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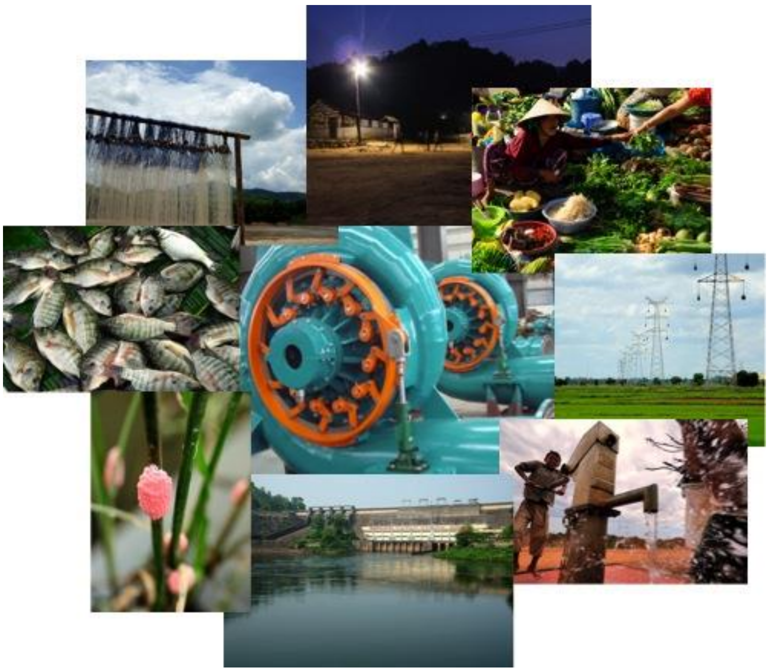

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Abbreviations and Acronyms

CA	Concession Agreement
CS	Counsil Study
DNF	Data Not Found
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
m3/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
ROW	Right Of Way
UMB	Upper Mekong Basin

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1 Introduction

The main focus for this Interim Report for the hydropower theme under the Council Study is the determination of hydropwer development scenarios for 2020 and 2040. It also highlights some of the environmental and social impacts of the hydroper development that will be subject to futher analysis in the Final Report.

It needs to be noted that the thematic study is a work in progress and that there is an interdependancy between the results of this and the other thematic reports. When these results become available a more comprehensive and final analysis of the hydropopwer development scenarions and their characteristics in terms of impacts and consequences for other sectors, will be carried out. The results of this analysis will therefore be detailed in the Final Thematic Report that will be delivered in 2017.

2 Status of the Hydropower Sector in LMB

2.1 Summary of Hydropower Projects Currently in Operation in the Lower Mekong Basin

The Mekong has become of the most active regions in the world for hydropower development with a large number of plants in operation, some projects under construction and an even larger number of hydropower projects being planned.

The first hydropower plant Ubol Ratana in Thailand had start-up of turbine no. 1 on in 1966. By late 2015 38 hydropower plants with installed power larger than 15 MW have been completed and in operation. Laos has the highest number of hydropower projects with 18 in Laos, followed by Vietnam with while there are 5 in Thailand. The total installed effect of the hydropower projects is 7 150 MW while the calculated annual energy production is close to 29 450 GWh.

In the table below the hydropower projects in the LMB that had been commissioned up till the end of 2015 is listed. Only hydropower projects with an installed effect of 15 MW or above have been included. Energy density for the projects have been calculated where figures for reservoir area at full supply level have been available. Energy density is a measure of the footprint of project in terms of installed effect per area of land inundated (MW divided by reservoir area). High energy density values indicate that the project has a good yield in relation to the area footprint of the reservoir. Run-of river (ROR) projects which normally have limited intake ponds, and not storage reservoirs, have the highest energy densities and thereby the lowest impacts in terms of land loss in relation to energy production.

Table 1: Commissioned Hydropower Projects in LMB by the End of 2015

	Project Name	COD	MW	Annual Energy GWh	Reservoir km^2	Energy Density MW/km^2
	Thailand					
1	Chulabhorn	1972	40	59	31	1.29
2	Pak Mun	1994	136	280	117	1.16
3	Sirindhorn	1971	36	90	288	0.13
4	Ubol Ratana	1966	25,2	56	410	0.06
5	Lam Ta Khong P.S.	2001	500	400	1430	0.35
	Laos					
6	Nam Ngum 1	1971	155	1002	370	0.42
7	Se Xet 1	1990	45	133,9	ROR	-
8	Theun- Hinboun	1998/2012	500	1251	105	4.76
9	Houay Ho	1999	152	450	37	4.11
10	Nam Leuk	2000	60	218	12.8	4.69
11	Nam Mang 3	2005	40	150	ROR	-
12	Se Xet 2	2009	76	309	20	3.8
13	Nam Lik 1-2	2010	100	435	24.4	4,10
14	Nam Theun 2	2010	1075	6000	450	2.39
15	Nam Ngum 2	2012	615	2300	122.2	5.32
16	Nam Ngum 5	2012	120	507	15	8.00
17	Xekaman 3	2013	250	1000,3	5.25	47.61
18	Nam Ngiep 3A	2014	44	152,3	ROR	-
19	Nam Ngiep 2	2015	180	732	-	-
20	Nam Khan 2	2015	130	558	-	
21	Houay Lamphan Gnai	2015	88	500	6.8	12.9
22	Nam Sun 3A	2015	69	278,4	-	-

	Project Name	COD	MW	Annual Energy GWh	Reservoir km²	Energy Density MW/km²
23	Nam Sun 3B	2015	45	173,5	-	-
	Vietnam					
24	Dray Hlinh 1	1990	45	100		
25	Yali	2002	720	3868	64.5	11.16
26	Se San 3	2006	260	1325	-	
27	Se San 3A	2007	96	479	-	
28	Dray Hlinh 2	2007	16	94	-	
29	Buon Tua Srah	2009	86	358	-	
30	Buon Kuop	2009	280	1459	37	7.57
31	Plei Krong	2009	100	501	80	1.25
32	Se San 4	2010	360	1649	54	6.67
33	Sre Pok 3	2010	220	1002	-	
34	Sre Pok 4	2010	80	360	-	
35	Se San 4A	2011	63	297	-	
36	Sre Pok 4A	2013	64	302	-	
37	Upper Kontum	2014	250	1056	-	
38	Hoa Phu	2014	29	113	-	
Total			**7 150**	**29 491**		

2.2 Profiles of Selected Major Hydropower Projects on the Lower and Upper Mekong Basin

In the following the LMB mainstream dams of Xayaburi and Don Sahong are briefly presented along with the tributary project Nam Ngiep 1. Additionally, key data for the largest operational hydropower project on the Lancang River in the Upper Mekong Basin are provided.

Xayaburi Hydropower Project

The Xayaburi Hydropower Project is a run-of-river hydropower scheme and is the first of its kind to be constructed on the mainstream of the lower Mekong. It is located at approximately 30 km east of Xayaburi town in Northern Laos. The scheme has an installed capacity of 1,285 MW and comprises the following main structures:

- Main Dam (820 m long and 32.6 m high)
- Navigation Locks
- Power house containing 7 x 175 MW and 1 x 60 MW Kaplan turbine generator units
- Gated spillway
- Fish Passage facilities
- Transmission lines

The MRC Prior Consultation Process (PNPCA) was conducted in 2010 and 2011 and resulted in a number of design modifications. Construction of the permanent works commenced in 2012 and is currently reported to be 50 % complete. Figure 1 shows the status of the works in June 2015.

Figure 1: Xayaburi Hydroelectric Project - June 2015 (courtesy of Poyry Engineering Ltd).

A review of design documents was undertaken by the Government of Lao PDR to assess compliance with MRC design guidelines and issues raised during the PNPCA. The review report (Xayaburi Hydroelectric Power Project Compliance Report, Poyry - August 2011) led to several subsequent design modifications. The following key changes were introduced

- Seismic design parameters based on a seismic hazard study;
- Adaption of the navigation lock to:
- Allow fish migration; and
- Increase safety of navigation;
- Introduction of low level outlets:
- 4 large low level outlets to pass sediment;
- Spillway, low level outlets and turbines to allow sediment routing;
- Adaption of fish passing facilities, including:
- Additional investigations into aquatic fauna and fish migration;
- Swimming performance tests on site with local species;
- Introduction of multiple fish pass facilities, fish locks / fish ladder, navigation lock and provision for future fish lift;
- Fish friendly turbine technology;
- Selecting an adaptive approach proving possibilities of later changes to the system.

Figure 2: Xayaburi General Layout.

Don Sahong Hydropower Project

The 260 MW Don Sahong Hydropower Project is a run-of-river scheme located in the Siphandone area of the Mekong in Southern Laos, less than 2 km upstream of Cambodian border. At Khone Falls, which is a part of Siphandone, the Mekong drops 20 to 30 m through a network of narrow braided channels comprising seven main channels and many more sub channels. The Don Sahong Project is located at the downstream end of the 5 km long Hou Sahong channel, which runs parallel to, and approximately 2 km west of, the Phaheng channel.

The scheme comprises a power station and a reinforced concrete barrage structure with embankment sections along the islands of Don Sadam and Don Sahong. A small headpond is formed by the embankments and the barrage structure. The powerhouse spans the 100 m wide Hou Sahong channel with a maximum height of 30 m above the natural river bed and features 4 x 65 MW Bulb turbine generator units. The upstream embankment dams on each side of the powerhouse will have an overall length of 7 km, with heights varying between 25 m above natural ground level at the powerhouse and 1 m at their upstream ends. The right hand embankment includes an emergency spillway.

Nam Ngiep 1 Hydropower Project

The project is located on the Nam Ngiep approximately 145 km northeast of Vientiane and about 40 km north of Pakxan. The plant comprises a main power station downstream of a main concrete gravity dam having a height of 148.0 m and crest length of 530.0 m. The reservoir has a surface area of 66.9 km^2. Water discharged from the main powerhouse will flow into a re-regulating pond, retained by a concrete labyrinth gravity spillway and flanking embankments having a height of 20.6 m and crest length of 90.0 m, serving a re-regulating power station. The main and re-regulating stations have installed capacities of 272 and 18 MW respectively

A 3D model of the main dam is shown in the figure below.

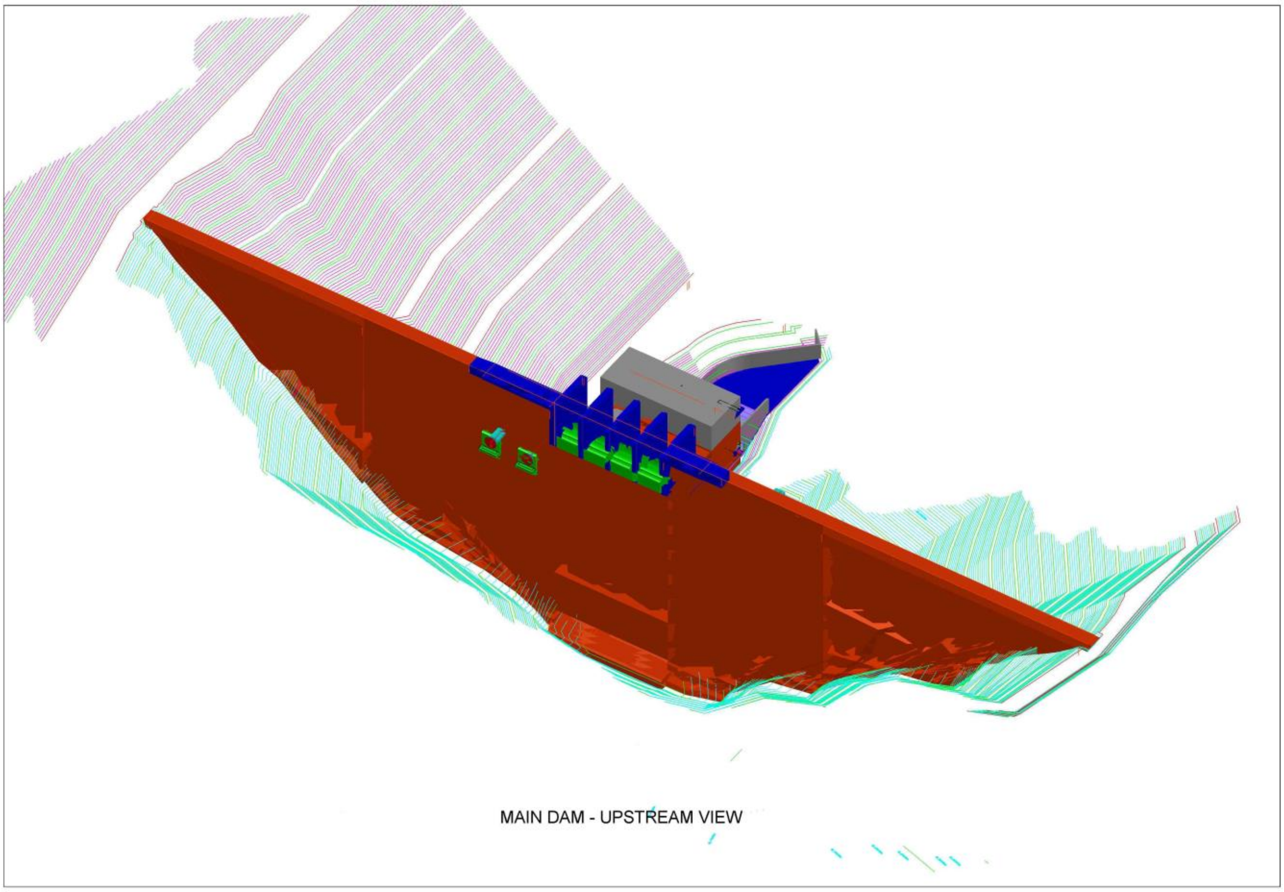

Figure 3: D model of Nam Ngiep Main Dam (source www.namngiep1.com).

