



Regional electricity trade in ASEAN

**The road ahead to an integrated
and greener electricity future**

October 2022

www.pwc.com/sg





Contents

Executive summary	3
ASEAN's movement towards renewable energy	4
ASEAN's existing electricity trade	8
ASEAN's regional grid initiatives	16
Key areas of focus for cross-border renewable energy	18
Annex A	21

Executive summary

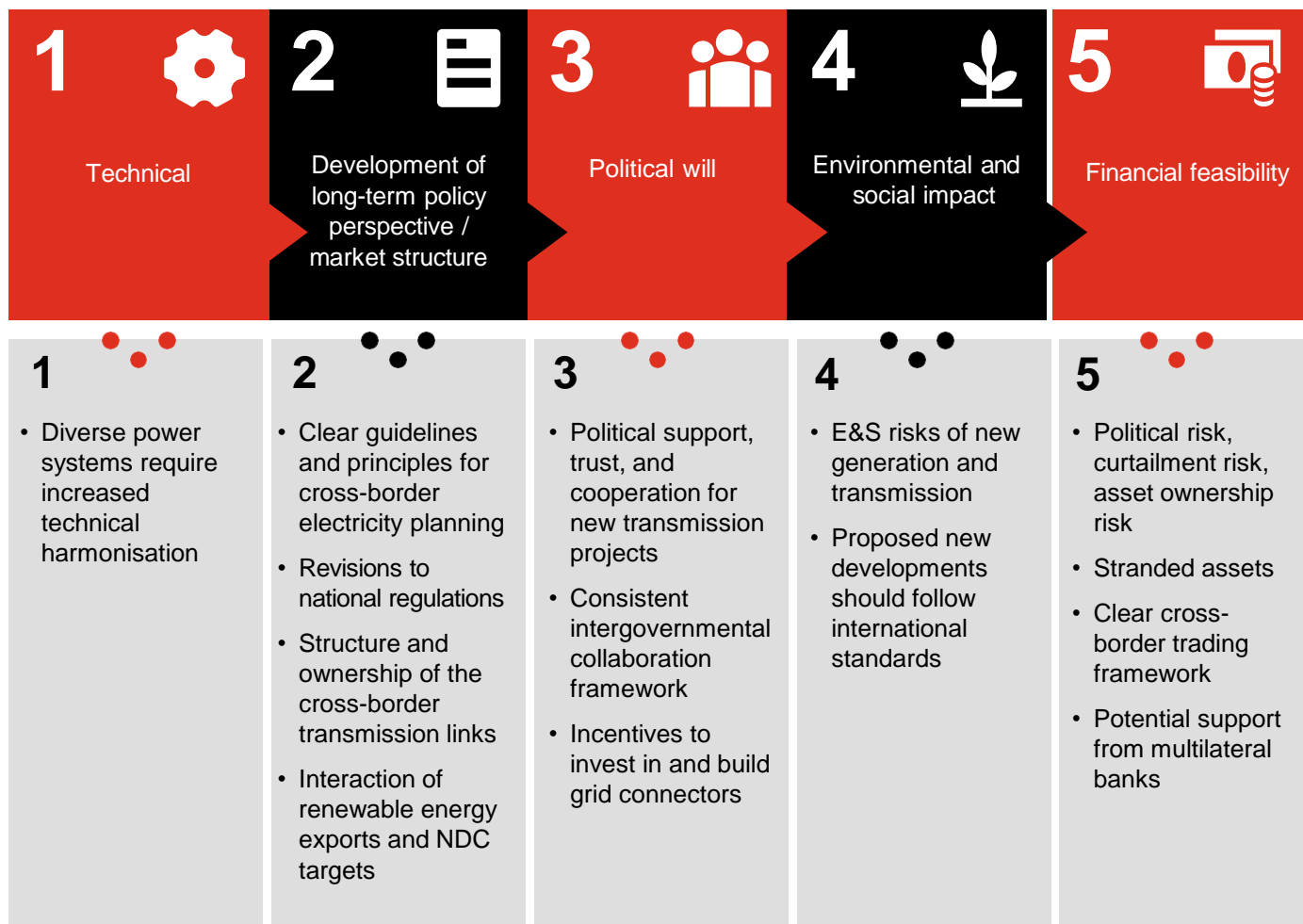
South East Asia's increasing demand for electricity along with the region's commitment to decarbonise means a need to rethink how the region can come together to achieve optimal electrification and decarbonisation goals.

ASEAN currently does not have an integrated electricity market. Each country's electricity market is managed and regulated individually by countries, and interconnection between national grids are limited. Power generation projects are also largely intended to meet domestic market demand.

There is significant potential for development of cross-border electricity trade, and eventually development of a regional electricity market. Cross-border transmission is not new to ASEAN, with at least 27 such links currently existing between ASEAN countries.

An integrated ASEAN power grid is expected to bring about significant benefits such as reduced cost and the ability to pool various renewable sources from countries with endowment advantages and supply to countries with significantly less resources. In addition, having an integrated power grid will allow countries to balance their power loads more efficiently by drawing required power from sources across the region. An integrated power grid would have more diversified and stable power sources. Hence, a plant failure would be less likely to significantly affect power supply across the region and the reserve margins can be minimised resulting in overall optimisation of resources and costs.

We consider key areas of focus for electricity imports and exports projects.



ASEAN's movement towards renewable energy

In our previous “Energy Transition Readiness in Southeast Asia” thought leadership publication, we assessed the levels of readiness for energy transition of the Southeast Asia countries based on six key criteria, including energy accessibility, energy reliability, energy affordability, energy sustainability, energy smartness, and energy trading, which outlined the steps that each country is taking in their movement towards renewable energy. Under energy trading, we focused on the opportunities and challenges in the development of the ASEAN Power Grid. In this piece, we explore the current electricity trade in Southeast Asia and challenges relating to regional trade of renewable energy.

Countries have committed to decarbonise

In 2020, the ASEAN region's GHG emissions from the power sector reached 668 Mton CO₂e¹. Coal, the biggest contributor of GHG emissions, contributed 72% while natural gas and oil contributed 26% and 2% respectively. In the region, the five largest contributors of GHG (Greenhouse Gas) emissions were Indonesia, Vietnam, Malaysia, Thailand, and the Philippines. With the growing GHG emissions, ASEAN has become one of the most vulnerable regions to climate change, with half of the ASEAN countries ranking in the top 20 of the world's countries most affected by extreme weather events².

ASEAN countries have made or updated their first Nationally Determined Contributions (NDC) targets in 2020 and 2021 and put in place plans to achieve NDC targets by 2030³.

Thailand targets to reduce GHG emissions by 20-25% from projected BAU (Business As Usual) level by 2030⁴. Thailand's forthcoming Long-term Low Greenhouse Gas Emission Development Strategy (LT-LEDS) and Climate Change Act is expected to aid the country in moving towards its NDC targets⁵.

Indonesia is aiming for an unconditional reduction target of 29% and conditional reduction target up to 41% of the BAU scenario by 2030⁶. Through the roadmap for transition to Net-Zero Emission, Indonesia aims to develop more renewable energy and reduce the use of coal-fired plants by up to 16.2 GW via the ADB Energy Transition Scheme⁷.

Vietnam unconditionally committed to reduce GHG emissions by 9% by 2030 below BAU levels, with a conditional target of reducing GHG emissions by 27% below BAU based on international support⁸. While the draft Power Development Plan 8 and Politburo's Resolution No. 55 supports the uptake of renewables, the development of coal is expected to continue, with coal capacity expected to double to over 40GW by 2030⁹.

Malaysia has set an unconditional target for 45% of carbon intensity reduction by 2030¹⁰. Like Thailand, Malaysia has also set out an LT-LEDS which is expected to be finalised by end of 2022¹¹.



¹ASEAN Centre for Energy (2022). Moving Beyond the NDCs: ASEAN Pathways to a Net-zero Emissions Power Sector in 2050, <https://aseanenergy.org/moving-beyond-the-ndcs-asean-pathways-to-a-net-zero-emissions-power-sector-in-2050/>

²ASEAN Centre for Energy (2020). Climate Change Highlights in ASEAN, https://accept.aseanenergy.org/wp-content/uploads/2020/03/Factsheet_Climate_Change_Highlights_in_ASEAN.pdf

³UNFCCC (2022). NDC Registry, <https://unfccc.int/NDCREG>

⁴UNFCCC (2022). Thailand's Updated Nationally Determined Contribution, <https://unfccc.int/sites/default/files/NDC/2022-06/Thailand%20Updated%20NDC.pdf>

⁵Climate Action Tracker (2021). Thailand Climate Policies and Action, <https://climateactiontracker.org/countries/thailand/policies-action/>

⁶UNFCCC (2022). Indonesia's Updated Nationally Determined Contribution, <https://unfccc.int/sites/default/files/NDC/2022-06/Updated%20NDC%20Indonesia%202021%20-%20corrected%20version.pdf>

⁷Energy Transition Partnership (2022). ASEAN Outlook for Zero Carbon Energy, <https://www.energytransitionpartnership.org/resource/asean-outlook-for-zero-carbon-energy/>

⁸UNFCCC (2022). Vietnam's Updated Nationally Determined Contribution, https://unfccc.int/sites/default/files/NDC/2022-06/Viet%20Nam_NDC_2020_Eng.pdf

⁹Climate Action Tracker (2021). Vietnam Climate Policies and Action, <https://climateactiontracker.org/countries/vietnam/policies-action/>

¹⁰UNFCCC (2022). Malaysia's Updated Nationally Determined Contribution, <https://unfccc.int/sites/default/files/NDC/2022-06/Malaysia%20NDC%20Updated%20Submission%20to%20UNFCCC%20July%202021%20final.pdf>

¹¹New Straits Times (2021). Malaysia Intends to Reduce Greenhouse Gas Emission by 45% by 2030, <https://www.nst.com.my/news/nation/2021/10/735618/msia-intends-reduce-greenhouse-gas-emission-45-pct-2030>

ASEAN's movement towards renewable energy



Singapore intends to peak emissions at 65 MtCO₂e around 2030, which allows it to achieve 36% reduction in emissions intensity from 2005 levels¹². Transformations in industry, economy and society through greater use of renewable energy and greater energy efficiency, adoption of advanced low-carbon technologies, and effective international collaboration were the three thrusts set out by the government to facilitate Singapore's low-carbon transition¹³.

