Background Paper 4B

Fostering Energy Market Synergies in the Mekong Subregion and ASEAN

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Fostering Energy Market Synergies in the Mekong Subregion and ASEAN

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The Mekong Subregion, where Cambodia, the Lao People's Democratic Republic (Lao PDR), Myanmar, Thailand, and Viet Nam are located, has great potential for energy cooperation and offers the opportunity to attain energy security, resilience, and low-carbon growth. In recent years, these countries have achieved remarkable progress in economic development. Together with rapid industrial growth and the implementation of rural electrification, electricity demand has increased rapidly. There is often a two-way relationship between the provision of energy services and poverty in Mekong. In many aspects, this relationship is a vicious cycle in which low-income economies which lack access to energy are often trapped in a reinforcing cycle of economic deprivation and the need to improve their living conditions, while using significant amounts of their very limited income on expensive imported energy choices. The link between energy and poverty is also demonstrated by the fact that poor households in rural areas constitute the bulk of an estimated 3 million–5 million people relying on traditional biomass for cooking, most of whom do not have access to grid electricity – particularly in Cambodia, the Lao PDR, and Myanmar. On the other hand, access to modern forms of energy is essential to achieve high levels of human development, generate employment opportunities, and support inclusive growth (Martchamadol and Kumar, 2013). In the next decade, electricity demand in the Mekong Subregion is expected to continue increasing at a high rate due to economic growth. The use of fossil fuels and renewable energy is not only associated with environmental and health impacts, but petroleum consumption and import dependence also greatly impact national budgets, trade balances, and household incomes. The exploitation of clean energy sources and cross-border energy trade are cost-effective options to meet the expected increase in electricity demand, achieve energy security, reduce carbon emissions, and contribute to economic competitiveness. The outlook for the energy system in the Association of Southeast Asian Nations (ASEAN) and the Mekong Subregion will depend on how leaders shape energy policy now to create a better and cleaner energy system. Thus, managing and investing in the energy transition will be key to shifting away from fossil fuel dependence towards more renewables, energy efficiency, a smart grid with the internet of things (IoT), and promising hydrogen fuels.

1. Availability and Use of Energy Resources in the Mekong Subregion

The Mekong Subregion has a vast variety of energy resources, including oil, natural gas, coal, and other renewables – mostly hydropower. Table 1 illustrates the distribution of such resources across the five countries. Thailand, Myanmar, and Viet Nam have extensive gas resources. The Lao PDR and Myanmar also have large hydropower potential. The Mekong River basin has a total catchment area of 795,000 square kilometres (km^2) and estimated potential of 285 terawatt-hours, with exploitable capacity mostly in the Lao PDR and Myanmar. The total exploitable hydropower potential is estimated at about 248,000 megawatts (MW). Less than 25% of the remaining potential is shared among the other three countries. The total installed capacity of hydropower generation in the five Mekong countries is estimated at about 21,035 MW, representing only 8% of the exploitable potential resources (Yu, 2003). Thailand has exploited almost all its hydropower resources.

Table 1: Availability of Energy Resources in the Mekong Subregion

Country	Type of Energy Resources Available		
	Fossil fuel	Renewable – Hydropower (MW)	
		Potential	Installed
Cambodia	Oil and gas	15,000	13
Lao PDR	Coal	18,000	663
Myanmar	Coal (230 t), crude oil (2.7 billion oil barrels), gas (450–560 bcm)	100,000	802
Thailand	Coal, gas	10,000	3,422
Viet Nam	Coal (33,000 t), oil, natural gas	15,000	4,155
Subregion	Total	158,000	9,055
	Total:	**248,000**	**21,035**
	Coal (81,421 Mtoe)		
	Lignite (11,475 Mtoe)		
	Crude oil (1,200 Mtoe)		
	Natural gas (1,645 bcm)		

bcm = billion cubic metres, Lao PDR = Lao People's Democratic Republic, MW = megawatt, Mtoe = million tons of oil equivalent, t = ton.
Source: Compiled from various sources.

The population, installed capacity, energy consumption, and carbon emissions of the Mekong countries varies widely, as shown in Table 2. Thailand is the key energy market in the region, with high installed capacity, per capita energy use, and carbon dioxide (CO_2) emissions. It accounted for more than 50% of total regional energy consumption in 2015. Viet Nam accounts for 27% of total energy demand. The remainder was consumed by Cambodia, the Lao PDR, and Myanmar.

Table 2: Current Status of Energy Use in the Mekong Subregion

Country	**Area** (1,000 km^2)	**Population** (million)	**GDP** ($ billion)	**Installed electricity capacity** (GW)	**Energy use** (TWh)	**Carbon dioxide emissions** (1,000 t CO_2)
Cambodia	181.04	13.97	36.82	0.26	0.98	4,180
Lao PDR	236.80	6.50	13.75	0.67	2.28	1,874
Myanmar	676.58	48.70	91.13	1.56	6.01	8,995
Thailand	513.12	62.80	596.50	24.76	144.08	295,282
Viet Nam	331.69	87.30	262.80	11.65	60.62	150,230

CO_2 = carbon dioxide, GDP = gross domestic product, GW = gigawatt, km^2 = square kilometre, Lao PDR = Lao People's Democratic Republic, t = ton, TWh = terawatt-hour.
Source: Compiled by the author from various sources.

Combined, the Mekong Subregion has insufficient indigenous fossil fuel resources to meet growing demand, and the share of imported fossil fuel is expected to increase, which has important energy security implications. From 1990 to 2015, electricity production in the Mekong Subregion increased at an average annual rate of 8.2%. During this period, growth was fastest in Viet Nam, followed by Cambodia and the Lao PDR. This is around twice the growth rate of the 10 ASEAN Member States (AMS) and three times the world growth rate. The region will see 4% annual growth in energy demand until 2040, amounting to a rise of 50% over 2015 levels (Kimura and Li, 2019). Electricity demand will double from 2010 to 2040 (Yoshikawa and Anbumozhi, 2019). Energy demand and electricity production will rise at the fastest pace in 2035. According to business-as-usual scenarios based on current policies and expected market developments, most demand will be met by fossil fuels such as coal (IEA, 2017). Rising fossil fuel demand from the Mekong region will also result in increased carbon emissions and local air pollution. Energy-related carbon emissions will increase by 61%, reaching 2.2 Gigatons. External costs related to air pollution from the combustion of fossil fuels will increase by 35% from $167 billion in 2014 to $225 billion in 2019 (ACE, 2017). This would equal around 5% of the region's gross domestic product (GDP) in 2040. These energy security and environmental challenges could be addressed by promoting cross-border energy trade, wherein surplus energy from one country is shared with other countries in the Mekong Subregion.