2.3 Profiles of Selected Major Hydropower Projects on Upper Mekong Basin

Description of the main hydropower schemes in operation in the Upper Mekong Basin (UMB), the Lancang River, are based on information from various sources.

Jinghong Hydropower Project

The Jinghong Dam Hydropower Project is located in the southern part of Yunnan Province, China. The project has mainly been designed for power generation but has also other functions such as providing better flood control and enhancing navigation. The construction of the scheme started in 2005, with the first unit entering commercial operation in 2008. The project was reportedly fully operational in 2009. The scheme has an installed capacity of 1,750 MW, and comprises the following main structures:

- Main Dam (RCC gravity dam, 704.5 m long and 108 m high).
- Power house containing 5 x 350 MW Francis turbine generator units
- Spillway structure
- Ship lock

Photo 2-1 Jinghong Dam (Source www.flickr.com)

Nuozhadu Hydropower Project

The Nuozhadu Hydropower Project is located in the Yunnan Province of China. The project is designed mainly for power generation but also fulfils multifunctional purposes such as flood control and improvement of downstream navigation. The scheme has an installed capacity of 5,850 MW, which is reported to be the largest hydropower station along the Lancang River and in Yunnan Province. The project comprises the following main structures:

- Main Dam (central core rockfill dam, 608 m long and 261.5 m high).
- Power house with 9 x 650 MW turbine generator units
- Gated side channel spillway.

The scheme has been operational since 2012, with the last unit commissioned in 2014. The reservoir created by the dam allows for major seasonal regulation.

Photo 2-2 Nuozhadu Hydropower Project (Source www.flickr.com)

Dachaoshan Hydropower Project

The Dachaoshan hydropower project, located on Lancang River, Yunnan province, is a single purpose project for power production. The project has an installed capacity of 1,350 MW and commenced commercial operation in 2003. The project comprises the following main structures:

- Main Dam (RCC gravity dam, 460 m long and 111 m high).
- Power house containing 6 x 225 MW Francis turbine generator units
- Crest overflow gated spillways

Photo 2-3 Dachaoshan Hydropower Project (Source www.flickr.com)

Manwan Hydropower Project

The Manwan hydropower project, located on Lancang River, has an installed capacity of 1,500 MW and comprises the following main structures:

- Main Dam (concrete gravity dam, 418 m long and 132 m high).
- Power house containing 5 x 250 + 1 x 300 MW Francis turbine generator units
- Crest gated spillway and a tunnel spillway

The Manwan Hydropower Station began operation in 1996 and has been subject of extensive studies as the first large scale hydropower station on the Lancang River.

Photo 2-4 Manwan Hydropower Project. (Source: www.flickr.com)

Xiaowan Hydropower Project

The Xiaowan hydropower project is a significant component of the Lancang River cascade. Its main purpose is electricity generation. It is the world's second highest arch dam at 292 m and it creates a large reservoir which is acting as a sediment retention buffer for the Manwan and Dachaoshan hydropower projects. The Xiaowan hydropower project has an installed capacity of 4,200 MW, and comprises the following main structures:

- Main Dam (double curvature arch dam, 902 m long and 292 m high).
- Power house containing 6 x 700 MW Francis turbine generator units
- Crest gated spillway and a tunnel spillway

The construction of the scheme commenced in 2002. The first unit entered commercial operation in 2009 and last unit was commissioned in 2010. The size of the reservoir created by the dam allows for major seasonal regulation.

Photo 2-5 Xiaowan Hydropower Project. (Source: Mekong River Commission)

Gongguoqiao Dam

The 900 MW Gongguoqiao hydropower project comprises the following main structures:

- Main Dam (gravity, roller compacted concrete dam, 356 m long and 105 m high).
- Power house containing 4 x 225 MW Francis turbine generator units
- Crest gated spillway and a tunnel spillway

Photo 2-6 Gongguoqiao Dam. (Source: www.flickr.com)

The construction of the project started in 2008 and the scheme commenced commercial operation in 2011. The last unit was commissioned in 2012.

3 Development Trends

A report by the International Energy Agency (IEA) and the Ministry of Mines and Energy of the Federal Republic of Brazil (Technology Roadmap: Hydropower) discusses how a doubling of the hydroelectricity production by 2050, could prevent annual emissions of up to 3 billion tonnes of CO_2 from fossil-fuel plants.

The report challenges the notion that the world's hydroelectric resources have peaked. Instead, it says emerging economies have significant potential to generate electricity from large plants. Hydropower is described as the leading renewable electricity generation technology worldwide, with new capacity additions since 2005 generating more electricity than all other renewables combined. The report emphasizes hydropower's advantages such as reliability, proven technology, large storage capacity, and very low operating and maintenance costs. Multipurpose benefits including flood control, irrigation, navigation and freshwater supply are also highlighted.

3.1 General Development Trends

Hydropower is seen as a cost-effective energy source in Laos which has a theoretical hydroelectric potential of about 26 500 MW excluding the mainstream Mekong. Of this, about 18 000 MW is technically exploitable, with 12 500 MW found in the major Mekong sub-basins and the remainder in minor Mekong or non-Mekong basins. At present the mainstream dams in Laos being constructed or planned represents a capacity of about 10 000 MW whereof 30% is by transboundary projects shared with Thailand. Around 25% of the country's hydropower potential has been developed over the past 40 years, but under the present government policy the rate of development has been accelerated to supply electricity to the rapidly growing economies of the region.

Vietnam's new strategy on renewable energy development from November 2015 affirms that hydro power contributes to local socio-economic development and power safety, and should be developed in line with local plans for small- and medium-sized hydro power plants on the basis of assessment of environmental impacts. Hydro power should provide nearly 90 000 GWh in 2020 and 96 000 GWh a year as from 2030, compared to 56 000 GWh in 2015. Whilst Vietnam has reserves of oil and coal and provides significant capacity, hydropower has traditionally provided an alternate cheap source of base load power. In 2012, hydro provided about 48 per cent of Vietnam's electricity, but by 2020 this is expected to drop to about 20 per cent.

The power generation from hydropower plants in Thailand represents about 3% of the total generation (natural gas, coal, renewable, oil, import). The import, representing about 7% of the total, and is delivered from hydropower plants in Laos. According to Dept. of Energy in July 2015, the target for renewable energy development in Thailand is to reach 25% of total energy consumption by 2021 from about 18% in 2015. The largest remaining potential within LMB is represented by the transboundary projects on the mainstream; e.g. Pak Chom and Ban Koum.

The power generation from hydropower plants in Cambodia represents about 56% of the total generation (hydro, oil, coal and biomass). The hydropower plant - Lower Se San 2 – is under construction and will add 400 MW to the already operable hydropower of 1 016 MW. The largest remaining potential within LMB is represented by the mainstream projects Stung Treng and Sambor.

In China, hydropower is promoted as the best possible alternative to coal-fired power stations. It is intended that hydropower development will significantly contribute to the target of 15 % of renewable energy by 2020.

3.2 Trends in the Lower Mekong Basin Countries

Existing hydropower capacity (within the LMB) has increased from 282 MW to 6 800 MW between 1990 and 2015. In the period from 2010 to 2015, hydropower development in Lao PDR proceeded at a significantly slower pace than envisioned in 2009. However, the updated national plans aims to accelerate hydropower development in the country.

The power demand and supply balance estimate for 2025 predicts that the total energy demand will increase to 815,000 GWH, of which 60% will be consumed in Thailand, 36% in Viet Nam, and 4% in Cambodia and Lao PDR. It is anticipated that gas and coal will remain the main sources of energy, accounting for 34% and 54% of energy demand in LMB countries, while hydropower's share increases to 12% followed by nuclear (5%) and other sources (5%).

In Thailand, gas (54%) will still be the main source of energy, followed by coal (24%), but hydropower (15%) will become increasingly important so as to reduce Thailand's dependence on non-renewable energy sources.

By 2025, it is expected that hydropower will meet 100% of domestic energy demand in Lao PDR and 88% in Cambodia, thereby reducing the dependency on non-renewable energy sources and achieving energy security. Hydropower will also play a major role in the economic development of Lao PDR through contributions to GDP, export earnings and government revenue. Similarly, Cambodia will also gain substantial economic benefits from hydropower development through a significant reduction in power costs as well as increased contributions to GDP and lower import costs.

Although the potential for hydropower development in the LMB is large, the very rapidly growing regional demand for power will by far exceed hydropower's potential to meet the energy requirements of LMB countries. In theory, all economically viable hydropower projects could therefore be developed if adverse environmental and social impacts can be adequately mitigated.

In summary, the hydropower generation capacity could increase to 29 000 MW in LMB provided that all the eleven MS Dams in LMB are developed. However, based on the results of the Hydropower Development Scenarios Report by MRC, it is more likely that the hydropower capacity will increase to about 22 000 MW in 2040, of which 82% would be developed in Lao PDR, 2% in Cambodia, 4% in Thailand and 12% in Viet Nam. Furthermore, hydropower will provide a renewable source of energy so as to reduce dependence on gas and oil. This will not only enhance regional energy security but also contribute towards a reduction in GHG emissions.

Finally, it is also expected that hydropower will be able to maintain an economic comparative advantage in relation to other energy sources in both the medium and the long term. Unit capacity costs of hydropower are significantly lower than other renewable energy sources as well as nuclear power and, with increasing gas and oil prices (in real terms), hydropower is likely to improve a comparative advantage relative to these non-renewable energy sources.

3.2.1 Discussion of national, regional and local plans

3.2.1.1 Early Development Scenario 2007

Figure 4 presents 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 Hlinh in Vietnam in 2007.

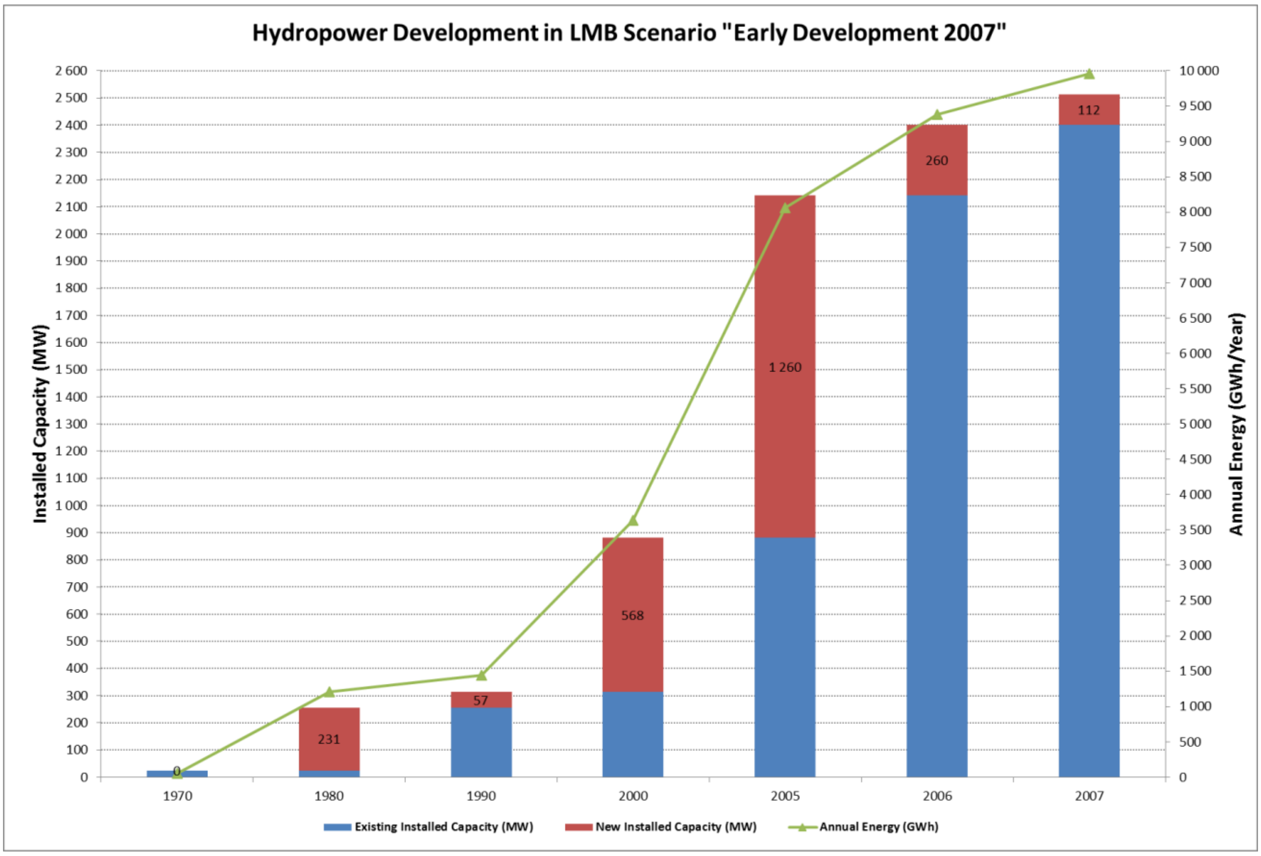

Figure 4: Hydropower Development in LMB - Early Development Scenario 2007

3.2.1.2 Definite Future Scenario 2020

The scenario for 2020 includes two mainstream projects, namely Xayaburi which is scheduled to be completed in 2019, and Don Sahong, scheduled to be completed in 2019 or 2020. It is not likely that any other mainstream dam would be completed before 2020.

