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MEKONG RIVER COMMISSION CONTRACT No. 027-2015

Consultancy to assist the Hydropower Thematic in Council Study

Development Scenarios

Final Report

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Abbreviations and Acronyms

CA	Concession Agreement
FS	Feasibility Study
FSL	Full Supply Level
GWh	one million kWh
kW	one kilowatt = one thousand Watt
kWh	one kilowatt hour
LMB	Lower Mekong Basin
MW	one thousand kW
m^3/s	cubic metres per second
mamsl	meter above mean sea level
mcm	million cubic metre
MOL	Minimum Operating Water Level
MOU	Memorandum of Understanding
MS	Mekong Main Stream
OWL	Operating Water Level
Pre-FS	Pre-Feasibility Study
PDA	Project Development Agreement

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Acknowledgement

The Mekong River Commission (MRC) has actively contributed to this study by formulating the scope of works and providing available data.

We would particularly like to acknowledge Messrs. Voradeth Phonekeo, Simon Krohn, Henry Manguerra and Piseth Chea.

Because of Mr. Piseth Chea's working stay in Norway in week 43 and his provision of valuable data and maps, we have included him as one of the authors of this report.

1 Introduction

This first report under the MEKONG RIVER COMMISSION CONTRACT No. 027-2015 “Consultancy to assist the Hydropower Thematic in Council Study” deals with hydropower development scenarios for the Lower Mekong Basin (LMB). LMB covers in this respect the sub-catchments of MRC’s member countries Lao, Vietnam, Thailand and Cambodia.).

2 Collection of Information

2.1 Key Reports

The following is a list of key reports that provide or make reference to information sources.

The **Optimization Study of Mekong Mainstream Hydropower** (Compagnie Nationale du Rhône, June 2009) for the Ministry of Energy and Mines – Lao PDR, provides an update of the mainstream cascade run-of-river projects Pak Beng, Luang Prabang, Xayabuly, Pak Lay and Sanakham with respect to performed studies, main data, social and environmental impacts and other considerations.

Council Study, **Work Plan: Formulation of Development Scenarios for the Hydropower Thematic Area**, 5th RTWG Meeting, Siem Rap, Cambodia, 13-14 August 2015.

Requisites for Concession Agreement: Requirements of MRC-1995 Agreement, presentation at Technical Workshop on Xayaburi HPP in Vientiane 15 July 2015, by Xaypaseuth Phomsoupha, Director General Department of Business Energy, Ministry of Energy and Mines.

MRC Basin Development Programme, **Planning Atlas of the Lower Mekong River Basin**, 2011

Long-Term Power Development Plan, **Planned Power System Diagram in Year 2022**, by Electricité du Laos.

The MRC website (***www.mrcmekong.org***) data portal to the Data and Information Services is also an important MRC information source for this project.

2.2 The hydropower database

The hydropower database named "Q3-2015-MASTER" and other relevant linked spreadsheets, collected and edited by Mr. Piseth Chea in MRC, have been an important basis for this report.

3 Early Development Scenario 2007

Figure 3-1 provides the accumulated historical figures for installed capacity (MW) and energy (GWh) from start-up of turbine no. 1 on the first hydropower plant Ubol Ratana in Thailand in 1966 until completion of Se San 3A and Dray Hinh in Vietnam in 2007. A corresponding map showing the locations of the hydropower dams is given in Enclosure 3-1.

