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Understanding Quality Energy-Related Infrastructure Development in the Mekong Subregion: Key Drivers and Policy Implications

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Abstract: *Many players have supported infrastructure development in the Mekong Subregion, bridging the missing links in Southeast Asia. While the influx of energy-related infrastructure development investments to the region has improved the livelihoods of millions of people on the one hand, it has brought about a myriad of challenges to the wider region in guiding investments for quality infrastructure and for promoting a low-carbon economy, and energy access and affordability, on the other hand. Besides reviewing key regional initiatives for infrastructure investment and development, this paper examines energy demand and supply, and forecasts energy consumption in the subregion during 2017–2050 using energy modelling scenario analysis. The study found that to satisfy growing energy demand in the subregion, huge power generation infrastructure investment, estimated at around $190 billion–$220 billion, is necessary between 2017 and 2050 and that such an investment will need to be guided by appropriate policy. We argue that without redesigning energy policy towards high-quality energy infrastructure, it is very likely that the increasing use of coal upon which the region greatly depends will lead to the widespread construction of coal-fired power plants, which could result in increased greenhouse gas and carbon dioxide emissions.*

Keywords: connectivity; energy infrastructure; fossil fuels; emissions; Mekong Subregion

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1. Introduction

The Mekong Subregion is linked by common energy challenges. There are challenges in maintaining economic growth and ensuring energy security, while curbing climate change and reducing air pollution. At the intersection of these challenges is the corresponding need to rapidly develop and deploy energy efficiency, low-emissions coal technology, and double the share of renewables in the energy mix towards more inclusive and sustainable growth, as the region's energy demand is expected to rise significantly over the next 30 years (Han, 2020c). Such an increase is bringing both opportunities and challenges, including climate change, which is a result of fossil fuels. Despite significant progress in recent decades in terms of energy poverty alleviation, countries such as Cambodia and Myanmar are still struggling to provide energy access to their rural populations.

The coronavirus disease (COVID-19) pandemic is another major challenge of our time. It has caused a global economic downturn, with economic output set to contract by 2.5% in 2020. This economic impact has also brought about low energy demand in all sectors. As a result, daily global emission levels fell by 17% in the first quarter of 2020 (Han, 2020a). However, as governments begin lifting restrictions and business activities resume, so too will the demand for energy. Economic recovery could see levels of carbon dioxide (CO_2) emissions bounce back very quickly. Indeed, global data from late May 2020 show record levels of CO_2 as countries started reopening their economies (2° Institute, 2020). The post-COVID-19 economic recovery will drive increased energy demand, which emphasises the need to secure investment to fill infrastructure gaps.

Quality infrastructure, connectivity, and innovation are considered key for the region to ensure prosperity and sustainable development. In fact, fast connectivity – along with high-quality infrastructure and human resources development in the Southeast Asian region – has already resulted in opportunities for growth. These developments have also lifted living standards through income generation and employment opportunities. They have enabled the region to participate in the production network at different degrees and made it ready to benefit from the global value chain in the near future as improved connectivity attracts more investment, cuts logistics costs, and creates synergies and location advantages (Han, 2018). The region is arguably fortunate to have different stakeholders supporting infrastructure improvement that has bridged the missing links in Southeast Asia. However, the influx of investment, particularly in energy infrastructure development, has raised questions about both sustainability and quality, as well as the identification of partners the region should prioritise working with to promote long-term development sustainability, quality, and innovation in the Mekong Subregion. This chapter aims to review and analyse major initiatives that drive energy-related infrastructure development in the subregion; conducts energy modelling and estimation for energy demand and supply in the subregion during 2017–2050; and, from there, draws key policy implications that guide high-quality, energy-related infrastructure development.

The chapter comprises seven sections. The second section discusses the study's approaches. The third section reviews regional platforms and initiatives for infrastructure development related to the Mekong Subregion by engaging relevant literature. The fourth section examines economic impacts brought by connectivity. The region's energy landscape, the required investment to meet the rising energy demand in the region for the foreseeable future, and the region's energy transition are discussed in the fifth and sixth sections. The final section concludes with policy implications.

2. The Study's Approach

This study employs several approaches to gathering data and information. Data on economic investment, in particular energy for the Mekong Subregion, are available in different forms and for time periods. The study relies on several past studies conducted by the Economic Research Institute for ASEAN and East Asia (ERIA) for the economic impacts brought by infrastructure connectivity in the Mekong Subregion. For project infrastructure investment, the study uses data and information from past projects and studies conducted by the Asian Development Bank (ADB). For the energy data and analysis, we conducted our own energy modelling and estimation for energy demand and supply for the Mekong Subregion. We also reviewed key regional initiatives for infrastructure investment and development platforms, such as quality infrastructure initiated by Japan at the G20 in Osaka; China's Belt and Road Initiative; the United States (US) Blue Dot Network (BDN); the Free and Open Indo-Pacific (FOIP); and other subregional initiatives, such as the Mekong River Commission, Lancang–Mekong Cooperation, and Mekong–Japan Cooperation.

Our analysis of the economic impacts brought by Mekong Subregion connectivity involves the quantitative assessment of existing and proposed infrastructure development up to 2030. The ERIA study on economic impact assessment employed a Geographical Simulation Model (GSM), which was developed to track the progress on quality infrastructure development in the Association of Southeast Asian Nations (ASEAN) and East Asia. Jointly developed by the ERIA and the Institute of Developing Economies in 2007, the model calculates the proposed infrastructure-related projects for connectivity and innovation and includes a sophisticated level of information on infrastructure development status to facilitate any assessment.

For energy demand and supply in the Mekong Subregion, we employ energy modelling using the Long-Range Energy Alternative Planning System (LEAP) software, an accounting system used to develop projections of energy balance tables based on final energy consumption and energy input and output in the transformation sector. Final energy consumption is forecast using energy demand equations by energy and sector and future macroeconomic assumptions. For consistency, the historical energy data in the Mekong Subregion used in this analysis came from the energy balances of the International Energy Agency (IEA) for the Organisation for Economic Co-operation and Development (OECD) and non-OECD countries (IEA, 2019). Energy demand and supply has two scenarios: the business-as-usual (BAU) scenario, reflecting each country's current goals, action plans, and policies; and the alternative policy scenario (APS), which includes additional goals, action plans, and policies that countries could achieve with their best efforts given energy policy reforms and technological development. The APS consists of assumptions such as more efficient final energy consumption, more efficient thermal power generation, and higher consumption of new and renewable energy and biofuels.

The study also quantifies the required investment for power generation demand from 2017 to 2050, using the following formula:

$$Investment(i) = GenCapacity(i) x \ Unit \ Cost \text{ (\$/GW)}$$

$$GenCapacity\ (i) = \frac{GWh(i)}{[24\ hours\ x\ 365\ days\ x\ CapF(i)]}$$

where *(i)* is the fuel type, such as coal, gas, hydropower, and renewables; *investment (i)* is the required investment amount of fuel type *(i)*; *GenCapacity (i)* is the generation capacity of fuel type *(i)* in gigawatts; and *CapF(i)* is the capacity factor of fuel type *(i)*.

The study does not consider other required investments in the power grid or connectivity costs. It only estimates the required generation to meet the growing demand from 2017 to 2050.

3. Review on Regional Initiatives for Infrastructure Development

3.1. Initiatives for Quality Infrastructure

The region is arguably very fortunate to have different stakeholders supporting infrastructure improvement in a manner that bridges the missing links in the wider ASEAN region. But quality is far more critical than quantity if the region is to develop sustainably. The region and particularly ASEAN, therefore, should focus on key development partners that promote long-term development sustainability, especially those that promote quality infrastructure, build responsible human resources, and bring new knowledge and innovation to the region. Some of the key players driving quality infrastructure in Southeast Asia are briefly discussed below.

