0.0	0.0	0.0	22.4	71.7	7.7	14.7	2.9
L091	Xedon 2	Xe Don	2021	54.0	319.0	100%	0%	0%	0%	96.1	0.0	0.0	0.0	96.1	403.2	43.4	52.7	2.2
L092	Xe Set 3	Xe Don	2020	20.0	74.0	100%	0%	0%	0%	22.8	0.0	0.0	0.0	22.8	34.5	3.7	19.0	6.1
L093	Xe Bang Nouan	Xe Bang Nouan	2021	18.0	79.1	100%	0%	0%	0%	24.2	0.0	0.0	0.0	24.2	117.2	12.6	11.5	1.9
L094	Xe Lanong 1	Xe Bang Hieng	2021	30.0	153.5	100%	0%	0%	0%	46.5	0.0	0.0	0.0	46.5	155.4	16.7	29.8	2.8
L095	Xe Lanong 2	Xe Bang Hieng	2018	20.0	103.5	100%	0%	0%	0%	31.4	0.0	0.0	0.0	31.4	78.3	8.4	22.9	3.7
L096	Nam Phak	Nam Phak	2018	75.0	307.0	100%	0%	0%	0%	94.1	0.0	0.0	0.0	94.1	137.3	14.8	79.3	6.4
L097	Xe Nam Noy 5	Xe Kong	2022	20.0	124.0	100%	0%	0%	0%	37.3	0.0	0.0	0.0	37.3	65.5	7.1	30.2	5.3
L098	Houay Lamphan	Xe Kong	2018	60.0	264.4	100%	0%	0%	0%	80.7	0.0	0.0	0.0	80.7	205.4	22.1	58.6	3.7
L099	Nam Kong 2	Xe Kong	2021	74.0	309.5	100%	0%	0%	0%	94.7	0.0	0.0	0.0	94.7	175.5	18.9	75.9	5.0
L100	Xe Xou	Xe Kong	2022	63.4	286.2	100%	0%	0%	0%	87.3	0.0	0.0	0.0	87.3	165.8	17.8	69.4	4.9
C001	O Chum 2	O Chum	1992	1.0	3.0	0%	0%	100%	0%	0.2	0.0	0.7	0.0	0.9	7.0	0.8	0.1	1.2
C002	Se San2 + Sre Pok 2	Se San	2016	480.0	2,311.8	0%	0%	30%	70%	153.7	0.0	157.2	-7.2	303.8	960.9	103.1	200.7	2.9
C003	Battambang 1	Sangker	NA	24.0	123.2	0%	0%	100%	0%	8.2	0.0	28.4	0.0	36.6	91.6	9.8	26.8	3.7
C004	Battambang 2	Sangker	NA	22.0	114.4	0%	0%	100%	0%	7.6	0.0	27.0	0.0	34.6	113.9	12.2	22.4	2.8
C005	Sambor	Mekong	2020	3,300.0	14,870.0	0%	20%	10%	70%	988.9	-76.9	345.7	205.0	1,462.7	7,394.1	787.6	675.1	1.9
C006	Stung Treng	Mekong	NA	980.0	4,870.0	0%	20%	10%	70%	323.9	-26.9	112.7	52.4	462.1	4,883.9	522.1	-60.0	0.9
C007	Pursat 1	Pursat	NA	100.0	442.9	0%	0%	100%	0%	29.5	0.0	105.4	0.0	134.8	261.8	28.2	106.6	4.8
C008	Pursat 2	Pursat	NA	10.0	42.1	0%	0%	100%	0%	2.8	0.0	10.1	0.0	12.9	112.0	12.1	0.8	1.1
C009	Lower Se San 3	Se San	NA	243.0	1,977.0	0%	0%	100%	0%	131.5	0.0	456.6	0.0	588.0	1,423.3	152.7	435.4	3.9
C010	Prek Liang 1	Prek Liang	NA	35.0	189.0	0%	0%	100%	0%	12.6	0.0	44.5	0.0	57.1	280.7	30.2	26.9	1.9
C011	Prek Liang 2	Prek Liang	NA	25.0	186.4	0%	0%	100%	0%	12.4	0.0	43.2	0.0	55.6	238.4	25.6	30.0	2.2