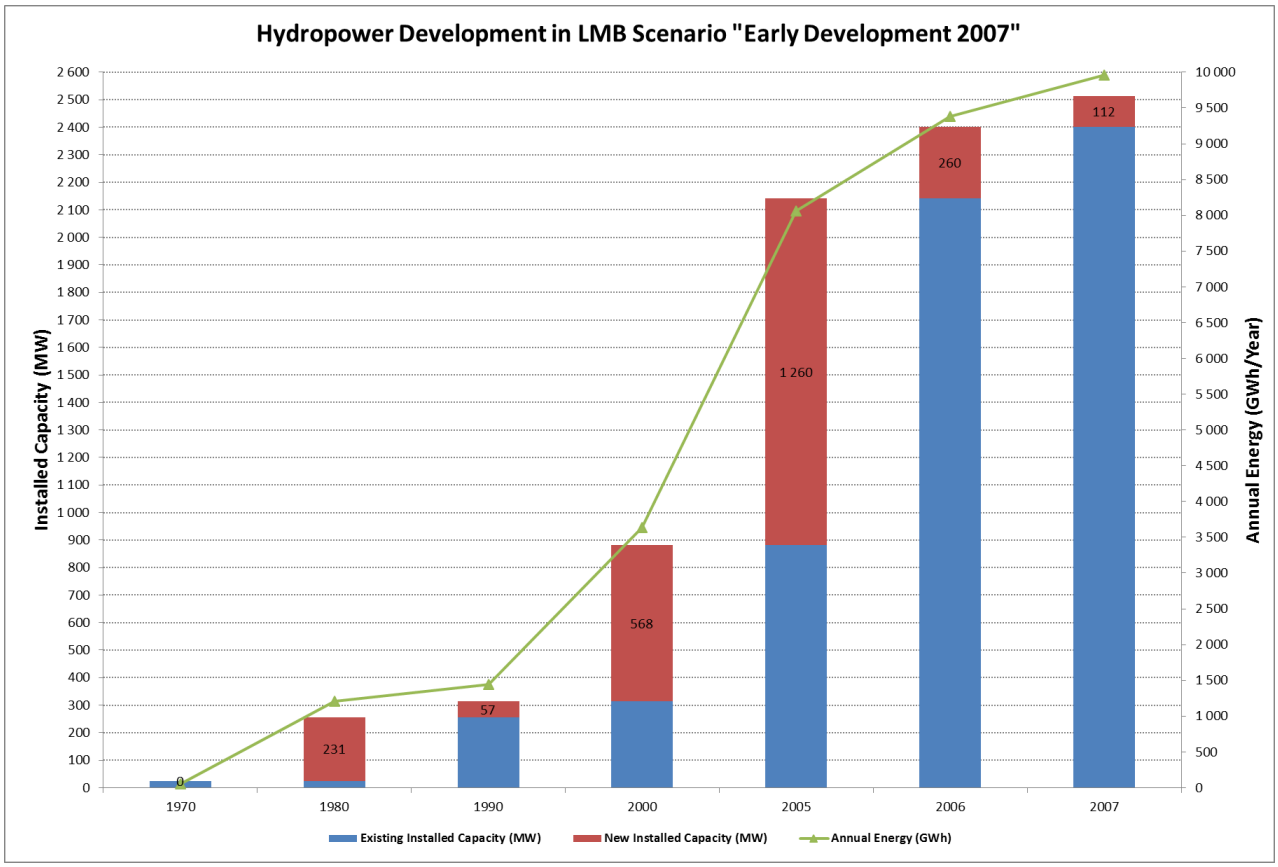


Figure 3-1 Hydropower development in LMB Early Development Scenario 2007

4 Hydropower development by 2015

Figure 4-1 provides the accumulated historical figures for installed capacity (MW) and energy (GWh) by the end of 2015.

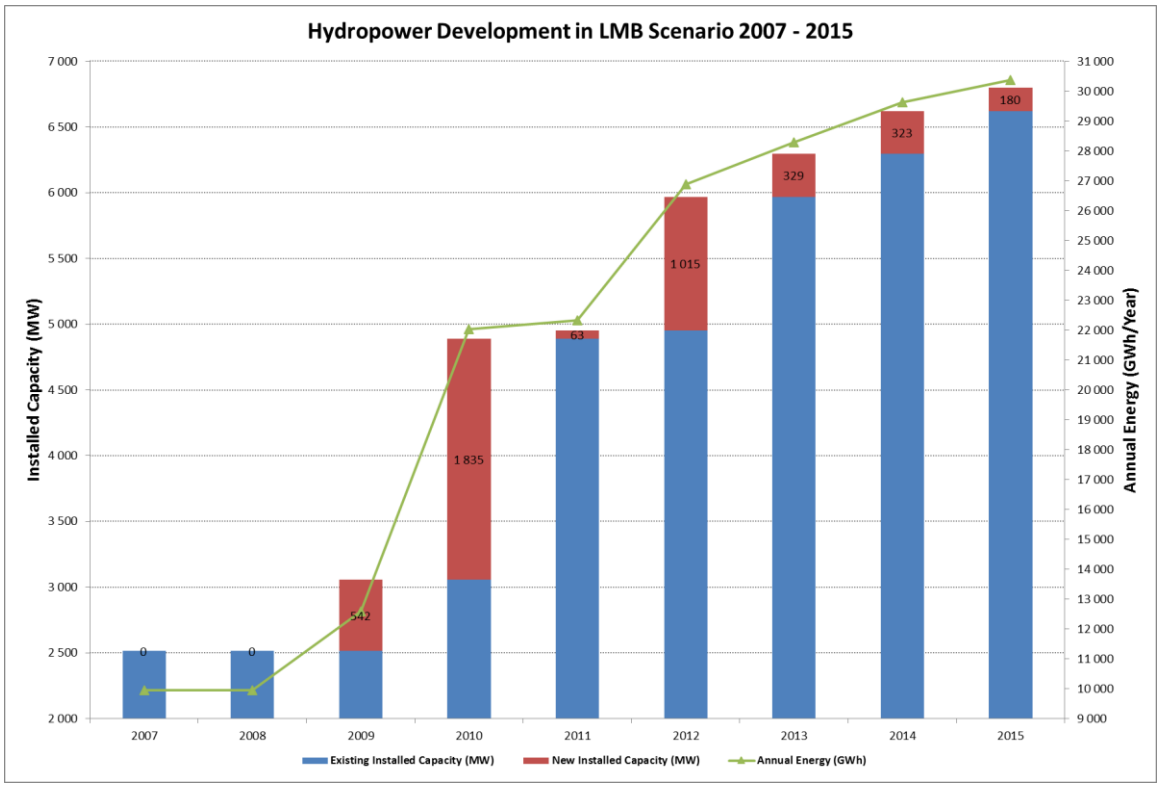


Figure 4-1 Hydropower development in LMB by 2015 (includes only projects above 15 MW)

5 Definite Future Scenario 2020

5.1 Assumptions and considerations

MS Dams – Base Scenarios

Xayaboury is scheduled to be completed in 2019, and Don Sahong is scheduled to be completed in 2018 or 2019 as preparations for the construction works have started or is about to start. It is not likely that any other MS Dam would be completed before 2020.

The mainstream dams in southern Laos and Cambodia (Ban Khoum, Phung Noi (ex Latsua), StungTreng and Sambor are included in the Planned Development Scenario 2040.

The layout (FSL, NMOL, active Storage, plant and spillway gate capacities etc.) will be updated if additional information can be made available by the NMC. Otherwise, updated assumptions will be made where the previous BDP assumptions are deemed no longer valid.

Operating rules and levels for these dams will also be changed. All run-of river storages will be kept as close as possible to FSL wherever possible to maximize head.

Mitigation: all mainstream dams will be deemed to be designed and operated in such a way as to meet the Preliminary Design Guidance. That means that they will have state of the art upstream and down-stream fish pass facilities. Spillway gates will be able to pass design floods and be set at levels that allow flushing/sluicing of sediments. The regime for flushing will be determined on the basis of the results of the MRC study on mitigation options (ISH0306) tested for the upstream cascade. In general, this will include:

- Coordinated sluicing at cascades (Pak Beng to Sanakham, Ban Khoum and Phung Ngoi, possibly Stung Treng and Sambor)
- Ramp rates and duration for flushing as per the ISH0306 findings.

