REGIONAL TRENDS REPORT

2022

TOWARD SUSTAINABLE ENERGY CONNECTIVITY IN ASIA AND THE PACIFIC

STATUS, TRENDS, AND OPPORTUNITIES

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Economic and Social Commision for Asia and the Pacific

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Foreword

Energy sits at the heart of economic growth and sustainable development in Asia and the Pacific, enabling rapid development and improving the welfare of billions of people across the region. Now, however, this growth is being challenged by significant increases in commodity costs driven by increased demand for energy and raw materials and the current geopolitical tensions. At the same time, the impacts of climate change are being increasingly felt in the region, with many countries experiencing record-breaking periods of drought, while others face increasingly extreme weather events and flooding. Transitioning to sustainable energy and mitigating the impacts of climate change are more critical than ever.

Unfortunately, the Asia-Pacific region is not on track to meet the Sustainable Development Goals, including Sustainable Development Goal 7 (SDG 7). Deployment of renewable energy and complementary technologies like energy efficiency, battery storage and, in particular, grids must increase significantly if the SDG 7 targets are to be met. However, there are many positive signs that suggest the transition to clean energy is accelerating. Renewable energy is more cost-competitive than ever, especially compared with the relatively high cost of oil, natural gas and coal, and these technologies are increasingly being recognized as contributors to energy security.

The focus of this report is on one strategy that can enable a more rapid, more secure and more affordable transition to clean energy, i.e., power system connectivity. Energy connectivity supports the integration of variable renewables, and enables access to a more diverse and lower cost set of resources. This strategy is widely recognized, including by ESCAP member States, which in 2021 endorsed the "Regional Road Map on Power System Connectivity". The vision, principles and nine strategies detailed in that document have guided the development of this report.

As this report explains in detail, there are many active efforts to increase connectivity in the Asia-Pacific region, including the development of subregional grid plans and pilot projects for multilateral power. Overall, however, progress on energy connectivity in Asia and the Pacific lags behind other parts of the world.

Accelerating progress on power system connectivity can, in turn, accelerate the energy transition. ESCAP will continue to work with stakeholders in the region and its member States to implement the Road Map strategies, and enable more secure, more efficient and more sustainable connectivity in the region. I hope that this report will provide a useful set of case studies and recommendations for enhancing policies in support of power system connectivity and the energy transition.

Hongpeng Liu
Director
Energy Division, ESCAP

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Executive summary

Sustainable Development Goal 7 (SDG 7) targets universal access to energy, an increased share of renewable energy in the global energy mix, and doubling the rate of energy efficiency improvement. While the Asia-Pacific region has made considerable progress in meeting SDG 7 targets, much more work needs to be done if the region is to achieve the 2030 Agenda. Progress in the Asia-Pacific region is, in particular, challenged by the fact that energy demand, closely linked to economic growth, is continuing to rise rapidly.

Power system connectivity stands out as an important tool for achieving SDG 7 targets, while also meeting overall increasing power demand. For example, power system connectivity enables renewables integration by increasing the geographic scale of power systems, allowing them to take advantage of complementarities in resource diversity, demand patterns and geographical location. In addition, power system connectivity can help to improve energy access by enabling hard-to-reach locations to be served by a neighbouring power system.

The opportunity for cross-border power connectivity in the Asia-Pacific region is significant, and there are numerous examples across Asia and the Pacific of efforts to increase cross-border power system connectivity. These include the ASEAN Power Grid, the South Asia Regional Initiative for Energy Integration, and the North-East Asia Power System Integration programme. These efforts, however, remain primarily in the development stage. Cross-border power system infrastructure continues to be developed on a primarily bilateral basis; while there some pilot projects to develop multilateral power trading, in contrast to other parts of the world, there are no regional power pools.

Recognizing both the potential value of power system connectivity in supporting sustainable development and obstacles to progress, in 2021 ESCAP member States endorsed the "*Regional Road Map on Power System Connectivity: Promoting Cross-Border Electricity Connectivity for Sustainable Development*."[1] The roadmap sets forward a vision, a set of principles, and nine strategies to accelerate progress on cross-border power system connectivity in the region.

Cross-border connectivity efforts are complex endeavours that can take many years to fully develop, with even mature efforts outside of the Asia-Pacific region continuing to evolve in response to technological and market changes. As a starting point, however, political support for connectivity initiatives is a fundamental prerequisite to drive collaboration as well as ensure sufficient resources can be brought to bear to develop regional power system masterplans and supporting institutional arrangements. While cross-border power system connectivity initiatives can take many forms, successful efforts are generally developed in a stepwise process based on voluntary principles, which seek to harmonize rules and regulations, develop necessary infrastructure and enable cross-border power trade.

Connectivity efforts have historically been driven by potential economic benefits (e.g., lower costs, the ability to earn export revenue), and they are increasingly recognizing the sustainability benefits of power system connectivity (e.g., increased integration of renewable energy). One barrier to power system connectivity is, however, concern over energy security, i.e., that cross-border power system connectivity can lead to over-reliance on external resources and exposure to disruptions. While such concerns are understandable, it is also important to recognize that connectivity can bring energy security benefits, including through diversification of resources. In practice, the potential for outages to spill across borders is relatively rare. However, it can be mitigated against through clear

1 See https://www.unescap.org/our-work/energy/energy-connectivity/roadmap

operational rules and communication, and power system connectivity can reduce exposure to other forms of energy connectivity, in particular imported fossil fuels.

As power systems and technologies evolve, so do the topics that can affect cross-border power system connectivity. For example, the electrification of end-uses such as transport will drive energy demand, and therefore will require an expansion of power generation and transmission infrastructure. Cross-border connectivity can make it easier to meet this increase in demand by allowing infrastructure to be built where it is most efficient to do so; however, this also presents a challenge as power system operators must manage power systems with changing demand and generation patterns.

Energy connectivity outside of the power sector is also evolving with, for example, renewable gases (e.g., hydrogen) emerging in importance. Hydrogen and other low-carbon fuels have implications for energy connectivity, both in terms of demand and supply, and should therefore be considered in decarbonization strategies.

Connectivity as a concept also has wider reaching implications than just the development of cross-border infrastructure and power trade. Island nations, for example, are at the forefront of climate change and deserve solutions that can help them mitigate and adapt to climate change. The economic case for developing integrated power systems among island nations in the Pacific is limited, but they can nevertheless benefit from collaboration on technical issues and potential new technologies.

Power system connectivity is not a new concept, but its application in Asia and the Pacific remains relatively limited. It is hoped that this report will serve to highlight the potential benefits of increased power system connectivity as a tool for sustainable development as well as and opportunities to accelerate progress in the region.

Introduction

Connectivity – or the ability of different and often diverse parts to work together in mutually beneficial ways – has emerged as one of the main concepts of our time. Connectivity brings economies and societies together across many different dimensions, including economic, political, institutional, socio-cultural, digital and energy.

Countries today face a number of interconnected challenges, including: the need to address climate change and transition to clean energy sources; the rising frequency of extreme weather events; the Covid-19 pandemic; and the ongoing conflict in Ukraine. The role of connectivity in addressing these issues is gaining traction.

Energy plays a pivotal role in achieving an array of interrelated development objectives, and it lies at the heart of the 2030 Agenda for Sustainable Development and the Paris Agreement on Climate Change. Sustainable Development Goal 7 (SDG 7) focuses on access to affordable, reliable, sustainable and modern energy for all, providing a guiding framework for developing and improving national energy systems. The reasoning is straightforward – energy options have an impact on the health and security of people, the same way they have an impact on the health and security of the planet.

In Asia and the Pacific, growth runs in tandem with pressing social, economic and environmental challenges. Notwithstanding Covid-19-induced economic slowdowns, the region remains the fastest-growing region in the world. According to the International Monetary Fund's April 2022 *World Economic Outlook,* economic growth for Asia in 2021 was 6.5 per cent, and is projected to be 4.9 per cent in 2022 and 5.1 per cent in 2023 – slower than historical trends, but still higher than much of the rest of the world (IMF, 2022).

However, uneven rates of economic growth may further divergence between advanced and emerging or developing economies in the region.[2] The COVID-19 pandemic exposed these differences and other important vulnerabilities. In addition, it showed the urgency behind the need to translate this economic dynamism into a more equitable distribution of the benefits of growth, the improvement of people's well-being and the achievement of the SDGs.

Continued energy availability remains a *sine qua non* condition of this economic dynamism. Overall, energy demand will maintain its rising trend, despite significant variations across subregions.[3] Meeting rising demand will require significant investments in national energy systems. Seen in another perspective, the strategies that states adopt to meet this demand will determine the future competitiveness, inclusiveness, sustainability and resilience of the whole region in the medium to long term.

The electricity sector plays a particularly critical role. Economic growth, population growth, urbanization rate, and new forms of transportation have been putting additional pressure on electricity demand. The Asian Development Bank (ADB) estimates that developing Asia's share of global electricity demand will grow to 43 per cent in 2030, with China and India accounting for 64 per cent of power consumption in the region. Universal electricity access is pivotal in overcoming energy poverty and inequality – factors thwarting education, people's health and well-being, gender equality and productivity levels. Hence, a swift transition to sustainable energy largely depends on how electricity needs are met, i.e., on how and where electricity is produced and consumed. This concern is amplified by the fact that the Asia-Pacific region is currently responsible for more than 50 per cent of global greenhouse gas emissions. More than 80 per cent of the projected global growth in coal demand will come from Asia and the Pacific.

Meeting electricity demand growth and achieving SDG 7 targets presents several challenges as well as opportunities. Alongside sustainability, the security of affordable and reliable energy supply remains at the top of priorities or concerns. The Asia-Pacific region is endowed with significant quantities of natural resources, both fossil and renewable. However, not only are resources unevenly distributed across the region, subregions and countries, they are also often located in remote areas, far from the demand centres where they are most needed.

Countries in the region differ in terms of level of development, energy needs and availability of domestic energy resources. In this context, increased cooperation on energy issues, including the sharing and trading of resources to address energy surpluses and deficits, would bring significant benefits.

As a specific form of energy cooperation, therefore, power grid connectivity to enable resource sharing and the integration of higher shares of renewable energy offers an appealing strategy to achieve energy transition while maintaining economic growth and energy security.

