RTE International
Tour Initiale
1, Terrasse Bellini
TSA 41000
92929 La Défense CEDEX

Tel: +33-1-41 45 66 88
Fax: +33-1-41 02 28 67
e-Mail: michel.caubet@orange.fr

http://www.rte-france.com

in Association with:

EDF
Hydro Engineering Center (France)

Nord Pool Consulting AS (Norway)

Power Planning Associates Ltd (UK)

Franklin Law Firm (France)

Centre for Energy Environment Resources Development (Thailand)

Project Office in Thailand
SLD Building (14th floor)
13 Soi Saladaeng 1, Silom Sub-district
Bangrak, Bangkok
Thailand 10500
Tel: +66 (0)2 235 58 17
Fax: +66 (0)2 236 95 74
e-Mail: t.lefevre@ceerd.net

http://www.gms-powertrade.net

ASIAN DEVELOPMENT BANK

RETA No. 6440

"Facilitating Regional Power Trading and Environmentally Sustainable Development of Electricity Infrastructure in the Greater Mekong Subregion"

FINAL REPORT

Component 1

Module 1

UPDATE OF THE GMS REGIONAL MASTER PLAN

EXECUTIVE SUMMARY

DATE: 15 October 2010

LIST OF UNITS AND ABBREVIATIONS

CCGT	Combined Cycle Gas Turbine
CUE	Cost of Unserved Energy
DO	Diesel Oil
FDI	Foreign direct investment
GJ	Giga Joule
GWh	Giga Watt hours
HV	High Voltage
HFO	Heavy Fuel Oil
HPP	Hydro power plant
IPP	Independent Power Producer
LOLP	Loss of Load Probability
LV	Low Voltage
m	meter
MV	medium voltage
MW	Megawatts
NG	Natural Gas
NE	National experts
O&M	Operating and Maintenance
NPV	Net Present Value
TPP	Thermal Power Plant

LIST OF ACRONYMS

EDL / EdL	Electricité du Laos
EGAT	Electricity Generation Authority of Thailand
EVN	Electricity of Vietnam
GMS	Greater Mekong Sub-region
Lao PDR	Lao People’s Democratic Republic
MEM	Ministry of Energy and Mines (Lao PDR)
MIME	Ministry of Industry, Mines and Energy of Cambodia)
PDP	Power Development master Plan
PEA	Provincial Electricity Authority of Thailand
PRC	People’s Republic of China

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

1. ORGANISATION OF THE REPORT

The present report presents the overview of Module 1 activities and findings. It is organised as follows:

- Objectives and organisation of Module 1
- Tasks 1 & 2 overview: data collection et "country reports".
- Task 3 overview: Review and update of national Power Development Plans (PDP).
- Task 4 overview: Generation planning criteria.
- Task 5 overview: Update of GMS regional Master Plan.

The conclusions and recommendations from the Study are presented at the end of this overview (cf § 6.4and § 6.5).

2. OBJECTIVES AND ORGANISATION OF MODULE 1 ACTIVITIES

2.1 OBJECTIVES AND ORGANISATION

2.1.1 OBJECTIVES

Within the general frame of work of the present Regional Technical Assistance (RETA 6440), the objective of Module 1 is to update the indicative Regional Master Plan in the GMS countries, for the period 2009 to 2025, by simulating the regional power systems with existing and potential power interconnections.

A first indicative Master Plan of the GMS has been established in 2002 by Norconsult , subsequently updated in 2008 by Soluziona Mercados . The present study will be carried out in the continuity of these previous studies and will largely bear on their findings.

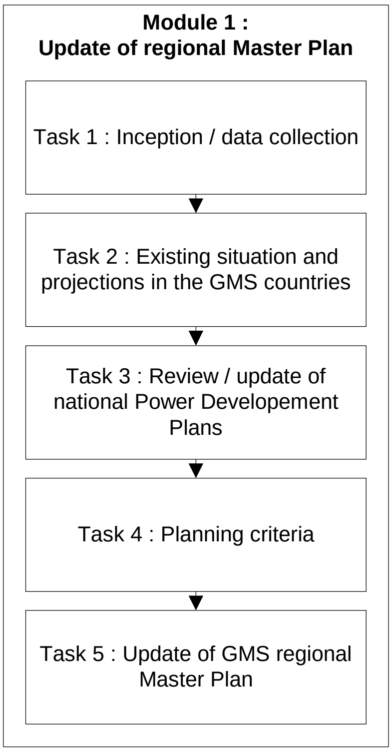
Within the general context of the uncertainties in global economic evolution over the time horizon considered, 2009-2025 (pace of development of each country, evolution of commodity prices, financing resources available, development of each individual generation of interconnection project), the general objectives of the indicative Regional Master Plan are also :

- to facilitate a convergence on a shared vision of a realistic, consistent and effective target interconnection network for the GMS countries in the next 15 years,

- to identify key opportunities and most important issues for the countries and region,

- to identify short terms actions (list of interconnection priority projects).

The Consultant have broken Module 1 into the following tasks:



These tasks were carried out in continuity with the 2002 and 2008 Master Plan studies (e.g. in relation to scenario identification and the selection of interconnection options) and in close cooperation with the Utility representatives and the GMS Working Group.

As per the TOR, transmission studies (load flow, stability, short-circuit, etc), impacts of power trades on national transmission systems, and identification of transmission reinforcements required within each country, are not within the scope of the project. However, also as indicated in the TOR, the requirements and specifications for further transmission studies (between countries and / or within each country) will be identified in Module 3 (Transmission Studies).

2.1.2 TASK 1 : DATA COLLECTION, REVIEW AND UPDATE

Task 1 was the starting point for the Consultant's activities within the project. The purposes of Task 1 were:

- to collect, review and update the data for the Study,

- to collect and review the latest relevant studies (interconnection projects and major power projects).

This Task was carried out by the National Experts, including the associated Task 1 country reports, under the supervision of the International Expert.

NB :

a - These tasks largely built on the previous studies and already collected data (e.g. TA, AFD 2006: Technical Assistance for Greater Mekong Subregion Power Trade Coordination and Development) b - Accordingly, the Consultant has planned his approach on the assumption that a database gathering all data relevant to the present Study exists and is readily available. If this database was incomplete or obsolete, this would impact the costs and delays of the projects. Furthermore, the Consultant assumes that the data sets used to run the previous simulations with the planning software (i.e SDDP input files used in Soluziona Mercados runs), will be made available at no extra cost or delay.

Output of Task 1: Task 1 "Data collection report" for each country.

2.1.3 TASK 2 : EXISTING SITUATION AND PROJECTIONS

The objective of the Task 2 was to establish, on the basis of the data collected in Task 1, the global picture on which the regional master plan study will be grounded. It covers the following three sub-tasks:

Sub-Task 2.1: Power demand forecast in each of the GMS country

- Overview of the economic situation (GDP, demography, electrification ratio, etc);
- Past demand evolution;
- Current load and variation patterns;
- System losses;
- Power demand projections (annual energy, peak load, load factor, losses);

The study is carried out on the most probable scenario;

Sub-Task 2.2: Power sector profile in each of the GMS country

- Overview of the economical situation (GDP, demography, electrification ratio, etc);
- Primary energy potential (volume, potential location, imports, etc.);
- Existing and planned generation mix (TPP, HPP, renewal energy, etc.);
- Generation candidates (TPP, HPP, renewal, etc.);
- Existing national Power Development Plan.
- Existing, planned and potential power trades.

Sub-Task 2.3: Fuel price projections

- Availability of fuels, current fuel price, fuel policy in each of the GMS country;
- Fuel calorific values
- International fuel price projections and fuel price projections to be considered in the Study.

These tasks were carried out by National Experts, including the writing of Task 2 country reports, under the supervision of the International Expert. The International Expert was responsible for Task 3 report on "Fuel price projection to be considered in the Study".

Output of Task 2: Task 2 "Existing situation and projections report" for each country.

2.1.4 TASK 3: REVIEW AND UPADTE OF NATIONAL POWER DEVELOPMENT PLANS (PDPS)

According to the Clarifications provided by ADB on June 24, 2008, China, Lao PDR, Thailand and Viet Nam had updated PDP over the period 2009-2025. Cambodia was the only country where the PDP is to be updated.

Therefore, the Consultant task was to:

- review the existing national PDPs of China, Lao PDR, Thailand and Viet Nam;
- assist Cambodia PDP in the update of Cambodia PDP (training on planning methodology and software, delivery of the planning software, assistance in the update of the PDP).

Output of Task 3:

- Task 3 "Training Report" and "Draft version of Cambodia 2009 PDP"
- Task 3 "Review of national PDPs".

2.1.5 TASK 4: INVESTMENT PLANNING CRITERIA

The Consultants of Module 1 and Module 3 (Transmission) reviewed the generation and transmission planning criteria under use by each of the GMS countries and proposed common generation and transmission planning criteria to be adopted for the interconnected system for the purpose of the present Study.

Output of Task 4: "Investment criteria plan Report".

2.1.6 LINKS WITH MODULES 2 AND 3 ACTIVITIES

Module 1 activities have been carried out in coordination with Modules 2 and 3 activities:

. Module 3 “Transmission Studies” provided to Module 1:

- The list of existing, committed, candidates interconnection projects,
- Investment costs and transmission capacities of generic interconnection projects.

. Module 1 provided to Module 2 “Evaluation of benefits”:

- The detailed outputs of the OPTGEN simulation run (marginal cost, generation, demand, power exchanges, etc).

In order to evaluate and compare the benefits provided by the interconnection projects in the various scenarios.

2.1.7 TASK 5: UPDATE OF THE GMS REGIONAL MASTER PLAN

The purpose of this task was to refine the previous indicative regional Master Plan in order to come up with an updated regional Master Plan, based on new or updated data, and on country representatives' feedbacks or analysis. The Consultant broke this task into the following sub-tasks:

Sub-task 5.1:

- Analysis of the potential power trades between the GMS countries;

Sub-task 5.2:

- Review of the indicative regional master plan prepared under AFD TA 2006.

- Update of list and characteristics of the regional generation and interconnection candidates.

- Determination of most relevant regional scenarios to be considered in Sub-Task 5.2 and identification of target interconnection scheme for year 2025.

- Validation by the Client and countries' representatives of the list of scenarios to be simulated.

Sub-task 5.3: Update of the regional master plan for the period 2009-2025:

- Simulation of the regional power system for the selected scenarios.

- Ranking of the interconnection projects, list of priority projects for the period 2009-2015.

- Conclusions and recommendations

2.1.8 ORGANISATION OF THE REPORTS PROVIDED BY MODULE 1

Module 1 works and outputs were gathered in the following reports:

Task	Name of the report	Number of report
	Executive summary	
1	Data collection	One report by country
2.1	Demand projection	One report by country
2.2	Power system	One report by country
2.3	Fuel resources	One report by country
2.3	Fuel price projections	One report for the GMS region

2.4	Summary of data and hypotheses	One report by country
3	National PDP review	One report by country (China, Laos, Thailand, Vietnam). No data available for Myanmar.
	Cambodia PDP assistance	One report for Cambodia
4	Investment planning criteria	One report for the GMS region
5.1 & 5.2	Potential power trade / Review of Master Plan 2008	One report for the GMS region
5.3	Regional Master Plan report	One report for the GMS region

Table 2.1-1 : List of Module 1 reports

2.1.9 VALIDATION STEPS AND WORKSHOPS FOR MODULE 1

Workshops	Associated Reports	Objectives
WS1: Inception	Inception	Updated work plan (including Workshops and validation steps).
WS2	Tasks 1 & 2	Validation of country data and hypotheses by Client and country representatives.
WS3	Tasks 3, 4, 5.1, 5.2	Validation of national PDPs (Task 3) and planning criteria (Task 4). Presentation of Task 5.1 & 5.2:"Potential power trade" and "Review of previous regional Master Plan". Validation of the scenarios to be considered in the Regional Master Plan.
WS4: Interim results	Task 5.3	Presentation of interim results. Validation of complements to be made.
WS5: Final workshop	Task 5.3	Presentation of final results.

Table 2.1-2 : List of Module 1 Workshops and validation steps

2.2 DIFFICULTIES ENCOUNTERED IN MODULE 1 ACTIVITIES

A number of unexpected difficulties were encountered during Module 1 activities, accordingly the Consultant had to take assumptions, fill the information gap or reduce the number of sensitivity cases:

- There was no regional data base gathering all the data necessary for the simulation of the regional power system.

- The SDDP modelling used in the previous Master Plan was too aggregated to be used for the present Study.

- While the PDP were declared to be readily available for all countries (except Cambodia), the Consultant received four different versions of the Laos PDP, and no PDP for the North / Center / South Vietnam regions.

However, the Consultant considers the Study reached its objective and points correctly the most important issues at stake.

3. TASKS 1 & 2: COUNTRY DATA AND PROJECTIONS

3.1 DATA COLLECTION AND COUNTRY REPORTS

In order to avoid unnecessary repetition, the most relevant outputs of this task (country demand projection, country resources and potential, country generation mixes) are presented in the Task 5 overview.

3.2 FUEL PRICE PROJECTIONS

Use of international fuel prices:

Most of the countries in the GMS region will have to import at least a part of the fossil fuels used in power generation in the medium term (coal in Cambodia, coal for the coastal provinces of China, Natural Gas and coal in Thailand, coal in Vietnam).

Apart of the HPP projects, the main fossil fuels (and TPP projects) in competition through the development of power trades in the GMS region will be:

- Gas-fired CCGT in Thailand,
- Coal-fired STPP in Cambodia, China and Vietnam.

The relevant fuel prices to properly evaluate the power trade potential in the GMS regional are the international fuel prices. Indeed:

- The use of subsidized fuel prices would mean power exports are subsidized by the exporting country (to the benefit of the importing country ...). Subsidies are a tool for a state to temporally promote the development of some parts of the economy, or to reallocate part of the national income of a country to support parts of the population. Generally speaking subsidies are not to be considered in economic studies when the point of view is the one of the country, and where the question is to find the best option for the country on the basis of the real cost paid by the country.
- The use of a fuel price or tariff set by government would present the same disadvantage and distortion.
- In the same way, no taxes are considered, the point of view being the one of the country.
- From the economic point of view, incremental exports from fossil fuels-fired TPP in one country would mean incremental fossils fuel import to supply fuel to these TPP.

- The international price reflects the fact that the fuels available in a country could, either be burned in the power plant or sold to the market. Accordingly, the market price is the best estimation of the real value of the fuels available in the country.

Fuel price projections:

For the update of the GMS regional Master Plan, the Consultant recommends to consider the following fuel price projections based mainly on the works of the World Energy Outlook[1] 2008 and 2009, and of the International Energy Outlook[2] 2009:

Crude oil price projection:

$\$_{2008}$/baril	2010	2011	2012	2013	2014	2015	2020	2025	2030
	80	86	92	98	104	110	117	123	130

Oil derivatives price projection:

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

Natural Gas price projection:

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

Coal price projection:

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

Table 3.2-1 : Fuel price projections for the GMS Master plan update

3.3 CO_2 PRICE SCENARIO

The evaluation of a reference CO_2 cost has been a subject of intense debates. Basically, there are three main approaches for the determination of the cost (or price) of CO_2:

- Cost associated with the social and economic consequences of the climate change (eg. damage approach),

- Cost associated with the actions to be carried out for reduction of emission (eg. cost of preventive measurements),

- Cost revealed by the market of CO_2 quota (e.g., market approach).

[1] The World Energy Outlook is an annual publication of the International Energy Agency.
[2] International Energy Outlook is an annual publication of the Energy Information Administration (USA)

These three approaches should theoretically lead to the same estimation, which is not the case due to the complexity of the problem.

A variety of values have been presented in the literature (from 10 to 300 $/t$CO_2$).

The World Energy Outlook 2009 described a Climate Policy Scenarios where energy sector is substantially cleaner, more efficient and more secure, in which annual energy-related CO_2 emissions peak just before 2020 at 30.9 Gt and decline thereafter to 26.5 GT in 2030. This alternative scenario, the "450 scenario" puts on track for ultimate stabilisation of the atmospheric concentration of greenhouses gases at 450 parts per million C02-equivalent.

In this scenario the CO2 is assumed to be traded in two separated markets the OECD+ and Other Major Economies (China, Russia, Brazil, South Africa and the Middle East).

To contain emissions at the levels required in the "450 scenario", the CO_2 price is estimated to reach:

- 50$/t in 2020, and 110 $/t in 2030 in OECD+,
- 50$/t in 2020, and 65 $/t in 2030 in the Other Major Economies.

The prices are set by the most expensive abatement option (for example, carbon capture and storage in industry in OECD+ in2030).

In line with this "450 scenario", the Consultant recommends to consider a level of 50 $/tC02 up to 2020, and 65$/t beyond for the sensitivity analysis to CO_2 price

4. TASK 3: REVIEW AND UPDATE OF NATIONAL PDPS

4.1.1 REVIEW OF NATIONAL PDPS

The China, Laos, Myanmar and Vietnam PDPs were to be reviewed:

- The last versions of the validated national PDPs reports have been provided by Cambodia, Laos, Thailand and Vietnam.
- Data on China PDPs have been provided by Chinese counterparts (but no reports).
- Neither data nor reports have been provided by Myanmar.

Vietnam PDP (MP VI) was found too obsolete and incomplete for the GMS Master Plan Study. The Consultant agreed with Vietnam representatives on new hypothesis to be considered:

  - Demand projections for Vietnam North, Center and South,
  - Projected installed capacity for coal-fired STPP, gas-fired CCGT, hydro plant, nuclear plants at 5 years interval for Vietnam North, Center and South,
  - Projected power import at 5 years interval for Vietnam North, Center and South.

Further to the present economic crisis, China, Thailand and Vietnam are currently updating their national PDP. These new PDPs, which will be released by the end of 2010 / beginning 2011, were not available for the GMS Master Plan update.

The following table presents the status of the national PDPs available and validated in the different countries:

Country	Period covered	Available version	Next PDP version
Cambodia	2010-2025	PDP 2006	- Draft PDP 2009 established with support of the Consultant. - Current work on new PDP 2010.
China	N/A	N/A	Work on PDP 2010 currently in progress (released end of 2010 ?)
Laos	2007-2016 with vision to 2020	PDP 2006 + additional updates provided to Consultant in 2009	N/A
Myanmar	N/A	N/A	N/A
Thailand	2010 - 2022	PDP 2007 rev 2	Draft data on PDP 2010 released in June 2010. (Final version: by end of 2010?)
Vietnam	2006-2015 with vision to 2025	MP VI - 2007	Work on MP VII currently in progress (Released by end of 2010?)

Table 3.3-1: Status of national PDPs available in each country

4.1.2 TRAINING AND ASSISTANCE FOR THE UPDATE OF CAMBODIA PDP

4.1.2.1 Objectives

Within the general scope of works of Module 1, the objectives given by the TOR of RETA 6440 regarding Cambodia PDP were to:

- Train Cambodia counterparts on planning methodology;
- Train Cambodia counterparts on the planning software recommended by the Consultant (OPTGEN);
- Deliver OPTGEN planning software to Cambodia ;
- Assist Cambodia counterparts in the updating of the Cambodia PDP (including some environmental and social concepts).

4.1.2.2 Main steps

The task were carried out in three main steps :

- PDP Working Session n°1, held in Phnom Penh from June 29 to July 3, 2009.

- Preparation of PDP Working Session n°2.
- PDP Working Session n°2, held in Phnom Penh from August 24 to 28, 2009.

An overview of these steps is presented hereafter.

4.1.2.3 PDP Working Session n°1

4.1.2.3.1 Objectives

The objectives of PDP Working Session 1 were to:

- o Model the Cambodia power system in OPTGEN planning software based on the data collected by Cambodia National Expert.
- o Train Cambodia experts on generation planning methodology and on the use of OPTGEN generation planning software.
- o Deliver OPTGEN planning software licenses to MIME, deliver a powerful PC to MIME in order to install and run OPTGEN, carry out first runs of OPTGEN.

This session was held in Phnom Pen from June 29 to July 3, 2009 and is described in details in the Module 1- Task 3 - "Cambodia PDP - Working Session 1" report.