Tributary projects

All tributary projects in Figure 5-1 scheduled for completion in 2018 or before is not commented on because the development/construction have reached a stage that they are likely to be commissioned within 2020.

Projects with capacity 15MW or less will not be modelled and directly assessed. However, the overall assessment should consider these dams, which are numerous across the tributaries, and could have significant impact on river connectivity for fish and sediment but may also have the opportunity for local multi-purpose uses.

The projects in Nam Ou requires some attention as they represent a considerable additional capacity/energy of more than 1 200 MW/5 200 GWh: Nam Ou 2, 5 and 6 are complete. Impounding of Nam Ou 2 and 6 started in October 2015, while impounding of Nam Ou 5 started in November. All units should be on line by April 2016 and the Project Completion Date is October 2016.

Construction of Nam Ou 1, 3, 4 and 7 started earlier in 2015 with road and bridge access works. The entire works will be undertaken by Sino Hydro and Power China. Construction plant from the First Phase Projects (Nam Ou 2, 5 and 6) is being de-mobilised and transferred to the Second Phase sites (Nam Ou 1, 3, 4 and 7).

It is expected that a period of just over 4 years will be required to commission the first units of the Second Phase Projects, which means that the projects will be partly completed by late 2019/early 2020 and fully completed in 2020. It is proposed to include these all in the Definite Future Scenario 2020.

A corresponding map showing the locations of the hydropower dams is given in Enclosure 5-1.

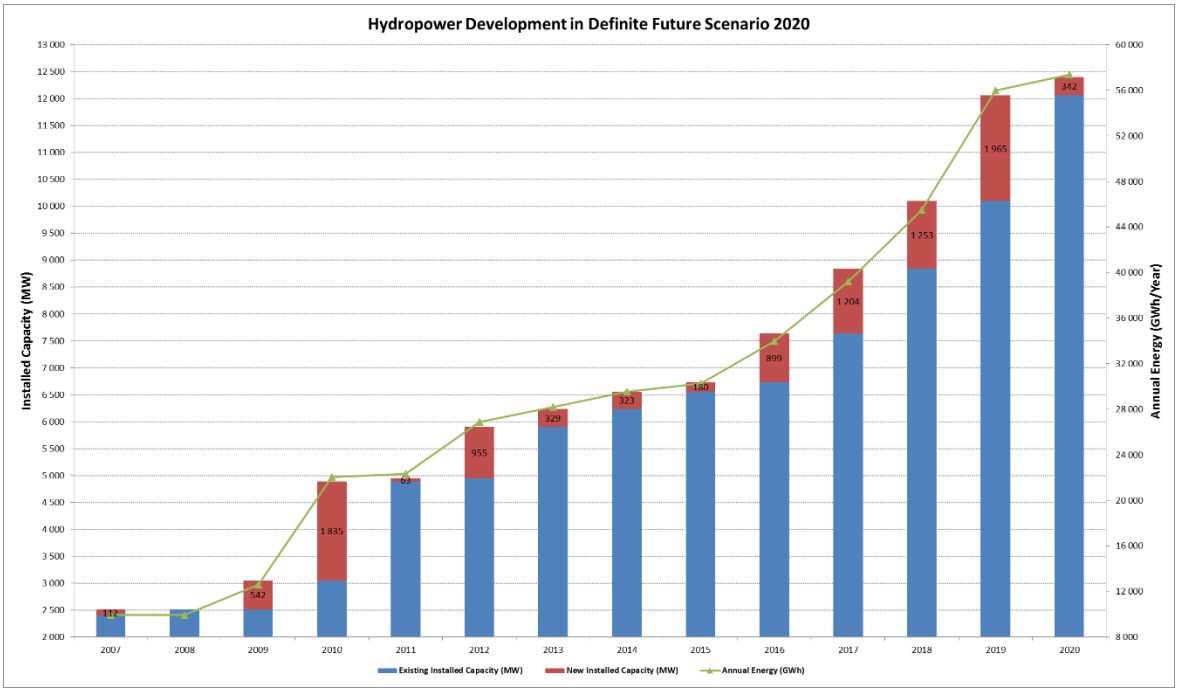


Figure 5-1 Hydropower development in LMB by 2020 (includes only projects above 15 MW)

6 Planned Development Scenario 2040

6.1 Assumptions and considerations

Table 6-1 provides the most complete list of hydropower projects being identified as under development in the LMB. The terms "Memorandum of Understanding" (MOU), "Preliminary Development Agreement" (PDA) and "Concession Agreement" (CA) are applicable to Laos only and "Prefeasibility Study" (Pre-FS) and "Feasibility Study" (FS) is applied for all countries. For the Planned Development Scenario 2040, most projects are in the MOU stage with Pre-FS and FS. For some projects, PDAs have been concluded while others are in the process of applying for PDA. Finally, some projects are even nearing the CA stage with a Power Purchase Agreement (PPA) under negotiation. Mainstream (MS) Dams are marked in red in the attached tables.

As the list reflects all identified hydropower projects that have attracted potential developers, it represents the most ambitious plan for hydropower development in the period 2020 – 2040.

Projects with capacity less than or equal to 15MW, in Laos subject to the provincial approval and governance processes, have not been included in the list.

The projects have reached different stages of development; some have been recently identified while others have been studied to feasibility level. It should be expected that future project development will result in increased or decreased capacity (MW) and energy (GWh) for some projects as further design and economic analysis is completed. It is likely that some projects will either be delayed till after 2040 or even cancelled because of high costs or environmental consequences. It is reasonable to assume that final figures for capacity and energy achieved within 2040 will be less than the total shown in Table 6-1. However, it may also be expected that additional projects may be identified and constructed before 2040.