Cambodia has set an emissions reduction target of 41.7% by 2030 compared to BAU¹⁴. Through its Long-Term Strategy for Carbon Neutrality, Cambodia has put in place a variety of mitigations which specifically target the agriculture, forestry, energy, transportation, industrial processes and product use, and waste sector¹⁵.

Laos has set an unconditional target for 60% GHG emission reductions compared to baseline scenario¹⁶. Renewable energy was a key focus in achieving the target as Laos aims to install 13GW of hydropower. If international support is provided, Laos is targeting to install 1GW of solar and wind, and 300MW of biomass¹⁷. During the COP26, 8 out of 10 ASEAN countries have announced their net zero target, with the earliest in 2050 and the latest in 2065¹⁸.

Given that the major ASEAN countries have ambitious GHG emission reduction targets, a developed electricity export-import market in the ASEAN region becomes increasingly relevant. This could aid ASEAN member countries to more efficiently achieve their NDC targets by 2030 and speed their movement towards net zero.

¹²UNFCCC (2022). Singapore's Updated Nationally Determined Contribution, <https://unfccc.int/sites/default/files/NDC/2022-06/Singapore%27s%20Update%20of%201st%20NDC.pdf>

¹³NCCS (2020). Singapore's Enhanced Nationally Determined Contribution and Long-Term Low-Emissions Development Strategy, <https://www.nccs.gov.sg/media/press-release/singapores-enhanced-nationally-determined-contribution-and-long-term-low-emissions-development-strategy>

¹⁴UNFCCC (2022). Cambodia's Updated Nationally Determined Contribution, https://unfccc.int/sites/default/files/NDC/2022-06/20201231_NDC_Update_Cambodia.pdf

¹⁵Cambodia National Council for Sustainable Development (2021). Cambodia's Long-Term Strategy for Carbon Neutrality, <https://ncsd.moe.gov.kh/resources/document/cambodia-LTS4CN-En>

¹⁶UNFCCC (2022). Laos' Updated Nationally Determined Contribution, <https://unfccc.int/sites/default/files/NDC/2022-06/NDC%202020%20of%20Lao%20PDR%20%28English%29%2C%2009%20April%202021%20%281%29.pdf>

¹⁷Enerdata (2022). Lao PDR Commits to Net-zero Emissions by 2050, <https://www.enerdata.net/publications/daily-energy-news/lao-pdr-commits-net-zero-emissions-2050.html>

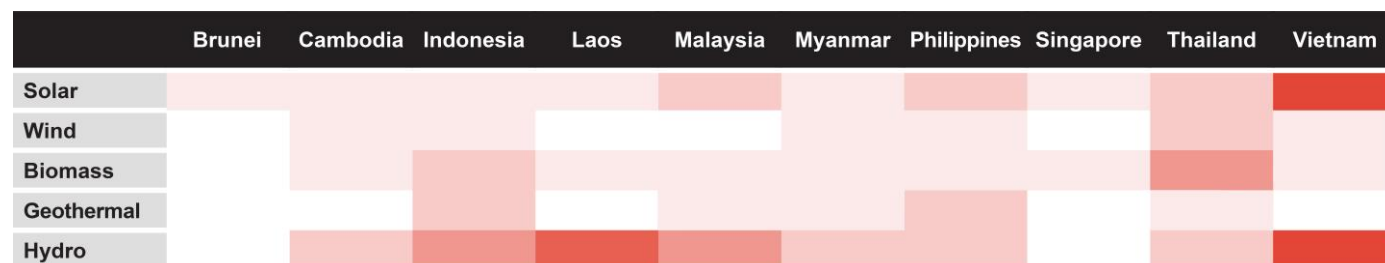
¹⁸Energy Transition Partnership (2022). ASEAN Outlook for Zero Carbon Energy, <https://www.energytransitionpartnership.org/resource/asean-outlook-for-zero-carbon-energy/>

ASEAN's movement towards renewable energy

Renewable energy potential in ASEAN

Countries in ASEAN produced 1,056 TWh of electricity in 2020¹⁹ with 283 GW of installed capacity²⁰. Around 76% of all ASEAN's power generation comes from coal- and natural gas-fired power facilities.

Chart 1: Renewable energy capacity in ASEAN countries (2020)



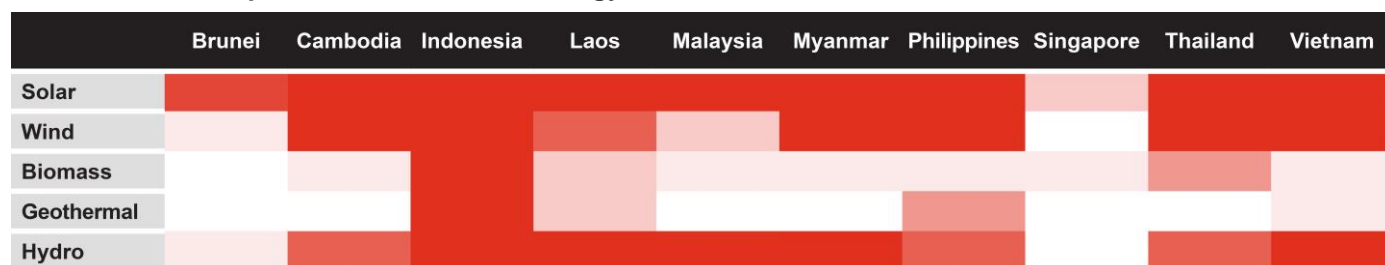
Source: US EIA

As ASEAN faces depleting energy reserves coupled with exponential growth in electricity demand, renewable energy is expected to be a solution to meet the energy demand. The percentage of solar and wind power production, out of all electricity production in ASEAN, has grown from 0.70% in 2016 to 1.73% in 2020. ASEAN countries – predominant among them Laos and Malaysia (Sarawak) – have long developed their hydropower resources; in total, 16.5% of ASEAN's total output is generated from hydropower. Laos' hydropower production as of 2020 is 170% more than its domestic consumption of electricity, and it exports up to 78% of its generation.

However, renewable generation in ASEAN still has a long way to go. We see countries such as Denmark having 50% wind power in their generation mix²¹. Variable renewable energy formed 23% of California's generation mix in 2020, and all renewables formed 33% of its energy mix²². On average, countries in ASEAN have 14% renewable energy in their generation mix²³.

The renewable energy capacity installed today does not tell the full story of the technical potential of each country. The technical potential of renewable production is set out in the chart below based on our analysis.

Chart 2: Technical potential of renewable energy in ASEAN Countries



Source: PwC analysis based on ASEAN Centre for Energy and National Renewable Energy Laboratory



¹⁹PwC Analysis based on IEA, Government Information, US EIA, Enerdata

²⁰US EIA Database

²¹Nordic Energy Research (2018). 10 Insights into the Nordic Energy system, <https://www.nordicenergy.org/wp-content/uploads/2018/06/10-Insights-A4.pdf>

²²California Energy Commission (2020). 2020 Total Electricity System Power, <https://www.energy.ca.gov/data-reports/energy-almanac/california-electricity-data/2020-total-system-electric-generation/2020>

²³IRENA (2022). Renewable energy Outlook for ASEAN: Towards a Regional Energy Transition (2nd Edition), <https://irena.org/publications/2022/Sep/Renewable-Energy-Outlook-for-ASEAN-2nd-edition>

ASEAN's movement towards renewable energy

Countries have unequal natural resource endowments, and this is challenging for countries without easy access to renewable energy development

Most countries in ASEAN have high technical potential for solar and wind development.

Vietnam has been able to exploit its solar potential with its feed-in-tariff regime implemented. Other countries such as Thailand, Myanmar, Indonesia and Philippines also have high variable renewable energy potential, in solar or wind, but are lagging behind Vietnam in their progress.

On the other hand, other countries in ASEAN have limited or non-diversified renewable energy resources. Countries like Brunei and Malaysia have more limited sources of renewable energy. Brunei only has high technical potential in solar, and while Malaysia has both solar and hydropower potential, most of Malaysia's hydropower resources are located on Borneo.