Cross-border and cross-regional electricity connectivity can help optimize resource utilization to ensure the security, affordability and sustainability of power systems. Technological advances (e.g., ultra-high-voltage direct current (UHVDC) transmission, smart grids, low carbon technologies, storage and energy efficiency solutions) have opened up

2 For the purpose of this report, developing economies or 'developing Asia' refers to low- and middle-income countries. High-income economies (those with a GNI per capita of US$ 12,696 or more) are referred to as developed economies or 'developed Asia' (World Bank, 2022b).

3 In the first semester of 2020, the effects of COVID-related containment measures contributed to marked declines in electricity demand. However, despite variations in the extent of the health crisis across countries (degrees of containment and vaccination levels), all countries saw demand recover as economic activities resume (IEA 2020a)

multiple opportunities to improve economic, social, security and environmental welfare. Moreover, the relationships built around the development of shared power infrastructure can open up opportunities for regional cooperation in other spheres.

The region as a whole confirmed the desirability of increased power system integration through the endorsement by member States of the "*Regional Road Map on Power System Connectivity: Promoting Cross-Border Electricity Connectivity for Sustainable Development*", at the ESCAP 77th Commission Session in April 2021. The Road Map includes a vision, a set of principles and the nine strategies listed below to support the development of interconnected, sustainable energy systems in the region:

- Build trust and political consensus for cross-border electricity trade;
- Develop a regional cross-border electricity grid master plan;
- Develop and implement intergovernmental agreements on energy cooperation and interconnection;
- Coordinate, harmonize and institutionalize policy and regulatory frameworks;
- Move towards multilateral trade and create competitive markets for cross-border electricity;
- Coordinate cross-border transmission planning and system operation;
- Mobilize investment in cross-border grid and generation infrastructure;
- Build capacities and share information, data, lessons learned and best practices;
- Ensure coherence of energy connectivity initiatives and the SDGs.

However, initiatives to increase cross-border power system connectivity remain primarily at the subregional level, and the majority of power trade is bilateral in nature. Therefore, there is still room for States to benefit from the implementation of the nine Road Map strategies.

Deepening regional power cooperation faces financial, technical and operational challenges. Among other factors, cross-border power system connectivity has been hampered by a lack of political will, concerns about energy security and difficulties in the regulatory alignment across borders.

As an overarching objective, this report aims to highlight the relevance of regional power connectivity in attaining sustainable development and energy security. It presents the current status of sustainable development and regional power connectivity in the Asia-Pacific region, pointing out the progress and prospects. It also provides insights into where action is most needed, highlights regional and non-regional examples of successful approaches and discusses the challenges to further deepen cooperation and cross-border power connectivity. In addition, it focuses on the existing coordination institutional mechanisms and discuss their challenges, and addresses relevant cross-cutting and emerging issues and their actual and potential impacts on regional power connectivity.

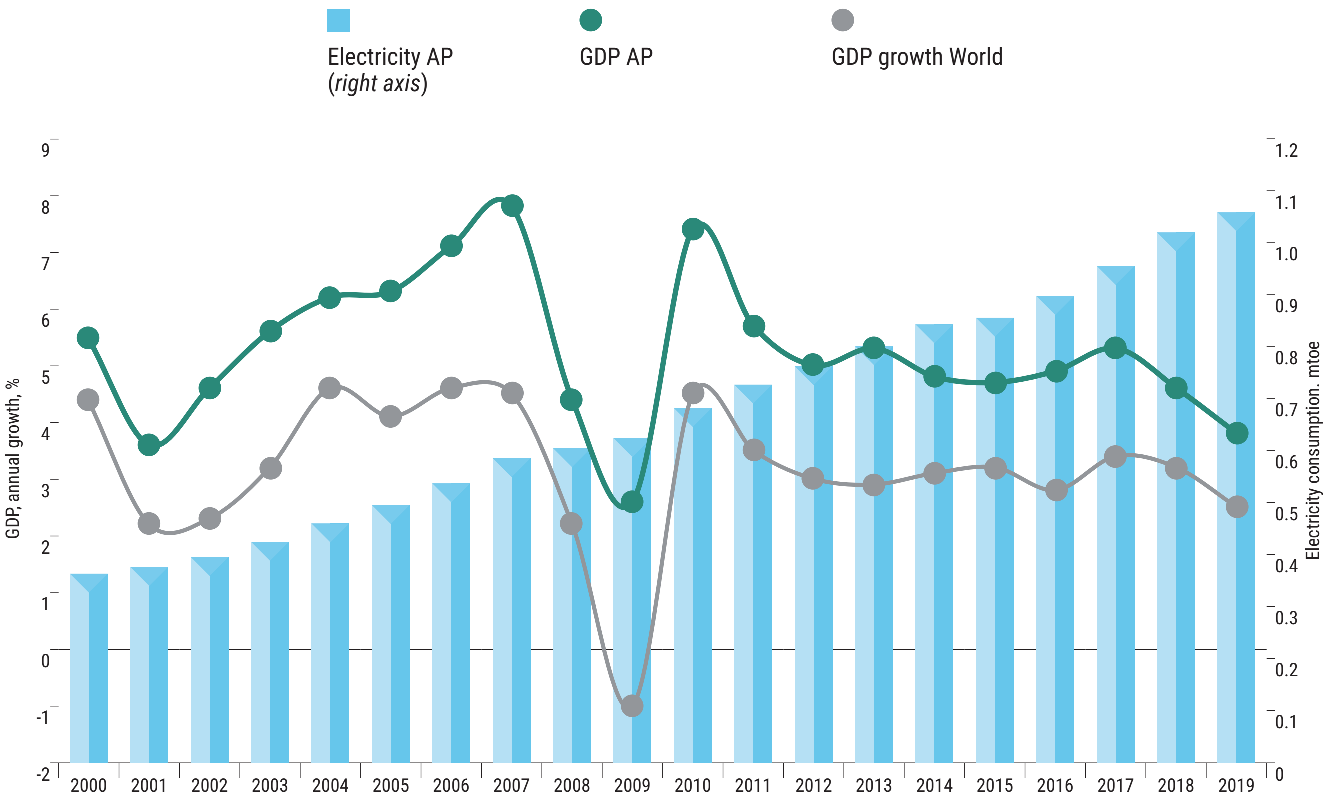
CHAPTER 1

Sustainable energy development: **Situation and trends**

1.1. Asia and the Pacific: A brief outlook and the role of **cross-border power connectivity**

The potential role of regional and subregional electricity connectivity in supporting economic growth while achieving the 2030 SDGs is particularly potent in Asia and the Pacific. The Asia-Pacific region has remarkable resource diversity, development needs and sustainability imperatives. Economically, the region has historically been one of the faster-growing regions in the world, and is increasingly viewed as a driver of global economic growth (ADB, 2011a).The impact of the global COVID pandemic and the ongoing conflict in Ukraine on economic growth, however, has been significant, and short- and medium-term economic prospects are uncertain.

Historically, economic growth and growth in electricity demand have been tightly linked, although in developed economies this relationship has decoupled. Economic growth has brought higher urbanization rates and increased consumption of modern technologies, including air conditioners and computers, all of which is driving and changing the shape of electricity demand. According to the International Energy Agency (IEA), during the past 15 years electricity in developed economies saw 0.4 per cent average annual growth despite average economic growth of 1.6 per cent per year. In emerging and developing economies during the same period economic growth averaged 5.4 per cent and electricity demand growth averaged 5.7 per cent



Source: ESCAP based on United Nations Statistics Division, NAMAD, IEA.

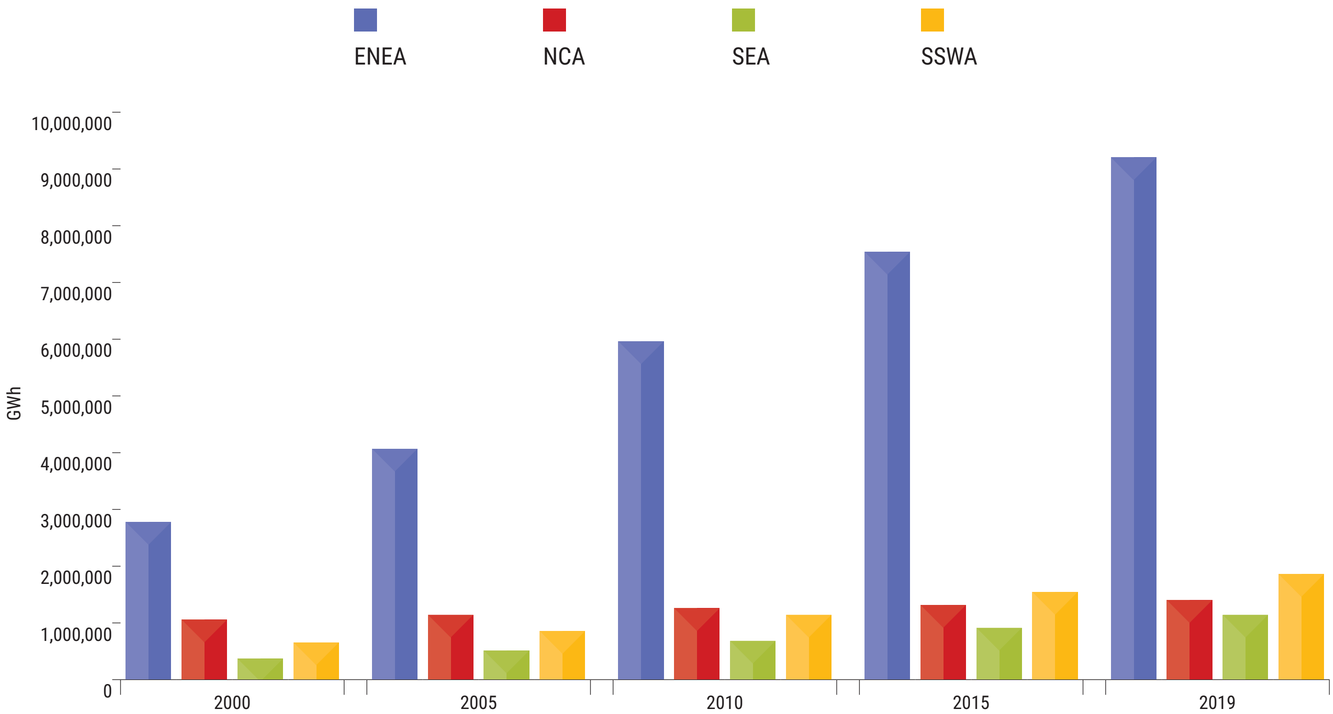
Figure 1 GDP average annual growth rate, % (left axis), Electricity final consumption, mtoe (right axis), 2000-2019

annually (figure 1). As a result, 93 per cent of the worldwide net growth in electricity demand from 2005 to 2019 originated in emerging and developing economies – and 58 per cent in China alone (IEA, 2020).