2. Best Energy Mix and Regional Grid Connectivity

A country develops energy infrastructure and decides on its energy mix based on the premise of energy security. However, when demand growth outstrips the capacity to supply the necessary domestic resources or when economically efficient power station development is difficult due to constraints such as high fuel transportation costs and power loss during transmission, importing electricity from neighbouring countries is considered. In light of the above, it may be possible to optimise or improve the efficiency of energy infrastructure investments in terms of supply stability, economic efficiency, and carbon emissions reduction if we consider ways to develop the cross-border infrastructure of power stations and grids on a subregional basis.

The region has several frameworks on grid connectivity. The Greater Mekong Subregion (GMS) Strategic Framework, signed in 1992, was the first effort by the five member countries plus China to formulate and adopt a development planning agreement which defined the vision, goals, and strategic thrust for cross-border infrastructure connectivity. This was complemented by the ASEAN Plan of Action for Energy Cooperation, 1999–2004, which focused on activities such as engaging cross-country energy dialogue, promoting energy security, and creating responsive policies to progressively enhance market reforms. The ASEAN Plan of Action for Energy Cooperation, 2016–2025 outlined the ASEAN Power Grid (APG) and the Trans-ASEAN Gas Pipeline as two of seven key cross-border cooperation programs. While these programs lay the foundation for greater regional energy cooperation to investigate cross-border energy supply options to realise larger energy markets and economies of scale, it remains unclear whether their implementation can help the GMS to achieve the objectives of energy security, affordability, and sustainability.

Defining and integrating the imperatives of energy security, affordability, and sustainability within the context of cross-border infrastructure connectivity, subregional cooperation often remains dynamic and contextual with increasing scope. Depending on the issue to be addressed, as few as three (APERC, 2007) to as many as 372 indicators (Sovacool, 2009) may be examined. In the broader sense, energy security refers to the availability and accessibility of all types of energy resources – both fossil and renewable – within national boundaries that have the potential to replace imported energy (Martchamadol and Kumar, 2013). The estimation of current and future available renewable energy resources, in conjunction with fossil fuels, is necessary to assess the need for cross-border energy connectivity investment in a low-carbon manner. The readiness of interconnected grids to integrate energy procured from renewable sources is an important characteristic that will improve the sustainability of cross-border energy projects. Affordability refers to the economic dimension regarding the price of the energy, which depends on the cost and quality of the interconnected infrastructure. Sustainability is the ability of cross-border infrastructure to efficiently enhance the effective utilisation of low-carbon energy sources such as hydropower. This can also serve as an indicator for technological innovations at the grid level to support renewable energy and policy innovations such as carbon pricing to promote the increased absorption of non-fossil energy resources.

From the perspective of energy sector resilience and quality infrastructure, recognising the limited global reserve of fossil fuel energy and unstable world fuel prices, and meeting the Paris Climate agreement targets, it is essential for the Mekong Subregion to accelerate cross-border connectivity and to promote open trade, facilitation, and cooperation in the energy sector and related industries in the requisite infrastructure.

3. Status of Cross-Border Energy Trade

The Mekong Subregion is a net importer of energy. In 2018, nearly 25% of the region's total primary energy consumption was imported. Thailand remains the largest importer of energy in the region, having to buy nearly 60% of its energy needs. Viet Nam and the Lao PDR import 100% of their transport fuels, such as gasoline (Yoshikawa and Anbumozhi, 2019). Myanmar is the only country in the region to remain a net exporter of energy.

Energy trade within the region started in 1971, when the Lao PDR and Thailand signed a power purchase agreement for importing electricity to the northeastern region of Thailand from Nam Ngum Hydropower Plant in the Lao PDR. Bilateral electricity trade progressively intensified as memoranda of understanding were signed between various governments, including Viet Nam. The existing energy trade flows in the Mekong Subregion are presented in Table 3. The trade is mainly from the Lao PDR to Thailand and Viet Nam, with a smaller amount happening between the Lao PDR and Cambodia.

Table 3: Status of Cross-Border Energy Trade, 2016 (GWh)

Mekong country	Imports	Exports	Total trade	Net imports
Cambodia	1,546	-	1,546	1,546
Lao PDR	1,265	6,944	8,210	−5,679
Myanmar		1,720	1,720	−1,720
Thailand	6,938	1,427	8,366	5,511
Viet Nam	5,599	1,318	6,917	4,281
Total	**15,348**	**9,861**	**26,759**	**-**

GWh = gigawatt-hour, Lao PDR = Lao People's Democratic Republic.
Source: Yoshikawa and Anbumozhi (2019).

Infrastructure connectivity is key for power trade. Cross-border power connections in the Mekong region are mainly via transmission lines of 110 kilovolts (kV) and 230 kV capacity, such as those between Nam Ngum and Xeset hydropower plants in the Lao PDR and Thailand. The first 500 kV cross-border transmission line within the GMS was constructed to connect Nam Theun 2 Hydropower Plant in the Lao PDR and Thailand.

In the Mekong Subregion, major load centres are concentrated in capital cities, except in Viet Nam where Ho Chi Minh City accounted for 40% of energy consumption in 2018. Amongst the Mekong countries, Vientiane is the capital with the highest ratio of energy consumption, at 75%, followed by Phnom Penh (56%), Bangkok (30%), and Hanoi (19%). The design and implementation of several 500 kV transmission lines between Cambodia, Myanmar, the Lao PDR, Thailand, and Viet Nam – connecting major cities – are ongoing

(Table 4). China's Yunnan Province is also connected to the Lao PDR, Myanmar, and Thailand by 115 kV lines.