4.1.2.3.2 Outputs

The main outputs of PDP Working Session n°1 were:

- o A first version of the Cambodia PDP and report was prepared by the Consultant prior Working Session 1 on the base of the data collected by Cambodia National Expert. This version was sent to Cambodia MIME on June 21, 2009, and presented at the PDP Working Session n°1.
- o Review and update with the Cambodia Experts (from MIME, EdC, MoE) of the data collected by Cambodia National Expert (demand projections, fuel resources in Cambodia, thermal and hydro plants characteristics, list and characteristics of thermal and hydro project candidates, power trades).
- o Training of Cambodia Experts on planning methodology and on OPTGEN planning software.

4.1.2.4 Preparation of the PDP Working Session 2

Further to PDP Working Session 1, and in order to proceed more smoothly and efficiently with the PDP update, the Consultant recommended on August 6, 2009 the creation of two groups:

- The PDP Strategic Group: in charge of definition of strategic directions, and validation of key hypothesis and results (High Level Officials and Decision Makers from MIME/EDC/EAC/MoENV).

- The PDP Working Group, expected to be composed of 4 to 5 persons, in charge of the operational update of the PDP, with the proper level of decision, and with access to the OPTGEN license and associated computer (Operational MIME/EDC/EAC/MoENV Staff).

4.1.2.5 PDP Working Session 2

4.1.2.5.1 Objectives

This session was carried out in Phnom Penh from August 24 to 28, 2009. The objectives were to:

a – On the first day of the Session, and with the PDP Strategic Group:

- Finalize the key hypotheses for the PDP update (demand projection, fuel availability and price projections, TPP and HPP characteristics, power trade scenarios).
- Determine the base case and two alternate cases to be considered in the PDP update.
- Presentation by the Consultant of the draft PDP and report prepared by the Consultant on the base of the data reviewed and updated during the first PDP Working Session, and further data received later on.

b – On the next days of the Session, and with the PDP Working Group:

- Make a detailed review and a final update of the data and hypotheses.
- Provide the PDP Working Group on additional training on Environmental Issues (link between Component 1 and 2 of RETA-6440).
- Prepare the finalized data set (i.e., 3rd version of data set).
- Run OPTGEN planning software on base and alternate cases defined by the PDP Strategic Group (i.e., 3rd version of draft PDP).

4.1.2.5.2 Main Outputs

- A total of 13 Cambodian Experts from MIME, EDC and MoENV were involved on the preparation of the draft PDP.
- As required by the PDP Strategic Group, a draft version of the Cambodia PDP 2009 was prepared for the base case and two alternate cases.

4.1.2.6 Conclusion and recommendations

The second PDP Working Session sees the completion of the works of the Consultant within the scope of works of RETA-6440 for the assistance for the updating of Cambodia PDP.

- Cambodia experts have been trained on generation planning methodology and on the use of OPTGEN generation planning software.
- OPTGEN planning software licenses and equipment have been delivered to Cambodia MIME.
- Two versions of draft Cambodia PDP, based on two versions of data base have been prepared by the Consultant (prior PDP Working Sessions 1 & 2)

- Two versions of draft Cambodia PDP reports have been prepared by the Consultant (prior PDP Working Sessions 1 & 2)

- A third version of a draft Cambodia PDP has been prepared with the Cambodia Experts (during Working Session 2).

Cambodia has now the necessary technical bases and planning software to further increase and develop on its own capability and skill in generation investment planning. This will provide Cambodia an improved capacity to master its future power development.

The complementary presentations on SEA, EPA, Transboundary Impacts, given by Component 2 Experts during PDP Working Sessions 1 & 2, emphasized the importance and challenges to integrate the environmental and social issues into the PDP process to cover the full aspects of the power planning on the development on the country.

In order to keep the momentum gained during these PDP Working Sessions, the Consultant made the following recommendations for the short/ medium term:

Continuation of the work on data and hypotheses:

The review of data carried out on Day 2 of the Working Session n°2 (which was the third review of data after the first carried out by Cambodia RETA-6440 National Experts, and the second one carried out with MIME, EdC and MoE representatives during Working Session 1) showed that the data set (demand projection, thermal and hydro data) for the Cambodia PDP was not yet completely consistent and solid. For example, the investment costs and generation data of some of the main HPP projects are grossly under or over-estimated. The demand projection is 3 years old and should be re-actualised.

This work of establishing consistent and updated data will probably require times and commitment from Cambodia PDP Working Team. Contacts and relations between different entities are required. For example:

- Ministry of Irrigation: for data and estimation of inflows series for the hydro candidates.

- Dispatch Center: for hourly load data in 2007 and 2008.

- Thermal Plant managers: for data on actual efficiency, generation statistics, O&M costs.

Creation of a Planning Team:

In line with the recommendation of a PDP Working Group for the works associated to RETA-6440, the Consultant recommends the creation of a Cambodia Planning Team having the responsibility of carrying out, on a regular basis, planning studies (over a time horizon of the next 20 years) covering the three fundamental fields :

- Medium / long term Demand projection.

- Generation Expansion Planning.

- Transmission Planning.

It is recommended to compose this Planning Team on an interdisciplinary basis with a group of 4 to 5 dedicated engineers from MIME, EdC, and MoE covering the technical capabilities :

- Demand projection.
- Generation Expansion Planning.
- Transmission Planning.
- Environmental and Social issues associated with power development

5. TASK 4: GENERATION PLANNING CRITERIA

5.1 GENERATION PLANNING CRITERIA USED IN THE GMS COUNTRIES

The following table presents the generation planning criteria currently used in the GMS countries.

	Cambodia	**China**	**Lao PDR**	**Myanmar**	**Thailand**	**Vietnam**	**GMS Master Plan Version 2008**
Discount rate	Base : 10%	N/A	Not used	N/A	N/A	10%	Base case : 8% Sensitivity : 10 and 12%
LOLP (hours/year)	48 hours in 2015 24 hours in 2020	N/A	Not used	N/A	24 hours	24 hours	Not used
Cost of Unserved Energy	1500 $/MWh in 2015	Not used	Not used	N/A	N/A	500 USD/MWh	Not used
Margin ratio	Not used	20%	15%	N/A	15%	Not used	Available capacity for GMS region = 1.1 x GMS region peak demand
Area protection level					Max imports : Laos = 6000 MW (=11% peak demand) Myanmar = 2 to 5 GW (< 10% peak demand)		Installed capacity of each country > 80% country peak demand
Planning model	OPTGEN	N/A	N/A	N/A	N/A	WASP + PDPAT II	ORDENA

Table 5.1-1 : Generation planning criteria used in the GMS region countries

5.2 RECOMMENDED GENERATION PLANNING CRITERIA FOR THE 2010 UPDATE OF THE GMS REGIONAL MASTER PLAN

The Consultant recommends the use of the following criteria.

Discount rate:

Base case =10%, sensitivity analysis with 8% and 12%.

LOLP:

24 hours / year.

This LOLP value is equivalent[3] to a Cost of Unserved Energy equal to 3500 $/MWh to be provided as an input to OPTGEN planning software.

Country area protection level:

Maximum total of power import: 20% of country peak demand.

[3] The relation between LOLP and CUE is (see appendix or Task 4 report for more details) :
A = CUE x LOLP with
A = annual cost of one garanteed kW of peak generation candidates (230 MW gas-fired OCGT) = 83$/kW (based on 650 $/kW investment cost, 91% availability, 25 year economic life and 10% discount rate)

6. TASK 5: GMS MASTER PLAN UPDATE AND INTERCONNECTION PRIORITY PROJECTS

Task 5 is organised along the following sub-tasks:

Task 5.1: Analysis of the potential power trades between the GMS countries.

Task 5.2: Review of the indicative regional master plan prepared under AFD TA 2006.

Task 5.3: Update of the regional master plan for the period 2009-2025. List of priority projects. Conclusions and recommendations.

6.1 TASK 5.1: POTENTIAL POWER TRADE BETWEEN THE GMS COUNTRIES

6.1.1 OBJECTIVES OF TASK 5.1

The objectives of Task 5.1 are to:

- Analyse the main drivers for economic power exchanges between the GMS countries (balance/demand situation in each country, costs of new generation development in the importing / exporting countries, costs of interconnection projects).
- Infer from this analysis the global picture of the potential power exchanges and economical power interconnection in the future GMS power market.

6.1.2 DEMAND PROJECTIONS

As a whole, the power demand in the GMS region will increase by a factor of 3.3 in the next 15 years, with an annual increase of the peak demand of 13 GW per year in 2025 (equivalent to 16 new 800 MW gas-fired CCGT per year).

The three major power consumers, and importers, are/will be China (more precisely Guangxi and Yunnan provinces and planned exports to Guangdong), Thailand and Vietnam:

a) China: the power demand will increase by a factor of 3.5 in the next 15 years. The total peak demand of Yunnan and Guangxi will increase by 3500 MW per year in 2025, while the power export to Guangdong will increase by an additional 1800 MW per year, totalizing 5300 MW per year (equivalent to 7 new 800 MW gas-fired CCGT per year).

b) Thailand: the power demand will increase by a factor of 2.3 in the next 15 years, with an annual increase of peak demand of 2800 MW per year in 2025 (equivalent to 3 new 800 MW gas-fired CCGT per year).

c) Vietnam: will catch up with Thailand demand in 2016. The power demand will increase by a 4.4 factor in the next 15 years, with an annual increase of 5700 MW per year in 2025 (equivalent to 6 new gas-fired CCGT per year).

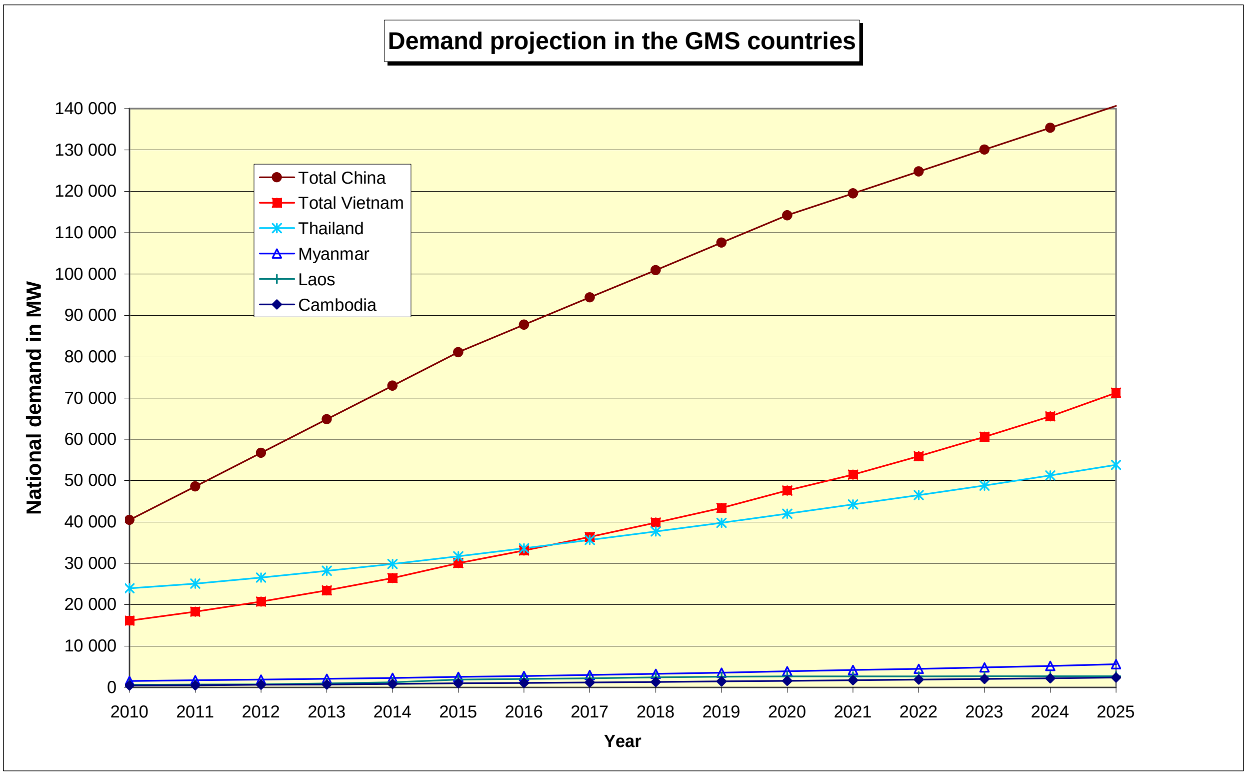


Figure 6.1-1 : Demand projections in the GMS countries (2010-2025)

	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025
Cambodia	467	516	652	717	866	1 008	1 122	1 219	1 325	1 440	1 610	1 752	1 894	2 048	2 216	2 401
China																
Yunnan	16 400	19 140	21 880	24 620	27 360	30 100	31 880	33 660	35 440	37 220	39 000	40 794	42 588	44 382	46 176	47 970
Guangxi	16 300	19 360	22 420	25 480	28 540	31 600	33 640	35 680	37 720	39 760	41 800	43 498	45 196	46 894	48 592	50 290
Export to Guangdong	7 800	10 120	12 440	14 760	17 080	19 400	22 200	25 000	27 800	30 600	33 400	35 200	37 000	38 800	40 600	42 400
Total China	40 500	48 620	56 740	64 860	72 980	81 100	87 720	94 340	100 960	107 580	114 200	119 492	124 784	130 076	135 368	140 660
Laos	618	702	768	927	1 256	1 911	2 060	2 209	2 461	2 613	2 665	2 669	2 674	2 680	2 688	2 696
Myanmar	1 573	1 730	1 903	2 094	2 303	2 533	2 761	3 010	3 281	3 576	3 898	4 190	4 504	4 842	5 205	5 596
Thailand	23 936	25 085	26 572	28 188	29 871	31 734	33 673	35 668	37 725	39 828	42 024	44 281	46 659	49 165	51 806	54 588
Vietnam																
North	6 587	7 385	8 290	9 294	10 413	12 355	13 282	14 571	15 909	17 307	19 436	21 336	23 174	25 119	27 179	28 879
Center	1 547	1 725	1 929	2 155	2 408	3 001	2 742	3 003	3 276	3 561	4 873	4 536	4 930	5 346	5 788	6 959
South	8 031	9 213	10 545	12 020	13 660	14 728	17 084	18 844	20 662	22 552	23 299	25 599	27 808	30 139	32 602	35 442
Total Vietnam	16 165	18 323	20 764	23 468	26 481	30 084	33 108	36 419	39 847	43 419	47 608	51 472	55 912	60 604	65 569	71 280
Total GMS	83 259	94 976	107 399	120 254	133 757	148 371	160 445	172 865	185 598	198 456	212 005	223 856	236 428	249 416	262 852	277 220

Table 6.1-1 : Demand projections in the GMS countries (2010-2025)

6.1.3 EXPORTERS IN THE FUTURE GMS POWER MARKET

Because of their increasingly large power demand, three countries will become the major power importers of the GMS: China (e.g., Yunnan and Guangxi provinces), Thailand and Vietnam. Their combined demand will represent 96% of the GMS peak demand in 2025.

The development of interconnections will allow these countries to substitute imported cost effective hydro generation to more expensive (and CO_2 emitting) domestic thermal generation.

The following paragraphs present an overview of the power situation in these three countries.

6.1.3.1 China

Power demand (Yunnan + Guangxi) and generation mix:

- Peak demand will increase by 3500 MW per year (in 2025), and reach 100 GW in 2025
- Export to Guangdong: 42.4 GW in 2025 through HVDC line (average 2000 MW /year increase between 2020 and 2025).
- The development of new generation capacity is based on hydro generation and on coal-fired STPP.

Issues at stake:

- The available hydro potential in Yunnan and Guangxi will not be enough to satisfy Guangdong demand in 2025 and to cover Yunnan and Guangxi peak demand in 2025. In particular, the current PDP - as reconstructed on the basis of available data (see Task 3 "Review of China PDP") - is not balanced from 2022 without for additional Import or additional coal-fired STPP. Power imports will be a necessity.
- Indeed, China[4] will have a 30 GW capacity gap in 2030 and has an import objective of 20 GW from GMS in 2030.
- While investment costs of new coal-fired STPP in Southern China are lower than in the other GMS countries, their development is severely restricted for environmental reasons (eg. it is no longer allowed to build additional coal-fired STPP close to some large cities). Accordingly, it is not realistic to consider power export from Chinese coal-fired STPP to other GMS countries.
- Accordingly, due to the huge power needs in Guangdong region, Guangxi and Yunnan will have a limited and local power export role (e.g., Supply of isolated grids in the bordering North Vietnam and North Laos provinces, and occasional opportunity exchanges with Vietnam taking advantage of temporary hydro surplus in China).
- Significant power export from China to Thailand load centres is not realistic: a HVDC line would be required, which would not be economical due to the long distance, and there is no significant export capacity from Yunnan and Guangxi regions, because of the huge demand of Guangdong region.
- In line with the previous observations, and according to discussion with the China representatives[5], China will invest in the development of hydro generation projects in Myanmar considering the huge demand in Southern China, mainly in the Guangdong Province.

Main rationale for economic power exchanges:

Power import will allow to save coal fired STPP development and to export the requested amount of power to Guangdong.

Natural suppliers:

⇨ Myanmar and Laos: the transmission costs will be minimised because of a common border.

⇨ Exports to Thailand: would not be economical because of long distance (and China own power needs place China as an importer not as an exporter).

[4] Information provided by China Representatives (Workshop 3, Bangkok January 2010).
[5] Field mission, August 2009 and Workshop n°2 Bangkok, Septembre 2009

- Exports to Vietnam: exports to Vietnam – if any - will become more the result of regional cooperation (current export of 700 MW to feed separated grid in Northern Vietnam) rather than pure economic basis (China will become the largest importer of the region in the coming years), or will take advantage of occasional and low scale hydro surplus conditions in China.

  Furthermore, future congestions on the Chinese grid due to large scale West to East power flow (to feed Guangdong region) would make mandatory network study to fully appreciate to possibility and magnitude of opportunity power exchanges between China and Vietnam.

  Accordingly, the analysis of possible interconnection between China and Vietnam would require a more focussed study outside the scope of work of RETA 6440. Indeed, a feasibility study of China-Vietnam interconnection is currently carried out by China and Vietnam. The study has been completed on the China side, but has started on Vietnam side. The current results have not be made available to the Consultant

6.1.3.2 Thailand

Power demand and generation mix:

- Peak demand will increase by 2800 MW per year (in 2025).
- The development of new generation capacity is based on gas-fired CCGT, with the addition of a few coal-fired STPP.

Issues at stake:

- Mitigation of risks (fuel source and price, power supplier) is sought through :
  - Diversification of generation mix: development of coal and nuclear plants in complement to the current large share of gas-fired CCGTs.
  - Diversification of imports sources: from Laos, Myanmar and Cambodia hydro generation.
- Significant level of power dependence / power security policy :
  - The level of power import in 2025 amounts to 14% of the peak demand (according to PDP rev2).
  - According to Workshop n°2 (Bangkok, September 2009), Thailand considers acceptable a level of import equivalent to the volume of MOU already signed :
    - 7000 MW from Laos, ie 13% of peak demand in 2025,

    - between 5000 MW and 9000 MW from Myanmar, i.e 9% to 16% of 2025 peak demand.
  - The Consultant considered that beyond 15% of peak demand, the economic benefits resulting from power import should be carefully balanced with the associated risks. This current Thailand PDP rev2 is in line with this 15% ratio.

Main rationale for economic power exchanges:

- Thailand will be a net power importer, in order to save Natural Gas (and coal).

Natural suppliers:

- Myanmar (for power and Natural Gas), Laos and Cambodia: because of a common border minimising transmission costs. (Indonesia is out of the scope of the Study).

6.1.3.3 Vietnam

Power demand and generation mix:

- Peak demand increases by 5700 MW each year (in 2025). Vietnam's power demand will catch up with Thailand demand in 2016.