Regarding tributary projects the Nam Ou cascade needs to be specifically mentioned as it represents a considerable additional capacity/energy of more than 1 200 MW/5 200 GWh. The Nam Ou 2, 5 have now all been commissioned. The Project Completion Date will be in October 2016.

Construction of Nam Ou 1, 3, 4 and 7 started 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) has been de-mobilised and transferred to the Second Phase sites (Nam Ou 1, 3, 4 and 7).

It is expected that the projects will be partly completed by late 2019/early 2020 and fully completed in 2020.

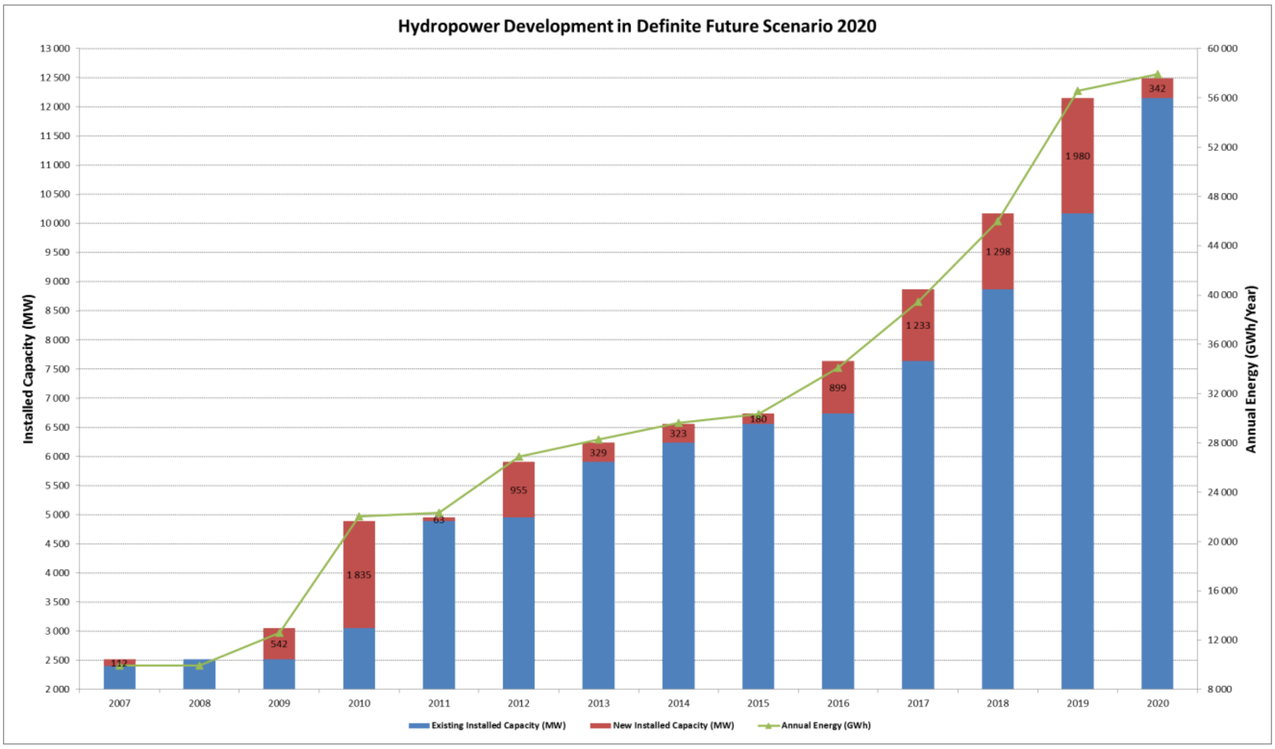

Figure 5: Hydropower Development in LMB – Definite Future Scenario 2020

3.2.1.3 Hydropower Development in the period 2020 - 2040

Table 2 provides the most complete list of hydropower projects being identified as being planned for development in period 2020 – 2040. The terms Memorandum of Understanding (MOU), Project Development Agreement (PDA) and Concession Agreement (CA) is applicable to Laos only while Prefeasibility Study (PFS) and Feasibility Study (FS) is applied for all countries. For the 2020 - 2040 scenario, most projects are in the MOU stage for PFS and FS. For some projects PDA has been signed while others PDA negotiations are ongoing. Finally, for a few projects the CA and PPAs are being negotiated.

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 15 MW have not been included in the list.

It should be expected that future feasibility studies will result in increase or decrease in capacity (MW) and energy (GWh) for some of the projects. It is also possible that some projects will either be delayed till after 2040 or even cancelled because of high cost or environmental consequences. It is reasonable to assume that final figures for capacity and energy achieved within 2040 will be lower than the totals shown in the Table 2. However, there is a possibility that a few new projects may be identified and developed before 2040.

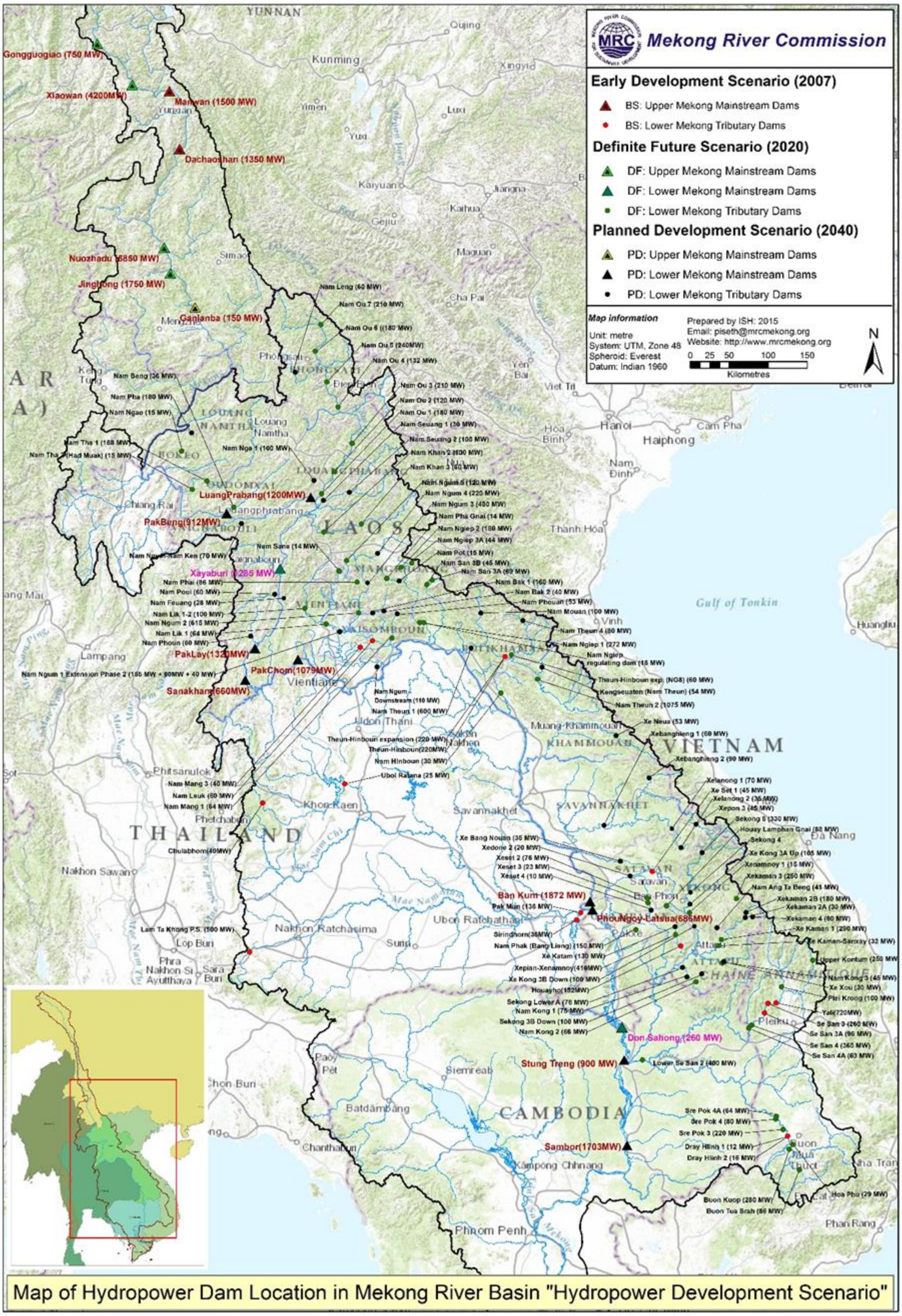

Figure 6: Map with Location of the HPPs included in the 2007, 2020 and 2040 Scenarioes

Table 2: Projects Planned for Development in the Period 2020 - 2040

Country	Project Name	Capacity MW	Energy GWh	Plant Factor %
Lao	Nam Pha	180,0	730	46 %
Lao	Nam Ngum 1 (extension phase 2)	40,0	*50*	14 %
Lao	Nam Phoun	60,0	276	53 %
Lao	Xe Katam	130,0	758	67 %
Lao	Nam Phouan	53	203	44 %
Lao	Nam Bak 1	160,0	744	53 %
Lao	Xelanong 2	35,0	143	47 %
Lao	Xedone 2	20,0	80	46 %
Lao	Xepon 3	45,0	167	42 %
Lao	Xepian-Houaysoy	50,0		0 %
Lao	Nam Seuang 1 (Suong)	30,0	114	43 %
Lao	Nam Seuang 2 (Suong)	108,0	385	41 %
Lao	Nam Seuang 3 (Suong)	42,0	147	40 %
Lao	Nam Seuang 4 (Suong)	47,1	156	38 %
Lao	Nam Seuang 5 (Suong)	72,0	242	38 %
Lao	Xekaman 4	80,0	318	45 %
Lao	Xekaman 2A	30,0	115	44 %
Lao	Xekaman 2B	180,0	564	36 %
Lao	Nam Theun 1	600,0	2595	49 %
Lao	Nam Ngum 3	480,0	2146	51 %
Lao	Pak Beng (Mekong Mainstream)	912,0	4846	61 %
Lao	Nam Boun 2	15,0	60	46 %
Lao	Xelanong 1	70,0	257	42 %
Lao	Nam Leng	60,0	227	43 %
Lao	Nam Ang Tha Beng	40,9	183	51 %
Lao	Phou Ngoy (Mekong Mainstream) Lat Sua	686,0	2751	46 %
Lao	Sanakham (Mekong Mainstream)	660,0	3696	64 %
Lao	Pakchom (Mekong Mainstream)	1 079,0	5318	56 %
Lao	Nam Mo 1	60,0	223	42 %
Lao	Nam Phak 1	28,0	107	44 %
Lao	Nam Phak 2	28,0	107	43 %
Lao	Nam Phak 3	40,0	152	43 %
Lao	Nam Poui	60,0	294	56 %
Lao	Nam Pot	15,0	71	54 %
Lao	Xe Xou	30,0	126	48 %
Lao	Nam Nga 1	100,0	434	50 %
Lao	Nam Ngum 4	220,0	822	43 %
Lao	Xebang Hieng 1	60,0	182	35 %
Lao	Xebang Hieng 2	90,0	288	37 %
Lao	Xe Bang Nouan	35,0	143	47 %
Lao	Nam Theun Keng Seua Ter	54,0	200	42 %
Lao	Xe Neua	53,0	209	45 %
Lao	Nam Feuang	28,0	113	46 %
Lao	Xe Lanong 3 (Ban Tang Earn)	80,0	306	44 %
Lao	Sekong 5	330,0	1613	56 %

