Wired for profit: Grid is the key to unlock ASEAN energy investment

Grid is the driver to unlock solar and wind markets and provide opportunities for fossil-dependent countries to be renewables exporters.

Published date: 15th May 2025
Lead author: Dr Dinita Setyawati
Other authors: Shabrina Nadhila

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About

This report summarises emerging challenges facing ASEAN in managing the grids and interconnections. It provides recommendations based on examples from Europe and Southern Africa for the arrangement of multilateral power trading in ASEAN. The report also analyses the potential of unlocking solar and wind in the region via planned interconnections and presents several clean flexibility options for ASEAN.

Highlights

30 GW	+26%	~182k
Solar and wind potential that can be harnessed along interconnection routes.	Potential rise in solar and wind generation share in Sumatra, Sarawak, Lao PDR, Cambodia, Brunei by 2030.	New jobs that could be created from these new solar and wind projects.

Executive summary

Shaping ASEAN’s clean, secure energy future with grids

Modern, flexible grids are essential to unlock ASEAN’s solar and wind potential, create new jobs and new market opportunities.

Rising solar and wind generation, as well energy demand from data centres and transport electrification is expected to take place in the region in the near future. This calls for a greater action on grids and interconnections to accelerate renewables build and bring various economic benefits such as jobs.

Most ASEAN countries have historically been fossil fuel dependent, but the energy landscape is rapidly changing. By 2030, solar and wind generation are projected to account for around 23–25% of the power mix, up from just 4% today. To realise this transition, grid infrastructure must evolve - becoming more modern, flexible and regionally integrated, and integrate six pillars that a good future grid development plan should include. Stronger grids can be achieved through comprehensive grid planning that include modernisation, expansion, adoption of flexibility options, regional integration, market reforms, and mobilisation of finance.

Some ASEAN countries have started to embed these priorities in their respective national energy policy. Yet, a stronger push for action from policymakers could help in securing finance and building investor confidence in grid infrastructure.

To date, only Cambodia, Malaysia and Singapore have signed the Global Energy Storage and Grids Pledge, which aims to deploy 1,500 GW of energy storage and 25 million kilometres of grid infrastructure globally by 2030. Grid development plans across ASEAN vary according to geographical landscape and require more data availability to assess whether their scale aligns with member governments' climate and clean energy goals.

ASEAN countries vary widely in their clean energy potential, with some having abundant capacity for solar and/or wind and others blessed with hydro and geothermal resources. For hydro-rich locations such as Borneo island and countries along the Mekong rivers, increased variability in hydro generation due to seasonal variations necessitates the diversification of renewable energy sources. Regional grid interconnection holds the key to using these resources in combination, boosting renewables use and economic growth.

Expediting the pace of connectivity could increase GDP across ASEAN by 0.8% to 4.6% and unlock a bigger market. To date, the development of multilateral power trade in ASEAN has been limited to several projects: the Lao PDR - Thailand - Malaysia - Singapore Power Integration Project (LTMS-PIP), and early initiation of Brunei Darussalam, Indonesia, Malaysia and the Philippines Power Integration Project (BIMP-PIP). To encourage further collaborations, proposed reforms include better coordinated planning for regional power trade arrangements.

Managing electricity grids and incorporating flexibility management strategies are vital to ensure a reliable energy system. This report accesses the strengths and challenges of key clean flexibility options, including pumped hydro, battery storage, demand-side management, as well as grids and interconnections for better insights.

To provide further insights, we also highlight experiences from European and South African power market structures to illustrate different trade mechanisms. These cases illustrate that interconnections can drive greater renewable energy penetration, enhance social welfare and improve security of supply to meet rising demand.

Ultimately, the focus should not be on whether ASEAN replicates other market models, but on building a resilient and connected market where solar and wind can be solutions for ensuring energy security.

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> **The role of the grid is more than just moving electricity. In ASEAN, a stronger and interconnected grid can create a robust renewable energy market, connecting countries, uplifting communities, and bringing clean energy to the darkest corners. Grid upgrade, coupled with clean flexibility tools can better prepare ASEAN for a renewables-based future.**
>
> **Dr Dinita Setyawati**
> Senior Energy Analyst, Asia
> Ember

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Thanks to Ember for their important new analysis of ASEAN’s energy future. As the report emphasizes, ASEAN’s future lies in a state-of-the-art energy system built on green and digital technologies and an ASEAN-wide integrated market for clean, green power. This report will be of great use to ASEAN as it adopts bold operational plans in the coming year.

Professor Jeffrey Sachs
President of the UN Sustainable Development Solutions Network

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Energy security is national security. The ASEAN region is therefore understandably accelerating its build-out of competitively priced and zero-emissions renewable energy this decade. EMBER’s report is particularly welcome to highlight the role of a flexible, modern grid in carrying green electrons from regions with abundant supply of land, water, solar and wind, to major demand centres and the many industrial and data centre zones in the region.

Dr Assaad Razzouk
Gurīn Energy

Key takeaways

01

ASEAN transmission grid expansion needs to roughly double to align with the IEA pathway

Between 2023–2030, Indonesia, Viet Nam, the Philippines and Thailand plan to add 45,076 km of transmission lines, accounting for roughly 45% of the scale envisaged in the International Energy Agency's (IEA) grid Announced Pledges Scenario. This indicates that roughly double the transmission expansion to 2030 required to deliver national clean energy and climate targets still needs to be planned.

02

The planned ASEAN grid routes are home to 30 GW of solar and wind potential

As much as 24 GW of solar and 5.6 GW of wind potential are located in Riau islands and Sumatra (Indonesia), Sarawak (Malaysia), Cambodia and Brunei, locations of some existing and planned new interconnection projects. The electricity generated from these potential projects could be shared with demand centres, providing a larger range of generation capacity from clean energy to meet future demand.

03

Regional collaboration can enable a robust renewable energy market in ASEAN

Collaboration can fast-track interconnection projects, create a renewable energy market, and leverage the diverse energy potential of ASEAN countries. Examples from Europe and the Southern African Power Pool (SAPP) show that interconnection projects managed by a regional coordinating association, such as ENTSO-E for Europe or the SAPP Coordination Centre, can accommodate sharing of resources and improve social welfare.

Chapter 1: Scene setting

Understanding ASEAN's grids planning strategy

Increased needs for electricity access and rising demand shape ASEAN's grid planning strategy.

The power grid is the backbone of the electricity system. Power lines transport electricity produced by generators to the final consumers, across different voltage levels. In ASEAN, where demand is skyrocketing and industries are expanding, the role of grids is becoming increasingly critical. Between 2013 and 2023, annual electricity demand in the region surged by around 50%, from 817 TWh to 1,277 TWh, with the majority accounted for by Indonesia, Viet Nam, Thailand and Malaysia. By 2030, electricity demand is set to rise by up to 41% again, redefining the scale and urgency of regional grid planning.

To accommodate this growth, utilities in the region are under pressure to satisfy the growing need to connect energy sources, which requires building more transmission lines to carry electricity and more substations to change voltage. Aging grids are being strategically replaced with high-capacity lines, and more high-voltage cables are being installed in each and in between countries to improve regional flexibility and energy security.

Shifting grid planning strategies for better renewable integration

Historically, grid investment in ASEAN focused on meeting peak demand and ensuring a secure, reliable and cost-effective electricity delivery, while today economic and climate goals play an increasing role. The electrification of heat, transport, and industry is rapidly accelerating electricity demand across ASEAN.