Singapore is maximising its solar deployment and is on track to achieve its target of 1.5 GWp by 2025 and at least 2 GWp by 2030. However, its solar potential is the smallest in ASEAN due to it being land constrained. Hence, solar will likely constitute only about 3% of the country's total electricity demand in 2030.

For countries which have significant technical potential in more than one area, they can develop renewable energy for their domestic needs as well as exports.

However, integration of increasing proportion of variable renewable energy into electricity grids will require significant investment into grid strengthening, and deployment of battery electric storage systems, control systems and smart grids to ensure secure and reliable electricity supply. In addition, widening control areas through interlinking of national grids to create a regional grid will also play a role in integrating variable renewable energy in ASEAN.



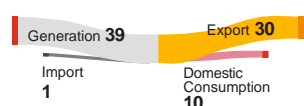
ASEAN's existing electricity trade

Countries in ASEAN are exporting and importing electricity regularly, although quantities for now are still small. Countries in ASEAN generate 1,053 TWh of electricity annually, and export 36 TWh of the generated electricity to other ASEAN countries. These flows tend to be bilateral and unidirectional – between two countries, where one country exports and the other imports.

Electricity exporters in the region

Currently, Laos, with its electricity generation surpluses, is the main exporter of electricity within ASEAN. Other countries such as Vietnam, Thailand, Malaysia and Myanmar also export.

Laos

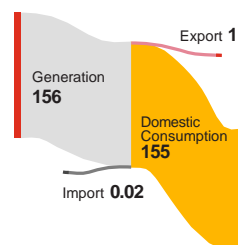


Units of diagrams in annual TWh
(2018-2020 average)

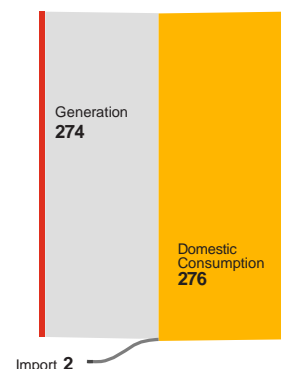
Laos aims to be called “the battery of Southeast Asia” by developing its hydroelectric power sector. Laos has significantly more generation technical capacity compared to its domestic consumption needs. Laos currently exports up to 78% of its generation. A surplus of generation capacity has been developed to provide stable, cleaner baseload electricity in the surrounding region. There has also been willingness from the private sector to sponsor and participate in these development projects, as well as early efforts by development organisations to assist in technical studies and provide guarantees and loans. For such projects to be scaled for regional trade, proper evaluation from an environmental and social impact assessment perspective is essential.

In Sarawak, Malaysia, the installed capacity under Sarawak Energy totals approximately 5,600 MW across Sarawak, with 3,500 MW of hydropower²⁴. Some of this renewable energy is anticipated to develop domestic industry under the Sarawak Corridor of Renewable Energy (SCORE) initiative in Samalaju Industry Park, intended to attract energy-intensive heavy industries²⁵. Given the deep potential for hydropower production in this region, Sarawak is also looking to export its energy to surrounding countries which include Indonesia, Brunei, and Singapore. There is currently one export link to export 200 MW to West Kalimantan (Indonesia), and there are early discussions on building transmission lines to export to other industry centres in Borneo.

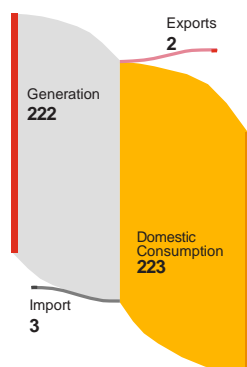
Malaysia



Indonesia



Vietnam



Vietnam and Thailand export around 1% of their generated electricity.

Both export on a limited basis to surrounding countries. Vietnam exports its excess hydropower in the South to Cambodia, especially in recent years with local drought in Cambodia affecting its domestic hydropower supply. Thailand used to export electricity to Laos during the dry season, before 2015. Since 2016, several large hydropower projects have come online in Laos, and now Thailand no longer exports to Laos. It still retains energy exchange transmission lines with Laos that facilitate electricity transmission between Laos' multiple grids.

Myanmar exports electricity from the 240MW Dapien-1²⁶ and 600MW Shweli-1²⁷ hydropower projects to China. China and Myanmar have been strengthening their power cooperation as part of the Belt and Road Initiative and to support the backbone grid of the China-Myanmar Economic Corridor.

Myanmar



²⁴Sarawak Energy (2022). Power Generation, <https://www.sarawakenergy.com/what-we-do/power-generation>.

²⁵Sarawak Energy (2022). Power Generation, <https://www.sarawakenergy.com/what-we-do/power-generation>.

²⁶SCMP (2021). China ramps up electricity imports from North Korea, Russia, Myanmar in bid to ease power crisis, <https://www.scmp.com/economy/china-economy/article/3153342/china-ramps-electricity-imports-north-korea-russia-myanmar>

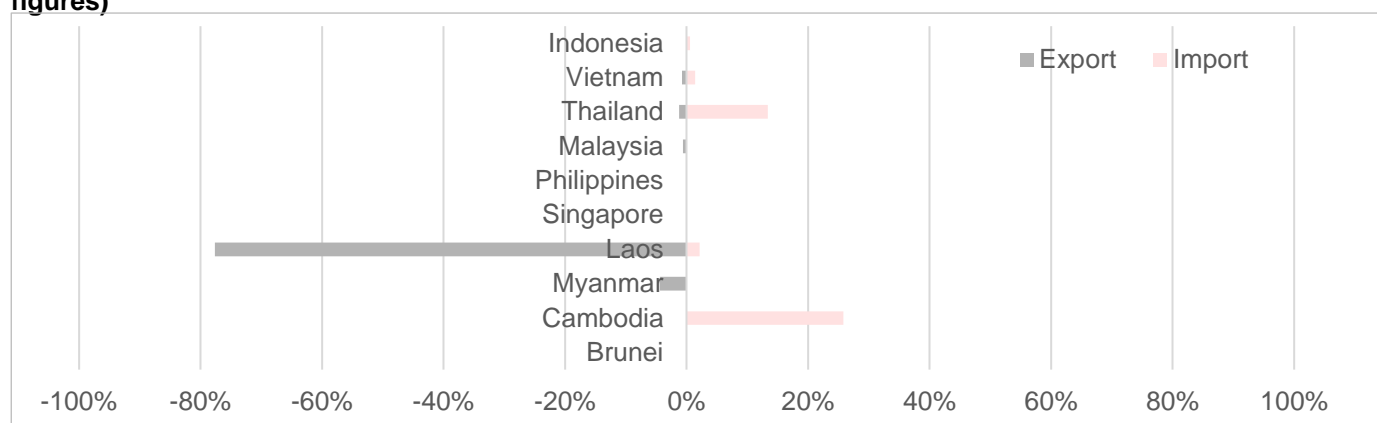
²⁷Power Technology (2021). Shweli I, Myanmar, <https://www.power-technology.com/marketdata/shweli-i-myanmar/>

ASEAN's existing electricity trade

Electricity importers in the region

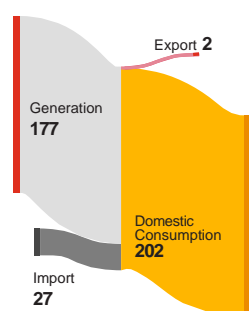
The countries around Laos – Thailand, Vietnam and Cambodia, all import electricity from Laos. In Borneo, Indonesia imports small amounts of hydropower from Sarawak. Laos reimports electricity from Thailand for purposes of energy transfer between its grids.

Chart 3: Percentage of exports, imports vs. generated energy in ASEAN countries (Averaged 2018-2020 figures)

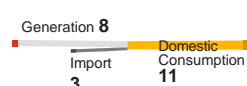


Source: PwC analysis based on IEA, Government information, US EIA, Enerdata
Note: Figures for Singapore's electricity imports are as of July 2022

Thailand



Cambodia



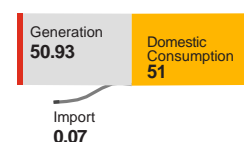
Units of diagrams in annual TWh
(2018-2020 average)

Cambodia and Thailand are the two main energy importers (going by percentage of their overall energy consumed).

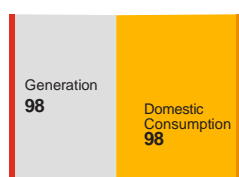
As shown in Chart 3, energy imports on average form 26% of Cambodia's total electricity consumption, due to local water shortages in Cambodia which impact its domestic hydropower generation. Similarly, Thailand imports 13% of its electricity use, to help meet its expected increase in domestic demand, and to expand its energy security²⁸, as part of Thailand's strategy to promote diverse energy sources²⁹.

Singapore recently started importing electricity through its import trials, one of which was the 100MW Lao PDR-Thailand-Malaysia-Singapore Power Integration Project (LTMS-PIP) on 23 June 2022. In 2021, the Singapore government announced Singapore's plans to import up to 4 GW of electricity by 2035, which would constitute around 30% of Singapore's electricity supply in 2035.

