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

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

http://www.rte-france.com

in Association with:

EDF
Hydro Engineering Center (France)

Nord Pool Consulting AS (Norway)

Power Planning Associates Ltd (UK)

Franklin Law Firm (France)

Centre for Energy Environment Resources Development (Thailand)

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

http://www.gms-powertrade.net

ASIAN DEVELOPMENT BANK

RETA No. 6440

"FACILITATING REGIONAL POWER TRADING AND ENVIRONMENTALLY SUSTAINABLE DEVELOPMENT OF ELECTRICITY INFRASTRUCTURE IN THE GREATER MEKONG SUBREGION"

FINAL REPORT

COMPONENT 1

MODULE 1

UPDATE OF THE GMS REGIONAL MASTER PLAN

APPENDICES

DATE: 15 OCTOBER 2010

LIST OF UNITS AND ABBREVIATIONS

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

LIST OF ACRONYMS

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

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

1. SUMMARY OF NATIONAL PDPS

The detailed national PDPs of the different countries are presented in Task 3 reports. The present paragraphs present the main features of these PDPs (except Myanmar PDP which was not available).

1.1 DEMAND PROJECTIONS

The following table presents the projection of the annual peak demand in the different countries:

Peak demand projection (MW)

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

Table 1.1-1: Projections of peak demand in the GMS (2010 - 2030)

1.2 PROJECTED INSTALLED CAPACITY PER COUNTRY AND FOR GMS MASTER PLAN "BASE CASE"

The following tables present the evolution of installed capacity in the different countries according to their national PDPs.

All the following data are given in MW.

Cambodia:

	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028
Total Existing Thermal	134	134	134	134	134	134	134	134	134	134	134	134	134	134	134	134	134	134	134
Total Existing Hydro	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12
Total Future thermal	101	101	201	201	501	501	501	501	501	501	501	501	751	751	1 001	1 001	1 001	1 451	1 451
Total Future Hydro	0	211	211	211	331	331	1 125	1 234	1 234	1 234	1 710	1 710	1 710	1 710	1 710	1 858	1 858	1 858	1 858
Total Imports	150	260	280	280	280	330	330	330	330	330	330	330	330	330	330	330	330	330	330
Total installed capacity + imports	397	718	838	838	1 258	1 308	2 102	2 211	2 211	2 211	2 687	2 687	2 937	2 937	3 187	3 335	3 335	3 785	3 785
Peak load	467	516	652	717	866	1 008	1 122	1 219	1 325	1 440	1 610	1 752	1 894	2 048	2 216	2 401	2 601	2 819	3 054

Table 1.2-1: Projected installed capacity - Cambodia

China:

	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028
Existing Thermal	21 348	21 348	21 348	21 348	21 348	21 348	21 348	21 348	21 348	21 348	20 548	20 548	20 548	20 548	20 548	20 548	20 548	20 548	20 548
Existing Hydro	27 992	27 992	27 992	27 992	27 992	28 952	28 952	28 952	28 952	28 952	28 952	28 952	28 952	28 952	28 952	28 952	28 952	28 952	28 952
Future thermal	2400	5600	5600	6800	6800	7800	14800	14800	14800	14800	21400	22720	25120	25120	25120	25120	25120	25120	25120
Future Hydro	14139	21100	27982	35113	41093	46143	47343	52143	56643	57443	58643	65193	65373	68273	68273	68693	68693	69293	69765
Total Imports	600	840	840	840	840	2 280	2 280	2 280	4 343	6 405	8 608	10 670	12 733	14 795	16 858	18 920	18 920	18 920	22 470
Additional required capacity (domestic o	0	0	0	0	0	0	0	2 000	3 000	8 000	8 000	8 000	8 000	8 000	11 000	14 000	21 000	28 000	31 000
Total installed capacity + imports	66 479	76 880	83 762	92 093	98 073	106 523	114 723	121 523	129 085	136 948	146 150	156 083	160 725	165 688	170 750	176 233	183 233	190 833	197 855
Peak load + export to Guandong	41200	49320	57440	65560	73680	81800	87720	94340	100960	107580	114200	119492	124784	130076	135368	140660	146286	152138	158223

Table 1.2-2: Projected installed capacity - China

Laos:

	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028
Existing Thermal	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Existing Hydro	457	457	457	457	457	457	457	457	457	457	457	457	457	457	457	457	457	457	457
Future thermal	0	0	0	0	0	100	100	100	100	100	100	100	100	100	160	160	160	160	160
Total future Hydro	151	296	496	726	1 253	1 902	2 393	2 629	2 896	3 313	3 313	3 431	3 491	3 551	3 551	3 715	3 715	3 715	3 715
Imports	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total installed capacity + import	608	753	953	1 182	1 710	2 459	2 950	3 186	3 453	3 869	3 869	3 987	4 047	4 107	4 167	4 331	4 331	4 331	4 331
Peak load	646	725	787	942	1 267	1 917	2 060	2 209	2 461	2 613	2 665	2 669	2 674	2 680	2 688	2 696	2 723	2 750	2 777

Table 1.2-3: Projected installed capacity - Laos

Thailand:

	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028
Total Existing Thermal	25 230	25 160	25 160	25 160	24 108	22 933	22 185	21 691	21 010	20 821	19 292	19 092	19 092	19 092	19 092	19 092	19 092	19 092	19 092
Total Existing Hydro	3 424	3 424	3 424	3 424	3 424	3 424	3 424	3 424	3 424	3 424	3 424	3 424	3 424	3 424	3 424	3 424	3 424	3 424	3 424
Total Future thermal	2 222	3 182	4 221	6 746	10 356	10 406	12 656	14 906	17 356	19 006	21 656	24 306	25 356	28 006	29 556	31 806	34 856	38 706	40 156
Total Future Hydro	41	79	79	79	79	79	79	79	79	79	79	79	79	79	79	79	79	79	79
Total Imports	1 620	2 217	2 437	2 437	2 437	3 907	3 907	4 712	4 712	4 892	6 082	6 082	6 329	6 929	7 712	7 712	8 235	8 235	11 785
Total installed capacity + imports	32 537	34 062	35 321	37 846	40 404	40 749	42 251	44 812	46 581	48 222	50 533	52 983	54 280	57 530	59 863	62 113	65 686	69 536	74 536
Peak load	23 976	25 125	26 652	28 268	29 951	31 814	33 753	35 748	37 805	39 908	42 104	44 361	46 739	49 245	51 886	54 668	57 600	60 689	63 944

Table 1.2-4: Projected installed capacity - Thailand

Vietnam:

	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028
Existing Thermal	9 076	9 076	9 076	9 076	9 076	9 076	9 076	9 076	9 076	9 076	9 076	9 076	9 076	9 076	9 076	9 076	9 076	9 076	9 076
Existing Hydro	10 066	10 066	10 066	10 066	10 066	10 066	10 066	10 066	10 066	10 066	10 066	10 066	10 066	10 066	10 066	10 066	10 066	10 066	10 066
Future thermal	2 720	4 220	6 910	13 710	17 810	19 810	22 210	24 610	26 210	26 210	26 210	28 610	31 910	34 670	39 470	42 370	47 870	54 270	60 370
Future Hydro	4 895	6 575	7 145	7 530	8 296	8 726	9 261	10 103	10 635	10 685	10 880	10 916	11 069	11 369	11 689	11 689	11 689	11 689	11 689
Nuclear (E + F)	0	0	0	0	0	0	0	0	0	0	2 000	2 000	2 000	3 000	3 000	4 000	4 000	4 000	4 000
Renewal (E+F)	225	406	587	768	949	1 267	1 357	1 447	1 537	1 627	1 717	1 827	1 937	2 047	2 157	2 267	2 267	2 267	2 267
Import from GMS	520	745	745	745	1 182	882	2 073	2 073	2 073	2 073	4 918	4 918	4 918	4 918	4 918	4 918	4 918	4 918	4 918
Installed capacity + imports	27 502	31 088	34 529	41 895	47 379	49 827	54 043	57 375	59 597	59 737	64 867	67 413	70 976	75 146	80 376	84 386	89 886	96 286	102 386
Peak load	16 165	18 303	20 723	23 465	26 569	30 084	32 977	36 147	39 622	43 432	47 608	51 609	55 947	60 650	65 750	71 280	76 733	82 603	88 923

Table 1.2-5: Projected installed capacity - Vietnam

GMS (without Myanmar, but including generation projects developed in Myanmar for export ro other GMS countries:

	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028
Existing Thermal	55 788	55 718	55 718	55 718	54 666	53 491	52 743	52 249	51 568	51 379	49 050	48 850	48 850	48 850	48 850	48 850	48 850	48 850	48 850
Existing Hydro	41 950	41 950	41 950	41 950	41 950	42 910	42 910	42 910	42 910	42 910	42 910	42 910	42 910	42 910	42 910	42 910	42 910	42 910	42 910
Future thermal	7 443	13 103	16 932	27 457	35 467	38 617	50 267	56 917	61 967	68 617	79 867	86 237	93 237	99 647	109 307	118 457	134 007	151 707	162 257
Future Hydro + renewval	19 451	28 667	36 500	44 426	52 001	58 448	61 558	67 635	73 024	74 380	76 341	83 155	83 658	87 028	87 458	88 300	88 300	88 900	89 372
Export oriented projects	2 890	4 062	4 302	4 302	4 739	7 399	8 590	9 395	11 458	13 700	19 938	22 000	24 310	26 972	29 818	31 880	32 403	32 403	39 503
Installed capacity	127 522	143 500	155 402	173 854	188 823	200 865	216 068	229 106	240 926	250 987	268 106	283 153	292 965	305 408	318 343	330 398	346 471	364 771	382 893
Peak load	82 453	93 989	106 255	118 952	132 333	146 623	157 632	169 663	182 173	194 973	208 187	219 883	232 038	244 700	257 907	271 704	285 943	300 999	316 922

Table 1.2-6: Projected installed capacity - GMS

2. MASTER PLAN "BASE CASE": DETAILED IMPORT HYPOTHESES PER COUNTRY

The PDP of each country are presented and discussed in Task 3 “Review of country PDP” reports. Complementary hypotheses were taken by the Consultant when necessary in order to build consistent PDPs for all countries (consistence between the list of generation export projects and import targeted by importing countries).

