Is ASEAN ready to move to multilateral cross-border electricity trade?

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Abstract

This paper reviews progress towards the establishment of an Association of Southeast Asian Nations (ASEAN) Power Grid (APG) and the key barriers to multilateral cross-border electricity trade in ASEAN. An analysis across political, technical, institutional, economic, environmental, social, and time dimensions is employed. Using a policy sequencing framework, the paper concludes it remains premature for ASEAN to pursue a strong form of power sector market integration on account of the sizeable barriers that currently remain, especially economic and institutional barriers. Focusing on bilateral power purchase agreements and large-scale investments in solar and wind power over 2022–2030 would help to develop stronger foundations for ASEAN to make steps toward deeper regional integration in the electricity sector in subsequent years, while also being consistent with renewables adoption goals.

Keywords: ASEAN, power grid, electricity trade, regional integration, renewable energy

Abbreviations[1]

[1] APG (ASEAN Power Grid), AIMS (ASEAN Interconnection Masterplan Study), ASEAN (Association of Southeast Asian Nations), GDP (gross domestic product), HAPUA (Heads of ASEAN Power Utilities/Authorities), Nord Pool (Nordic Electricity Market), PPA (Power Purchase Agreement), SAPP (Southern African Power Pool), and SIEPAC (Central American Electrical Interconnection System).

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The Australian National University Grand Challenge: *Zero-Carbon Energy for the Asia-Pacific* transdisciplinary research project is a $10m investment between 2019 and 2023 that aims to help transform the way Australia trades with the world. It comprises five interrelated projects: Renewable Electricity Systems, Hydrogen Fuels, Energy Policy and Governance in the Asia-Pacific, Renewable Refining of Metal Ores, and Indigenous Community Engagement. The Grand Challenge's goals include developing zero-carbon export industries, creating new paradigms in benefit-sharing, and developing technologies, polices and approaches which can be applied in the Asia-Pacific and beyond.

1 Introduction

The Association of Southeast Asian Nations (ASEAN) has been working toward regional electricity interconnectivity through an ASEAN Power Grid (APG) since 1997. The development of the APG was planned to commence with cross-border bilateral connections and to subsequently expand to greater levels of multilateral integration. The ASEAN Plan of Action for Energy Cooperation 2016–2025 (ASEAN Centre for Energy, 2020a) is the current document that sets objectives for moving toward regional connectivity. It prioritizes the expansion of multilateral power trade as part of the ASEAN Economic Community 2025 agenda.

Conceptually, there are three broad models for cross-border electricity trade: the bilateral model, multilateral model, and unified model (International Energy Agency, 2019a). Under a bilateral approach, trade occurs between two jurisdictions. Bilateral trade can be unidirectional (such as Thailand importing from Lao PDR) or bidirectional (such as the two-way power trade that exists between Lao PDR and Vietnam).

Multilateral trade involves several or more jurisdictions. A light form of multilateral trade entails unidirectional flows and use of "wheeling" charges to an intermediary country. An example is the current case of Lao PDR exporting electricity to Malaysia via Thailand. Deeper models of multilateral trade include either multidirectional trade among differentiated markets via multilateral power purchase agreements (PPAs) or trade among harmonized markets. Typically, excess generation in domestic markets is traded and trade needs to be coordinated by regional institutions that have mandates to collect information on excess supply and demand, match potential trades, and collect and distribute revenues (International Energy Agency, 2019b). Examples include the Southern African Power Pool (with multilateral, multidirectional trade among differentiated markets) and the European Union Internal Energy Market (with multilateral, multidirectional trade among harmonized markets).

Under the unified model, regional institutions are responsible for some or all of the tasks involved in managing the power system across multiple jurisdictions (International Energy Agency, 2019a). In a pure version, all generation clears in a single wholesale market. For example, the Nordic Electricity Market, or "Nord Pool", has a unified market structure with differentiated operations.

The National Electricity Market (NEM) in Australia, which operates across several states, is a unified market with a single system operator (Australian Department of Industry Science Energy and Resources, 2020).

The degree of integration increases as one goes from the bilateral model to the multilateral and then unified models of trade (Table 1). A common characteristic of the models is that integration occurs at the wholesale level, while retail activities remain under the purview of participating jurisdictions (International Energy Agency, 2019b).

Table 1. Cross-border electricity trade models

Trade model	Trade mode	Example	Degree of integration and complexity
Bilateral	Unidirectional	Thailand imports from Lao PDR	
	Bidirectional	Lao PDR ↔ Vietnam	
Multilateral	Unidirectional involving a transit country	Lao PDR exports to Malaysia via Thailand	
	Multidirectional among differentiated markets	Southern African Power Pool	
	Multidirectional among harmonized markets	European Union Internal Energy Market	
Unified	Unified market structure, differentiated operations	Nord Pool	
	Unified market and operations	Australian National Electricity Market	

Source: Adapted from International Energy Agency (2019a); International Energy Agency (2019b); Australian Department of Industry, Science, Energy, and Resources (2020).

A number of prior studies have explored the potential for multilateral and unified cross-border trade in electricity in ASEAN in line with the ASEAN vision (for example Chang and Li, 2013; Aalto, 2014a,b; International Energy Agency, 2015; Li and Kimura, 2016; Ahmed et al., 2017; Lu et al., 2021). Barriers to the realization of an APG have also been discussed (for example, Wu, 2016; Shi et al., 2019; Owen et al., 2019; Li et al., 2020). However discussions could pay more attention to when ASEAN should proceed to multilateral and unified cross-border electricity trade. An overly ambitious time schedule may stretch ASEAN's thin financial and institutional resources, a particular concern in the post-pandemic recovery period. There are also some fundamental barriers to market integration and cross-border trade that are not quickly surmountable and that may be more successfully overcome under a more gradual, sequenced approach.

In the current paper we review progress to date in the development of the APG and the challenges involved in moving to a model of deeper multilateral trade or to a unified market. To our knowledge, the paper is the first to assess the likely timeframes required for key barriers to be overcome using a policy sequencing framework (Pahle et al., 2018). This framework emphasizes the importance of the ordering and speed of reform and integration efforts. The paper also reviews two aspects of the APG that have not been examined in detail in previous studies. These are the transaction costs and environmental costs of APG establishment (Aalto, 2014b; Wu, 2016).