Table 6-1: Identified projects under development (MOU, Pre-FS, FS, PDA/CA) that are proposed to be online by 2040(includes only projects above 15 MW)

Country	Project Name	Capacity (MW)	Energy (GWh)	Plant Factor (%)
Lao	Nam Pha	180	730	46
Lao	Nam Ngum 1 (extension phase 2)	40	*50*	14
Lao	Nam Phoun	60	276	53
Lao	Xe Katam	130	758	67
Lao	Nam Phouan	53	203	44
Lao	Nam Bak 1	160	744	53
Lao	Xelanong 2	35	143	47
Lao	Xedone 2	20	80	46
Lao	Xepon 3	45	167	42
Lao	Xepian-Houaysoy	50	DNF	DNF
Lao	Nam Seuang 1 (Suong)	30	114	43
Lao	Nam Seuang 2 (Suong)	108	385	41
Lao	Nam Seuang 3 (Suong)	42	147	40
Lao	Nam Seuang 4 (Suong)	47	156	38
Lao	Nam Seuang 5 (Suong)	72	242	38
Lao	Xekaman 4	80	318	45
Lao	Xekaman 2A	30	115	44
Lao	Xekaman 2B	180	564	36
Lao	Nam Theun 1	600	2 595	49
Lao	Nam Ngum 3	480	2 146	51
Lao	**Pak Beng (Mekong Mainstream)**	912	4 846	61
Lao	Xelanong 1	70	257	42
Lao	Nam Leng	60	227	43

Country	Project Name	Capacity (MW)	Energy (GWh)	Plant Factor (%)
Lao	Nam Ang Tha Beng	41	183	51
Lao	**Phou Ngoy (Mekong Mainstream) Lat Sua**	686	2 751	46
Lao	**Sanakham (Mekong Mainstream)**	660	3 696	64
Lao	**Pakchom (Mekong Mainstream)**	1 079	5 318	56
Lao	Nam Mo 1	60	223	42
Lao	Nam Phak 1	28	107	44
Lao	Nam Phak 2	28	107	43
Lao	Nam Phak 3	40	152	43
Lao	Nam Poui	60	294	56
Lao	Xe Xou	30	126	48
Lao	Nam Nga 1	100	434	50
Lao	Nam Ngum 4	220	822	43
Lao	Xebang Hieng 1	60	182	35
Lao	Xebang Hieng 2	90	288	37
Lao	Xe Bang Nouan	35	143	47
Lao	Nam Theun Keng Seua Ter	54	200	42
Lao	Xe Neua	53	209	45
Lao	Nam Feuang	28	113	46
Lao	Xe Lanong 3 (Ban Tang Earn)	80	306	44
Lao	Sekong 5	330	1 613	56
Lao	Nam Khan 4	47	DNF	DNF
Lao	Nam Ngum - Nam Kaen	70	370	60
Lao	Nam Kong 1	75	469	71
Lao	Nam Mouan	100	439	50
Lao	Nam Ngao	20	85	49
Lao	Nam Theun 4	80	130	19
Lao	**Ban Koum (Mekong Mainstream)**	1 872	8 433	51
Lao	**Luang Prabang (Mekong Mainstream)**	1 200	5 600	53
Lao	**Pak Lay (Mekong Mainstream)**	1 320	5 948	51
Lao	Nam Bak 2	40	205	59
Lao	Nam Ngum downstream	110	463	48
Lao	Sekong 4	300	1 901	72
Lao	Sekong 3A (Up)	105	411	45
Lao	Sekong 3B (Down)	100	394	45
Lao	Sekong Lower A	76	388	58
Lao	Sekong Lower B	50	200	46
Lao	Nam Tha 2	25	149	68
Lao	Xepian Hpuay Jod	21	79	43
Vietna	Duc Xuyen	58	181	36
Cambo	**Sambor**	1 703	7 691	52
Cambo	**Stung Treng**	900	5 096	65
Total		**16 415**	**75**	**52**

Figure 6-1 illustrates the development in capacity and energy generation up to 2040 in accordance with Table 6-1 above. The expansion in the period 2020 – 2040 may look ambitious compared to the period 2007 – 2020, but in terms of increases in installed capacity the difference is no so big with average annual increases of 821 and 780 MW respectively.