3.1.1. G20 Principles for Quality Infrastructure Investment

Japan has been pioneering and promoting quality infrastructure for many years to empower Asia as a growth centre to drive the global economy. Most importantly, at the G20 in Osaka in June 2019, Japan successfully launched an initiative, known as the G20 Principles for Quality Infrastructure Investment, as a key to promoting investment for sustainable development. According to the Ministry of Finance, Japan (2019), the principles took into account many aspects of sustainability to ensure that quality infrastructure is in harmony with local environments, communities, and people's livelihoods through generating local employment and facilitating technology transfer. So far, Japan has committed $110 billion for quality infrastructure in Asia from 2015 to 2020 (Han, 2020b). Such a commitment will accelerate financial resource mobilisation into the region from private companies around the globe. This is in line with Japan's global commitment to promote high-quality infrastructure investment to address sustainable economic growth and reduce poverty and disparity.

Japan's promotion of quality infrastructure in Southeast Asia can be seen in the country's efforts to enhance ASEAN's connectivity through core land and maritime corridors and soft infrastructure development. The land corridors are high-quality hard infrastructure developments. They connect the South China Sea and the Indian Ocean; develop the Southern Economic Corridor that connects Ho Chi Minh City, Phnom Penh, Bangkok, and Dawei; and establish the East–West Economic Corridor (EWEC) that extends from Da Nang to Mawlamyaing in Myanmar as a trading centre and seaport, connecting Southeast Asia to India and beyond. Another hard infrastructure development is the Maritime Economic Corridor, which consolidates connectivity through the development of port and port-associated industries as well as energy and information and communication technology networks, in major cities. This allows the Mekong Subregion to connect to Brunei Darussalam, Indonesia, Malaysia, the Philippines, and Singapore, thus enhancing connectivity across ASEAN.

3.1.2. Belt and Road Initiative

In recent years, China has also invested enormously in Asian infrastructure through its Belt and Road Initiative (BRI). The BRI is a major Chinese strategy aiming to push China's economic links to Southeast Asia, South Asia, Central Asia, Pacific Oceania, Africa, and the Baltic region (Central and Eastern Europe) through various infrastructure and development projects (Yu, 2017). The BRI has been officially renamed several times since 2013 when Chinese President Xi Jinping announced the policy. It was previously called One Belt, One Road; the Silk Road Economic Belt; and the 21st-Century Maritime Silk Road. The policy was more fully articulated in 2015 as a vision statement, and numerous supporting policy documents have since been produced to support the implementation of the vision statement.

The BRI is expected to involve over $1 trillion in investments, largely in infrastructure development, for ports, roads, railways, and airports, as well as power plants and telecommunications networks (OECD, 2018). Financing sources will include those typical of Chinese overseas investments, such as Chinese banks (commercial and policy), bonds, state-owned enterprises, private Chinese equity, private/public partnerships, the Asian Infrastructure Investment Bank, and others. However, it is expected that Chinese banks will continue to be the main source of financing for Chinese overseas projects, including those along BRI routes. Numerous projects have been proposed or are already in development. According to data from the Ministry of Commerce, China (2016), from January to August 2016, Chinese companies signed almost 4,000 project contracts in 61 countries. The value of these projects amounted to close to $70 billion.[1]

There are growing concerns from recent experiences of BRI megaprojects that have come under a host of criticism. There is fear that the BRI could be a *debt trap* due to the high interest rates associated with some of the BRI's projects, as in the notorious case of Sri Lanka's Hambantota Port (Abi-Habib, 2018; Geraci, 2020; Sultana, 2016). There are concerns that projects under the BRI are not transparent

[1] Data on BRI investments are known to vary, particularly since it is unclear if existing projects are retroactively categorised by the Chinese government as BRI investments. This figure from the Ministry of Commerce is considered official.

and that the BRI itself will be damaging to the environment (Russel and Berger, 2019) because it does not offer explicit guidelines on how Chinese investors should regard environmental protection or civil society (Friends of the Earth US, 2016). There is also fear that the BRI is modern *Chinese colonialism*, often taking as an example the Chinese presence in Africa, and connecting to the long-standing *yellow peril* phobia (see, for example, Grammaticas (2012) and Wu (2013). There is another fear that, despite its effectiveness in relation to construction speed (Sultana, 2016), the projects under the BRI are not sustainable but are the cause of environmental and social issues (OECD, 2018). China's official responses have been mostly on the defensive, trying to delink the BRI from geopolitical or hegemonic ambitions, arguing that BRI projects 'benefit the local population' and are opportunities for 'shared development' (see, for example, Cheong (2019)).

The BRI is considered as a second wave of Chinese overseas investment and should be seen as a renewed version of the Chinese policy, also known as China's 'Go Global' strategy (Friends of the Earth US, 2016). This policy was the first to call on Chinese enterprises and industries to 'go out' and invest abroad. It is also seen as the key driver to advance China's interests overseas, and demonstrates its growing influence as a rule-shaper in the economic governance of the region and beyond (Yu, 2017), something that countries in the Mekong Subregion need to deal with carefully. However, if the BRI is to be successful, the Principles for Quality Infrastructure Investment initiative will need to be considered in all infrastructure investments, and local communities developing BRI projects will have to play an active role. In addition, host-country stakeholders will need to improve the quality of their governance systems.

3.1.3. Blue Dot Network

In November 2019, the US, Australia, and Japan came together to establish what is now known as a trilateral BDN to help develop and promote quality infrastructure in the Indo-Pacific region and around the world. Focusing on transparency and sustainability, the BDN aims to set a standard of excellence in infrastructure development. Hansbrough (2020) argued that the BDN is primarily a vision of what global infrastructure should look like. In the eyes of many observers, the BDN is also seen as an alternative to China's BRI, or a counter to the rising debt traps and low-quality infrastructure that boost quantitative and non-transparent aspects of the projects (see, for example, Geraci (2020), Panda (2020), Lyn (2020), McCawley (2019), Heydarian (2020)).

According to the US Department of State (n.d.), the BDN is a multi-stakeholder initiative seeking to bring together governments, the private sector, and civil society to encourage the adoption of trusted standards for quality global infrastructure development in an open and inclusive framework. It also encourages responsible construction and lending practices through international norms. Infrastructure projects have to follow the G20 Principles for Quality Infrastructure Investment, aimed at sustainable lending and borrowing; the G7 Charlevoix Commitment on Innovative Financing for Development; and the Equator Principles, which mandate financial institutions to assess and manage environmental and social risks in a given project. Projects that aim for certification under the BDN will have to give an undertaking that they adhere to these principles. The undertaking will then be scrutinised. Certification by the BDN means that a project is high-quality and has transparent origins, much like an 'organic' label for produce. Likewise, a country that agrees to follow BDN standards signifies that its government values high-quality infrastructure that benefits local communities.

The BDN plans to certify projects around the world (whose investment totals an estimated $94 trillion) that meet high-quality infrastructure standard over the next 2 decades (Kuo, 2020). This will meet the projected infrastructure investment need identified by ADB (2017) up to 2040. In Asia alone, the investment will require some $26 trillion from 2016 to 2030, or $1.7 trillion per year, if the region is to maintain its growth momentum, eradicate poverty, and respond to climate change (ADB, 2017).

The BDN looks promising for the Mekong Subregion and for the world, as it seeks to build the robust, resilient infrastructure essential to a country's growth and its people's well-being (Basol and Basar, 2020). But this remains to be seen. The initiative has not been fully fleshed out and project financing facilities are amongst the many details that have to be clarified (McCawley, 2019; Kuo, 2020).

3.1.4. Free and Open Indo-Pacific

The region has also witnessed another initiative called the FOIP, as a mechanism complementary to other initiatives for infrastructure investment. In Japan, former Prime Minister Shinzo Abe unveiled the FOIP concept in August 2006, just before his first term as Japan's leader, and formally laid it down as a strategy in 2016 (Satake, 2019; Szechenyi and Hosoya, 2019). In late 2017, the US also launched a new FOIP (Arase, 2019), but it was not until 2019 that the concept was actually formalised (US Department of State, 2019).