Is ASEAN ready to move towards more ambitious forms of multilateral electricity trade during 2021–2025? We conclude that it would be better for the time-being to continue to maintain a principal focus on bilateral contracting between individual ASEAN countries and the development of unidirectional sub-regional arrangements. The future of cross-border electricity trade in ASEAN could also benefit from a strong focus on utility-scale non-hydro renewable energy projects, particularly solar and wind power. This approach would help to reduce the sustainability concerns that currently slow the development of cross-border electricity trade links. There are numerous examples of projects that would be suited to bilateral trade across borders, including solar projects in Indonesia selling power to land-poor Singapore.

The paper argues that sustained progress in bilateral trade connections would help to pave the way for subsequent steps toward deeper market integration, perhaps after 2030. Bilateral PPAs would help to build greater institutional understanding and cooperation across jurisdictions and are a good fit for the current electricity markets of key ASEAN countries such as Indonesia, where PPA contracts dominate power procurement arrangements.

The paper is structured as follows. Section 2 provides an overview of the ASEAN electricity sector and cross-border electricity trade. Section 3 discusses the methods. Section 4 reviews progress toward the APG. Section 5 analyzes key barriers faced in the pursuit of greater multilateral and/or unified cross-border electricity trade flows in ASEAN. Section 6 discusses the way forward, including sequencing and other key issues. Section 7 concludes. Lessons from ASEAN's experience are highly relevant for other regions seeking to increase cross-border electricity interconnectivity, including elsewhere in the Asia-Pacific. The paper should thus be of broad interest with respect to

electricity sectors outside the ASEAN region.

2 Overview of the ASEAN electricity sector and cross-border electricity trade

2.1 Electricity sector

ASEAN has 10 member countries: Brunei Darussalam, Cambodia, Indonesia, Lao PDR, Malaysia, Myanmar, the Philippines, Singapore, Thailand, and Vietnam. With a combined population of about 650 million, a gross domestic product (GDP) of about US$3,100 billion, and a real GDP growth rate of around 5% per annum in 2019 (prior to the COVID pandemic), ASEAN is a sizable and opportunity-rich bloc (Department of Foreign Affairs and Trade, 2019). The region has been experiencing a rapid increase in electricity demand, with annual generation more than tripling over 1995–2015 and exceeding 1,000 TWh in 2017 (International Energy Agency, 2019b). Indonesia is the region's largest electricity consumer, using 235 TWh in 2017 (International Energy Agency, 2020). Thailand, Vietnam, Malaysia, and the Philippines consumed 198, 185, 152, and 86 TWh respectively. ASEAN power generation remains dominated by fossil fuels, which contributed about 78% of the electricity mix in 2019. Hydropower is another important source, contributing about 14%. Other renewables contributed only about 7% (International Energy Agency, 2022).

ASEAN has abundant renewable resource availability in the form of hydro, solar, and wind resources. It has some of the best hydropower potential in the world (International Renewable Energy Agency, 2018), with Myanmar alone having a potential installed hydro capacity of 100 GW. For Indonesia this is 75 GW, Vietnam 35 GW, and Lao PDR 26 GW (International Hydropower Association, 2020). Myanmar, Cambodia, Thailand, and Vietnam also particularly have strong solar irradiance with averages of 1,500–2,000 kWh/m^2 annually and potential capacity factors of over 20%. Vietnam and the Philippines are among countries that have substantial potential for offshore wind power (International Renewable Energy Agency, 2018).

ASEAN member states have diverse electricity sectors. Brunei Darussalam, Cambodia, Lao PDR, and Myanmar maintain largely vertically-integrated market structures and traditional state-owned utilities. Indonesia, Malaysia, Thailand, and Vietnam have introduced some level of wholesale competition via private independent power producers at the generation level, with transmission

and distribution remaining largely state-run (Owen et al., 2019). These countries have a single-buyer wholesale market structure, with retail tariffs regulated and controlled by the government. Final electricity prices in these countries typically do not incorporate all of the costs involved in the delivery of electricity to the final consumer (International Renewable Energy Agency, 2018). This has meant that government financial support to electricity utilities in the form of capital or other injections has been required.

2.2 Cross-border electricity trade

To date, most cross-border power trade in ASEAN has occurred among the Mekong countries (Shi et al., 2019; ASEAN Centre for Energy, 2020b). Some also occurs between Malaysia and Indonesia and also Malaysia and Singapore. China has been ASEAN's main external electricity trade partner, and Myanmar participates in some electricity trade with India and Bangladesh (USAID, 2018). Total electricity imports plus exports between ASEAN countries and with external partners increased from 14 TWh in 2007 to 54.7 TWh in 2017 (U.S. Energy Information Agency, 2020). The largest net importer is Thailand, with net electricity imports of 23.4 TWh in 2017, followed by Cambodia (1.5 TWh), Indonesia (1.1 TWh), and Vietnam (0.6 TWh).

By far the largest current electricity exporter in ASEAN is Lao PDR, which exported 21.3 TWh in 2017 – 80% of its overall electricity generation (U.S. Energy Information Agency, 2020). Lao PDR is pursuing a target of continuing to ramp up its electricity exports and becoming the battery of Southeast Asia (Kyophilavong et al., 2017). It has signed agreements to supply 9,000 MW of power to Thailand, 6,000 MW to Cambodia, and 5,000 MW to Vietnam by 2030. Given its abundant hydro and solar resources, another major potential exporter is Myanmar, however development progress in that country has been hindered by the political situation. The main future importers in ASEAN are likely to be Thailand, Vietnam, Singapore, and Indonesia (Jiang et al., 2020). Thailand has the potential to become a major regional electricity trading hub by transmitting electricity from Lao PDR and Myanmar to Malaysia and Singapore.

Most cross-border electricity trade has been based on bilateral contracts involving unidirectional flows. Only one multi-country project has commenced: a still relatively small pilot involving Lao PDR, Thailand, and Malaysia that started at 100 MW in 2018 and was expanded to 300 MW in 2020.

Under this arrangement Lao PDR exports electricity to Malaysia via Thailand, with a wheeling method being used to determine the revenues going to Thailand. In 2022 this project will be extended to include Singapore, which plans to commence 100 MW of power imports from Lao PDR (Straits Times, 2021). This is an important first step in multilateral trading, but given the small number of countries involved and the unidirectional flow, is only an introduction to the possibilities that exist (ASEAN Centre for Energy 2020b).