Singapore



Philippines



Brunei



Philippines and Brunei currently do not export and import any electricity from the region. Brunei, being on the same land mass as Sarawak, can potentially import electricity from other parts of Borneo via land transmission links.

²⁸Greater Mekong Subregion (2022). Lao PDR Ramps Up Electricity Exports to Vietnam, <https://greatermekong.org/lao-pdr-ramps-electricity-exports-viet-nam>.

²⁹Stimson (2022). Alternative Development Pathways for Thailand's Sustainable Electricity Trade with Laos, <https://www.stimson.org/2022/alternative-development-pathways-for-thailands-sustainable-electricity-trade-with-laos/>

ASEAN's existing electricity trade

Examples of cross-border electricity export projects by Laos

Most of these cross-border electricity trade projects have some form of bilateral Government involvement. Projects are also kickstarted with heavy private sector and development agency involvement. Projects can also be pure private sector projects, which gain permitting and licenses in both countries.

Examples of some of the export projects are given below.

	Project	Ownership	Capacity	COD	Cost
Multilateral (Hydropower)	Laos-Thailand-Malaysia Power Integration Project (LTM-PIP) Phase 1: Hydropower export from Laos to Malaysia	Various Governments	100 MW	2018	NA
	Laos-Thailand-Malaysia-Singapore Power Integration Project (LTMS-PIP) Phase 2: Hydropower export from Laos to Singapore	Various Governments	100 MW	2022	NA
Bilateral (Hydropower)	Nam Theun 2: Hydropower export from Laos to Thailand	EDFI (40%), EGCO (35%), LHSE (25%)	1,070 MW	2010	USD 1.45 billion capex
	Nam Ngum 2: Hydropower export from Laos to Thailand	CK Power Public (28.5%), EDL (25%), RATCH Group (25%)	615 MW	2013	USD 832 million capex
	Nam Ngum 3: Hydropower export from Laos to Thailand	Nam Ngum 3 Power Company EDL (20%), CSE (55%), EGATi (25%)	440 MW	2014	USD 780 million capex
Coal	Hong Sa Mine Lignite-fired Power Plant and Mine: Thermal power export from Laos to Thailand	Banpu Power (40%), RH International (Singapore) (subsidiary of RATCH Group) (40%), LHSE (20%)	1,878 MW	2015	USD 3.71 billion capex (includes power plant and mine)
	Boualapha Coal Fired Power Plant and BOT Transmission Line Facilities: Thermal power export from Laos to Vietnam	Lanexang Property and Power, Power Line Engineering, Shanghai Electric	2,000 MW	Est. 2024	NA
	Kaluem: Thermal power export from Laos to Cambodia	Xekong Thermal Power Plant Company Limited, subsidiary of Phonesack Group	1,800 MW	Est. 2025	USD 3-4 billion capex (includes power plant and transmission line)
Wind	Lamam: Thermal power export from Laos to Cambodia	TSBP Sekong Power and Mineral Company Limited	600-700 MW	Est. 2025	> USD 1 billion capex
	Monsoon Wind Power Plant - Tanh My: Wind power export from Laos to Vietnam	IEAD (Impact Energy Asia Development), a partnership between Impact Wind Investment (55%) and BCPG (45%)	600 MW	Est. 2025	USD 930 million capex
Transmission line investment	220kV Laos-Vietnam Transmission Line: Multiple generation sources of power export from Laos to Vietnam	BCPG	800 MW	Est. 2022	NA

Definitions

EDFI = Electricite de France International

EGCO = Electricity Generating Public Company of Thailand

LHSE = Lao Holding State Enterprise

CSE = Charoen Sekong Energy Company

EGATi = EGAT International Company

ASEAN's existing electricity trade

Grid infrastructure is a physical limitation to increased trade

Electricity exports and imports require fixed infrastructure to be built on a point-to-point basis³⁰. With global and regional push for renewable energy, opening up new transmission to connect the multitude of new sources is crucial for users to access the future green generation. As current grids are mostly built and upgraded by grid owners rather than electricity generators, centralised and timely planning is required to ensure that upgrades occur in sync with generation and that the grid/ transmission owners are incentivised to do so.

Countries such as Cambodia, Thailand and Vietnam have existing connections to other countries in ASEAN, this allows for energy exports, and the project arrangements can be precedents for future transmission line and energy project developments.

For other countries such as Myanmar, Indonesia and Philippines which have strong solar or wind potential, developing cross border transmission projects in these countries might require more regulatory and policy issues to be worked out as they do not have any ASEAN cross-border transmission precedents. It is not very clear whether Indonesia's government policy and regulations currently support electricity export, although industry players have been proposing changes to support development of some proposed renewable energy projects in border regions.

Due to geographical features, countries in ASEAN may have limitations on domestic grid connectivity between production and demand, e.g. Malaysia has its hydropower resources located on Borneo, which is not connected by land to Peninsular Malaysia. For these reasons, these countries have potential interest in renewable energy imports.

Singapore is also looking beyond its shores to access low-carbon energy. Currently, the Singapore government is working towards importing 4GW of low-carbon electricity by 2035, which will form 30% of Singapore's electricity supply in 2035, as part of Singapore's efforts to enhance energy security by diversifying energy supply sources.

In Asia, efforts have been ongoing to develop a regionally connected grid since 1997, led by ASEAN and other regional bodies together with member country governments. To date, initiatives to establish shared grids are still in development.

However, there is continuous progress towards developing cross border transmission links to export and import electricity. As of 2022, there are 27 export links in ASEAN. 16 of these transmission links are more than 115 kV and allow for larger energy transfers.

Land transmission links

In total, Laos has 20 connection points with its neighbours, see Chart 4 below. The links are predominantly to Thailand, but recently new links to Cambodia and Vietnam are being developed.

Of these export links, Laos-Thailand have the largest number of cross-border transmission links. There are two kinds of links: first, 115kV power exchange links, where power is exported and reimported to another grid in Laos, due to poor connectivity between Laos' grids. The energy exchanges between the grids are facilitated by direct interaction of the grid operators (e.g. the 5 interconnection points between Laos and Thailand, facilitated by EGAT and EDL). Second, export links or foreign IPP links, which directly import a specific project's generation to the importing country's grid, e.g. EGAT imports power under a PPA, directly from the IPP which is generating in Laos³¹.

Other countries in ASEAN have limited export links to their neighbours. Peninsular Malaysia, for instance, is connected at two points, to the north with Thailand, and to the south with Singapore. There have been discussions within the ASEAN Power Grid group of interconnection between Peninsular Malaysia and Sarawak, however, this was designated by the group as a later-stage priority in the list of potential cross border transmission links to develop³², and to date no announcements on further progress have been made.

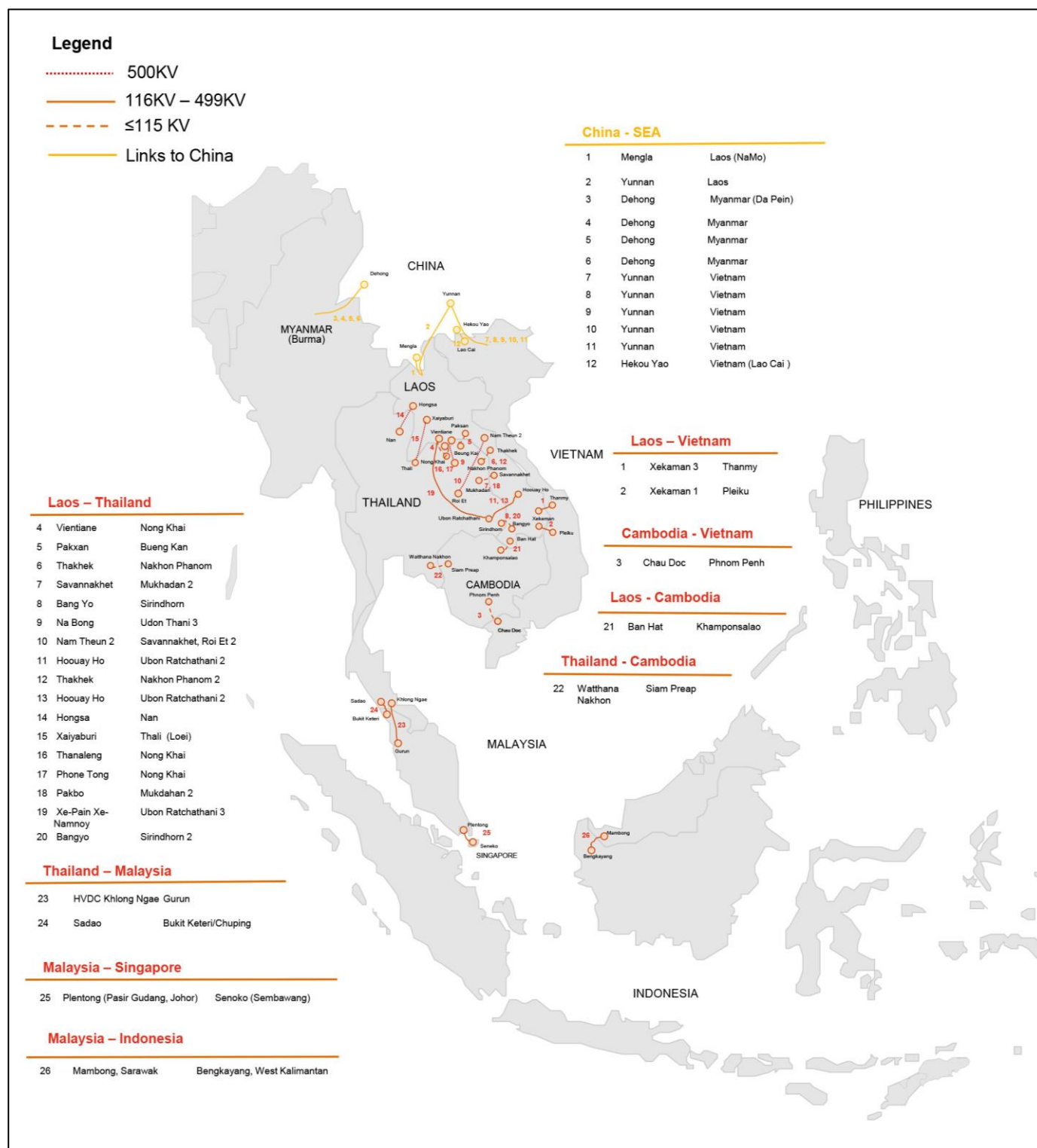
³⁰Piped Natural Gas (PNG)'s transmission infrastructure is similarly inflexible.