Table 4: Ongoing Cross-Border Transmission Lines in Mekong Subregion

No.	Location	Interconnection points	Voltage (kV)	Capacity (MW)	Length (km)
1	Myanmar–China (Yunnan)	Shweli 1 HPP–Dehong	220	600	120
2		Dapein 1 HPP–Dehong	500	240	120
3	Lao PDR–Thailand	Nam Theun 2 HPP–Roi Et 2	500	950	304
4		Houay Ho HPP–Ubon 2	230	126	230
5		Theun Hinboun HPP–Thakhek (Lao PDR)–Nakhon 2 (Thailand)	230	434	176
6		Nam Ngum 2–Na Bong (Lao PDR)–Udon 3	230	600	187
7		Hongsa TPP–Nah (Thailand)–Mae Moh 3	500	1,878	325
8		Xayaburi HPP–Thali Kon Kaen 4	500	1,220	390
9		Pakse–Ubon 3	500	400	90
10		Takhek–Nakhon Phanom	115	160	61
11		Nam Leuk HPP–Pakxan–Bueng Kan	115	80	11
12		Phontong–Nong Khai 1	115	160	51
13		Pakbo–Savannakhet–Mukdahan 2	115	80	5
14		Xeset HPP–Sirindhorn HPP–Ubon 1	115	80	61
15	Viet Nam–Cambodia	Chau Doc–Phnom Penh	220	200	111
16	Lao PDR–Viet Nam	Xekaman 3 HPP–Thanh My	220	250	115
17		Xekaman 1 HPP (Hatxan)–Pleiku	220	300	120
18		Xekaman 4 HPP–Ban Soc–Pleiku	500	80	120
19		Nam Mo HPP–Ban Ve	220	120	200
20	Thailand–Cambodia	Aranyaprathet–Banteay Manchey	115	80	40
21	China (Yunnan)–Viet Nam	Xinqiao–Lao Cai	220	300	56
22		Maguan–Ha Giang	220	200	51
23		Maomatiao–Ha Giang	110	115	n/a
24		Hekou–Lao Cai	110	91	20
25	China (Yunnan)–Lao PDR	Mengla–Na Mo	115	35	60
26	China (Guangxi)–Viet Nam	Fangcheng–Mong Cai	110	25	60

HPP = hydropower plant, km = kilometre, kV = kilovolt, Lao PDR = Lao People's Democratic Republic, MW = megawatt, TPP = thermal power plant.
Source: World Bank (2019).

The main catalyst for the cross-border projects is the Electric Power Forum, established in 1995. This intergovernmental institution adopted a two-pronged approach of establishing (i) physical infrastructure, such as transmission lines, to facilitate power dispatch across borders; and (ii) institutional and policy frameworks that augment cross-border power trade. To advance power trade, an international agreement on power trade was signed and a committee for regional power trade coordination was established. The committee meets annually to set the rules governing trade and establishing new infrastructure. The Vientiane Plan of Action is another agreement, which listed about 73 activities that focus on institutional and financial capacity building for enhanced power trade across the Mekong Subregion. The benefits from cross-border integration of the energy sector across the GMS are calculated to total $200 billion or 17% savings from total energy costs over the 20-year period from 2010 to 2030 (ADB, 2008). A 6% reduction in import dependence was also anticipated. In light of the above, it may be possible to optimise or improve the efficiency of energy infrastructure investments in terms of supply stability, economic efficiency, and a reduction in emissions and pollution, if we consider ways of developing the cross-border infrastructure of power stations and grids on a subregional basis.

However, numerous barriers confront cross-border energy infrastructure development. These have been classified as regulatory, technical, and political and environment, which need to be systematically evaluated to assess the full benefits of future cross-border projects. Regulatory barriers include distorted energy prices, such as the existence of pervasive subsidies, which have negative consequences on cross-border energy infrastructure investments. Technical barriers include the grid codes, capacity, and engineering characteristics of transmission lines. Unequal starting points in power purchase agreements hinder the development of cross-border projects. While integrating renewable energy into existing grids brings carbon benefits, large-scale construction of hydropower is found to have a negative impact on the living environment. A more structured methodology is needed to estimate the net costs and optimise the full benefits of cross-border connectivity in the Mekong Subregion.

4. Priorities in Cross-Border Grid Connectivity in the Mekong Subregion

As indicated above, two initiatives are under way for developing power connectivity in the Mekong region. The Asian Development Bank (ADB) initiated the GMS Program in 1992, in which multisectoral partnership was developed in the subregion, including China (Yunnan Province and Guangxi Zhuang Autonomous Region). The program envisions a stepwise process to integrate the current and planned interconnections listed in Table 4. The four steps for integrated cross-border connectivity are as follows:

Step 1: Formulate a power purchase agreement for one-way power sales under which an independent power producer in one GMS country sells power to a utility in a second country, using dedicated transmission lines established.

Step 2: Institute power trade between two GMS countries, initially using spare capacity in dedicated stage 1 transmission lines, and eventually using other third-country transmission facilities.

Step 3: Interconnect all GMS countries with 200–300 kV lines, after introducing centralised operations, with a regional system operator that will facilitate third-party participation in energy trading.

Step 4: Make all the GMS countries accept the legal and regulatory challenges to enable a free and competitive electricity market with independent third-party participation.

Another initiative on cross-border interconnection is the APG, which covers five countries in the lower Mekong River basin. The plan for the APG is to make power grid interconnections on bilateral terms, then gradually expand to a subregional basis, leading to an integrated APG system. As one of the physical energy infrastructure projects in the Master Plan on ASEAN Connectivity, the APG is designed to enhance electricity trade across borders – aiming to meet rising electricity demand and improving access to energy services in the region. As of 2015, six bilateral interconnections had been put in operation, linking Singapore and Peninsular Malaysia; Thailand and Peninsular Malaysia; and connecting to Cambodia, the Lao PDR, and Viet Nam via Thailand. Following 2015, a new initiative was announced by four AMS – the Lao PDR, Thailand, Malaysia, and Singapore – to undertake a detailed project to explore multilateral cross-border power trade from the Lao PDR to Singapore, which could serve as a pathfinder to enhance multilateral electricity trading.

The progress of the APG projects in the Mekong region is presented in Table 5, including seven hydropower projects with 4,152 kilometres (km) of transmission lines, integrating the existing connections, and four new projects having a combined transmission length of 2,469 km.