Most exported power from Lao PDR to Thailand, Cambodia, Myanmar, and Vietnam is generated using coal and, in particular, hydro sources (International Energy Agency, 2019b). Coal power generation contributes to global warming and local and regional air pollution, with related health consequences (Timonen et al., 2019). Hydro dams lead to dislocation of downstream communities and biodiversity losses (McCartney and Brunner, 2020). Both types of generation run against Principle 6 of the ASEAN Power Grid Consultative Committee Resolution for developing power trade: "Multilateral power trade should support the development of sustainable power systems" (International Energy Agency, 2019b). About 50 hydro dams have been built in Lao PDR during 2005–2020 and about another 50 potential dams are in the pipeline (McCartney and Brunner, 2020).

ASEAN has high potential for solar and wind power generation for both domestic use and cross-border trade. Potential capacities for land-based solar PV and wind power at sites with a levelized cost of electricity of less than US$150/megawatt-hour (MWh) have been estimated to be about 30,500 GW and 1,380 GW respectively (Lee et al., 2020). Together this is about 144 times the year-2017 total installed generation capacity (222 GW) (International Energy Agency, 2019b). There are also sizeable offshore and floating solar and wind opportunities in areas such as southern central Vietnam (World Bank 2019a,b; Do et al. in press). Some areas are more richly endowed than others, opening up potential gains from trade. For example, Mekong countries have larger solar generation potential than countries on the equator (Lee et al., 2020). Singapore and Brunei Darussalam are land-constrained and so may be particularly able to benefit from imports from neighbours.

Figure 1 presents data for ASEAN's economic openness by product, represented by trade as a percentage of production. This is calculated using the formula:

Openness index = 100*(Exports + imports)/Domestic production

(1)

Figure 1 reveals that current cross-border electricity trade is tiny relative to cross-border trade in dry natural gas, coal, and the economy as a whole. This is despite the fact that electricity is cheaper to transport than a bulky commodity such as coal if the infrastructure to do so (in the form of transmission lines) exists. Without the transmission infrastructure and institutional frameworks for cross-border electricity trade in ASEAN, large untapped opportunities remain.

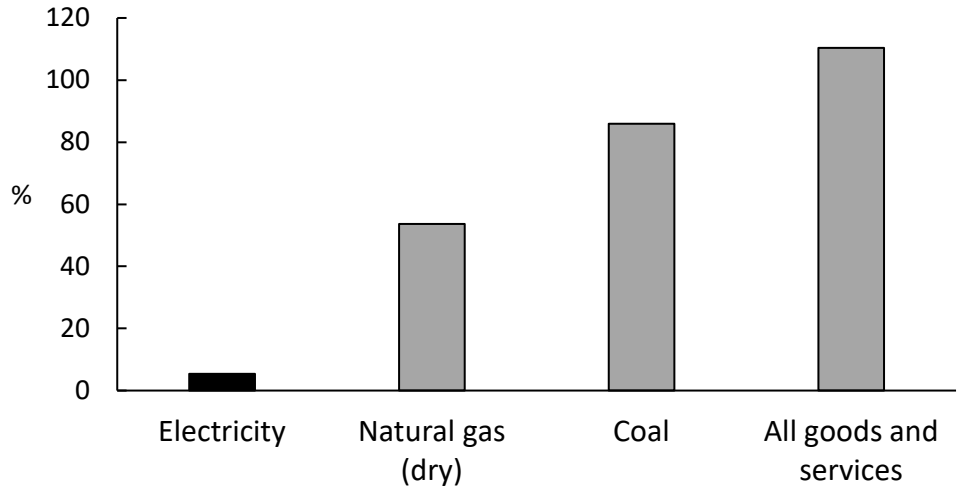

Figure 1. Openness index by product for ASEAN, %, 2016 (U.S. Energy Information Agency, 2020).

Note: Calculations for electricity, natural gas, and coal are based on physical measures. The calculation for all goods and services is based on aggregation in US$ value terms. Electricity generation is net. Natural gas is dry only (not liquefied). National borders are used.

3 Methods

To review progress toward the APG, we used Google Scholar as a search engine for journal articles on ASEAN cross-border electricity trade. This choice is due to its wide coverage (Lacey-Barnacle et al., 2020). The key words “ASEAN electricity trade” and “ASEAN power grid” were included as search terms, resulting in 118 articles as of February 2022. The Google search engine was also used to identify government reports and news articles containing updated facts and figures. We then compared APG outputs reported in the documents against expected results and deadlines.

We next reviewed the barriers to cross-border electricity trade in ASEAN using an analysis framework comprising political, technical, institutional, economic, environmental, and social dimensions (Puka and Szulecki, 2014; Do et al., 2020; Yang et al. 2021). To examine the likely timeframe to overcome the barriers, we employ a sequencing policy framework that recognizes that incremental steps are essential to achieving ambitious long-term goals and the order of these steps matters (Leipprand et al., 2018; Pahle et al., 2018).

We define transaction costs as resources including the time, effort, and money involved in setting up and operating a regionally-integrated electricity market, other than the infrastructure costs (McCann et al., 2005). Environmental costs are defined as the external costs imposed on ecosystems and on the communities whose livelihoods depend on them (Roth and Ambs, 2005).

4 Progress towards the APG and potential benefits

The idea of expanding electricity trade to a regional scale has been actively discussed in ASEAN since the early 1980s, but ASEAN did not establish a plan for an APG until 1997. The development of the APG was initially intended to commence with cross-border bilateral agreements and to then be expanded to a sub-regional basis. Progress towards an overall APG has been relatively slow, although a key exception is rapid growth in electricity exports from Lao PDR.

The APG is one of two main physical energy infrastructure projects in the Master Plan on ASEAN Connectivity 2025, the other being the Trans-ASEAN Gas Pipeline. The official design of the APG includes three sub-systems. The north system covers Cambodia, Lao PDR, Myanmar, Thailand, and Vietnam. The south system bridges Thailand, Indonesia (Sumatra, Batam), Malaysia (Peninsular), and Singapore. The east system connects Brunei Darussalam, Malaysia (Sabah, Sarawak), Indonesia (West Kalimantan), and the Philippines (Figure 2).