At the same time, the cost of wind and solar has been declining rapidly. During the decade to 2020, the cost of wind and solar power fell by 55% and 85%, respectively. The cost of batteries, increasingly used to store renewable electricity, also fell by 85% over the same time period. This shifts the logic of grid planning. No longer should grids be built to serve just peak demand, but to fully integrate these technologies and intermittency, and to manage supply variability within and across countries. That means focusing on grid development at both national and regional levels.

Transmission expansion in ASEAN needs to roughly double to align with the IEA pathway

According to the International Energy Agency (IEA), more than 80 million kilometres of power grids must be added or refurbished globally by 2040 to facilitate the energy transition. In line with this, the Global Energy Storage and Grids Pledge aims to deploy 1,500 GW of energy storage and 25 million kilometres of grid infrastructure by 2030. For Southeast Asia specifically, IEA estimates that 1.7 million km transmission and distribution grid should be added between 2021 and 2030, with around 6% comprising transmission lines and 94% distribution lines.

However, collective national plans from some countries fall significantly short of these needs.

Since data on transmission lines is relatively more accessible than distribution lines, we are focusing our analysis on them. Transmission lines transport electricity from generating stations to substations where it is stepped down in voltage and delivered to end-users via distribution lines. As greater electrification expands across transportation and household sectors, distribution and transmission grids should be prioritised. Transmission grid investment is equally critical to enable long-distance interconnections and resources sharing to avoid curtailments. These interconnections are essential for integrating large-scale renewable energy, balancing regional supply and demand, improving energy security and future energy system resilience.

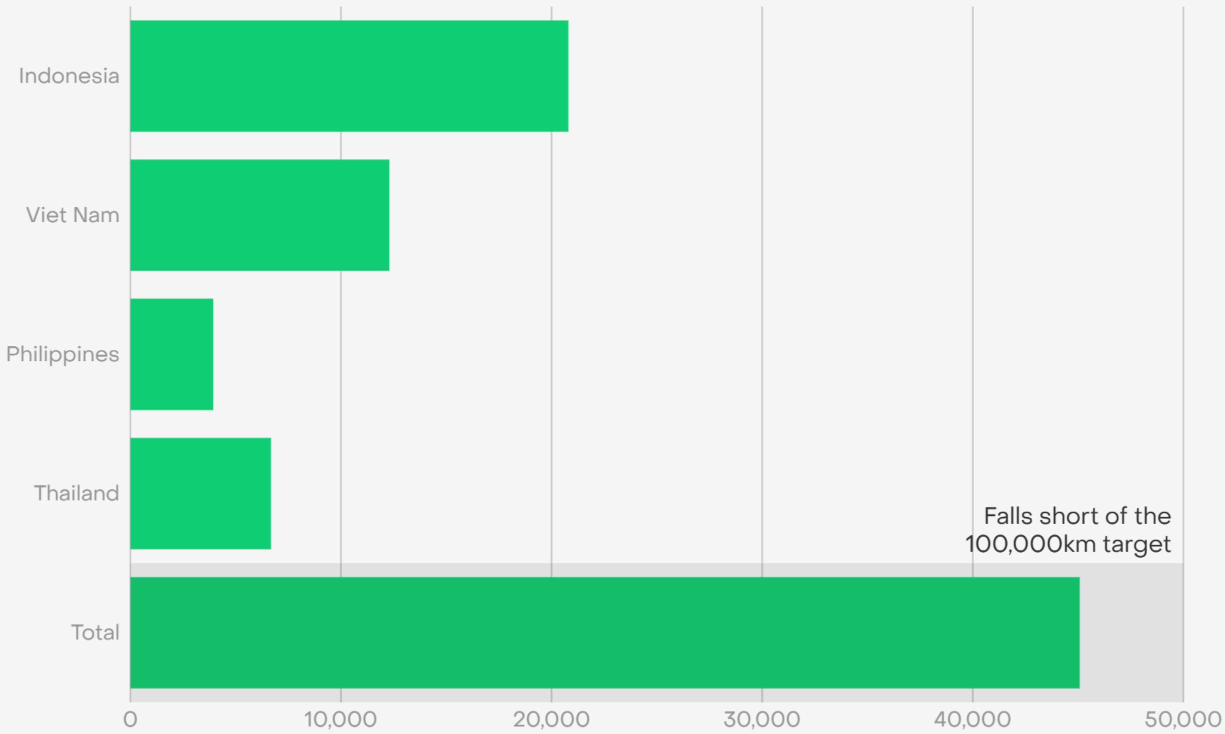
Between 2023 and 2030, Indonesia plans to add 20,798 km of transmission lines. Viet Nam's expansion plans include 12,300 km of transmission lines by 2030. The Philippines plans to add 3,935 km of transmission lines and Thailand will add 6,677 km, both by 2030. Overall, the combined total in these four countries' plans accounts for around 45,078 km - about 45% of the IEA's Announced Pledges Scenario (APS) transmission line expansion target of 100,000 km for Southeast Asia, between 2021-2030.

There is a lack of available data on transmission expansion plans across several ASEAN countries, which poses a challenge in assessing regional plans against the IEA pathway. For instance, while four countries account for the vast majority of existing grid infrastructure in the region, there is limited data for other ASEAN countries.

This indicates that the majority—approximately over half—of the required transmission expansion needs to be planned by countries to align with the regional pathway. The APS corresponds with announced national ambitions and targets as of September 2022 and provides a benchmark for the grid development that would be required to meet climate pledges.

ASEAN grid development targets need to roughly double to align with the IEA pathway

New transmission line (2023-2030) in km, combined voltages



Source: Ember's analysis of Indonesia's RUPTL, Viet Nam's PDP 2021-2030, EGAT Transmission Projects, NGCP Transmission Development Plan 2023-2040
Certain countries could not be assessed due to lack of data. The combined total accounted for around 45,076 km - about 45% of the IEA's Announced Pledges Scenario (APS) transmission line expansion target for the region, 2021-2030.

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The urgency of grid development was reinforced at COP29 through the Global Energy Storage and Grids Pledge which set a goal of adding or refurbishing 25 million kilometres of grids by 2030.

Chapter 2: Challenges and opportunities

ASEAN grids need better policy alignment and clean technologies

Rapid growth of wind and solar parks call for better grid planning and implementation.

Modernisation of the national grid is urgently needed to accommodate the rapid rise of renewables and evolving energy demands. At the same time, a significant financing gap threatens to stall progress, underscoring the need to unlock investment at scale. Addressing these challenges will require stronger alignment of strategies and more effective partnerships across governments, industry, and financiers.

Quite a few ASEAN countries have recognised the importance of grids in solving power transmission issues. In response to the power disturbance in 2019, Indonesia's state-owned electricity company, PLN, implemented plans to expand transmission line infrastructure and enhance the integration of generation, transmission, and distribution management systems. These improvements aim to detect anomalies more efficiently and mitigate disruptions in the power supply.

Similarly, grid operators in Vietnam and the Philippines addressed power outage incidents caused by the tropical cyclone seasons by upgrading their power infrastructure. These upgrades focused on strengthening grid resilience, improving response mechanisms, and enhancing overall reliability in the face of extreme weather events.

Additionally, with increased solar and wind deployment plans and interconnections of the ASEAN power grids being planned, advanced technologies are essential for optimising grid operations and ensuring regional power system stability. At the 2024 ASEAN Grid Operation Technical Workshop, innovations such as Wide Area Monitoring, Protection, and Control (WAMPAC) systems, micro-synchrophasors, and micro-phasor measurement units (PMUs) were discussed as tools to improve cross-border grid coordination and real-time grid management.

To ensure countries derive the full benefits of the next phase of the transition, it is necessary to implement grid solutions at scale and across the entire system.