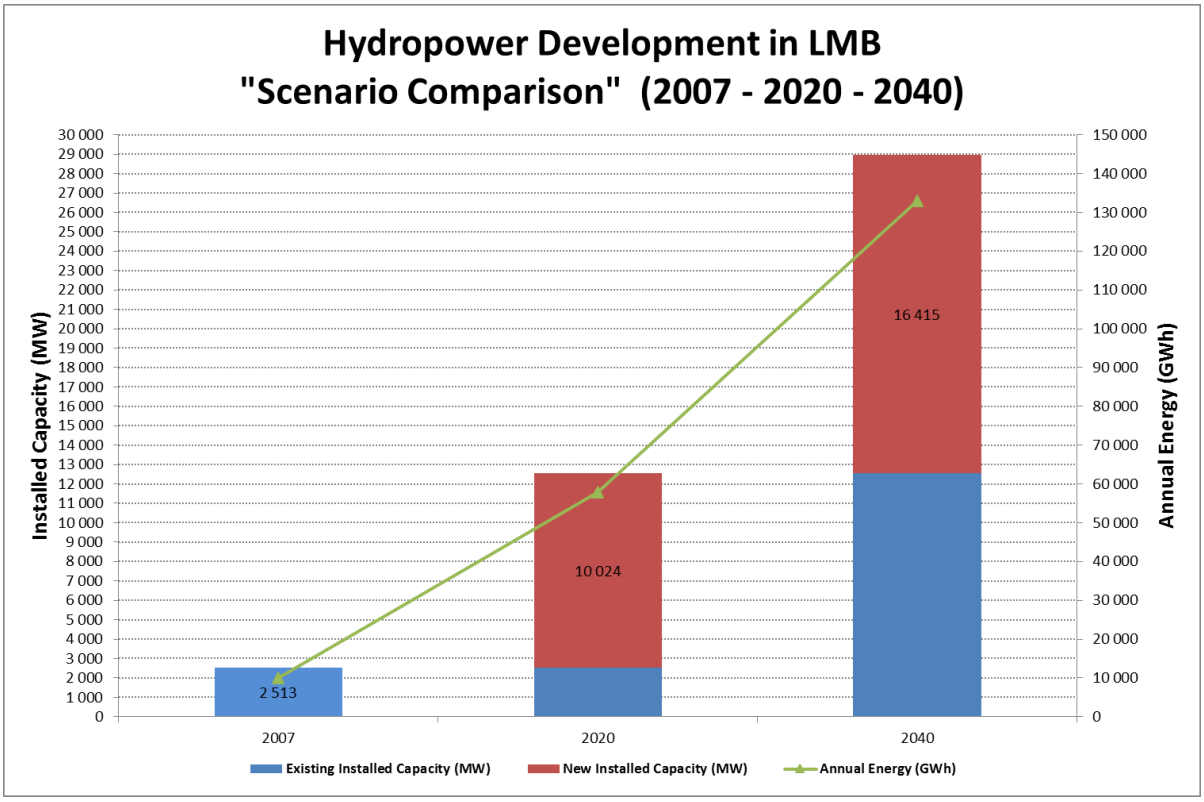


Figure 6-1 "Scenario Comparison" 2007 – 2020 – 2040 (includes only projects above 15 MW)

7 Hydropower Sub-Scenario HPS1 2040

7.1 Assumptions and considerations

Operation, mitigation and design parameters will be as for the Planned Development Scenario 2040. As before, all dams are expected at least to comply with the PDG requirements.

The intention of this scenario is to compare the influence on the Council Study assessments of the mainstream dams situated in the upper Laos area with those further downstream in southern Laos and Cambodia. This difference was evident in both the BDP2 Scenario assessment and also the Delta study, which found the dams in the Cambodian floodplain to have the most impact on fisheries and the fine grained sediments. This scenario allows the Cumulative Impact Assessment to compare full and part mainstream and tributary dam development.

7.2 Consideration of MS Dams that will be included in the HPST1

The updated figures for the MS Dams in the LMB are provided in the following table. It should be noted that different sources give different figures for some parameters.

Table 7-1: Main characteristics for MS Dams -1

Project Name	Full Supply Level	Max Head	Rated Head	Turbine Flow	Installed Power	Energy
	masl	m	m	m^3/s	MW	GWh/year
Pak Beng	340	20	16.0	7 250	1 230	4 846
Luang Prabang	320	Appr. 40	33.0	4 976	1 410	5 600
Xayaburi [1)]	275	35	28.5	5 110	1 285	7 370
Pak Lay	240	25	18.6	8 880	1 320	5 948
Sanakham	215	18-19 [2)]	6.4	9 000	660	3 696
Pak Chom	192	DNF	22	Appr. 5 600	1 079	5 318
Ban Koum	115	DNF	18.6	11 700	2 000	8 433
Phou Ngoy	97.5	DNF	10.8	10 000	800	2 751
Don Sahong 3)	DNF	25	DNF	1 600	260	2 000
Stung Treng	52	DNF	11.6	9 800	900	5 096
Sambor	40	22.9	16.5	17 668	2 600	11 740

1) Xayabouri is under construction, about 50% completed and scheduled for operation in 2019
2) Tail water level measured by the developer in low flow period in January 2009 at 210.65 mamsl
3) Preparations for construction have started

DNF: Data Not Found

The plant factor expressed in percentage represents the ratio of the actual power output of the project over a period of time, to its theoretical power output if water was available to be diverted through the turbines at maximum turbine flow. The plant factor for the MS Dams are given in the table below.

Table 7-2: Main characteristics for MS Dams -2

Project name	**Turbine flow**	**Installed power**	**Energy**	**Plant factor**	**Live storage**	**Peaking period** [1)]
	m^3/s	MW	GWh/year	%	mcm	hours
Pak Beng	7 250	1 230	4 846	45	780	30
Luang Prabang	4 976	1 410	5 600	45	120	7
Xayaburi	5 110	1 285	7 370	65	212	12
Pak Lay	8 880	1 320	5 948	51	317	10
Sanakham	9 000	660	3 696	64	132	4
Pak Chom	Appr. 5 600	1 079	5 318	56	808	40
Ban Koum	11 700	2 000	8 433	48	DNF	DNF
Phou Ngoy	10 000	800	2 751	39	530	15
Don Sahong [2)]	1 600	260	2 000	89	115	32
Stung Treng	9 800	900	5 096	65	518	15
Sambor	17 668	2 600	11 740	52	465	12

1) The peaking period is calculated to empty the live storage at full turbine flow (without any inflow).
2) Because of topographic conditions the Don Sahong HPP will only divert a portion of the river flow. Therefore the installed power has been optimized to operate at maximum capacity most of the year as reflected by a very high plant factor of 90%.

It should be noted that Xayabouri has a plant factor of 65%. This is a reference project for the other MS Dams as it has had the most optimisation of production and plant scale. It is assumed that the final and optimized plant factor for the other MS Dams will come closer to Xayabouri's plant factor through further design optimisation. Given that peaking operation, maybe with the exception of Pak Beng, will either not be allowed for or not be beneficial, one should expect that the plant factors for Luang Prabang, Pak Lay, Pak Chom, Ban Koum and Phou Ngoy will be increased.