Table 5: Cross-Border Energy Transmission Connectivity under APG Program

Cross-border connectivity	Existing	Ongoing	Future	Total
Thailand–Lao PDR	3,584	2,469	1,865	7,328
Lao PDR–Viet Nam	248	1,879	NA	538
Thailand–Myanmar	-	290	11,709–14,859	11,709–14,859
Viet Nam–Cambodia	200	-	-	200
Lao PDR–Cambodia	NA	-	-	300
Thailand–Cambodia	120	300	2,200	2,320
Total	**4,152**	**2,469**	**15,774–18,924**	**22,395–25,545**

APG = ASEAN Power Grid, Lao PDR = Lao People's Democratic Republic, NA = not applicable.
Source: ADB (2014); Kutani and Li (2015).

Evaluation studies by these organisations reflect multiple economic benefits of cross-border interconnectivity. In the case of Lao PDR–Thailand connectivity, the benefits are more evident in the Lao PDR. Exports of electricity as a percentage of GDP increased five times from 1.63% in 1994 to 34.2% in 2010. The hydropower plants built to export electricity to Thailand have benefited rural communities in the Lao PDR with electrification. In 1995, only 45% of households nationwide had access to electricity, but this increased to 75% of households in 2005 (ADB, 2008).

5. Low-Carbon Energy Development in the Mekong Subregion

Compared with other countries in the region, Thailand has made impressive progress with low-carbon energy development. Alternative energy sources (solar, wind, biofuel, biogas, and mini-hydropower) account for 12% of Thailand's overall energy use, and the government is targeting an increase to 25% by 2021 (Anbumozhi and Tuan, 2015). The main policy and regulatory framework for reaching this target is the Alternative Energy Development Plan, announced in 2012. The projected quadrupling of installed alternative energy capacity over the period from 2000 up to 2021 is expected to derive from dramatic advances in solar and wind power, a doubling of biomass energy, and a multiple increase in mini-hydropower. The main support for renewable energies in Thailand is the feed-in tariff premium, differentiated according to technology, capacity, and location. Other mechanisms in support of investment in renewable energy in Thailand are financial incentives in the form of grants and low-interest loans, fiscal incentives in the form of exemption from import duties, and personal income tax and corporate income tax provisions.

Viet Nam has renewable energy resources such as hydropower, biomass, wind energy, geothermal energy, and solar energy. So far, these clean energy sources have not been widely used due to a lack of policy initiatives and the absence of a supportive institutional framework. However, Viet Nam has ambitious targets for the development of renewable energy technologies, described in the National Master Plan for Power Development, 2011–2020 with Outlook to 2030 or the Power Development Plan VII. The share of renewable energy in electricity generation is expected to grow from 3.5% in 2010 to 6.5% in 2020, 6.9% in 2025, and 10.7% in 2030. Targets are set for four renewable energy sources: wind, solar, biomass, and small hydropower. Originally, a feed-in tariff for wind power was approved by the Prime Minister's Decision No. 37/2011/QD-TTG in 2011. A fixed price of $0.078 per kilowatt-hour (kWh) is offered for a grid-connected onshore wind project. However, compared with other countries in the region and the world, the support price of wind power in Viet Nam is too low and is not attractive to national and international investors (Anbumozhi and Tuan, 2015). In 2018, the Prime Minister amended Prime Minister's Decision No. 39/2018/QD-TTg (Decision 39), stating that the wind feed-in tariff (excluding value-added tax) would be D1,928 per kWh (equivalent to $0.085 per kWh) for onshore wind power projects and D2,223 per kWh (equivalent to $0.098 per kWh) for offshore wind power projects (Hoang and Mitchell, 2018).

Other supporting mechanisms for grid-connected biomass co-generation and solid waste power projects were also approved by 2014, which regulated a fixed price of $0.058/kWh for biomass co-generation, $0.1005/kWh for incineration technology, and $0.0728/kWh for the burial of solid waste (Anbumozhi and Tuan, 2015). The government has provided many additional incentives to encourage investment in renewable energy, including import duty exemptions, an incentive rate for corporate income, and the exemption or reduction of land use fees/rental.

The Lao PDR's low-carbon energy development strategy, approved in 2011, defined the capacity required to achieve a 30% share of renewable energy in the total energy use in 2025. This is the most ambitious target in the Mekong region. However, large hydro is not included as part of this target – only installed capacity and generation for small hydropower are specified. In 2011, the total installed and operational capacity of the Lao PDR was 2,566 MW for both domestic consumption and export, of which 1,987 MW was used for the export market in Thailand and Viet Nam (ADB, 2013). The installed capacity of renewable energy sources was around 28 MW in 2015. In 2016, the Lao PDR added 599 MW of installed hydropower capacity, bringing its total installed capacity to 4,168 MW (International Hydropower Association, 2016).

Myanmar has significant renewable energy potential, but little of the country's solar, wind, and biomass energy potential had been exploited by 2015. The focus had been on hydropower investments. The total installed renewable capacity was about 150 MW in 2015. The Ministry of Energy is targeting an additional 600 MW of renewable energy, which represents 17% of the current installed capacity in 2017. At present, there are no specific renewable energy incentives. However, the government announced a new foreign investment law in 2017 which offers general foreign investment incentives, including, for example, tax exemptions, income tax relief, and targeted customs duties for the importation of machinery and equipment, which could be applied to renewable energy promotion (US Commercial Service, 2019).

Compared with other countries, in 2015, the development of renewable energy in Cambodia is still limited to a demonstration project. Financial incentives for renewable energy are not yet in place. Some investment incentives under the Investment Law, 1994, are available, such as tax exemptions and import duty exemptions. Cambodia does not have a renewable energy development target, but this is linked to the electrification program to achieve full electrification of villages by 2020 and 70% household electrification by 2030. Some of the main components of this program are solar, wind, mini and micro hydro, biogas, and biomass. Financial resources for the development of renewable energy are mainly from foreign countries, in the form of donations or grants. Access to finance is considered one of the main barriers to the implementation of low-carbon energy development in Cambodia (ACE, 2017).

