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Integrated Energy Resources Planning for the ASEAN Countries and Southern China

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Abstract - Regional integration for planning of new generation and strategic international transmission lines constitutes a significant strategy for the expanding economies of South China and ASEAN's rapidly expanding economies. This region has seen very significant economic growth since the late 1990s, which has consequently put great pressure on their energy systems. China and the ASEAN countries have been discussing free trade for while which has included the issues of increased cooperation in energy planning and trade in the region. Exploring the use of the hydro power potential in Southern China and the ASEAN countries such as Laos and Burma is one particular issue. This paper discusses some environmental issues related with regional hydro power development and suggests strategies for hydro power development that will provide reduced environmental impact. It also discusses the optimal energy resources planning with a free power trade system. Preliminary results from the Purdue Electricity Trade Model show that cost savings in excess of $11 Billion dollars over the next 10 years could be achieved under the "hydro dams" case, and $19.3 billion could be saved under the run-of-river case in Yunnan.

I. Introduction

Energy has been a serious issue facing both the ASEAN (Association of Southeast Asia Nations) countries and China due to their fast economic growth. In Southern China especially the Yunnan Province, there are abundant hydro power resources. The power however cannot be easily transmitted to industrial regions of the country due to very long distances and associated costs. It will be easier to export hydro power to some ASEAN countries such as Thailand. The development of hydro power in Southern China has also been a contentious issue due to ecological and other environmental concerns. The originally proposed cascade hydro power plants in the upper Mekong River in Yunnan (LanChangJiang) have been on and off for the past two years due to the objection of environmental groups. A similar situation exists with the proposed 13 cascade hydro power plants along NuJiang (Nu River), where construction has been put on hold due to the objection of some environmental groups. Apparently, run-of-river hydro power projects might be better alternatives for the originally proposed big dams, which would have much smaller environmental impacts to the region. Run-of-river hydro power projects should have good economic value because the large region feeding the upper Mekong and Nu Rivers is subtropical with plentiful rainfall and is dense in vegetation for reserving water. Through late spring until summer time, water from the melting snow in the QingHai-Tibet plateau provides needed water for the drier season. The annual average water flow rate is 15060 cubic meters per second [1]. Further more, the net water head from the plateau to the lower section of the Mekong River is over 5,000 meters [23]. In other words, considerable water is supplied all year around along the river, which is good for run-of-river hydro power production.

Run-of-river hydro power projects are much less contentious in the Greater Mekong region because they do not alter the water flow patterns much. This may be important not only from the environmental point of view, but also from the political and diplomatic point of view because down stream countries such as Thailand have been concerned with the massive hydro dams proposed in Yunnan. According to [23], the minimum water out flow to prevent sea water intrusion at the Mekong River mouth is 3,000 cubic meters per second.

Under the above scenario, the Purdue Energy Modeling Research Groups (PEMRG) has conducted a preliminary study on a joint optimization of expanding both the transmission and generation expansions across the combined Southern and ASEAN region. Free power trade is assumed in the model thus being consistent with proposed free trade agreement between China and the ASEAN countries. The results show that cost savings of almost $20 billion could be achieved under free trade and run-of-river hydro power construction in Yunnan.

Several major policy issues confront the Chinese and the ASEAN energy planners. These include the future plans for new hydropower stations in the region, the use of natural gas from the regions combined massive reserves of over 256Tcf, and the power transmission expansion and integration in the Greater Mekong region. Other policy includes privatization of the power sector in the ASEAN countries in the near term.

Based on this initial regional data and modeling, it is proposed that there are now good grounds for an extensive ASIAN and Yunnan regional expansion modeling study be conducted with regional partners. This will then fully demonstrate the benefits from greater regional cooperation and show detailed cost effectiveness of (cost minimizing) planned collective expansion projects that will provide the most attractive investments.

The earlier study, conducted by the NorConsult, also gives good insights into the region's initiative for coordinated regional energy planning [2]. Certain enhancements are now to be added to this earlier study by the Purdue Energy Modeling team. These enhancements will include:

(1) Regional long-term planning of both transmission and generation in the Yunnan Province and all 10 nations of ASEAN including the benefits of under water power transmission cable.
(2) The Purdue models provide an optimization methodology with cost minimization for operational as well as fixed capital costs. Both generation and transmission capacity expansions is considered simultaneously.