Solar and wind are set to rise to at least 23% of ASEAN's power mix

Currently, most of ASEAN countries' electricity systems are based on fossil fuels. Coal plants typically operate as baseload generation, while geothermal, biomass, large hydropower and gas plants provide flexibility, ranging from baseload to peak demand. As of 2023, Indonesia owns the largest fossil fuel power capacity at 78 GW, followed by Thailand with 44 GW, Viet Nam with 35 GW, Malaysia with 32 GW and the Philippines with 20 GW.

Renewable energy, particularly wind and solar, is still in early stages of deployment in most countries. With the exception of Vietnam, which leads the region with 23 GW of installed wind and solar capacity. In contrast, other countries have capacities ranging from 0.7 GW to 5 GW. However, due to the lack of pricing mechanism and grid constraints, Viet Nam had to reduce the utilisation rate of its largest solar farm by as much as 40% in 2022.

To provide solutions to such curtailments, the country is currently implementing a large-scale energy storage project in the South Central region where solar farms installed capacity is around 70% of total solar capacity.

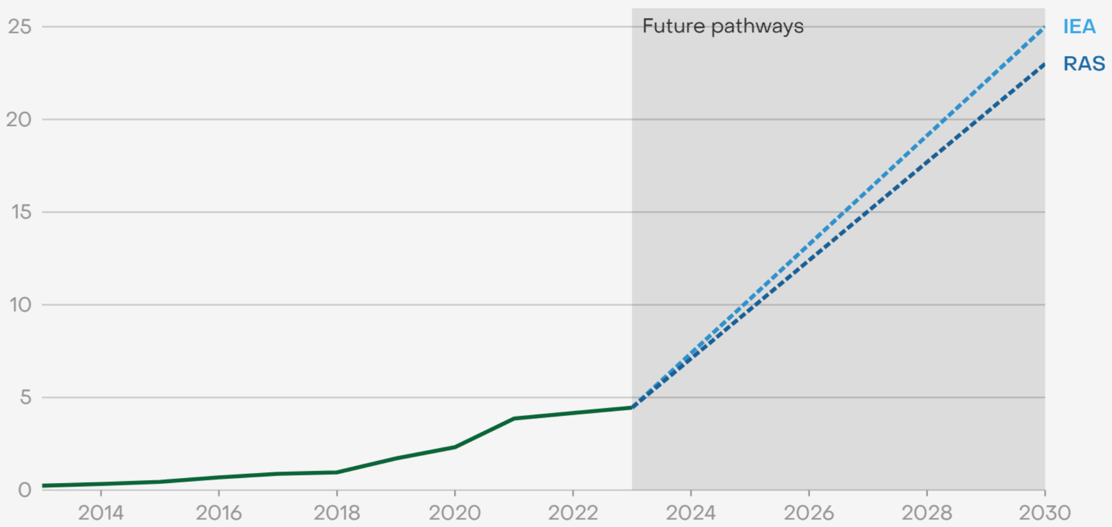
Countries located along the Mekong river and the island of Borneo have abundant hydro resources. However, there was a drop in hydro production spurred by droughts and seasonal variations that necessitates diversification of renewable energy sources.

Collectively, the ASEAN power system has 8 GW of wind and 26 GW of solar capacity, with a regional target to increase this by 51 GW for solar and 109 GW for a combination of wind, hydro, geothermal and bioenergy by 2040.

Viet Nam's experience highlights the importance of grid and flexibility, when curtailments happened over concerns of power system stability. Due to the under-capacity of transmission grids, the government and state utility of Viet Nam have been cautious about issuing further policies to promote wind power. Grid operators in the region are currently assessing long-term power system planning practices, and analysing system effects and cost implications of greater solar and wind integration. Particularly, since solar and wind energy sources are projected to increase according to scenarios by the ASEAN Centre for Energy and the IEA.

Wind and solar are forecast to generate between 23% and 25% of electricity in ASEAN by 2030

Share of electricity generation (%)



Source: Regional Aspiration Scenario (RAS) based on ASEAN Energy Outlook 8 (AEO8), IEA's net zero roadmap

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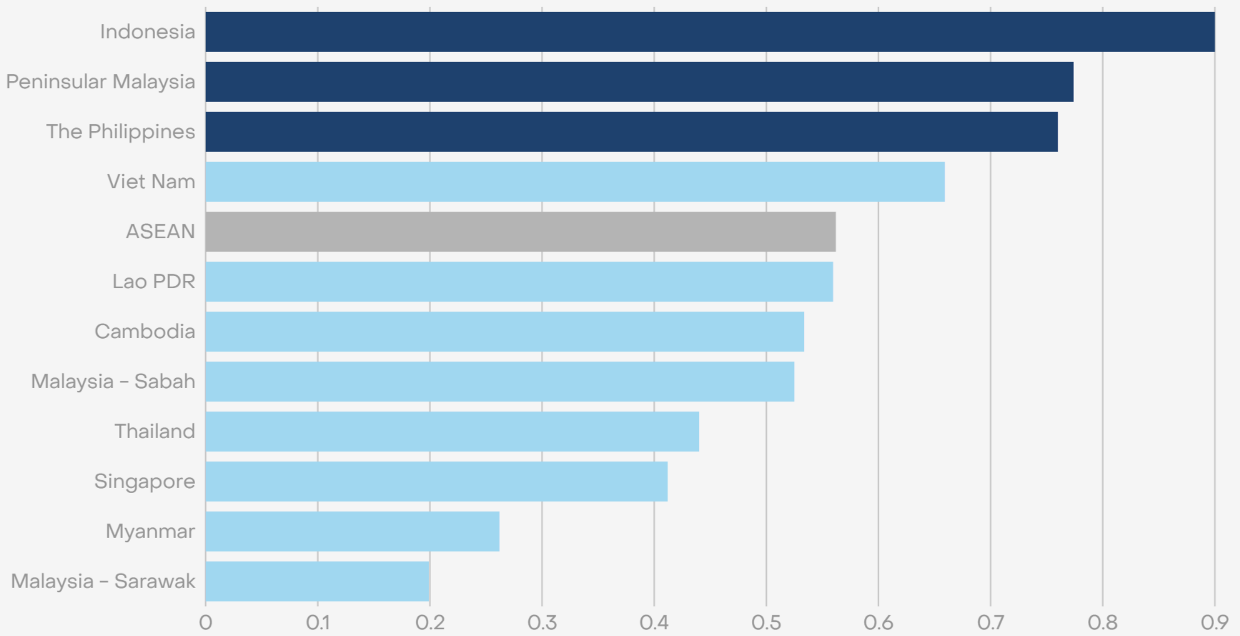
Emission-intensive ASEAN grids

Grid emission factors represent the amount of emissions produced per kilowatt-hour (kWh) of electricity generated. These factors vary by grids depending on the energy mix and overall grid efficiency. Grids that rely primarily on fossil fuel-based electricity generation tend to have higher emissions, which significantly influence the approach to electrification infrastructure development.

In ASEAN, some of the highest grid emission factors are observed in Indonesia's Sumatra (0.9 tCO2e / MWh), Java-Bali-Madura (0.9 tCO2e / MWh) and the Philippines's Mindanao (0.8 tCO2e/MWh). These figures highlight the environmental cost of electricity in these areas as the region advances electrification across multiple sectors, including transportation and cooking.