In summary, Thailand has achieved early success in low-carbon energy system development, mainly by relying on important support measures that include subsidies and feed-in tariffs. However, this measure of success is based on renewable energy capacity expansion and does not necessarily capture other indicators such as energy security, innovation, job creation, and environmental impact mitigation. Moreover, an integrated strategy that sets clean energy targets, priorities for renewable energy technologies, and skills development is still lacking. In the case of Thailand, these additional considerations could be used as lessons learned, to be shared and to help advance the development and use of low-carbon energy development throughout the region.

6. Factors Constraining Full Integration of Renewables in Cross-Border Grid Connectivity

Achieving energy security and affordability, and meeting intended nationally determined contribution targets, remain the objective of future energy development in Mekong countries. More investment in cross-border interconnectivity means reduced emissions from the energy sector and addressing growing concerns in the heterogeneity of global commitments. However, there are several barriers to the operationalisation of this connectivity. The operation of interconnecting transmission lines may be roughly divided into passive and active operations. In passive operations, interconnecting transmission lines are used only when an excess or shortage in the power supply ability emerges for some reason on the premise that each country maintains the supply and demand balance based on the concept of energy security. In active operations, interconnecting transmission lines are used for maximising the economic benefits of facility operations by balancing the power supply capacity of each country and the demand in the subregion. Active operation may be what the GMS is aiming for, as demand for power is increasing rapidly in every country and an integrated energy market is desired.

As cross-border transmission progresses and the use of interconnections expands, the benefits for the entire system in the region will increase. Therefore, it is necessary to carry out structural formulation and system design for the management and operation of interconnections while the Mekong countries are still making considerations and deliberations. Additionally, to accelerate the interconnection projects in progress in the GMS and materialise the benefits of electric power interchange, some conditions need to be satisfied. In this regard, the following region-wide actions are required: (i) overall optimisation and adjustment of power infrastructure development plans that fully integrate renewables, (ii) the harmonisation of technical standards and energy pricing mechanisms, and (iii) the establishment and authorisation of regulatory and consultative bodies to support Mekong-wide energy market integration.

The Mekong region has generally abundant potential for renewable energy development and, once harnessed, this potential could be integrated into grid networks. However, cooperation and harmonisation are very limited. There is room to increase cooperation and harmonisation for individual countries and the region as a whole. The expansion of renewables such as wind, solar, biomass, and geothermal would increase diversity, assuming that they do not completely displace fossil fuel sources. However, an increased share of renewable energy in power generation at the country level may have alternative impacts. For example, it could result in a higher cost of electricity or less jobs. The impacts of expanded renewable energy uptake in place of coal are not very clear from a net cost–benefit perspective.

There are few initiatives on regional cooperation, apart from joint studies on the renewable energy support mechanism for bankable projects, off-grid rural electrification approaches, and renewable energy technical standards. To help shape influential renewable energy policies and increase the deployment of cross-border transmission lines, several feasibility studies have been undertaken by international organizations on topics such as (i) CO_2 reduction – a greater role for renewable energy in the ASEAN power generation sector; and (ii) the impacts of renewable energy integration through grid connection. Since countries in the region are at different levels of development, interregional cooperation on regulatory standards – and exchange of information and lessons learned on pilot and demonstration projects, best practices, and benchmarking – would facilitate rapid progress. Cambodia, the Lao PDR, and Myanmar have the opportunity to benefit from other experiences such as those of Thailand, Malaysia, and Viet Nam in implementing successful policy reforms through interregional cooperation. Energy policy and planning in the region has been developed individually, as countries are at different stages of development. That said, the governments require capacity building to define the necessary policies and redefine the planning process under the agreed framework of the ASEAN Plan of Action for Energy Cooperation, 2016–2025.

7. Managing the Energy Transition in Mekong in the Context of ASEAN Energy Cooperation

The world is undergoing an energy transformation from a system based on fossil fuels to a system based on cleaner energy use, including renewable and cleaner use of fossil fuels, to reduce global greenhouse gas (GHG) emissions and avoid the most serious impacts of climate change. Addressing the energy transition towards a cleaner energy system has been a common goal, as reflected in the Paris Climate Agreement, where global leaders agreed to set a goal of limiting global warming to well below 2°C compared with pre-industrial levels.

Although the common goal has been reached, policy measures and actions undertaken have varied from country to country – reflecting different socioeconomic, political, and geographical contexts. The energy transition is an economic problem, since the present financial system tends to prioritise immediate profit, discounting medium- and long-term advantages. Therefore, new and clean technology seems more expensive than the conventional fossil fuel-based energy system. So, we have a policy problem in the sense that we need to allocate economic resources for the transition to ensure equitable and affordable access to energy for everyone.

According to the *Energy Outlook* of the Economic Research Institute for ASEAN and East Asia (ERIA), demand for fossil fuels (oil, coal, and natural gas) in the ASEAN region will almost triple from 507 million tons of oil equivalent (Mtoe) in 2015 to 1,393 Mtoe in 2040 under the business-as-usual scenario (Kimura and Phoumin, 2019). This demand growth will be driven mainly by the objectives of ensuring energy security, fuel supply stability, and affordability. Even under the advanced policy scenario, assuming more aggressive energy efficiency and higher penetration of non-fossil fuels, the fossil fuel demand in 2040 is projected to be 1,027 Mtoe, double the 2015 level. Notwithstanding ongoing efforts in the East Asia Summit[37] region to promote energy efficiency and renewable energy sources, fossil fuels will play a crucial role in the energy mix of the ASEAN region. Managing the energy transition in ASEAN will need to include the presence of fossil fuels (coal, oil, and natural gas) in the short and medium term of transition. What matters is how to explore the way to use fossil fuel in an environmentally sustainable manner to act as a bridge to a carbon-free energy future, rather than simply ruling out them completely. For the successful implementation of the energy transition and climate change policy objectives, policymakers will need to balance other equally important policy objectives – energy security, energy access, and affordability. For instance, policies that ban public financing on clean coal technology (CCT) could be counterproductive in terms of climate mitigation since lack of finance for highly efficient but more expensive CCT would simply result in the deployment of cheaper and less efficient technologies such as critical or subcritical technology and more CO_2 emissions.