The IEA's January 2022 Electricity Market Report confirmed that global demand growth is concentrated in emerging and developing Asia (figure 2). The report also notes that, as economies rebound from the impact of COVID-19, most countries in the region are expected to see continued demand growth to 2024, with the regional growth rate stabilizing at around 4 per cent annually on average, slightly below pre-pandemic levels but still above the global average of less than 3 per cent (IEA, 2022a).

The composition of energy systems in Asia-Pacific countries reflects a combination of economic development and domestic energy resource endowments, or the lack thereof. Some countries have significant domestic reserves of low-cost fossil fuel resources; some have high renewable potential, but lack the economic conditions to develop renewable energy resources; others are resource-poor overall and are therefore import-dependent.

Of course, there is significant diversity within and between these categories. India and Indonesia, for example, have significant amounts of domestic coal resources, and utilize high-levels of coal generation in their power systems, while also having significant potential renewable energy resources. The Islamic Republic of Iran, Malaysia and Thailand, on the other hand, have significant domestic resources of natural gas, and relatively high shares of natural gas-fired generation. Similarly, countries with significant hydropower potential, such as Bhutan, Nepal, and Tajikistan, base their power systems on those resources. Clearly, the relative availability of domestic resources has an impact on national choices in energy supply strategies (Kharbanda, 2019).



East and North-East Asia (ENEA) – China, Democratic People's Republic of Korea, Hong Kong (China), Japan, Mongolia, Republic of Korea. North Central Asia (NCA) – Armenia, Azerbaijan, Georgia, Kazakhstan, Kyrgyzstan, Russian Federation, Tajikistan, Turkmenistan, Uzbekistan. South-East Asia, excluding Timor-Leste (SEA) – Brunei Darussalam, Cambodia, Indonesia, Lao People's Democratic Republic, Malaysia, Myanmar, the Philippines, Singapore, Thailand, Viet Nam. South and South-West Asia, excluding Afghanistan, the Islamic Republic of Iran, Bhutan, Maldives and Turkey (SSWA) – Bangladesh, India, Nepal, Pakistan, Sri Lanka (ESCAP, 2019b).
Source: ESCAP calculations based on IEA.

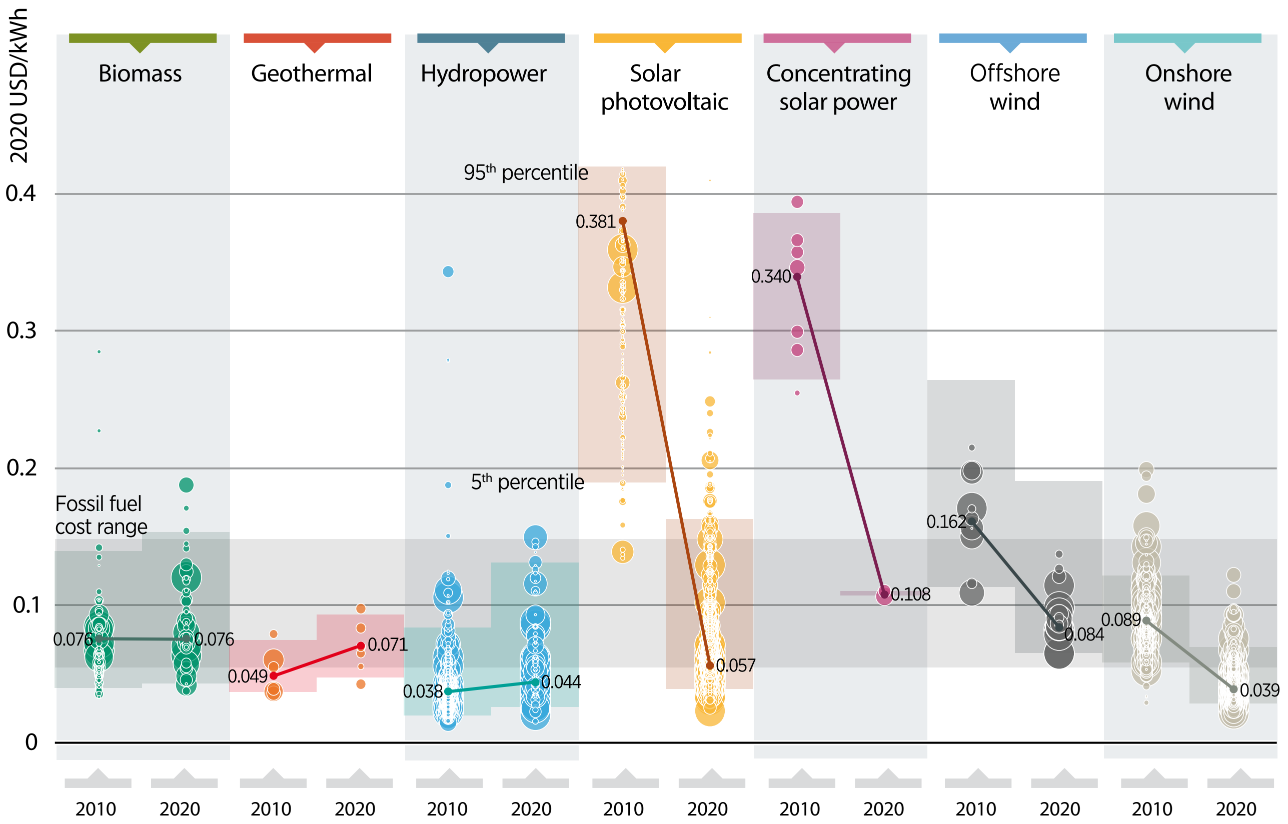
Figure 2 Total gross production of electricity by sub-region, GWh, 2000-2019

In this context, cross-border power connectivity emerges as a tool to address the availability, affordability and security of energy supplies (often referred to as the "energy trilemma") by allowing countries to (Kharbanda, 2019):

- Leverage diversity by taking advantage of resource complementarities;
- Respond to increasing and increasingly varied energy demand;
- Boost access to clean energy by enhancing the integration of renewable energy resources.

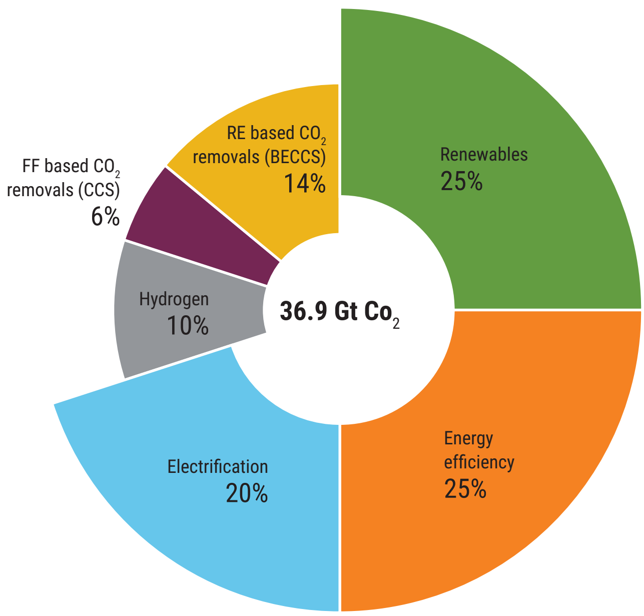
1.2. Status of SDG 7

Sustainable Development Goal 7 (SDG 7) – ensuring access to affordable, reliable, sustainable and modern energy for all – provides a clear target for energy sector development across three dimensions of access to electricity, renewable energy resources and energy efficiency. Globally the share of people with access to electricity grew to 91 per cent in 2020, although this also means that 733 million people still lack access. In the Asia-Pacific region, universal access to electricity in urban areas has nearly been achieved, with the urban electrification rate in Central Asia and South Asia at 100 per cent in 2020, and in East Asia and South-East Asia and Oceania reaching 99 per cent. Rural areas, however, lag behind, with electrification rates in 2020 at 94 per cent in Central Asia and South Asia, 97 per cent in East Asia and South-East Asia, and 74 per cent



Source: IRENA, 2021b.

Figure 3 Levelized cost of different renewable energy technologies, 2010-2020



Source: IRENA, 2021b.

Figure 4 Six components of the energy transition strategy

in Oceania (World Bank, IEA, IRENA, UN and WHO, 2022).