The Vietnam grid is characterized by a North to South power flow explained by the nature of the Vietnam power mix in the North, Center and South regions:

- The North region, representing 40% of the demand, is dominated by coal-fired plants and hydro generation (69% coal-fired STPP, 28% hydro in 2025).
- The Center region, representing 10% of the demand, is dominated by hydro generation (68% hydro, coal-fired STPP in 2025).
- The South region, representing 50% of the demand, is diversified between gas-fired CCGT, coal-fired STPP and hydro generation (21% NG and HFO, 44% coal, 28% hydro).

Issues at stake:

- Vietnam own hydro potential will be absorbed by the domestic power demand by 2025.
- According to MoiT, Vietnam will become net coal importer by 2012. Plans are made to reduce gradually coal exports.

Main rationale for economic power exchanges:

- Power import will reduce import of coal in the North region and Natural Gas in the South region
- Vietnam currently exports to Cambodia (because of lack of power development in Cambodia).

Natural suppliers:

- Hydro generation from Laos, Cambodia (minimisation of transmission costs).

6.1.4 Exporters in the future GMS power market

Three countries of the GMS are rich in large hydro power potential: Laos, Myanmar, and Cambodia to a lower extend. These countries will become the key exporters of the GMS, with a combined 44 GW hydro potential available at a cost lower than 100$/MWh.

The development of hydro export generation projects will bring the following benefits to these countries: development of electrification, reduction of electricity cost, additional cash resources for the country development.

6.1.4.1 Laos

The following table and figure show that:

- Most of Lao PDR hydro potential is located in the "Northern" and "Central 1" regions, with a total of 10000 MW available - after having covered the own needs of Lao domestic demand up to 2025 - at a cost lower than 50$/MWh, and a total of 6200 MW at a cost lower than 40$/MWh.
- 3500 MW is available at a cost lower than 50$/MWh in the "Southern" region, and 750 MW at a cost lower than 40$/MWh.

MW	Central 1	Central 2	Northern	Southern	Total
<40$/MWh	4 878	0	1 325	750	6 953
40-50$/MWh	3 266	0	108	2 672	6 046
50-80 $/MWh	282	165	180	533	1 160
80-100 $/MW	0	0	0	20	20
>100 $/MWh	30	30	3	0	63
Costs NA	0	0	0	30	30
Total	**8 456**	**195**	**1 616**	**4 005**	**14 272**

Table 6.1-2: Lao PDR hydro potential and costs

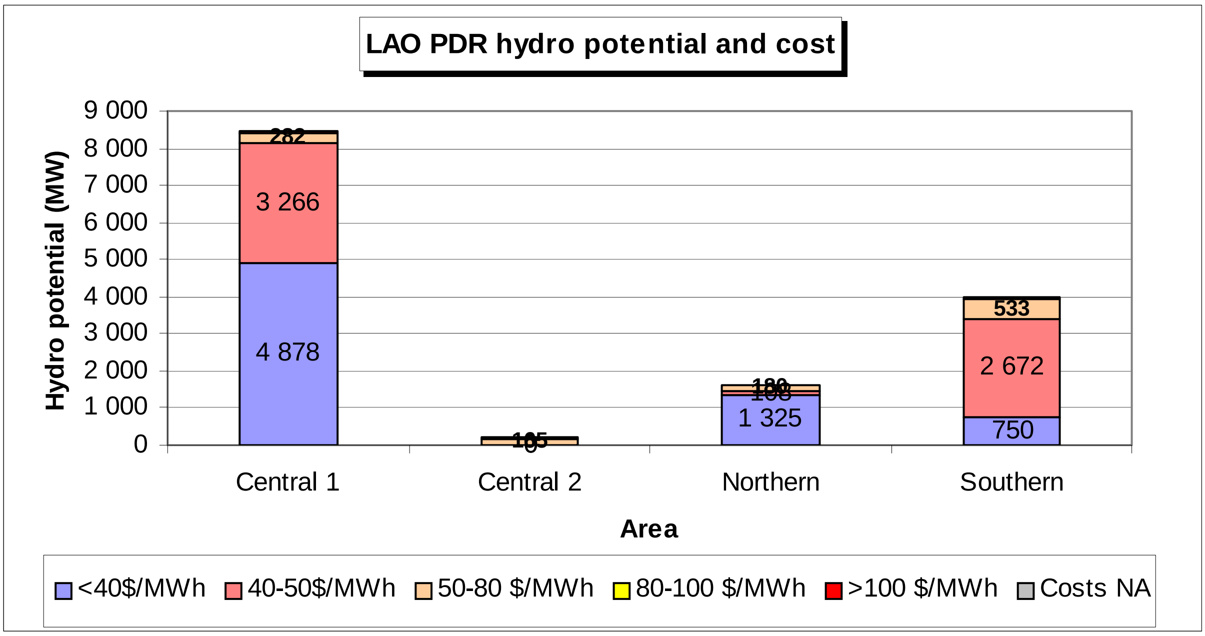


Figure 6.1-2 : Lao PDR hydro potential and costs

6.1.4.2 Myanmar

The list of potential hydro projects available for export, after having supplied Myanmar domestic demand (up to 2025) and excluded all committed export hydro projects (up to 2015) totalizes 28 GW.

Out of this list, data on investment cost is available only for 20 GW (from GMS Master Plan version 2008 Study) as shown in the following figure:

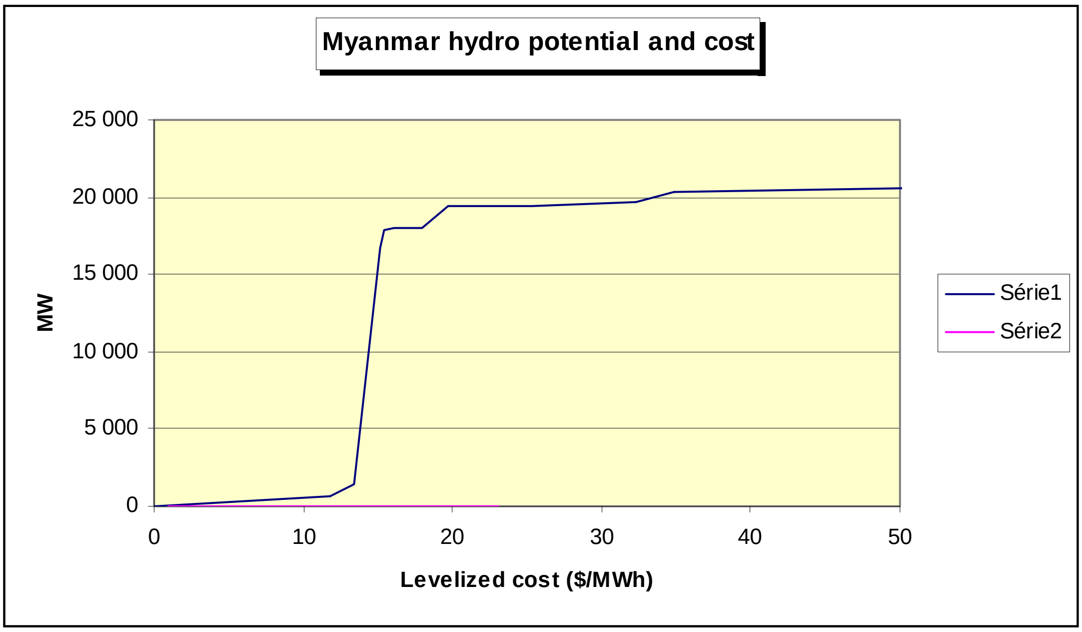


Figure 6.1-3 : Myanmar hydro potential and cost

For the hydro projects with no cost data, the Consultant assumed a conservative 25 $/MWh.

Accordingly, a total of 28 GW would be available at a cost lower than 25$/MWh.

6.1.4.3 Cambodia

The list of potential hydro projects available for export after having supplied Cambodia domestic demand up to 2025, and excluding all committed export hydro projects (before 2015) totalizes between 2 to 4 GW (depending on the design capacity of Sambor HPP[6]).

The following figure presents the volume of hydro potential available for export according to their cost, assuming a 2600 MW capacity for Sambor HPP. 2600 MW are available at a cost lower than 50$/MWh (i.e., Sambor HPP):

[6] Sambor HPP project is estimated from 450 to 2600 MW according to design option.

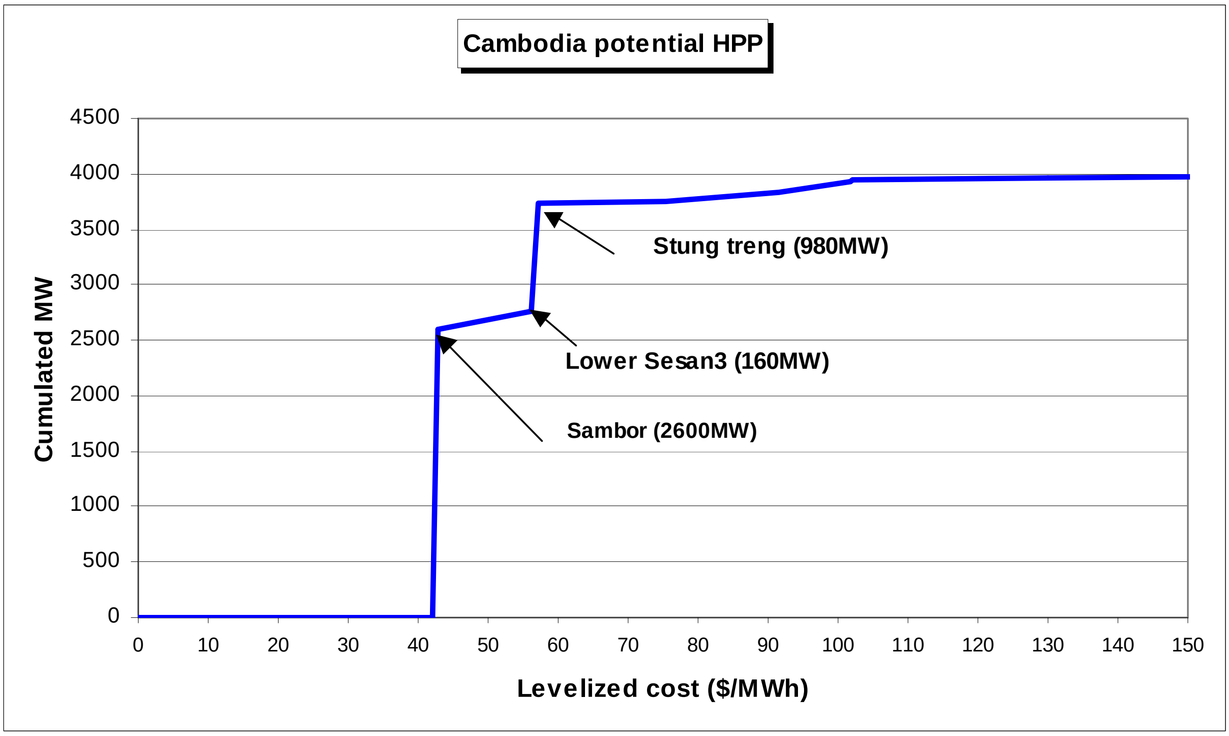


Figure 6.1-4 : Cambodia hydro potential and cost

6.1.5 NORMATIVE EVALUATION OF POTENTIAL INTERCONNECTIONS

An interconnection project is profitable when the price gap (difference of costs of generation between the exporting and importing countries) is greater than the cost of transmission.

As the costs of generation in the exporting countries have been presented in the previous paragraph, this paragraph presents hereafter:

- The cost of transmission,
- The cost of generation saved in the importing countries,
- The resulting evaluation of potential interconnection in the GMS.

6.1.5.1 Normative cost of AC interconnections

The list of potential interconnection projects between the GMS countries (see Module 3 report) shows that typical line lengths between neighboring countries are between 200 to 400 km.

The following table provides a simplified estimation of the cost of this type of projects for an increasing capacity of 500 MW, 1000 MW and 2000 MW at N-1 security (detailed data are presented in Module 3 report) :

Case	Voltage level kV	Line length km	Capacity (MW) MW	Const. cost M$	Power delivered GWh	Cost $/MWh
5a	500 kV	200	500	167.2	2450	9.1
6a	500 kV	400	500	297.9	2450	16.1
3a	500 kV	200	1000	242.0	4900	6.6
4a	500 kV	400	1000	152.4	4900	12.2
1a	500 kV	200	2000	449.5	9800	4.2
2a	500 kV	400	2000	312.1	9800	9.9

Table 6.1-3 : Typical cost of interconnection and transmission costs – 500 kV AC Lines

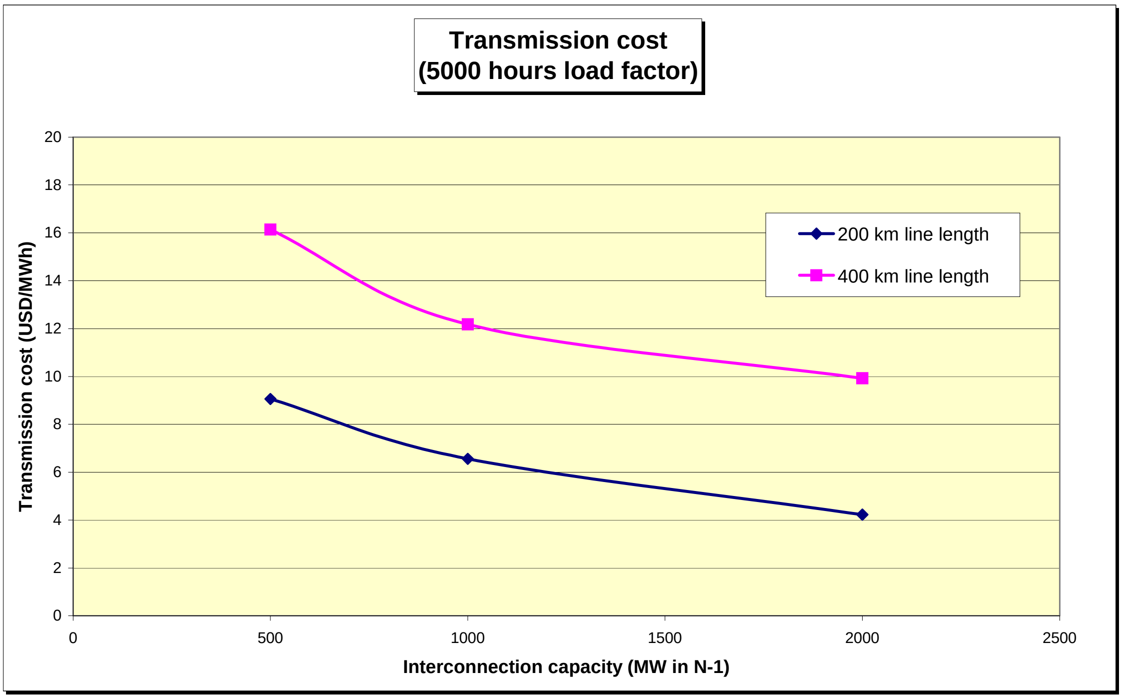


Figure 6.1-5: Transmission cost ($/MW) according to capacity (MW)

<u>Comments</u>:

- The transmission cost ($/MWh) is roughly proportional to the line length and roughly double when going from 200 km to 400 km.
- For a given length, the transmission cost ($/MWh) decreases by roughly 50% when the interconnection capacity double, thus favoring larger capacity when possible.
- Finally, depending on the actual length and capacity of the line, the transmission cost is in the range of 4 to 16 $/MWh. This transmission cost will have to be compared to the generation cost gap between the importing and exporting country.

6.1.5.2 Import side: cost of new generation in the importing countries

As presented in Task 2 "Country" reports the development of new thermal generation is based on :

- Coal-fired STPP in China,
- Gas-fired CCGT, and to a much lesser extent coal-fired STPP in Thailand,
- Coal-fired STPP in North Vietnam, and a mix of coal-fired STPP and gas-fired CCGT in South Vietnam.

The following figure presents the evolution of the levelized cost of generation[7] from 2010-2025:

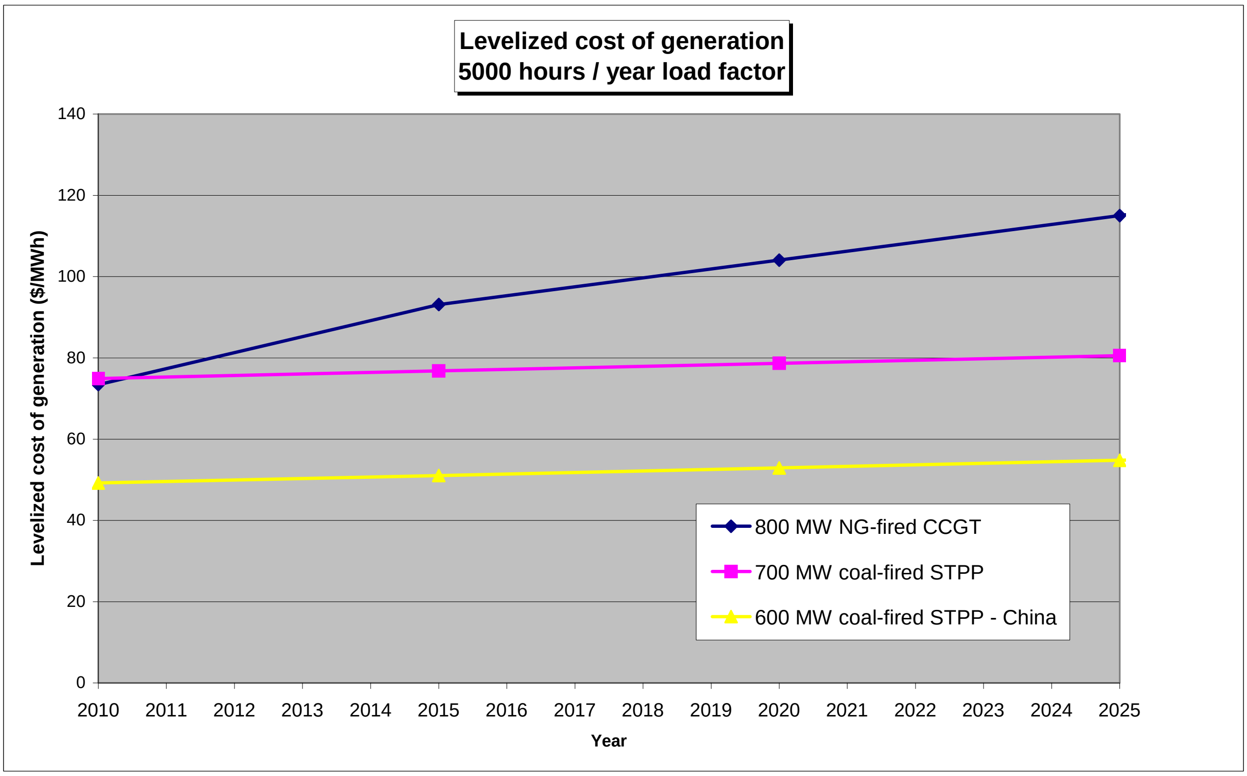


Figure 6.1-6 : Levelized costs of generation ($/MWh) in the importing countries

Levelized cost of generation (5000 hours /year) :

$/MWh	800 MW NG-fired CCGT	700 MW coal-fired STPP	600 MW coal-fired STPP - China
2010	73.4	74.9	49.2
2015	93.1	76.8	51.1
2020	104.1	78.7	52.9
2025	115.0	80.6	54.8
2030	125.9	82.4	56.7

Table 6.1-4 : Levelized costs of generation (for 5000 h/year load factor)

[7] Investment costs are presented in Task 2 country reports, fuel cost projections are presented in Task 2.3 report.

It is interesting to note that the investment costs represent only 15 to 25 % of the levelized cost of NG-fired CCGT, and about 50% of the cost of coal-fired-STPP.

In other words, the fuel cost represents 75 to 85% of the cost of NG-CCGT generation, and 50% of coal-fired CCGT.