The energy transition and its shift towards a cleaner energy system will have fundamental impacts for ASEAN and the global economy. The pace at which countries have adopted low-carbon policies has resulted in drastic changes in the cost of the energy system. One of the greatest challenges that the energy transition presents is the cost and associated know-how technologies and infrastructure of adopting and integrating a higher share of renewables into the energy system. Another equally important issue is the changing geopolitical landscape, where fossil fuel producing countries will need to move at a similar pace to adopt a new, diversified, economic model to cope with change. It is important to note that the shift in and pace of the energy transition will involve costs and investment in all energy-related infrastructure, and it will hugely affect the affordability of energy. Bridging the gap from the current energy system to a cleaner energy system will need to consider the role of cleaner use of fossil fuels, and innovative technologies that can reduce CO_2 and GHG emissions. Therefore, urgent steps need to be taken to decarbonise the energy sector through pathways to a low-carbon economy – requiring rapid deployment of the clean use of fossil fuel technologies, renewable energy development, and a doubling of energy efficiency – given that the energy sector accounts for two-thirds of global GHG emissions.

7.1. Investment Outlook and Energy Transition

The rapid projected increase in energy demand in ASEAN will require coordinated and appropriate energy supply infrastructure and investments to ensure the region's energy sustainability, development, and environment. Investments in some new and renewable energy, and clean technologies, still face unstable and costly energy supply. Thus, ASEAN leaders will need to promote energy policy targets and clean technology penetration in the

[37] The East Asia Summit has 18 members – the 10 ASEAN countries (Brunei Darussalam, Cambodia, Indonesia, the Lao PDR, Malaysia, Myanmar, the Philippines, Singapore, Thailand, and Viet Nam) along with Australia, China, India, Japan, New Zealand, the Republic of Korea, the United States, and Russia.

energy system, perhaps learning from well-established European Union (EU) infrastructure for the low-carbon economy. Investments in low-carbon technologies and renewables are important to manage the energy transition towards cleaner energy use and addressing critical environmental challenges. While the Organisation for Economic Co-operation and Development (OECD) will likely oppose financing for coal-fired power plants, ASEAN is installing more coal-fired power plants to meet the increasing energy demand to fulfil energy affordability and accessibility. Therefore, coal use in ASEAN's energy transition should be more environmentally friendly – using the best available technology to reduce pollutants and emissions – while gradually increasing the penetration of renewables. The EU could assist ASEAN in huge areas of cooperation towards a cleaner and lower carbon economy through the transfer of technologies and investments.

The world's cumulative demand for energy infrastructure investment is projected to be $60 trillion from 2014 to 2040 (IEA, 2017) or $2.7 trillion per year. For Southeast Asia, about $1.7 trillion of cumulative investment in energy supply infrastructure to 2035 is required, with 60% in the power sector (IEA, 2013). While IEA (2013) predicted the investment needed for energy infrastructure, the current investment deficit in the energy sector – encompassing the extraction, generation, and distribution of traditional fossil fuels as well as renewable sources – is yet to be solved. Hence, funding the gap for the required energy investment is a key issue for ASEAN countries. Energy infrastructure and clean technologies are costly, requiring large investments, and various stakeholders are involved. Such stakeholders discuss whether investments in clean energy-related infrastructure projects are 'bankable', 'financeable', and 'investable', as each stakeholder looks at projects from a different perspective in terms of the return on their investment. For example, investors such as banks, governments, and developers differ on the risk/return profile of a given project. Generally, a 'bankable' project is a project that a bank is willing to finance. However, bank financing is only one component of the capital investment structure, and most private investors seek much higher returns on their investment. Therefore, the terms 'financeable' and 'investable' are used if a green project appears to be a strong project, with stable revenue, a suite of credit guarantees, political risk insurance, and expected single-digit or mid-teen returns. This is far below the hurdle rate for risk-adjusted equity investments for frontier market projects. In addition, green projects usually face many risks unless they have government guarantees.

Finance for energy infrastructure projects requires a mix of investors (developer and/or private equity firms or corporate investors) and debt providers (commercial banks or public sector funding). Within a particular capital structure, for example, a project may receive equity investment from a private equity firm or group of investors, with wrap-up insurance from development finance institutions such as the Multilateral Investment Guarantee Agency, Overseas Private Investment Corporation, International Finance Corporation, World Bank, and ADB; or pledged debt from a bank. Institutional investors may participate either directly or through a private equity allocation or the purchase of other financing options such as government infrastructure bonds. Most infrastructure investment is financed by the public sector, public–private partnerships (PPPs), or external official development assistance for emerging AMS. For PPPs, the AMS have different levels of infrastructure policies, financing methods, and financial capacity. PPPs have been significantly developed and utilised in Malaysia, Indonesia, Thailand, the Philippines, and Singapore. Whilst Cambodia and Viet Nam are yet to formalise the PPP modality, private sector participation has become increasingly important in infrastructure development. The Lao PDR and Myanmar have potential for renewable energy development, although they face multiple challenges – from lack of fiscal sources to fiscal sustainability. PPPs still play a less significant role in Brunei Darussalam, which has abundant public financial resources to build infrastructure.

7.2. Making Better Use of Coal in the Energy Transition

Coal, as the most abundant and reliable energy resource, will continue to be the dominant energy source in power generation to meet fast-growing electricity demand in the ASEAN region and emerging economies around the world. However, coal use has been drastically reduced in the OECD countries and developed economies because of the increased use of natural gas, renewables, and advanced technologies. ASEAN's share of coal use in power generation was 32% in 2015 and it is projected to increase to 42% by 2040, while the share of gas was 42% in 2015 and it is expected to drop to 37% in 2040 (Kimura and Phoumin, 2019). The increased use of coal for power generation in ASEAN countries will lead to widespread construction of coal-fired power plants, which will result in increased GHG and CO_2 emissions if the best available CCTs are not used. Meanwhile, the climate narrative at the United Nations Climate Change Conference (COP 25) in 2019 and the 2020 COP will likely enforce the ban on public coal financing, not limited to the OECD but throughout the world, utilising financial instruments to influence multilateral development banks and all OECD members not to invest in the use of coal. The efforts of developed economies to ban coal financing have merit, but the unintended impacts of such policies need to be understood. The technological development of CCTs has been achieved quickly in developed nations, while the transfer and diffusion of technological know-how of the CCTs to the developing world has been slow. Actions taken to abate CO_2 and GHG emissions have gained momentum in developed economies, especially OECD countries, while developing nations cannot afford the available technologies to reduce CO_2 and GHG emissions. Further, China is leading the financing of coal-fired power plants in developing economies, as it is not bound to OECD rules and obligations to ban coal financing.