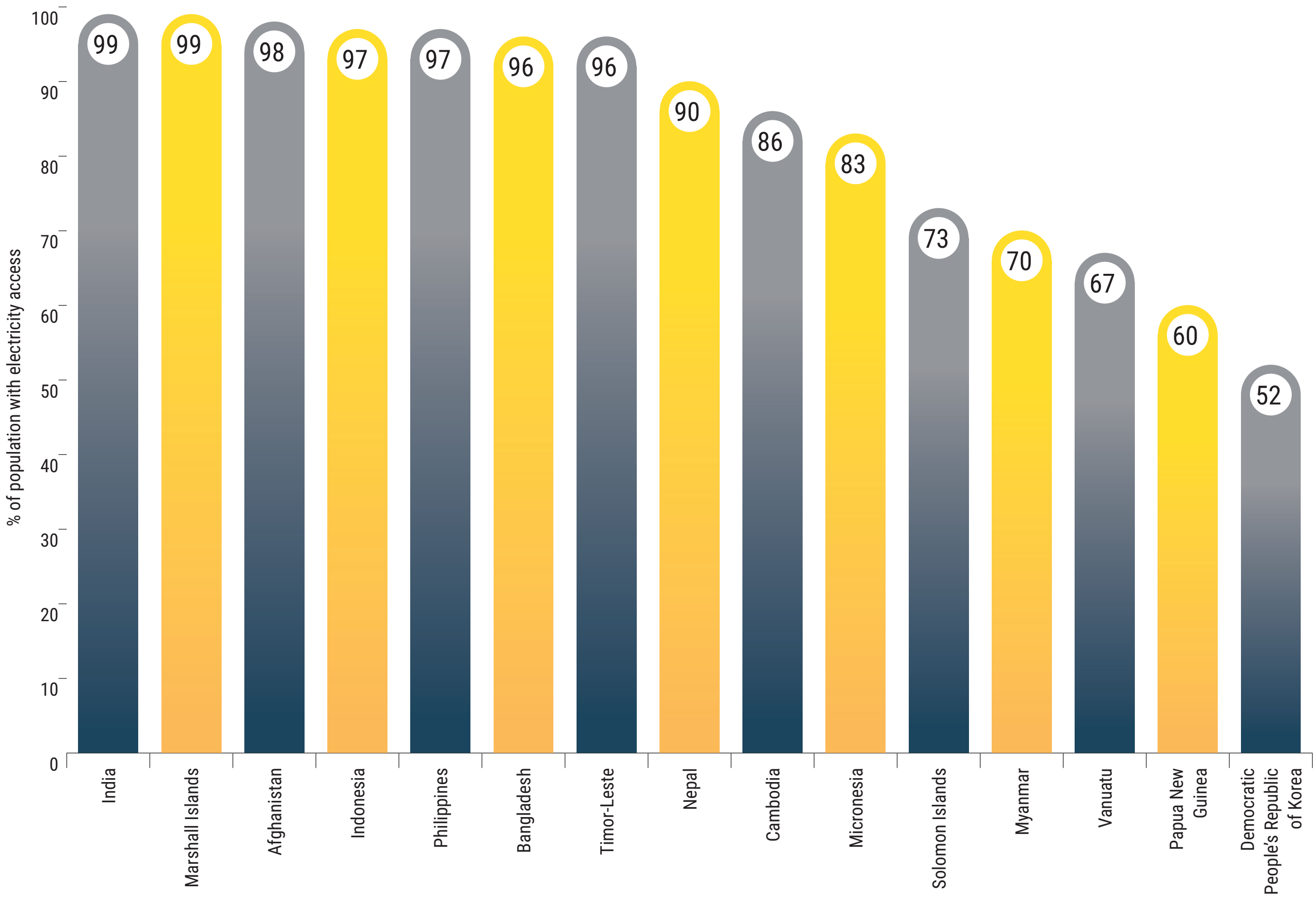
The cost of renewable energy technologies, meanwhile, has decreased dramatically in recent years which, combined with incentive policies, has led to a significant expansion of their use (figure 3).

At the same time, improving energy efficiency is a critical tool for enabling energy transition. For example, according to IRENA, energy efficiency makes up 25 per cent (figure 4) of the climate mitigation solutions required to keep global temperature at 1.5 degrees C.

The following sections examine the components of SDG 7 – energy access, clean cooking, renewable energy and energy efficiency – and their status in more detail.

Energy access

The Asia-Pacific region has made notable progress in achieving universal access to electricity. For example, energy poverty has been effectively eliminated in Central Asia and the Caucasus, with nearly 100 per cent of the population in this subregion having access to electricity. East Asia and South-East Asia are approaching universal access, with more than 98 per cent of the population having access to electricity as of 2020. The most significant advances in electrification were Bangladesh and India, which saw annual access growth rates of close to 2 percentage points between 2010 and 2020. The pace of electrification was highest in Timor-Leste, Cambodia and Afghanistan, where access increased by more than 5 percentage points per year during the same period (World Bank, IEA, IRENA, UN and WHO, 2022).



Source: World Bank, IEA, IRENA, UN and WHO, 2022.

Figure 5 Countries of Asia and the Pacific with electricity access deficits, 2020

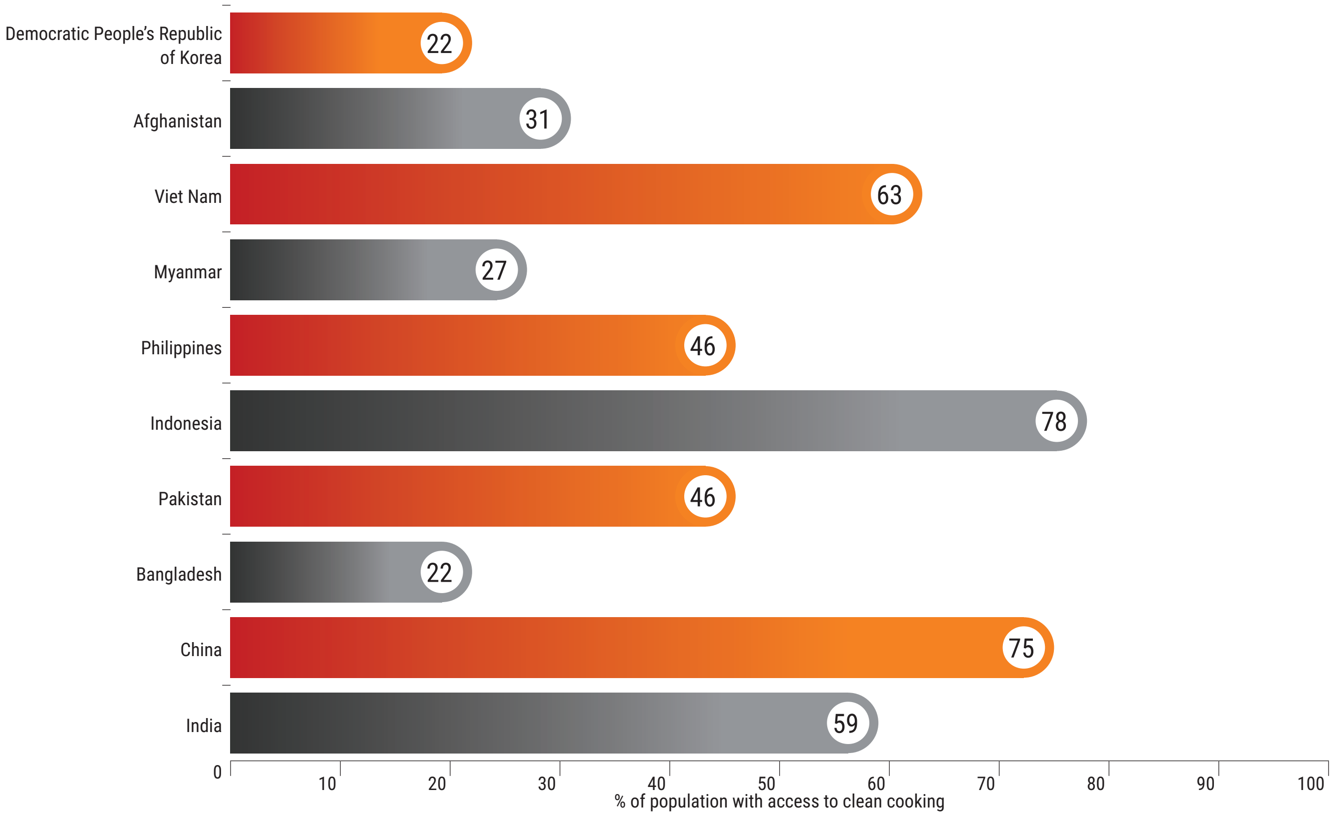
However, overall regional progress in access to electricity rates masks unequal progress across certain subregions. As of 2020, of the world's top 20 countries with access deficits, four were in the Asia Pacific region: Pakistan (54 million), India (14 million), Myanmar (16 million) and the Democratic People's Republic of Korea (12 million) (figure 5).

The Pacific Small Island Developing States (SIDS) have made significant progress towards achieving SDG 7. Fiji, Kiribati, Nauru, Palau, Samoa and Tuvalu have all achieved 100 per cent electricity access. From 2000 to 2020, Papua New Guinea and Solomon Islands implemented successful electrification programmes, increasing the electricity access rate from 9 per cent to 60 per cent, and from 5 per cent to 73 per cent, respectively.

Improvements in access to electricity are, in some cases, the result of strategies to increase power supply and expand distribution through national grids and off-grid solutions. Although national grid expansions have driven the larger trend, falling costs for renewable, energy-based mini-grids and standalone systems, combined with growing regional technical capacities, have made off-grid solutions increasingly viable options for difficult-to-reach areas (ESCAP, 2019a).

Clean cooking

According to the ESCAP Regional Trends Report 2021, clean cooking has not yet received adequate policy attention in the Asia-Pacific region (ESCAP, 2021b). The Clean Cooking Alliance reports that four million people die every year from illnesses associated with smoke from cooking, while the World Health Organization (WHO) reports that in poorly ventilated dwellings, indoor smoke can be 100 times higher than acceptable levels of fine particles. Inefficient cooking practices and the subsequent pollution have negative health impacts that include pneumonia, stroke,



Source: World Bank, IEA, IRENA, UN and WHO, 2022.

Figure 6 Ten countries in Asia and the Pacific with the largest number of people lacking access to clean fuels and technologies, (average for 2016-2022)

ischemic heart disease, chronic obstructive pulmonary disease and lung cancer. Exposure particularly has an impact on the health of women who are traditionally involved in cooking and young children who stay with them.

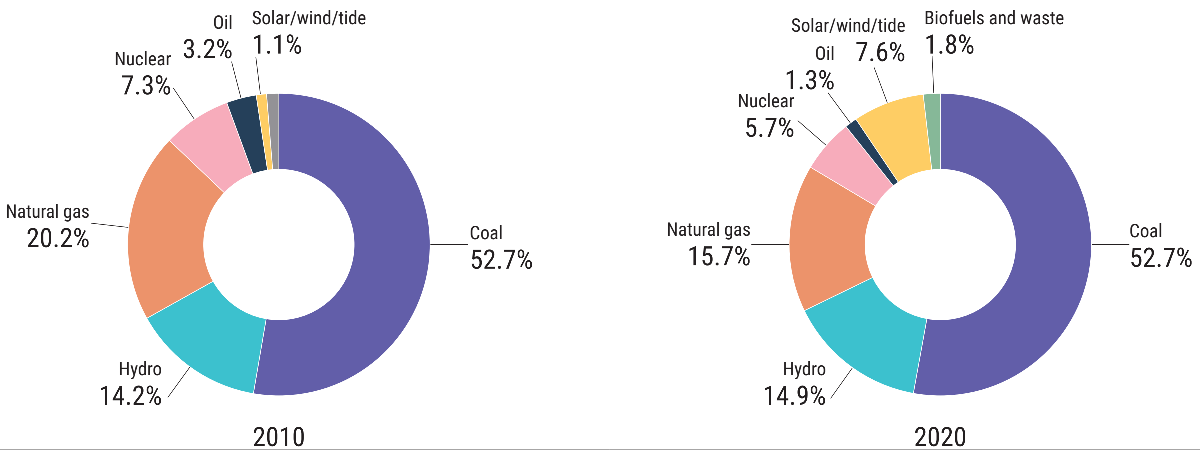
Asia and the Pacific is home to around 60 per cent of the global population that has no access to clean cooking solutions. At least 1.6 billion people from the region primarily rely on open fires or simple stoves for their cooking needs. However, clean cooking progress is varied at the subregional level. Improvements in the access rate are driven by the most populous low- and middle-income countries – China, India, Indonesia and Pakistan. However, India still accounts for the largest share of access deficit in the world with 548 million people without access to clean cooking, followed by China where 352 million people are without access (figure 6).