(3) Improved regional modeling to cope water inflows into the hydro schemes, and environmental impact of hydro on lower regions and preservation.
(4) The inclusion of realistic distributed generation options at each node of the model to more accurately capture the competition between centrally generated electricity provided by the grid and locally generated electricity provided by small diesel or gas powered generation systems.
(5) The ability to provide decision makers with a set of locational marginal prices (LMP) at each node. These LMPs provide signals for the construction of new transmission capacity.
(6) The Purdue modeling builds upon the Mekong integrated transmission system recommendations of earlier studies, with capacity optimized. The benefits of trade from a fully interconnected regional grid are preliminarily quantified. The demonstration model in this paper shows cost savings in the order of 10% or more from free trade of electricity in the region than the isolated systems.

A 21 node model is used in the first preliminary modeling work (Figure 1). It can be seen that five nodes are provided for the regions of Thailand, three nodes for Malaysia, Philippines, and Indonesia.

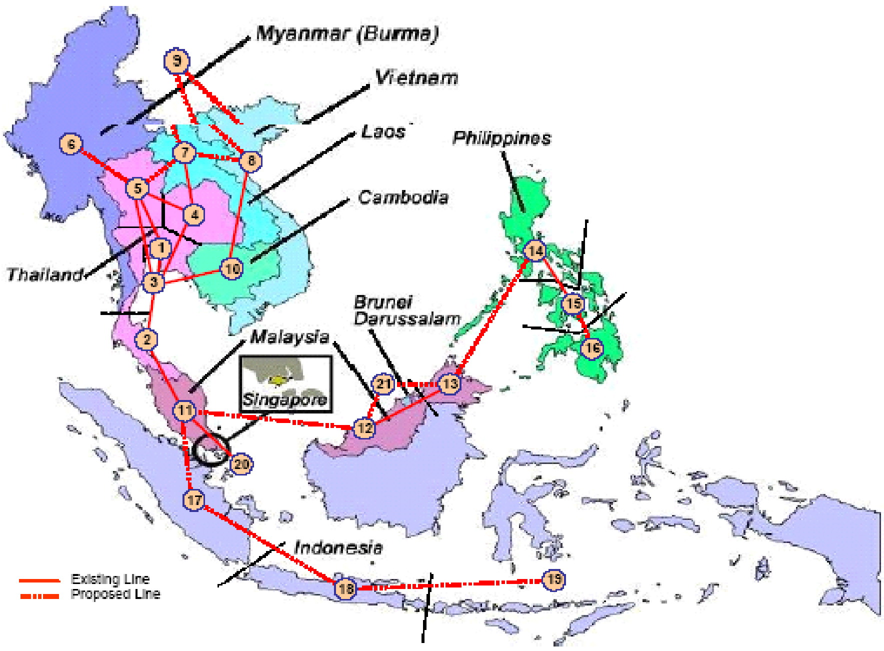

Figure 1. The Network Topology of the ASEAN-Yunnan 21 Node Demonstration Model (Yunnan is node 9).

The ASEAN region has over 108 GW of generating capacity (Table 1) with much of the 2004 generation taking place in Indonesia, Malaysia, the Philippines and Vietnam. The ASEAN-Yunnan data in Table 1 is the most recent 2004 data that includes new hydropower in

Vietnam [2]. There is rapid growth in electricity demand across the whole region with 6.4% per annum in Thailand, 10% in much of Indonesia, 12% in Cambodia, 5.7% in Singapore, and 5.8% in Yunnan Province (Table 2). The 2004 regional peak demand is 68,401 MW and by 2014 this is forecast to be more than doubled at 143,658 MW.

Table 1. 2004 ASEAN-Yunnan Generation in the Demonstration Model (MW)

Node	Existing Thermal	Existing Hydropower	TOTAL
Thailand-Bangkok-1 3,	121	0	3121
Thailand South – 2	8,618	331	8,949
Thailand Central – 3	7,651	1,058	8,709
Thailand East – 4	710	744	1,454
Thailand North – 5	2,799	1,253	4,052
Burma – 6	912	390	1,302
Laos – 7	9	643	652
Vietnam – 8	6,903	4,368	11,271
Yunnan PRC – 9	2,719	6,400	9,119
Cambodia – 10	143	0	143
Malaysia Peninsula – 11	13,663	2,092	15,755
Malaysia Sarawak – 12	723	94	817
Malaysia Sabah – 13	714	71	785
Philippines Luzon – 14	10,435	1,781	12,216
Philippines Visayas – 15	1,579	0	1,579
Philippines Mindanao - 16	669	1,004	1,673
Indonesia Sumatra – 17	1,081	458	1,539
Indonesia Java – 18	13,394	2,100	15,494
Indonesia East – 19	3,569	458	4,027
Singapore – 20	8,919	0	8,919
Brunei - 21	707	0	707
TOTAL	89,038	23,245	112,283