If not paired with more sustainable energy development, increasing coal use in emerging Asia will have negative effects on the region's environmental security. With the projected increase in coal-fired generation capacity, both local pollutants – CO_2 and GHG emissions – will become major issues in the future. Based on the global GHG emissions data (US Environmental Protection Agency, 2020), emissions from fossil fuel combustion and industrial processes contributed about 78% of the GHG emissions increase from 1970 to 2011. The largest emitters of global GHG emissions are China, the United States, India, and Russia (Frohlich and Blossom, 2019). With substantial new generation capacity required to generate power, unabated coal-fired power generation plants are increasingly being constructed in developing Asia. These trends bring forward the urgent need to address the environmental sustainability of powering emerging Asia's economic development and the need for the deployment of CCT.

7.3. How to Scale Up the Penetration of Renewables

While economic growth has increased the affordability of renewable energies around the world, many emerging economies are still at the early stage of development. In AMS that can afford more investment in renewable technologies, an important concern is the need for electricity storage and smart grids to support higher renewable energy penetration levels in the electricity sector. Smart grid technologies already make significant contributions to electricity grids in some developed countries of the OECD. However, these technologies are undergoing continual refinements and improvements, so they are vulnerable to potential technical and nontechnical risks. Renewable energy growth will thus be constrained by infrastructure development as well as by the evolution of technology. This includes capacities for assessing and predicting the availability of renewable energy sources. These capacities offer additional benefits, notably the promise of higher reliability and overall electricity system efficiency.

As a climate narrative, renewable energy provides a bright prospect for the world's energy sector. AMS will have to follow the worldwide trends and expand their renewable energy industries. Due to technological advances, the greatest growth potential of renewable energies will come from wind, solar, and biofuel power, which will be competitive with traditional fossil fuels. Amongst the AMS, there is ample scope for growth in hydroelectricity, particularly in less developed economies such as Cambodia, Myanmar, and the Lao PDR. In several AMS, there is potential for growth in geothermal energy. Therefore, the largest reduction in CO_2 emissions is expected in the power sector, by introducing renewable energy as much as possible. To achieve high penetration of renewables in the power system, huge investment is needed in power system integration that enables coordination of the interplay between distributed generation (wind power plants, mega-solar photovoltaic plants, and rooftop solar photovoltaic systems on buildings); market systems; demand response technologies; and information technology (data acquisition and communication). Such coordinated power system integration, using IoT, is known as a smart grid system. ASEAN can learn lessons from the EU, which has achieved high penetration of renewables using IoT or smart grid systems – involving a complex arrangement of infrastructure whose functions depend on many interconnected elements. Thus, investment in smart grid system components will have huge potential to fulfil future electrical system demand.

8. Potential of New Type of Clean Energy Source – Hydrogen

Hydrogen is the most abundant element in the universe, and it has the potential to fuel the economy while emitting few or no emissions. Hydrogen can be used as clean energy for vehicles, heating, electricity generation, industrial processes, and energy storage.

The EU's ambition to make Europe the first climate-neutral continent in the world by 2050 will involve a significant role for hydrogen fuel, as an enabler, to achieve carbon neutrality. Hydrogen is high on the EU's agenda, as there is overwhelming agreement amongst countries regarding the importance of hydrogen in a carbon-neutral Europe (McKenna, 2020). In early 2019, the EU launched the Innovation Fund, which is a promising tool to support hydrogen applications in hard-to-abate sectors such as steel manufacturing. For many years, the focus has been on power generation and how to decarbonise it, but EU policy is now examining sectors that are more difficult to decarbonise. There is a big focus on steel, but the EU is also looking at refineries, the chemical sector, and transport, including heavy-duty and maritime transport. Europe's focus is on accelerating the production of green hydrogen from renewable sources, but there is still a long way to go and most likely this will not happen at scale until 2030. In the meantime, it will have to rely on large-scale conventional production methods combined with carbon capture technology – otherwise known as 'blue' hydrogen.

ERIA research on hydrogen energy has identified significant potential hydrogen energy supply and demand in the East Asia Summit region. An ERIA study (Kimura and Li, 2019) projected growth in hydrogen adaptation and usage in all sectors by 2040, with the cost of hydrogen reducing from \$0.90/Nm^3 in Japan in 2018 to \$0.30–\$0.40/Nm^3 in 2040, which is a competitive target price for gasoline. China is one of the biggest potential producers and consumers of hydrogen energy. It aims to get 1 million fuel-cell vehicles on its roads by 2029, and will have invested more than \$17 billion in hydrogen by 2023. Japan is promoting the global adoption of hydrogen for vehicles, power plants, and other potential uses. The use of hydrogen is expanding in the transport sector and its adoption is gaining momentum. For example, in 2020, Tokyo Metropolitan Government will increase the number of hydrogen buses in its fleet to 100 and Sarawak Local Government will start to operate hydrogen buses.

While countries around the globe, especially the OECD countries and China, try to promote the introduction of hydrogen fuels, there are various cost and institutional barriers. There are two major barriers to developing green or clean hydrogen energy. First, there is a lack of comprehensive and valid feasibility studies on potential renewable or clean energy to hydrogen projects, as well as the energy infrastructure network for transportation and distribution. Second, there are institutional and regulatory barriers to enabling hydrogen projects. For example, the current regulations of power grid companies have no capacity to transmit the curtailed renewables or integrate energy from nuclear and hydrogen production facilities to meet market demand. They do not have incentives to build dedicated new lines for such purposes. Further, current power sector regulations do not allow on-site production of hydrogen at renewable power stations, using curtailed electricity.