The present appendix gathers the main elements relative to the associated generation export projects for the three importing countries in the Master Plan "base case"

2.1 GENERATION EXPORT PROJECTS FOR CHINA

IMPORTS / EXPORTS :		MW	GWh	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Existing	Existing Imports				600	600	840	840	840	840	840	840	840	840	840	840	840	840	840	840	840	840	840	840	840	840
	From Myanmar																									
	Shewli 1	600	4 022		600																					
	Dapein 1	240	1 065				240																			
Committed	Imports																									
	From Myanmar																									
Project	Future Imports			0	0	0	0	0	0	0	1 440	1 440	1 440	3 503	5 565	7 768	9 830	11 893	13 955	16 018	18 080	18 080	18 080	21 630	21 630	21 630
	From Myanmar			**0**	**0**	**0**	**0**	**0**	**0**	**0**	**1 440**	**1 440**	**1 440**	**3 503**	**5 565**	**7 768**	**9 830**	**11 893**	**13 955**	**16 018**	**18 080**	**18 080**	**18 080**	**21 630**	**21 630**	**21 630**
	Shewli 2&3	1 440	7 305								1 440															
	"7 projects"	16 500	86 873											2 063	2 063	2 063	2 063	2 063	2 063	2 063	2 063					
	Tasang	3 550	17 722																					3 550		
	Dapein 2	140	633													140										
	From Laos :																									
	Total Imports	**MW**		**0**	**600**	**600**	**840**	**840**	**840**	**840**	**2 280**	**2 280**	**2 280**	**4 343**	**6 405**	**8 608**	**10 670**	**12 733**	**14 795**	**16 858**	**18 920**	**18 920**	**18 920**	**22 470**	**22 470**	**22 470**

Table 2.1-1 : Generation export projects for China

Rationale:

- 700 MW power export from China to Vietnam to feed isolated grid in North Vietnam up to 2015 (ie. until the end of the present power exchange contract). No exchange after 2015 because China and Vietnam will be large power importers.
- Schedule of Myanmar export projects agreed on at Workshop 3 (Bangkok, January 2010).
- Tasang HPP assumed to be shared equally between China and Thailand.
- No import from Laos in the “base case”.

2.2 GENERATION EXPORT PROJECTS FOR THAILAND

IMPORTS :					2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Existing			MW	GWh																							
	Malaysia		330		**330**																						
	Lao PDR		367		**367**																						
Committed			MW	GWh																							
	Lao PDR (Nam theun2)		920	5 936		920																					
	Lao PDR (Nam Ngum2)		597	1 976				597																			
	Lao PDR (expansion Theun Hin bun)		220	1 395					220																		
	Hongsa lignite (TPP)		1 470	12 877								1 470															
Project		$/MWh	MW	GWh																							
Lao PDR	Nam Theun 1 HPP (tariff MOU	48.8	523	1 840																			523				
	Nam Ngum 3 HPP (tariff MOU	36.8	440	2 077										440													
	Nam Ngiep 1 HPP (tariff MOU	35.0	247	1 327															247								
	Nam Ou HPP (tariff MOU term	44.5	1 043	4 080												120					923						
Myanmar	Hutgyi HPP		1 300	7 325													1 190										
	Tanintharyi HPP		600	3 476																600							
	Tasang HPP (7000 MW * 0.5)		3 550	17 722																				3 550			
	Maikhot lignite (TPP)		365											365													
	Total Imports				**697**	**1 617**	**1 617**	**2 214**	**2 434**	**2 434**	**2 434**	**3 904**	**3 904**	**4 709**	**4 709**	**4 829**	**6 019**	**6 019**	**6 266**	**6 866**	**7 789**	**7 789**	**8 312**	**8 312**	**11 862**	**11 862**	**11 862**

Table 2.2-1 : Generation export projects for Thailand

NB:

- The capacity indicated in the table is not the installed capacity of the projects, but the share of capacity for Thailand.

Rationale:

- The Thailand PDP 2007 rev 2 only provides an annual target for import from Malaysia, Myanmar and Laos. The list of associated export oriented generation projects was not provided (except for the ”committed” projects) nor the splitting between import from North and South Laos.

- Import from Laos :

    - The Consultant ranked as first priority the HPP whose tariffs MOU have been terminated. These projects are those expected to have been studied at the most advance level, and consequently the ones possible to be build at the earliest (in the 2015 to 2020 horizon).

    - Furthermore, all these HPP projects have seasonal reservoirs which are more favorable for generation regulation than run of river projects.

- o Accordingly, no HPP projects are assumed to be developed in Laos South for export to Thailand.

- o In the base case, the only hydro projects left available in Laos South (given the hydro projects devoted for export to Vietnam) are 1872 MW Ban Kum (44.4$/MWh – 8434 GWh) and 360 MW Don Sahong (31.6 $/MWh – 2375 GWh) on Mekong River, both being run of river (which is less favorable for generation because of no seasonal regulation).

- Import from Myanmar: Tasang HPP commissioning was selected in accordance with the combined import needs of China and Thailand.