Grid emission factors in fossil-dependent countries are nearly twice the ASEAN average

Grid emission factor (tCO2e / MWh)



Source: National statistics and policy documents with latest data available between 2017 and 2024, IGES List of Grid Emission Factors, Asian Development Bank (2017) Guidelines for Estimating Greenhouse Gas Emission
Cambodia's data is taken from national grid, Indonesia's data is the average between Java-Madura-Bali and Sumatera grids, Philippines' data is the average between Luzon Visayas and Mindanao grids. For Malaysia, Peninsular, Sabah and Sarawak operate independent power lines. ASEAN average is obtained from Schaper and Yang (2021)

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For instance, while electric vehicles (EVs) eliminate tailpipe emissions, their sustainability benefits depend on the emissions from electricity generation. As a result, regions with carbon-intensive grids must prioritise decarbonisation efforts alongside EV adoption to fully realise the environmental advantages of electrification.

Integrating diverse flexibility options into ASEAN's evolving grid

There are various clean flexibility options that can be integrated into energy systems, each with different applications and technical requirements. Clean flexibility is the process of balancing supply and demand to maintain grid stability, by storing renewable electricity for later use, shifting non-critical demands to periods where supply is abundant and sharing it across the grid. Such flexibility options may include battery storage, pumped hydro storage and demand-side management. Grids and interconnectors are also essential clean flexibility tools to allow the sharing of resources.

Pumped hydro

The pumped hydro storage system, or pumped hydro, uses the height difference between two reservoirs to store energy. The system is operated by pumping the water between two dams. Water is pumped using off-peak electricity and discharged in peak hours. The two reservoirs are connected by penstocks, with a height difference ranging from 50 to 800 meters.

Pumped hydro is often considered as a mature technology to provide grid stability and support the development of intermittent renewable energy, such as wind and solar. The system is capable of storing energy for daily, weekly or monthly cycles, and can operate over annual and pluri-annual cycles. The technology could also play a role in dealing with load problems emerging from strong seasonal fluctuations in electricity consumption and supply seasonal variations due to increasing use of intermittent power sources.

With long-duration storage (+8 hours) and low operating cost, pumped hydro can provide inertia, providing more stability to the grid.

In Southeast Asia, with the use of pumped hydro, the electricity sector could in principle achieve a penetration rate of solar and wind resources between 78%-97%, achieving between 1,170-1,480 GW in a scenario where there is optimal sharing of hydropower resources across the region. However, given the competition of land with other infrastructure development, geographically feasible, commercially and socially acceptable sites selected for pumped storage are becoming scarce. The high capital cost and long gestation period for this technology could also be potential barriers to adopt.

Currently, 2.7 GW of pumped hydro is under construction and the remaining 13.3 GW is in various stages of development. The Philippines introduced a target of 4.3 GW of pumped hydro in the 3rd Green Energy Action Plan for 2025-2035. Similarly, Viet Nam aims to deploy 2.4 GW of pumped hydro by 2030 according to the Power Development Plan (PDP8). Indonesia is promoting this technology in the National Electricity Master Plan, with 3.7 GW projects in the pipeline. Thailand has projects underway in the provinces with a combined capacity of 2.5 GW by 2037.

Battery Energy Storage Systems (BESS)

BESS offers significant benefits, particularly with its fast response times and modular, scalable design. Technologies like lithium-ion batteries can respond in milliseconds, making them ideal for frequency regulation and short-term balancing in grid operations. As the costs of these batteries continue to fall, they present an increasingly cost-effective solution, especially for applications requiring quick power adjustments.

However, challenges remain, particularly for long-duration storage. Despite their advantages in rapid response, energy storage solutions often face high upfront costs per megawatt-hour (MWh) for systems that provide extended discharge durations. Most systems currently only last 2 to 4 hours, limiting their ability to provide sustained energy during non-solar hours. Additionally, there are environmental concerns surrounding the extraction and use of raw materials for batteries. These factors highlight the trade-offs involved in scaling energy storage technologies.

There have been some projects integrating solar and battery in ASEAN. For example, a 45 MW storage project in Thailand, a 4 MW BESS facility in the Power Development Plan, a 400 MWh in Malaysia's Sabah, and a combined 3.5 gigawatt-peak () of solar power capacity with 4.5 GWh of battery storage in the Philippines. Indonesia and Singapore are also developing 2 GW solar plus 8 GWh of utility-scale BESS ventures. Additionally, Indonesia is planning to develop a 50 MW Kalseltengtimra Solar Power Plant with a 14.2 MWh BESS in the new capital city, Nusantara. In Singapore, LFP Energy Storage Systems that can store and deliver up to 200 MW of power for one hour in a single discharge are being built to enhance grid reliability.

Demand-side management (DSM)

Demand side management (DSM) offers a low-cost flexibility option for grid operators, helping to reduce strain during peak demand periods. DSM adjusts electricity use by controlling end-user devices to enhance grid flexibility, in response to increased renewable energy integration.

By incentivising consumers to adjust their usage patterns, DSM can balance supply and demand, preventing grid overloads and reducing the need for expensive peak generation. smart meters and targeted incentives make these adjustments more feasible and scalable. An example of a demand-side management tool is 'peak shaving', or levelling consumption during peak hours. This strategy is mainly employed by industrial and commercial power consumers to minimise the occurrence of high peaks. In China, peak shaving is now integrated into spot market mechanisms, providing a market-based solution to grid imbalances.

Despite its potential, DSM faces challenges that hinder broader adoption, particularly in ASEAN countries. Effective DSM implementation requires supportive policies, regulatory frameworks, and consumer participation, all of which are still lacking in many regions. Furthermore, the successful integration of DSM relies on digital infrastructure and market readiness, which remain underdeveloped in several ASEAN countries. These barriers highlight the need for a concerted effort to align policy, infrastructure, and consumer engagement to fully realise the benefits of demand-side management.

In ASEAN, the Philippines Department of Energy issued a circular establishing a framework for energy storage systems (ESS) to support variable renewable energy integration. The ESS will be applied to serve a variety of functions in electricity management, including energy generation, peak shaving and ancillary services.

Another tool, smart electrification refers to the optimisation of the charging of EVs, and use of heat pumps or electric stoves, in accordance with sunny hours on a daily basis. As ASEAN is slated to become more electrified, managing the demand has the potential to become a large source of flexibility.

Grids and interconnections

Strengthening and expanding grid interconnections across ASEAN is vital to scale up renewable energy while improving grid efficiency. By linking national grids, countries can share clean energy resources across borders—reducing the risks of curtailments and smoothing variability from solar and wind over a wider geographic area. Grids also offer temporal and spatial flexibility, helping optimise system operations across daily, seasonal and regional patterns. This enables more cost-effective renewable integration, as nations can balance supply and demand more flexibly, alleviating constraints on the grid and making better use of surplus generation.

However, turning this vision into reality comes with hurdles. Cross-border grid projects require strong political coordination, harmonised regulations, and long-term investment commitments. Development timelines can span years, and investors may view such projects as high-risk due to the complexity of regional governance and financing structures. Overcoming these barriers will require bold leadership, policy alignment, and innovative investment frameworks to realise the full benefits of a connected ASEAN power system.

Expediting the pace of connectivity will bring economic benefits, with projected GDP growth ranging from 0.8% to 4.6% and the creation of 2000 to 9000 new jobs annually. More interconnection capacity will allow for more renewables penetration. As a result, positive impacts could be generated. These include better economic exchange, increased energy supply and renewable generation assets to be optimised across interconnected countries.

Other flexibility options

Other clean flexibility technologies are also available. Though many currently face some technical limitations (e.g. balancing the wind-solar-hydro flexibility since there is only a small solar and wind capacity in ASEAN), their small-scale applications (e.g. household battery storage) and minor relevance in the decarbonisation path (e.g. CCGT).