Country	Project Name	Capacity MW	Energy GWh	Plant Factor %
Lao	Nam Khan 4	47,0		0 %
Lao	Nam Ngum - Nam Kaen	70,0	370	60 %
Lao	Nam Kong 1	75,0	469	71 %
Lao	Nam Mouan	100,0	439	50 %
Lao	Nam Ngao	20,0	85	49 %
Lao	Nam Theun 4	80,0	130	19 %
Lao	Ban Koum (Mekong Mainstream)	1 872,0	8433	51 %
Lao	Luang Prabang (Mekong Mainstream)	1 200,0	5600	53 %
Lao	Pak Lay (Mekong Mainstream)	1 320,0	5948	51 %
Lao	Nam Bak 2	40,0	205	59 %
Lao	Nam Ngum downstream	110,0	463	48 %
Lao	Sekong 4	300,0	1901	72 %
Lao	Sekong 3A (Up)	105,0	411	45 %
Lao	Sekong 3B (Down)	100,0	394	45 %
Lao	Sekong Lower A	76,0	388	58 %
Lao	Sekong Lower B	50,0	200	46 %
Lao	Nam Nua 1	15,0	57	43 %
Lao	Nam Ou 8	15,0	57	43 %
Lao	Nam Houn 1	15,0	57	43 %
Lao	Nam Houn 3	15,0	57	43 %
Lao	Nam Boun 2	15,0	57	43 %
Lao	Nam Boun 3	15,0	57	43 %
Lao	Nam Hoy	15,0	57	43 %
Lao	Nam Tha 2	25,0	149	68 %
Lao	Nam Pha 2	15,0	57	43 %
Lao	Nam Mak	15,0	57	43 %
Lao	Nam Soui	15,0	57	43 %
Lao	Nam Bak	15,0	57	43 %
Lao	Nam Mud	15,0	57	43 %
Lao	Nam Mee	15,0	57	43 %
Lao	Nam Lik (Kaeng Luang) 1/2A	15,0	92	70 %
Lao	Nam Feuang Lower	15,0	57	43 %
Lao	Nam Sun (Had to)	15,0	57	43 %
Lao	Nam Ngom upper	15,0	57	43 %
Lao	Nam Jath 2	15,0	57	43 %
Lao	Nam Sun 2	15,0	57	43 %
Lao	Nam Jath 1	15,0	57	43 %
Lao	Xe Kham Phor	18,0	68	43 %
Lao	Xepian Hpuay Jod	21,0	79	43 %
Lao	Xedone 2	15,0	57	43 %
Lao	Nam Ka Ouan	14,8	56	43 %
Lao	Nam Yeung 7	15,0	57	43 %
Lao	Houay Pa Air	15,0	57	43 %
Lao	Nam Pee 2	14,8	56	43 %
Vietnam	Duc Xuyen	58,0	181	36 %
Cambodia	Sambor	1 703,0	7 691	52 %
Cambodia	Stung Treng	900,0	5 096	65 %
Total		**15 940**	**72 804**	**52 %**

Figure 7 illustrates the development in capacity and energy generation up to 2040 in accordance with Table 2 above. The expansion in the period 2020 – 2040 appears ambitious compared to the period 2007 – 2020, however, the annual increase in the later period is about 820 MW compared to about 780 MW in the first period.

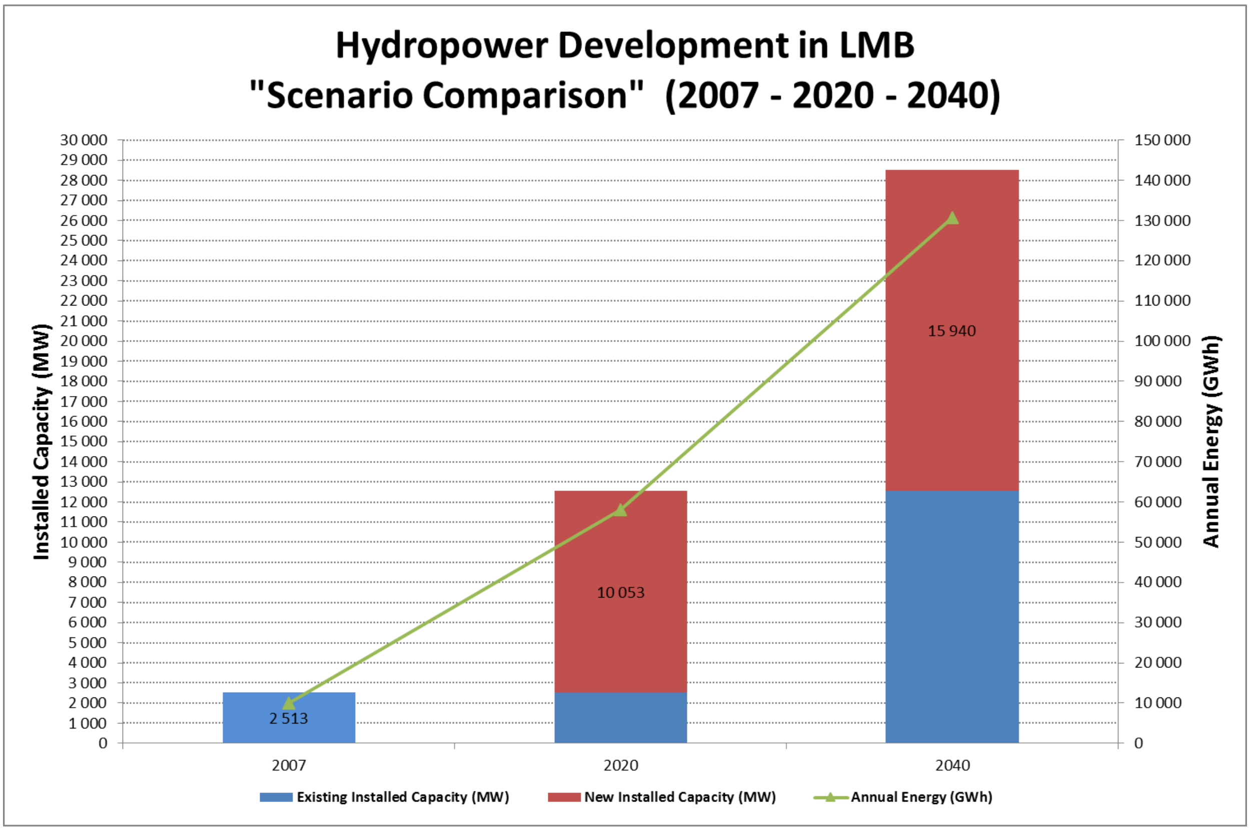

Figure 7: Scenario Comparison 2007 – 2020 – 2040

3.2.1.4 Hydropower Development Sub-Scenario 1 (HPS1)

Assumptions and Considerations

This scenario refers to HPP Thematic Sub-scenario HPS1 with «No joint operation" where each hydropower dam is operated to maximize its separate energy production. The "No joint operation" implies that operational constraints as reservoir sediment flushing, water flows for fish passages, water requirements for navigation, flow requirements versus water quality etc. have not been reflected in the energy production figures included except for Xayaburi. HPS1 corresponds to Option 1.1. "5 Project Cascade incl. Pak Beng, Luang Prabang, Xayaburi, Pak Lay and Sanakham" in the ISH0306 Study.

Realisation of Mainstream Dams

The updated figures for the mainstream dams in the LMB are presented in Table 3. It should be mentioned that different sources give different figures for some parameters.

Table 3: Main Characteristics for Mainstream 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 [1)]	340	20	18.0	5 771	912	4 775
Luang Prabang	320	Appr. 40	33.0	4 976	1 410	5 600
Xayaburi [2)]	275	35	28.5	5 110 + 242	1 285	7 400
Pak Lay	240	25	18.6	8 880	1 320	5 948
Sanakham	215	18-19 [3)]	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[4)5)]	73	Appr. 25	17	1 600	260	2 044
Stung Treng	52	DNF	11.6	9 800	900	5 096
Sambor	40	DNF	16.5	12 000	1 703	7 691

1) Latest figures for turbine flow, installed power and energy from 2014 Feasibility Study.
2) Xayaburi is under construction, about 50% completed and scheduled for start operation in 2019.
3) Tail water level measured by the developer in low flow period in January 2009 at 210.65 masl.
4) Preparations for construction have started.
5) Latest figures from “Questions and answers from Don Sahong Project”, Ministry of Energy and Mines, Lao PDR.

The plant factor in % represents the usage time for the installed power if the available water volume is diverted through the turbines at maximum turbine flow. The plant factor for the mainstream dams are given in the table below.

Table 4: Main Characteristics for Mainstream Dams - 2

Project name	Turbine flow	Installed power	Energy	Plant factor	Live storage	Peaking capacity [1)]
	m^3/s	MW	GWh/year	%	mcm	hours
Pak Beng	5 771	912	4 775	60	196	19
Luang Prabang	4 976	1 410	5 600	45	120	101
Xayaburi	5 110+242	1 285	7 400	66	212	36
Pak Lay	8 880	1 320	5 948	51	317	17
Sanakham	9 000	660	3 696	64	132	7
Pak Chom	Appr. 5 600	1 079	5 318	56	808	147
Ban Koum	11 700	2 000	8 433	48	DNF	DNF
Phou Ngoy	10 000	800	2 751	39	530	92
Don Sahong [2)]	1 600	260	2 044	90	25	11
Stung Treng	9 800	900	5 096	65	518	261
Sambor [3)]	12 000	1 703	7 691	52	465	196

1) The peaking capacity is calculated on the basis of time needed to empty the live storage at full turbine flow (with average 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%.
3) The project has been downscaled from 2 600 MW to 1 703 MW to reduce the environmental and social consequences.

Xayaburi has a plant factor of 66%. This is a reference project for the other mainstream projects and it is assumed that the final optimization of the other MS Dams will result in plant factors that are closer to Xayaburi's plant factor. Peak operation is not currently permitted on the mainstream river. For Xayaburi it is a requirement of Annex J (Integrated Social and Environmental Obligations) of the Concession Agreement that the project is operated as a pure run of river power plant. Given that peaking operation 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 by reducing the installed power.

The Tables above list 11 mainstream dams. Xayaburi is under construction scheduled for completion in 2019, and preparations for the construction works for Don Sahong started late 2015 with planned completion before 2020. These two plants are included in the Definite Future Scenario 2020. It is assumed that Pak Beng, Luang Prabang, Pak Lay and Sanakham will be commissioned before 2040. It is uncertain that the remaining five mainstream dams marked grey in the tables will be developed before 2040. Some constraints related to each and one of the projects are given below.

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

Ban Koum; a transboundary project shared by Thailand and Lao, environmental and social conflicts (fishery, resettlement), project development in early stage with limited 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 of much lower rated head and installed power (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.

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 by 10 years in 2010 (in report authorised by MRC "Will Baxter: Cambodia most exposed dam threats").

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), further development recommended to be delayed by 10 years in 2010 (in report authorised by MRC "Will Baxter: Cambodia most exposed dam threats").

General criteria for examination of tributary projects

The list of hydropower projects in Reference Future Scenario 2020 – 2040 have been subject to an examination with regards to the following aspects a far as relevant data have been available:

1. Transboundary projects (e.g. with reservoir in one country and dam & power station in another country);
2. High costs (above 8 US cents per kWh) (depending on access to reasonably reliable investment and production figures);
3. Plant Factor less than 40% which most often is an indication of high costs;
4. Social and environmental red flags such as inundation of large areas of land and/or resettlement consequences;
5. For Laos only projects with an installed effect of 15 MW or more have been included in the scenario analysis;
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;
7. Hydropower potential in Thailand's provinces in the Northeast (Chiang Rai, Chiang Mai and Phayao) of Lower Mekong;

Specific observations for examination of tributary projects

1. *Transboundary projects* A dam project named "Lower Sre Pok", with the dam located in Lao but close to the border between Lao and Vietnam, is a transboundary project because the inundated area will come within Vietnam. It is probable that only a Vietnamese developer will be entitled to develop the project. It is not known if project development has started. This project is not included in Table 2.

2. *High costs* It should be noted that the available cost figures are old and relates to different development stages (MOU, Pre-FS, FS). Cost comparison has therefore limited value until "higher quality" cost figures become available.

3. *Plant Factor less than 40%*

    i. The Nam Ngum 1 Project (Extension Phase 2) has a plant factor of 14%, However, this is a thoroughly studied peaking power project for which the low plant factor is justified.

    ii. Nam Seuang 4 and 5 both have a plant factor of 38%: The projects are located upstream in Nam Seuang with the smallest catchment of all the Nam Seuang projects. It is therefore questionable if these projects are development before 2040.

iii. Xebang Hieng 1 and 2 have plant factors of 35% and 37% respectively. Both projects are located in Savannakhet Province relatively far away from the present nearest grid connection. 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.

iv. Xekaman 2B has a plant factor of 36% and it is therefore a question whether it will be developed or not. However, it is assumed that it will be developed within 2040.

v. Nam Theun 4 has 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. It is far from any grid connection which will require investment in a relatively long transmission line. Because of the low plant factor, long distance to the grid and the fact that it is only ranked as having medium national priority, it is assumed that Nam Theun 4 will not be developed before 2040.

vi. The Duc Xuyen Project is located just upstream of the cluster of plants in operation on the Sre Pok River with only a short distance to the grid and nearest access road. It is therefore 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* Potential social and environmental red flags, so severe that the overall layout of projects would have to be changed, have generally not been identified for many dams (Sambor is an exemption with the new smaller alternative). However, the reason for this is probably the level of study the projects presently are at.