Progress in the Pacific has been relatively slow. Only Nauru and Palau have achieved a rate of access to clean cooking above 90 per cent. In Kiribati, Micronesia, Papua New Guinea and Solomon Islands, less than 10 per cent of the population has access to clean cooking fuels and technology. However, some countries have made notable progress. For example, from 2000 to 2018, the Marshall Islands increased the share of population with the access to clean cooking from 15 per cent to 65 per cent.

While more efficient technologies greatly reduce the costs of cooking, in many cases consumers cannot afford the upfront investment needed to switch to cleaner, but often more expensive, alternatives. Apart from financial challenge for expanding clean cooking, changing the mindset of households to replace traditional cooking (use of kerosene stoves and open fire) is seen as one of the key barriers. While a transition to clean cooking is necessary, due to a lack of financing and limited attention in the policymaking sphere clean cooking initiatives have had insufficient impact. Several tools are available to help countries design programmes and policies that enhance clean cooking as part of clean household energy transition. They include, for example, the World Bank's Clean Cooking Planning Tool, SeforAll's Integrated Energy Planning Tool and the Clean Cooking Alliance's Clean Cooking Explorer or the WHO Clean Household Energy Solutions Toolkit. They were created to help countries design and implement clean household energy policies to accelerate clean cooking progress.

Renewable energy

Progress in renewable energy deployment varies between different sectors. Clear improvements can be seen in electricity production (figure 7). In East Asia and South-East Asia, for example, renewable energy capacity grew from 134 watts



Source: ESCAP based on IEA.

Figure 7 **Electricity production by product in Asia and the Pacific, 2010-2020** to 460 watts per capita from 2010 to 2020, mainly due to additions of wind and solar power. The three countries in the region showing the most growth are the Lao Peoples Democratic Republic, China and the Republic of Korea. China alone contributed more than 54 per cent of the global annual increase in renewable electricity generation. Half of China's growth came from wind and solar PV, while more than 40 per cent came from hydropower. China was also responsible for the largest increase in non-renewable electricity consumption, followed by India, hinting at the challenge that countries face as they try to simultaneously increase the deployment of renewable energy and meet rising demand (World Bank, IEA, IRENA, UN and WHO, 2022).

Despite the growth in renewable energy consumption worldwide, the share of renewable sources in total final energy consumption (TFEC), excluding traditional uses of biomass, increased by just 2.7 percentage points from 2010 to 2019 and represented only 11.5 percent of TFEC in 2019.

The Pacific Islands are extremely dependent on imported petroleum for commercial energy. Only Papua New Guinea (PNG) has proven (and developed) significant oil and gas resources. Larger Melanesian countries like PNG and Fiji have sufficient land area and mountains to support larger scale hydropower installations. All of the Island states, however have an excellent solar resource which slightly increases toward the equator.

The cost of renewable energy technologies is decreasing every day, while their efficiency is increasing, which contributes to the expansion of their use. The development of renewable energy sources will help the countries of Asia and the Pacific to reduce their dependence on fossil fuels as well as improve the environmental situation, which is especially important in cities where coal-fired power plants are now located.

Energy efficiency

Improving energy efficiency offers great opportunities for reducing the energy intensity of economies and sustainable development. Energy intensity in the Asia-Pacific region remains above the world average and varies subregionally.

With the exception of North Asia and Central Asia, and the Pacific, during the 2010-2018 timeframe the rates of energy intensity improvements more than doubled over the 1990-2010 baseline period across Asia-Pacific subregions, bringing the Asia-Pacific region closer to the global target rate of improvement. It is important to note that between 1990 and 2010, many countries in Central Asia and the Caucasus made significant progress in improving energy efficiency through economic restructuring and replacement of outdated equipment. However, the energy intensity of many of the region's economies is still above the global average, so further actions, including by Governments, are needed to improve the results already achieved.

In most Pacific countries the energy intensity is still lower than the world average due to an economic structure with a low share of the industrial sector. From 2000 to 2018, energy intensity grew in Fiji, Kiribati, Marshall Islands, Micronesia and Tonga mostly because of growing electrification and economic development (ADB, 2011b).

A multi-sectoral approach should be taken to realize energy efficiency improvement potential. Energy saving opportunities can be found in the residential, commercial and transport sectors. Policies such as an appliance minimum energy performance standard and labelling scheme and building codes should be considered to leverage the energy reduction potential, while also providing positive financial gains.

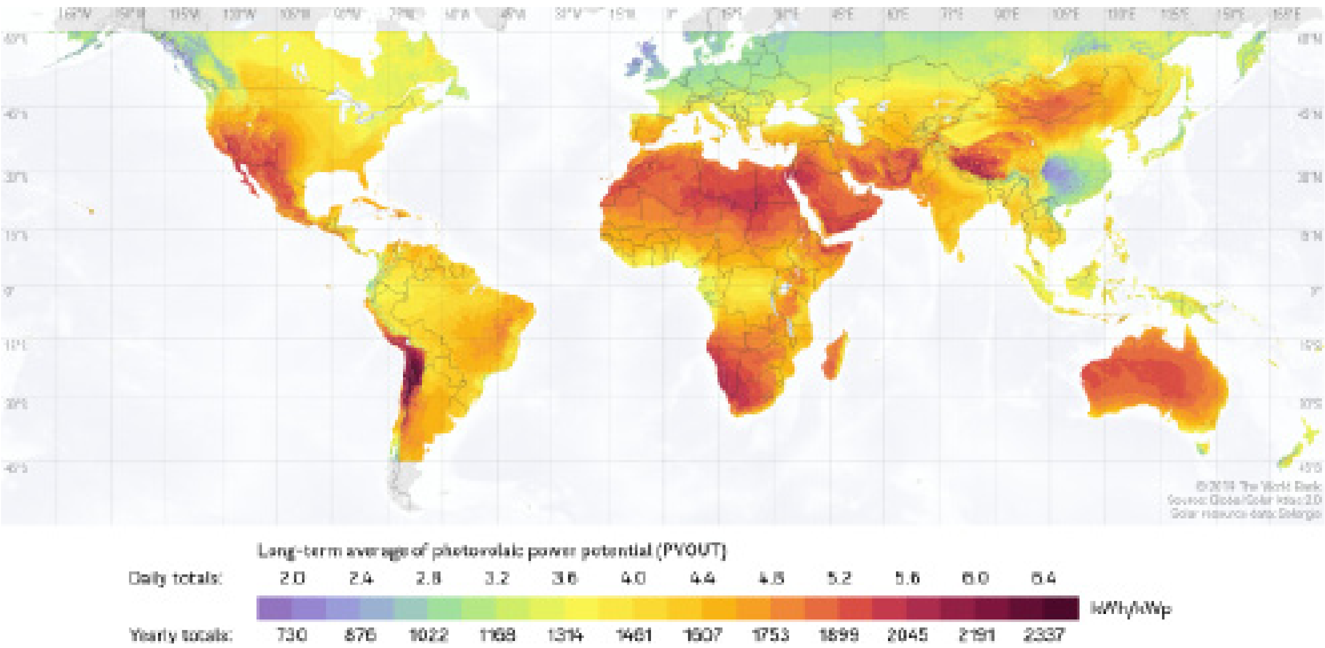
1.3. Energy connectivity for **achieving** SDG 7

There is tremendous untapped potential for renewable energy in Asia and the Pacific. However, renewable energy resources are unevenly distributed both within subregions and across the region as a whole (figures 8 and 9).

As the share of renewable energy generation increases, power systems will become increasingly dependent on weather patterns. Increased power system connectivity can allow greater use of variable renewable energy by taking advantage of natural variations in weather patterns as well as renewable energy technologies that are heavily location-specific, such as hydroelectric power, by pooling generation over larger geographic areas. In this way, power grid connectivity can contribute to the transition to renewable energy (ESCAP, 2018a).

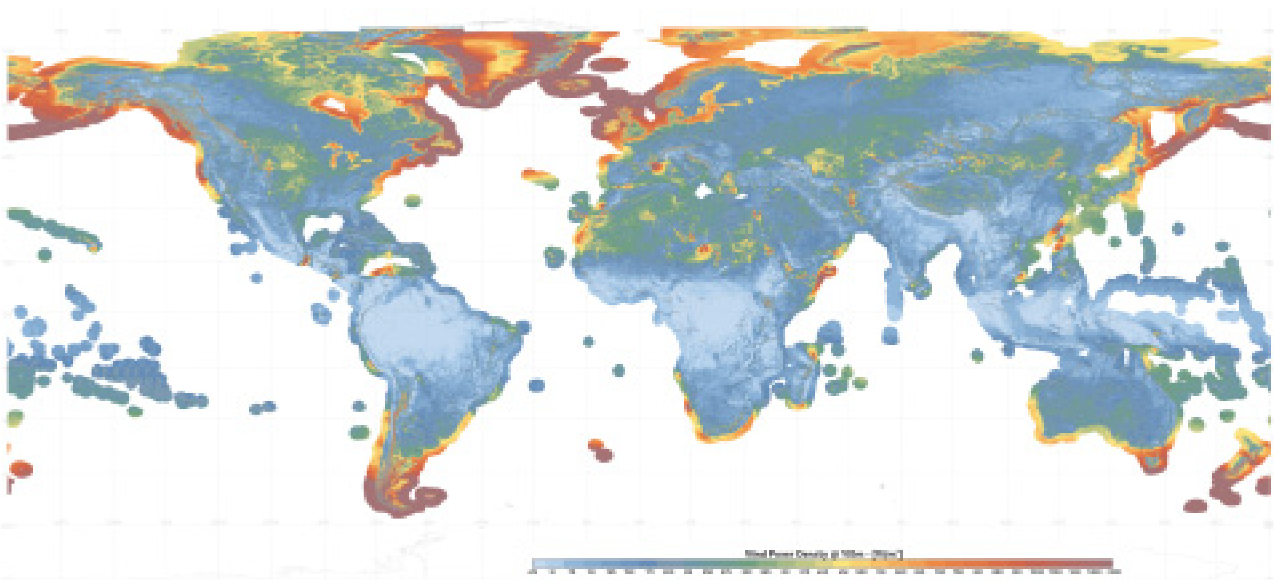
Historically and increasingly, countries have sought to take advantage of this natural diversity. Some countries are already net exporters of electricity (Bhutan, India and the Islamic Republic of Iran), while others are net importers (Pakistan, Bangladesh, Turkey and Nepal). By deepening regional energy cooperation and advancing cross-border electricity connectivity and trade, Governments are focusing on the possibilities associated with diversity, highlighting the value of complementarities, rather than focusing on the limitations derived from specific circumstances. Through regional energy/electricity trade, these diversities become strengths, allowing countries to take advantage of low-cost abundant resources across their borders, or to ensure energy security during times of domestic resource scarcity.