³¹Electricity Generating Authority of Thailand (2016). The role of cross-border power trade in meeting demand, <http://www.bigconnectivity.org/beta/sites/default/files/2017-03/01-Session%201.5-Thailand%20Case.pdf>

³²Malaysia Prime Minister's Department Economic Planning Unit (2013). Malaysia's Recent Development in RE & ASEAN Power Connectivity, <https://www.unescap.org/sites/default/files/Mr.%20Sabar%20Md%20%20Hashim%20-%20Malaysia%20Presentation.pdf>

ASEAN's existing electricity trade

Chart 4: Cross-border transmission between ASEAN countries



Source: PwC analysis. Full list of sources in Annex A.

ASEAN's existing electricity trade

Land transmission links (cont'd)

There is presently one instance of multilateral cross-border transmission in ASEAN, the LTMS-PIP pilot. The multilateral electricity transmission is intended to import a fixed capacity of 100 MW to Singapore, from Laos, wheeled through Thailand and Malaysia. This is wheeled using existing transmission infrastructure.

Thus far, all the links constructed have been land transmission links. ASEAN has a more challenging geography compared to Western Europe and other regional electricity markets, with islands and separated land masses which will need subsea cables to make cross border transmission connections.

Subsea cable transmission

Subsea cable cross-border transmission is an increasingly important subject in ASEAN. The nature of subsea cable transmission links is different from overhead transmission links, as it involves a different set of stakeholders and permitting approvals. Other subsea cabling challenges for investors are the higher costs, environmental approvals, regulatory and policy approvals, and the less understood risks of the cross-border transmission cable investment which may lead to more difficulty with financing. Most importantly, due to the high capex cost and lack of precedents in many countries for regional connectivity, discussions of asset ownership and potential sharing of use among various users becomes an essential part of the conversation.

Some upcoming projects such as the Request for Proposals by EMA³³, to import 4GW electricity to Singapore by 2035, will be pathfinders in establishing more regional connectivity with potentially new transmission subsea cable links.

The electricity imports are likely to be from multiple sources; and as Singapore is connected only to Malaysia by land, it is likely that there will be other subsea cable connections, or more multilateral wheeling arrangements established through this initiative for electricity import.

Towards greater grid integration in ASEAN

The above transmission links consist of a mix of private and public sector investments in electricity export projects. The number of transmission links are growing, and there is potential for significantly more cross-border transmission to take shape.

Greater integration of the transmission network in the region would benefit stakeholders by enabling investors to seek the lowest available LCOE regionally and allowing countries to plan investments in generation more efficiently. There are diversification benefits to expanding connectivity as this can help manage reserve margin on a regional basis and hence optimise overall system costs.

³³EMA (2022). Second Request for Proposal (RFP2), <https://www.ema.gov.sg/electricity-imports-rfp2.aspx>

ASEAN's existing electricity trade

An example of an integrated electricity market: Nord Pool³⁴

The Nordic Electricity Market (Nord Pool) links the four main Nordic nations, Norway, Denmark, Sweden and Finland, and the Baltic countries, Estonia, Latvia and Lithuania, and is now also fully integrated with EU power markets. The development of the Nordic power market began in the early 1990s in response to two pressures:

1. to improve the economic performance of national power sectors through market liberalization, initially in Norway, and
2. to take advantage of the complementary fuel mix in each of the four countries.

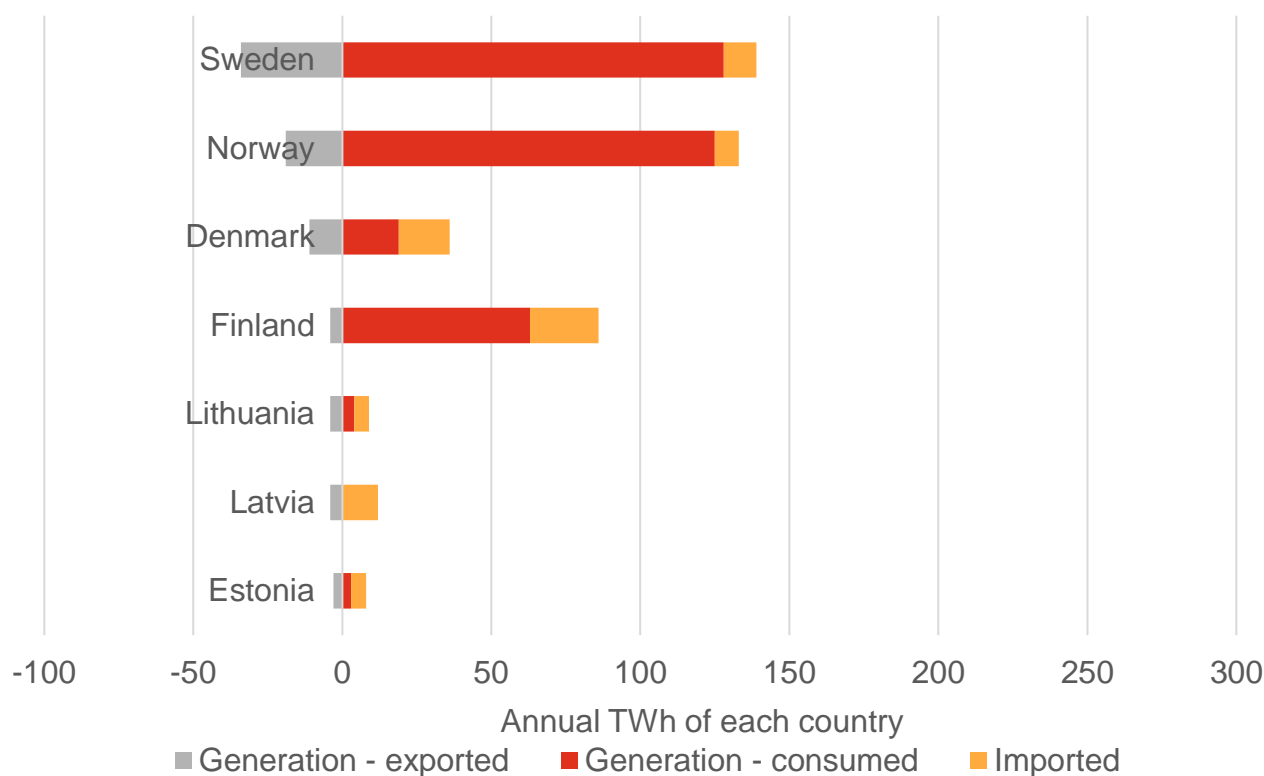
In contrast to the top-down EU approach to market integration, the development of the Nordic power market took place on an incremental and voluntary basis, driven by the utilities themselves.

Another key difference is that the regulation of the Nord Pool is based on principles agreed upon unanimously by the respective national governments for rules designed by the European Commission.

Generation supply³⁵

Having traded electricity in a common electricity market for 30 years, to date the Nordic and Baltic region countries generate ~420 TWh annually. In 2018-2020, these countries export 78.5 TWh and additionally import 81.5 TWh. The variation is large across countries. In contrast, ASEAN generates 1,053 TWh annually, and exports 3.42% of its electricity generation which amounts to 36 TWh.

Chart 5: Generation quantities and import-export flows of Nordic and Baltic countries (Averaged 2018-2020 figures)



Source: PwC analysis based on IEA, US EIA

³⁴Energy Studies Institute (2016). Connecting ASEAN through the Power Grid: Next Steps, <http://www.asean-aemi.org/wp-content/uploads/2016/06/AEMI-ACEF2016-ConnectingASEANPolicyBrief-PhilipAndrewsSpeed.pdf>.