5. *Hydropower potential in Thailand* The catchments of Nam Mae Kok and Nam Mae Ing cover about 17 000 km^2 of Thailand’s northeastern provinces Chiang Rai, Chiang Mai and Phayao. The area is characterized by mean annual rainfalls ranging from 1 000 to 2 000 mm and elevations between 200 – 1 000 masl. There are a number of irrigation projects in the area and development of hydropower projects may therefore prove to be challenging. As a minimum it is estimated that three run-of-river projects totaling 60 MW with energy generation of 200 GWh could be developed before 2040.

Summary of assumptions for HPS1 2020 – 2040

The table below provides a summary of the findings in Chapter 7 with reference to the Planned Development Scenario 2020 – 2040.

Table 5: Summary of Assumptions

Criteria	Capacity (MW)	Energy (GWh)
Planned Development Scenario 2020 - 2040	15 940	72 804
Less MS Dams Pak Chom, Ban Koum, Phou Ngoy, Stung Treng, Sambor	6 482	29 289
Less Nam Seuang 4 and 5, Xebang Hieng 1, Nam Theun 4 and Nam Thong	269	727
Plus potential of unidentified projects	390	1 500
Plus potential in Thailand's provinces in the northeast	60	200
Total	**8 739**	**41 088**

3.2.1.5 Preliminary Considerations for HPP Thematic Sub-Scenarios HPS2 and HPS3

Scenario HPS2

HPS2 has been described by the Council Study as follows: Level of Development as for HPS1 with Joint Reservoir Operation and good coordination among all mainstream dams and by taking into account operation for navigation lock, minimum flow, fish passages, sediment flushing as well as measures to maintain acceptable water quality during and after flushing. HPS2 corresponds to a combination of Option 1.2 and 1.3 "5 Project Cascade + Sediment Flushing + Hydro Peaking" in the ISH0306 Study.

The Scenario definition will hence be as *"As Option 1.1 but with sediment management by reservoir drawdown during frequent (2 year) floods at all 5 projects following the Xayaburi strategy and incorporating hydro peaking to transfer limited flow to high tariff times of day and days of the week when river flows drops below installed capacity."*

In coordination with the ISH0306 Study team the following aspects will be discussed in the Hydropower Thematic Assessment Report:

- Outage of energy production during sediment flushing
- Reservoir filling period after sediment flushing
- Water flows for fish passages and environmental flows and associated loss of energy production
- Water abstractions for navigation and loss of energy

Evaluation of the effects of the above aspects will be based on interpretation of results from the model runs, when they are available.

Scenario HPS3

HPS3 has been described by the Council Study as follows: With some basin wide Joint Operation and good coordination among all main stream dams and most tributary dams to strengthen flood management and flood protection measures throughout the LMB as well as to maximize navigation potential.

In coordination with the thematic teams for “Flood protection and floodplain infrastructure” and “Navigation” the following aspects will be discussed in the Hydropower Thematic Assessment Report:

- Loss of energy production during reservoir drawdown because of measure taken by the authorities as a precaution to damp expected flood
- Loss of energy production because of water demands for navigation locks and navigation in reservoirs and river stretches

3.2.2 Uncertainties and Changes in Plans

Changes in the plans/trends may result from external factors such as changes in national priorities, economic growth, policies, budgets, technologies, etc.

3.3 Technological Trends and Innovations

Relevant trends in energy development and new science or technologies that may be interesting for the member countries are described in the following. The technologies that are presented does not form a complete list as their applicability will depend on the project specific conditions and characteristics for each of the member countries. It should also be noted that the presented new science or technologies may have been adopted in hydropower projects in LMB already.

3.3.1 Hydro reservoirs for large scale balancing of wind and solar power

CEDREN (Centre for Environmental Design of Renewable Energy), which is based in Norway, was established to conduct long-term research for tomorrow’s energy system, addressing technical, environmental and social issues for hydropower and environmental impacts of wind power and transmission lines. A new project within CEDREN (HydroBalance) is presently studying opportunities and challenges for using existing Norwegian hydro reservoirs to balance intermittent energy sources in the Nordic and European grid, with special focus on wind power.

According to preliminary studies, future installed wind power development may reach a capacity of 100 000 MW or more in and around the North Sea within the next 10-20 years. Analysis based on measured and modelled wind data indicates that the output from the combined wind power system will be highly variable, and may be as low as 10 % of the capacity or less over periods lasting several days and up to a week or two.

Preliminary results from the first phase of HydroBalance study include possible solutions for developing 20 000 MW of new peaking and pumped storage hydropower capacity using only existing reservoirs. This could be of interest to many countries that are in the process of increasing the proportion of renewable energy in their electrical supply as this will generally result in an increase in wind and solar power generation. Since it is not possible to store energy generated by wind and solar plants, there will be an increased need to balance the difference between consumption and wind/solar generation. Hydroelectric power systems can contribute significantly to such balancing through the storage of water in reservoirs, either by storing inflow or by pumping water from a lower reservoir to a higher one. This type of compensation for the difference between electricity production and consumption is known as "balance power". Norwegian hydroelectric reservoirs have considerable storage capacity and there is great international and national interest in Norway's ability to supply balance power services over various time scales to the European market.

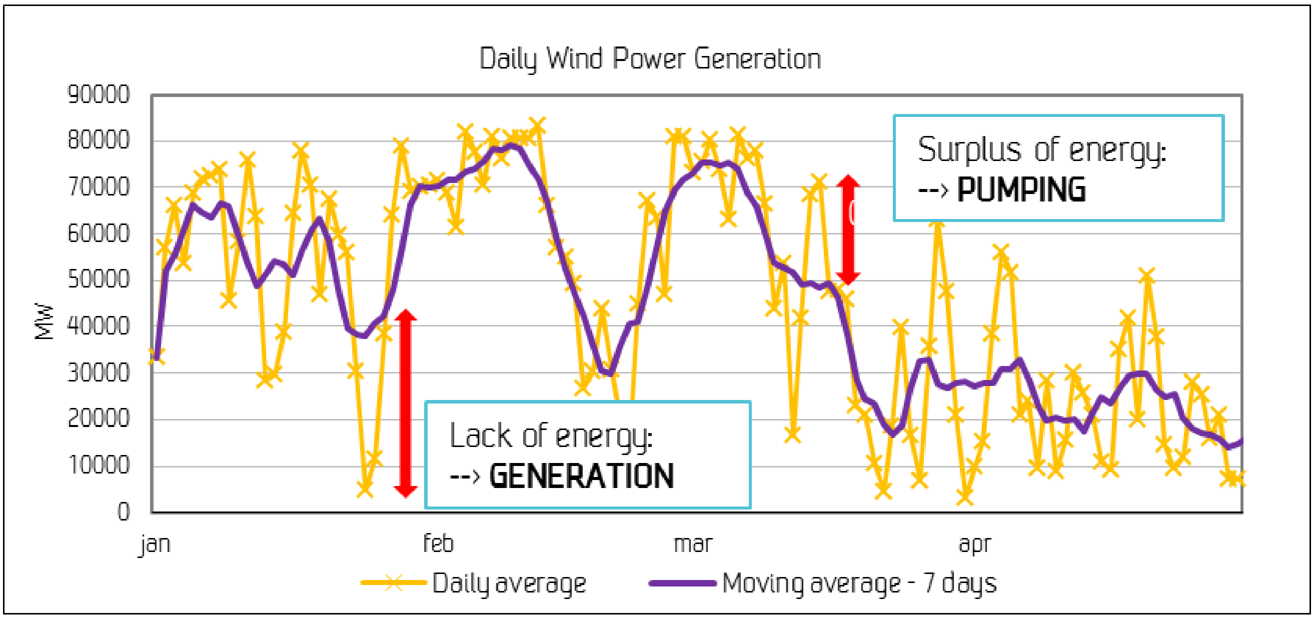

Figure 8: Example Surplus and Deficit Periods of Wind Power

A modified version of the Norwegian project "HydroBalance" for use of existing and future hydropower reservoirs in Laos and Vietnam would provide an assessment of the potential benefits for the producers (Laos and Vietnam) and consumers (Thailand, Cambodia, Vietnam and other non-members of MRC) of "balance power". The need for increased installed power and grid connection would have to be analysed. Environmental impacts including water level variations, erosion and sediment yield, water quality have to be studied, as well as potential impacts on fish, ecosystems, biodiversity and livelihood.

3.3.2 Surge Tank Research in Austria and Norway

Modern high-head hydropower plants, and in particular pumped storage plants (PSP), are designed with increasing high water discharge and higher requirements to flexible operation. To improve the hydraulic performance and allow for more flexible operation, research on surge tank design is conducted in Norway and Austria. Two types of surge tanks are discussed, the throttled chamber surge tanks (TCST) of Austria, and the air cushion surge tanks (ACST) of Norway. Both represent the current state-of-the-art in these countries. For the TCST, the challenges of long chambers are given special attention. The different layouts of TCST and ACST are illustrated in Figure 9.

The main benefits of the ACST compared to the TCST are:

- Reduced water hammer,
- Enables more flexible and faster operation,
- Enables tunnelling directly from power house to reservoir,
- Reduction of necessary steel lining is possible,
- Reduced risk of underpressure near the surge tank,
- No surface access required.

Tunnelling in a straight line from the reservoir to the power house is made possible by the ACST since it does not require a separate surface access. The direct tunnelling may be less expensive compared to horizontal headrace tunnel and pressure shaft. The direct tunnelling and deep position of the ACST also avoids potential problems regarding topography. A topography with too high or too low overburden in the position of the surge tank has been the main reason for selecting the ACST in many of the Norwegian hydropower plants.

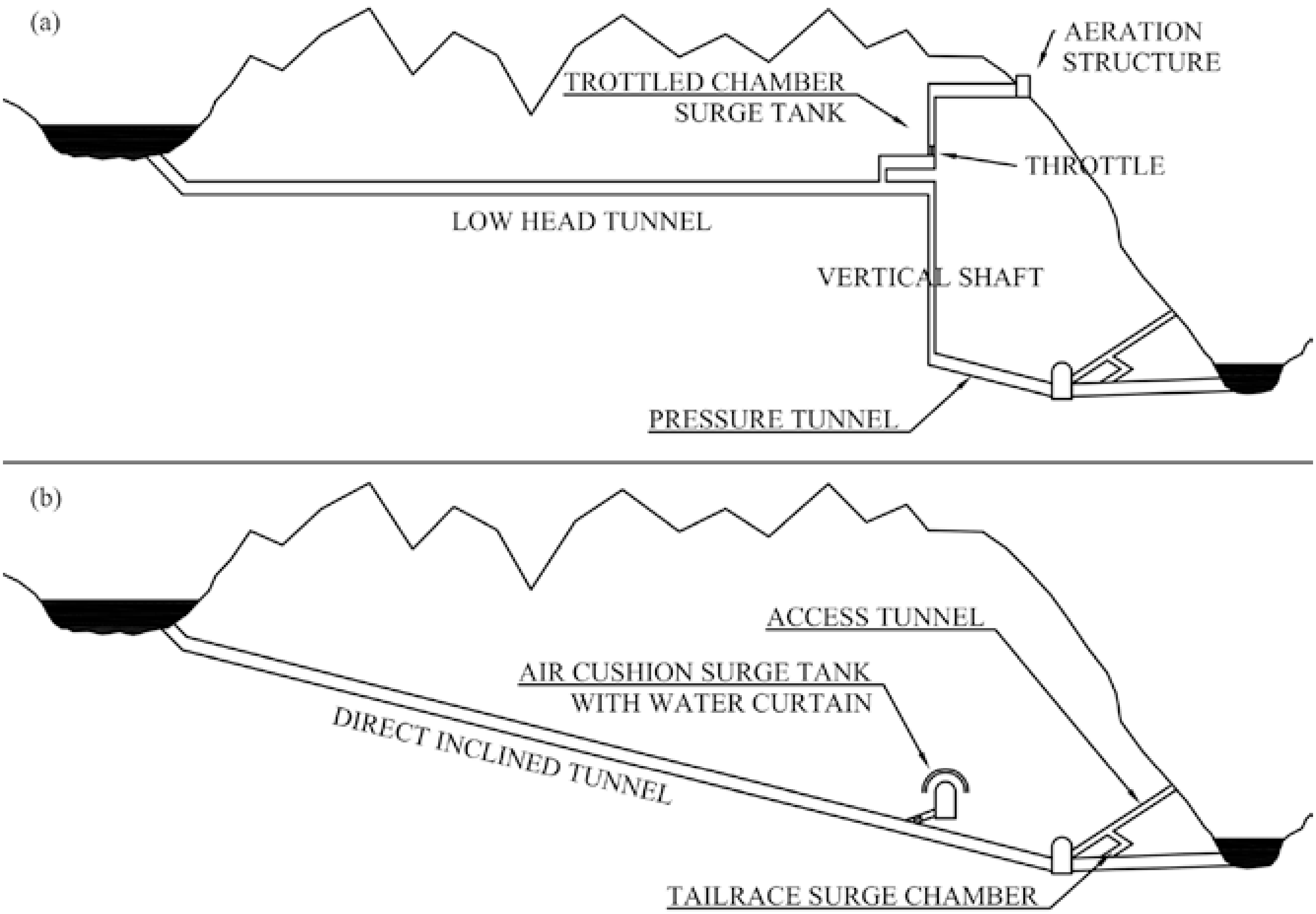

Figure 9: Throttled chamber surge tank (a) and air cushion surge tank (b)

3.3.3 Roller Compacted Concrete (RCC) Dams

In the early 1980's the first RCC dams were being proposed and successfully built in the US and Australia. By the end of 1985 there had been only 7 large (greater than 15m; ICOLD) RCC dams completed. By the end of 1990 this number had risen to 59 RCC dams completed (Dunstan 1992) while presently over 450 RCC dams have been built worldwide with another 50 planned or under construction. Some on the RCC dams are now reaching heights approaching 300 m.