Extending from Japan in the east to India in the west, the FOIP involves middle and major powers such as Japan, the US, Australia, and India; and other regional partners. It seeks to build a vision for Asia established around the concept of a strong coalition of like-minded regional democracies. However, a host of scholars and analysts have viewed the FOIP as a mechanism that provides the region with alternatives to China's BRI (Berkofsky, 2018; Brewster, 2018; Maslow, 2018; Herberg, 2020) or for countering China's influence (Berkofsky, 2018; Ford, 2020; Kawashima, 2020; Swaine, 2018; Valencia, 2018). The Government of Japan, nevertheless, views this differently. The FOIP is an inclusive concept that ultimately aims to incorporate China and other powers in an inclusive political and economic system in the Indo-Pacific (Satake, 2019). It is also a comprehensive framework or vision for Japanese regional policies, mostly its economic and development cooperation, such as infrastructure development and support for regional connectivity (Ministry of Foreign Affairs, Japan, 2016, 2017; Editorial Desk of the *Gaiko (Diplomacy)*, 2018).

Despite different views, the Mekong countries welcomed the FOIP. For example, they welcomed Japan's commitment to support their efforts made in line with ASEAN's Outlook on the Indo-Pacific (Ministry of Foreign Affairs, Japan, 2017, 2019). Perhaps they saw this as another option for quality infrastructure projects. As Swaine (2018) argued, infrastructure development initiatives under the FOIP could prove instrumental for both engaging and challenging China by advancing common principles for economic development and enabling developing countries to choose their own economic paths free from coercion. In this respect, the cooperative and competitive elements of the China challenge could merge as the allies pursue dialogue with Beijing on rules and norms while attempting to dilute its influence.

3.1.5. The Mekong River Commission

The Mekong River Commission (MRC) is another key driving force behind quality energy infrastructure development in the region. As the only treaty-based river basin organisation in the region, the 25-year-old MRC has put in place two crucial strategies to guide its four member countries – Cambodia, the Lao People's Democratic Republic (Lao PDR), Thailand, and Viet Nam – in assessing and developing hydropower projects in the Lower Mekong Basin (LMB) to optimise transboundary benefits while minimising adverse cross-national impacts.

One of them is the basin-wide Sustainable Hydropower Development Strategy (SHDS) for the LMB adopted in 2001 by the MRC Council of Ministers, the organisation's highest governing body. The SHDS recognises that while each member country has the full responsibility and right to plan and implement hydropower projects nationally, the MRC is tasked with striking a balance between regional and basin needs, and economic development and environmental protection (MRC, 2016). The SHDS thus sets out strategic priorities and actions at the basin level to address hydropower opportunities and risks, and strengthens basin-wide cooperation and sustainable development (MRC, 2001). It also draws a close linkage between the energy and water sectors because the need for linked planning between the energy and water sectors is now more critical than ever before in the Mekong Region.

The Preliminary Design Guidance for Proposed Mainstream Dams in the LMB is another key strategic guidance resource. Adopted in 2009, it provides performance targets and principles for the design and operation of mainstream dams to help avoid, minimise, and mitigate harmful effects and limit the potential for substantial damage (MRC, 2009). It seeks to establish a common design and operational approach, aiming to meet common objectives and mitigate commonly understood risks, and making it possible for developers to plan for and undertake the assessments and designs for mitigation and management measures as early as possible in the project cycle.

However, both documents are ageing and need to be revisited. With rapid development in the basin, especially in the hydropower sector, it is important that the documents are updated, taking into account major changes the basin has faced over the last two decades. Studies by the MRC (MRC, 2018, 2019, 2020; MRC/Basist and Williams, 2020) and others (Kummu and Varis, 2007; Kondolf, Rubin, and Minear, 2014; Kuenzer et al., 2013) have indicated that hydropower dams constructed on the mainstream in the upper part in China where the river is called the Lancang and on the lower reaches where the river is called the Mekong and on tributaries in the LMB had changed the natural flow regime of the river, yielding both opportunities and risks on hydropower development now and in the future. Gathering the significant economic and greenhouse gas (GHG) reduction benefits offered through hydropower development should not come at the expense of the unique and abundant ecosystem services and biodiversity on which so many communities in the basin depend. Besides, although the MRC has a critical role to play in water diplomacy and energy infrastructure development in the region, this and its wider role have not received sufficient credit (Kittikhoun and Staubli, 2018). Thus, the Mekong River Commission (MRC) needs to evolve, and its founding member countries need to empower it further if the Mekong River is to develop sustainably and responsibly (Sok et al., 2019; An, Kittikhoun, and Meas, 2020).

3.1.6. Lancang–Mekong Cooperation

The Lancang–Mekong Cooperation (LMC), despite its relatively young age, is one of the most rapidly progressive and notable platforms in the Mekong Subregion. In 2012, Thailand proposed an initiative for sustainable development of the Mekong Subregion, which received a positive response from China. At the 17th China–ASEAN Summit held in November 2014, Chinese Premier Li Keqiang proposed the establishment of the LMC Framework, which was welcomed by the other five Mekong countries. In March 2016, China and the other five Mekong countries held their first LMC Leaders' Meeting, which released the Sanya Declaration and officially launched the LMC mechanism (LMC, 2017).

Although the LMC seeks to promote many aspects of cooperation on security, economic, cultural, agriculture, and poverty reduction issues (LMC, 2017; Gong, 2020; Zhang and Li, 2020), the major driving force is seen through its emphasis on infrastructure development for the region. Some of the major examples are Myanmar's Kyaukpyu Port and gas pipeline, the Lao PDR and Thailand's high-speed railway projects, Cambodia's irrigation systems and transport infrastructure, and more plans to develop better capacity for navigation along the Mekong River (Busbarat, 2018).

As a subregional cooperation mechanism connecting the six countries along the Mekong River, the LMC has seen China emerge as a willing investor and guarantor as part of its wider BRI. While a comprehensive list of LMC projects is not publicly available, the LMC has provided financial support for at least 132 projects in the Mekong Region as of 2018 (*The ASEAN Post*, 2019). During the LMC Ministerial Meeting in 2019, the LMC proposed a further 101 projects, all of which were considered fast-track – to be carried out in 1 year or less – in the six Mekong countries (LMC, 2019b) to respond to 'socio-economic demands and water related challenges' (LMC, 2019a: 2). The LMC, like the BRI, is often promoted as an effective platform that offers countries in the Mekong Subregion the resources they need for development (see, for example, Liena, Juan, and Pengfei (2018); Qingrun (2018); *Xinhau* (2020a, 2020b); Xing (2017)).

Critics, however, have voiced strongly that China is using the LMC to build its regional strategic influence and that the LMC per se does not promote good governance. China's strong interest in driving the development of the LMC stemmed from gaining substantial control over the Mekong Subregion, delimiting the influence of external actors such as the US and Japan, and pushing forward its neighbourhood diplomacy (Biba, 2018; Middleton and Allouche, 2016). While the LMC can be a building block for stronger regional multilateralism, it can also work against the advancement of broader ASEAN regional cooperation and marginalise other Mekong Subregion bodies (Busbarat, 2018). Amongst all the seemingly unchecked development that has flourished as a result of the LMC, perhaps none has had such an impact on local communities and the environment as the dams that have sprouted up across the region, where China has taken the role of developer or funding agency (*The ASEAN Post*, 2019). While Chinese investment in infrastructure development through the LMC is a welcome source of capital for

Mekong countries, Southeast Asia should approach it more critically to avoid development that later becomes a debt trap, does not last, and only benefits the few.