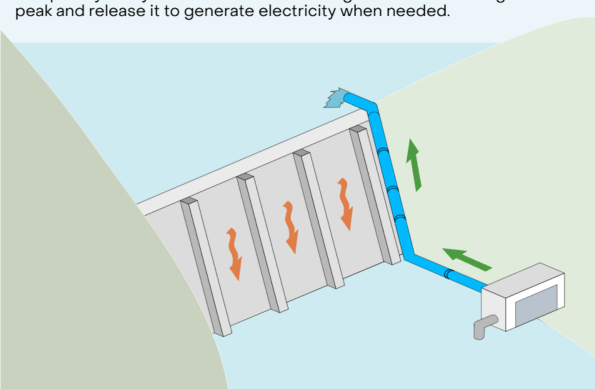
Industrial demand-side as a flexibility application could be potential if the lack of data transparency is being addressed. Other options, day-ahead market and intraday market will work in the multi-buyer market structure.

While these solutions may play a limited role today, many could become more impactful over time as technologies mature, markets evolve, and policy framework improves. In the future, these technologies and applications may play a more prominent role in the provision of grid–stabilising services.

Clean flexibility options for ASEAN

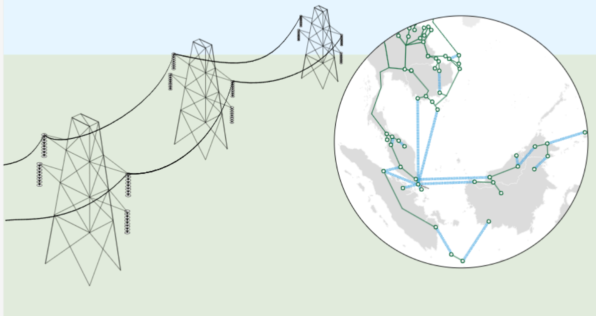
Pumped hydro

Pumped hydro systems move water to a higher reservoir during off-peak and release it to generate electricity when needed.



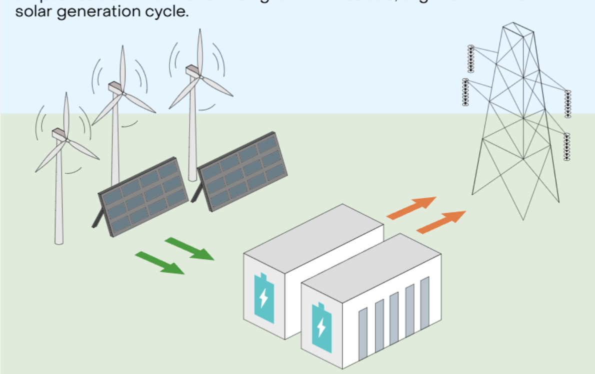
Grids and interconnections

Grids and interconnections enhance flexibility by balancing energy supply across regions and seasons, optimising power line use, and reducing grid constraints.



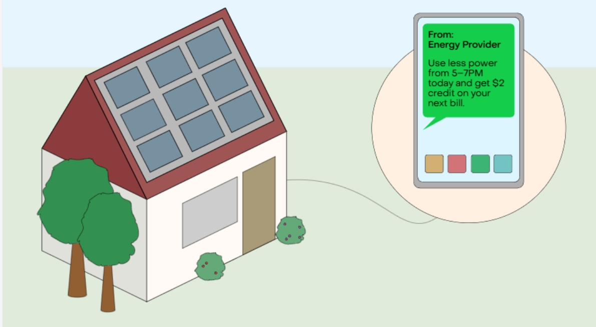
Battery-storage

Battery storage absorbs excess electricity when generation surpasses demand and releasing it when needed, aligned with the solar generation cycle.



Demand-side management

Demand-side management adjusts electricity use by controlling end-user devices to enhance grid flexibility, in response to increased renewable energy integration.



Source: Ember

Chapter 3: Grid and connectivity

Interconnected ASEAN: An idea whose time has come

Interconnected grids can maximise renewables potential and unlock a new renewable energy market for fossil-dependent countries.

To address the twin challenges of rising energy demand and the need for low-carbon electricity access, ASEAN Member States have been planning a unified regional energy integration since 1997. The ASEAN Power Grid (APG) envisions power sector integration through the development of grid infrastructure and a regional power market, comprising multiple cross-border transmission projects categorised into northern, southern, and eastern sub-regions.

Under the ASEAN Interconnection Master Plan Study (AIMS), eighteen transmission interconnection projects are being prioritised, including key cross-border and inter-country interconnections such as Singapore-Riau Islands, Peninsular Malaysia–Sarawak, Kalimantan–Java and Sumatra–Java. The ASEAN Power Grid, including all the transmission interconnection projects, is expected to be fully established by 2045, underscoring the urgency of addressing key challenges related to regional grid planning. ASEAN is projected to have an interconnection capacity of 17,550 MW by 2040, based on the ASEAN Interconnection Masterplan (AIMS) III and will contribute to 2,824 km development of electricity grids in the ASEAN region.

Despite years of discussion, regional grid interconnection in Southeast Asia has yet to take off. But that may be about to change. A convergence of forces—rising renewable energy deployment, growing electricity demand, more affordable transmission technologies, and a rare window for political cooperation—is creating the conditions for breakthrough progress. Solar and wind are scaling rapidly across the world, creating opportunities for surplus generation that could be shared across borders. At the same time, rising electricity needs in the region make it clear that smarter, integrated systems are essential to ensure reliable, low-cost power.

Enablers are lining up. High-voltage transmission technologies and infrastructure financing have become more accessible, lowering the barriers to long-distance power exchange. The Lao PDR–Thailand–Malaysia–Singapore Power Integration Project (LTMS-PIP) shows that cross-border trade is technically and commercially feasible.

The upcoming Brunei Darussalam-Indonesia-Malaysia-Philippines Power Integration Project (BIMP PIP), replicating the success of LTMS-PIP, is expected to produce a feasibility study by 2025. Other interconnection projects are proposed to be a priority, including the connection between Peninsular Malaysia - Sumatra - Singapore, Sarawak - Brunei, and the lines connecting Lao PDR, Viet Nam, Cambodia and Myanmar. While these developments are promising, efforts need to be accelerated to maximise the full benefits.

Amid global geopolitical uncertainty, enhanced regional cooperation can offer a hedge against supply shocks and price volatility. The ASEAN Energy Ministers have issued a joint declaration to achieve a sustainable energy supply through interconnectivity. Building on this, stronger governance should be established to pursue unified electricity connectivity and a region-wide coordinated electricity market.

For the ASEAN Power Grid plan to become a reality, it must be aligned with a corresponding financing framework to facilitate its implementation.