There are many issues to take into consideration when designing a large dam (> 15 metres). When considering RCC for a dam project there must be proper resources available for the site to make it more economic. These site specific conditions include the following:

- Adequate foundation conditions
- Adequate aggregate sources in close proximity to the dam site
- Supply of cement
- Supply of a natural pozzolan or fly ash

Particular and critical resources are the access of fly ash or natural pozzolanic material as most RCC dams use considerably more fly ash or pozzolan than conventional concrete (CVC). This is an advantage over CVC dams as the use of high amounts of fly ash (pozzolanic materials) are in most cases cheaper. Another significant advantage is the environmental concerns of the respective types of dam construction. RCC dam have a smaller footprint and require substantially less masses than earth- and rockfill dams.

The environmental footprint of a RCC dam in terms of quarries, excavated areas, borrow areas and environmental runoff can be considerably less than for earth- and rockfill dams.

Another significant advantage with in the development of RCC dam construction is the fact that the diversion schemes can be significantly reduced in size with further cost savings and reducing the overall construction schedule as the RCC dams can be overtopped during flood stages without any significant damage to the main structure.

It should be noted that the Nam Gnouang Dam (2013), 480 m wide and 65 m high, creating the NG Reservoir, is an RCC dam. In normal operation the dam releases water through the NG Powerhouse, which generates up to 60 MW of electricity for domestic supply to Electricité du Laos (EDL). From the NG Powerhouse the water flows into the Nam Theun and down to the original Theun-Hinboun (TH) Dam. Also the Dachaoshan Dam in the UMB, completed in 2003, is an RCC dam with dam height 111 m a length 460 m.

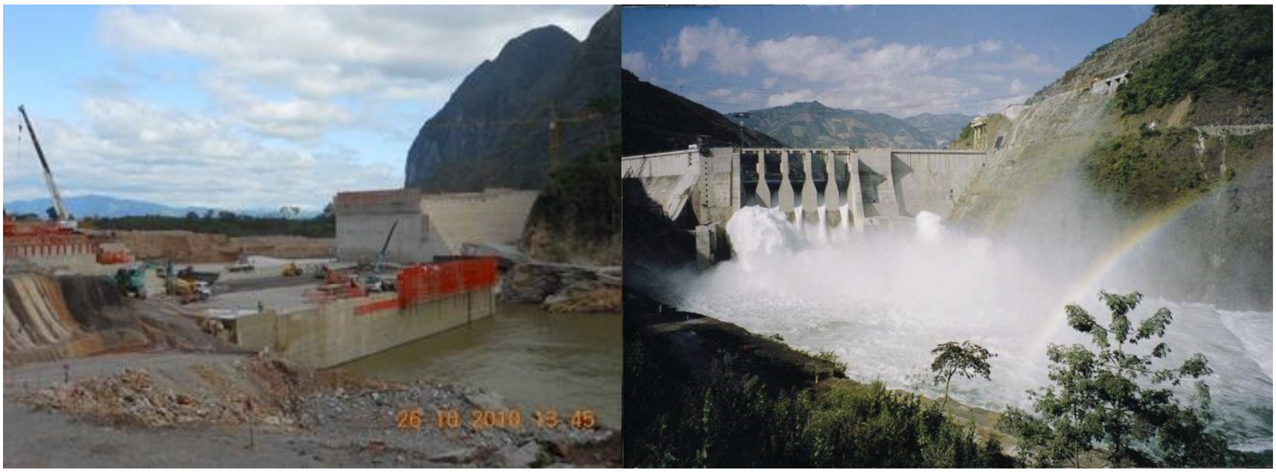

Figure 10: Nam Gnouang RCC Dam (Left) and Dachaoshan RCC Dam (Right)

3.3.4 Plastic Concrete Cut-off Wall for Dam Abutments

The name refers to a cast in place wall, excavated with conventional equipment under bentonite slurry. Subsequent concreting is done with a deformable, watertight, plastic concrete, composed of 100-200 kg/m^3 cement, 1,800-2,000 kg/m3 well graded aggregate and 30-40 kg/m3 bentonite. Typical wall thickness is 0.6 m.

This method allows to install very deep walls (50 m or more), but for very large depths, wall thickness should be increased to 1 or 1.2 m in order to reduce the risk of gaps near panel joints which may be caused by deviations.

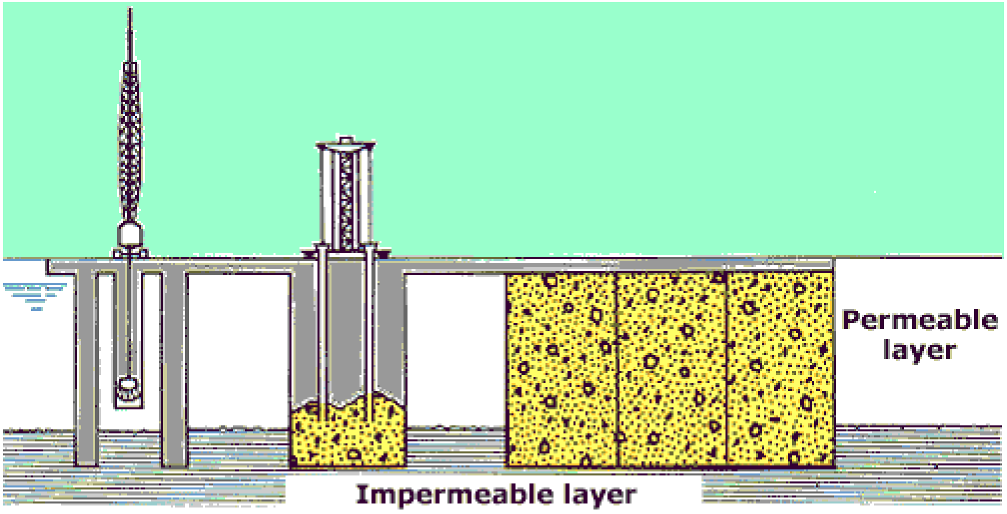

Figure 11: Stages for Construction of Concrete Plastic Cut-off Walls

Construction of the Plastic Concrete Cut-off Wall at Hinze Dam in Australia in 2009 is a reference project. One of the principal geotechnical issues identified for the Hinze Dam Stage 3 Project was the potential for internal erosion and piping within the extremely complex geology at the right abutment. A plastic concrete cut-off wall was selected as the best solution to reduce the risk of piping to acceptable levels and careful planning of this work was required to manage a range of key project risks that included complex technical challenges, potential risks to dam safety, the environment, the surrounding community as well as delivering the works on a tight construction schedule to an agreed budget value. The 220 m long and up to 53 m deep cut-off wall is the largest wall of this type constructed to date within Austria.

Figure 12: General view of construction of Cut-off Wall at Hinze Dam in Austria

Plastic concrete cut-off walls should be considered for mainstream dams and tributary dams in the member countries where water tight or impermeable rocks are situated deep under permeable soils at the dam abutments. Construction of plastic concrete cut-off walls in the dam abutments reduces the environmental footprints compared to construction of gravity or earth- and rockfill dams.

3.3.5 Variable Speed Motor-Generators for Pumped Storage Plants

Some recognized international suppliers of electromechanical equipment (GE, Voith, Andritz and others) have developed variable speed (or asynchronous) motor-generators for pumped storage plants.

Key benefits.

- Regulation of the amount of energy absorbed in pumping mode, facilitating energy storage when power levels on the network are low, in addition to reducing the number of starts and stops and finally helping to regulate the network frequency or voltage in pumping mode
- Operating close to the turbines optimal efficiency point, which results in a significant increase in global plant efficiency
- Smoother operating (for example at partial load), elimination of operation modes prone to hydraulic instability or cavitation, resulting in improved reliability, reduced maintenance and increased lifetime. It also results in a reduction in the Pump turbine submergence level, reducing civil engineering costs
- Operating in a wider head range, increasing the availability of the plant and facilitating installation of pumped-storage plants on sites characterised by wide head variations
- Helping to rectify sudden voltage disruptions/variations caused by network problems thanks to instantaneous power output adjustment

Figure 13: Upper and Lower Reservoirs at Pumped Storage Plant Goldisthal in Germany

Technical parameters for Goldisthal are:

Installed capacity

- 1,060 MW with 4 pump turbines á 265 MW, thereof:
  - 2 pump storage units with asynchronic-motor-generators (variable speed)
  - 2 pump storage units with synchronic-motor-generators

Construction time from 1997 to 2004, and commissioning from 2003 to 2004.

3.3.6 Fish-Friendly Turbines

While hydropower is classified as renewable power, that doesn't mean there is no environmental harm. In addition to concerns about loss of habitat and silt build ups, one of the main concerns is the effect on fish populations.

China's Yangtze River basin, for example, is home to about 360 species of fish, one third of that nation's total number of fish species. The 22.5 GW Three Gorges Dam across the Yangtze, which displaced 1.3 million people in creating a 360 mile reservoir behind the dam, also resulted in a 50% to 70% drop in the commercial harvests of four types of carp, and threatened several endangered species with extinction. Similar concerns have been expressed about power projects in the Mekong River and Amazon River basins.

Research is ongoing to improve turbines so that instead of screens or other mechanisms to help fish avoid going through the turbine, fish can pass through safely.

One of the results of this research is the Voith Minimum Gap Runner (MGR). The MGR is based on a conventional Kaplan turbine, but with much smaller gaps between the runner and the turbine walls. Because of these smaller gaps, fish do not get trapped and crushed by the runner.

The first field testing of the MGR was done at the Bonneville dam in Oregon, and showed a 1.5% injury rate compared to a 2.5% injury rate at an adjacent Kaplan turbine.

3.3.7 Water or Air-filled Rubber Gates for Flood Diversion

Sumitomo of Japan Obermeyer of USA and Hydroconstruct of Austria are producing types of inflatable rubber gates for various purposes of water control. The gates can be either air or water filled. Advantages compared to conventional gates in steel such as flap gates and sector gates are:

- A flexible weir structure with no impediment to floating debris
- Stable and step less variable controllability of reservoir level (± 1.5 cm)
- Autonomous, self-acting flood relief
- Ideal for damming broad watercourses
- Gate height up to 4 – 5 m
- Single-piece weir widths of more than 50 meters
- Ideal for erection on both level and curved spillway structures
- Small maintenance expense
- Economic layout
- Environmentally-friendly operation without lubricants
- Low operating costs due to minimal use of extraneous energy

Figure 14: Water Filled Rubber Gate

Figure 15: Air-filled Rubber Gate

4 Direct Socio-Economic Impacts

4.1 General Impacts

In the description of conceptual framework for valuation and evaluation of hydropower dams, the Guidelines on the Multi-Purpose Evaluation of Hydropower Projects[1] distinguish between direct impacts, indirect costs and benefits and external impacts:

- **Direct impacts** are described as those relating to construction and the resulting services provided, including but not limited to electricity, irrigation water and water for municipal and industrial supply, flood control and fisheries.
- **Indirect costs and benefits** are described as the indirect effects that accrue to the economy. These are secondary impacts from changes in quantities and prices as the direct impacts of the project ripple through the economy.
- **External impacts** are described the environmental and social impacts that have a series of socio-economy: unit values for valuation of resettlement, loss of land for agriculture, loss of agricultural production, water for domestic and industrial use, water for irrigation, reduced catch from fisheries, social, environmental and economic consequences.

In the following only the direct impacts are commented on.

In addition to the direct socio-economic impacts related to the services resulting from the hydropower dams mentioned above, the direct socioeconomic impacts should also include:

- **Job creation** As all mainstream Mekong dams and many of the tributary dams are large construction works taking years to complete, it can be expected that a large number of local people will be engaged in the construction works for each dam. It can also be expected that there will be considerable employment in the operational phase.
- **Resettlement** Due to the establishment of reservoirs and the footprint of project components, as well as **c**hanges in downstream flood regimes, relocation of villages and livelihood restoration for the resettlers will be required for a number of mainstream and tributary projects.
- **Agriculture** Loss of land for agriculture and the associated agricultural production is often one of the direct impacts of projects. Also changes in area under irrigation and the possible change in production due to this change should be considered.
- **Navigation** A service rendered from construction of navigation locks, and a direct impact not mentioned in the listing above. When the costs of construction of locks are included in the total project costs, also benefits related to these costs should be included (increased navigation possibilities compared to navigation without construction of the dam).