3.1.7. Mekong–Japan Cooperation

Mekong–Japan connectivity is another important dimension for the Mekong Region. It aims to promote infrastructure development in the region and to enhance institutional connectivity through the improvement of systems, development of Special Economic Zones (SEZs) and other industrial bases, industrial promotion measures, improvement of customs procedures, and people-to-people connectivity to ensure that the whole region benefits from growth (Verbiest, 2013). Key pillars of cooperation in the development of infrastructure are to fill the missing links of the East–West and Southern Economic Corridors. Once the links are filled, they will connect the corridors more smoothly through the improvement of systems such as customs procedures; they will also promote land development along the corridors (e.g. the development of industrial parks, industrial promotion measures, and so on) and improve access from neighbouring areas to corridors so that the region can develop as a whole. Finally, they will help to promote the development of industrial human resources that will support growth in the region and strengthen people-to-people networks.

It can be argued that the Mekong Subregion has benefited significantly from the infrastructure improvement brought by official development assistance support from Japan, with high-quality roads, bridges, and other hard and soft infrastructure.

4. The Economic Impacts of Connectivity and Infrastructure Investment

4.1. The Economic Impacts of Connectivity in the Mekong Subregion

The coordinated development of soft and hard infrastructure is also essential to maintain growth in the region. The new international division of labour calls for a novel approach to infrastructure development, in which the Mekong Subregion is prepared to participate actively in the promotion of economic corridors: the Southern Economic Corridor, the EWEC, and the North–South Economic Corridor.

These economic corridors – together with the fast acceleration of domestic infrastructure development including SEZ, urban amenities, and other economic activities – have already promoted regional participation in the production network by reducing the cost of service links that connect remote locations. Mekong Subregion connectivity is just one piece of the puzzle in ASEAN connectivity with the rest of the world. China's BRI is another very large 'connectivity for development' strategy, linking China to Eurasian countries and the rest of Asia.

As the region embarks on rapid infrastructure development, quality infrastructure, connectivity, and innovation are key to ensure prosperity and sustainable development. Infrastructure development and stages of economic development can be explained by the development of recent economic theories: fragmentation theory and new economic geography (ERIA, 2015). The theory classifies infrastructure projects into three tiers. Tier 1 includes projects that serve countries/regions that are already in production networks and have started forming industrial agglomerations. Tier 2 consists of projects supporting countries/regions that are about to participate in production networks. Tier 3 is comprised of projects in remote areas where participation in production networks is difficult in the short run, but where better and more reliable connectivity can generate new business models in agriculture, mining, tourism, and other industries. Thus, the ultimate aim of quality infrastructure and services development is in tier 1, in which some ASEAN Member States are experiencing and enjoying quality growth, particularly Singapore and to some extent Brunei Darussalam. Malaysia and Thailand are also doing well, with the quality of infrastructure in tier 2 possibly moving to tier 1 in the near future. The Mekong Subregion has achieved lower middle-income status, improving infrastructure quality from tier 3 and possibly joining tier 2 in the near future. Indonesia and the Philippines have achieved middle-income status and infrastructure development is in the early stage of tier 2, likely catching Malaysia and Thailand in the near future.

By and large, connectivity and innovation promote agglomeration forces and dispersion forces generated by production–consumption interactions in both internal and external economies in which people and ideas can move easily. Agglomeration forces mean that economic activities and people are attracted to the core, where positive agglomeration effects are found in the form of the ease of finding business partners and proximity to the market, etc. On the other hand, dispersion forces generate movements of economic activities and people from the core to the periphery. One source of dispersion forces is negative agglomeration effects or 'congestion' in the core, which includes wage increases, land price hikes, traffic congestion, and environmental pollution (ERIA, 2015).

One practical example of new economic geography creating 'location advantages' through connectivity and innovation is Cambodian labour force migration. Currently, about 1 million (out of a population of 16 million) Cambodians are in Thailand working in unskilled labour-intensive sectors and the informal sector rather than in Phnom Penh. The question is: How can Phnom Penh attract labour from rural areas and, at the same time, attract production blocks from Thailand? If the wage gap between Bangkok and Phnom Penh is too large, people will not move to Phnom Penh; however, at the same time, production blocks may be motivated to move. On the other hand, if the wage gap is too small, production blocks will not move even though people may flow into Phnom Penh. Then, how can Phnom Penh attract both production blocks and people? The answer is the improvement of location advantages and liveability in Phnom Penh.

Another example is the Mekong–India Economic Corridor (MIEC)/EWEC connecting Ho Chi Minh (HCM) City, Phnom Penh, Bangkok Metropolitan Area, and Dawei. This has great potential to become a major manufacturing corridor in the near future. However, the question is how to attract labour and investment to Dawei. In this regard, the MIEC will need to have at least three projects implemented at the same time – industrial estates, highway connection to Thailand, and a deep seaport. According to Han (2018), the road situation between Phnom Penh and HCM City was relatively bad in 1999. Before the road was upgraded, travel time from Phnom Penh to HCM City was about 9–10 hours, and cross-border trade at Moc Bai (Viet Nam)–Bavet (Cambodia) was worth about $10 million per year. However, the situation was completely changed in 2014 after both hardware and software infrastructure were implemented between Phnom Penh and HCM City. The travel time was reduced to 5–6 hours, and cross-border trade at Moc Bai–Bavet grew to $708 million per year (ERIA, 2015). Further, connectivity promoted other economic development corridors, such as investment brought to Trang Bang Industrial Park (in Moc Bai), consisting of 41 projects with $270 million in new investment, creating about 3,000 jobs.

The top 10 beneficiaries from the MIEC, based on ERIA (2015), are Dawei, Phnom Penh, Dong Nai, Kawthoung, HCM City, Kandal, Sihanoukville, Banteay Meanchey, Svay Rieng, and Battambang. For Phnom Penh, it was estimated that the connectivity would increase gross domestic product (GDP) by almost 400% as a cumulative impact over 2021–2030. ERIA also estimated the remainder of the economic corridor in the Mekong Subregion, and found significant impacts for all participating countries in the connectivity.

For power connectivity in the Greater Mekong Subregion (GMS), ERIA's study on energy markets in ASEAN and East Asia examined the power trade and development in the subregion for the foreseeable future (Han and Kimura, 2014). The study showed that the 2030 Scenario (in which the GMS realises the potential of hydropower) will provide both economic and environmental benefits. The GMS at large will benefit by about $40 billion and reduce CO_2 emissions by almost 70 million tons per year. For ASEAN power connectivity as a whole, the study estimated that ASEAN would save $25 billion over 20 years by substituting hydropower for fossil fuels.

4.2. Infrastructure Investment Projects in the Mekong Subregion

The GMS regional investment framework, 2014–2022 (RIF 2022) pipeline projects consist of 143 investment projects requiring $65.7 billion and 84 technical assistance projects requiring $295 million (GMS Secretariat, 2019). Of the total 227 prioritised projects, which require investment of about $66 billion, there are financing gaps for 121 projects amounting to $27 billion (about 40% of the total investment). Of the projects currently identified with available financing, 70% have government financing, 18% have ADB financing, 6% have financing through other development partners, and 6% have private sector investment or public–private partnerships.

Table 1: Regional Investment Framework 2022 Summary by Sector

	Number of projects			Cost estimates ($ million)		
Sector	**Investment**	**TA**	**Total**	**Investment**	**TA**	**Total**
Transport	85	12	97	55,753	10	55,763
Energy	11	8	19	2,230	15	2,245
Agriculture	9	10	19	1,695	96	1,791
Environment	3	4	7	560	13	573
Health and other HRD	4	7	11	702	22	724
Urban development	7	6	13	1,147	10	1,157
Others/BEZ	6	6	12	2,085	8	2,093
Tourism	12	17	29	1,430	83	1,513
TTF	3	9	12	91	17	108
ICT	3	5	8	28	22	50
Total	**143**	**84**	**227**	**65,722**	**296**	**66,017**

BEZ = border economic zone, HRD = human resources development, ICT = information and communication technology, TA = technical assistance, TTF = transport and trade facilitation.
Source: ADB (2019).