2.3 GENERATION EXPORT PROJECTS FOR VIETNAM

Laos -N -> Vietnam-N					2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
		MW	GWh	$/MWh																							
	Nam Et 1	60	265										60														
	Nam Et 2	135	601										135														
	Nam Et 3	250	1 315										250														
	Luang Prabang	1 400	5 437	42													1 400										
	Nam Mo	105	602														105										
	Nam Xam 1	112	369														112										
	Nam Xam 3	196	650										196														
	Nam Chien	148	627	37													148										
	Nam Ou 7	180	725	76													180										
	Total import from Laos-N (incremental) :				0	0	0	0	0	0	0	0	641	0	0	0	1 945	0	0	0	0	0	0	0	0	0	0
	Total import from Laos-N :				0	0	0	0	0	0	0	0	641	641	641	641	2 586	2 586	2 586	2 586	2 586	2 586	2 586	2 586	2 586	2 586	2 586

Table 2.3-1 : Generation export projects for Vietnam North

Laos -S => Vietnam-C					2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Committed	Imports	MW	GWh																								
Lao PDR	Xekaman 3, Xekong	225	983					225																			
	Xekaman 1,Attapeu	258	1096								258																
	Xekaman 4B,Xekong	74	301								74																
	Dak Emeule,Xekong	105	506								105																
Project	Imports Laos South	MW	GWh	$/MWh																							
	Mekong at Latsua	800	3 504	46													800										
	Xekaman 4A	96	375	51									96														
	Xekaman 2A	64	242	56.7									64														
	Xekaman 2B	100	381	55													100										
	Xekong 4	383	1 901	46																							
	Xekong 5	218	1 201	47																							
	Xepian	390	1 748	43									390														
	Total incremental import Laos-S-> Vietnam-C							225	0	0	437	0	550	0	0	0	900	0	0	0	0	0	0	0	0	0	0
	Total import Laos-S-> Vietnam-C							225	225	225	662	662	1 212	1 212	1 212	1 212	2 112	2 112	2 112	2 112	2 112	2 112	2 112	2 112	2 112	2 112	2 112

Table 2.3-2 : Generation export projects for Vietnam Center

Rationale:

- 700 MW power export from China to Vietnam to feed isolated grid in North Vietnam up to 2015 (i.e., until the end of the present power exchange contract). No exchange after 2015 because China and Vietnam will be large power importers.

- The target import level from Laos North, Laos South and Cambodia was provided by Vietnam (Meeting in Hanoi, Jan 2010) as first views on Vietnam Master Plan VII.

- The list of export oriented projects was selected on the base of information provided by Laos and Vietnam

2.4 IMPORT HYPOTHESES FOR CAMBODIA

- From Vietnam: 100 MW in 2010, 200 MW in 2011 up to 2015.
- From Laos: 10 MW in 2010, 60 MW in 2015.
- From Thailand: 40 MW in 2010 and 2011, 60 MW in 2012.

3. MASTER PLAN "CASE 2000 MW" - ADDITIONAL RESULTS

3.1 POWER FLOWS

Interconnections between Myanmar and China :

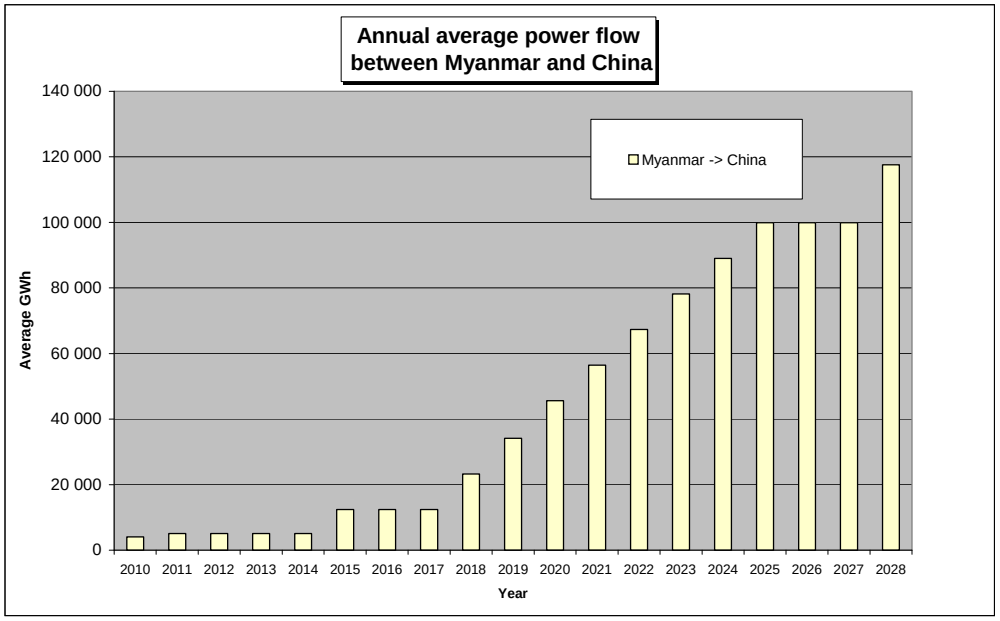

Figure 3.1-1 : Case 2000 MW - Annual energy flow between Myanmar and China

Interconnections between Laos-North and Vietnam-North:

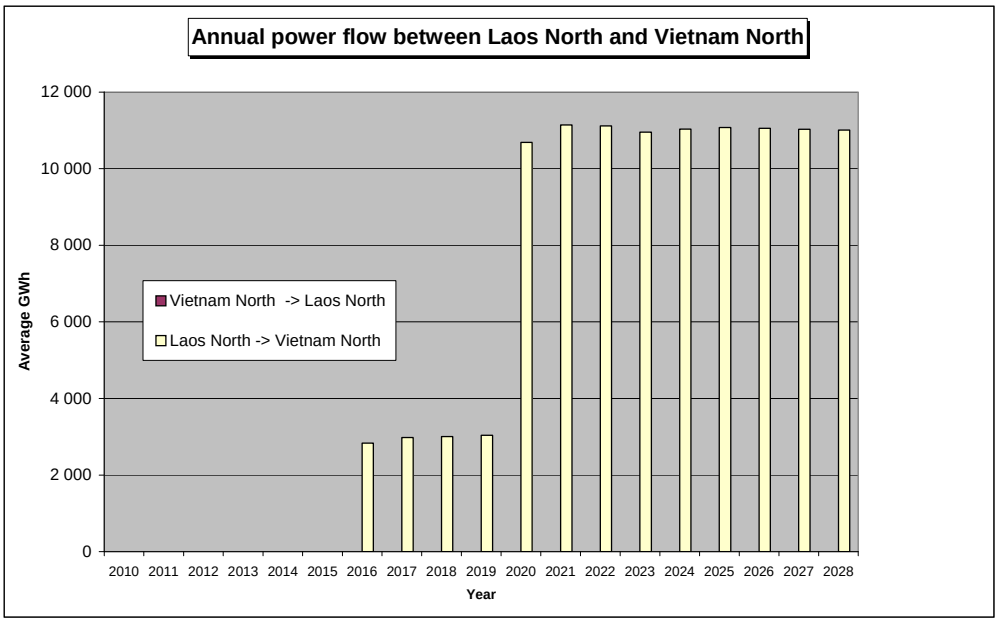

Figure 3.1-2 : Case 2000 MW - Annual energy flow between Laos N and Vietnam N

The development of the power exchanges follows the pace of development of the hydro projects in Laos (e.g., Luang Prabang HPP project – 1400 MW – is commissioned in 2020).

The monthly power exchanges follow the seasonality of hydro generation (maximum during the wet season):

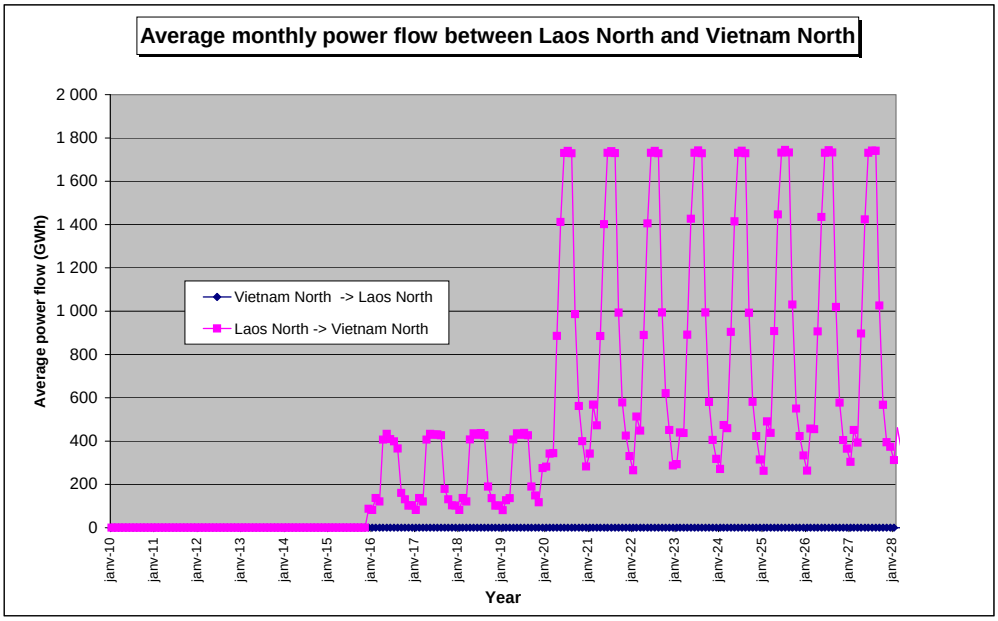

Figure 3.1-3 : Case 2000 MW - Monthly energy flow between Laos N and Vietnam N

Interconnections between Laos and Thailand:

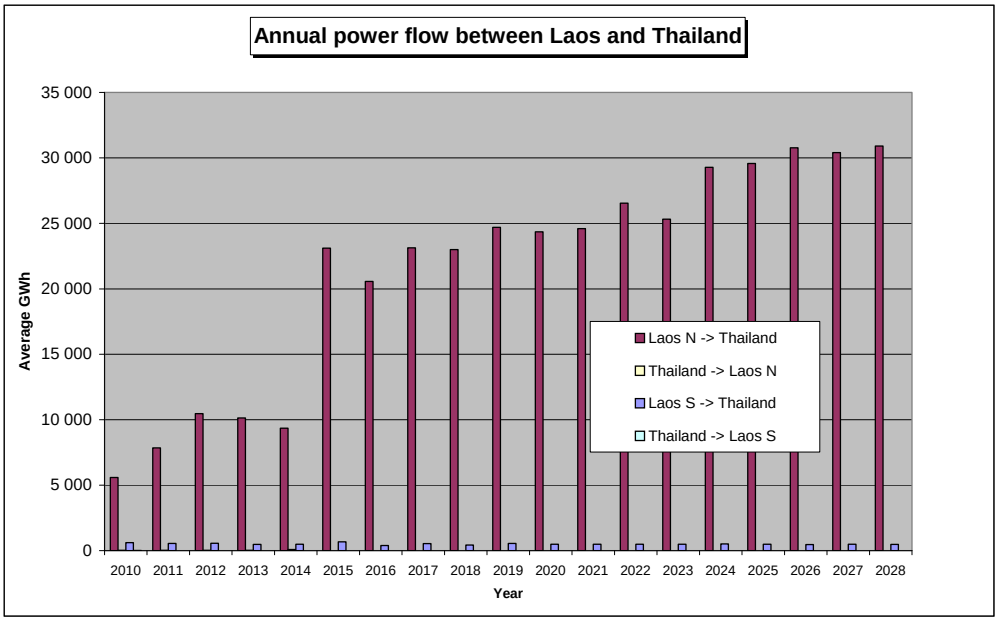

Figure 3.1-4 : Case 2000 MW - Annual energy flow between Laos and Thailand

The development of the power exchanges follows the pace of development of the hydro and thermal (Hongsa lignite 1470 MW is commissioned in 2015) projects in Laos.

3.2 MARGINAL COSTS

The load marginal cost (equivalent to short term marginal cost[1]) is an output of OPTGEN model[2].

The load marginal cost is in relation with the incremental cost of generation of the various TPP of the various generation mixes. The evolution of the incremental cost of the main thermal generation candidates is reminded for the planning period in the following figure. This evolution follows the fuel price evolution:

[1] STMC = incremental cost of an incremental MWh to be supplied by the power system, the structure and capacity of the generation being left unchanged (ie. No new capacity).
[2] Load marginal cost = derivative of the operation cost function with respect to the demand. In other words, the cost associated with an additional MWh of generation. This cost includes fuel cost and variable O&M costs.

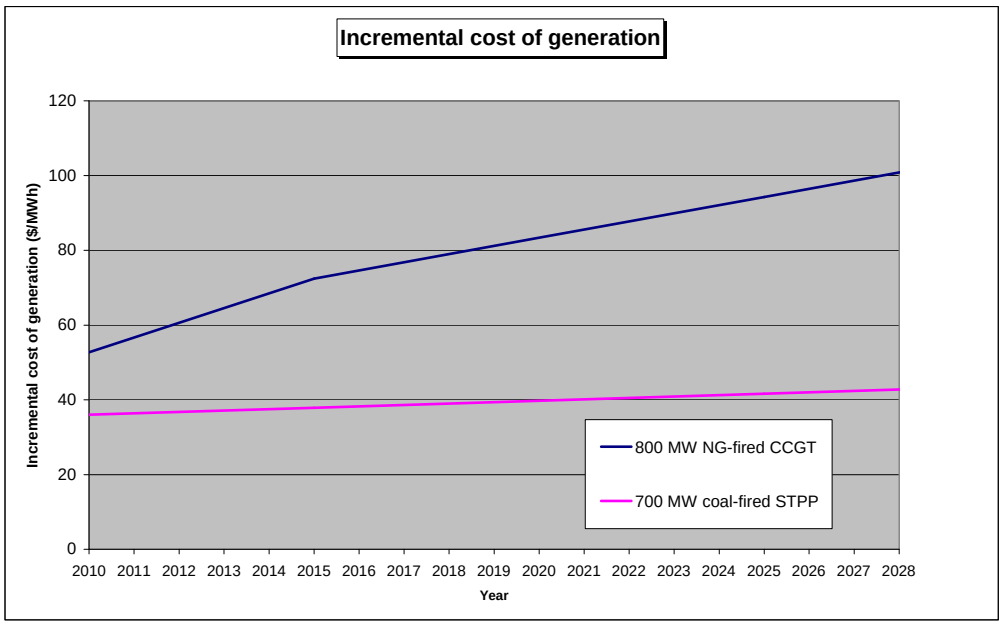

Figure 3.2-1 : Evolution of the incremental cost of thermal candidates

The following figure presents the evolution of the average annual marginal cost over the 2010-2028 period:

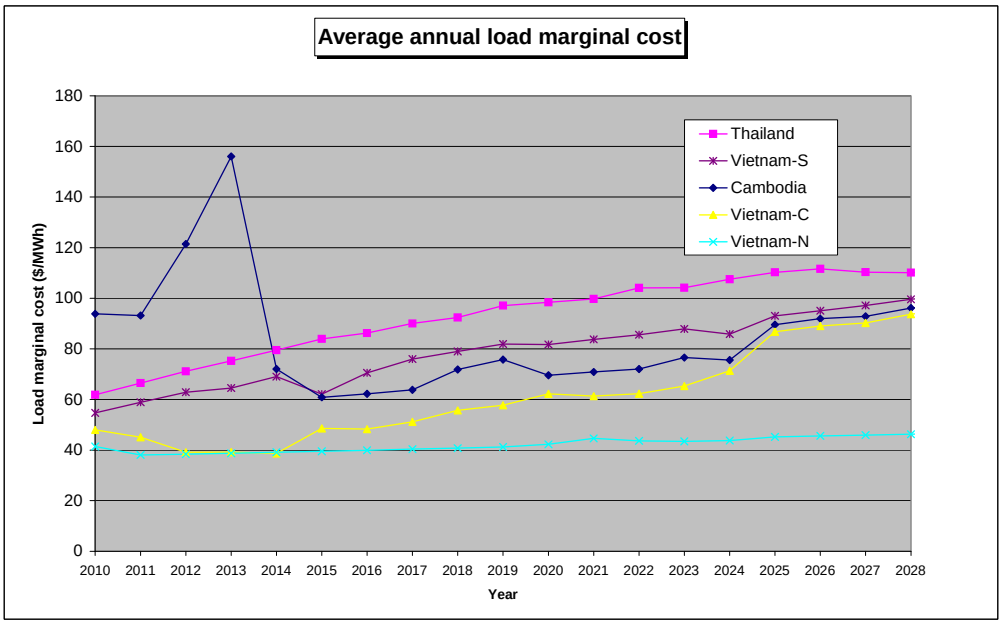

Figure 3.2-2 : Case 2000 MW – Average annual load marginal cost

Up to 2014 the highest marginal costs are observed in Cambodia because of the lack of generation capacity and resulting power shortage. Then comes the marginal cost of Thailand (based on gas-fired CCGT), the marginal cost of Vietnam South (based on a mix of gas-fired CCGT and coal-fired STPP), and finally the marginal cost of Vietnam Center and North (based on a mix of HPP and coal-fired STPP).

After 2014, the highest marginal cost is observed in Thailand because of the highest incremental cost of gas-fired CCGT, compared to coal-fired STPP in Cambodia and Vietnam.

Next to Thailand marginal cost, Vietnam South marginal cost is the highest because of the generation mix composed of gas-fired CCGT and coal-fired STPP.

The lowest marginal cost is observed in Vietnam North with a generation mix dominated by coal-fired STTP.

The evolution of the capacity of interconnection and the resulting level of congestion of the different interconnections explains the evolution of the marginal cost of Vietnam Center:

- Generally speaking, congestion leads to a difference of marginal cost between both ends of interconnection, while an oversize interconnection equalizes the marginal cost at both end. The settling marginal costs at both ends depend on the amount of generation at both ends of the lines and on its incremental costs.

- For example, the progressively saturating Vietnam N -> Vietnam Center from 2014 to 2025 explains the increasing marginal cost in Vietnam Center.

- On the other hand, because the Vietnam Center -> South interconnection is no longer saturated in 2025, the marginal cost in Vietnam Center convergences to the marginal cost between Vietnam South (thanks to Vietnam Center – Laos South, Laos South – Cambodia, Cambodia – Vietnam interconnection).

- This various episodes of congestion is more easily observed in the evolution of the monthly marginal cost :