9. Conclusions

The benefits of subregional cooperation amongst the Mekong countries on energy security, affordability, and sustainability are high. However, countries will need to address many of the technical and regulatory barriers to achieve the multiple benefits of interconnections. What will determine the realisation of future cross-border energy connectivity are not only technical limitations, but also political and regulator limitations. Mekong countries are developing their national power development plans, low-carbon implementation frameworks, and priority actions for the Sustainable Development Goals. However, these plans are usually initiated at bilateral or national level and need more subregional focus to better capture new opportunities with cross-border energy infrastructure development. Therefore, while countries develop their own energy strategies, they should work together to formulate subregional targets within their own energy and power development strategies for operationalising cross-border connectivity. This would allow for enhancing energy security and reduced emissions, as determined by several completed studies. The social benefits of such an approach are clear in terms of employment and local development. Nevertheless, the following key policy options are recommended to realise the planned cross-border interconnections:

- Conduct an overall assessment, optimisation, and adjustment of planned cross-border power connectivity plans to provide detailed information for public and private decision makers about the quantity, quality, and location of APG and GMS master plan projects, technical standards, and institutional capacities.
- Develop a comprehensive renewable energy investment roadmap as a strategy to show bold leadership in removing the barriers to integration and to make new investments more cost-effective at the grid level through regulations, incentives, and capacity building for taking credit risks.
- Earmark financial resources for power market integration, by expanding the ASEAN Infrastructure Fund to drive private investments with clear policy signals.

The emerging digital and industry 4.0 revolution is also set to transform energy demand and supply in the Mekong Subregion. The adoption of smart transport, housing, and manufacturing on a large scale will have a profound impact on both energy demand and the optimisation of energy supply at the national level. A sound policy and market design will be critical in steering a digitally enhanced energy system along more efficient, secure, and stable grid connectivity across the borders.

Mekong subregional cooperation should also be viewed in the context of ASEAN's overall economic, social, and political dynamics, which have made the region one of the fasting growth regions. However, ASEAN also faces the challenges of growing energy demand, energy security, and energy affordability to steer such growth. While the OECD has achieved a rapid reduction in GHGs in response to the climate commitment of COP 21, ASEAN seems to be struggling to achieve a balance between economic growth, energy affordability, and availability. Much of the future energy mix of emerging AMS will rely on coal use for power generation. Many AMS are locked into coal use for many years, as the contracts of coal-fired power plants are for 20–35 years. Thus, ignoring coal use in ASEAN means ignoring the reality of and emissions from coal use. Treating coal use as part of the energy transition in ASEAN is essential to address energy affordability and climate change impacts. The deployment of CCT is urgent in the ASEAN region. Although ASEAN energy targets include more renewables, they remain expensive in terms of system costs. The inability of traditional grids to achieve higher penetration of renewables is another constraint. Smart grids using IoT will be a new green investment infrastructure to allow more penetration of renewables, but they need significant investment such as hard grids, applications, data management, and human resources. Hydrogen fuel will be the next clean energy source due to its versatility for use in many sectors. The promotion and adoption of hydrogen fuel will be key in moving towards clean energy. The EU and developed economies are leading hydrogen research and development. ASEAN will need to catch up, learn, and adopt the application and uses of hydrogen in the economy.

Moreover, in moving towards a clean energy future, ASEAN needs to deal with the current and future new generation capacity of coal to generate power. Coal-fired power generation plants are increasingly being constructed in developing Asia. This trend underlines the urgent need to address the environmental sustainability of powering emerging Asia's economic development and the need for the deployment of CCT.

- The current climate narrative and policy approach of banning coal use should be reviewed to assist emerging Asia to afford CCTs, provided that less costly alternative energy options are available for emerging Asia in the medium term to meet energy demand. Treating CCT as a technology solution in the energy transition will be a win–win solution for a climate-friendly world that is reflective of Asia's need for energy accessibility and affordability.

- Emerging Asia will rely on the CCTs available in the market at an affordable price. The up-front costs of such ultra-supercritical (USC) technology or advanced ultra-supercritical (A-USC) technologies are higher than those of supercritical and subcritical technologies. Thus, it is necessary to lower the up-front cost of A-USC or USC through policies such as attractive financial/loan schemes for USC technologies, or a strong political institution to deliver public financing for CCTs to emerging Asia.
- A policy framework should clearly state the corporate social responsibilities of developed and developing economies, by highlighting the near- and long-term policy measures for the coal industry and coal-fired power generation, with the acceleration of research and development on the commercialisation of carbon capture sequestration, utilisation, and storage. Business models will need to be developed around carbon capture sequestration, utilisation, and storage.
- Public consultations or local participation are needed regarding the potential impacts of the selected coal technologies/CCTs. However, for emerging Asia, the governments may not emphasise such local participation. Thus, an active local organisation is needed to disseminate information on the potential harm resulting from less-efficient coal-fired power plants.

- China, the leading public financier of coal-fired power plants in Asia, will need to embed environmental standards in its funding mechanism to ensure that the deployment of coal-fired power plants uses at least USC technologies in emerging Asia.

International assistance and cooperation will be crucial to move ASEAN to a high level of renewable energies through smart grid investment and cooperation. Such investment areas include the following:

- Investment in 'hard' infrastructure – in-country physical grid components; APG connectivity; the power generation, transmission, and distribution network; and energy storage facilities – to balance load fluctuations caused by higher renewable energy penetration.
- Investment in telecommunications services that monitor, protect, and control the grid – wide area networks, field area networks, home area networks, and local area networks.
- Investment in data management, which ensures proper data mining and utilisation, to facilitate smart grid applications.
- Investment in tools and software technologies that use and process information collected from the grid to monitor, protect, and control the hard infrastructure layer and reinforce the grid to allow the integration of renewable energy.

Hydrogen energy-related industries will be a huge investment in the future. It is essential to consider the clear policy road map of hydrogen adaptation and usage in all sectors. Below are key policy directions for investments in hydrogen:

- There is huge potential for investments in hydrogen production from renewables and nuclear energy. Curtailed electricity from renewable energies is suitable for hydrogen production, but clear policies and regulations are needed to promote such hydrogen production.
- For hydrogen vehicles to be widely adopted, hydrogen refuelling stations and hydrogen transportation and storage facilities need to be developed.
- Public awareness and willingness to pay, together with public financing for the hydrogen production and supply chain, are key to promote investment.
- Governments need to establish targets for hydrogen penetration/uses in all sectors. Energy policy and targets to promote hydrogen uses will encourage investment in supply chains.

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