The RIF 2022 is heavily skewed towards transportation sector projects, as the table shows. However, inter-sectoral linkages, such as tourism supported through transport networks, are more prominent in the RIF 2022. Furthermore, there is an increase in transportation subsectors, with new projects in ports and waterways, logistics, and border crossing, which were missing or underrepresented in earlier pipelines. Railway infrastructure, because of its greenfield nature and extensive civil works, continues to make up the bulk of the required investment costs in the RIF 2022. Some railway projects have commenced, with domestic budgets and bilateral assistance from China. The GMS Railway Association is assessing which railway lines to prioritise for the subregion and examining alternative modalities to address the vast financing needs for rail infrastructure (GMS Secretariat, 2019; ADB, 2016). In addition to projects in new transport subsectors in the RIF 2022, projects in border area or border zone development involve multisectoral interventions such as road and/or border infrastructure, trade facilitation, technical and vocational education and training, schools, urban infrastructure, and tourism.

The GMS Tourism Infrastructure for Inclusive Growth projects also take this multisectoral approach.

Of the total transport sector investment projects, as shown in the table, railways took 62% of the total (about $35 billion investment in the RIF 2022), followed by roads and bridges at 36% (about $20 billion). If the railway, road, and bridge projects under construction and potential new projects are realised in the near future, the GMS will be a region of connectivity by rail and road, which will play out very well for connectivity to Malaysia and Singapore. Thus, the flows of goods and services could see potential increases in volume, positively affecting economic growth in the region.

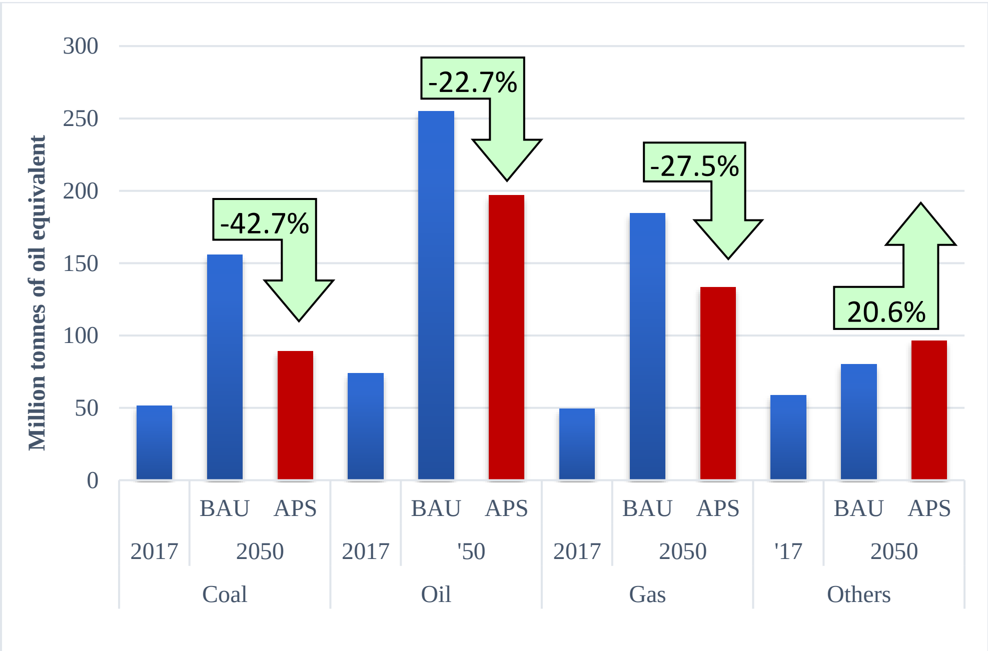
5. Energy Landscape in the Mekong Subregion

5.1. Energy Supply in the Mekong Subregion

The total primary energy supply (TPES) in the Mekong Subregion (Cambodia, the Lao PDR, Myanmar, Thailand, and Viet Nam) is projected to increase by 189% in the BAU scenario, and by 121% in the APS from 2017 to 2050. In actual amounts, it will increase from 234 million tonnes of oil equivalent (Mtoe) in 2017 to 675 Mtoe in the BAU scenario, and to 516 Mtoe in the APS by 2050. It is observed that the Mekong Subregion is heavily dependent on fossil fuel consumption (oil, coal, and gas). Based on the baseline data in 2017, the fossil fuel share in the energy supply is around 75% of the total in the Mekong Subregion. It is projected that the Mekong Subregion will see growing dependency on fossil fuels in the future. In this regard, the study results showed that by 2050, the share of fossil fuels in the energy supply will be about 88% in the BAU scenario and 81% in the APS. In actual amounts, the combined coal, oil, and gas in the energy supply is expected to increase from 175 Mtoe in 2017 to 595 Mtoe in the BAU scenario and to 420 Mtoe in the APS in 2050. Oil is the dominant energy source in the energy supply, followed by natural gas and coal (Figure 1). Oil is expected to increase from 74 Mtoe in 2017 to 255 Mtoe for the BAU scenario and to 197 Mtoe for the APS in 2050. Natural gas is expected to increase from 49.3 Mtoe in 2017 to 184.3 Mtoe for the BAU scenario and to 133.6 Mtoe for the APS in 2050. Coal will increase from 51.6 Mtoe to 155.8 Mtoe for the BAU scenario and to 89.3 Mtoe for the APS in 2050. Other sectors, including biomass, wind, solar, and electricity, will see increases from 58.8 Mtoe in 2017 to 80.0 Mtoe for the BAU scenario and to 96.5 Mtoe for the APS in 2050.

The difference between the BAU scenario and the APS is the energy saving potential in the TPES. Coal will see the largest energy saving, with potential of 42.7%, followed by 27.5% for natural gas and 22.7% for oil. These large energy savings are expected from the implementation of energy efficiencies, with improved efficiency in thermal power plants and energy efficiency in end-use sectors such as transportation, industry, commercial, and residential sectors. The Mekong Subregion is expected to see an increase in renewables of about 20.6% in the energy supply mix by 2050 (Figure 1).

Figure 1: TPES by Energy Source, BAU vs APS



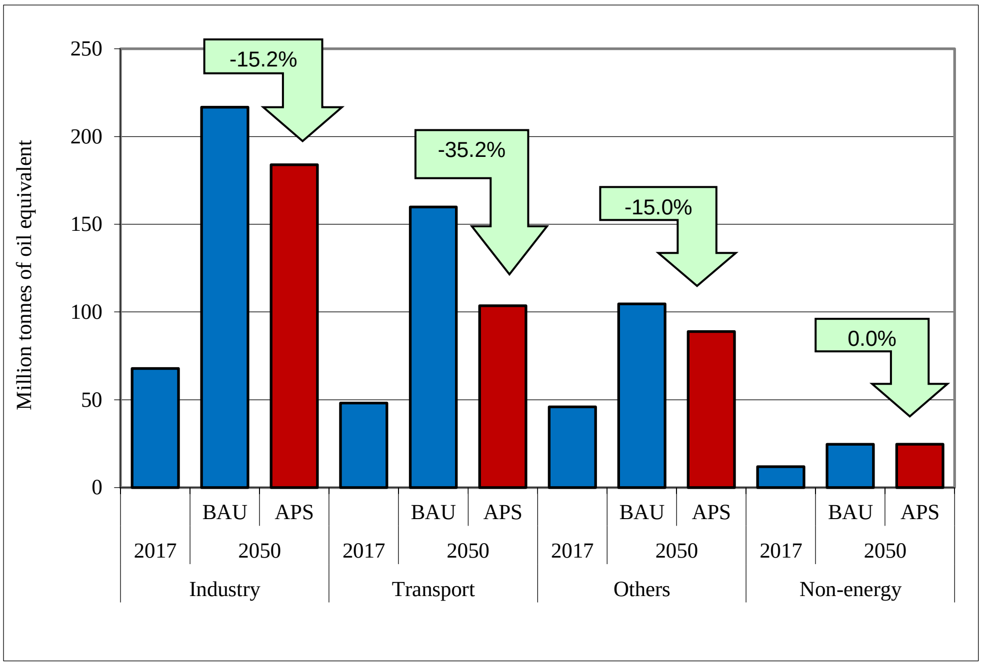
APS = alternative policy scenario, BAU = business as usual, TPES = total primary energy supply.
Source: Authors' calculations.