Incremental cost of generation / levelized cost of generation :

$/MWh	800 MW NG-fired CCGT	700 MW coal-fired STPP	600 MW coal-fired STPP - China
2010	72%	48%	64%
2015	78%	49%	65%
2020	80%	51%	67%
2025	82%	52%	68%
2030	84%	53%	69%

Table 6.1-5 : Share of fuel costs in the levelized cost of generation

6.1.5.3 Evaluation of potential interconnections

Interconnection projects are justified economically when the price gap between both ends is larger than the transmission cost. The following figure compares for the fuel prices projected[8] in 2015:

- The potential of hydro power available for export, and its levelized cost, in Laos, Myanmar and Cambodia,
- The levelized cost of new thermal generation[9] to which hydro export would substitute to in China, Thailand and Vietnam,
- The cost per MWh of transmission between the countries.

[8] Fuel price projections are from Task 2.3 "Fuel price projections" report.
[9] for 5000 hours/year load factor

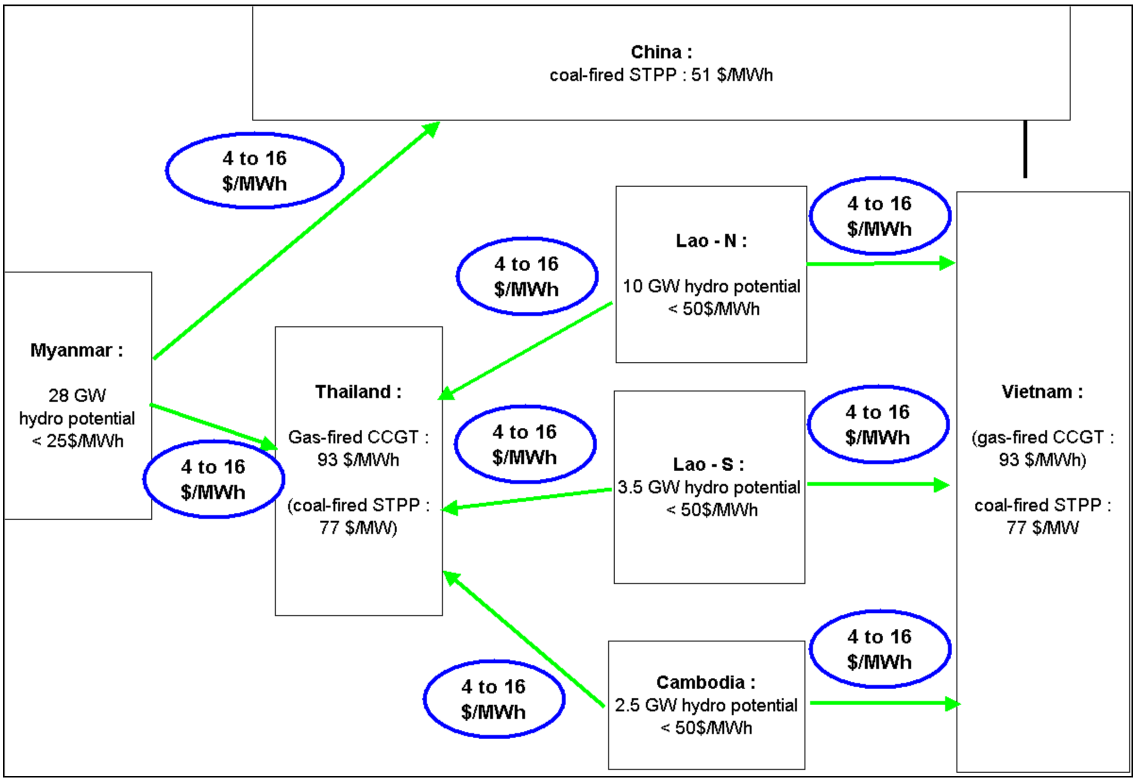


Figure 6.1-7 : Generation and transmission costs in the GMS countries (year 2015)

The following comments can be made:

<u>Export from Laos and Cambodia</u>:

- The costs of transmission from Cambodia / Laos to Thailand / Vietnam are roughly equivalent because of equivalent interconnection line lengths (9 to 16 $/MWh for 200 to 400 km line length and 500 MW capacity).

- With an average cost of transmission between 9 to 16 $/MWh (for 500 MW interconnection capacity), the power export from new hydro generation in Laos or Cambodia (16 GW capacity with levelized cost < 50$/MWh for the total of Laos and Cambodia) would be competitive with new coal-fired or gas-fired generation in Thailand and Vietnam (levelized cost> 77 $/MWh). The global per units savings would be greater than 10 $/MWh. Going to a larger interconnection capacity would reduce the transmission cost.

As the development of new thermal generation is mainly based on coal-fired STPP in Vietnam and gas-fired CCGT in Thailand, the substitution of hydro generation import to thermal generation would induce larger savings in Thailand (substitution to 93 $/MWh gas-fired CCGT rather than 77 $/MWh coal-fired STPP).

The differentiation and ranking between the different actual transmission projects would require more detailed (pre-feasibility and feasibility) transmission and also generation (HPP) studies.

<u>Export from Myanmar</u>:

Hydro power export from Myanmar is largely competitive with NG-fired CCGT in Thailand (<25 $/MWh versus 93 $/MWh)

The price gap with new coal-fired STPP in Yunnan/Guangxi is lower (<25$/MWh versus 51$/MWh), but still largely outbalance the transmission cost (between 4 to 16$/MWh depending on the line actual capacity and length).

China / Vietnam exchanges:

Generation costs are lower in China than in Vietnam (51 $/MWh versus 77 $/MWh for coal-fired STPP) because of lower investment costs (fuel costs are assumed to be identical). However, and as explained in §6.1.3.1, the challenge for Guangxi and Yunnan provinces is to provide enough generation to Guangdong region. Accordingly, it does not seem realistic to have any significant level of power export from China to Vietnam except for specific reasons (eg. to feed isolated small sub-grids in Northern Vietnam).

Furthermore, from the economic point of view, considering the large volume of cost effective potential hydro generation available in Laos North (N, C1 and C2 areas), it is more economical to supply Vietnam North from Laos North rather than from China.

6.1.6 A FIRST VIEW OF THE FUTURE GMS POWER MARKET

A competitive hydro potential (< 50$/MWh) available for export in the GMS:

Apart from the hydro projects already committed up to 2015, and from the requirements of Cambodia, Laos and Myanmar domestic demands, there is remaining total of 45 GW hydro generation available for export, with a levelized cost lower than 50 $/MWh : 28 GW in Myanmar, 13 GW in Laos and 4 GW in Cambodia. This level of cost is significantly competitive to alternate domestic generation in China, Thailand and Vietnam (new coal-fired STPP and/ or gas-fired CCGT depending on the country).

Development of hydro power imports already considered in the national PDPs:

In comparison to this 45 GW competitive hydro potential, the importing countries have considered the development of a total of 20 GW new hydro import in their own PDPs from 2015 to 2025: at least 14 GW in China, 3.6 GW in Thailand, and 2.6 GW in Vietnam.

Accordingly, further to what is already planned in the current PDPs up to 2025, there is a remaining potential of hydro export of 25 GW: 9 GW in Myanmar, 12 GW in Laos and 4 GW in Cambodia.

Economic justification of interconnection projects:

Myanmar, Laos and Cambodia will evolve as key power exporters in the region thanks to their large hydro potential.

Because of similar distances between the different countries (border to border interconnections), the various interconnection projects are roughly equivalent from the point of view of the cost of transmitted MWh : 4 to 16 $/MWh (from 200 km 500 MW to 400 km 2000 MW AC).

- Interconnections between Laos / Cambodia <-> Thailand and Laos / Cambodia <-> Vietnam :

The profitability of these interconnection projects is largely positive because the price gap between the cost of the saved energy in the importing country (e.g., 93 $/MWh for gas-fired CCGT or 77 $/MWh for coal-fired STPP, in 2015) and the cost of imported hydro generation (< 50$/MWh) is largely greater than the cost transmission: 4 to 16 $/MWh (depending on line length and capacity).

- Interconnections between Myanmar <-> China and Myanmar <-> Thailand:

Again the profitability of these interconnection projects is largely positive with a price gap between the cost of the saved energy in the importing country (e.g., 93 $/MWh for gas-fired CCGT or 51 $/MWh for coal-fired STPP in China), and the cost of imported hydro generation (< 25$/MWh) largely greater than the cost transmission: 4 to 16 $/MWh.

Ranking of interconnection projects:

The different interconnection projects have similar costs (between 4 to 16 $/MWh depending on their actual length and capacity). The largest generation price gap is between Thailand and Myanmar (93 $/MWh gas-fired CCGT in Thailand versus cost lower than 25 $/MWh for hydro generation in Myanmar).

However, all previously interconnections listed above are largely beneficial, and the differentiation and ranking between the different actual transmission projects would require more detailed studies (pre-feasibility and feasibility of transmission and HPP projects studies).

Energy security, fuel diversity and supply risk:

The appropriate level of development of new interconnections in the GMS should not be only determined by the hydro potential and its cost, the financial constraints setting the pace on generation and interconnection investments, but also by the issue of energy security and associated supply risks.

As per their current PDPs, Thailand will import 14% of its peak demand in 2025, China (i.e. Yunnan, Guangxi and export to Guangdong) 13% of peak demand and Vietnam 7% of peak demand.

Going beyond a ratio greater than 15 to 20% would require a careful analysis of the balance between the economic benefits and the increased supply risk (depending among others on the number of suppliers and mitigation of hydrological variability).

Benefits from diversification to power market:

While the maximum level of power imports for a country should be examined in terms of national energy security, access to power market is also a source to mitigate national risk, such as:

- Hydro risks (i.e. : diversification between different hydro basins, risks of lack of power in dry season can be mitigated by power import),

- Fuel price/availability risk (which can be mitigated as long as such risks are not correlated with other countries),

- Deficit risk (which can be mitigated by power import).

6.2 TASK 5.2: REVIEW OF GMS MASTER PLAN 2008

This paragraph gathers the main observations of RETA-6440 Consultant on Master Plan 2008.

Main lessons learned from MP 2008 Study:

- All interconnections are required at the soonest, except two interconnections commissioned later on (China – Thailand North and China – Laos North, these projects are no longer in the candidate list of Master Plan 2010 Study).

- This result is in line with Module 1 Task 5.1 report findings (though on the basis of different data and approach) showing that most interconnection projects are economically justified (except China/Thailand, and China/Vietnam).

- From 2012 on, there are subsequent stages of interconnection re-enforcements to increase the volume of power exchanges.

Lack of analysis of the power / supply balance and rationale for economic power exchanges:

- Master Plan 2008 report does not provide background analysis on :
  - Primary energy resources availability and location,
  - Cost to develop generation investment,
  - Possible power exchanges after satisfying country domestic demand.
- Accordingly, the main drivers for power exchanges are not explained. This analysis is provided in Module 1 Task 5.1 report "Potential Power Trade between the countries of the GMS".

Target margin ratio for the GMS region: 10%:

- This target value looks rather low considering the current values used in China (20%), Thailand (15%), Vietnam (20 to 25%). As this value is significantly lower than for the isolated countries, it means that generation capacities will be "saved" in the interconnected case, simply because of the adoption of this low margin ratio (this is particularly true for China and Vietnam).

Underrated hydro potential:

For some reasons (use of local fuel costs?), the key driver of power exchanges in MP2008 are the fuel costs differences between countries. Compared to the "isolated" case[10], only 1200 MW HPP are developed in the whole GMS (in fact in Laos and Cambodia) in the base case[11], while Laos develops 5000 MW thermal capacity specifically for exports (cf Master Plan page 155).

	Thermal plants	Hydro plants
China	+ 3600 MW	0 MW
Cambodia	0 MW	+ 550 MW
Laos	+ 5000 MW	+ 710 MW
Myanmar	0 MW	0 MW
Thailand	- 14648 MW	0 MW
Vietnam	+ 227 MW	0 MW
Region	- 4400 MW	+ 1200 MW

Table 6.2-1 : Comparison of installed thermal & hydro capacity
Base case versus isolated case - MP 2008 (cf. page 155)

Accordingly, the use and the benefits (reduction of fuel cost and emissions) of the large hydro potential in the GMS is underestimated in Master Plan 2008.

Distortions in MP2008 results:

- The three main reasons for the distortions observed in the Master Plan version 2008 results are:

  a) Use of local fuel prices instead of international prices,

  b) China not considered as a major power importer,

  c) Oversized (i.e., unbalanced) Myanmar PDP.

Some examples of these distortions are provided hereafter:

- a) The large power flows from Vietnam to Thailand noted in MP2008 are explained partly by the use of local fuel prices resulting in a substitution of gas-fired CCGT in Thailand (5.4$/MBTU) by gas-fired CCGT (3.8 $/MBTU) in South Vietnam (while local fuel prices do not reflect the actual value of fuel a country could retrieve from power trade).

- b) China has not been considered as one of the main importers of the GMS. Compared to the "no interconnection" case, China develops in the "base case" 3600 MW additional thermal capacity and Laos 5000 MW additional thermal capacity for export to Thailand (reduction of 15000 MW thermal capacity in Thailand - cf MP2008 Page 155).

[10] Isolated case : only existing interconnections are considered. There is no development of any new interconnection.
[11] Base case : optimal development of interconnection, with 80% area protection level, limited import form Myanmar.

- c) Myanmar PDP was not balanced, the installed capacity is equal to 3 to 5 times the peak demand[12]. This means that power exports are readily available "for free" (ie. no additional generation capacity is to be built to provide exports).

  Another example of resulting distortion can be observed in "Myanmar" case (which is the case where the transmission capacity with Myanmar is increased over 2000 MW). Compared to the "base case", there is a 2850 MW additional hydro capacity developed in Myanmar, but a total of 8000 MW thermal capacity savings in China, Thailand and Vietnam. This unbalance between the added developed capacity in Myanmar and the saved thermal capacity is the result of the oversized Myanmar PDP. Accordingly, part of the cost savings attributed to development of interconnections with Myanmar is in fact due to oversized Myanmar PDP (cf. MP 2008 page 131).

6.3 TASK 5.3: UPDATE OF GMS MASTER PLAN

6.3.1 OBJECTIVES

As per the TOR of the RETA-6440 project, the objectives of the GMS Master Plan update are to :

- Update the GMS Master Plan for the period 2009-2025 by simulating the regional power system with existing and potential planned power interconnections.
- Run simulations of the model for a variety of regional power system scenarios.
- Identify the potentially beneficial regional interconnection projects based on the Master Plan, and compile a list of priority projects according to their merits.

6.3.2 OPTGEN PLANNING AND OPERATION SOFTWARE

The optimal operation of the GMS power system over the 2010-2025 period is simulated with OPTGEN planning and operation software developed by PSR Company (Brazil).

Key features:

The key features of OPTGEN for the present Study are the ability to:

- Simulate the optimal operation of several power systems (i.e., several countries) linked by interconnections over a large time horizon (e.g., 2010-2025),
- Determine the optimal capacity and commissioning dates of future interconnections linking the different power systems,
- Determine the optimal operation of hydro reservoirs, based on inflows data (wet/average/dry historical hydro series) and hydro plant characteristics: capacity (MW), storage (hm^3), energy ($MW.m^{-3}.s^{-1}$).

[12] Cf MP2008 page 84-86: 4000 MW overcapacity in 2021 and 10000 MW overcapacity in 2024.

Objective function:

The objective cost function given to OPTGEN is :

Min [NPV (Investment costs + O&M costs + Fuel costs + Unserved energy cost + Externalities)]

Within the following constraints:

- For each node: balance between demand and supply (including import / export).
- For each interconnection: power transit lower or equal to interconnection capacity.

The variables of decision are the interconnection capacities and commissioning dates. The commissioning dates for generation are given to the model as per national PDPs.

In other words, OPTGEN has two main functions:

- Optimal operation : simulation of the operation of an optimal power market taking advantage, at each time step, of the lowest cost available in any country, within the limits allowed by the capacity of the interconnections linking the countries.
- Optimal decision on interconnection capacities: determination of the optimal capacity and commissioning date of candidate interconnections.

6.3.3 HIGH LEVEL VIEW OF THE TARGET INTERCONNECTION SCHEME IN 2025

The next figure outlines a realistic picture of the GMS interconnection backbone in 2025.

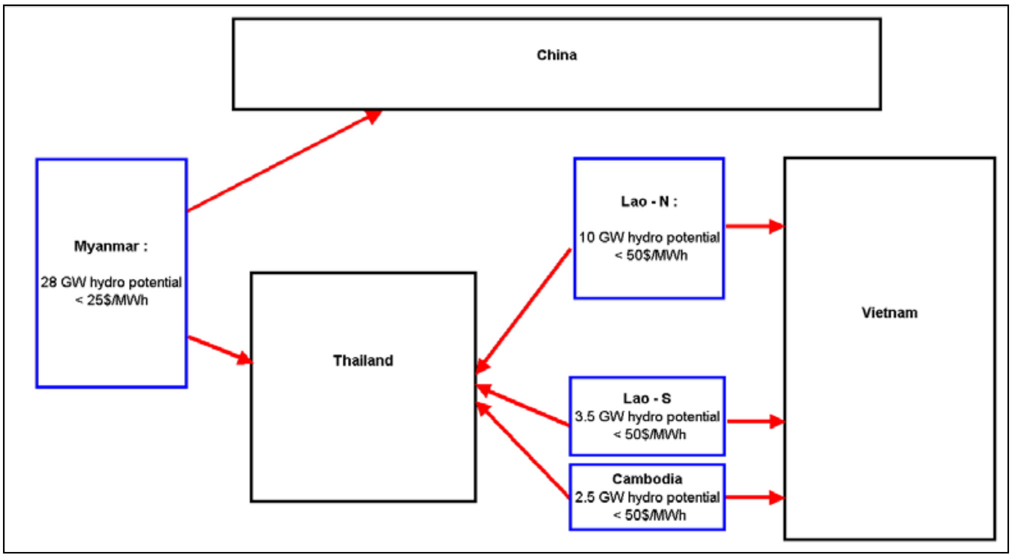


Figure 6.3-1 : High level view of the GMS target interconnection scheme in 2025

The analysis carried out in Task 5.1 confirmed the general economic justification of the various interconnections depicted above on the basis of generation and transmission costs.

The following comments can be made on this target interconnection grid.

Two East-West backbones between Thailand / Vietnam:

One of the key elements of the proposed scheme is the two East-West routes linking:

- In the "North" : Thailand / North Laos / North Vietnam,
- In the "South" : Thailand / South Laos & Cambodia / Central & South Vietnam[13].

These two East-West backbones will allow hydro power exports from Laos/Cambodia to Thailand/Vietnam, but also will provide:

- Indirect link for possible power exchanges between Thailand and Vietnam (through Laos or Cambodia),
- Power exchanges to Cambodia and Laos to support these power systems from thermal generation in Thailand or Vietnam on very dry hydro conditions.

Vietnam North / South grid balance:

Because of its long North – South span, and the location of demand centres (40% of Vietnam demand is in the Northern area, 40% in the Southern area) it is preferable to feed power exports to Northern and Southern Vietnam in order to balance the load flow within Vietnam internal grid. This is made possible by the proposed interconnection scheme. However, specific network study (not within the scope of the present RETA-6440 study) would be necessary to investigate the appropriate balance between North, Central and South imports.

South Laos, Cambodia, South/Central Vietnam:

Because of the number and geographic proximity of hydro projects in Southern Laos, Cambodia on one hand, and the proximity to load areas in Center and Southern Vietnam on the other hand, there is a variety of possible interconnections between these four areas. More detailed investigations and focussed studies (e.g., RETA 6440 - Package III) would be necessary to evaluate the different possibilities, which are largely dependant on national grid development and the actual hydro projects selected for development.

Laos North / South internal connection :

91 % of Laos demand is located in Laos North/Central 1 areas. Laos South demand could be covered by the development of export IPP in the South. Accordingly, there is no need to develop a major North to South Laos backbone to support future export/import routes in the GMS market.

China - Laos:

No interconnection project between China and Laos was identified at Workshop n°2 (Bangkok, September 2009). However, the possibility of an interconnection giving the possibility to import power from Laos was evoked at Workshop n°2 (Bangkok January 2010). This option will be considered in the sensitivity analysis.