C012	Lower Sre Pok 3	Sre Pok	NA	204.0	1,101.6	0%	0%	100%	0%	73.3	0.0	259.6	0.0	332.8	1,641.7	176.1	156.7	1.9
C013	Lower Sre Pok 4	Sre Pok	NA	143.0	772.2	0%	0%	100%	0%	51.4	0.0	182.1	0.0	233.5	1,019.0	109.3	124.2	2.1
C014	Stung Sen	Stung Sen	NA	23.0	124.2	0%	0%	100%	0%	8.3	0.0	29.3	0.0	37.6	153.8	16.5	21.0	2.3
V001	Upper Kontum	Se San/ Dak Bla/Dak Ngh	2011	250.0	1,056.4	0%	0%	0%	100%	70.3	0.0	0.0	36.7	107.0	380.8	41.0	66.0	2.6
V002	Plei Krong	Se San/ Kroong Po Ko	2008	100.0	417.2	0%	0%	0%	100%	27.7	0.0	0.0	14.8	42.5	226.6	24.3	18.2	1.7
V003	Yali	Se San	2001	720.0	3,658.6	0%	0%	0%	100%	243.3	0.0	0.0	93.9	337.2	741.6	79.4	257.8	4.2
V004	Se San 3	Se San	2006	260.0	1,224.6	0%	0%	0%	100%	81.4	0.0	0.0	35.8	117.2	300.6	32.3	84.9	3.6
V005	Se San 3A	Se San	2007	96.0	475.0	0%	0%	0%	100%	31.6	0.0	0.0	12.8	44.4	129.2	13.9	30.5	3.2
V006	Se San 4	Se San	2009	360.0	1,420.1	0%	0%	0%	100%	94.4	0.0	0.0	54.9	149.3	403.5	43.4	105.9	3.4
V007	Se San 4A	Se San	2008	0.0	0.0	0%	0%	0%	100%	0.0	0.0	0.0	0.0	0.0	17.5	1.9	-1.9	0.0
V008	Duc Xuyen	Sre Pok/Krong Kno		49.0	181.3	0%	0%	0%	100%	12.1	0.0	0.0	7.7	19.8	97.4	10.5	9.3	1.9
V009	Buon Tua Srah	Sre Pok/Krong Kno	2009	86.0	358.6	0%	0%	0%	100%	23.8	0.0	0.0	12.7	36.6	155.0	16.7	19.9	2.2
V010	Buon Kuop	Sre Pok	2009	280.0	1,455.2	0%	0%	0%	100%	96.8	0.0	0.0	35.9	132.7	369.4	39.7	93.0	3.3
V011	Dray Hlinh 2	Sre Pok	2007	16.0	85.0	0%	0%	0%	100%	5.7	0.0	0.0	2.0	7.7	19.4	2.1	5.6	3.7
V012	Sre Pok 3	Sre Pok	2009	220.0	1,060.2	0%	0%	0%	100%	70.5	0.0	0.0	27.9	98.4	325.1	35.0	63.5	2.8
V013	Sre Pok 4	Sre Pok	2009	70.0	329.3	0%	0%	0%	100%	21.9	0.0	0.0	9.3	31.2	58.9	6.3	24.8	4.9
V014	Dray Hlinh 1	Sre Pok	1990	12.0	94.0	0%	0%	0%	100%	6.3	0.0	0.0	0.9	7.2	0.0	0.0	7.2	0.0
T001	Chulabhorn	Nam Phrom	1972	40.0	93.0	0%	100%	0%	0%	6.2	-2.6	0.0	0.0	3.6	45.7	4.9	-1.4	0.7
T002	Huai Kum	Nam Phrom	1982	1.2	2.0	0%	100%	0%	0%	0.1	-0.1	0.0	0.0	0.1	19.6	2.1	-2.0	0.0
T003	Nam Pung	Nam Pung	1965	6.3	15.0	0%	100%	0%	0%	1.0	-0.4	0.0	0.0	0.6	14.6	1.6	-1.0	0.4
T004	Pak Mun	Mun	1994	136.0	280.0	0%	100%	0%	0%	18.6	-7.9	0.0	0.0	10.7	491.1	52.8	-42.1	0.2
T005	Sirindhorn	Lam Dom Noi	1971	36.0	86.0	0%	100%	0%	0%	5.7	-2.4	0.0	0.0	3.3	45.8	4.9	-1.6	0.7
T006	Ubol Ratana	Nam Pong	1966	25.2	56.0	0%	100%	0%	0%	3.7	-1.6	0.0	0.0	2.1	65.0	7.0	-4.9	0.3