There is growing consensus on the virtues of regional energy cooperation, particularly in the cooperation/integration of power generation and transmission plans among different countries. Across the globe,



Disclaimer: The boundaries and names shown and the designations used on this map do not imply official endorsement or acceptance by the United Nations. Dotted line represents approximately the Line of Control in Jammu and Kashmir agreed upon by India and Pakistan. The final status of Jammu and Kashmir has not yet been agreed upon by the parties.
Source: Global Solar Atlas.

Figure 8 Photovoltaic solar potential, world map, 2019



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Source: Global wind atlas.

Figure 9 Wind power density potential, world

international institutions and other players have emphasized the potential role of cross-border power connectivity in addressing the pressing challenges facing the world's energy systems. The value of regional and interregional approaches that can, among other advantages, enhance the deployment of renewable and sustainable energy by facilitating the sharing of experiences, reduce transaction costs and increase economies of scale was emphasized in the Resolution of the 75th session of the United Nations General Assembly, adopted on 21 December 2020 (United Nations, 2020). At the national level, more and more power development plans are incorporating power system connectivity opportunities.

Interconnected grids and multilateral power trade have a role to play, both in meeting rising demand and responding to changing demand patterns. Power system connectivity enables the more efficient use of generation and the development of generation at lower per unit costs by taking advantage of economies of scale, making it possible to meet rising demand at lower cost. Power system connectivity can make it easier for countries to manage expected spikes in demand or other events that might undermine electricity security (Kharbanda, 2019).

Advances in power grid technologies, including the increasing cost-effectiveness of high voltage direct current (HVDC) transmission, open up the possibility for longer distance power transmission, while also bringing technical benefits, such as better control of power flow, reactive power management and allowing interconnected grids to work in asynchronous mode, isolating power system faults on each side. Thus, HVDC presents advantages for cross-border interconnection of power systems with different operating parameters. For distances exceeding 600 kilometres, HVDC offers a more economical solution for power transmission compared to alternating current systems, and is preferred for submarine connections longer than 40 km to 50 km. On the other hand, its decreasing cost is also opening up possibilities for using HVDC for shorter route lengths (ESCAP, 2018a).

Strengthening cooperation at the regional level, connecting regional energy markets, sharing best practices and developing regional cross-border power grid connectivity advances economic integration and sustainable development, increases energy security and supports the achievement of SDG 7.

CHAPTER 2
Cross-border power **system connectivity initiatives** in Asia and the Pacific

Several strategies of the Regional Road Map for Power System Connectivity in Asia and the Pacific ("Road Map") emphasize the need to develop common frameworks to advance regional connectivity. Two of these strategies focus on grid planning:

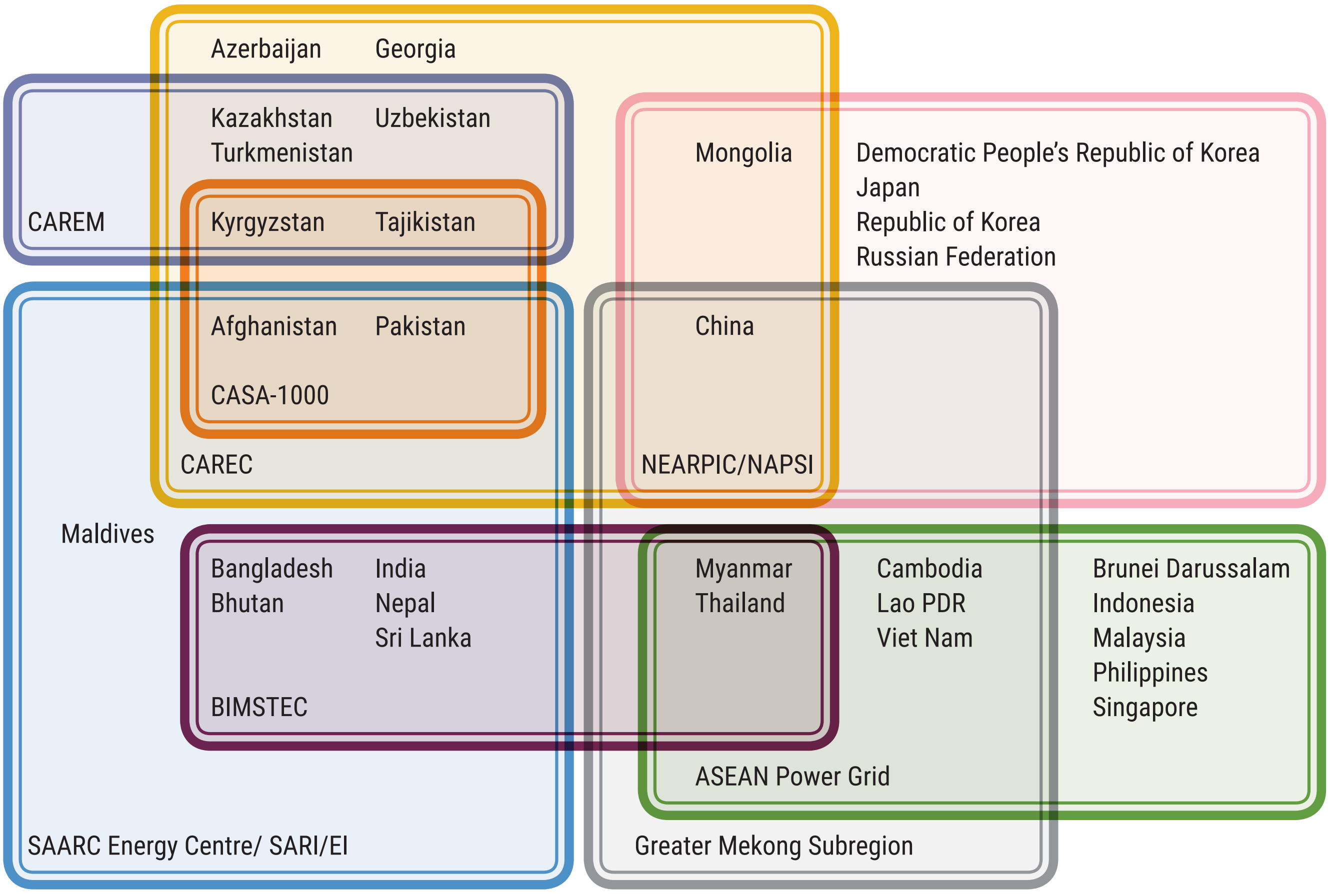
> Strategy 2. Develop a regional Masterplan;
>
> Strategy 6. Coordinate transmission planning and operation.

Grid master plans that cover more than one country require cooperation and coordination among relevant institutions on a multilateral basis. While Strategy 2 calls for a regional master plan, they can be first developed on a subregional basis and then coordinated at the regional level. Effective development of regional or subregional grid plans requires some facilitation of collaboration between countries including, for example, by subregional and regional organizations.

This chapter looks at the existing connectivity initiatives in the Asia-Pacific region to develop grid plans, primarily on a subregional or cross-subregional basis. There are a number of existing, and at times overlapping, initiatives in the region that support cooperation on power system connectivity specifically, and/or energy issues more generally. Many of these initiatives, and the countries that participate in them, are summarized in figure 10.

The main findings of this chapter are:

- The existence of numerous initiatives to increase cross-border power system connectivity, especially at the subregional level, demonstrates that benefits of connectivity are widely recognized;



Source: ESCAP.

Figure 10 Existing power system connectivity and energy cooperation initiatives in Asia

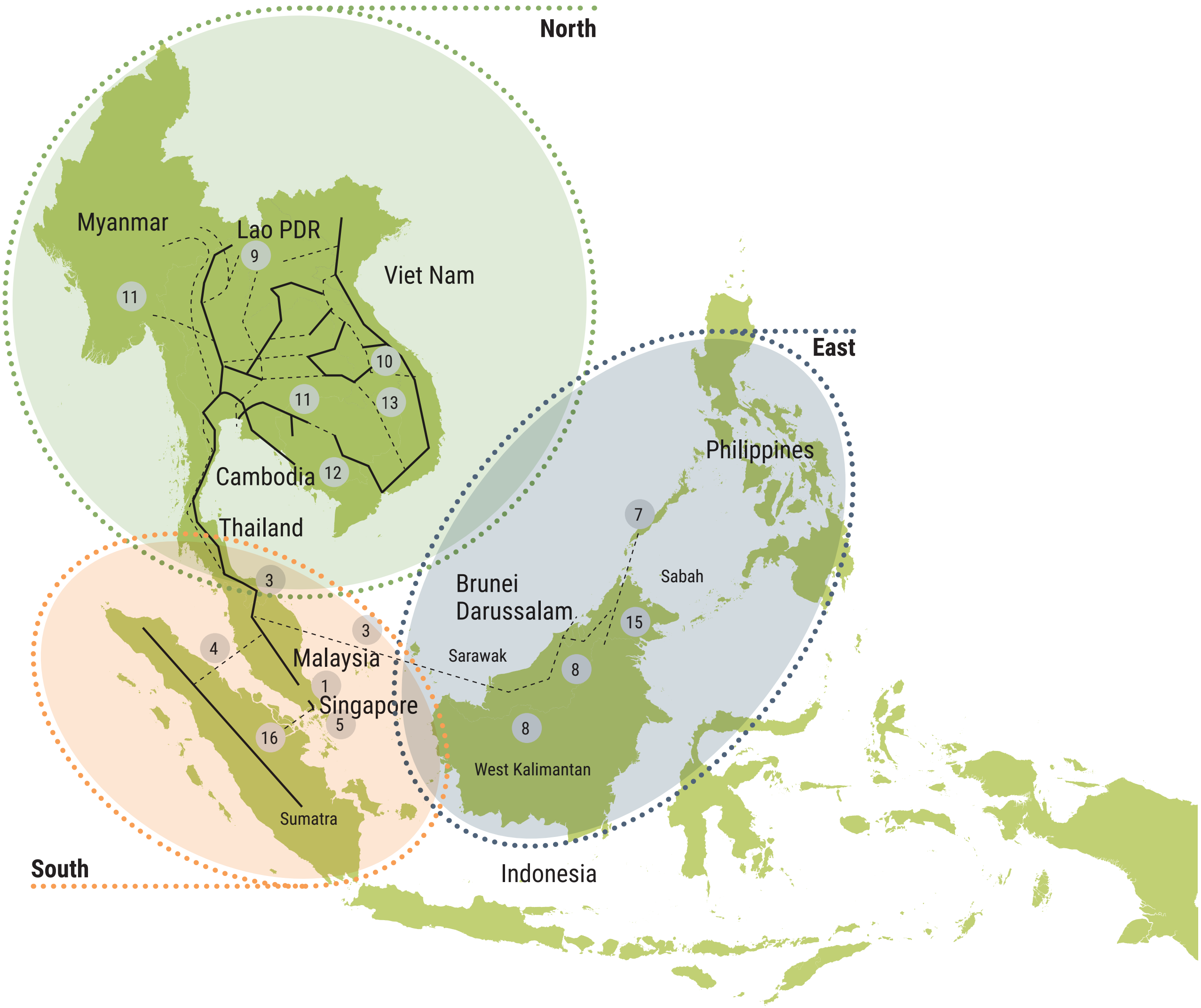
- Despite the multilateral nature of these initiatives, existing cross-border power integration efforts have been primarily developed on a bilateral basis, and most trade is uni-directional;
- In contrast to other regions, multilateral connectivity initiatives in Asia and the Pacific have, in many cases, not moved beyond the discussion stage;
- In several subregions a shared vision and master plan for connectivity has yet to be developed which, in part, may be due to the lack of political support for the initiatives and the absence of supportive institutions.