³⁵Nord Pool Group (2022). Market Members, <https://www.nordpoolgroup.com/en/the-power-market/The-market-members/>

ASEAN's existing electricity trade

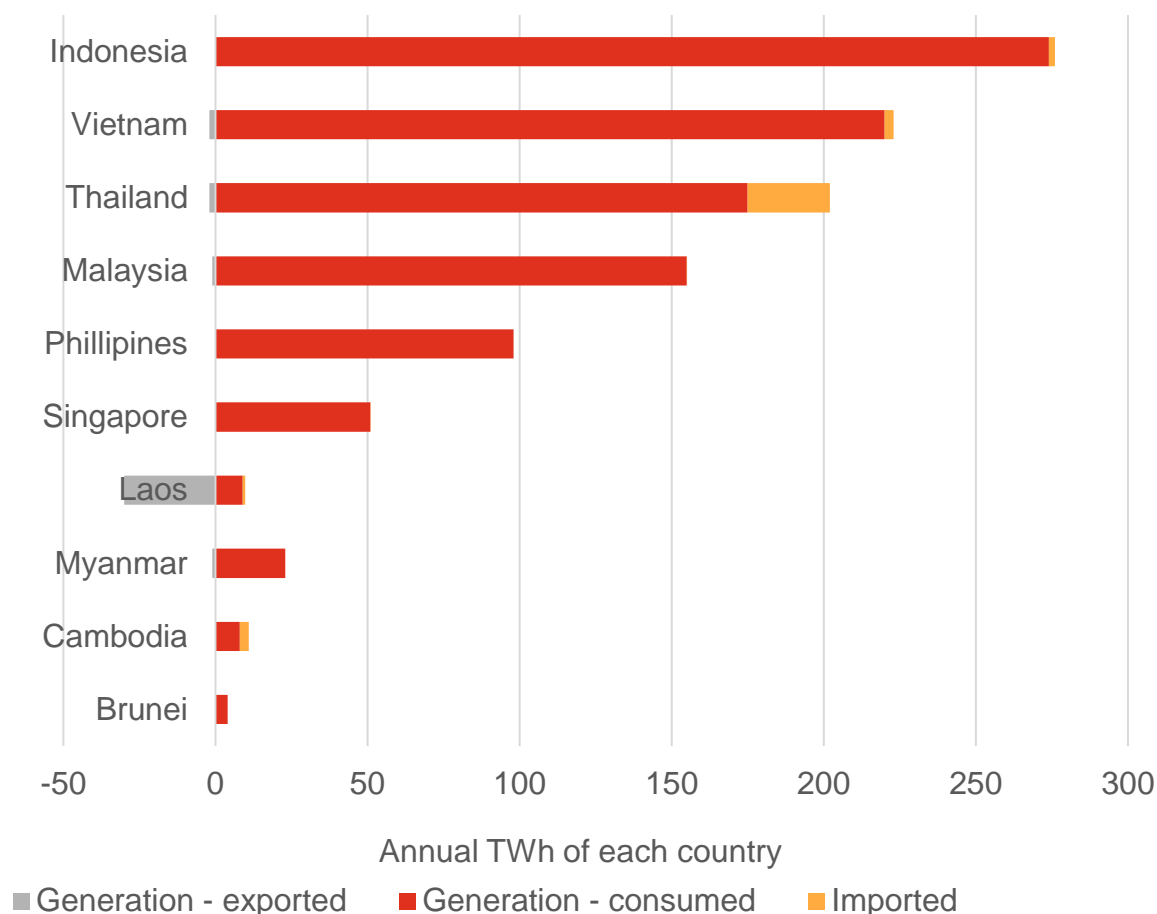
An example of an integrated electricity market: Nord Pool (cont'd)

In a year with normal rain and snow fall, hydro power accounts for half of the Nordic countries' electricity demand.

In Norway almost all power is generated by hydro power while Sweden and Finland have a mixture of hydro, nuclear and thermal power (steam driven). Denmark uses predominantly thermal power, but wind power is becoming increasingly important. In Estonia and Lithuania, there is mostly thermal driven power. Bidirectional flows around countries like Denmark illustrate the role of interconnectors in balancing variable wind power, alongside local flexibility. In dry years, Nordic countries become more dependent on the import of power from other countries: Russia, Estonia, Netherlands, Poland and Germany.

In the Nordic region, interconnectors join countries across land and sea, while a common Nordic spot market ensures efficient trade across subnational price zones. This cooperation increases security of supply, lowers system costs and facilitates the integration of renewables. This supports the security, affordability and greenness of the Nordic electricity system³⁶.

Chart 6: Generation quantities and import-export flows of ASEAN countries (Averaged 2018-2020 figures)



Source: PwC analysis based on IEA, Government information, US EIA, Enerdata

Note: Figures for Singapore's electricity imports are as of July 2022

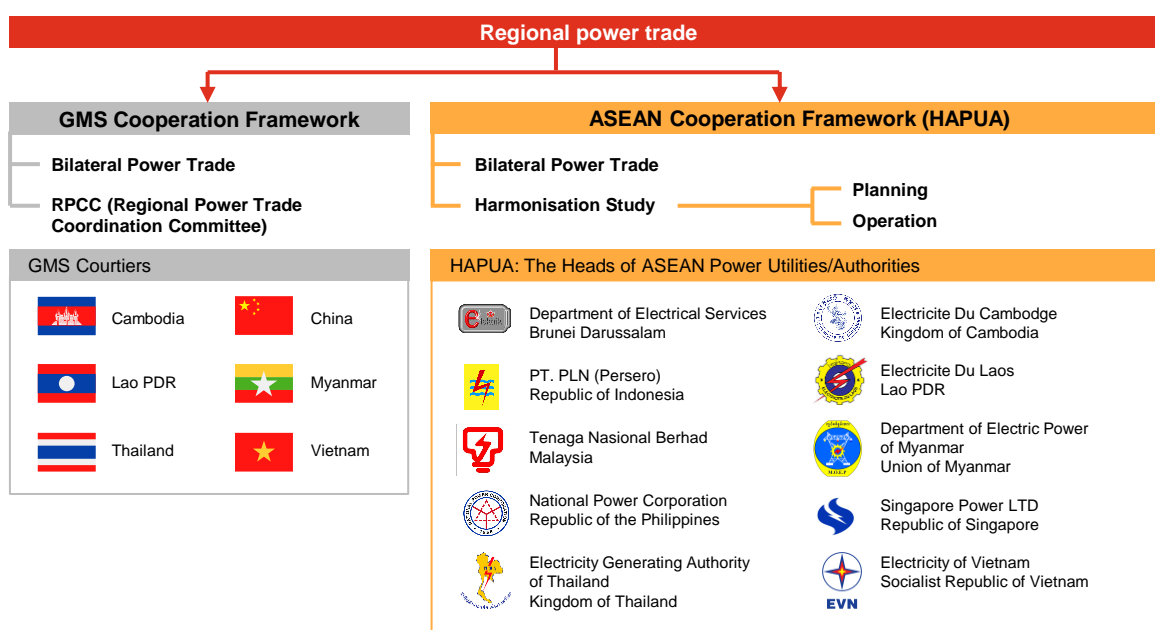
³⁶Nordic Energy Research (2018). 10 Insights into the Nordic Energy System, <https://www.nordicenergy.org/wordpress/wp-content/uploads/2018/06/10-Insights-A4.pdf>

ASEAN's regional grid initiatives

Regional grid integration initiatives

Two main regional initiatives are broad umbrellas for discussions between ASEAN countries - GMS Cooperation Framework and HAPUA. The ASEAN Centre for Energy, multilaterals and other development organisations are also key long-standing participants in developing ASEAN's regional grid connectivity.

Diagram 7: The two leading regional initiatives for ASEAN grid integration



GMS Cooperation Framework

GMS Cooperation Framework was established in 1992 with the Heads of Governments of the 6 member countries. There are three tiers of discussion:

- Leaders' Summit (held every 3 years with heads of governments)
- Ministerial conference
- Working group in priority sectors.

The Regional Power Trade Coordination Committee (RPTCC) meets annually to discuss the current development status of regional power integration.

HAPUA

HAPUA was formed in 1981 with the country representatives of power utilities forming its council, and is the Specialised Energy Body (SEB) in-charge of the ASEAN Power Grid (APG) which is a priority project. ASEAN has been working towards 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 towards regional connectivity. It prioritises the expansion of multilateral power trade as part of the ASEAN Economic Community 2025 agenda. ASEAN as a region has a target of integrating 23% share of renewable energy in electricity supply and 35% share in installed power capacity by 2025³⁷.

³⁷IRENA (2022). Renewable Energy Outlook for ASEAN: Towards a Regional Energy Transition (2nd Edition), <https://irena.org/publications/2022/Sep/Renewable-Energy-Outlook-for-ASEAN-2nd-edition>

ASEAN's regional grid initiatives

ASEAN Centre for Energy (ACE)

ACE is an intergovernmental organisation representing the 10 ASEAN Member States' interests in the energy sector. ACE serves as a catalyst for the economic growth and development of the ASEAN region through initiating, coordinating, and facilitating national as well as joint and collective activities on energy.

ACE was established as an organisation that operates with the capacity to conclude agreements with states, local or international organisations and be a party to legal proceedings. These functions and decisions are governed by a council, comprising the leaders from the ministry of energy from 10 countries, which determines the policy direction for the Centre.