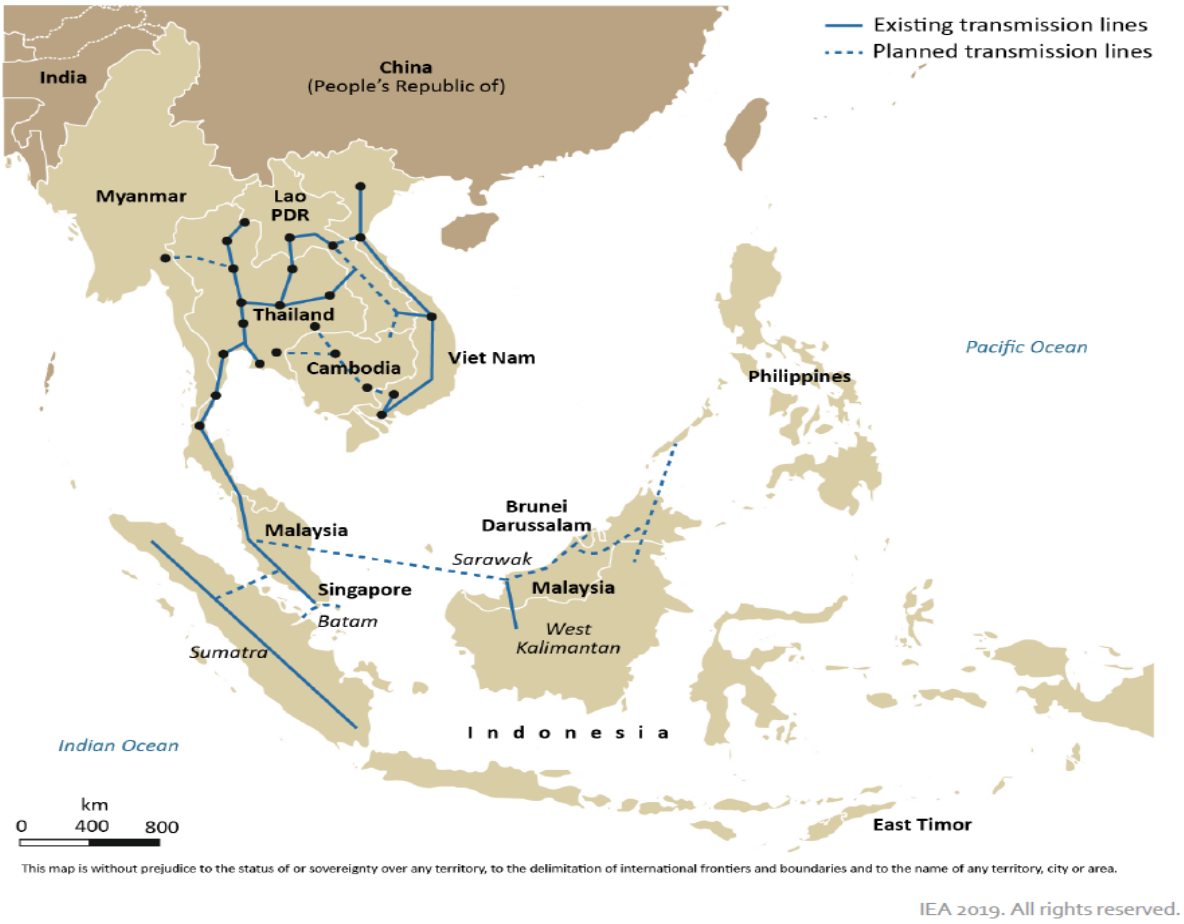

Figure 2. Asian Power Grid (International Energy Agency, 2019b).

By the end of 2010, six bilateral pairings of ASEAN countries had cross-border interconnections under the APG network: Malaysia-Singapore, Thailand-Malaysia, Lao PDR-Thailand, Thailand-Cambodia, Vietnam-Cambodia, and Lao PDR-Vietnam (ASEAN Secretariat, 2010). By December 2020, eight of 16 key cross-border APG interconnections were in operation, as shown in Table 2 (ASEAN Centre for Energy, 2020a). Progress on other connections such as Peninsular Malaysia-Sumatra (project number 4) and Sarawak-Sabah-Brunei (number 8) is still ongoing. The ASEAN Plan of Action for Energy Cooperation 2016–2025 Phase II has left the completion dates for some remaining projects open (ASEAN Centre for Energy, 2020a).

Table 2. Progress in APG interconnection projects.

Project code	Interconnection	Capacity as of December 2020 (MW)
North system		
9	Thailand-Lao PDR phase 1	5,427
10	Lao PDR-Vietnam phase 1	538
11	Thailand-Myanmar	-
12	Vietnam-Cambodia	200
13	Lao PDR-Cambodia	200
14	Thailand-Cambodia	230
South system		
1	Peninsular Malaysia-Singapore	525
2	Thailand-Peninsular Malaysia	300
3	Sarawak-Peninsular Malaysia	-
4	Peninsular Malaysia-Sumatra	-
5	Batam-Singapore	-
16	Singapore-Sumatra	-
East system		
6	Sarawak-West Kalimantan	230
7	Philippines-Sabah	-
8	Sarawak-Sabah-Brunei	-
15	East Sabah-East Kalimantan	-

Source: Compiled by the authors using information from the International Energy Agency (2019b), ASEAN Centre for Energy (2020a,b), REGlobal (2020), and various internet sources. Note: Project codes are as defined in the ASEAN Interconnection Masterplan Study (AIMS).

Among the potential benefits, the development of an APG has the potential to enhance security of supply for the region by enabling effective utilization of resources across geographical locations (Shi et al., 2019; ASEAN Centre for Energy, 2020b). Some countries would gain by being able to export electricity at certain times, while others would gain by being able to import lower-cost electricity. Some countries may both import and export (Antweiler, 2016). Reserve capacity could also be shared, which could boost energy security. It has been estimated that ASEAN would be able to save about US$1–3 billion per year in total operating costs due to a reduction in average supply costs of about $1–3/MWh by cross-border electricity trade even without new interconnections relative to a scenario without cross-border electricity trade (International Energy Agency, 2019c).