Sources: GMS Final Report Volume III June 2002, ASEAN Centre for Energy, Philippines Department of Energy 2003, Investment Coordinating Board Indonesia 2002, US Embassy in Singapore 2003

Table 2. Existing Peak and Demand Growth in GMS and ASEAN Countries for 2004-2014

Country SuperNode	Population Pop	2004-Current Peak Demand	2014-Projected Peak Demand	N	Region Node	Peak Demand	Generation Sale	Demand Growth	Ten-Year Growth
	M	MW	MW			MW	GWh	%	Factor
Thailand	61.80	16682	31022	1	Thailand-MEA	7053	9034	6.4	1.860
				2	Thailand-South	1165	6680	6.4	1.860
				3	Thailand-Central	5565	69138	6.4	1.860
				4	Thailand-Northeast	1322	3440	6.4	1.860
				5	Thailand-North	1577	20721	6.4	1.860
Myanmar	48.10	780	1593	6	Myanmar	780	4401	7.4	2.042
Lao PDR	5.10	167	361	7	Lao PDR	167	865	8.0	2.159
Vietnam	76.30	4890	11899	8	Vietnam	4890	26722	9.3	2.433
Yunnan, PRC	41.90	5257	9238	9	Yunnan, PRC	5257	31635	5.8	1.757
Cambodia	11.60	114	364	10	Cambodia	114	586	12.3	3.190
Malaysia	23.80	10866	25252	11	Malaysia-Peninsula	10060	56210	8.9	2.339
				12	Malaysia-Sarawak	543	2874	7.9	2.145
				13	Malaysia-Sabah	263	1913	7.7	2.105
Philippines	78.30	8509	16973	14	Philippines-Luzon	6454	40141	7.3	2.023
				15	Philippines-Visayas	1006	6257	7.5	2.061
				16	Philippines-Mindanao	1049	6524	5.8	1.757
Indonesia	209.00	16314	38644	17	Indonesia-Sumatra	1838	9954	10.1	2.629
				18	Indonesia-Java	12581	68137	8.6	2.292
				19	Indonesia-East	1895	10263	10.1	2.628
Singapore	4.10	4423	7700	20	Singapore	5,139	31,986	5.7	1.741
Brunei	0.34	399	614	21	Brunei	399	2621	4.4	1.538
Total	560.34	68401	143658						

Sources: World Bank Report 2000-2001, Institute of Energy Economics Japan 2002, GMS Report Volume II June 2002, Japanese Committee for Pacific Coal Flow 2002-2001, Philippines Department of Energy 2003, Investment Coordinating Board Indonesia 2002, ASEA Center for Energy 2003

The hydropower potential of the region is a major planning activity (Table 3). The future size of the role of natural gas is also a major topic of debate. Hydropower in the Mekong Subregion and Yunnan is well documented [2]. The extensive reserves of natural gas in Indonesia and Malaysia also will play an important part in regional energy trade modeling. The Southern China-ASEAN demonstration model is illustrated in Figure 1 with descriptions of each node given in Table 4.

Table 3. Natural Gas Potential in ASEAN and China (Source: eia.gov/emeu/)

Country	Natural Gas Reserves (TCF)
Thailand	13.3
Burma	10.0
Laos	0.0
Vietnam	6.8
China	53.3
Cambodia	0.0
Malaysia	75
Philippines	3.8
Indonesia	92.5
Singapore	0
Brunei	13.8

Table 4. The 21 Nodes in the Demonstration ASEAN-Yunnan Model

Country SuperNode	Node Number	Region Node
Thailand	1	Thailand-MEA
	2	Thailand-South
	3	Thailand-Central
	4	Thailand-Northeast
	5	Thailand-North
Myanmar	6	Myanmar
Lao PDR	7	Lao PDR
Vietnam	8	Vietnam
Yunnan, PRC	9	Yunnan, PRC
Cambodia	10	Cambodia
Malaysia	11	Malaysia-Peninsula
	12	Malaysia-Sarawak
	13	Malaysia-Sabah
Philippines	14	Philippines-Luzon
	15	Philippines-Visayas
	16	Philippines-Mindanao
Indonesia	17	Indonesia-Sumatra
	18	Indonesia-Java
	19	Indonesia-East
Singapore	20	Singapore
Brunei	21	Brunei