5.2. Final Energy Consumption in the Mekong Subregion

In the total final energy consumption (TFEC), industry accounts for the largest share, followed by transportation, and other commercial and residential sectors, as Figure 2 shows. Energy consumption in the industrial sector is expected to increase from 68 Mtoe in 2017 to 217 Mtoe for the BAU scenario and to 184 Mtoe for the APS by 2050. Energy consumption in the transport sector is predicted to increase from 48 Mtoe in 2017 to 160 Mtoe for the BAU scenario and to 104 Mtoe for the APS by 2050. For other sectors, including the commercial and residential sectors, energy consumption is expected to increase from 46 Mtoe in 2017 to 105 Mtoe for the BAU scenario and to 89 Mtoe for the APS by 2050. The non-energy sector (naphtha) is also used in the TFEC, especially for the refinery and petrochemical industries, with its use remaining the same for the BAU scenario and the APS in 2050.

Energy saving is expected to be highest for the transportation sector at 35.2%, 15.2% for the industrial sector, and 15.0% for the commercial and residential sectors, as indicated in Figure 2. The reduction in energy consumption in the final energy sector will derive from fuel efficiencies in the transportation, industry, commercial, and residential sectors (e.g. the introduction of more efficient heat and power, a shift to electric vehicles, hybrid and fuel cell vehicles, more efficient electric appliances, and energy-saving buildings).

Figure 2: TFEC by Sector, BAU vs APS



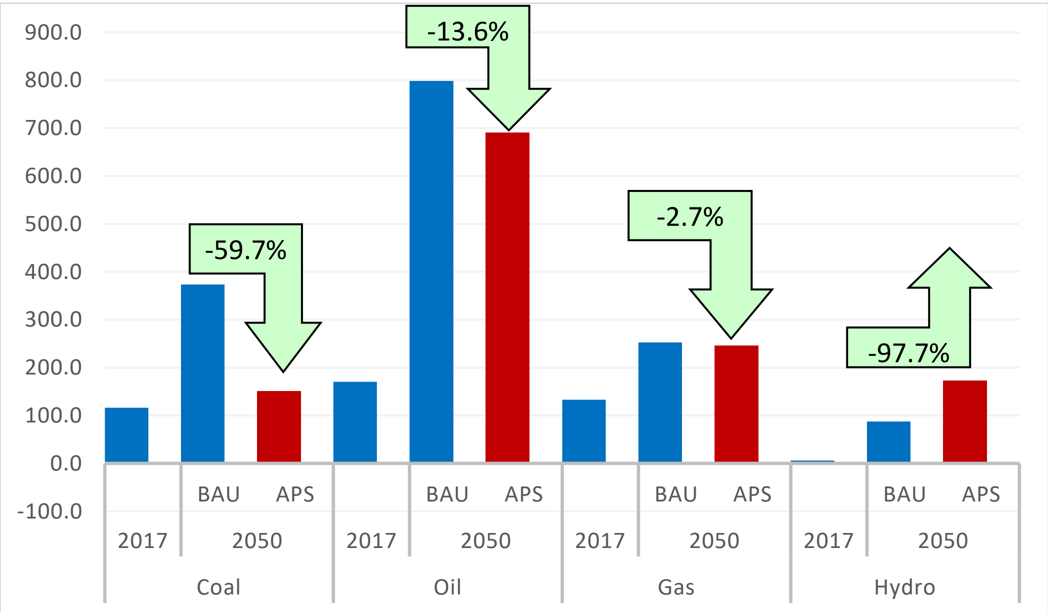
APS = alternative policy scenario, BAU = business as usual, TFEC = total final energy consumption.
Source: Authors' calculations.

5.3. Power Generation Mix in the Mekong Subregion

In the power sector, remarkable progress has been made in the subregion over the past 2 decades. This includes rural electrification access, rapid provision of large-scale and high-volume national grid systems, successful mobilisation of indigenous resources, the adoption of new technologies, the gradual share of renewables into energy mix, and the beginnings of cross-country trade. However, the future energy landscape in the Mekong Subregion will rely on today's actions/policies and investment to change course towards a cleaner energy system.

Natural gas is the dominant fuel source in power generation, followed by coal and hydropower, as Figure 3 shows. Natural gas is expected to increase from 170.4 megawatt-hours (MWh) in 2017 to 798.7 MWh in 2050 in the BAU scenario and to 690.3 MWh in the APS by 2050. Electricity from coal-fired power generation will increase from 116 MWh in 2017 to 374 MWh in the BAU scenario and 150 MWh in the APS by 2050. Electricity from hydropower is expected to increase from 133 MWh in 2017 to 252 MWh in the BAU scenario and to 245 MWh in the APS by 2050.

Figure 3: Total Power Generation (TFEC) by Energy Source, BAU vs APS



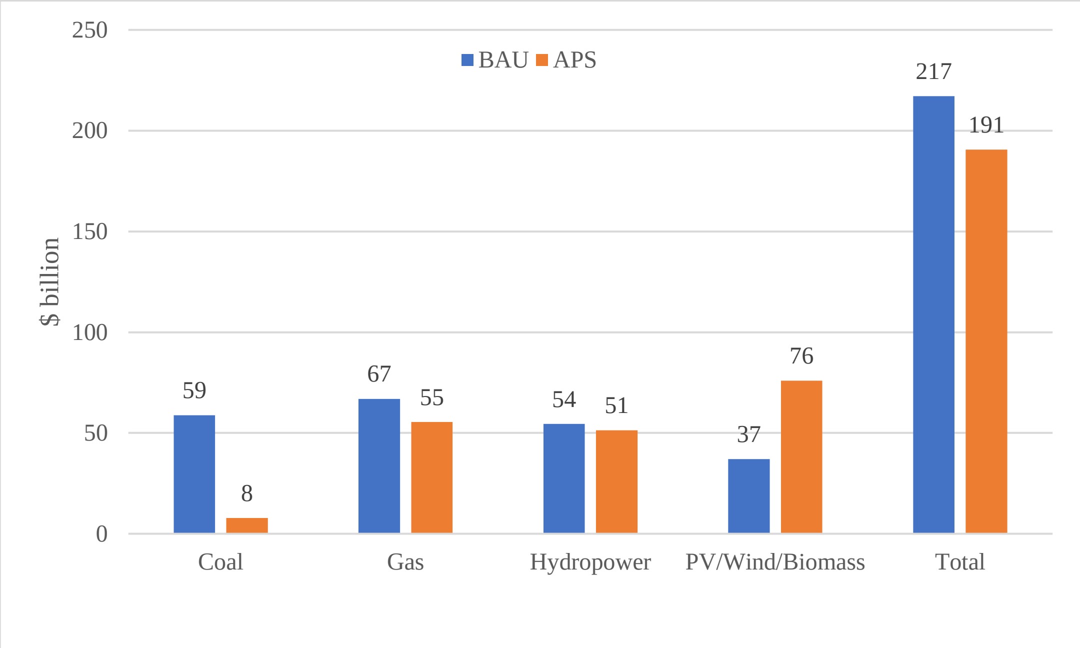
APS = alternative policy scenario, BAU = business as usual, TFEC = total final energy consumption.
Source: Authors' calculations.

Electricity from ‘others’ (including biomass, wind, and solar) will see a large increase from 6.2 MWh in 2017 to 87.2 MWh in the BAU scenario and to 172.4 MWh in the APS by 2050. Significant energy saving is expected in coal-fired power generation (59.7% saving, a reduction from BAU to the APS) followed by the gas combined cycle (13.6%). Energy saving in power generation is expected due to the introduction of high thermal efficiency. Electricity from renewables such as biomass, wind, and solar is expected to increase sharply by 97.7% due to upscaling renewables in the power mix in the APS scenario compared with the BAU scenario.