Another potential benefit is in the integration of renewable energy into the electricity market (ASEAN Centre for Energy, 2020b; Boz et al., 2021). More geographically diversified power systems are better suited to the integration of higher shares of intermittent renewables, as they allow for a smoothing of resource availability. The APG could thus contribute to a reduction in greenhouse

gas emissions, although whether it would do so depends on the extent to which renewables are chosen over fossil alternatives (Lu et al., 2021). Cross-border electricity trade could also help to reduce energy poverty, particularly in the context of small-scale trade for remote communities such as along Myanmar's border with Thailand and Malaysia's border with Indonesia (International Energy Agency, 2019d).

5 Barriers to multilateral and unified cross-border electricity trade in ASEAN

We classify barriers to either a region-wide multilateral model or a unified model of cross-border electricity trade in ASEAN into political, technical and institutional, economic, environmental, and social dimensions.

5.1 Political mistrust

ASEAN leaders have shown some political interest in working toward increasing cross-border electricity trade, as seen in the "ASEAN Economic Blueprints" and in annual ASEAN Minister of Energy Meetings and Senior Officials Meetings on Energy to oversee the cooperation process. There has been cooperation at the operational level, with the Heads of ASEAN Power Utilities/Authorities and the ASEAN Centre for Energy coordinating the implementation of Plans of Action on Energy Cooperation (ASEAN Centre for Energy, 2020a,b). However a key challenge has been a lack of sufficient political trust and support for the APG agenda (Wu, 2016; Halawa et al., 2018). It is difficult to move to a deep form of integration for such a strategically vital industry without this.

Some ASEAN members attach high importance to the concepts of sovereignty and nationalism. This can easily translate into protectionism (Andrews-Speed, 2016). For example, Indonesia's existing regulations allow for the possibility of electricity imports but give priority to national generation capacity and stipulate that national sovereignty should not be violated (Aalto, 2014b). The notion of self-sufficiency has also been a key barrier to cross-border electricity trade elsewhere (Singh et al., 2018; Nangia, 2019; Remy and Chattopadhyay, 2020; Valickova and Elms, 2021).

Risk aversion has some underlying roots. Many vital systems, such as national defence systems, depend on electricity (International Energy Agency, 2019b). Electricity is also a special commodity in that supply must instantaneously meet demand (Aintweiler, 2016). While storage, backup systems and supply diversification can be in place, some countries have nevertheless to date sought to avoid relying too heavily on their neighbours – especially strategic rivals – for significant flows of electricity (Yao et al., 2021). This is despite the high reliance on international trade for more storable energy products such as coal and natural gas (as observed in Figure 1). The fundamental strategic importance of electricity is likely to continue to increase over time as it continues to account for a growing share of final energy use (Helm and Hepburn, 2019).

Another reason why electricity is a relatively special case is that trade relies on fixed transmission infrastructure. Consider the alternative cases of oil and liquefied natural gas (LNG): there are many suppliers of these products, so consuming countries can typically divert to alternative suppliers if necessary (Brinkerink et al. 2019). Oil and LNG are also more easily stored, so buffers can be maintained. Thus, an energy-poor country such as Singapore has to date chosen to rely on importing fuels to generate most of its electricity rather than importing electricity, despite ample opportunities for the latter (International Energy Agency, 2019a). Singapore's preference for flexibility has been highlighted by its decision to build LNG terminals to reduce reliance on fixed cross-border gas pipelines from Indonesia and Malaysia.

Concerns about imported electricity can become even more pronounced when trade involves multiple countries, as potential hold-up and free-riding problems can be exacerbated (Oseni and Pollitt, 2016; Brinkerink et al. 2019). Investments in cross-border transmission connections are inflexible and irreversible; once built, interconnectors are only useful for electricity transmission between the trading partners and nothing else. Inflexibility provides a reason to go slow on these connections in the face of the risk of stranded assets.

Despite the cross-border hold-up issues, it should be remembered that electricity trade is only one way in which countries interact (Overland, 2019). If one country were to disrupt the electricity supply of another, there are other ways by which the country could be punished, for example via reductions in trade in another good or service or diplomatic punishments. There are also avenues

for political risk insurance such as the Multilateral Investment Guarantee Agency (World Bank, 2020).

Altogether, ASEAN's electricity cooperation has followed the ASEAN mode of governance, which is characterized by largely informal institutional cooperation with non-binding consequences (Aalto, 2014b; Andrews-Speed, 2016). At meetings, governments often discuss and agree on general and easy points. Complex issues relating to long-term projects are often postponed or remain unresolved because regional electricity integration is seen as a long-term process well beyond the usual political cycle (Nangia, 2019). "Spill-around" – the situation in which limited progress is made with relatively uncoordinated efforts (Schmitter 1970) – has been observed instead of deep regional integration. The political barriers have often been mentioned in academic documents rather than in government reports. They have often received inadequate attention.

5.2 Technical and institutional incompatibilities

ASEAN has a challenging geography relative to Western Europe or North America due to having many islands. There are also technical and institutional challenges given that a unified electricity market would require the harmonization of technical standards and operational procedures at the regional level (Aalto, 2014b; Sanchez Miranda, 2020). This would be a complex task given the diversity of ASEAN and of its power systems in terms of standards, specifications, and protocols for electricity transmission and distribution (Shi et al., 2019). Market integration also requires information sharing, yet ASEAN countries are not always keen to do so when it comes to this sector, including because of data sensitivities relating to national security concerns (Aalto, 2014b). Harmonization requires improved institutional capacities of participating utilities, including the ability to command a common language, probably English (International Energy Agency, 2019b). This requires staff training and document translation. The more integrated the market model, the greater the challenge.

Institutional harmonization would require revisions to various national regulations (Sanchez Miranda, 2020). These include regulations on cross-border licencing, non-discriminatory access to networks, competition in generation, and import tariffs (Li et al., 2020; Yao et al., 2021). A factor that reportedly contributed to Singapore being slow to join the Lao PDR-Thailand-Malaysia trading

arrangement is that Singapore has a competitive wholesale market for electricity and is hesitant to contract for a fixed quantity of supply (Owen et al., 2019). Greater Mekong Subregion countries have yet to finish technical standard harmonization, despite starting this work with the assistance of the Asian Development Bank in 1995 (Owen et al., 2019). An APG, with a considerably bigger scale and more diverse setting, is much more complex.