China - Vietnam interconnection:

[13] At this level of analysis, "South" should be understood as "South and Centre" Vietnam (i.e from Da Nang to Southern Vietnam)

As discussed in Task 5.1 report, a China-Vietnam interconnection does not appear relevant for large scale power flows because China and Vietnam are both importers. The connection between Laos and Vietnam has more economic justification (because of larger hydro potential in Laos and price gap between Laos HPP and Vietnam TPP).

Export from hydro generation in Myanmar to Vietnam through China (or Laos) could be an option, but would probably be less competitive[14] than direct imports of hydro generation from Laos North / Central 1 to Vietnam.

6.3.4 INTERCONNECTION GRID AND NODE MODELING

Further to the first views on the GMS interconnection scheme presented above, the present paragraph details the interconnection and node modelling actually adopted in OPTGEN software.

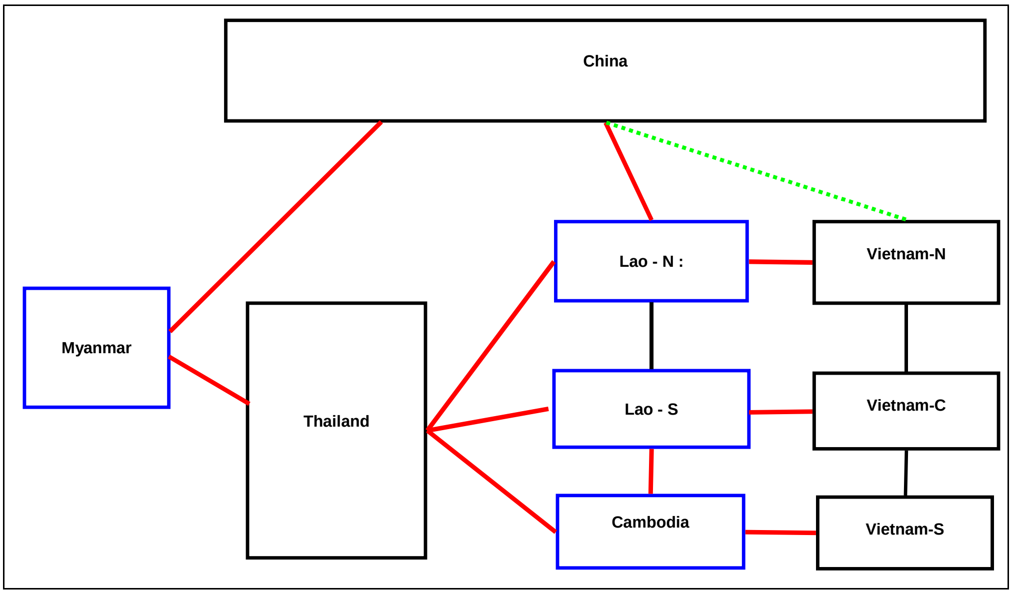
Load-flow studies and national grid representation:

According to the TOR of RETA-6440, load-flow studies, whether internal to the grid of a country or for interconnections between countries are not within the scope of the present study. The Consultant will determine whether load-flow analysis is needed in particular cross-border connections, and if so, prepare terms of reference for such studies, in consultation with the GMS countries.

Accordingly, the adopted modeling of the GMS grid is focused on cross-border interconnections and does not consider national grids (and possible internal national congestion), with the exception of Vietnam (see hereafter).

GMS node modelling adopted for the Study:

The following figure describes the transmission network and node modelling adopted for the GMS Master Plan update (version 2010):



[14] HPP generation cost in Myanmar are lower than 25$/MWh, transmission cost from Myanmar to Vietnam, if through a 1500 km HVDC line would add about 20$/MWh, resulting in a 45 $/MWh of the energy delivered to Vietnam. By comparison, more than 6000 MW hydro potential is available in North/Central 1 areas in Laos at a cost lower than 40$/MWh. More accurate information of Myanmar HPP would be necessary to clear out this possibility.

Figure 6.3-2 : Interconnection grid and node modelling for GMS Master Plan 2010

Colour code:

Green colour: Existing interconnections.

Red colour: Interconnections (existing or candidates).

Black colour: Internal transmission routes.

The rational for this modelling is the following:

- China (Yunnan and Guangxi provinces) : modelled as one node because of highly meshed transmission networks.
- Cambodia: modelled as one node, because most of the power demand is located in the Phnom Pen area.
- Laos: modelled as two nodes, Laos-N (in fact gathering Northern and Central 1 areas) and Lao-S, because of the two distinct geographical locations of Laos hydro potential. About 91% of the country demand is in Laos-N and 10% in Laos-S. The demand of Laos-S is provided by Laos-S IPP. There is no need for a major Laos-N to Laos-S link for import / export purpose. A 200 MW link is assumed to be available from 2016 between Laos-N and Laos-S as suggested by Laos PDP grid map.
- Myanmar: modelled as one node, since its local demand is small compared to the power exports to China and Thailand.
- Thailand: modelled as one node, because of its strong and developed transmission grid. Internal transmission congestions resulting from the development of power exchanges will have to be checked in load-flow studies outside the scope of the present Study.
- Vietnam: modelled as three nodes because the internal transmission limits will have a direct impact on the amount of possible power import coming from Laos-N, Laos-S, or Cambodia. About 10% of the country demand is in Vietnam-C (Pleiku), 40% in Vietnam-N (Nho Quan, Ha Tinh, Da Nang) and 50% in Vietnam-S (Than Dinh).

  In absence of complementary load-flow studies, and on the basis of the information provided by IEV (Hanoi meeting, January 2010), a constant 1200 MW maximum capacity is assumed between Vietnam-C and Vietnam-N, and 2000 MW between Vietnam-C and Vietnam-N.
- Laos-S to Cambodia interconnection: while this link is not suggested by the analysis carried out in §6.1, this interconnection candidate was included in the modelling in order to deal with the congestion observed between Vietnam-S and Vietnam-C (see simulation results in Task 5.3 report).

Additional information on GMS modelling with OPTGEN software:

- Cambodia, Laos, Thailand and Vietnam will be fully modelled in OPTGEN: demand projection and complete description of generation mixes.

- China: will become the largest power importer in the GMS region, targeting a total of 30 GW import. Accordingly, China will be represented in the modelling through its importing capacity from the GMS countries (i.e. not modelled as a node with demand projection and description of generation mix). Considering the large size of Guangxi and Yunnan generation mix, a detailed modelling would be very complex and would take a long time for limited additional benefits in the results. Furthermore, the West to East large power flow through Guangxi and Yunnan resulting from import from Myanmar and export to Guangdong would require a careful study – largely outside the scope of RETA 6440 - in order to properly model the Yunnan + Guangxi system.

- Myanmar: no PDP is available for Myanmar. Furthermore, the national demand of Myanmar is low compared to the amount of power export. Accordingly, only the hydro projects dedicated to power export will be modelled in Myanmar node.

The various interconnections are described more thoroughly in the following paragraph.

6.3.4.1 List of existing interconnection schemes

The following table (from Module 3 report) presents data on existing interconnections between GMS countries.

Project reference	Location 1	Location 2	Voltage	Capacity	Length	Year
A	Xinqiao, Yunnan, China	Lao Cai, Vietnam	220 kV	250 – 300 MW	56 km (in China)	2006
B	Maguan, Yunnan, China	Ha Giang, Vietnam	220 kV	200 MW	51 km (in China)	2007
C	Shewli I HPP, Myanmar	Dehong, Yunnan, China	220 kV double circuit	600 MW	2 x 120 km	2008
D	Chau Doc, Vietnam	Phnom Penh, Cambodia	220 kV (Vietnam) 230 kV (Cambodia) double circuit	100 MW in 2009 and 200 MW from 2010 onwards.	111 km	2009
E	Nam Theun 2 HPP, Laos	Roi Et 2 substation (via Savannakhet, Laos), Thailand	500 kV double circuit	1,000 MW	304 km (Roi Et to NT2)	December 2009
F	Houayho HPP, Laos	Ubon 2, Thailand	230 kV	150 MW	230 km	1999
G	Theun Hinboun HPP, Laos	Sakhonnakhon, Thailand	230 kV	200 MW	176 km	1998

Table 6.3-1 – Existing interconnections (as per end 2009)

In additional to these, lower voltage interconnection exist between:

- Laos and Cambodia: for 10 MW export capacity to Cambodia,
- Thailand and Cambodia: for a 40 MW export capacity to Cambodia.

These, along with national infrastructure at 500 kV, are illustrated on the map below. The energy flows are currently as follows:

- China is importing from Myanmar (the Shweli 1 HPP)
- Vietnam (north) is importing from China

- Thailand is importing from the HPPs in Laos
- Cambodia is importing from Laos, Thailand and Vietnam.

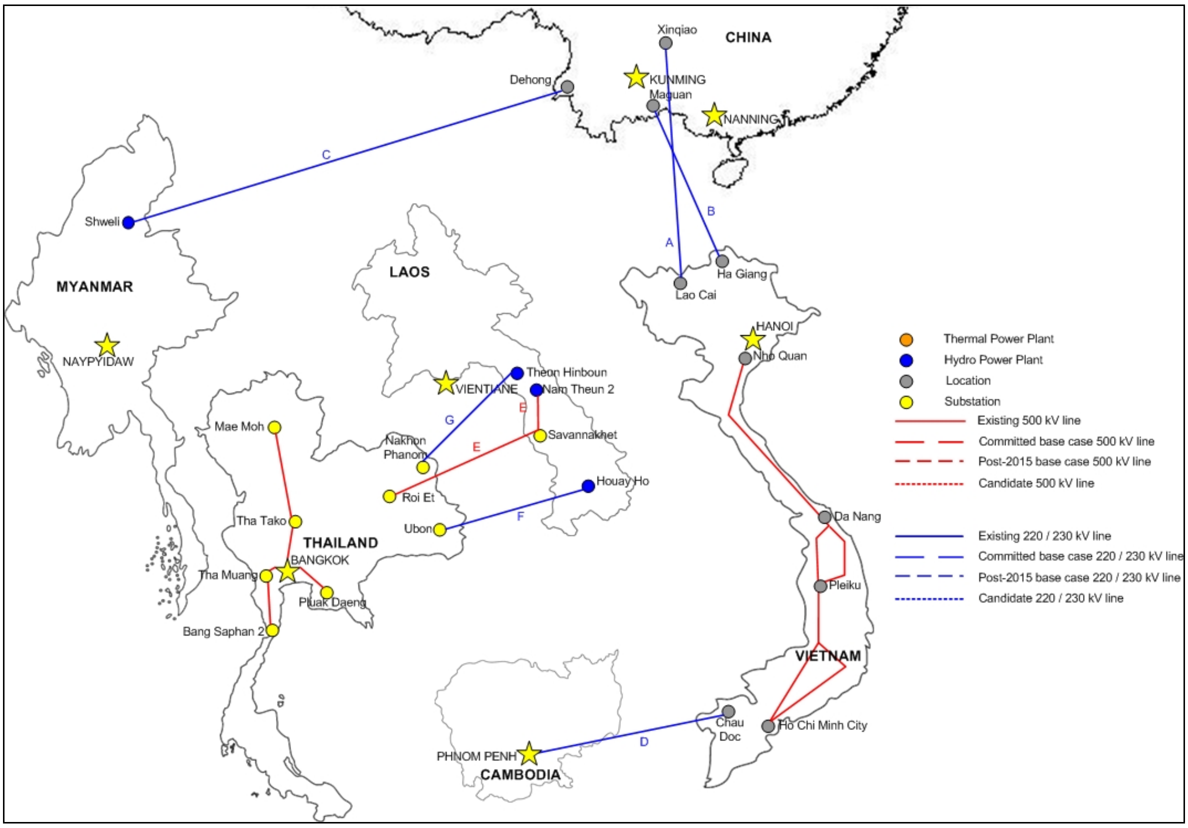
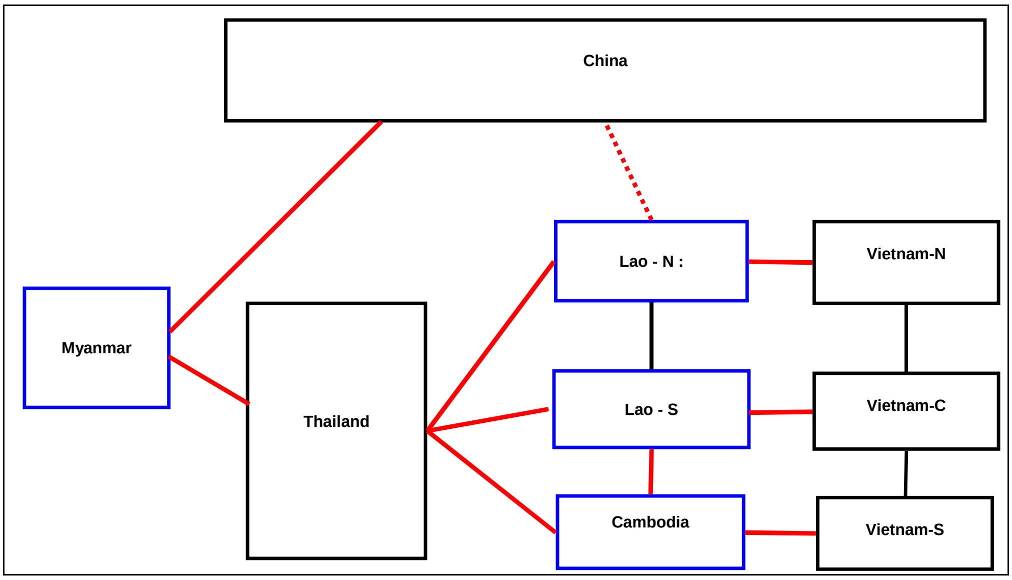


Figure 6.3-3 – GMS map showing existing interconnections (as per 2009)

As the above diagram indicates, there is currently relatively little interconnection capacity between the GMS countries. Such interconnections that do exist are primarily associated with specific hydro schemes, and take the form of connections into the neighboring power network to deliver power exports from these power plants.

6.3.4.2 Committed and candidates interconnection projects considered in MP2010

The list of interconnection projects considered in the MP2010 are those described in the figure below:



As such, the following pairs of countries require interconnection schemes:

- Myanmar – China
- Myanmar – Thailand
- Laos North – Thailand
- Laos South – Thailand
- Laos North – Vietnam North
- Laos South – Vietnam Centre
- Cambodia – Vietnam South
- Cambodia – Laos South
- Cambodia – Thailand

These interconnection projects can be classified in two types:

- "Committed" interconnection projects:

  They are due to be commissioned up to and including 2015 – these are “committed base case” projects. These projects are considered as being already approved.

- Generic interconnections projects:

  For the base case scenario to make up for the shortfall between expected levels of import in national PDPs and the committed base case projects, and also for possible alternate development scenarios.

As explained in Module 3 report, the candidate projects that have been identified from sources other than the countries’ PDPs will not get used in the model directly. However, it is important that the information gathered about these projects is retained for future reference. The intention is therefore to compare the out-turn interconnection requirements with the known candidate schemes once the model has been run; where interconnection requirements have been identified, these can be associated with base case projects post-2015[15] or candidate projects where possible. For example, the results of running the model may show that a certain amount of capacity is required between two countries. If there is a candidate or post-2015 base case project between these two countries, that will be identified as being a possible solution. Where such an identified project does not exist, a generic interconnection would be proposed.

6.3.4.2.1 List of committed interconnection projects

These are the projects committed before 2015 and considered to be already approved. They are illustrated in the map and table below:

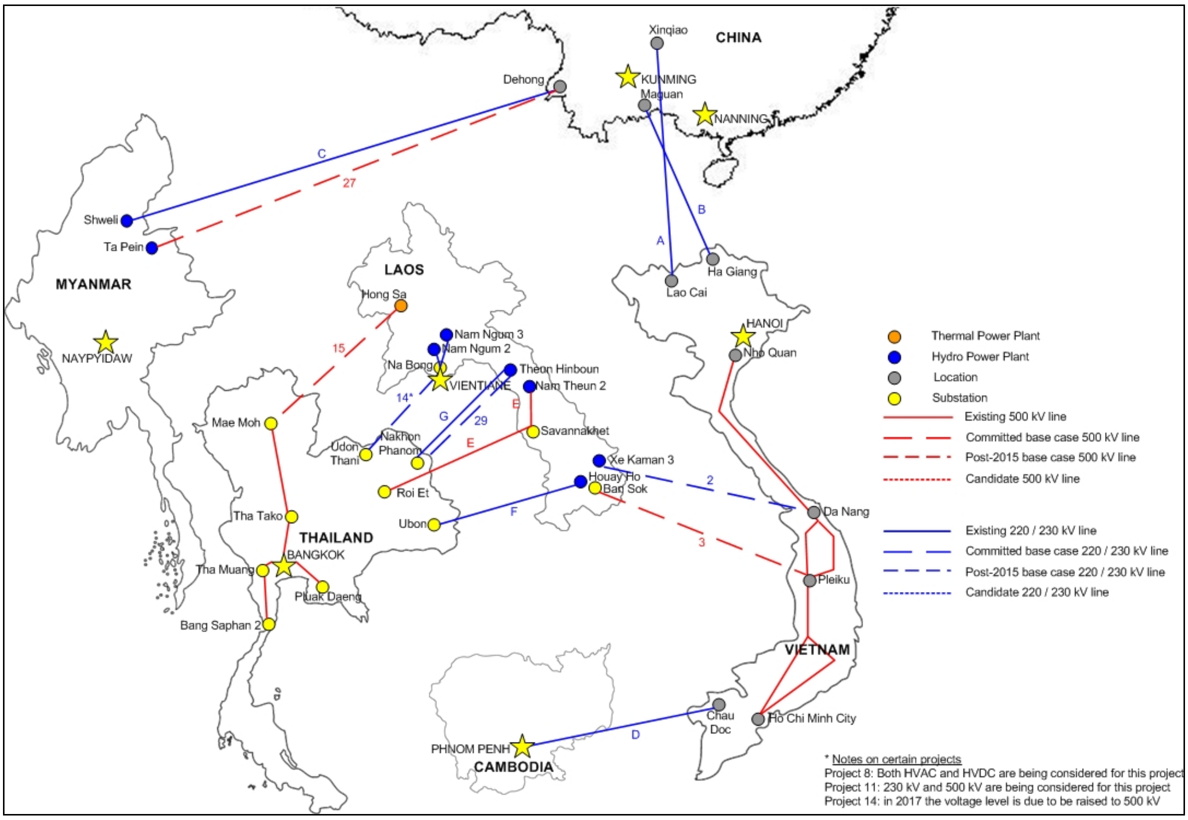


Figure 6.3-4 : Map of committed interconnection projects

[15] 2015 being the cut-off date for the commissioning of committed projects, i.e. those whose planning and/or construction is already under way.

Project reference number	Location 1	Location 2	Voltage	Capacity	Length	Year
2	Xe Kaman 3 HPP, south Laos	Da Nang (Hoa Khanh substation), central Vietnam	220 kV double circuit	250 MW	135 km	2010
3	Ban Soc / Ban Hat, south Laos	Pleiku, Vietnam	500 kV double circuit	1,000 MW	190 km	2014
7a	Lower Se San 2 HPP, Cambodia	Pleiku, Vietnam	230 kV double circuit	200 MW	230 km	2016
14	Na Bong, Laos (Ngum2 and Ngum3 HPP)	Udon Thani, Thailand	230 kV in 2010 500 kV in 2015	605 MW in 2011 and additional 440 MW in 2017	107 km	2010 (230kV) 2017 (500kV)
15	Hong Sa TPP, Laos	Mae Moh, Thailand	500 kV Three or four circuits	1470 MW	340 km	2015
27	Dapein HPP Myanmar	Daying Jian (near Dehong) China	500 kV single circuit	240 MW	120 km (estimated)	2011
29	Theun Hinboun expansion HPP Laos	Nakhon Phanom Thailand	230 kV single circuit	220 MW	90 km	2012

Table 6.3-2 : List of committed interconnections - MP 2010

The construction costs of these projects are not considered in the analysis (sunk costs).