II. The Modeling Approach

The optimization model for this work is very similar to the models developed for other regional power pools by energy research groups at Purdue University [4, 19, 21]. It is a cost minimization model considering both capital and operational costs over a long time period (from 10 to 20 years). Within each year, representative hours are used for detailed operational simulation. In addition to modeling, PPDG (Power Pool Development Group at Purdue) has a great deal of experience organizing and conducting informational workshops and short courses, both at Purdue and in other countries. Its work with the Southern Africa Power Pool (SAPP) and the West African Power Pool (WAPP) has established an international scope to the modeling work of PEMRG (Purdue Energy Modeling Research Groups). The SUFG (State Utility Forecast Group) technical expertise and PPDG international modeling partnership experience place the PEMRG as an ideal choice for working with the ASEAN and South China energy planners to establish a regional long-term electricity expansion plan and power pooling infrastructure [12-22].

The ASEAN-Yunnan electricity trade and capacity expansion long-term model is described fully in the Purdue website [3] with special reference to the pool infrastructure development work with the Southern African Power Pool (SAPP) and the West African Power Pool (WAPP). Full details of the modeling background and formulation as well as a general training manual are available in the literature [4, 5, 19, 21].

The ASEAN & Yunnan regions have so many developments taking place in the electricity sector from investment in new hydropower plants to major international investments being considered. Restructuring, privatization in all the energy industries, the trans ASEAN Gas Pipeline, private and foreign investment, future of IPPs, and promotion of competitive arrangements in the energy markets are all major issues across ASEAN states today [6-11].

The ASEAN region and Yunnan Province PRC is a vast geographical area with a population of over 560M people (Table 2). It is an area with great energy potential in its rivers and natural gas resources. It is essential therefore that this appropriate energy resource data and proposed new generation and transmission projects are included in the optimization work. Table 5 summarizes the energy sources in each of the countries of the proposed model.

Table 5. Generation Potential in ASEAN and Yunnan

Legends: H - Hydropower, NG - Natural Gas, Nuc - Nuclear power, Geo - Geothermal power potential.

Country	H	NG	Coal	Oil	Nuc	Geo	Export	Import
Cambodia	✓	-	-	✓	-		-	✓
Thailand	-	✓	✓	-	-	-	-	✓
Laos	✓	-	-	-	-	-	✓	-
Vietnam	✓	✓	✓	✓	✓	✓	-	-
Yunnan	✓	-	✓	-	-	-	✓	-
Myanmar	✓	✓	✓	✓	-	-	✓	-
Malaysia	✓	✓	✓	-	-	-	-	-
Indonesia	✓	✓	✓	-	-	✓	-	-
Philippines	-	✓	-	-	-	✓	-	-
Singapore	-	✓	-	✓	-	-	-	-
Brunei	-	✓	-	-	-	-	-	-

Table 6. Modeling Proposed New Generation (MW)

Country SuperNode	N	Region Node	Proposed Thermal MW	Proposed Hydro MW
Thailand	1	Thailand-MEA	0	0
	2	Thailand-South	3414	0
	3	Thailand-Central	6946	660
	4	Thailand-Northeast	0	0
	5	Thailand-North	0	0
Myanmar	6	Myanmar	100	7213
Lao PDR	7	Lao PDR	720	5444
Vietnam	8	Vietnam	6735	4671
Yunnan, PRC	9	Yunnan, PRC	3600	8650
Cambodia	10	Cambodia	330	228
Malaysia	11	Malaysia-Peninsula	15421	600
	12	Malaysia-Sarawak	1000	0
	13	Malaysia-Sabah	1000	0
Philippines	14	Philippines-Luzon	5430	0
	15	Philippines-Visayas	1050	0
	16	Philippines-Mindanao	750	0
Indonesia	17	Indonesia-Sumatra	5000	0
	18	Indonesia-Java	20000	0
	19	Indonesia-East	5000	0
Singapore	20	Singapore	8000	0
Brunei	21	Brunei	1000	0
		Total	85496	27466

Source: GMS Final Report Volume III June 2002, Philippines Department of Energy 200

Two sets of generation data are inserted into the ASEAN-Yunnan model:
(a) Existing generation capacity for each country/node (Table 1).
(b) Proposed new generation projects for which no decision has yet been taken (Table 6).