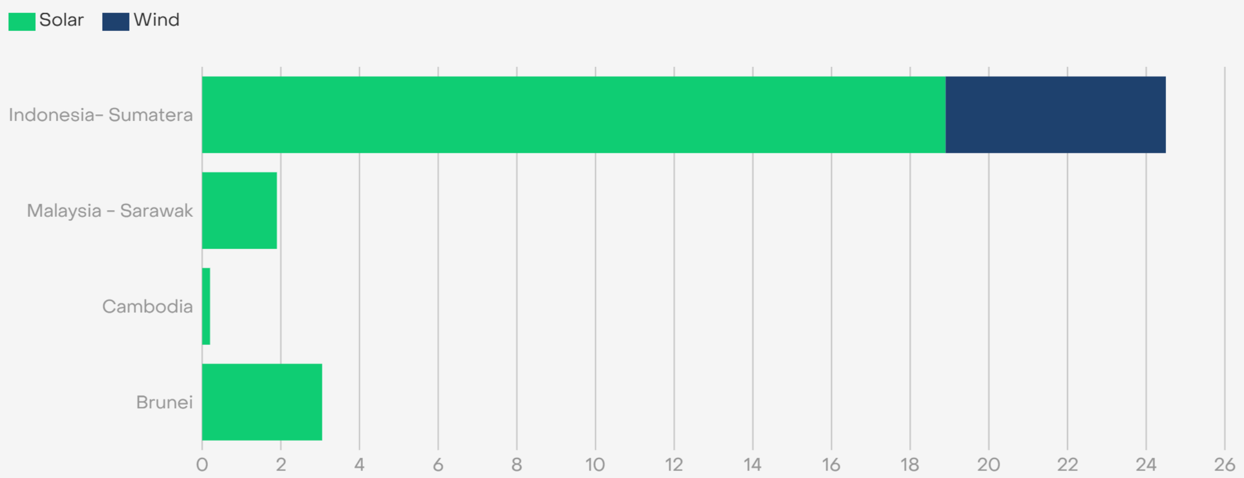
This includes harmonising technical standards of the electricity system, completing the AIMS Phase 3 Studies—such as minimum requirements for multilateral power trading, integrated resource and resilience planning (IRRP), grid codes, technical standards harmonisation, wheeling charge methodologies, third-party access and effective transaction settlement mechanisms—while ensuring regulatory compliance and grid stability. The market forces and policy momentum are aligned to facilitate the shift from bilateral power trade to building a cohesive, renewables-driven regional power market.

ASEAN grid routes are home to abundant solar and wind potential

Several ASEAN countries and provinces have plans for more solar and wind projects, reflecting growing momentum toward renewable energy development. Based on the Global Energy Monitor's list of ongoing solar and wind projects, Sumatra and the Riau Islands have a planned installation of 14 GW of solar power in the pipeline by 2035 but have no planned wind projects. Lao PDR is constructing 4.8 GW of solar and 4.9 GW of wind capacity by 2035, respectively. Cambodia is developing a 2.9 GW of solar and 0.2 GW of wind by 2035. Brunei is currently building 0.03 GW of solar capacity, while 0.1 GW of solar capacity is under construction in Sarawak and is expected to be operational by 2030.

30 GW of solar and wind could be unlocked along planned ASEAN grid routes

Capacity in gigawatts



Source: Values were derived by comparing planned construction (sourced from the Global Energy Monitor Solar and Wind Tracker) with estimated economic potential in selected interconnection areas.
Solar potential in Sumatera was calculated using geographic potential multiplied by a 10% effective conversion efficiency. Wind potential in Sumatera was taken from the Indonesia Energy Outlook 2016. For Sarawak, government targets (MIDA) were used; Cambodia's target was based on its 2040 projections, and Brunei's estimate was based on floating solar potential.

By enabling power exchange between countries, ASEAN grid interconnection could be the potential driver to unlock the additional 24 gigawatts of solar and 5.6 gigawatts of wind capacity in resource-rich ASEAN countries. For example, clean power generated along the BIMP (Brunei Darussalam-Indonesia-Malaysia (Sabah & Sarawak) -Philippines) grid connection could supply electricity to Indonesia's Kalimantan, considering the plan to build the new Nusantara Capital City. Similarly, clean power generated in Cambodia and Sumatra could be delivered to Singapore. More interconnection would also be helpful in spreading peak load distribution and minimising outages, compensating low production of renewables in one region by a power supply from another.

Achieving the increase in solar and wind use across ASEAN will require a combination of greater investment, stronger off-taker commitments, and supportive measures such as land allocation, flexible local content requirements, and an improved ease of doing business. While the challenges are significant, modern, flexible and interconnected grids present an opportunity: resource-rich countries can help strengthen energy security across the region by supplying clean energy to countries with limited solar and wind potential.

In countries where interconnection projects are prioritised, for example Indonesia-Sumatra, Malaysia-Sarawak, Cambodia, Lao PDR and Brunei plan to construct 27 GW capacity of solar and wind by 2035. For instance, as a coal-producing region with relatively low electricity demand, Sumatra currently lacks sufficient incentives to develop solar energy. However, interconnection could change that by enabling electricity exports to the Singapore market. Similarly, improved interconnection among hydro-rich areas such as Cambodia, Sarawak, and Lao PDR could help incentivise solar and wind development. On top of these planned installations, there is scope to boost further growth given the economic potential for solar and wind in some of these geographies.

ASEAN's power demand is projected to reach 1,626 terawatt-hours by 2030. According to the updated power development plan, solar and wind capacity are expected to reach around 101 GW, with estimated generation approximately 11%, or 177 terawatt-hours, of that demand.

A 30 GW of solar and wind that can be unlocked has the potential to generate 109 terawatt-hours of electricity, opening opportunities for countries to exceed their national targets.

Creating a robust renewable energy market through interconnection

There are bottlenecks to creating the market for cross-border power trade in ASEAN, in the form of economics and institutional obstacles, creating a fundamental barrier to market integration and cross-border power trade. These include financial and institutional constraints in the post-pandemic recovery period. Questions also arise in the market model that could be adopted; supply chain stability in the midst of the US tariff and reliability and resilience risks tied to a model of an unified power market.

This trajectory could be part of a wider goal in driving the economic growth of the countries. Countries such as Lao PDR and Viet Nam are already venturing their electricity sales to a new market, Singapore, through the cross-border power exchange and interconnection across Lao PDR, Thailand, Malaysia and Singapore. This will be further amplified by the development of offshore wind farms in Viet Nam, as well as solar and battery projects in Indonesia, with more power to export.

Cross-border electricity trade also allows countries to benefit from additional financing by establishing a regional Renewable Energy Certificate (REC) trading framework. Beyond electricity trading, environmental attributes such as RECs can incentivise utilities and/or power plant owners to invest in renewables by earning extra revenue from the sale of REC to companies committed to using renewables in their operations.

The closer integration of mainland and archipelagic ASEAN will open new transit routes. This could potentially incentivise fossil-reliance countries like Brunei to champion the energy transition, via the BIMP (Borneo - Indonesia - Malaysia - Philippines) Power Grid Interconnection Project (PIP).

Ember's calculation, using metrics for 30 GW of new solar and wind projects, shows that around 182,000 jobs could be created from 30 GW installations. There is potential for ASEAN to expand the local employment impacts by creating a local supply chain for solar and wind, so the jobs include manufacturing roles, installation, maintenance, and support services.

The ASEAN grid interconnections can unleash a robust regional renewable energy market

Existing and planned interconnections in selected locations* and 2030 electricity demand in the ASEAN region

Source: ASEAN Centre for Energy (2023), Global Energy Monitor, Findings of ASEAN Interconnection Masterplan Study (AIMS) III Phase 1 & 2 Update (2023), NREL (2020), Sani et al. (2021) and national policy documents.
*Lines includes selected projects based on the ASEAN Interconnection Masterplan Study (AIMS) III. Points in the map does not reflect the overall interconnection plan and grid infrastructure in ASEAN countries and particularly highlights cross-border interconnections. TBC: Planned lines according to ASEAN Interconnection Projects Plan.
**Ongoing projects up to 2024.

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Nimble strategies to create modern, flexible grids

Coordinated planning and unified voices in grid planning will unlock solar and wind potential.

A shift in grid planning already underway. For example, Singapore and Malaysia prioritise digitalisation to support better grid stability, grid operations and absorption of intermittent energy sources, Thailand plans to transfer more electricity to neighbouring countries via smart interconnections, and the Philippines is merging grid planning with the development of renewable energy zones.