6.3.4.2.2 List and characteristics of candidates projects

OPTGEN will select the optimal interconnection projects to be commissioned from 2015 to 2028 from a list of generic candidates of various capacities.

A range of capacity will be examined for each interconnection in order to select the optimal commissioning date and capacity for each interconnection.

These interconnection projects are not actual projects, which may vary on actual line route and connecting points at both ends. They are generic projects meant to realistically represent the cost of delivering power from one node to another in order for OPTGEN to take the correct decision.

The following tables present the list of candidates:

Country 1	Country 2	Length	Capacity in N-1	Number of circuits	Cost
		(km)	(MW)		(million USD)
Laos North (Luang Prabang)	China (Mojiang)	350 km	600 MW	2	279.5
			1200 MW	3	443.9
			1800 MW	4	559.0
Myanmar (Shamo)	China (Dali)	350 km	500 MW	2	250.4
			1000 MW	3	397.6
			1500 MW	4	500.7
			2000 MW	5	648.0

Table 6.3-3 : Cost of interconnection candidates with China

NB: The large hydro “Seven projects” in Myanmar totalizes a 16 500 MW export capacity to China, assumed to be progressively put in operation from 2018 to 2025 by blocks of 2000 MW. Accordingly, it is also assumed the associated interconnection is gradually put in operation by blocks (and cost) of 2000 MW.

Country 1	Country 2	Length	Capacity in N-1	Number of circuits	Cost
		(km)	(MW)		(million USD)
Myanmar (Minesat)	Thailand (Mae Moh)	250 km	600 MW	2	188.7
			1200 MW	3	299.8
			1800 MW	4	377.5
			2400 MW	5	488.6
			3000 MW	6	566.1
			3600 MW	7	677.2
			4200 MW	8	754.8
			4800 MW	9	865.9
Laos North (Luang Prabang)	Thailand (Mae Moh)	300 km	600 MW	2	221.4
			1200 MW	3	351.6
			1800 MW	4	442.8
			2400 MW	5	573.0
			3000 MW	6	664.2
Laos South (Ban Sok)	Thailand (Ubon Rat.)	150 km	500 MW	2	119.7
			1000 MW	2, with compensators	131.6
			1500 MW	3, with compensators	209.1
Cambodia (Phnom Penh)	Thailand (Pluak Daeng)	400 km	500 MW	2	283.0
			1000 MW	3	449.5
			1500 MW	4	566.0

Table 6.3-4 : Cost of interconnection candidates with Thailand

Country 1	Country 2	Length	Capacity in N-1	Number of circuits	Cost
		(km)	(MW)		(million USD)
Laos North (Luang Prabang)	Vietnam North (Son La)	250 km	600 MW	2	188.7
			1200 MW	3	299.8
			1800 MW	4	377.5
			2400 MW	5	488.6
			3000 MW	6	566.1
Laos South (Ban Sok)	Vietnam Centre (Pleiku)	200 km	500 MW	2	152.3
			1000 MW	3	242.0
			1500 MW	4	304.7
Cambodia (Phnom Penh)	Vietnam South (HCMC)	200 km	500 MW	2	152.3
			1000 MW	3	242.0
			1500 MW	4	304.7
			2000 MW	5	394.3

Table 6.3-5 : Cost of interconnection candidates with Vietnam

Country 1	Country 2	Length	Capacity in N-1	Number of circuits	Cost
		(km)	(MW)		(million USD)
Laos South (Bansok)	Cambodia (Phnom Penh)	400 km	500 MW	2	283.0
			1000 MW	3	449.5
			1500 MW	4	566.0
			2000 MW	5	732.5

Table 6.3-6 : Cost of interconnection candidates with Cambodia

The following table presents the cost of reinforcement of the Vietnam Center to South transmission (not considered as candidates, but as alternatives):

Country 1	Country 2	Length	Capacity in N-1	Number of circuits	Cost
		(km)	(MW)		(million USD)
Vietnam Center	Vietnam South	350 km	1500 MW	4	500.7
			2000 MW	5	648.0
			3000 MW	6	838.5

Table 6.3-7 : Cost of transmission reinforcement between Vietnam Center and Vietnam South

Other characteristics associated with interconnections:

- Annual O& M cost: 2% investment cost.
- Duration of construction: 3 years.
- Disbursement schedule: 25%, 50%, 25%.

6.3.5 MASTER PLAN SIMULATION RESULTS

6.3.5.1 Summary list of simulation runs

Eight different cases were simulated with OPTGEN software:

Name	Description
Base case	- 10% discount rate. - Expansion of interconnections as required by the power exchanges considered in the current national PDPs. - Optimal transmission capacity between Vietnam Center and South determined by OPTGEN (5000 MW from 2015).
Case-2000MW	- Idem to base case, but with constant 2000 MW transmission capacity between Vietnam Center and South.
High export	- Idem to base case, but with 2400 MW additional export from Laos North to China, and 1200 MW additional export from Laos North to Vietnam North
No-expansion	Only existing and committed interconnection projects until 2015 are considered. No additional interconnection is added to the system after 2015.
CO2	Same four cases as above, but with CO_2 cost = 50$/t until 2020, and 65 $/t beyond.

Table 6.3-8 : List of simulation runs

6.3.5.2 GMS Master Plan “base case”

6.3.5.2.1 Definition

The base case corresponds to the level of development of interconnections required by the power imports expected in the current versions of China, Thailand and Vietnam PDPs, complemented and amended by the assumptions agreed at Workshop 3 (January 2010, Bangkok).

Indeed, these different PDPs as provided by the countries were not up to date (e.g., Vietnam PDP MP VI was outdated), nor completely defined (generation export oriented projects were not systematically identified), nor completely consistent between themselves.

Accordingly, the Consultant took hypotheses to update, complete and fill the gaps in these PDPs[16].

More precisely, the man hypotheses in the "base case" are as follows:

- Up to 2015: the development of "committed" interconnection projects is as described in § 6.3.4.2.1.
- The level of power import is given in the following table :

Importing country	Import in 2025	Percentage of country 2025 peak demand[17]
China	18 900 MW (from Myanmar)	14%
Thailand	Total import : 7 700 MW - 5100 MW from Laos N & C - 150 MW from Laos S - 2100 MW from Myanmar - 330 MW from Malaysia	15%
Vietnam	Total import : 5100 MW - 2600 MW from Laos-N & C - 2100 MW from Laos-S - 400 MW from Cambodia	6.5%

Table 6.3-9 : "Base case": level of imports

Explanations and justification of hypotheses are provided in Module 1 Task 5.3 report.

6.3.5.2.2 Results

The following table presents the schedule of existing, committed and candidate interconnection projects in the GMS Master Plan base case:

[16] See Task 3 'Review of PDP" country reports and Task 5.3 Appendix given a synthesis of the list of generation export projects for each country.
[17] For China : percentage of peak demand + export to Guangdong

		2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	
		Existing	**Committed**					**Projects**													**Total projects**
China	Laos																				0
	Myanmar	600	240				1440			2000	2000	2000	2000	2000	2000	2000	2000			4000	20000
Thailand	Myanmar								400			1200			600					3600	5800
	Laos-N	1140	600	220			1500	0	600	0	0	0	0	300	0	1200	0	0	0	0	2100
	Laos-S	147																			0
	Cambodia	40		60																	0
Vietnam-N	China	720																			
Vietnam-N	Laos-N							600				1800									2400
Vietnam-C	Laos-S		225			1000		0	0	0	0	900	0	0	0	0	0	0	0	0	900
Vietnam-S	Cambodia	100	220					200													200
Laos-S	Cambodia	20					40														0

Table 6.3-10: Base case - Schedule of new interconnections (MW)

Benefits provided by the expansion of interconnections:

Compare to a “no expansion” case, where only the interconnection projects committed up to 2015 are developed, this “base case” provides :

- A global cost savings for the Greater Mekong Subregion of 14 310 M$ (discounted value over the 2010-2030 period). These savings come mainly from the substitution of hydro generation[18] to fossil fuel generation (coal-fired and gas-fired). More precisely, a total reduction of the fuel cost of 19390 M$ is observed over the 2010-2030 (in Present Worth Value) associated with an increase of 5 080 M$ of the investment (in both interconnection and HPP cost) over the same period of time.

- A reduction of CO_2 emission by 14.2 Mt / year in 2020.

Remarks on Vietnam PDP:

- Because of the structure of Vietnam future generation mix considered in MP VI (dominated by low cost coal-fired STPP in the North, and more expensive gas-fired CCGT in the South), the Study showed that a constant 2000 MW transmission capacity between Vietnam South and Center is suboptimal. Going up to 5000 MW would be beneficial, allowing additional power "import" from coal-fired STPP located in Vietnam North to save the generation from more expensive NG-fired CCGT located in Vietnam South.

- However, these remarks on the optimal transmission capacity within Vietnam national transmission grid are largely dependant on the hypotheses considered for the development Vietnam power generation mix, which are known to be largely obsolete in the Vietnam MP VI used for the study (Vietnam MP VII will be released by end of 2010?). Indeed, from 2013-2015 Vietnam will start to import part of the coal necessary to the coal-fired STPP. This leads to the opportunity to "re-balance" the future Vietnam generation mix, developing more coal-fired STPP in Vietnam South than considered in MP VI, which would in turn reduce the need of large power transit between North and South Vietnam.

6.3.5.3 Case 2000 MW

The main results of this case concern the Vietnam transmission grid:

- If no cost CO_2 emission is considered, a 2000 MW transmission capacity between Vietnam Center and South is suboptimal; a 5000 MW capacity would be beneficial for the reasons explained in "base case".

- If a cost for CO_2 emission is considered (50$/t$CO_2$ until 2020 and 65 $/t$CO_2$ beyond), the price gap between natural gas fired CCGT in Vietnam South and coal-fired STPP in Vietnam North reduces and a constant 2000 MW transmission capacity becomes sufficient.

- As for the base case, the validity of this conclusion is limited by the obsolescence of the present Vietnam Master Plan VI.

[18] Strictly speaking, there is also some substitution of lignite-fired generation to gas-fired generation (import from Laos Hongsa lignite TPP to Thailand, and import from Myanmar Maikhot lignite TPP to Thailand).

6.3.5.4 High export case

In the “base case”, the remaining hydro potential left in 2028 is concentrated in Myanmar (about 7 GW), and on the mainstream of Mekong river: 9 large scale run of river HPP projects from 1000 to 1400 MW installed capacity (out of a total of 11 identified hydro projects).

Increasing the hydro based export compared to the “base case” situation would obviously increase the generation savings for the region, but a realistic evaluation of the Mekong River potential (number and capacity of the hydro projects) could only be made through a Cumulative Impact Assessment study of the mainstream Mekong River.

6.3.5.5 CO2 emissions

- Compared to the "no expansion case", the CO_2 emission in the “base case" are reduced by 46.4 Mt per year in 2020, and by an additional 14.5 Mt / year in the "high export" case.
- One third of these savings is in Vietnam, the other two third in China.

6.3.5.6 Comparison with GMS Master Plan 2008 results

The main differences of hypotheses with the MP 2008 are:

- Use of international fuel price instead of local / subsidized price,
- Use of consistent investment and homogeneous costs for generation and transmission projects for the whole region,
- Mostly hydro-based power export instead of thermal-based power export,
- Updated demand projection.

The MP2010 reaches most of the same conclusions as MP2008, except for the following lines which are not developed or reinforced in MP2010 :

- Thailand-China,
- Thailand- Laos South,
- China- Vietnam North.

6.3.5.7 Comparison of generic interconnection requirements with identified projects

As discussed in Module 3 report, a set of interconnection projects were identified; some of these were classified as committed base case, and these have been used in the base case model (see §6.3.4.2.1). The rest of these projects (referred to as post-2015 base case and candidates) are to be compared with the requirements identified in the model.

The following table shows the interconnection requirements identified by the base case model run, and the identified projects which are consistent with these interconnection requirements.

Interconnection requirement				Identified projects				
Importing country	Exporting country	MW required	Year	Project reference number	Location 1	Location 2	Capacity	Year
China	Myanmar	2000	2018					
		2000	2019					
		2000	2020					
		2000	2021					
		2000	2022					
		2000	2023					
		2000	2024					
		2000	2025					
		4000	2028					
Thailand	Myanmar	400	2017	28	Mai Khot substation, Myanmar (export)	Mae Chan substation, Thailand (import)	369	2016
		1200	2020	As below.				
		600	2023	As below.				
		3600	2028	16	Ta Sang HPP, Myanmar (export)	Mae Moh, Thailand (import)	7100	2029
Thailand	Laos North	600	2017	26	Saiyaburi, Laos north (export)	Khon Kaen, Thailand (import)	1200 - 2600	2016
		300	2022	As above				
		1200	2024	As above				
Vietnam North	Laos North	600	2016	5b	Xam Nau, Laos north (export)	Nho Quan, VN north (Import)	2500	2016
		1800	2020	As above				
Vietnam Centre	Laos South	900	2020					
Vietnam South	Cambodia	200	2016	7a	Lower Se San 2 HPP, Cambodia (export)	Pleiku (or Tay Ninh), Vietnam South (import)	200	2017

Table 6.3-11: Comparison of identified projects with interconnection requirements

It can be seen that a number of the identified projects are consistent with the interconnection requirements. In these cases, the capacity of the identified projects closely matches that of the requirement. It is notable that the projects that the GMS countries have identified and are considering are consistent with the results of the base case model results.

In some cases, the scheduling of the line could be reconsidered. For example, the model has identified a need for increasing amounts of import from Myanmar to Thailand from 2020 to 2028. A single project, with project reference number 16, has been identified which meets this need, but is not planned to be operational until 2029. If this project were to be commissioned earlier (from 2020) with phased increases, this project would meet the interconnection requirements identified by the base case model.

- The table also shows that there are some requirements that are not covered by any interconnection projects that have been identified during the course of this project. Most notably, the significant import requirements from Myanmar to China. Interconnection between these two GMS countries has been identified as a priority in Section 6.3.7. There is another gap between the requirements and the identified projects, between Vietnam Centre and Laos South. Projects will therefore need to be developed by the GMS countries to address these requirements.

6.3.6 RESILIENCE ANALYSIS

This paragraphs complements the analysis made previously through simulations of the interconnected GMS system with OPTGEN, in order to evaluate the resilience (or robustness) of the GMS Master Plan base case, and more precisely the resilience of interconnection investment decisions under variation of key economic factors.

The evaluation of the benefits of interconnections between GMS countries is based upon projections of key parameters whose values could be different than anticipated in the future: interconnections investment costs, HPP investment costs and fuel prices.

The hypotheses taken for the base case are presented in Task 2 report (investment cost of new generation units, fuel price projections), and § 6.3.4.2.2 of present Task 5.3 report (investment cost of interconnections.

The resilience analysis consists in determining, for each interconnection, the break even point, related to each of these parameters, beyond which the interconnection would turn unprofitable.

The levelized cost of the interconnection projects considered above ranges from 7 to 12 USD/MWh, which is much lower than the price gap observed between the importing and exporting countries, ranging from 30$/MWh (for coal-fired STPP dominated importing power system) to 50 $/MWh (for gas-fired CCGT dominated importing power system).

Accordingly, all these interconnection projects are largely profitable as shown by the following table giving the economic savings provided by each interconnection, evaluated as the difference between the price gap (between importing and exporting countries) and the cost of interconnection[19]) :

	Myanmar-China	Laos North-China	Myanmar-Thailand	Laos North-Thailand	Laos North-Vietnam North	Laos-South-Vietnam South (via Vietnam Center)	Cambodia-Vietnam South
benefits of the interconnection ($/MWh)	13	5	74	42	20	38	33 to 59

Table 6.3-12 : Economic savings ($/MWh) provided by candidate interconnections

The resilience analysis shows that the profitability of the interconnection projects between GMS countries resists negative price shocks (either interconnection and HPP costs, or fuel price). The following table gives in percentage the maximum increase of interconnection investment cost, the maximum increase of HPP investment cost, or decrease of fuel cost, compatible with the profitability of the interconnection projects (breakeven points):

[19] For further details on the calculation, see part 3.7.2 and 3.7.3.

	Myanmar-China	Laos North-China	Myanmar-Thailand	Laos North-Thailand	Laos North-Vietnam North	Laos-South-Vietnam South (via Vietnam Center)	Cambodia-Vietnam South
resilience to interconnection costs	144%	50%	1057%	525%	286%	240%	471% to 842%
resilience to HPP costs	52%	15%	296%	102%	49%	85%	57% to 184%
resilience to fuel price	-37%	-15%	-59%	-59%	-57%	-41%	-42% to -76%

Table 6.3-13 : Resilience of interconnection projects

- Interconnection investment costs can be multiplied by 2 to 10 (depending on interconnection project) without affecting the profitability (except China-Laos North: +50% in interconnection costs can turn the interconnection unprofitable).
- HPP investment costs can be multiplied by 1.5 to 4 (depending on interconnection project) without affecting the profitability (except China-Laos North: +15% in HPP costs in Laos can turn the interconnection unprofitable).
- Fuel price can decrease by 35 to 70% (compared to fuel price projection in the base case) without affecting the profitability (except China-Laos North: -15% in coal price in China can drive the interconnection to be unprofitable).

The interconnection projects linking hydro to gas-fired CCGT dominated thermal systems[20] are the most resilient to any cost or price shocks: Cambodia-Vietnam South, Laos South -Vietnam South, Laos North -Thailand and Myanmar-Thailand.

Interconnection projects linking hydro systems to coal-fired STPP dominated thermal power systems have a lower, but still good resilience, especially to the HPP costs: Myanmar-China and Laos North-Vietnam North. An increase in HPP costs by +50% may cancel their profitability.

One interconnection project is not very resilient to cost shocks: the interconnection project between China and Laos North. A slight increase of the HPP investment costs in Laos (+15%), or a decrease of the coal price (-15%), or an increase of the interconnection (+50%) can turn this project unprofitable. But some other – non economic - drivers might motivate the development of this project (huge power demand in China).

6.3.7 MULTI-CRITERIA RANKING AND PRIORITY INTERCONNECTION PROJECTS

6.3.7.1 Rationale and criteria

The Master Plan approach is an important input to the ranking of regional interconnection projects. However, ranking and defining priority projects interconnection projects involves several aspects:

- Economic criteria.
- Potential for export and import.

[20] gas-fired CCGT dominated generation system will experience the higher marginal costs because of the increase of gas price.

- Supply safety and diversification of import.
- Grid and PDP issues.

These different aspects are discussed more in details hereafter.

- 1 - Economic criteria:

The economic criterion is obviously the one and foremost criterion.

- o Price gap compared to interconnection cost :

A first way to rank interconnection is to calculate the economic benefit derived from each interconnection; this benefit is calculated as the difference between the price gap between both countries and the transmission cost.

Table 6.3-12 reminds the economic savings provided by each interconnection, evaluated as the difference between the price gap (between importing and exporting countries) and the cost of interconnection[21]: it can be seen that the most profitable interconnections (based upon economic evaluation) are those allowing exports from export oriented hydro generation project to countries (or areas) dominated by gas-fired power generation (Thailand and Vietnam South), because of the high cost of NG generation in the future (leading to huge price gap).

- o Resilience (or robustness) to changes of key factors (investment costs and fuel prices) :

A complementary way to determine an economic ranking of interconnections is to examine the resilience of their profitability to changes of the key economic factors: investments costs of hydro power plants dedicated to export, investment costs of interconnections, and fuel price (coal or NG).

In the Table 6.3-13, it can be seen that the profitability of all interconnections is very resilient to interconnect investment cost increase: the interconnection investment cost can be multiplied by more than 2 without affecting the profitability of the project. The only exception is the interconnection between China and Laos North: the price gap is very low, mainly because coal generation costs are low in China (because of low investment cost). But the main driver for the development of this interconnection is not the economic driver, but the increasing China demand, as seen afterward.