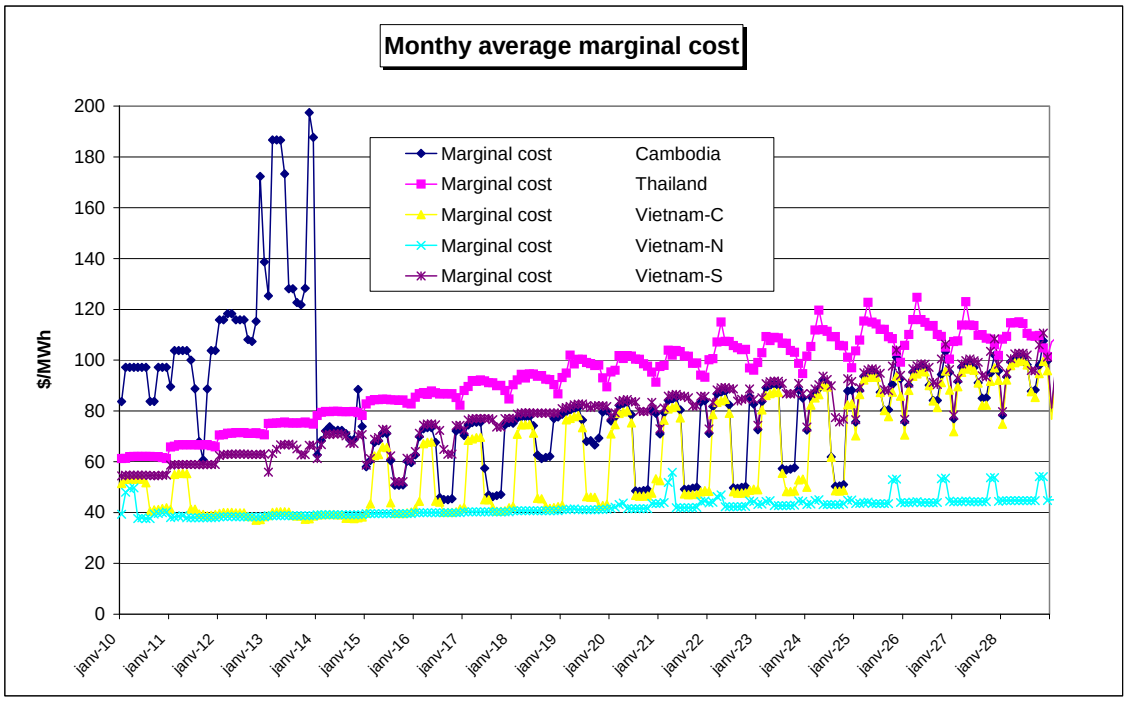

Figure 3.2-3 : Case 2000 MW – Average monthly load marginal cost

Some additional comments can be made:

- Thailand: the increasing seasonality of marginal cost results from the increasing share of hydro import (and the associated seasonality of inflows, with Myanmar import from 2020).

- Vietnam-S: the marginal cost follows the general trend of Thailand because of the share of gas-fired CCGT in this generation mix, though with a lower cost because of power import from Vietnam South, Cambodia hydro, Vietnam-North coal power, and from Laos South hydro.

- Vietnam-C: the marginal cost converges to Vietnam-N marginal cost when the link between Vietnam-N to Vietnam-C is not congested.

- On the other hand, Vietnam-C marginal cost converges to Vietnam-S marginal cost, when the Vietnam-C to Vietnam-N link is congested.

These episodes of congestion can be observed in more details in the following monthly power flows:

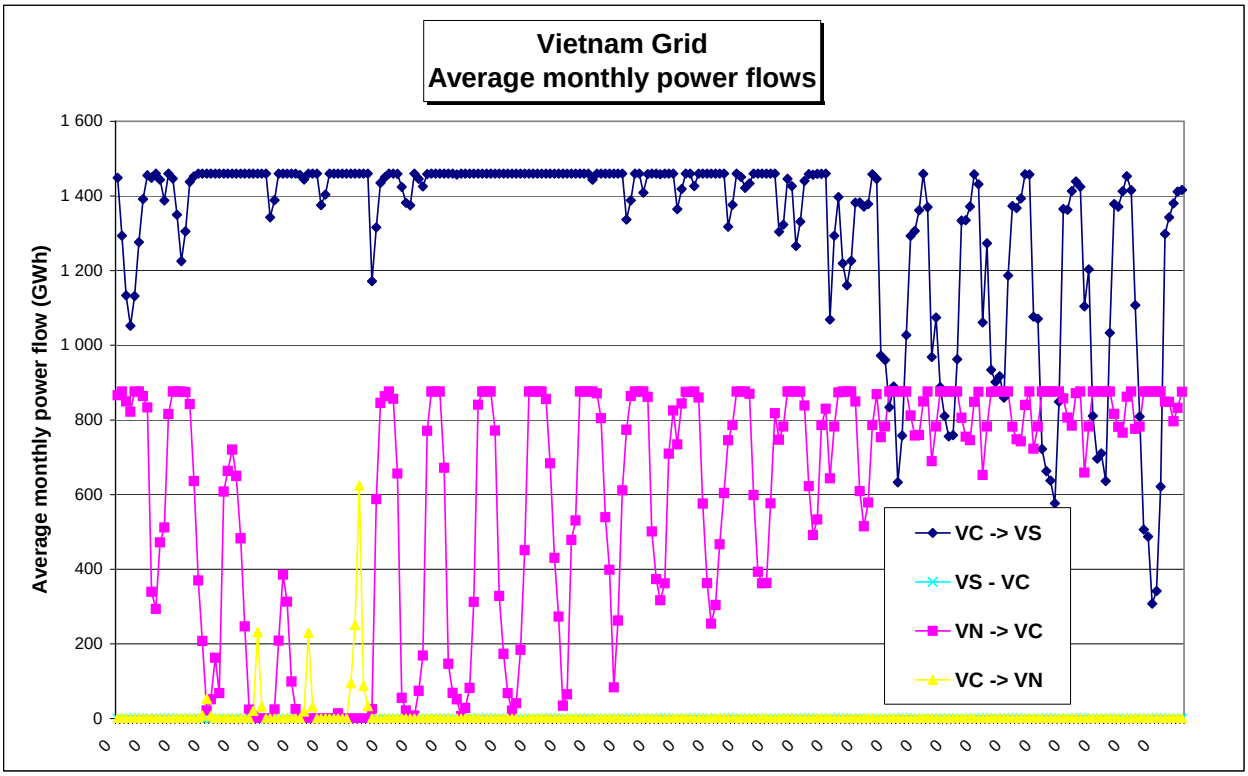

Figure 3.2-4 : Case 2000 MW – Average monthly power flow within Vietnam