The assumption in this Scenario is that the remaining five MS Dams marked grey in the tables above will not be developed before 2040. Some serious constraints related to each of the projects are given below.

Pak Chom; a transboundary project shared by Thailand and Lao, requires the resettlement of a large number of people, project development is in the early stage with little progress.

Ban Koum; a transboundary project shared by Thailand and Lao, there are environmental and social conflicts (fishery, resettlement), project development is in an early stage with little progress.

Phou Ngoy; solely within Lao, about same dam height as for Ban Koum but longer dam (1 300 m versus 800 m), capacity smaller than for Ban Koum because much lower rated head (800 MW versus 2 000 MW), energy smaller than for Ban Koum (2 751 GWh versus 8 433 GWh). FS has been going on for some years and is still not finalized, environmental and social conflicts are likely.

Stung Treng; solely within Cambodia, requires a long dam for a limited head, inundation of about 212 km^2, the reservoir length about 50 km, environmental and social conflicts (fishery, resettlement), further development recommended to be delayed. In addition, the economics of the development seems marginal due to the large structure and based on investigations and information gathered during the BDP Scenarios assessment.

Sambor; solely within Cambodia, requires a long dam for a limited head, capacity 2 600 MW requires 18 km long dam with more than 600 km^2 inundated area, capacity 1 703 MW requires more than 2 km long dam with more than 60 km^2 inundated area, environmental and social conflicts (fishery, resettlement) may also occur and development may be delayed to allow for re-design to be considered.

7.3 General criteria for examination of tributary projects to include in HPST1

The list of hydropower projects in Planned Development Scenario 2040 has been examined with regard to the following aspects (where relevant data is available):

1. Transboundary tributary projects will need to be reviewed and potentially excluded due to high likelihood of not proceeding (e.g. with reservoir in one country and dam & power station in another country).
2. Projects with high costs are unlikely to proceed with current proposed scale and design (above 8 US cent per kWh) (depending on access to reasonably reliable investment and production figures)
3. Projects with Plant Factor less than 40% most often indicate high costs and poor economics; these are also less likely to proceed;
4. Social and environmental red flags such as large inundation of land or ecologically sensitive areas and/or significant resettlement consequences
5. Projects 15MW or less are excluded from direct assessment.
6. The potential of unidentified projects to be discovered and developed, i.e. projects that have not been identified to date but will be identified and realized in the period 2016 – 2040

7.4 Specific observations for examination of tributary projects

1. Transboundary projects;
   A project named “Lower Sre Pok”, located not far from the Vietnamese border will be a transboundary project because the backwater will extend into Vietnam. It is not known if project development has started. This project is not included in Table 6-1.

2. High costs;
   Available cost figures may be out of date and relate to projects at very different development stages (MOU, Pre-FS, FS). Cost comparison has therefore limited value until “higher quality” cost figures can be provided.

3. Plant Factor less than 40% (ref. Table 6-1 and project figures for plant factor);

   Nam Ngum 1 (extension phase 2) with plant factor 14%: This is a thoroughly studied peaking power project for which the low plant factor is justified.

   Nam Seuang 4 and 5 both with plant factor 38%: The projects are located upstream in Nam Seuang with the smallest catchment of the Nam Seuang projects. Development before 2040 is doubtful.

   Xebang Hieng 1 and 2 with plant factor of 35% and 37% respectively: Both projects are located in Savannakhet Province presently without connection to the grid. Based on this fact combined with low plant factor and medium national priority ranking it is assumed that only Xebang Hieng 2 will be developed before 2040.

   Xekaman 2B with plant factor of 36%: It is impossible to evaluate the probability of development of this project. It is therefore assumed that it will be developed before 2040.

Nam Theun 4: There are two figures for capacity (30 and 80 MW), while the energy generation is the same (130 GWh) in both cases. The plant factor of 19% relates to the capacity which seems to be the most recent. Far from the grid, medium. Based on this fact combined with low plant factor, long distance to the grid and medium national priority ranking it is assumed that Nam Theun 4 will not be developed before 2040.

Duc Xuyen: This project is located just upstream of the cluster of plants in operation in the River Sre Pok, with a short distance to the grid and nearest access road. It is assumed that the project will be developed even though the present figures indicate a plant factor of only 36%.

4. Social and environmental red flags;
   Possible social and environmental red flags, so severe that the layout of projects would have to changed, have not been identified. However, the reason for non-identification is probably missing project information.

5. Identified projects at the MOU phase in Laos in the range of 10 -15 MW totalling about 800 MW whereof an estimated 50 % will be realized;
   The Lao Government has recently issued MOU's for about 60 smaller projects with capacity in the range of 10 – 15 MW and energy generation of about 3 000 GWh. It is assumed that 50% of the projects will be abandoned because of high costs, missing funds, costly connection to the national grid, social and environmental issues, legal disputes etc.

6. The potential of unidentified projects, i.e. projects that have not been identified by now but will be identified and realized in the period 2016 – 2040;
   It should be noted that a mapping of the remaining hydropower potential in the member countries requires a lot of skilled resources and several years to accomplish. As a very conservative approach it is likely that this will make up for the 50% reduction in capacity and energy of the 10 – 15 MW projects mentioned above.

7.5 Summary of assumptions for HPS1 2040

The table below provides a summary of the findings in Chapter 7 with reference to the Planned Development Scenario 2040.