The capital cost data for the set of proposed new generation in the model if too high will tend not to be selected in the optimization process. Similarly if the fuel and operational costs are very high in the existing power stations then these will tend not to be switched on in favor of long-term cheaper to run new stations.

The transmission lines that interconnect each node are required for trade to take place and for the gains from deeper regional integration in energy trading to be realized. The existing lines in the region have estimated values placed in the ASEAN-Yunnan Demonstration Model. These lines are given a load carrying capability of 250MW and if the demand for trade is high these existing lines are permitted to expand their capacity as much as is needed for keeping the total regional costs to a minimum (10,000MW is the parameter value for the limit on line expansion). New proposed transmission lines (overland and submarine) with initial capacities of 500MW are available (Table 7).

Table 7. Proposed International Transmission Capacities in the ASEAN-Yunnan Region

Line	Region Node From	Node-Node	Region Node To	Existing Line Cap Original MW	Existing Line Cap Expanded MW	Proposed Line Cap Initial MW	Proposed Line Cap Expanded MW
1	Thailand-MEA	1–3	Thailand-Central	250	10000	-	-
2	Thailand-MEA	1–5	Thailand-North	250	10000	-	-
3	Thailand-South	2–3	Thailand-Central	250	10000	-	-
4	Thailand-Central	3–4	Thailand-Northeast	250	10000	-	-
5	Thailand-Central	3–5	Thailand-North	250	10000	-	-
6	Thailand-Northeast	4–5	Thailand-North	250	10000	-	-
7	Thailand-Northeast	4–7	Lao PDR	250	10000	-	-
8	Vietnam	8–10	Cambodia	250	10000	-	-
9	Thailand-Central	3–10	Cambodia	250	10000	-	-
10	Thailand-South	2–11	Malaysia-Peninsula	250	10000	-	-
11	Malaysia-Peninsula	11–20	Singapore	250	10000	-	-
12	Malaysia-Sarawak	12–13	Malaysia-Sabah	250	10000	-	-
13	Philippines-Luzon	14–15	Philippines-Visayas	250	10000	-	-
14	Thailand-North	5–6	Myanmar	-	-	500	10000
15	Thailand-North	5–7	Lao PDR	-	-	500	10000
16	Lao PDR	7–8	Vietnam	-	-	500	10000
17	Lao PDR	7–9	Yunnan, PRC	-	-	500	10000
18	Vietnam	8–9	Yunnan, PRC	-	-	500	10000
19	Malaysia-Peninsula	11–12	Malaysia-Sarawak	-	-	500	50000
20	Malaysia-Sarawak	12–21	Brunei	-	-	500	10000
21	Malaysia-Sabah	13–21	Brunei	-	-	500	10000
22	Malaysia-Sabah	13–14	Philippines-Luzon	-	-	500	10000
23	Philippines-Visayas	15–16	Philippines-Mindanao	-	-	500	10000
24	Malaysia-Peninsula	11–17	Indonesia-Sumatra	-	-	500	10000
25	Indonesia-Sumatra	17–18	Indonesia-Java	-	-	500	10000
26	Indonesia-Java	18–19	Indonesia-East	-	-	500	10000

III. Results and Analysis

In this section, we first show the results of constructing hydro dams in Yunnan, and then contrast the results to the ones from run-of-river alternatives. The preliminary results show that run-of-river hydro power projects should be constructed instead of big hydro dams even from the point of view of economics.

A. Results from the case when large dams are constructed in Yunnan

Under this case, the capital cost for hydro projects are about $1,500/kW for all countries in the model. The capital costs for gas and coal plants can be found in [24]. This initial ASEAN-Yunnan demonstration model shows that with free trade of energy across the region massive cost savings are to be made in the order of $11.9B over the ten year period, 2005 to 2014. This 10.7% total cost saving ($99.1B instead of $110.7B with no trade, Table 8) over ten years demonstrates the great economic benefits to the region from promoting free trade of energy.

The total costs of new transmission capacity for the ten year planning horizon is over one billion dollars with free trade, and if lines are built for security and reliability purposes only to supply reserve power then still an investment of $730M is to be expected for the case without free trade. This level of investment in transmission is about 1% of the total cost for the 10 year horizon. Free trade is the most cost effective investment strategy for the region if big dams are the only choices in Yunnan. The infrastructure for energy transfer is a critical policy for the whole region. With free trade it is seen that more than $14B is saved from fuel costs for 2004 to 2014 (Table 8).