5.4. Required Power Generation Investment to Meet Rising Demand in the Mekong Subregion

To satisfy growing energy demand in the Mekong Subregion, huge power generation infrastructure investment is necessary from 2017 to 2050, as indicated in Figure 4. This study estimates that \$191 billion–\$217 billion will be needed for cumulative investment in power generation in coal, gas, and hydropower. The investment in natural gas combined cycle power generation will require \$55 billion–\$67 billion for the BAU scenario and APS from 2017 to 2050. Coal-fired power generation will require around \$59 billion in the BAU scenario. However, coal-fired power plant (CPP) capacity may be reduced in the APS, depending on the Mekong Subregion’s energy policy. In this case, the estimate for coal-fired power investment could drop to about \$8 billion from 2017 to 2050. For renewables such as solar photovoltaic (PV), wind, and biomass, the required investment is expected to increase from \$37 billion in the BAU scenario to \$76 billion in the APS. More broadly, at the ASEAN level, the *Energy Outlook* projects that \$2.1 trillion will be required for oil, gas, coal, and power supply (IEA, 2017). More than 60% of investment goes to the power sector, with transmission and distribution accounting for more than half.

Figure 4: Investment in Power Generation by Energy Source, BAU vs APS



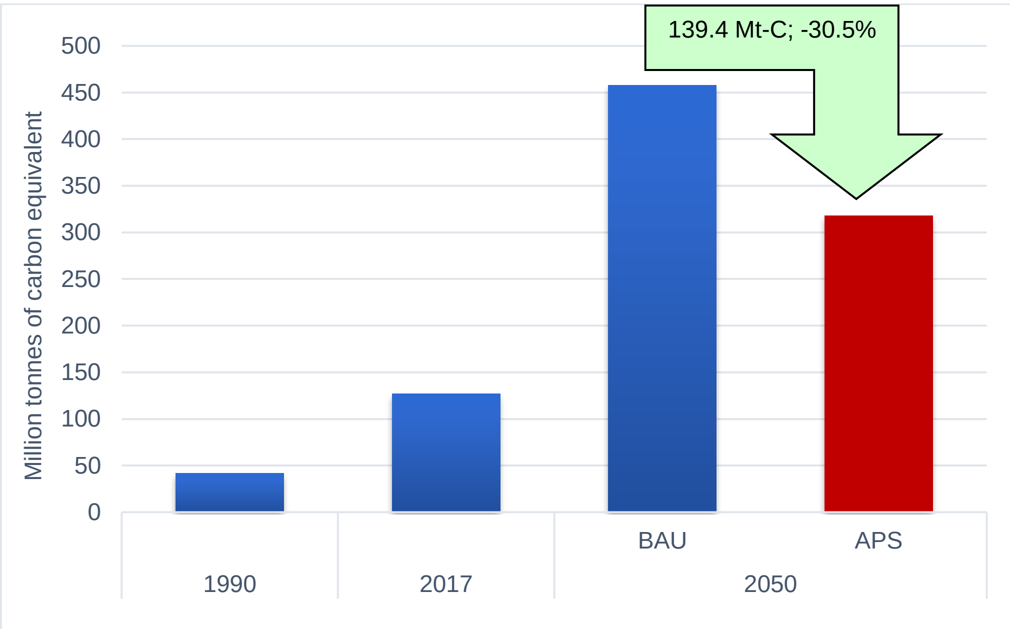
APS = alternative policy scenario, BAU = business as usual, PV = photovoltaic.
Source: Authors' calculations.

Thus, the huge potential for energy infrastructure related investment will need to be guided by the appropriate policy to promote quality infrastructure and resilience in the Mekong Subregion for growth and sustainability.

5.5. Carbon Dioxide Emissions in the Mekong Subregion

The region will continue to rely on fossil fuel consumption in the foreseeable future (Figure 5). This is mainly because of the presence of the high combined share of fossil fuels in the power generation mix of the Mekong Subregion, at 67% in 2017 and 78% in the BAU scenario by 2050, as well as the high share of fossil fuel use in the TFEC. CO_2 emissions rose from 42 million tonnes of carbon equivalent (Mt-C) in 1990 to 127 Mt-C in 2017. CO_2 emissions are expected to rise to 457 Mt-C in the BAU scenario and to 318 Mt-C in the APS by 2050.

Figure 5: CO_2 Emissions in the Mekong Subregion, BAU vs APS



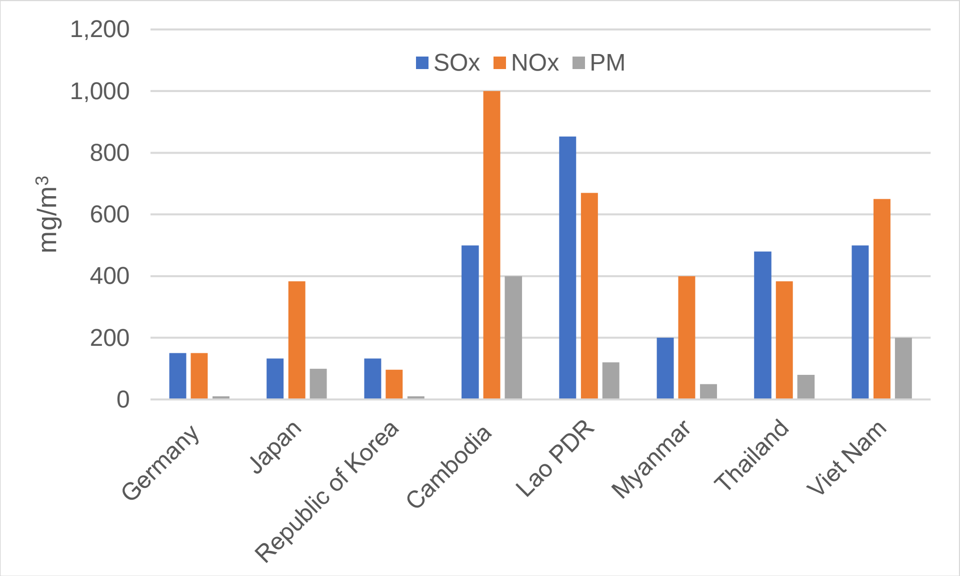
APS = alternative policy scenario, BAU = business as usual, CO_2 = carbon dioxide, Mt-C = million tonnes of carbon equivalent.
Source: Authors' calculations.

Thus, the clean use of fossil fuels through clean technology deployment is indispensable in decarbonising the Mekong Subregion's emissions, as also recently shown in a study by Han, Kimura, and Arima (2020). Further, natural gas should be promoted as a transitional fuel to bridge towards more renewable energy in the future.

6. Energy Transition in the Mekong Subregion

The Mekong Subregion faces mounting challenges in matching its energy demand with sustainable energy supply. This is because the regional reliance on fossil fuel consumption is projected to last until 2050. The transition to a lower-carbon economy will require the region to develop and deploy greener energy sources and clean use of fossil fuels through innovative technology such as high-efficiency, low emissions (HELE) technologies. Coal-use patterns in the region reflect the rising demand for electricity to power and steer economic growth. Hence, building low-efficiency CPPs is an obvious choice for power-hungry emerging Southeast Asia due to lower capital costs. However, such plants cause more environmental harm and health issues due to air pollution, CO_2, and other GHG emissions. Widespread coal power plant construction could also point to the low environmental standards for coal-fired power generation in the Mekong Subregion (Mitsuru et al., 2017). The Mekong Subregion countries have relatively high allowable emissions in terms of sulphur oxides (SOx), nitrogen oxides (NOx), and particulate matter (PM) (Figure 6). This means that countries in the subregion have lower emissions standards than advanced countries such as Germany, the Republic of Korea, and Japan, where clean coal technology (CCT) is mandatory.