- o Synthesis of economic ranking :

The following table shows a ranking of all these interconnections based upon the previous economic criteria (rank 1 = highest priority):

[21] For further details on the calculation, see part 3.7.2 and 3.7.3.

Ranking benefits/resilience	Myanmar-China	Laos North-China	Myanmar-Thailand	Laos North-Thailand	Laos North-Vietnam North	Laos-South-Vietnam South (via Vietnam Center)	Cambodia-Vietnam South
benefits of the interconnection ($/MWh)	6	7	1	3	5	4	2
resilience to HPP costs	5	7	1	3	5	4	2
resilience to fuel price	6	7	1	1	1	5	1
Economic ranking (benefits+resilience to cost shocks)	6	7	1	3	4	5	2

Table 6.3-14 : Economic ranking of interconnection projects

According to a pure economic ranking, the interconnections with countries dominated by NG power generation (Thailand and Vietnam South) would be preferred.

The interconnections with China come at the end of this pure economic ranking because of the lower price gap between China and HPP in Myanmar or Laos.

However, the only economic point of view is not sufficient to determine which interconnection projects have the highest priority. Other complementary parameters have to be considered.

- <u>2 - Potential of export and need for import</u>:

  - Potential of export:

Some countries (especially Laos) have a large and diversified potential of hydro projects that could be dedicated to exports (these projects are distributed over a large area of the country: in the North, Central 1 and South areas). This means that interconnection projects in this type of country are less risky and non dependant on specific hydro project. Even if an interconnection project is implemented, and not the HPP project that was supposed to be commissioned in order to provide export through this line, it will be possible to find other cost effective hydro projects in the same area in order to use this interconnection line.

Moreover, because of this large hydro potential and the large demand of neighboring countries, there is no doubt there will be future increase in the transmission capacity. Accordingly, it might be justified to build interconnections with capacities larger than expected by the strict least cost approach.

Regarding the type of hydro plant, and from the generation point of view, hydro projects with seasonal reservoirs give more flexibility in operation than run of river projects.

  - Need for import:

In some situations, interconnections are not only a way to benefit from a price gap between two countries, but also the only way to balance an increasing demand in the long term. That is the case for China, which is looking to import 25 – 30 GW from the neighboring countries in order to balance its huge future demand. In this case, a low or even slightly negative price gap can be accepted.

- 3 – Supply safety / Diversification of power imports:

  - Supply safety is increased through diversification of import sources: geographic diversification to mitigate hydro risk (different hydro regimes), country origin diversification to mitigate supply risks, increase of grid mesh to mitigate grid contingencies. This is the case for Thailand for example.

  - Ratio of import : even if the price gap is high with neighboring countries, most countries would like to limit their share of imports in the total power supply in order to keep the control on the main part of power supply with a large part of domestic supply. This is the case with Thailand: the price gap with the neighboring countries is high and the hydro potential in these countries is also high, but Thailand doesn't want to import more than 15% - 20% of its national peak demand[22].

- 4 - Grid and PDP aspects / Level of studies:

  - Regional integration (number of countries involved in the interconnection):

  Some interconnections allow a real regional integration between GMS countries by creating a link between several importing and exporting countries. This type of interconnection favors regional integration and the development of regional power trades.

  - Increased meshed grid:

  Provides better resilience to grid contingencies.

  - Interconnection projects impacted by options taken in national PDPs:

  An example is given by the PDP of Vietnam. From about 2015, Vietnam will have to import part of its coal. This opens the possibility to develop coal-fired STPP directly close to the load center in Vietnam South. If such an option is taken, the price gap between Laos-S (or Cambodia) and Vietnam South will be reduced and become comparable to the price gap between Laos-N and Vietnam-N. The profitability of interconnections between Laos South (or Cambodia) and Vietnam South would be lower (but still high).

[22] This ratio depends on the number of exporting countries

- o Level of advance of related studies :

Developing an interconnection project is a rather long process involving different steps of technical and non technical studies for the interconnection project, but also for the associated generation export projects (Desktop Study, Feasibility Study, Design Study, tendering process, commercial agreement, etc). Accordingly, the priority projects for the next 10 years are necessarily among the projects which have been studied to the more advanced level.

Further more, a number of more related and more focused studies are either ongoing : Package III (Cambodia – Laos Vietnam interconnection study), China – Vietnam interconnection study, Thailand PDP, Vietnam PDP, or have just been started :Cumulative Impact Assessment of some of the HPP projects on mainstream Mekong River, Vietnam grid reinforcement study. These studies will bring significant new information and / or data for the next update of the GMS Master Plan, and would possibly answer issues that could not be tackled within the time frame and scope of works given to the present RETA-6440 Study.

6.3.7.2 Analysis by country

In this paragraph, each interconnection project is evaluated along the previous criteria from the point of view of the importing country.

6.3.7.2.1 Projects to China

China – Myanmar interconnection:

Economy	- Economic benefit : 13 $/MWh (saves coal-fired generation) - Resilience HPP investment cost : 52% - Resilience fuel price : -37%
Export potential / need for import	- Export potential : Myanmar = very large potential = 28 GW (to be shared with Thailand) - China target for import : China : 30 GW in 2030
Diversification	- hydro regime different than China / Laos
Grid / PDP / studies	- huge imports are necessary to balance the China demand
Base case	- 18 000 MW import from Myanmar to China in 2028

Table 6.3-15 : Evaluation of China - Myanmar interconnection

China – Laos interconnection:

Economy	- Economic benefit : 5 $/MWh (saves coal-fired generation) - Resilience HPP investment cost : +15% - Resilience fuel price : -15%
Export potential / need for import	- Export potential : Laos = large potential = 10 GW in Laos North - China target for import : 30 GW in 2030
Diversification	- Hydro regime different than Myanmar / China. - Diversification of imports (Myanmar + Laos)
Grid / PDP / studies	
Base case	0 MW

Table 6.3-16 : Evaluation of China - Laos interconnection

Conclusion for China:

- The interconnection project between Myanmar and China ranks first because of larger price gap and the huge Myanmar hydro potential.
- China-Laos ranks second because of a lower price gap and hydro potential in Laos (shared with Thailand and Vietnam).

6.3.7.2.2 Project to Thailand

Thailand – Myanmar interconnection:

Economy	- Economic benefit : 74 $/MWh (saves gas-fired generation) - Resilience HPP investment cost : +296% - Resilience fuel price : -59%
Export potential / need for import	- Export potential : Myanmar = very large potential = 28 GW (to be shared with China) - Thailand targets a total 8 GW import in 2025 (from neighboring countries)
Diversification	- Hydro regime different than Laos N / S / Cambodia
Grid / PDP / studies	
Base case	- 5500 MW import from Myanmar to Thailand in 2025

Table 6.3-17 : Evaluation of Thailand - Myanmar interconnection

Thailand - Laos N and Thailand - Laos S interconnection:

Economy	- Economic benefit : 42 $/MWh (saves gas-fired generation) - Resilience HPP investment cost : +102% - Resilience fuel price : -59%
Export potential / need for import	- Export potential : Laos N = 10 GW, Laos S = 3.5 GW (to be shared with Vietnam) - Thailand targets a total 8 GW import in 2025 (from neighboring countries)
Diversification	- Hydro regime different than Myanmar - Number of seasonal reservoirs larger in Laos North than Laos South (given the list of Laos South HPP projects devoted to export to Vietnam)
Grid / PDP / studies	- To be checked with grid study - Tariff MOU already discussed (though now obsolete) for HPP in Laos North
Base case	- Import from Laos - N = 2400 MW in 2025 - Import from Laos - S = 150 MW in 2025

Table 6.3-18 : Evaluation of Thailand - Laos interconnection

Thailand – Cambodia interconnection:

Economy	- Economic benefit : 39 to 65 $/MWh (saves gas-fired generation) - Resilience HPP investment cost : +57% to +184% - Resilience fuel price : -42% to -76%
Export potential / need for import	- Limited Export potential : Stung Treng (980 MW) and Sambor : 450 MW (up to 2600 MW depending on studies) - Thailand targets a total 8 GW import in 2025 (from neighboring countries)
Diversification	- Hydro regime less favorable; inflows in dry season are lower than in Laos - Only run of rivers projects (for large scale projects)
Grid / PDP / studies	- To be checked with grid study
Base case	- 60 MW export from Thailand to Cambodia (no additional exchanges between Cambodia to Thailand over 2010-2028

Table 6.3-19 : Evaluation of Thailand – Cambodia interconnection

Conclusions for Thailand:

- All of these interconnections are largely profitable (compared to domestic gas-fired CCGT generation).
- Diversification of imports (countries and hydrology) favors the development of these interconnections, at least between Myanmar-Thailand and Laos North -Thailand.
- The list of the first interconnection projects to be developed depends largely on the list of most promising exported oriented generation projects. This list corresponds to the HPP (or TPP) having being studied at the most advanced level, from technical studies and commercial point of view (tariff MOU). Grid study would be necessary. Accordingly, the priority would be on Myanmar – Thailand interconnection and Laos North- Thailand interconnection, as indicated in the GMS Master Plan “base case”.
- Thailand - Cambodia interconnection seems less promising because of much lower hydro potential, less favorable hydro regime, and technical study of HPP projects at a less advanced level.
- These “North” or “South” interconnections will contribute to build a future East-West backbone between Thailand, Laos and Vietnam.

6.3.7.2.3 Projects to Vietnam

Laos North - Vietnam North interconnection:

Economy	- Economic benefit : 20 $/MWh (saves coal-fired generation)l - Resilience HPP investment cost : +49% - Resilience fuel price : -57%
Export potential / need for import	- Export potential from Laos N = 10 GW (to be shared with Thailand and possibly China) - Vietnam need for import : expected 2600 MW in Vietnam PDP
Diversification	- Between Laos N and Laos S
Grid / PDP / studies	- Pending studies : Package III (Cambodia-Laos-Vietnam) interconnection study, Vietnam MP VII, Vietnam grid reinforcement study
Base case	- 2600 MW transmission capacity in 2025

Table 6.3-20 : Evaluation of Laos North – Vietnam North interconnection

Laos South - Vietnam South (via Vietnam Center) interconnection:

Economy	- Economic benefit : 38 $/MWh (saves NG in Vietnam South) - Resilience HPP investment cost : +85% - Resilience fuel price : -41%
Export potential / need for import	- Export potential from Laos S = 3.5 GW (to be shared with Thailand) - Need of import : 2200 MW in the PDP
Diversification	- Between Laos N and Laos S
Grid / PDP / studies	- Depends on Vietnam National PDP, impact N/S flow within Vietnam grid => requires transmission study, - Pending studies: Package III (Cambodia-Laos-Vietnam) interconnection study, Vietnam MP VII, Vietnam grid reinforcement study.
Base case	- 2100 MW transmission capacity in 2025

Table 6.3-21 : Evaluation of Laos South– Vietnam South interconnection

Cambodia - Vietnam South interconnection:

Economy	- Price gap : 39 to 65 $/MWh (saves gas-fired generation) - Resilience HPP investment cost : +57% to 184% - Resilience fuel price : - 42% to –76%
Export potential / need for import	- Export potential: low = Stung Treng: 980 MW – Sambor: 450 MW, no seasonal regulation, only daily peaking reservoirs. - Need of import : target 400 MW import from Cambodia in Vietnam PDP
Diversification	- Between Laos N and Laos S and Cambodia hydrology
Grid / PDP / studies	- Origin of power is closer to load center (HCMC) than power coming from Laos South (or Laos North)
Base case	400 MW in 2025 (L. Sessan II + complementary exchanges)

Table 6.3-22 : Evaluation of Cambodia – Vietnam South interconnection

Conclusions for Vietnam:

- The Vietnam grid is characterized by :

  - Two large demand centers located in the North (Hanoi region with 40% of the country demand) and in the South (HCMC region with 40% of the country demand).

  - A long North – South grid span.

  Accordingly, even if the North-South Vietnam capacity transmission can be enhanced (a study on this issue is currently carried out in Vietnam), balancing the Vietnam grid will require power imports both to the North region and to the Center / South region.

  Both types of transmission projects are profitable, and will be needed at 2020-2025 horizon. The economic advantage is for Laos South to Vietnam Center / South interconnection because of the highest generation cost experienced in Vietnam South (gas-fired CCGT versus coal-fired STPP in Vietnam North). However, because Vietnam is expected to become a net coal importer by 2013-2015, this situation might evolve in the future and become less so clear-cut. Indeed, it would be possible to import coal directly in the South region, and develop coal-fired generation close to HMCC demand center, thus reducing the pressure for significant North to South transmission capacities within Vietnam grid. These issues are largely outside the scope of the present GMS Master Plan study but have a direct impact on what could be the priority transmission projects to develop between Vietnam, Laos and Cambodia.

- Economic benefits of these interconnections (in other words the ranking between the North and South interconnections) will depend largely on the options taken in the new Vietnam PDP: possibility to import coal and develop coal-fired STPP in the South, reinforcement of the grid North / Center / South transmission capacity.

- In first analysis, interconnection with Cambodia might look more favorable from the grid point of view (closer to the Ho Chi Minh City large load center), and from economic point of view (larger price gap), however :

    - Cambodia hydrology is less favorable (drier dry season) and both Cambodia large HPP projects offer no seasonal regulation[23] (Stung Treng and Sambor are both daily peaking plants).

    - Hydro projects in Cambodia need to be studied at a more advanced level in order to determine more precisely their design (especially the installed capacity and the storage capacity) and their construction costs.

    - Moreover the price gap might be reduced (and become equivalent to Laos North to Vietnam North exchanges) if coal was imported in Vietnam South in order to develop coal-fired STPP in the South.

- Diversification of hydro regimes would support the development of both North and Center / South interconnection projects.

- A cumulative Impact assessment is highly recommended on Mekong River for better evaluation and combined design of Cambodia / Laos South HPP projects.

- In conclusion, the development of both North and South interconnections is promising :

    - a North interconnection (Laos North – Vietnam North),

    - a South interconnection (Laos – South / Cambodia – Vietnam Center / South).

- As for the “South” interconnection[24], the ranking and choice between the various routes (“Laos-South -> Vietnam Center -> Vietnam South”, “Laos-South -> Cambodia -> Vietnam South”, “Cambodia -> Vietnam South”) should be made in more focused studies (eg Package III), on the basis of actual network transmission studies, refined evaluation of Cambodia Mekong River projects[25], and in the lights of the new elements that will be provided by the Vietnam MP VII (once completed by the end of 2010), in particular considering the various options between developing coal-fired STPP burning imported coal in Vietnam South versus increasing the capacity of the North / South Vietnam transmission line. Other issues such as the operation of a bilateral or a trilateral transmission line should be evaluated.

- NB: China – Vietnam North interconnection is currently under study in Vietnam, and was not selected as explained in Task 5.1 report.

6.3.7.3 Priority projects for the next 10 years

In the next 20 - 30 years all the countries of the GMS will become interconnected, either for large scale power trades based on hydro export, or for lower scale opportunity power exchanges taking advantage of temporary surplus or needs in the different countries.

[23] Except Lower Sessan II HPP
[24] This remark does not refer to the export of Lower Sessan II HPP which is in the GMS Master Plan “base case”.
[25] Eg 450 MW (?) Sambor and 980 MW Stung Treng HPP

If the focus is set on the 2015-2025 period, the priority interconnection projects would be those allowing large scale power exchanges between hydro rich countries and thermal dominated importing countries. Looking at the whole GMS region, the previous discussion allows to identify these priority interconnection projects:

- Between Myanmar to China: because of the hydro potential in Myanmar and the huge needs of imports for China.

- Between Myanmar to Thailand: because of the price gap between the two countries and the important hydro potential in Myanmar.

- Between Laos North to Thailand: because of the huge hydro potential in Laos and the large price gap between the two countries.

- Between Laos S to Vietnam S (through Vietnam C) : Because of the hydro potential in Laos south (3,5 GW in South) and the large price gap between the two countries.

- Between Laos North to Vietnam North: Because of the hydro potential in Laos and the price gap between the two countries.

- Between Cambodia to Vietnam South: for the export of Lower Sessan II HPP.

With a levelized cost of transmission between 7 to 11 $/MWh, to be compared to a price gap between importing and exporting countries of 30$/MWh (for coal-fired STPP dominated generation mix) to 50 $/MWh (for gas-fired CCGT dominated generation mix), all these projects are largely profitable.

For the following group of other interconnection projects, complementary studies and / or the completion of ongoing studies, are required to identify the best among the possible options:

- Interconnection between Thailand and Laos South.

- Trilateral interconnection between Laos South / Cambodia / Vietnam Center and South.

- Interconnection between Cambodia and Thailand.

This does not mean these projects are a bad choice, but that additional studies are required. Accordingly, this second group of interconnection projects are for a further time horizon (beyond 2025).

6.4 CONCLUSIONS

6.4.1 THREE POLES OF DEVELOPMENT

The findings of the GMS Master Plan 2010 Study allow to outline the picture of future medium term (2025 horizon) power market in the GMS region:

- The largest power exchanges between the GMS countries will be based on hydro power export from Laos and Myanmar, toward China, Thailand and Vietnam[26].

- Because of the anticipated continuous fuel price increase, the interconnections selected in the GMS Master Plan 2010 are largely resilient (ie. robust) to an increase of the interconnection construction costs.

- The GMS regional transmission grid will develop around three main poles :

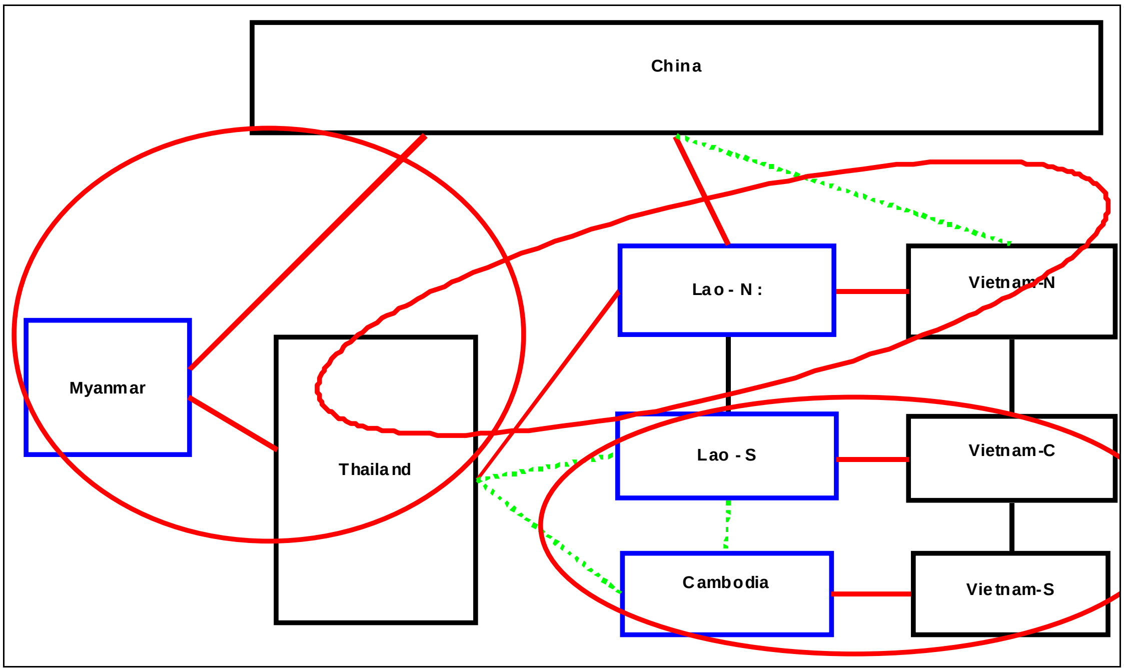


Figure 6.4-1: Main poles of development of the future GMS transmission grid

NB : dashed green line = existing interconnections (in 2010).