T007	Lam Ta Khong P.S.	Lam Ta Khong	2001	500.0	0.0	0%	100%	0%	0%	0.0	0.0	0.0	0.0	0.0	1,258.6	135.0	-135.0	0.0

ANNEX B - REPLACEMENT COST OF POWER



		LAOS	THAILAND	CAMBODIA	VIETNAM
REFERENCE GENERATION TECHNOLOGY		diesel	combined cycle	diesel	coal fired steam
FIXED COST CALCULATION					
UNIT EPC	$/kW	400.00	700.00	400.00	2000.00
IDC	%	7.00%	15.00%	7.00%	18.00%
UNIT IDC	$/kW	28.00	105.00	28.00	360.00
UNIT CAPITAL COST	$/kW	428.07	805.15	428.07	2360.18
ECONOMIC LIFE	years	15	25	15	30
CAPITAL RECOVERY FACTOR (10% DISCOUNT RATE)		0.131	0.110	0.131	0.106
UNIT ANNUAL CAPITAL COST	$/kW	56.28	88.70	56.28	250.37
FIXED OPERATION AND MAINTENANCE COST	% of Capital per Year	3.00%	3.00%	3.00%	1.50%
UNIT FIXED OPERATION AND MAINTENANCE COST	$/kW	12.84	24.15	12.84	35.40
UNIT ANNUAL FIXED COST	**$/kW**	**69.12**	**112.86**	**69.12**	**285.77**
CAPACITY FACTOR	%	80.00%	60.00%	80.00%	80.00%
EQUIVALENT FULL CAPACITY UTILIZATION	hours per year	7,008	5,256	7,008	7,008
EQUIVALENT ENERGY COST	$/kWh	0.010	0.021	0.010	0.041
EQUIVALENT ENERGY COST	$/MWh	9.86	21.47	9.86	40.78
VARIABLE COST CALCULATION					
FUEL TYPE		diesel	natural gas	diesel	coal
UNIT FUEL COST	$/Mbtu	27.58	3.50	27.58	5.51
HEAT RATE	btu/kwh	10,000	7,000	10,000	8,000
VARIABLE COST FUEL	$/MWh	275.79	24.50	275.79	44.09
VARIABLE OPERATION AND MAINTENANCE	% of fuel cost	5.00%	3.00%	5.00%	7.00%
VARIABLE OPERATION AND MAINTENANCE	$/MWh	13.79	0.74	13.79	3.09
TOTAL VARIABLE COST	**$/MWh**	**289.58**	**25.24**	**289.58**	**47.18**
REFERENCE VALUE OF POWER					
CAPACITY VALUE	**$/kW-year**	**69.12**	**112.86**	**69.12**	**285.77**
ENERGY VALUE	**$/MWh**	**289.58**	**25.24**	**289.58**	**47.18**
MONOMIC VALUE IN $/MWH AS A FUCNTION OF LOAD FACTOR	**LOAD FACTOR**				
	0.10	**368.48**	**154.07**	**368.48**	**373.40**
	0.20	**329.03**	**89.65**	**329.03**	**210.29**
	0.30	**315.88**	**68.18**	**315.88**	**155.92**
	0.40	**309.30**	**57.44**	**309.30**	**128.73**
	0.50	**305.36**	**51.00**	**305.36**	**112.42**
	0.60	**302.73**	**46.71**	**302.73**	**101.55**
	0.70	**300.85**	**43.64**	**300.85**	**93.78**
	0.80	**299.44**	**41.34**	**299.44**	**87.96**