These developments mark the beginning of a necessary shift.

Coherent policies and financing mechanisms are key to modernise ASEAN grids

Grid development priorities in ASEAN differ at regional and national levels of energy planning. At the regional level, grid development plans encompass priority infrastructure projects shaped by both regional and national energy models, power trading frameworks, and potential financing sources—including governments, multilateral development banks, international organisations, and private foundations.

At the national level, however, grid development plans primarily focus on transmission and distribution expansion, as seen in Indonesia's PLN Electricity Supply Business Plan (RUPTL). Beyond transmission and distribution expansion, there are limited details on strategies for grid modernisation in Indonesia's electricity sector plan.

This absence of modernisation strategies may be linked to the fact that grid scales are expanding without significant changes in the power supply mix, leading national grid operators to show less concern about grid fluctuations. For example, between 2018 and 2023, Indonesia added only 0.6 TWh of solar and 0.3 TWh of wind capacity. Similarly, the Philippines added just 1.2 TWh of solar and 0.9 TWh of wind during the same period. However, this perception should change as ASEAN is expected to increase the deployment of solar and wind in the coming years.

Additionally, the regulated monopoly structure of grid networks in countries such as Indonesia often discourages companies from modernising infrastructure or embracing innovation at the pace of other industries. The reason being is a monopolised structure does not incentivise utilities like Indonesia's PLN to modernise the grid, and its legal mandate is to provide affordable electricity even if it's sourced from coal.

To accelerate progress, utility financing and/or Public-Private Partnership model should be designed to manage a spectrum of risks, including technical, regulatory, commercial, and political, through leveraging existing ASEAN partnerships and exploring the establishment of a dedicated APG financing facility. Developing a common-use asset financing approach by involving development partners and commercial banks, such as through Public-Private Partnership (PPP) can attract significant investment. This can be in the form of existing initiatives such as the Just Energy Transition Partnership (JETP) or engaging directly with multilateral development banks, as seen in Cambodia's ADB-funded grid reinforcement project.

ASEAN countries need a future-ready grid development planning

To facilitate the growth of a robust renewables market, grid policies in ASEAN must evolve to support a system that is clean, reliable, flexible, and inclusive. Grid development planning should enable the transformation, expansion and modernisation of this critical infrastructure. While the local contexts differ, based on current literature and scholarship, we identified six broad categories or pillars that a good future grid development plan should include.

1. Smart grid modernisation

Upgrade existing grid infrastructure with digital tools and smart technologies. Policies should support the deployment of smart meters, automation, real-time monitoring, and cybersecurity systems to enable a more intelligent, responsive grid that can efficiently manage variable renewables.

2. Strategic grid expansion

Extend and strengthen the physical grid to connect generations from variable energy resources and reach growing demand. Planning and investment in new transmission lines—especially to renewable-rich zones—and extending access to underserved areas are critical to unlock clean energy potential.

3. System flexibility and resilience

Equip the grid to adapt to fluctuations in supply and demand while withstanding shocks, enabling the power system to maintain balance between generation and load under uncertainty, and changes in needs, technologies and conditions.

Flexibility policies should enable energy storage, demand response, and fast-ramping resources. Resilience measures should address climate risks, grid hardening, and cyber threats.

4. Regional integration and interconnection

Build regional power systems that share resources and improve efficiency through trade. Policies should promote cross-border interconnectors, harmonised standards, and regional planning to unlock diverse renewable energy resources and balance supply across borders.

5. Market and regulatory reforms

Create open, transparent, and competitive power markets at the regional level that support clean energy. This includes unbundling of utilities, open access to the grid, cost-reflective pricing, and enabling participation of new players like prosumers and storage providers.

6. Sustainable finance and investment mobilisation

Ensure long-term financing for grid upgrades, new infrastructure, and innovation. Governments should deploy financial instruments -such as green bonds, public-private partnerships, and risk guarantees can de-risk projects and mobilise both domestic and international capital.

Grid modernisation and interconnection emerge as key themes in the grid development plans of several ASEAN countries

Country	Grid development plans	Policies
Singapore	Harnessing DERs to enhance grid resilience by providing energy, ancillary services or demand response services to shift energy usage to off-peak periods; Enhancing grid planning, control and maintenance efforts such as through the development of digital solutions such as the grid digital twin, distributed energy resources management system to optimise manpower and reduce manual processes; Exploring solutions to maintain grid stability.	Future Grids capabilities roadmap (latest update as per January 2025)
Malaysia	Upgrading the smart grid features and enabling the grid for third party access for corporate green power.	National Energy Transition Plan (2023 onwards)
Viet Nam	Automation of transmission and distribution grid, as well as Smart Grid applications to allow monitoring the real-time supply-demand balance at the user level; discussion to establish interconnection with Lao PDR; power grid development and cross-border transmission as key energy transition programs in JETP	Smart Grid Roadmap (2023 onwards)
Indonesia	Smart grid application in Java-Bali system to improve grid resilience and efficiency; grid modernisation as investment focus area in JETP	National Medium-term Development Plan (2021 onwards)
The Philippines	Improve overall system protection, improve grid reliability, reduce the technical & non-technical power and energy loss, better respond to changes in demand and supply, and improve grid resilience; Identification of economic zones with high renewable energy resources and combined them with grid planning	Smart and Green Grid Plan (SGGP) - upcoming, Grid Planning and Competitive Renewable Energy Zones (CREZ)
Thailand	Trainings, and development and installation of Smart Grid technology to improve power system flexibility, RE forecast and enabling technologies; pilot projects for the third-party access and direct PPA for data centers	Smart Grid Development Master Plan (2015-2036); ASEAN Power Grid Interconnections Project Profiles
Cambodia	To achieve the recent target for household electrification of 95% of households being connected to the national grid by 2030, continuing national grid expansion, and improving power grid interconnection in the Greater Mekong Subregion.	Cambodia Basic Energy Plan (by 2030); 2023 solar guidelines

Such a framework helps governments, regulators, and development partners align grid policy with the evolving needs of renewable-dominated power systems.

Embedding the six-pillar framework into national grid strategies will help ASEAN countries move from reactive grid expansion to proactive system transformation.

The building blocks for stronger grids are there, need stronger emphasis on implementation

Country	Smart grid modernisation	Strategic grid expansion	System flexibility and resilience	Regional integration and interconnection	Market and regulatory reforms	Sustainable finance and investment mobilisation
Singapore	✓		✓	✓	✓	✓
Malaysia	✓	✓	✓	✓	✓	✓
Viet Nam	✓	✓	✓	✓	✓	✓
Indonesia	✓	✓	✓			✓
The Philippines	✓	✓	✓	✓	✓	✓
Thailand	✓	✓	✓	✓	✓	✓
Cambodia	✓	✓	✓	✓	✓	✓

Source: Ember

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Interconnections in other parts of the world

Examples from Europe and Southern Africa show the benefits of grid capacity expansion and coordination, including better integration of wind and solar and resource distribution.

Europe

One example of a very developed integrated power system is Europe's power system consisting of cross border, high voltage cables linking national power grids and shared market rules. It is the world's largest interconnected grid with 400 interconnectors, linking 600 million customers and 93 GW of capacity. Managed by the European Network of Transmission System Operators for Electricity (ENTSO-E), the interconnected grid integrates 39 Transmission System Operators (TSOs) across Europe to enable electricity supply and demand in response to price signals.