Table 7-3: Summary of assumptions for HPS1 2040

Item	Capacity (MW)	Energy (GWh)
Planned Development Scenario 2040	16 415	75 208
Less MS Dams Pak Chom, Ban Koum, Phou Ngoy, Stung Treng, Sambor	-7 379	-33 338
Less Nam Seuang 4 and 5, Xebang Hieng 2, Nam Theun 4	-289	-816
Less 50% of small hydro < 15 MW with MOU recently	-390	-1 500
Plus potential of unidentified projects	+390	+1 500
Total	**8 747**	**41 054**

8 Hydropower Sub-Scenario HPS2 2040

8.1 Assumptions and considerations

The intention of this scenario is to compare the influence on the Council Study assessments of the tributary and mainstream dams in the Mekong as a whole with improved design and coordinated (and cooperative) operations to further reduce the impacts of these dams on a basin scale.

As for the HPST1 Scenario the previous studies have found the dams in the lower reaches of the Mekong to have the most impact on fisheries and the fine grained sediments. In addition studies by the MRC[1] and the Wild and Loucks (in Hipel et al, 20152) have indicated that the redesign and operations of hydropower in the Mekong basin can reduce the impacts of these developments. Many of these operational changes will require significant transboundary cooperation and negotiation. The nature of the 1995 Mekong Agreement promotes this type of cooperation.

The intention of this Scenario is to allow the indicative exploration of the benefits of this type of cooperation for coordinated planning and operation. It allows the Cumulative Impact Assessment to provide an indicative assessment for MCs consider for future discussion and negotiation. It is not intended as a considered recommendation; there will be many alternative options that may be considered along these lines. These options will be considered further in the MRC Hydropower Strategy as set out in the Strategic Plan 2016-2020.

Operation parameters will, in general, be as for the Planned Development Scenario 2040. As before, all dams are expected to contain at least the PDG compliance design features. However, the main change will be to test if there are any operational options that may assist to mitigation some of the more significant impacts. These may include:

- Restoration of Tonle Sap pulse flows if considered practical and economic though coordinated operation;
- Flood Mitigation through reservation of "air space" for flood storage in HP dams; (potential to be

[1] MRC, 2016: "Development of Guidelines for Hydropower Environmental Impact Mitigation and Risk Management in the Lower Mekong Mainstream and Tributaries", ISH0306.

[2] Hipel et al, 2015; "Conflict Resolution in Water Resources and Environmental Management"

considered under the Flood Sub-Scenarios)

- Improved river connectivity for fisheries through the allowance for intact river reaches at strategic locations in the Mekong. This may include considerations to retrofit fish passage to certain smaller scale irrigation and HP structures. Advice on these aspects will come out of the MRC, 2016 (ISH0306) study.
- Revised design and/or operational changes for major tributary and mainstream dams where deemed practical and economic.

8.2 MS Dams that will be included in the HPST2

The figures for the MS Dams in the LMB are provided in the tables below. Re-design options will be provided through the assessments made in the MRC, 2016 study (ISH0306).

Project name	Full Supply Level	Max head	Rated head	Turbine flow	Installed power	Energy
	masl	m	m	m^3/s	MW	GWh/year
Pak Beng	340	20	16.0	7 250	1 230	4 846
Luang Prabang	320	Appr. 40	33.0	4 976	1 410	5 600
Xayaburi[3]	275	35	28.5	5 110	1 285	7 370
Pak Lay	240	25	18.6	8 880	1 320	5 948
Sanakham	215	18-19[4]	6.4	9 000	660	3 696
Pak Chom	Excluded due to transboundary nature of the project development reducing the probability of development by 2040.					
Ban Koum	Excluded due to transboundary nature of the project development reducing the probability of development by 2040.					
Phou Ngoy	Design and Operations to be modified to balance project economics and basin scale impacts.					
Don Sahong	DNF	30	DNF	1 600	260	2 000
Stung Treng	Design and Operations to be modified to balance project economics and basin scale impacts. To be elaborated through the ISH0306 Study (MRC, 2016)					
Sambor						

DNF: Data Not Found

[3] Xayaburi is under construction, about 50% completed and scheduled for operation in 2019

[4] Tail water level measured by developer in low flow period in January 2009 at 210.65masl.

Project name	Turbine flow	Installed power	Energy	Plant factor	Live storage	Peaking period [1)]
	m^3/s	MW	GWh/year	%	mcm	hours
Pak Beng	7 250	1 230	4 846	45	780	30
Luang Prabang	4 976	1 410	5 600	45	120	7
Xayaburi	5 110	1 285	7 370	65	212	12
Pak Lay	8 880	1 320	5 948	51	317	10
Sanakham	9 000	660	3 696	64	132	4
Pak Chom	Excluded due to transboundary nature of the project development reducing the probability of development by 2040.					
Ban Koum	Excluded due to transboundary nature of the project development reducing the probability of development by 2040					
Phou Ngoy	Design and Operations to be modified to balance project economics and basin scale impacts.					
Don Sahong [2)]	1 600	260	2 000	89	115	32
Stung Treng	Design and Operations to be modified to balance project economics and basin scale impacts. To be elaborated through the ISH0306 Study (MRC, 2016)					
Sambor						

1) The peaking period is calculated to empty the live storage at full turbine flow (without any inflow).
2) Because of topographic conditions the Don Sahong HPP will only divert a portion of the river flow. Therefore the installed power has been optimized to operate at maximum capacity most of the year as reflected by a very high plant factor of 90%.

8.3 Summary of assumptions for HPS2 2040

The table below provides a summary of the findings in Chapter 8 with reference to the Planned Development Scenario 2040.