Resistance from incumbent utilities augments these difficulties. State-owned utilities in countries such as Indonesia are likely to not want to forego their current market dominance to enter a more competitive context (International Renewable Energy Agency, 2018; Owen et al., 2019). Some high-cost electricity generators (including those owned by state-owned utilities) would also become uncompetitive if wholesale prices were to converge under a strong form of market integration (Oseni and Pollitt, 2016; International Energy Agency, 2019a). Being risk averse and keen to protect their incumbent positions, electricity utilities often favour the status quo (Oseni and Pollitt, 2016). With strong lobbying power, they can use various technical reasons to slow moves to regional integration. It would take a major round of reform within key countries such as Indonesia to bring state-owned electricity utilities to a ready state for active cross-border competition and trade at the wholesale level.

5.3 Economic barriers

Several economic analyses of the APG have been conducted, including the ASEAN Interconnection Master Plan Study (AIMS) completed in 2003 (AIMS I) and a second version in 2010 (AIMS II). As of early 2022, an AIMS III is currently being developed. Cost analysis for ASEAN multilateral cross-border electricity trade has largely focused on physical construction costs. Other aspects such as transaction costs and cost sharing have often been under-examined. We focus on these aspects here.

5.3.1 Transaction costs

Setting up a regional power market would involve costs for upgrading the capacity of existing institutions and/or the establishment of a new centralized entity (Oseni and Pollitt, 2016). Market integration requires considerable time and resources and a variety of formal institutions to be developed (Aalto, 2014a). Establishing a new centralized institution would be ambitious over a

short time horizon. Countries may not agree on even simple matters such as its location, as has been the case for the proposed Regional Power Coordination Centre in the Greater Mekong Subregion (Weatherby and Eyler, 2017).

Another type of transaction cost involves dispute resolution. Relevant multilateral legal frameworks regulating cross-border trade include the World Trade Organization and the Energy Charter Treaty (Oseni and Pollitt, 2016; Sanchez Miranda, 2020), yet ASEAN countries have yet to become parties to the latter. These legal frameworks are also likely to be inadequate in facilitating investment in cross-border transmission and electricity trade due to the complexity of cross-border electricity trade (Sanchez Miranda, 2020). The Multilateral Investment Guarantee Agency also only provides political risk insurance for up to 20 years (World Bank, 2020), shorter than the life of cross-border transmission assets. It is likely that there would thus be sizeable transaction costs in establishing and enforcing dispute resolution mechanisms in the case of cross-border electricity infrastructure in ASEAN (Aalto, 2014a; McCann et al., 2005).

5.3.2 Cost sharing

It is unclear how the financing of APG connections and institutions would be shared. Cost sharing could be in proportion to each party's net benefits (International Energy Agency, 2019a), yet it is difficult to quantify and agree on these (Yao et al., 2021). In practice, cost sharing typically needs to be determined by political agreement and following broader principles (International Energy Agency, 2019a). Political mistrust in cross-border electricity trade makes this quite challenging, as discussed above. ASEAN also has a much smaller budget than another key transnational entity, the European Union (Aalto, 2014a).

Some ASEAN countries had quite high external public debt levels even before the COVID-19 crisis, with the external public debts of Lao PDR, Malaysia, and Vietnam equal to 63%, 52%, and 44% of their GDPs respectively in 2019 (International Monetary Fund, 2021). Consequently, public borrowing for projects such as cross-border transmission connections can face constraints, particularly given the many other development priorities in the post-COVID era. Improving cross-border interconnections is not among the top investment priorities of many countries

(International Energy Agency, 2019a). Investment would also be needed in domestic transmission systems to facilitate greater cross-border trade (Oseni and Pollitt, 2016).

While the private sector plays a key role in electricity generation in some ASEAN countries (Wu, 2016), without strong government backing it is often not keen to invest significantly in cross-border transmission infrastructure given the costs and risks involved, despite the improvements in high-voltage direct current (HVDC) cables that have been witnessed (Aalto, 2014b; Nangia, 2019; Shi and Yao, 2020). While multilateral development banks may be interested, no significant investments have been made to date (International Energy Agency, 2019b).

5.4 Environmental impacts

The construction of transmission lines has an environmental cost, and particularly so given that some border regions are relatively pristine. Cross-border interconnections may also in some settings encourage greater use of coal, which itself would bring environmental and social costs. The Hongsa Power Plant and Mining Project, for example, was built in 2015 in Xayaboury Province, Lao PDR, with a capacity of 1,473 MW and the key aim of exporting electricity to Thailand (Tran and Suhardiman, 2020). Project risks include water pollution, damage to wilderness, damage to local livelihoods, air pollution, and climate change (McCartney and Brunner, 2020). At a regional scale, coal power plants are estimated to cause about 20,000 excess deaths per year in ASEAN (Koplitz et al., 2017).

The establishment of an APG could also open the way for new hydrodams in the Mekong region. This would impose external environmental and social costs on riparian countries (Lu et al., 2014; Wu, 2016; Grafton et al., 2019; Hirsch, 2020; Tran and Suhardiman, 2020; Yong, 2020; McCartney and Brunner, 2020). The external costs from losses of capture fisheries and sediments, biodiversity reduction, and social impacts resulting from the development of 11 hydropower dams in the Lower Mekong Basin have been estimated to be about US$18 billion in present value terms (Intralawan et al., 2018). Hydro dams in the Mekong also pose risks to the livelihood of millions of people (McCartney and Brunner, 2020). Similarly, the development of hydropower dams in Sarawak, Malaysia for electricity exports to Indonesia and Brunei Darussalam risks negative impacts such as land grabs, biodiversity loss, and undermining the traditional lives of indigenous people (Cook et

al., 2017). Unfortunately, environmental and social costs have tended to be underweighted in environmental impact assessments of hydropower projects because the assessments have been typically limited to only a short distance from the dam site (Hirsch, 2020). In a delta environment, the full implications for fish stocks and ecosystem services can be sizeable.