Since the establishment of electricity interconnection arrangements through the ASEAN Power Grid (APG) under the ASEAN Vision 2020 adopted in the Second ASEAN Informal Summit in Kuala Lumpur 25 years ago, ASEAN has already built 7,720 MW of cross-border interconnections. Expanding from bilateral to multilateral, around 32.8 GWh of electricity was traded between Laos and Malaysia through Thailand under the Lao-Thailand-Malaysia Power Integration Project (LTM PIP) during 2018-2021.

The snail's pace of progress may be seen from the outside. Still, harmonising regulatory, technical issues or commercial regimes between the countries is never an overnight work—especially where the government-funded projects have primarily invested in transmission infrastructure through the State-Owned Enterprises (SOE).

The ASEAN Interconnection Masterplan Study (AIMS) III, a recent study by the ASEAN Centre for Energy (ACE) and HAPUA which was endorsed by the 10 ASEAN Ministers on Energy, estimated that with increasing shares of variable renewable energy in ASEAN, multilateral power trade could benefit the ASEAN Member States in terms of both increased system security and economic efficiency due to resource sharing. By 2040, ASEAN will require 24,385 MW of interconnection capacity with an investment of around USD 771 billion.

The successful commencement of the Lao PDR-Thailand-Malaysia-Singapore Power Integration Project (LTMS-PIP) on 23 June 2022 using existing interconnections, marking a historic milestone in the region as it is the first multilateral cross-border electricity trade involving four countries. As of 31 July 2022, 72 GWh of electricity has been traded. It is a showcase of the strong commitment from the governments to advance multilateral power trade in ASEAN.

However, escalating this effort requires strong private sector support, considering the required investment. International best practice shows that the suitable business models for privately financed transmission grids are through long-term contracts through concession or BOOT (built, own, operate and transfer) scheme.

The governments' continuous efforts at the national and regional level are expected to increase the level of confidence in the private sector to mitigate the risks in enabling the investment environment in terms of permitting, transparency, tax regime, macroeconomy, and political risk, among others.

In support of the ASEAN governments, the ASEAN Centre for Energy (ACE) and HAPUA are introducing the interconnection screening methodologies to help ASEAN identify high-priority cross-border interconnections and facilitate the conduct of pre-feasibility and detailed feasibility studies for project development with the support of the various development partners, which we expect can attract more interest and investment from the private sector.

Beni Suryadi

Manager, ASEAN Centre of Energy



Other agencies such as JICA, USAID, AFD, World Bank, as well as ADB are involved in cross-border trade projects in the ASEAN region in various forms.

Key areas of focus for cross-border renewable energy

Key benefits of developing more cross-border renewable energy in ASEAN:

Given this different renewable energy mix potential in different countries in ASEAN, there are three key reasons to develop more cross border electricity projects.

- For governments, the key benefit of a regional grid would be the economies of scale as they can harness the technical potential of the renewable source for supply locally as well as regionally, and hence benefit locally from overall lower LCOE. Governments can also optimise the plans for local transmission upgrades by using renewable energies with differing load profiles to complement each other, and ensuring that there is an appropriate mix of renewables in the overall capacity mix. The impact of variable renewables on load balancing can also be minimised with co-development of other baseload renewables and widening control areas.
- For investors, they can produce at scale where it is cheap and feasible, and sell where the demand is higher. An integrated grid expands the possibilities for investors and leads to a greater number of potential bankable projects.
- For consumers, the lower cost of electricity should in the long-run lead to lower electricity prices, if balanced correctly against increased cross-border transmission investment cost.

Areas that require greater clarity for the long-term development of the electricity trade in the region are:

Technical:

ASEAN's power systems are diverse in their standards, specifications, and protocols for electricity transmission

and distribution³⁸. Hence, for trade of electricity across multiple borders in ASEAN, increased technical harmonisation and operational procedures for the power systems may be required.

Development of long-term policy perspective / market structure:

The electricity policies in the region will need to incorporate a long-term vision rather than a trade-by-trade perspective. Clear guidelines and principles will be needed to support the design of regional generation capacity, demand management, the types of market in operation, how the electricity would be supplied, how transmission grids should look and operate, cross-border licencing, non-discriminatory access to networks, competition in generation, and import tariffs³⁹.

Current cross-border transmission links require offtake and transmission arrangements to be individually discussed, rather than a common framework being made available to project developers for transmission across select countries. There may be a need for a central power coordinator who can synchronise cross-grid operations, address the structure and ownership, and cost and benefit sharing mechanisms.

The interaction of export of renewable energy towards the Nationally determined contribution (NDC) targets of each country will also play a key role in countries more actively participating in electricity trade.

³⁸Clifford Capital (2021). Cross-border Energy Importation Project: A Singapore Perspective, [https://www.cliffordcap.sg/resources/ck/files/IA%20Article%20-%20Cross-border%20energy%20importation%20project%20A%20Singapore%20perspective%20\(CCPL\)%20-%20vF.pdf](https://www.cliffordcap.sg/resources/ck/files/IA%20Article%20-%20Cross-border%20energy%20importation%20project%20A%20Singapore%20perspective%20(CCPL)%20-%20vF.pdf)
³⁹Clifford Capital (2021). Cross-border Energy Importation Project: A Singapore Perspective, [https://www.cliffordcap.sg/resources/ck/files/IA%20Article%20-%20Cross-border%20energy%20importation%20project%20A%20Singapore%20perspective%20\(CCPL\)%20-%20vF.pdf](https://www.cliffordcap.sg/resources/ck/files/IA%20Article%20-%20Cross-border%20energy%20importation%20project%20A%20Singapore%20perspective%20(CCPL)%20-%20vF.pdf)

Key areas of focus for cross-border renewable energy

Political will:

The bilateral / multilateral cross border trade of electricity needs strong political support as this, if properly done, would help build the renewable energy ecosystem in exporting countries. This ecosystem should also help the exporting country to progress towards their own decarbonisation targets. However, political trust between the countries in the region is important to progress this in the right direction.

Development of consistent intergovernmental collaboration framework for infrastructure planning and permitting will make grid expansions across the border (including subsea cable) less problematic, but changes to make the process more streamlined will certainly be necessary.

In addition, mechanisms to improve incentives to invest in and build grid connections at local, national and regional scales are also required.

Environmental and social (E&S) impact:

Generation as well as transmission (including subsea cable) projects often have E&S risks, such as relocation, water and air pollution, resettlement, impact on aquatic resources and biodiversity, impact on livelihoods (e.g. fisheries), etc. Proposed cross-border interconnections may open the way for new power plants and subsea cabling which should follow the E&S requirements as per international standards.

Financial feasibility:

Plentiful long-term capital is waiting for bankable infrastructure projects in the region. Hence the developer and Governments have to work through bankability issues that may be relevant for export projects like political risk, curtailment risk, asset ownership risk for cross-border assets etc⁴⁰. Multilateral banks are keen to support regional integration and energy transition, especially if done with E&S safeguards.

Private financiers are concerned about transmission assets as once they are built, they are non-moveable, and any impact to supply or offtake will result in the asset not being used. In extreme cases, this may lead to stranded assets.

Without a clear cross-border electricity trading framework, private sector developers are unable to plan for regional electricity infrastructure, instead they are focused on country level investment opportunities and constraints. With a clear cross-border trading framework, developers will be able to plan for local and cross border transmission upgrades, mix of renewables in the overall generation capacity mix of more than one country, storage of electricity for energy security etc. Investors will deploy their capital efficiently to produce where it is cheap and feasible and sell where the demand is higher ideally resulting in lower electricity prices for consumers in the region in the long run.

⁴⁰Clifford Capital (2021). Cross-border Energy Importation Project: A Singapore Perspective, [https://www.cliffordcap.sg/resources/ck/files/IA%20Article%20-%20Cross-border%20energy%20importation%20project%20A%20Singapore%20perspective%20\(CCPL\)%20-%20vF.pdf](https://www.cliffordcap.sg/resources/ck/files/IA%20Article%20-%20Cross-border%20energy%20importation%20project%20A%20Singapore%20perspective%20(CCPL)%20-%20vF.pdf)

Contacts



Ling Tok Hong
Deals and Private Equity Leader
+65 9690 0802
tok.hong.ling@pwc.com