Table 8. Demonstration ASEAN-Yunnan Model 2004 to 2014 Regional Costs with Free Trade and with No Trade Permitted with Hydro Dams In Yunnan.

New Generation Capacity (MW)	Total Regional Cost for 10 years ($ Billion)	Total Regional Cost for New Transmission ($ Billion)	Total Regional Cost for Fuel ($ Billion)
Free Trade	99.14	1.04	57.71
No Trade	110.70	0.73	72.88

Further detailed results from the Purdue Demonstration ASEAN-Yunnan Long-Term Model are shown in [24] (available at the website of PPDG). The results from the model show that with free trade, Yunnan will expand its hydro by about 1,741 MW (this result is obtained under the assumption that Yunnan will not increase its power export to other regions of China). Considering the big hydro potential in Yunnan, this is not very much because the costly hydro dams and transmission. The total hydro expansion cost is about 22.38 billion without free trade and about 27.01 with free trade.

B. Results from the case when run-of-river projects are constructed in Yunnan

Under this case, the capital cost for hydro projects is about $1,500/kW for other countries while the capital cost in building run-of-river projects in Yunnan is reduced by about 53% ($700/kW is used as the capital cost of run-of-river projects in Yunnan). As a result, hydro power capacity in Yunnan is increased from less than 2,000 MW without free trade to about 10,158 MW with free trade, under the assumption that the run-of-river hydro power plants will produce the same amount of energy as the hydro power plants of big dams. The total transmission cost will be increased to about $2.0846 billion with free trade due to increased power exporting from Yunnan, compared with $0.7353 billion without free trade (about 0.27 billion is added to the internal transmission construction due to run-of-river projects in Yunnan). The results show that fuel cost savings would be $23.9 billion from free trade for the region over 10 years, and the total cost savings would be almost $19.3 billion ($103.8 billion vs 84.5 billion, as seen in Table 9).

The construction of run-of-river hydro power plants is not affected much by the capital cost used for the run-of-river plants. When the capital cost is reduced from $700/kW to about $500/kW, very similar amount of run-of-river capacity is constructed.

More transmission is constructed under the free trade case and the run-of-river hydro power construction in Yunnan. In fact, the model expands the transmission capacity by about 10,000 MW from Yunnan to Laos and Vietnam for exporting power from Yunnan to the ASEAN countries. Most of the power goes to Thailand through Laos. Vietnam also takes a small portion of the hydro power produced in Yunnan.

Table 9. Demonstration ASEAN-Yunnan Model 2004 to 2014 Regional Costs with Free Trade and with No Trade Permitted with Run-of-River Hydro Projects in Yunnan.

New Generation Capacity (MW)	Total Regional Cost for New Generation ($ Billion)	Total Regional Cost for New Transmission ($ Billion)	Total Regional Cost for Fuel ($ Billion)
Free Trade	84.50	2.0845	43.067
No Trade	103.89	0.7353	67.967

C. Comparison between the case with dams and the case with run-of-river

We only compare the case with free trade. Under the free trade scenario, the total cost from the “dams” scheme in Yunnan would be $99.14 billion, and the total cost from the run-of-river scheme in Yunnan would be $84.5 billion for the 10 years. The total cost savings for the regions would then be $14.64 billion over 10 years. The results show that due to the construction of run-of-river hydro power projects in Yunnan, $1.464 billion could be saved for the combined region with free trade. The results are based on the assumption that the run-of-river power plants will produce the same amount of energy as the hydro power plants with dams. This assumption, while may not be completely true, is reasonable because the upper Mekong River has relatively constant flows in a year.

IV. Summary and Future Research

The paper shows that improved energy market integration and encouraging free trading of electricity trade between South China and the ASEAN countries can make significant energy costs savings for the combined region. The issue of construction of run-of-river hydro power plants in Yunnan is clearly to have major consequences to the region and the modeling can quantify how the associated benefits will bring even greater cost savings to this important regional market. Run-of-river hydro power plants will also cause such smaller impact to the ecological system requiring minimum population displacement. Hence, it is suggested that policy makers in China might take a careful look at the run-of-river scheme in developing hydro power plants for Yunnan. Run-of-river schemes could be considered as a top policy priority for energy planners in these partnering nations.

The study is only preliminary and more research is now needed. Future research might include improved project cost estimates, better modeled quantification of energy production potential from regionally specified Yunnan run-of-river hydro power plants in Yunnan, and the associated environmental impact from the specifications.

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