Cross-border environmental impacts are likely to impede progress toward multilateral and unified cross-border electricity trade (Wu, 2016). For example, local communities and civil society in Cambodia, Thailand, and Vietnam are not always keen to support an approach that would incentivise additional dams being built upstream (Suhardiman and Middleton, 2020; Tran and Suhardiman, 2020; Yong, 2020). More generally, there are concerns about countries competing on an uneven playing field in terms of environmental standards. Singapore has a domestic carbon tax, for instance, whereas Malaysia and for example Vietnam are yet to adopt one (Do and Burke, 2021). It would be undesirable to see "leakage" of electricity production across the border simply to avoid paying this tax.

Subsidies and policy distortions further exacerbate the issue (Oseni and Pollitt, 2016). In Indonesia, a domestic market obligation exists that places downward pressure on the price of coal, thus contributing to artificially low electricity generation costs (Burke et al., 2019). If Indonesia were to export coal-fired power to neighbouring countries, there may be disputes about whether this is fair.

ASEAN's current reliance on coal-fired power and hydropower for cross-border electricity trade is unsustainable. There is a particular risk that coal power projects for electricity export in Lao PDR will become stranded assets due to both growing competition from alternative energy sources and growing environmental concerns (Tran and Suhardiman, 2020). Climate change may also exacerbate the negative impacts of hydro dams. For example, climate change-induced droughts in the Mekong region have increased risks of insufficient water availability for dam operations in the dry season (McCartney and Brunner, 2020).

5.5 Social aspects

The APG differs from the Nord Pool, Southern African Power Pool (SAPP), and the Central American Electrical Interconnection System (SIEPAC), where participating countries have a long history of

political, economic, and cultural interactions that paved the way for the development of multilateral cross-border electricity trade. ASEAN countries tend to have more sizeable ongoing differences (Aalto, 2014a). Decades of preparing for multilateral cross-border electricity trade based on bilateral PPAs with support from multilateral development banks are common aspects of the history of the development of the SAPP and SIEPAC (Oseni and Pollitt, 2016; Nangia, 2019), while strong support from business and civil society have been key factors in the Nord Pool's success (Andrews-Speed, 2016). These enabling conditions are currently still being developed in ASEAN.

6 The way forward

6.1 Time dimension

The majority of the barriers to multilateral and unified cross-border electricity trade in ASEAN will require long-term efforts to address. Table 3 provides assessments of whether the barriers are likely to be surmountable this decade or only over a longer time dimension. While ongoing preparations should continue (ASEAN Centre for Energy, 2020a,b), many barriers would need a timeframe extending beyond 2030 to be adequately addressed. Most of the barriers that ASEAN plans to address during 2021–2025 are technical and institutional (ASEAN Centre for Energy, 2020a). Crucial political barriers are not mentioned in the current plan and are unlikely to be addressed in the short term, as significant cooperative efforts are needed that will take time to be fostered (Shi et al., 2019). The public good nature of the APG also means that it would take years to establish effective regional mechanisms to address some of the economic and environmental barriers to the APG (Hirsch, 2020). A move to a deeper multilateral model of electricity trade is thus highly unlikely during 2022–2030 and would likely only become realistic in the years beyond 2030.

Table 3. Time dimension for addressing barriers to ASEAN cross-border electricity trade.

Barriers		Estimated time dimension to address	
		2021–2030	Beyond 2030
Political	• Concerns over imported electricity		X
	• "ASEAN way" of largely informal institutional cooperation with non-binding consequences		X
Technical and institutional	• Geographically dispersed grids		X
	• Incompatibilities of technical standards and operational procedures	X	
	• Limited data sharing	X	
	• Language differences	X	

Barriers		Estimated time dimension to address	
		2021–2030	Beyond 2030
	• Regulation and market incompatibilities		X
	• Incumbent utilities' resistance		X
Economic	• Large transaction costs of setting up and operating regional electricity market		X
	• Lack of dispute settling mechanisms	X	
	• Distorting subsidy		X
	• Unclear cost sharing mechanisms	X	
	• Limited financial resources		X
	• Lack of financial mobilization incentives		X
Environmental	• External environmental costs of types of traded electricity		X
	• Concerns about countries competing on an uneven playing field in terms of environmental standards.		X
Social	• Lack of supportive regional cooperation norms		X
	• Lack of business and civil society support		X

Source: Authors' compilation from Aalto (2014b); Wu (2016); Sanchez Miranda (2020); Owen et al. (2019); Shi et al. (2019); ASEAN Centre for Energy (2020a,b); Yao et al. (2021).

6.2 Bilateral cross-border electricity trade as a pragmatic approach

For the foreseeable future, continued development of bilateral cross-border electricity trade offers a practical way forward. Such trade can be structured in the form of bilateral PPAs in which trading partners agree on prices and quantities (International Energy Agency, 2019a). PPA terms can be reached via either bilateral negotiation or, in situations where there are multiple potential suppliers such as solar power supplies from Indonesia, by auctions. To help to share project development risks, electricity importers could invest directly in the generating assets and transmission infrastructure, as in the case of Thailand importing from Lao PDR. The bilateral model can also involve bidirectional trade in which the parties import and export via different PPAs, as in the current electricity trade between Lao PDR and Vietnam.

A bilateral model based on PPAs has fewer requirements for technical and institutional harmonization at initial stages than a more integrated approach. Bilateral negotiations are faster, easier, and more likely to maintain political trust. It is also easier to put in place measures to address environmental and social issues and agree to cost sharing arrangements on a bilateral basis. The model is a good fit with the current electricity market structures of key ASEAN countries given their heavy reliance on PPAs (Aalto, 2014b). Among the potential trading pairs are Lao PDR-Vietnam, Lao PDR-Thailand, Vietnam-Cambodia, Malaysia-Singapore, Indonesia-Singapore, Indonesia-Malaysia, and Myanmar-Thailand. Each of these pairs have relatively stable political relationships.

Bilateral interconnections could gradually underpin greater connectivity and integration over time and a subsequent move to more multilateral arrangements (Aalto, 2014b; Wu, 2016; Singh et al., 2018). Continuing with the bilateral model for the short to medium term could also enable ASEAN countries to continue to improve grid flexibility via domestic reforms in preparation for a potential deepening of integration in the future (Huang et al., 2019). There are also opportunities to expand trade in ancillary services for system safety, security, and reliability (Sanchez Miranda, 2020). Success in boosting regional interconnectivity is more likely if a well thought-through policy sequencing approach is followed, as seen in the overcoming of some political challenges in other global and regional efforts such as the introduction of carbon pricing in Europe (Meckling et al., 2017).