Jennifer Tay
Partner, Infrastructure Leader
+65 8876 9300
Jennifer.c.tay@pwc.com



Saumya Rao
Director, Deals Infrastructure
+65 9987 8750
Saumya.rao@pwc.com

Acknowledgements

Christine Kng
christine.kng@pwc.com

Tze Haung Ong
tze.haung.ong@pwc.com

Ryan Lee Wai Hoe
ryan.whl.lee@pwc.com

Esther Fu
esther.gey.fu@pwc.com

Annex A: List of transmission links in Chart 4

Laos – Vietnam		Thailand – Cambodia	
1	Xekaman 3 – Thanmy ⁴¹	22	Wattana Nakhon – Siam Preap ⁶⁵
2	Xekaman 1 – Pleiku ⁴²	Thailand – Malaysia	
Cambodia – Vietnam		23	HDVC Khlong Ngae – Gurun ⁶⁶
3	Chau Doc – Phnom Penh ⁴³	24	Sadao – Bukit Keteri/Chuping ⁶⁷
Laos – Thailand		Malaysia – Singapore	
4	Vientiane – Nong Khai ⁴⁴	25	Plentong – Senoko ⁶⁸
5	Pakxan – Bueng Kan ⁴⁵	Malaysia – Indonesia	
6	Thakhek – Nakhon Phanom ⁴⁶	26	Mambong – Bengkayan ^{69 70}
7	Savannakhet – Mukhadan 2 ⁴⁷	China – SEA	
8	Bang Yo – Sirindhorn ⁴⁸	1	Mengla – Namo ⁷¹
9	Na Bong - Udon Thani 3 ^{49 50}	2	Yunnan – Laos ⁷²
10	Nam Theun 2 – Savannakhet, Rot Et 2 ^{51 52}	3	Dehong – Da Pein ⁷³
11	Houay Ho – Ubon Ratchathani 2 ⁵³	4	Dehong – Myanmar ⁷⁴
12	Thakhek – Nakhon Phanom 2 ⁵⁴	5	Dehong – Myanmar
13	Houay Ho - Ubon Ratchathani 2 ⁵⁵	6	Dehong – Myanmar
14	Hongsa – Nan ^{56 57}	7	Yunnan – Vietnam ⁷⁵
15	Xaiyaburi – Thali ⁵⁸	8	Yunnan – Vietnam
16	Thanaleng – Nong Khai ⁵⁹	9	Yunnan – Vietnam
17	Phone Tong – Nong Khai ⁶⁰	10	Yunnan – Vietnam
18	Pakbo – Mukdahan 2 ⁶¹	11	Yunnan – Vietnam
19	Xe-Pain Xe-Namnoy – Ubon Ratchathani 3 ⁶²	12	Hekou Yao – Lao Cai ^{76 77}
20	Bangyo – Sirindhorn 2 ⁶³		
Laos - Cambodia			
21	Ban Hat – Khamponsalao ⁶⁴		

- ⁴¹Greater Mekong Subregion (2019). Country Report: Laos.
<https://www.greatermekong.org/sites/default/files/Attachment%2011.4.%20LAO.pdf>
- ⁴²Greater Mekong Subregion (2019). Country Report: Laos.
<https://www.greatermekong.org/sites/default/files/Attachment%2011.4.%20LAO.pdf>
- ⁴³Vietnam Electricity (2019). Chau-Doc -Ta Keo 220kV transmission line: 10 years with 10 billion kWh.
<https://en.evn.com.vn/d6/news/Chau-Doc-Ta-Keo-220kV-transmission-line-10-years-with-10-billion-kWh-66-163-1736.aspx>
- ⁴⁴JICA (2020). Stimulation of Supply/Demand Balance.
https://openjicareport.jica.go.jp/pdf/12328027_03.pdf
- ⁴⁵JICA (2020). Stimulation of Supply/Demand Balance.
https://openjicareport.jica.go.jp/pdf/12328027_03.pdf
- ⁴⁶Greater Mekong Subregion (2019). Country Report: Laos.
<https://www.greatermekong.org/sites/default/files/Attachment%2011.4.%20LAO.pdf>
- ⁴⁷Greater Mekong Subregion (2019). Country Report: Laos.
<https://www.greatermekong.org/sites/default/files/Attachment%2011.4.%20LAO.pdf>
- ⁴⁸Greater Mekong Subregion (2019). Country Report: Laos.
<https://www.greatermekong.org/sites/default/files/Attachment%2011.4.%20LAO.pdf>
- ⁴⁹Greater Mekong Subregion (2019). Country Report: Thailand.
<https://www.greatermekong.org/sites/default/files/Attachment%2011.5.%20THA.pdf>
- ⁵⁰The Diplomat (2015). Laos Gets Plugged In.
<https://thediplomat.com/2015/08/laos-gets-plugged-in/>
- ⁵¹Greater Mekong Subregion (2019). Country Report: Laos.
<https://www.greatermekong.org/sites/default/files/Attachment%2011.4.%20LAO.pdf>
- ⁵²Power Technology (2010). The Nam Theun 2 Hydropower Project
<https://www.power-technology.com/projects/namtheun2/>
- ⁵³Greater Mekong Subregion (2019). Country Report: Laos.
<https://www.greatermekong.org/sites/default/files/Attachment%2011.4.%20LAO.pdf>
- ⁵⁴Greater Mekong Subregion (2019). Country Report: Thailand.
<https://www.greatermekong.org/sites/default/files/Attachment%2011.5.%20THA.pdf>
- ⁵⁵Greater Mekong Subregion (2019). Country Report: Thailand.
<https://www.greatermekong.org/sites/default/files/Attachment%2011.5.%20THA.pdf>
- ⁵⁶Greater Mekong Subregion (2019). Country Report: Thailand.
<https://www.greatermekong.org/sites/default/files/Attachment%2011.5.%20THA.pdf>
- ⁵⁷Hongsa Power Company Limited.
<http://www.hongsapower.com/index.php?model=cms&view=item&layout=page&id=22>
- ⁵⁸Greater Mekong Subregion (2019). Country Report: Thailand.
<https://www.greatermekong.org/sites/default/files/Attachment%2011.5.%20THA.pdf>
- ⁵⁹Greater Mekong Subregion (2019). Country Report: Thailand.
<https://www.greatermekong.org/sites/default/files/Attachment%2011.5.%20THA.pdf>
- ⁶⁰Greater Mekong Subregion (2019). Country Report: Thailand.
<https://www.greatermekong.org/sites/default/files/Attachment%2011.5.%20THA.pdf>
- ⁶¹Greater Mekong Subregion (2019). Country Report: Thailand.
<https://www.greatermekong.org/sites/default/files/Attachment%2011.5.%20THA.pdf>
- ⁶²Greater Mekong Subregion (2021). Country Update: Thailand.
https://www.greatermekong.org/sites/default/files/rptcc28/6%20-%20Country%20Presentation_Thailand.pdf
- ⁶³Greater Mekong Subregion (2021). Country Update: Thailand.
https://www.greatermekong.org/sites/default/files/rptcc28/6%20-%20Country%20Presentation_Thailand.pdf
- ⁶⁴Greater Mekong Subregion (2019). Country Report: Laos.
<https://www.greatermekong.org/sites/default/files/Attachment%2011.4.%20LAO.pdf>
- ⁶⁵Greater Mekong Subregion (2019). Country Report: Thailand.
<https://www.greatermekong.org/sites/default/files/Attachment%2011.5.%20THA.pdf>
- ⁶⁶Greater Mekong Subregion (2019). Country Report: Thailand.
<https://www.greatermekong.org/sites/default/files/Attachment%2011.5.%20THA.pdf>
- ⁶⁷Malaysia Prime Minister's Department Economic Planning Unit (2013). Malaysia's Recent Development in RE & ASEAN Power Connectivity
<https://www.unescap.org/sites/default/files/Mr.%20Sabar%20Md%20-%20Hashim%20-%20Malaysia%20Presentation.pdf>
- ⁶⁸Malaysia Prime Minister's Department Economic Planning Unit (2013). Malaysia's Recent Development in RE & ASEAN Power Connectivity
<https://www.unescap.org/sites/default/files/Mr.%20Sabar%20Md%20-%20Hashim%20-%20Malaysia%20Presentation.pdf>
- ⁶⁹ADB (2011). IEE: Regional: Trans Borneo Power Grid: Sarawak to West Kalimantan Transmission Link (Malaysia Section)
<https://www.adb.org/sites/default/files/project-document/61208/44921-01-reg-ieee.pdf>
- ⁷⁰Malaysia Prime Minister's Department Economic Planning Unit (2013). Malaysia's Recent Development in RE & ASEAN Power Connectivity
<https://www.unescap.org/sites/default/files/Mr.%20Sabar%20Md%20-%20Hashim%20-%20Malaysia%20Presentation.pdf>
- ⁷¹Greater Mekong Subregion (2019). Country Report Laos.
<https://www.greatermekong.org/sites/default/files/Attachment%2011.4.%20LAO.pdf>
- ⁷²Greater Mekong Subregion (2019). Country Presentation by CSG.
<https://www.greatermekong.org/sites/default/files/Attachment%2011.2.%20PRC.pdf>
- ⁷³South China Morning Post (2021). China ramps up electricity imports from North Korea, Russia, Myanmar in bid to ease power crisis.
<https://www.scmp.com/economy/china-economy/article/3153342/china-ramps-electricity-imports-north-korea-russia-myanmar>
- ⁷⁴Greater Mekong Subregion (2019). Country Presentation by CSG.
<https://www.greatermekong.org/sites/default/files/Attachment%2011.2.%20PRC.pdf>
- ⁷⁵Greater Mekong Subregion (2019). Country Presentation by CSG.
<https://www.greatermekong.org/sites/default/files/Attachment%2011.2.%20PRC.pdf>
- ⁷⁶China Daily Global Edition (2022). Electricity trading resumes with Vietnam
<https://global.chinadaily.com.cn/a/202205/06/WS6274e6cba310fd2b29e5b1a5.html>
- ⁷⁷Greater Mekong Subregion (2019). Country Presentation by CSG.
<https://www.greatermekong.org/sites/default/files/Attachment%2011.2.%20PRC.pdf>