- A - The North West pole will connect Myanmar to China and Thailand:
    - Taking advantage of a 28 GW hydro potential in Myanmar, substituting to more expensive thermal coal-fired generation in China and gas-fired generation Thailand.
    - Large power interconnections (up to about 20 GW in 2028) between Myanmar and China will be developed: the development of these interconnections will be paced

[26] With the addition of specific lignite-fired thermal projects.
This large scale power exchanges do not exclude lower scale opportunity exchanges taking advantage of temporary surplus situation in either countries.

along the possible schedule of development of the associated large scale HPP projects in Myanmar, and also by the development of the Chinese internal transmission infrastructure necessary to transmit this large West to East power transits within CSG grid up to Guangdong region.

- Large power interconnections between Myanmar and Thailand will be developed (> 5500 MW in 2028).

- B - The East-West Northern link will connect Thailand, Laos North, Vietnam North and possibly China :
  - Taking advantage of the 10 GW hydro potential in Laos North, substituting to thermal generation in Thailand, Vietnam North, and possibly China.
  - This link will open the possibility to opportunity exchanges between Thailand and Vietnam if any surplus situation was to occur in one of these countries, as well as exchanges between Laos and Thailand or Vietnam in case of very dry hydrological conditions in Laos.
- C - The Southern pole will connect Cambodia, Laos South, Vietnam Center and South :
  - Taking advantage of the 5 GW hydro potential in Cambodia and Laos South[27].
- This development of the GMS power market along these three relatively independent sub regional poles is in line with the emergence of subregional markets preceding the development of an integrated regional market, as explained further in Module 4 report. Indeed the full development of an integrated regional market does take a significant length of time as shown by the following figure presenting the various sub-regional power markets currently existing in Western Europe (2010).

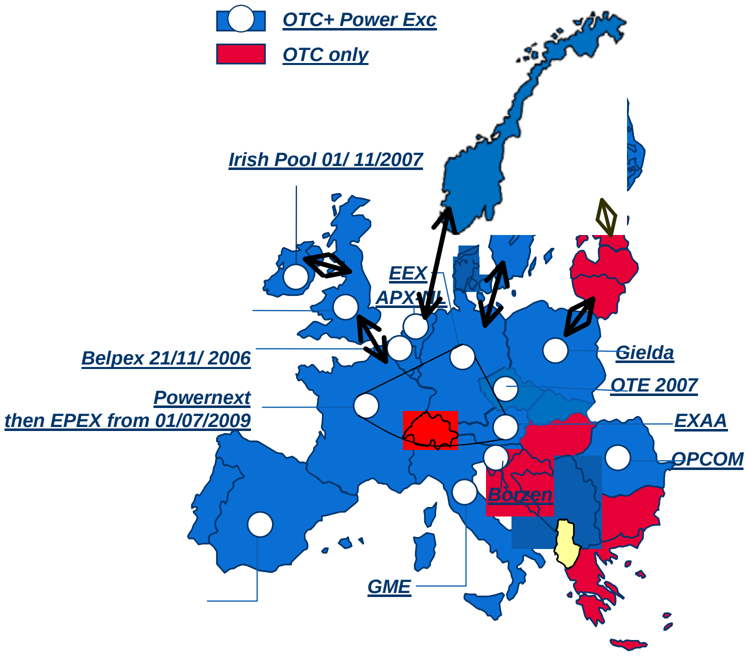


Figure 6.4-2: Current existing sub-regional power market in Western Europe

[27] Or 7 GW potential if the capacity of Cambodia Sambor HPP is assumed to be 2000 MW instead of 450 MW)

6.4.2 GMS MASTER PLAN 2010

The following table presents the schedule of existing, committed and candidate interconnection projects in the GMS Master Plan base case:

		2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	
		Existing	Committed					Projects													Total projects
China	Laos																				0
	Myanmar	600	240				1 440			2 000	2 000	2 000	2 000	2 000	2 000	2 000	2 000			4 000	20 000
Thailand	Myanmar								400			1 200			600					3 600	5 800
	Laos-N	1 140	600	220			1 500	0	600	0	0	0	0	300	0	1 200	0	0	0	0	2 100
	Laos-S	147																			0
	Cambodia	40		60																	0
Vietnam-N	China	720																			
Vietnam-N	Laos-N							600				1 800									2 400
Vietnam-C	Laos-S		225			1 000		0	0	0	0	900	0	0	0	0	0	0	0	0	900
Vietnam-S	Cambodia	100	220					200													200
Laos-S	Cambodia	20					40														0

Table 6.4-1: Base case - Schedule of new interconnections (MW)

<u>Benefits provided by the expansion of interconnections</u>:

Compare to a “no expansion” case, where only the interconnection projects committed up to 2015 are developed, this “base case” provides :

- a global cost savings for the Greater Mekong Subregion of 14 310 M$ (discounted value over the 2010-2030 period),
- a reduction of CO_2 emission by 14.2 Mt / year in 2020.

<u>High export case</u>:

In the “base case”, the remaining hydro potential left in 2028 is concentrated in Myanmar (about 7 GW), and on the mainstream of Mekong river : 9 large scale run of river HPP projects from 1000 to 1400 MW installed capacity (out of a total of 11 identified hydro projects).

Increasing the hydro based export compared to the “base case” situation would obviously increase the generation savings for the region, but a realistic evaluation of the Mekong River potential (number and capacity of the hydro projects) could only be made through a Cumulative Impact Assessment study of the mainstream Mekong River.

<u>Remarks on Vietnam PDP</u>:

- Because of the structure of Vietnam future generation mix considered in MP VI (dominated by low cost coal-fired STPP in the North, and more expensive gas-fired CCGT in the South), the Study showed that a constant 2000 MW transmission capacity between Vietnam South and Center is suboptimal. Going up to 5000 MW would be beneficial, allowing additional power "import" from coal-fired STPP located in Vietnam North to save the generation from more expensive NG-fired CCGT located in Vietnam South.
- However, if a cost for CO_2 emission is considered (50$/t$CO_2$ until 2020 and 65 $/t$CO_2$ beyond), the price gap between the coal-fired STPP in the Vietnam North and gas-fired CCGT in Vietnam South will be reduced and a constant 2000 MW transmission capacity would be sufficient.

- These remarks on the optimal transmission capacity within Vietnam national transmission grid are largely dependant on the hypotheses considered for the development Vietnam power generation mix, which are known to be largely obsolete in the Vietnam MP VI used for the study (Vietnam MP VII will be released by end of 2010?). Indeed, from 2013-2015 Vietnam will start to import part of the coal necessary to the coal-fired STPP. This leads to the opportunity to "re-balance" the future Vietnam generation mix, developing more coal-fired STPP in Vietnam South than considered in MP VI, which would in turn reduce the need of large power transit between North and South Vietnam.

Comparison with GMS Master Plan 2008 results:

The main differences of hypotheses with the MP 2008 are:

- Use of international fuel price instead of local / subsidized price,
- Use of consistent investment and homogeneous costs for generation and transmission projects for the whole region,
- Mostly hydro-based power export instead of thermal-based power export,
- Updated demand projection.

The MP2010 reaches most of the same conclusions as MP2008, except for the following lines which are not developed or reinforced in MP2010:

- Thailand-China,
- Thailand- Laos South,
- China- Vietnam North.

6.4.3 PRIORITY INTERCONNECTION PROJECTS

All transmission projects planned until 2015 are considered as committed, i.e., already approved:

Project reference number	Location 1	Location 2	Voltage	Capacity	Length	Year
2	Xe Kaman 3 HPP, south Laos	Da Nang (Hoa Khanh substation), central Vietnam	220 kV double circuit	250 MW	135 km	2010
3	Ban Soc / Ban Hat, south Laos	Pleiku, Vietnam	500 kV double circuit	1,000 MW	190 km	2014
7a	Lower Se San 2 HPP, Cambodia	Pleiku, Vietnam	230 kV double circuit	200 MW	230 km	2016
13	Nam Theun 2 HPP, Laos	Roi Et 2, Thailand	500 kV double circuit	1,000 MW	304 km	2010

14	Na Bong, Laos	Udon Thani, Thailand	230 kV in 2010 500 kV in 2015	225 MW in 2010 1,000 MW in 2015	107 km	2010 2015
15	Hong Sa TPP, Laos	Mae Moh, Thailand	500 kV Three or four circuits	1,700 MW	210 km	2015

Table 6.4-2 : List of interconnections projects committed up to 2015

Accordingly, this paragraph considers the priority between the interconnection projects beyond 2015 and up to 2025.

The question of priority between the interconnection projects can be tackled from the country or from the regional point of view.

In addition to the economic criterion (i.e., savings provided by the interconnection project) other criteria are involved in ranking the interconnection projects:

- The volume of potential export (i.e., resources in the exporting country).
- Level of advance of the export-oriented hydro generation project study (desktop study, pre-feasibility study feasibility study, design study), of the associated agreement (MOU, PPA), and the duration of the construction of underlying HPP (or TPP) projects. As a thumb rule, the study process can last a total of 2 to 5 years, and the construction between 3 to 6 years depending on the project characteristics.

  This implies that the interconnection projects to be built in the period 2015-2020 will be associated with hydro projects which are already at an advanced stage of study.
- The need for import of the receiving country (in that case, a lower price gap between both countries would be accepted),
- Complementary aspects:
  - Diversification of sources of import,
  - Grid conditions,
  - Uncertainties or incompleteness of data: some projects might be affected by data gaps, associated studies available only at early stage, dependence on evolution of other factors.

6.4.3.1 Priority per country

Projects to China:

- The interconnection project between Myanmar and China ranks first because of larger price gap and the huge Myanmar hydro potential.
- China-Laos ranks second because of a lower price gap and hydro potential in Laos (shared with Thailand and Vietnam).

Projects to Thailand:

- Interconnections between Thailand and Myanmar, Laos and Cambodia are largely profitable (compared to domestic CCGT generation).
- Diversification of imports (countries and hydrology) favors the development of these interconnections, at least between Myanmar-Thailand and Laos North -Thailand.
- The list of the first interconnection projects to be developed depends largely on the list of most promising exported oriented generation projects. This list corresponds to the HPP (or TPP) having being studied at the most advanced level, from technical studies and commercial point of view (tariff MOU). Grid study would be necessary. Accordingly, the priority would be on Myanmar – Thailand interconnection and Laos North- Thailand interconnection, as indicated in the GMS Master Plan “base case”.
- Thailand - Cambodia interconnection seems less promising because of much lower hydro potential, less favorable hydro regime, and technical study of HPP projects at a less advanced level.
- These “North” or “South” interconnections will contribute to build a future East-West backbone between Thailand, Laos and Vietnam.

Projects to Vietnam:

- The Vietnam grid is characterized by :
    - Two large demand centers located in the North (Hanoi region with 40% of the country demand) and in the South (HCMC region with 40% of the country demand).
    - A long North – South grid span.

Accordingly, even if the North-South Vietnam capacity transmission can be enhanced (a study on this issue is currently carried out in Vietnam), balancing the Vietnam grid will required power imports both to the North region and to the Center / South region.

Both types of transmission projects are profitable, and will be needed at 2020-2025 horizon. The economic advantage is for Laos South to Vietnam Center / South interconnection because of the highest generation cost experienced in Vietnam South (gas-fired CCGT versus coal-fired STPP in Vietnam North). However, because Vietnam is expected to become a net coal importer by 2013-2015, this situation might evolve in the future and become less so clear-cut. Indeed, it would be possible to import coal directly in the South region, and develop coal-fired generation close to HMCC demand center, thus reducing the pressure for significant North to South transmission capacities within Vietnam grid. These issues are largely outside the scope of the present GMS Master Plan study but have a direct impact on what could be the priority transmission projects to develop between Vietnam, Laos and Cambodia.

- Economic benefits of these interconnections (in other words the ranking between the North and South interconnections) will depend largely on the options taken in the new Vietnam PDP: possibility to import coal and develop coal-fired STPP in the South, reinforcement of the grid North / Center / South transmission capacity.

- In first analysis, interconnection with Cambodia might look more favorable from the grid point of view (closer to the Ho Chi Minh City large load center), and from economic point of view (larger price gap), however :

    - Cambodia hydrology is less favorable (drier dry season) and both Cambodia large HPP projects offer no seasonal regulation[28] (Stung Treng and Sambor are both daily peaking plants).

    - Hydro projects in Cambodia need to be studied at a more advanced level in order to determine more precisely their design (especially the installed capacity and the storage capacity) and their construction costs.

    - Moreover the price gap might be reduced (and become equivalent to Laos North to Vietnam North exchanges) if coal was imported in Vietnam South in order to develop coal-fired STPP in the South.

- Diversification of hydro regimes would support the development of both North and Center / South interconnection projects.

- A cumulative Impact assessment is highly recommended on Mekong River for better evaluation and combined design of Cambodia / Laos South HPP projects.

- In conclusion, the development of both North and South interconnections is promising :

    - A North interconnection (Laos North – Vietnam North),

    - A South interconnection (Laos – South / Cambodia – Vietnam Center / South).

- As for the "South" interconnection[29], the ranking and choice between the various routes ("Laos-South -> Vietnam Center -> Vietnam South", "Laos-South -> Cambodia -> Vietnam South", "Cambodia -> Vietnam South") should be made in more focused studies (eg Package III), on the basis of actual network transmission studies, refined evaluation of Cambodia Mekong River projects[30], and in the lights of the new elements that will be provided by the Vietnam MP VII (once completed by the end of 2010), in particular considering the various options between developing coal-fired STPP burning imported coal in Vietnam South versus increasing the capacity of the North / South Vietnam transmission line. Other issues such as the operation of a bilateral or a trilateral transmission line should be evaluated.

6.4.3.2 Priority projects for the next 10 years

In the next 20 - 30 years all the countries of the GMS will become interconnected, either for large scale power trades based on hydro export, or for lower scale opportunity power exchanges taking advantage of temporary surplus or needs in the different countries.

If the focus is set on the 2015-2025 period, the priority interconnection projects would be those allowing large scale power exchanges between hydro rich countries and thermal dominated

[28] Except Lower Sessan II HPP
[29] This remark does not refer to the export of Lower Sessan II HPP which is in the GMS Master Plan "base case".
[30] Eg 450 MW (?) Sambor and 980 MW Stung Treng HPP

importing countries. Looking at the whole GMS region, the previous discussion allows to identify these priority interconnection projects:

- Between Myanmar to China: because of the hydro potential in Myanmar and the huge needs of imports for China.
- Between Myanmar to Thailand: because of the price gap between the two countries and the important hydro potential in Myanmar.
- Between Laos North to Thailand: because of the huge hydro potential in Laos and the large price gap between the two countries.
- Between Laos S to Vietnam S (through Vietnam C): Because of the hydro potential in Laos south (3,5 GW in South) and the large price gap between the two countries.
- Between Laos North to Vietnam North: Because of the hydro potential in Laos and the price gap between the two countries.
- Between Cambodia to Vietnam South: for the export of Lower Sessan II HPP.

With a levelized cost of transmission between 7 to 11 $/MWh, to be compared to a price gap between importing and exporting countries of 30$/MWh (for coal-fired STPP dominated generation mix) to 50 $/MWh (for gas-fired CCGT dominated generation mix), all these projects are largely profitable.

Assuming the transmission projects listed in § 6.3.4.2.1, are operational before 2015, the next group of transmission projects to be developed in the 2015-2020 horizon are:

	Additional transmission capacity required in the 2015-2020 horizon
Myanmar-China	6 000 MW
Myanmar - Thailand	1600 MW
Thailand – Laos North	600 MW
Vietnam North – Laos N Vietnam Center- Laos C Vietnam South - Cambodia	2400 MW 900 MW 200 MW (associated with Lower Sesan 2)

Table 6.4-3: Priority projects for 2015-2025

The development of these interconnections will be paced along the development of the associated generation export oriented projects.

For the following group of other interconnection projects, complementary studies and / or the completion of ongoing studies, are required to identify the best among the possible options:

- Interconnection between Thailand and Laos South.

- Trilateral interconnection between Laos South / Cambodia / Vietnam Center and South.

- Interconnection between Cambodia and Thailand.

This does not mean these projects are a bad choice, but that additional studies are required. Accordingly, this second group of interconnection projects are for a further time horizon (beyond 2025).

6.5 RECOMMENDATIONS

The Consultants recommends developing future actions along three main directions:

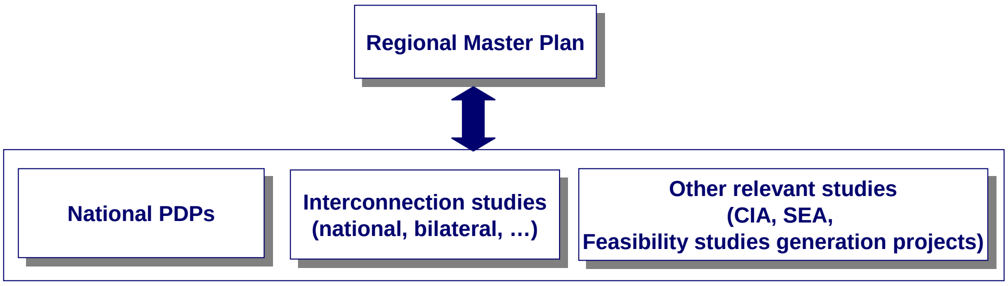
- Better assessment of the hydro generation potential,
- Regional and national studies,
- Capacity building.

Better assessment of hydro generation potential:

- The main mechanism for power exchanges in the GMS will be based on large scale hydro generation export. Accordingly, one of the main determinants of the development of the GMS interconnection grid is the list and location of the "best" and "more promising" export-oriented hydro projects in the GMS region. As a consequence :
    - There is a need to refine investment costs, hydrology, and social / environmental impacts of these hydro export projects.
    - A large part of the economical power export potential in Cambodia and Laos is from large (1000 to 1400 MW) HPP projects on Mekong River. Accordingly, the Consultant recommends to carry out a cumulative impact of these Mekong River projects to answer the following questions: What are the impacts of such projects on fishery, navigation, resettlement, etc…? What is the realistic potential considering social and environmental impacts? What is the "realistic" dimensioning of these projects? What is the global ranking of these Mekong River HPP projects (based on all these elements) and the "best group of HPP projects".
    - Assessment of the environmental and social impacts of all major hydro projects is required in order to take into account these externalities in the planning model.
    - Improvement of the hydrology of Myanmar and Vietnam HPP projects is required. Historical inflows series in m3/s were not available for Myanmar and Vietnam HPP projects. A better representation of hydro variability in these countries is possible in the future version of GMS Master Plan provided these inflows series are made available.

Regional and national studies:

- A regional Master Plan study is part of an iteration process involving wide scope analyses (regional SEA, regional Master Plan) and more focussed studies (national studies, interconnection studies, CIA, EIA, feasibility studies of HPP projects, etc) :



- A number of national or regional studies are currently undergoing :
  - National PDP updates in China, Thailand, Vietnam,
  - Cambodia-Laos-Vietnam interconnection study (ADB- Package III),
  - Vietnam grid reinforcement study,
  - China – Vietnam interconnection study,
  - Cumulative Impact Assessment of hydro projects on mainstream Mekong River.

  The general vision of the GMS Master Plan will be certainly enriched by the results of these new studies. Accordingly, the Consultant recommends reviewing the findings of the 2010 GMS Master plan in views of these future new results.

- Transmission study on the North – South transits on Vietnam national grid:
  - There is a need for load flow studies, stability analysis, evaluation of maximum transit capacity and options of grid reinforcements, impact on Vietnam North / Center South PDP, impact on the possible amount of import from Laos South and Laos North. At Workshop n°4 (Bangkok, June 2010) the Vietnam representatives indicated that a Consultant has been selected to study to the various options of reinforcement of the Vietnam grid.
  - The outcome of the new Vietnam PDP update will probably have a strong impact on the options of transmission development between Laos South, Cambodia, Vietnam Center and South. In particular: how much power can be imported from Laos South through Vietnam Center to Vietnam South load Center, how many HPP projects can be developed in Vietnam Center.

- Further to the previously mentioned studies, there is a need to launch studies on:
  - Priority interconnection projects.
  - Large scale HPP projects (in particular on Mekong River mainstream).

- <u>Capacity building</u>:

It is recommended to enhance the development of transmission and generation investment planning skills in the GMS. It particular, it is recommended to create a devoted Power Development Plan team in Cambodia.