The MRC database includes information on impacts for each of the identified hydropower plants. This includes the following:

- Re-regulation storage (yes/no)

[1] See Guidelines on the Multi-Purpose Evaluation of Hydropower Projects (ISH02), Annex 1: Economics Practice Guide, Draft Report July 2015.

- Number of persons resettled
- Environmental impact scorecard (hourly/seasonal flow regime, ecosystem, micro climate)
- Social impact scorecard (resettlement, tourism and recreation, flood control, navigation, job creation, water supply)

The database also includes information on investments, including figures for social and environmental mitigation costs. The data refers to years, but more important for the reliability of the data is that the projects are in different study phases with varying uncertainty.

4.2 Detailed Analysis of the Development Scenarios

The hydropower thematic study includes three scenarios and three sub-scenarios. In the final the scenarios will be further analysed when information from other thematic reports under the Council Study has become available.

- **Baseline Scenario 2007** This scenario 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 Hlinh in Vietnam in 2007.
- **Definite Future Scenario 2020** The scenario includes dams in both mainstream Mekong and tributaries that are expected to be commissioned by 2020. Projects with capacity of less than 15 MW have not been considered.
- **Reference Future Scenario 2020 – 2040** This scenario provides a complete list of hydropower projects being identified as under development in the LMB. The list reflects all identified hydropower projects that have attracted potential developers, and thus represents the most ambitious plan for hydropower development in the period 2020 – 2040. Projects with capacity less than 15 MW have not been included.

The following three sub-scenarios are included:

HPS1: including five projects in mainstream Mekong (Pak Beng, Luang Prabang, Xayaburi, Pak Lay and Sanakham, corresponding to option 1.1 in ISH0306 study) and the tributary dams. Each dam designed and operated to maximize energy generation.

HPS2: development as in HPS1, but with joint reservoir operation and coordination among mainstream Mekong dams for reservoir flushing and operation of fish passages and navigation locks.

HPS3 development and coordination among mainstream Mekong dams as in HPS2, but in addition also coordination between mainstream dams and most tributary dams to strengthen flood management and flood protection measures as well as maximize navigation potential.

The Council Study includes five teams working on other subjects than to hydropower (irrigation, agriculture and land use change; domestic and industrial water use; flood protection and floodplain infrastructure; navigation and cumulative assessment) as well as five discipline teams (hydrology; climate change; biological resources; macro-economy and socio-economy).

For carrying out the analysis of direct socio-economic impacts of the different development scenarios, the hydropower thematic team will require input from some of the other thematic teams and discipline teams:

Irrigation, agriculture and land use change: change in area used for agriculture and change in area under irrigation.

Domestic and industrial water use: change in water use.

Flood protection and floodplain infrastructure: change in flood regime and impact on settlements (need for relocation during flood) and area inundated of floods/agricultural production.

Navigation: regime for use of navigation locks.

Macro-economy: discount rates.

Socio-economy: unit values for valuation of resettlement, loss of land for agriculture, loss of agricultural production, water for domestic and industrial use, water for irrigation, reduced catch from fisherie.s

4.3 Socio-Economic Impacts for Selected Major infrastructures

Don Sahong Hydropower Project is chosen as a case. The socio-economic impacts are in general as follows:

- Mekong River Flows, and downstream impacts from their modification
- Fish Migration and Fisheries in the Lower Mekong
- Resettlement of displaced people
- Social and livelihoods impacts, and
- Health and Nutrition

The socio-economic impacts are described more in detail in **Error! Reference source not found.**.

Table 6: Potential Socio-Economic Impacts on Don Sahong HPP

Potential impact	Impact Areas	Impact Duration and Period	Impact Significance
Employment opportunities	Project areas, and surrounding villages	During the construction	Positive major positive impact
Housing and resettlement need	Project area; 11 families & houses on DSH and Don Sadam need to resettle	Entire project life	Potential minor negative impact can be mitigated
Loss of infrastructure	Project areas, and surrounding villages		Potential positive impact. Infrastructure will be improved by project
Loss of fishery	Hou Sahong, Hou Sadam, Hou Xang Pheuak	Entire project life without mitigation	Potential major negative impact that possibly can be mitigated
Loss of paddy lands	29.4 hectares	Entire project life	Potential minor Negative impact can be mitigated
ROW for Access roads	Affected and surrounding villages	Entire project life	Potential major positive impacts; having new access roads
Power supply	Affected and surrounding villages	Entire project life	Potential major positive impacts on local and surrounding villages

5 Scenario Impact Assessments

5.1 Scenario Assessments

The Hydropower Thematic Report will assess the impacts of the three main development scenarios as considered during the 3rd RTWG Meeting (see table below).

Table 7: Main Development Scenarios for the Council Study.

Scenario	Name	Level of Development*					
		ALU	DIW	FPF	HPP	IRR	NAV
1	Early Development Scenario 2007	2007	2007	2007	2007	2007	2007
2	Definite Future Scenario 2020	2020	2020	2020	2020	2020	2020
3	Hydropower Development in the period 2020 - 2040	2040	2040	2040	2040	2040	2040

Note:
***Levels of developments for the various thematic areas: ALU = Agric/Land-use Change; DIW = Domestic and Industrial Water Use; FPF = flood protection/floodplain infrastructure; HPP = hydropower; IRR = irrigation; and NAV = Navigation**

Additionally there are three thematic hydropower sub-scenarios that will be assessed with respect to environmental, social and environmental impacts (likely impacts and risks, and needs for further information, are discussed in sub-chapters 5.2 to 5.4). The thematic sub-scenarios are based on the 2040 Planned Development Scenarios, incorporating *plausible deviations*[2] in the planned level of development for the thematic area of interest. The HPP sub-scenarios are:

- **HPS 1**: No joint operation, i.e. each hydropower dam will be designed and operated for maximized energy production. This scenario refers to HPP Thematic Sub-scenario HPS1 with «No joint operation" where each hydropower dam is operated to maximize its separate energy production. The "No joint operation" implies that operational constraints as reservoir sediment flushing, water flows for fish passages, water requirements for navigation, flow requirements versus water quality etc. have not been reflected in the energy production figures included, except for Xayaburi. HPS1 corresponds to Option 1.1 "5 Project Cascade" in the ISH 0306 Study which reads as follows:
    - **5 Projects Cascade:** Pak Beng, Luang Prabang, Xayaburi, Pak Lay and Sanakham assuming fish passage design similar to Xayaburi. No draw down and sediment management strategy at the 5 schemes. Cascade to operate at 100% base load at full supply level 24 hours per day, 7 days per week. Impacts on fisheries and aquatic ecology, water quality, sediments and geomorphology and hydrology will be compared with baseline conditions.

[2] A plausible deviation is the result of external factors such as changes in national priorities, policies, budgets, technologies, etc.

- **HPS 2:** Level of Development as for HPS1 with Joint Reservoir Operation and good coordination among all mainstream dams and by taking into account operation for navigation lock, fish passages, sediment flushing as well as measures to maintain acceptable water quality during and after flushing. HPS2 corresponds to a combination of Option 1.2 and 1.3 "5 Project Cascade + Hydro Peaking" in the ISH 0306 Study and constitutes as follows:
    - **5 projects Cascade + Flushing + Hydropeaking**: Sediment management by reservoir draw down during frequent (2 year) floods at all projects following the Xayaburi strategy and incorporating hydro peaking to transfer limited flow to high tariff times of day and days of the week when river flows drops below installed capacity. Assessment of impacts of hydropeaking on head pond levels, tail water levels and wave propagation to inform judgements on acceptable hydropeaking amplitudes and ramp rates in relation to hydro safety, navigation, fish stranding and geomorphology.
- **HPS3** has been described in the Council Study as follows, and has no corresponding ISH0306 Option: With some basin wide Joint Operation and good coordination among all mainstream dams and most tributary dams to strengthen flood management and flood protection measures throughout the LMB as well as to maximize navigation potential. In coordination with the thematic teams for "Flood Protection and Floodplain Infrastructure" and "Navigation" the following aspects will be discussed in detail in the Final Hydropower Thematic Assessment Report:
    - Loss of energy production during reservoir drawdown because of measure taken by the authorities as a precaution to damp expected flood
    - Loss of energy production because of water demands for navigation locks and navigation in reservoirs and river stretches.

Possible generic impacts of HPS1-3 on environment, social and economic issues are discussed in the following Chapters (5.2-5.5).

5.2 Flow, Sediment, Water quality and Flood Risk

Flow Regimes

Development of hydropower on the Mekong mainstream will have significant impacts on flows. A number of studies have looked at the Mekong flow regime, most recently the ISH0306 (MRC, 2015 and 2016), which summarises the present status of knowledge regarding this topic. Apart from information from MRC's databases the discussion of potential flow impacts has been based on a few important studies such as Räsänen (2008) and Kumma and Sarkula (2008)

The Mekong has a relatively well defined and predictable seasonal flow cycle with the onset and end of the high flow season varying only a few weeks from year to year. The transition periods between high and low flows are also relatively narrow, normally occurring within a period of 3-5 weeks. The ISH0306 Study concludes that development of hydropower projects with storage reservoirs on both the Mekong mainstream as well as on the tributaries, has the potential to shift the timing of the transition zones as well as alter the magnitude of the floods (MRC, 2015 and 2016).

However, the actual impact will to a large degree depend on the location of the storage dams in the Mekong river basin. In terms of origins of the Mekong mainstream flow the specific yields, that is the yearly amount of runoff in mm, increases from west to east while at the same time there are two major tributary regions in Laos (Nam Ngum,/Nam Theun / Nam Hinboun and Se bang Fai/ Se Done), and in Cambodia and Vietnam (Se Kong / Se San / Sre Pok). These two tributary regions are the dominant contributors to the flow at Kratie in Cambodia with on an average 19% (Laos) and 23% (Cambodia / Vietnam). The contribution from the Upper Mekong (Lancang) this far down in the Lower Mekong basin is 16% while the contribution from Thailand is only 6% of the total flow. However, further upstream the Upper Mekong share gradually increases with for instance 65% of the dry season flow at Vientiane.

It is expected that large reservoirs also will have an impact on more extreme floods and draught events. However, the study by Räsänen (2014) indicated that the occurrence of extreme floods and draught and flood events are correlated with larger scale weather phenomena (El Niño / La Niña) that makes it difficult to distinguish between causes. However, changes in extremes, particularly low flows can definitely be expected due to the establishment of larger storage reservoirs in the Mekong basin, particularly on the Upper Mekong (Lancang) but also on major tributaries.

The Lancang reservoirs will have a significant impact on the annual flows in the Lower Mekong with a 28% regulation capacity of the annual flow at Chiang Saen and about 5% of the total yearly flow of Mekong.

The expected results of the changes in the flow regime are manifold, but the most important changes are in summary:

- Change in timing of the transition zone affects fisheries and fish migration
- Change in flow velocities affect both fishery and sediment transport/erosion
- Change in flood season duration and magnitude affects particularly the sediment/erosion and will have a major impact on the Tonle Sap system
- Change in dry season flow will affect salt intrusion in the Mekong delta

One major aspect of the expected flow changes is the effect this may have on the Tonle Sap reverse flow system as is very sensitive to the changes in the duration and magnitude of the flood season. One important study of the potential impacts of establishing large storage reservoirs on the Mekong River and on its tributaries was carried out by Kumma and Sarkkula in 2008. The results of these study indicate that there will be a shift in the timing of the inundation period and extension in Tonle Sap due to the altered flow regime in the Mekong caused by the reservoirs. It is generally concluded that the area along the lake shore that becomes inundated during the high flow season will decrease, while the duration of the inundation period will increase. This will in turn lead to changes in the ecology of the wetlands and coastal zones of the lake.

Options for mitigating changes in flows are limited but includes:

- Develop joint operation rules for releases
- Design multiple large gated spillways/outlets at multiple levels, and low level sediment outlets
- Mimicking of 'natural' flow regimes (artificial releases, environmental flows)
- Maintain seasonal patterns through HP operations
- Annual sediment sluicing to maintain seasonal pulse
- Creation of offsets of residual impacted habitats and areas
- Floodplain and wetland rehabilitation

<u>Water Quality</u>

Establishment of reservoirs on the Mekong mainstream and on tributaries will inevitably entail water quality changes both upstream and downstream of reservoirs. The Preliminary Design Guideance of the MRC (MRC, 2009) identified the main water quality risks to be changes to the status of the physical and chemical water quality that can have an impact on the downstream ecosystem as well as geomorphology.