Item	Capacity (MW)	Energy (GWh)
Planned Development Scenario 2040	+16 415	+75 208
Less MS Dams Pak Chom, Ban Koum, Phou Ngoy, Stung Treng, Sambo	To be confirmed through the ISH0306 study and other regional studies in January to March 2017.	
Less Nam Seuang 4 and 5, Xebang Hieng 2, Nam Theun 4 and Nam Thong		
Less 50% of small hydro < 15 MW with MOU recently		
Plus potential of unidentified projects		
Total		

9 Data needs for socio-economic modelling

For the further analysis and modelling of the socio-economic implications of the hydropower development scenarios, a number of parameters and data will need to be estimated. The matrix overleaf list these parameters along with the data sources and the specialists that will be responsible for providing them

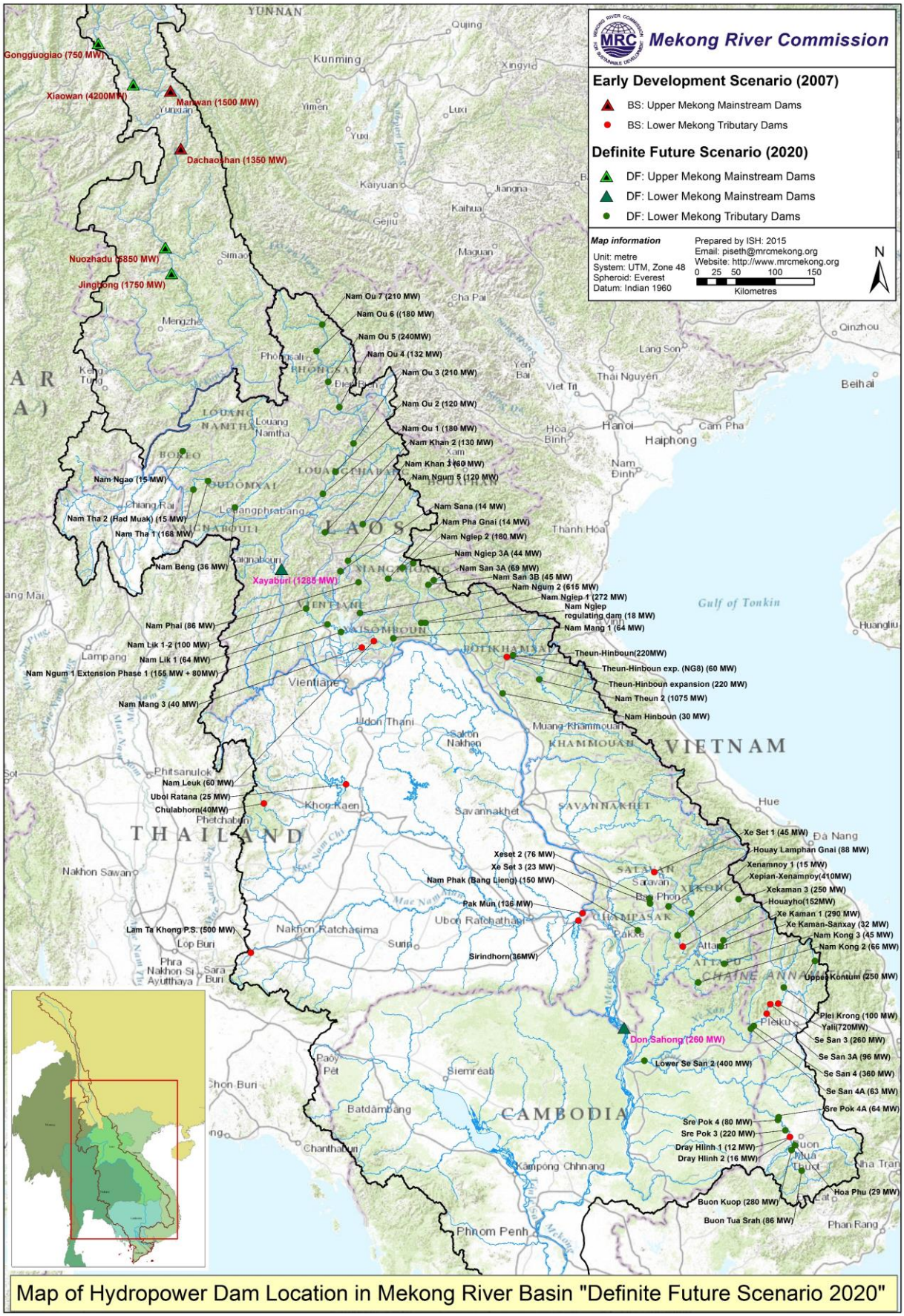
Unit	Data Source	Comment/Responsibility	Baseline (incl, 2020/2040 without hydropower/irrigation) YES / NO Lao PDR Thailand Cambodia Vietnam	*Comments (resolution re time and space)*	Scenarios (incl, 2020/2040 without hydropower/irrigation) YES / NO Lao PDR Thailand Cambodia Vietnam	*Comments (resolution re time and space)*
MW	Hydropower database	Hydropower database requires updating by hydropower thematic team ((ISH)				
GWh	Hydropower database	Hydropower database requires updating by hydropower thematic team (ISH)				
GWh US$ per MWh	Hydropower database	Hydropower database and assessment of alternative power generation options requires updating by hydropower thematic team (ISH)				
US$ million	Hydropower database	Hydropower database requires updating by hydropower thematic team (ISH)				
US$ million	Hydropower database	Hydropower database requires updating by hydropower thematic team (ISH)				
person years	Hydropower database	To be estimated by Economist in consultation with the hydropower thematic team (ISH)				
No. households US$ per household	HEP project documents	To be estimated by Economist and Social Scientist in consultation with the hydropower thematic team (ISH)				
US$ million per HEP project	HEP project documents	To be estimated by the hydropower thematic team (ISH) based on mitigation measures undertake for other HEP projects				

F

Enclosure 1: Map of hydropower dam locations in MRB "Early Development Scenario 2007"

Map of Hydropower Dam Location in Mekong River Basin "Early Development Scenario 2007"

Enclosure 2: Map of hydropower dam locations in MRB "Definite Future Scenario 2020"



Enclosure 3: Map of hydropower dam locations in MRB "Planned Development Scenario 2040"