Figure 6: Emissions Standards for Newly Constructed CPPs in Selected Countries (SOx, NOx, and PM)



CPP = coal-fired power plant, Lao PDR = Lao People's Democratic Republic, mg/m^3 = milligram per cubic metre, SOx = sulphur oxides, NOx = nitrogen oxides, PM = particulate matter.
Source: Mitsuru et al. (2017).

Major harmful air pollutants, such as SOx, NOx, and PM, come from fossil fuel and biomass power plants, which therefore need to be carefully regulated. It is known that short-term exposure to sulphur dioxide (SO_2) can harm the human respiratory system and make breathing difficult.

Thus, the Mekong Subregion's leaders may need to consider more strongly the promotion of CCT, higher standards or stringent environmental regulation for CPPs, and effective enforcement. This may push investors to select more advanced technologies, especially ultra-supercritical technology, for CPPs. Such plants are considered clean power because they use coal more efficiently and cleanly than traditional subcritical CPPs. Furthermore, supporting frameworks to ensure that developing countries can afford CCT are urgent because the up-front investment costs of CCTs are much higher than those of traditional CPP technologies.

The role of natural gas in the energy transition cannot be overlooked. This is because it can be used as a bridging fuel between high emissions fuels, such as coal and oil, to cleaner energy systems in which renewables and clean fuels take the major share in the energy supply mix. The prospects for using natural gas in the Mekong Subregion are good, with demand likely to quadruple depending on the future stability of gas and liquefied natural gas (LNG) prices in the market; whether a competitive gas/LNG market can be created in Southeast Asia; and the role of gas/LNG from Australia, the US, and other sources. The region is expected to be a key market for future gas demand, thus gas infrastructure investment, such as gas pipelines and LNG terminals, will be crucial in supporting the demand for gas in the region (Kobayashi and Han, 2018).

In the current situation, hydropower accounts for quite a large share of the energy mix in the Mekong Subregion. However, as energy demand is expected to increase further, hydropower sources will be fully utilised. Thus, the share of renewables, such as wind, solar, and biomass, will play a critical role in the future clean energy system in the Mekong Subregion. The lower cost of these renewables will make it possible for a higher share of wind and solar in the energy mix (Denholm and Cochran, 2015). Since electricity from wind and solar sources is variable and intermittent, there is a need to invest in grid infrastructure with smart grids, using the internet of things (IoT) and other technology to predict electricity production.

The Mekong Subregion may benefit greatly from the development of renewable hydrogen, as the region has large hydropower potential and the possibility of a higher share of solar and wind power (see Han, Kimura, and Arima (2020)). Thus, electricity from wind and solar plus other unused electricity during low-demand hours should be converted to hydrogen as stored energy. Fast-moving technological development will drive down the cost of hydrogen production in the future and give hydrogen a bigger role in the clean energy future (IRENA, 2019). Thus, the Mekong Subregion may need to prepare a roadmap for rolling out a hydrogen plan in the future.

7. Conclusions and Policy Implications

The Mekong Subregion's fast connectivity – including rail, road, port, aviation, and energy infrastructure – has integrated the region further in terms of compressing time and space for the movement of goods and services. However, the wider ASEAN region faces challenges in guiding investments for long-term sustainability, especially on quality infrastructure. In the region, key players channel their investments through regional and subregional initiatives and platforms such as China's BRI and LMC, the US BDN, the FOIP, the MRC, and Mekong–Japan Cooperation. Although there is a clear need for resilience and quality infrastructure in the Mekong Subregion, policy measures and actions undertaken in each country towards high-quality infrastructure vary, reflecting the differences in socio-economic, political, and geographical contexts. Thus, this makes it difficult for the region to promote sustainable growth and a low-carbon economy, energy access and affordability, and resilient and sustainable quality infrastructure.

As the Mekong Subregion continues to rely on fossil fuels, its energy transition will need to consider cleaner use through clean technology investment such as CCT and other high-quality energy infrastructure. Currently, investment in renewable energy and clean technologies is unstable and high in cost. These challenges need to be addressed through political commitment to ensure that an energy technology development and deployment support framework can scale up the share of renewables and clean fuels. Without redesigning energy policy towards high-quality energy infrastructure, it is very likely that the increasing use of coal will lead to the widespread construction of CPPs, which, without the employment of the best available CCT, will result in increased GHG and CO_2 emissions (Han, 2020c; Han, Kimura, and Arima, 2020).

The investment opportunities for energy-related infrastructure are huge. This study estimates that around $190 billion–$220 billion will be required from 2017 to 2050 for power generation alone. However, this estimate does not include the transmission and distribution network, LNG terminals, and refineries. The challenge will be to ensure quality infrastructure to promote sustainability in the region. Energy sustainability in the Mekong Subregion requires an increase in the share of renewables in the energy mix. Currently, it is dominated by coal, gas, and hydropower. Although intermittent renewables (solar and wind) comprise the most abundant energy resources in the region, they have so far taken a minimal share of the power mix.

Key Policy Implications

As this study has shown, what countries in the Mekong Subregion will need, as development accelerates and climate change intensifies, is an environmentally friendly, logistically feasible, and economically responsible alternative energy source and infrastructure. Derived from this study, the following key policy implications are provided with this consideration in mind.

First, the region will need to promote quality infrastructure investment. Given the region's vulnerability to climate change, resilient and high-quality infrastructure will play a key role in the region's long-term sustainability. Thus, regional and subregional platforms and initiatives such as the BRI, quality infrastructure by Japan, the BDN, and other subregional initiatives will need to promote high-quality infrastructure investment. For instance, the region should and will need to discuss the quality and standards that can guide investment to meet the need for high-quality infrastructure. Willingness to pay could be a barrier because of the high cost of quality infrastructure. Thus, a mechanism to reduce costs through innovative financing will be key for the successful deployment of high standards in the region.

Second, the current climate narrative and policy approach of banning coal use will need to be reviewed to assist emerging Asia to afford CCT. This is primarily because there are less available alternative energy options in the medium term to meet energy demand. Treating CCT as a technological solution in the energy transition will be a win–win solution for a climate-friendly world as Asia faces energy accessibility and affordability. Emerging Southeast Asia will rely on whatever CCTs are available in the market at affordable prices. The up-front costs of such ultra-supercritical technology or advanced ultra-supercritical technology are higher than supercritical and subcritical technologies. Thus, it is necessary to lower the up-front costs through policies such as attractive financial/loan schemes or a strong political institution to deliver public financing for CCTs in the region.

Third, there is a need for public consultation on and local participation in the potential impacts of any selected power plant infrastructure and technologies. However, for the Mekong Subregion, the government institutions have not emphasised such local participation strongly enough just yet. Thus, an active organisation or mechanism is needed to disseminate information on the potential harm resulting from less efficient CPPs.

Fourth, the region will see a rise in LNG imports to meet demand. Thus, the region's leaders will need to consider energy policy to increase the use of LNG in the future as a bridging fuel towards a clean energy future. Redesigning policy to promote LNG use will, to some extent, reduce coal use in the power mix. The countries in the Mekong Subregion should investigate the LNG infrastructure gap to develop policy to promote investment. This includes LNG terminals, pipelines, regasification plants, transportation, and storage.

Fifth, the region will need to prepare for a sharp increase in renewable energy from wind, solar, and biomass in the energy supply mix; and at the same time, promote the use of clean fuels and clean technologies. It will also need to look wider in terms of power grid connectivity. In this case, investment in 'hard' quality infrastructure will need to be connected to ASEAN.

Finally, the Mekong Subregion should boldly increase the portion of funding in the economic recovery package on green energy investment, as it will promote jobs, environmental protection, and social benefits for long-term sustainability. Governments and financial institutions may need to promote the financing of green projects through green bonds or other financial instruments. Of course, the region will also need to work on carbon credits in the future, as this will promote renewable and clean technology development.

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