Analysis of MRC's Water Quality Monitoring Network (WQMN) results from the mid-eighties to date indicate the following trends:

- Warming of water and reduction in seasonal differences between Chiang Saen and the downstream sites
- Electric Conductivity decreases with distance downstream and is highest during the dry season

- Nutrient values (total nitrogen and phosphorous) in the mainstream Mekong tend to decrease downstream between Chiang Saen and Kratie, and then increase in the delta

The ISH0306 Study (MRC, 2015) identifies the following potential impact on water quality downstream of impoundments (reservoirs)

- Changes to the seasonal temperature regime of the river
- Reductions in the dissolved oxygen content
- Increases in iron, manganese or other metals, contaminants or nutrients associated with low dissolved oxygen conditions in the impoundment
- Fluctuating temperature, electrical conductivity or other parameters in the downstream environment associated with peaking operations
- Very high dissolved oxygen concentrations associated with aeration of water during power station generation or subsequent aeration
- Changes to water quality due to inter-basin transfer of water of a different water quality status

Mitigation options for water quality changes including sediment prosed in the ISH0306 Study include:

- Design and construction multiple large gated spillways/outlets, and low level sediment outlets or bypass structures
- Annual sediment sluicing to maintain seasonal pulse
- Limitation of retention time by planning and construction of large bypass-systems
- Assess and implement suitable turbidity thresholds with regard to natural floods for aquatic species
- Minimise sediment runoff through design of access roads & seasonal work schedules
- Implementation of habitat improvements in head of impoundment
- Protection and armoring of downstream banks if required
- Catchment management to reduce erosion and sediment runoff into reservoirs
- Development and implementation of environmental flow rules. i.e. minimum flow and dynamic flow
- Operating rules to maintain geomorphic processes in both catchments
- Periodic flood releases in the river water is abstracted from to maintain channel capacity

<u>Geomorphology and Sediments</u>

The key risks and impacts associated with hydropower development in the Lower Mekong Basin is in the ISH0306 Study (MRC, 2015) summarised as follows:

- Water logging and loss of vegetation and increased bank erosion due to changes in seasonal flows caused by uniform releases
- Reduction in occurrence of minor floods leading to channel narrowing through encroachment of vegetation
- Increased risk upstream of flooding and floodplain stripping
- Change in relationship of flow and sediment transport
- Erosion and / or deposition due to tributary rejuvenation

- Rapid wetting (saturation) and drying of banks leading to erosion (bank slumping) due to peaking operation of power plants
- Reduction in sediment availability downstream of dam leading to increased erosion
- Changes to the grain-size distribution of sediment downstream contributing to channel armoring and alteration of habitats
- Erosion and landslips in the reservoir drawdown zone due to wave action
- Channel narrowing due to vegetation encroachment caused by decreased flow in the basin water is abstracted from in the case of trans-basin projects
- Increased flow in receiving basin leading to increased bank erosion and bed incision

Options for mitigation of negative impacts on sediment transport and geomorphology include:

- Annual sediment sluicing to maintain seasonal pulse
- Design of low level sediment outlets and bypass structures
- Floodplain and wetland rehabilitation

Differences in Scenarios

The three scenarios considered in this report are likely to have relatively similar implications for flow regimes, sediment transport and water quality. However, it is possible to predict that there most likely will be differences in the magnitude of the impacts between the three scenarios. The possible differences between the scenarios is set out in the following.

HPS1 This scenario supposes that there is no coordination between owners and operators of the five mainstream hydropower dams when it comes to sediment flushing and operation and management of the reservoirs. The dams will be operated with the intention to maximize energy production and to avoid any losses in energy outputs that can potentially be caused by sediment flushing and precautionary drawdowns of reservoirs to dampen and manage forecasted flood events. More sediments are thus likely to be retained in the reservoirs than compared with a situation where coordinated sediment flushing is performed by all the five mainstream plants in conjunction with each other. This may have impacts for downstream water quality in terms of less suspended solids and diminished sediment loads in the downstream reaches. The reduced sediment loads, and also changes in sediment size distribution, may again lead to increased downstream erosion as there will be less sediment deposition in the river channel. With regard to possibilities for dampening and managing naturally occurring floods this scenario has the lowest mitigation potential compared to HPS2 and HPS3.

HPS2 HPS2 represents a situation with coordinated reservoir operation and common operation rules when it comes sediment flushing and flood management. This will present the owners and operators, as well as the authorities, with a better opportunity to manage floods to some degrees, and in that way trying to limit flood damages in terms of loss of crops and assets. Joint flushing operations will also contribute to a limitation of changes in downstream water quality in terms of sediment loads and suspended sediments. However, the fact that this scenario entails peaking operations, which may lead to relatively rapid reservoir drawdowns, is a factor that may lead to increased slumping and erosion along the reservoir shores and in the drawdown zones. This will again lead to an increased siltation and sedimentation process within the reservoirs that will necessitate more frequent and comprehensive sediment flushing operations.

HPS3 This scenario, which also includes tributary dams, supposes a basin wide approach for the Lower Mekong when it comes to coordination in terms of reservoir management and hydropower plant operations. In relation to the possibilities to manage and implement coordinated and concerted flushing operations to let sediments pass downstream, this scenario has the biggest potential to mitigate and to some degree limit the negative effects of downstream altered sediment flows and water quality status.

The same would also the case with the possibilities for flood management and flood dampening. Considering that the tributary reservoirs generally will have a larger storage capacity than the five mainstream reservoirs, the contribution of the tributary dams could be significant and thus represent a considerable added mitigation potential.

5.3 Environmental Impacts

Fisheries and Aquatic Biodiversity

The ISH0306 Study identifies a number of environmental impacts of hydropower development on the Mekong mainstream and on its tributaries. For fisheries and aquatic biodiversity the main impacts are:

- Morphological alterations and habitat loss due to delayed floods, increase of dry and decrease of wet season flows
- Bank erosion, increased erosion and bed incision causes habitat degradation
- Increased bank erosion and bed incision due to increased flow in recipient rivers in connection with trans basin hydropower projects
- Upstream filling up of deep pools and downstream: loss of habitat structures (sand bars) and reduced connectivity to tributaries and floodplains (incision).
- Loss of migration/spawning triggers
- Loss of productivity due to reduced flood pulse (increase in permanently flooded and decrease in seasonally flooded area).
- Stress due to water quality changes
- High drifting rate of fish and macroinvertebrates due to fast increase of flow velocity
- Stranding of fish and macroinvertebrates
- Disruption of migration for spanning and feeding and isolation of sub-populations (loss of river connectivity)
- Fish kills by turbine and spillflow passage
- Delay/ deposition of drifting eggs & larvae
- Loss/ reduction of fish species adapted to free flowing rivers
- Stranding of fish and macroinvertebrates due to water level changes within impoundment
- Fish kills and alteration of habitats due to reservoir flushing

Possible mitigation measures for limiting negative impacts of hydropower development on the Mekong mainstream and tributaries include:

- Design and construction of fish pass/ bypass channels for up and downstream migration
- Design of measures for fish protection
- Ensure river connectivity during construction
- Assessment of population functionality (life cycle)

Biodiversity, Natural Resources and Ecosystem Services

The changes in annual and inter annual flows will affect the timing of flow to wetlands and floodplain riparian habitats as well as changes in wetlands ecosystems through altered sedimentation patterns and nutrient deliveries. Changes in inundation of downstream floodplains and wetlands due to reduced peak floods in the wet season has the potential to cause losses in wetlands and floodplain habitats and thereby loss of biodiversity.

Differences between Scenarios

HPS1 Represents a situation with no coordination of flow releases for fish passage and absence of bypass channels for upstream and downstream migration passages, this scenario represents the most restricted, or even lack of, possibilities, to mitigate to some degree the negative impacts to fish populations and aquatic biodiversity caused by construction of mainstream dams. Also in relation to downstream changes to wetland habitats and reduced inundation of floodplains, which effectively means a reduction in feeding areas for fish, this scenario is the least promising of the three scenario alternatives. This is due to the changes in flood regimes with reduced maximal floods and changed sedimentation patterns which may lead to increased downstream erosion.

HSP2 Represents a situation where dams and reservoirs of the five main hydropower projects are operated in conjunction, and with coordination of fish pass flows and sediment flushing. In relation to HSP1 this represents, to some degree, increased possibilities for mitigation of negative impacts on fish biodiversity and fish populations. Compared to HPS1 this scenario is in general better when it comes to reducing the impacts on downstream wetlands and floodplains as sediments to a larger degree can be passed downstream and natural peak floods more easily mimicked by joint dam operations.

HSP3 With a joint Lower Mekong Basin wide approach, including the tributary dams, to sediment flushing, fish passage and flood management, HPS3 has the best potential for mitigation of negative impact on aquatic biodiversity, downstream wetlands and floodplain habitats. This is partly due to the relatively large contribution to the negative impacts in the Mekong mainstream that the tributary dams represent. This is because the tributaries are important spawning and feeding habitats for fish migrating up from the Mekong. Inclusion of tributary dams in Lower Mekong Basin wide and concerted sediment flushing operations will also increase the amount of sediments passed downstream and into the Mekong, thus contributing to reduce negative impacts on sediment deposition. Finally, with a basin wide approach tributary reservoirs can play an important role in flood management and mimicking natural floods so as to help maintain wetlands and floodplain habitats.

5.4 Social Impacts

The socio-economic impacts of hydropower development on the Mekong mainstream and on its tributaries may be grouped into a few broad categories:

- Physical displacement of settlements and communities necessitating resettlement and relocation
- Loss of fixed non-movable assets
- Loss of livelihoods in terms of agricultural land, pasture land and forest resources due to reservoir and the footprint of a project in terms of project infrastructure such as roads and project components
- Reduction or loss of access to fish and other aquatic resources that are important for traditional livelihoods including protein supply and cash income
- Loss of riverbank gardens for food and vegetable production
- Increased wet season flood risk for downstream communities in the vicinity of recipient rivers in trans-basin projects
- Indirect social impacts during the construction phase such as pressure on social services due to population influx and increased risk for human trafficking.

The mitigation of social impacts can be considered at masterplan level by selection of hydropower development options that does not entail comprehensive and large scale resettlement. At feasibility study level selection of alternatives should be guided by the need to minimise resettlement and displacement of people. At the feasibility study stage preparation of a Resettlement Plan (RAP) and / or a Social Development Plan (SDP) is required while during the detailed design and construction stages detailing and operationalization of the safeguard plans are normally done. It is important to keep focusing on the livelihood restoration of resettled households throughout the whole hydropower planning and construction stage with an early start to livelihood support activities. Experience with livelihood restoration is that it requires time and goes well beyond the construction phase and into the operation phase. Developers need to be aware of this and make resources and funding available to achieve the set resettlement targets in terms of health, education and income levels.

Differences between Scenarios

On a general level it can be predicted that there will be differences in likely social impacts between the different development scenarios for the Mekong mainstream presented in the foregoing sections of this report. Each of the scenarios in relation to social impacts are considered below.

HPS1: According to this scenario there will be no cooperation and joint management and operation of the 5 Project Cascade on the mainstream. This scenario probably represents the most comprehensive social impacts as there will be no cooperation on sediment flushing, and possibly no fish passages through the whole cascade. While it cannot be expected that the fish passages will maintain a near present day situation when it comes to fish migration and fish populations, this scenario will probably be the most negative in terms of fisheries and fish populations in the mainstream Mekong. Communities along the mainstream are still to a considerable degree depending on and benefitting from the river fisheries as a source of food and proteins as well as deriving an income it. Consequently, the impacts in terms of less biodiversity and possibly fish stocks translates into a considerable social impact as well.

With regard to transport of goods and people on the Mekong mainstream a realisation of the HPS1 scenario will effectively section the river into limited navigable stretches and necessitate the construction of port facilities upstream and downstream of the dam sites. This will make the transport of goods less attractive and efficient and possibly also make the shipment of goods more expensive. Without navigation locks in all of the mainstream dams, todays thriving tourism associated with boat travel on the river may suffer a significant decline as the river journey becomes less interesting and more cumbersome. Incomes of tourism for local communities along the river may thus decline.

HPS2 The HPS2 scenario includes and supposes a well-developed coordination and cooperation between the owners and operators of the mainstream hydropower plants when it comes to sediment flushing, periodical water flows for fish passages and navigation. With existence of fish passages in all the five mainstream dams and joint operation of them, the chances for maintaining some of today’s fish species diversity, and thus their populations, increases. The incomes and dietary supplement for the local communities the Mekong fisheries represent today may therefore suffer less negative impacts as compared to the HSP1 scenario. It may also be speculated that tourism will manage to retain more of the traffic on the Mekong with marketing passing through navigation locks as a possible added attraction of the journey itself.

HPS3 This scenario represents the most advanced and highest level of cooperation and coordination between the owners and operators of the mainstream and tributary dams in the Lower Mekong Basin. As with scenario HPS2 it entails joint operation of reservoirs with respect to navigation, fish passage and sediment flushing but has in addition the potential to enable a larger degree of flood management and flood protection in the case of naturally occurring flood events. In this respect the scenario may represent a positive social impact as it may reduce crop damages and loss of assets which normally are caused by natural floods.

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