2.1. South-East Asia

ASEAN Power Grid

The countries of the South-East Asia subregion have long pursued a strategy of increased cross-border energy integration, both on a bilateral basis and collectively, in particular through efforts to develop the ASEAN Power Grid (APG) and the Trans-ASEAN Gas Pipeline (TAGP).[4]

4 APG and TAGP are two of the seven programme areas of the ASEAN Plan of Action for Energy Cooperation (APAEC). Although TAGP represents an important form of connectivity, for the purpose of this report, only APG is analysed.



Disclaimer: The boundaries and names shown and the designations used on this map do not imply official endorsement or acceptance by the United Nations.
Source: ACE, 2020b.

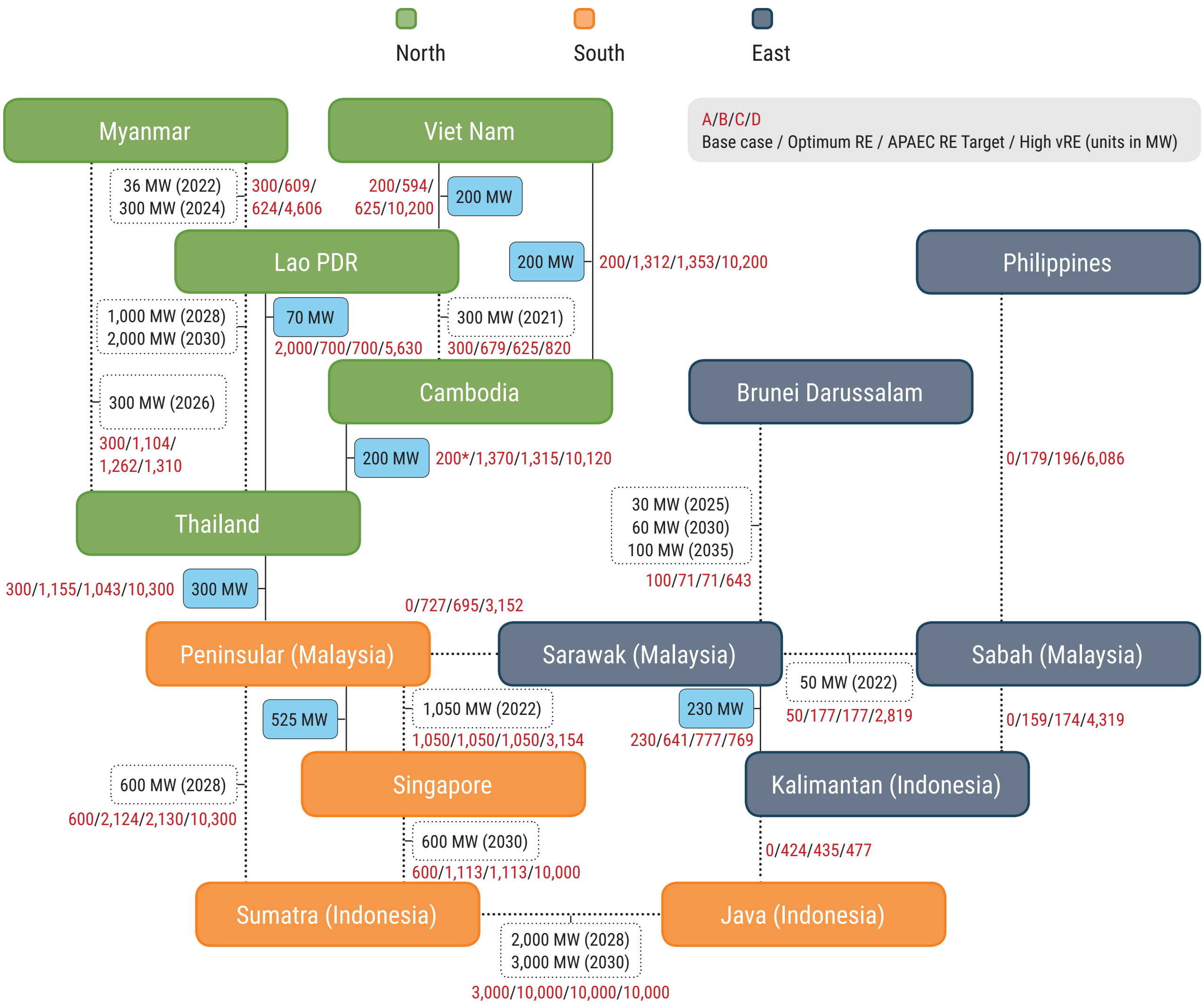
Figure 11 ASEAN Power Grid sub-systems

The APG initiative, first articulated in 1997 as part of the ASEAN Vision 2020,[5] is an ambitious effort to link the power grids of the ASEAN countries together through the development of cross-border transmission lines ("interconnectors") and the harmonization of technical standards and markets. The objective was to take advantage of resource diversity and to lower power system costs through economies of scale and shared investments (Hiebert, M. 2012).

5 The idea of power system interconnection as one of the specific areas of energy cooperation was put forward before the endorsement of the ASEAN Vision in 1981 (third AEMMEC), 1983 (fourth AEMMEC) and 1989 (eighth AEMMEC).

The development of the APG was formally endorsed by ASEAN member States at the 16th ASEAN Ministers of Energy Meeting (AMEM) in 1998. In particular, "the Ministers expressed the view that an integrated and coordinated planning policy approach for the ASEAN Power Grid's implementation would pave the way for greater opportunities for enhancing intra-regional electricity trade, developing business opportunities and promoting joint or cross-border investment in energy projects in the ASEAN Member Countries."

At the 17th AMEM in July 1999, the Heads of the ASEAN Power Utilities/Authorities (HAPUA) were asked by ASEAN member States to



Source: ASEAN Centre for Energy.

Figure 12 AIMS III interconnector capacity scenarios

provide the first comprehensive vision for a fully integrated subregion, in the form of the ASEAN Interconnection Masterplan Study (AIMS). The final AIMS report was endorsed at the 21st AMEM in 2003, became the reference document for electricity interconnection projects in the subregion, a fact that was reinforced in the Memorandum of Understanding on the ASEAN Power Grid, signed in 2007 (ASEAN, 2007).

The ASEAN Interconnection Masterplan Study I divided the subregion into two: the East System and the West System. A subsequent subregional study, AIMS II (published in 2010) divides ASEAN into three subsystems (figure 11):

- System A (Upper West System), including Cambodia, the Lao Peoples Democratic Republic, Myanmar, Thailand and Viet Nam;
- System B (Lower West System), including peninsular Malaysia, Singapore and Sumatra (Indonesia); and
- System C (East System), including Brunei Darussalam, the Philippines, Sabah (Malaysia), Sarawak (Malaysia) and West Kalimantan (Indonesia).

AIMS II identified 16 interconnection projects spread across the three subsystems. It also introduced the concept of staged development. The first stage involves the development of bilateral connections within subregions; in the second stage, projects will connect small regions; and in the third stage, projects will be integrated into a full ASEAN-wide power grid. AIMS II also found that full development of APG could avoid the need to develop a relatively modest 154 MW capacity and would result in savings of US$ 1.87 billion by 2025 (ACE, 2020b).

The APG, however, remains only partially developed. Since the publication of AIMS II, a total of 7,645 MW of interconnections have been developed between: Malaysia-Singapore; Thailand-Malaysia; Thailand-Lao Peoples Democratic Republic; Lao People's Democratic Republic -Viet Nam; Viet Nam-Cambodia; Sarawak-Kalimantan; and Thailand-Cambodia (ACE, 2020a).

At the 39th AMEM in 2021, the ASEAN member States endorsed the third AIMS study, AIMS III. Building off from the previous two studies, AIMS III looked more explicitly at the potential for an increased cross-border power system to help meet the target of a 23 per cent renewable share in energy mix by 2025, and increased shares of renewable energy to 2040 (ASEAN, 2019). Its findings are summarized in figure 12.

The three AIMS studies represent a coordinated effort by ASEAN member States to advance development of the APG, and the endorsement of these studies by ASEAN member States suggests that there is still political support for this project. However, the AIMS studies themselves do not guarantee APG development, as that still needs to be integrated into national development plans and negotiated on a bilateral basis. Future work on AIMS III and beyond will focus on market mechanisms to enable more multilateral power trading among ASEAN member States, which will hopefully provide an incentive for the development of specific interconnectors and increased integration (USAID, 2021a).