In spite of the grid's need for modernisation, the EU appears to be on the right track toward its dual goals of updating the grid and ramping up renewables. There are continued roll-out of grid-enhancing technologies, renovation of high-voltage transmission lines, and an accelerated renewable energy permitting process. Additionally, two groups of countries CORE (Austria, Belgium, Croatia, the Czech Republic, France, Germany, Hungary, Luxemburg, the Netherlands, Poland, Romania, Slovakia and Slovenia) and Nordics (Norway, Sweden, Denmark, and Finland) have been pioneering Flow-Based Market Coupling, which improves efficiency of exchanges thus favouring security of supply and improvement of social welfare.

Here, where renewable energy shares are rapidly growing, there is significant potential and need to deploy clean flexibility solutions. Clean flexibility is even more important given the long queues for grid connections, which are one of the bottlenecks for wind energy expansion in the EU. Grid operators have a strong opportunity to balance power demand and supply through interconnections and clean flexibility tools such as battery storage, demand-side flexibility and pumped hydro storage. Such real-time trading is possible because of the established markets (intra-day and balancing markets) which allow coordination of power purchases by TSOs across Europe. This balancing is further simplified as ENTSO-E can oversee and coordinate grid operators across Europe.

Southern Africa

In Southern Africa, power connectivity has progressed significantly. The Southern African Power Pool (SAPP) comprises 22 utility companies from 13 countries. To unlock financing, a dedicated facility known as the Regional Transmission Infrastructure Financing Facility (RTIFF) project was scheduled to run from 2020-2025. The RTIFF project receives funding from the World Bank to the Common Market for Eastern and Southern Africa (COMESA) and the Trade and Development Bank (TDB).

The underlying purposes behind this regional power sector integration are to enhance energy security, bring economies-of-scale in investments, facilitate financing, enable greater renewables penetration and allow sharing of complementary resources. For South Africa, the aim was to meet future increases in demand by importing low-cost hydropower from its northern neighbours. The trading agreement also facilitates the expansion of the grid to connect members not connected on the SAPP grid, and introduces a short-term energy market (STEM) to cater for the trading of surplus energy under existing contracts. STEM has been replaced by a fully competitive day-ahead market (DAM).

Unlike the EU which has a dedicated regional transmission system operator, SAPP operates under an intergovernmental memorandum of understanding (MoU) and operating agreements. These agreements authorised and guaranteed the inter-utility contractual obligations and operating agreements.

In the onset, there was no new capacity expansion of any significant size developed. However, since 2007, there has been an urgency in expanding generation capacity. Cooperation has also resulted in the sharing of benefits in auxiliary services and demand-side management measures. For example, the reserve margin can be reduced.

Since its inception, SAPP has aimed to share excess generation among its members through bilateral and multilateral agreements. Despite challenges such as competitive market barriers and obstacles in renewable energy project development, its success in fostering cooperation and transitioning to a competitive market could serve as a valuable model for the ASEAN market.

Ultimately, the focus should not be on whether ASEAN replicates the SAPP or European power systems, but on building a resilient and connected market. Currently, ASEAN remains at a stage where utility-scale electricity trade occurs bilaterally and unidirectionally, often involving transit countries. The key issue here is achieving a shared understanding amongst the ASEAN's power market players that energy security could be enhanced through sharing of solar and wind resources.

More than financing, but a coordinated planning and implementation

Developing the ASEAN Power Grid is not just a matter of securing financing—it requires meticulous coordination, planning and implementation. At the onset, evaluating infrastructure requirements is crucial given the variation in market structure across ASEAN countries. The right incentives could motivate grid development in both multi- and single-buyer systems. The establishment of a system operator composed of representatives from Member States' grid operators could assume responsibility for network planning and investment needs (e.g. this role could be delivered by HAPUA - Heads of ASEAN Power Utilities/ Authorities, ASEAN Power Grid Consultative Committee (APGCC) and ASEAN Energy Regulators Network (AERN)). Then, a dedicated ASEAN fund could accelerate the physical interconnection of the Southeast Asian electricity system.

A unified grid demands standardised grid codes and agreed wheeling charges to ensure seamless operation across borders. Additionally, a centralised platform is needed to mediate multilateral power trade, ensuring an efficient and resilient trading system, taking in the form of unified market and operations, while tagging environmental attributes to parties involved.

Grid operators must also prepare for the technical challenges of an integrated regional power network. These include the coordination of trading across borders, disruptions from intermittent solar and wind power, the complexities of long-distance transmission, and the broader implications for energy security. Addressing these issues requires robust flexibility measures to ensure that electricity flows reliably across the region, meeting the needs of all ASEAN nations.

The Greater Mekong grids connecting China, Cambodia, Myanmar, Laos, Thailand and Viet Nam serve as an example where innovations could be applied. Since the onset of the Inter-governmental Agreement on Regional Power Trade signing in 2002, the power trade has been limited to a few uncoordinated bilateral cross-border exchanges of electricity. Key obstacles include inadequate infrastructure consisting of low-voltage lines, inflexible power trade agreements, a lack of third-party access, and the absence of a regional coordinating body.

To advance power connectivity at a higher level, infrastructural and political innovations can deliver system-wide benefits. Infrastructure efforts should prioritise planning for clean flexibility to maximise existing interconnection capacity and reduce stress on the power grid. Meanwhile, political support for a shared vision of a more interconnected ASEAN can drive further progress. With growing discussions on wheeling charges and third-party access at the regional level, the region appears to be on the right track.

Key takeaways

Turbocharging grids to develop the market for renewables

To tap into a greater renewable energy market, ASEAN must emphasise future-ready grid development planning.

With the rise of clean energy technologies, renewables in the region are set to grow exponentially to meet increasing demand. There is no better time than now for ASEAN member countries to focus on stronger grids to keep pace with competition for foreign investments with requirements for clean energy, namely modernisation, expansion, adoption of flexibility options, regional integration, market reforms, and mobilisation of finance. Additionally, ASEAN's commitment to ensure all member countries grow together means market-level development in the renewable energy sector is fuelling larger demand for interconnections.

Sharing of renewable energy resources will happen at a more rapid pace in the future. Grids and interconnections, as enablers of these evolving dynamics, will bring cost reduction potential, faster net-zero emission vision, enhance energy security, attract more investment and create more jobs. As ASEAN moves toward deeper regional energy integration, prioritising grid infrastructure and political solutions will be essential to unlocking new opportunities and ensuring a more interconnected and resilient power system.

Beyond physical infrastructure, enabling data sharing across the region—while maintaining strong privacy protections—will be crucial for advancing innovative business models, streamlining bureaucratic processes and attracting new investment.

Another critical area often overlooked is the implications of electrification, particularly the infrastructure needed for electric vehicle (EV) charging. Building strong incentives for operators to use green energy could accelerate grid modernisation efforts, making the system more flexible and capable of handling growing electricity demand.

Ultimately, aligning grid investments with the evolving energy landscape will be key to ASEAN's transition toward a more sustainable, efficient and competitive power system.

Supporting materials

Methodology

Solar and wind capacity

This study assesses the gap between ASEAN's projected power demand and the required renewable energy capacity to align with net-zero targets. To quantify the additional capacity required, we analyse national energy statistics, literature and assess solar and wind economic potential in key interconnection countries. We use the assumption the geographic potential multiplied by a rule-of-thumb effective conversion efficiency, of 10% from the technical potential for solar energy in Sumatra.

Job creation

The metrics used assesses the job creation potential of the renewable energy technologies industry within the economy—specifically, jobs per megawatt (jobs/MW) for solar and wind—and is intended as an exercise for interpreting statistics related to the area of job creation potential from these technologies.

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Cover image

Aerial photo of an electric tower in Sindang Jaya, Banten, Indonesia.

Credit: Tom Fisk / Pexels