Light models of multilateral trade that include trade via intermediary countries are also highly prospective, with the Lao-Thai-Malaysia (and soon Singapore) sub-regional trading model a worthy model for further development. Looking further ahead, if harmonization of technical standards and regulations can be successfully achieved, and if more countries can make progress in the establishment of competitive wholesale electricity markets, the underpinnings would then be stronger for a move toward a deeper and broader form of power trade integration in ASEAN. Political will is a requisite. Such a move may be sub-regional in nature, with some countries not participating.

The absence of an ambitious agenda towards deep regional economic integration in ASEAN (Ishikawa, 2021) means that realistically it is likely to be many more decades before a unified model of electricity trade becomes a possible option for the region as a whole. The level of integration observed in the Nord Pool, for example, is not likely for ASEAN in the foreseeable future.

6.3 Trade with partners outside ASEAN

In terms of partners outside ASEAN, there is substantial potential for expanded trade with China. China exported about 37 TWh to Vietnam, Myanmar, and Lao PDR in 2018 (China Southern Power Grid, 2019) and has shown interest in supplying to other ASEAN countries (ASEAN Centre for Energy, 2017). Under the Belt and Road Initiative, funding can be accessible for investment in such interconnectivity (Feng et al., 2020).

Another potential exporter is Australia, which has a large endowment of solar and wind resources plus available land (Lu et al., 2021; Burke et al. 2022). Australia has maintained a relatively stable political relationship with ASEAN and, with total merchandise trade of A$91 billion in 2018, is among ASEAN's largest trade partners (Australian Department of Foreign Affairs and Trade, 2019). The Sydney Declaration of the Australian-ASEAN Summit 2018 paves a path for expanding trade to renewable energy. Challenges include a lack of prioritization by the Australian Government and the costs of building subsea transmission systems to the closest ASEAN countries such as Indonesia and Singapore (Halawa et al., 2018). There is currently a private sector project proposal to develop an Australia-Asia PowerLink connection to Singapore via Indonesian waters (Sun Cable, 2021).

ASEAN also has potential electricity trade opportunities with India and Bangladesh (USAID, 2018). These largely depend on Myanmar, where political issues loom large (Yang et al., 2021). Other opportunities could come from trade via subsea HVDC cables to tap the offshore wind power potential in East Asian economies such as Japan, South Korea, and Taiwan (Itiki et al., 2020). These resources would serve as a natural complement to domestic solar power in ASEAN countries.

6.4 Sustainable energy

Solar and wind power are now dominating new investment in electricity generation capacity around the world (Burke and Do, 2021). Analysis suggests that there are opportunities for ASEAN to move to a mostly solar and wind (plus off-river pumped hydro energy storage) system at a competitive levelized cost of electricity of US$55–115/MWh (Lu et al., 2021). Solar and wind have the potential to be associated with lower environmental and social costs than fossil fuels and hydropower, especially if sited in relatively low-impact locations. Vietnam is an example of an ASEAN country that is currently seeing substantial investment in renewables (Do et al., 2020; 2021). There are also sizable potentials in other countries, for example onshore and offshore solar PV in Indonesia (Silalahi et al., 2021). Countries will be more likely to engage in cross-border electricity trade if electricity is green (Wu, 2016; Adeoye and Spataru, 2018; Overland, 2019).

Increased cross-border electricity trade with solar and wind power could enable ASEAN countries to increase the ambitions of their Nationally Determined Contributions (NDCs) under the Paris Agreement. The pegging of the current NDCs to highly inflated business-as-usual emission scenarios means that emissions have been and are allowed to increase. Under the current trajectory, ASEAN's renewable energy share (excluding traditional biofuels used by households) in total primary energy supply has been projected to reach only 24.5% by 2030 while it should be 41% to be on track to achieve the 1.5^{o}C target under the Paris Agreement (ASEAN Centre for Energy, 2020b). Ramping up of cross-border bilateral electricity trade during 2022–2030 while preparing for more regional integration in the post-2030 period would have the potential to help to facilitate the ASEAN decarbonization toward long-term net-zero emission targets.

7 Conclusion

We have reached a key moment in terms of future plans for cross-border electricity trade in ASEAN. Progress on ASEAN power trade has altogether been relatively slow, with the notable exception of Lao PDR, which has rapidly increased its electricity exports. We conclude that aiming for much in the way of ASEAN electricity market integration by 2025 is impractical and that a more practical way forward is to focus on bilateral cross-border contracts for the time being. Efforts to prematurely accelerate either multilateral or unified cross-border electricity trade may stretch already-thin resources and be frustrated due to the existence of a range of barriers, from economic to institutional. This is particularly relevant in the post-COVID context in which other priorities abound. Appropriate sequencing of steps, and an initial focus on priorities such as harmonization of technical standards, may pave the way for more decisive integration in due course.

A principal focus on bilateral PPAs provides an attractive approach in that they are easier to implement than deeper forms of integration. The bilateral PPA model is also a good fit with the PPA-oriented models used in the electricity sectors of key ASEAN countries such as Indonesia. As bilateral interconnections are built and familiarity with cross-border trade in electricity grows, stronger foundations would exist for a move towards a more integrated model of cross-border electricity trade after 2030. Domestic reforms to electricity sectors would also help to both boost competitiveness and create more conducive conditions for future progress toward multilateral

trade models.

Importantly, ASEAN should ideally pursue electricity market development in a sustainable manner via a focus on projects that minimize negative externalities. There is growing potential for a rapid expansion in investment in solar and wind power for both domestic and cross-border applications. This would help ASEAN to meet its renewables adoption and emission reduction targets and also the Sustainable Development Goals. The ASEAN case is relevant for discussions on cross-border electricity trade and renewable energy transition in other regions, for example South Asia, West Africa, and North Africa.

Further research on opportunities for scaling up ASEAN cross-border electricity trade would be useful. Studies on cost sharing could also provide useful insights into suitable mechanisms. Specific quantification of the environmental costs of cross-border interconnections could also be carried out. Additional research on the political economy of regional interconnectivity in the era of renewable energy could also shed additional light on both barriers to and opportunities for fruitful cross-border trade in clean energy.

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