Gaps and opportunities for South-East Asia

Despite notable progress on APG development, much more needs to be done to achieve a fully integrated subregional power system. As far back as the 2007 memorandum of understanding (MoU) on the APG, ASEAN member States recognized that while the APG will create economic benefits and opportunities for power exchange and trade among the them, there are also challenges to progress. Article III of the MoU highlights six cross-border issues that countries must address (ASEAN, 2007):

1. Technical;
2. Financing;
3. Taxation and tariffs;
4. Regulatory and legal frameworks;
5. Electric power trade;
6. Third party access.

Today, as in 2007, a main obstacle to full APG development is the unequal level of readiness of ASEAN member States for increased cross-border power system integration. Countries have differing economic conditions, different physical infrastructure, and diverse regulatory and policy environments. Hence, the need for harmonization across a number of critical areas, including technical specifications, financing models, cross-border taxes and tariffs, and regulatory and legal frameworks.

The IEA 2019 study, *Establishing Multilateral Power Trade in ASEAN*, confirmed these barriers and offered important recommendations on the minimum political, technical and institutional requirements required to establish multilateral power trading in the region (IEA, 2019).

Building on these recommendations, ASEAN member States are currently implementing follow-up actions, targets and timelines, as acknowledged at the 39th AMEM in September 2021 (ASEAN, 2021):

- Development of minimum requirements for multilateral market development, regulatory framework, and grid code and technical standards;
- Development of recommendations on the role of ASEAN Energy Regulators Network (AERN) in multilateral power trade (MPT);

- Conduct of capacity-building activities to support the development of institutional and regulatory capacities at the regional level;
- Review of the ASEAN Power Grid Consultative Committee (APGCC) Terms of Reference, considering the region's deepening efforts towards regional power integration, and clarification of the institutional roles and relationships of other APG-related bodies; and
- Progress of the consultative meetings among APG-related bodies to develop the required institutional and regulatory capacities to advance MPT.

Furthermore, as pointed out in the sixth ASEAN Energy Outlook, critical enablers of success include embedding integration projects within a larger programme of regional cooperation, co-developing transmission and electricity trading, establishing and empowering institutions to manage the integration effort, and implementing appropriate data systems and information-sharing (ACE, 2020b)

Finally, opportunities also lie in the coordination between the APG and the effort to develop an integrated power system in the Greater Mekong Subregion (GMS), discussed in more detail in the section on cross-subregional initiatives.[6] The GMS countries, which include five of the 10 ASEAN member States, aim to develop cross-border power system infrastructure and multilateral trading system. Several steps have been taken towards this end, including the preparation of common grid codes. Much of this work is relevant in an APG context as well, but these efforts remain disconnected. To avoid inefficiencies, work on the APG should take account of these and other developments and vice versa.

2.2. South Asia and South-West Asia

Several countries in South Asia and South-West Asia have developed bilateral electricity interconnections and power trade. For South Asia in particular, given its geographical position, India is naturally at the centre of many of these power exchange opportunities, playing the roles of energy importer, exporter and (potentially) transit country.

To date, power connectivity projects in South Asia have been limited to bilateral interconnection and power trade between India-Nepal, India-Bhutan and India-Bangladesh (Government of India, 2022). There is also one small interconnector between India and Myanmar (South-East Asia). In November 2021, Nepal began trading power in the Indian Energy Exchange (IEX), enabling exports from Nepal to India for the first time (Kathmandu Post, 2022), while Bhutan began trading power on the exchange in April 2022. Currently there is around 1,500 MW of import capacity and 1,050 MW of export capacity between India and neighbouring countries, but there are plans to increase this to around 6,950 MW total (import 4,500 MW and export 2,450 MW) by the end of 2022 (figure 13) (Central Electricity Authority, 2019).

India is particularly notable for its investments in developing and integrating its domestic grid ("one nation, one grid") (Power Grid Corporation of India, 2022). Given the size and complexity of the Indian power system, and the division of roles and responsibilities between the federal and state-level governments, in many ways this effort is comparable to international cross-border connectivity.

Pakistan is also heavily investing in its domestic power transmission system. One of the vehicles for such transformation is the China-Pakistan Economic Corridor (CPEC). In February 2021, for example, the 660kV Matiari-Lahore high-voltage direct current (HVDC) transmission project was inaugurated under CPEC. The project has brought new technology to Pakistan and will evacuate power from power plants located in Sindh to northern load centres to meet their energy needs.

6 GMS will be presented in the ambit of cross-subregional connectivity examples.

Existing	Planned
INDIA-NEPAL (700 MW of power exported from India to Nepal)	
Existing	Planned
Various 11kV, 33kV, 132kV and 220kV lines; 400kV D/C transmission line through Dhalkebar (Nepal) - Muzaffarpur (India)	400kV D/C Gorakhpur (India) – Butwal (Nepal) line; 400kV D/C Dhalkebar (Nepal) – Sitamarhi (India) line; 132kV D/C Nanpara, Bihar (India) – Kohalpur (Nepal), stringing of second circuit of 132kV line Kataiya (India) – Kushaha (Nepal) and 132 kV Raxaul (India) – Parwanipur (Nepal)
INDIA-BHUTAN (1,500 MW of power exported from Bhutan to India)	
Existing	Planned
Various 400kV, 220kV and 132kV lines	Punatsangchu-I (1,200 MW) and Punatsangchu-II (1,020 MW) HEPs in Bhutan, expected to be commissioned by 2024-2025 (transmission system for transfer of this power from these projects to India is already in place); Mangdechhu (720MW)
INDIA-BANGLADESH (1,160 MW of power exported from India to Bangladesh)	
Existing	Planned
400kV D/C lines through Baharampur (India)- Bheramara (Bangladesh), together with 2x500 MW HVDC back-to-back terminal at Bheramara	Development of a 765kV Double Circuit cross-border electricity interconnection between Katihar (India), Parbotipur (Bangladesh) and Bornagar (India)
INDIA-MYANMAR (3 MW of power exported from India to Myanmar)	
Existing	Planned
11 kV transmission line from Moreh in Manipur (India) to Tamu town in Myanmar	Strengthening of more low-capacity links at various places along the border is being jointly planned. A high-capacity link between the countries is also under discussion.

Source: ESCAP with information from the Ministry of Power, Government of India, and National Electricity Plan (vol. II).

Figure 13 India's interconnections with neighbouring countries, current and planned

Several countries have a comprehensive framework for transmission planning. However, while there are many efforts to support power system collaboration in the region through, for example, the South Asian Association for Regional Cooperation (SAARC) and the South Asia Regional Initiative for Energy Integration (SARI/EI), as of now there is no subregional framework or initiative specifically focused on power system planning.

Gaps and opportunities for South Asia and South-West Asia

South Asia faces critical challenges in meeting expected increases in electricity demand and ambitious targets for emissions reductions. The potential benefits of increased cross-border power system connectivity for the subregion include: (a) optimal utilization of transmission lines; (b) security of supply; (c) higher penetration of variable renewables; (d) lower generation reserve margins; (e) avoided/deferred investments in transmission and generation capacities; (f) more optimal use of generating resources across SAARC countries; (g) reduction of environmental costs by increasing availability of cleaner sources of supply, economic exploitation of large hydro potential in north-eastern India, Nepal and Bhutan which requires access to larger regional markets for the electricity generated; and (h) utilization of currently stranded capacity and increase in plant load factor (Rajendra, 2020). Alongside the potential for hydropower, there is also significant untapped potential for low cost solar and wind generation.

The Governments of India and Pakistan have investigated the potential for developing a power link between Amritsar (India) and Lahore

(Pakistan). Due to political obstacles, however, there has been no progress.

An interconnection between India and Sri Lanka is also under discussion. A feasibility study has been completed for a proposed 400kV HVDC grid interconnection between Madurai (India) and Anuradhapura (Sri Lanka). The link would have a length of 387 km, including 127 km of submarine cables, with an initial capacity of 500 MW and a future potential of 1,000 MW (ESCAP, 2018a). Sri Lanka relies on hydropower, oil and coal for its power needs. It has committed to not building any coal plants until after 2037 and relying on gas and renewables to meet its demand growth. Interconnection with India would help it to reduce the need for new capacity additions and to sell surplus power. Given the current economic situation in Sri Lanka, an interconnection with India could also potentially give the country access to lower cost generation resources in the short term, and the opportunity for exporting renewable energy in the medium to long term.

Bhutan and Nepal have very high technical potential for hydropower generation, amounting to many multiples of their domestic needs. Other economies, such as Pakistan and India, have significant potential for wind and solar power. Bangladesh currently utilizes its declining gas resources for power generation and has limited hydropower. Its power sector needs to be supplemented by other sources in order to meet its growing demand, for which cross-border electricity trade (CBET) is a key opportunity.

While plans for interconnections are developing in South Asia, there is a clear need for more coordinated planning on a larger subregional scale. Coordinated planning could start with a subset of countries. However, ideally any planning of cross-border connectivity should be shared in a coordinated and consistent way across the entire subregion to ensure that all countries could potentially benefit.

2.3. East Asia and North-East Asia

Electricity connectivity and trade in East Asia and North-East Asia has been mostly bilateral, and mainly aimed at near-border trading of electricity. Trade currently exists between Russian Federation-Mongolia, Russian Federation-China, and Mongolia-China. Mongolia's power system operated in parallel with the former Soviet Union's, as part of the large power system of USSR interconnection and East European countries, called "Mir". The first transmission line between the Russian Federation and China was put in operation in 1992, and interconnections exist between China and Mongolia, primarily supporting the export of power from China to Mongolian mining and processing plants in the south of the country (Kharbanda, 2019). Although existing interconnections are limited, some ambitious interconnection plans have been proposed including, for example, the Asian Development Bank's Northeast Asia Power System Integration (NAPSI) project, which is described in the next chapter.

Gaps and opportunities for East Asia and North-East Asia

While numerous studies have demonstrated the potential benefits from increased power systems in North-East Asia,[7] there are at present no institutions coordinating regional interconnection planning. As a first step, therefore, it would be helpful to establish permanent multistakeholder platforms. As there are many different ongoing and proposed studies for power system integration in the subregion, such a platform could avoid the problem of a plethora of parallel or overlapping initiatives that lack coordination. Establishing a common intergovernmental arrangement with a clear strategic vision on which all countries agree could facilitate dialogue on the effective development and implementation of power interconnections across the subregion, while remaining flexible enough to allow countries to make progress at their own pace.

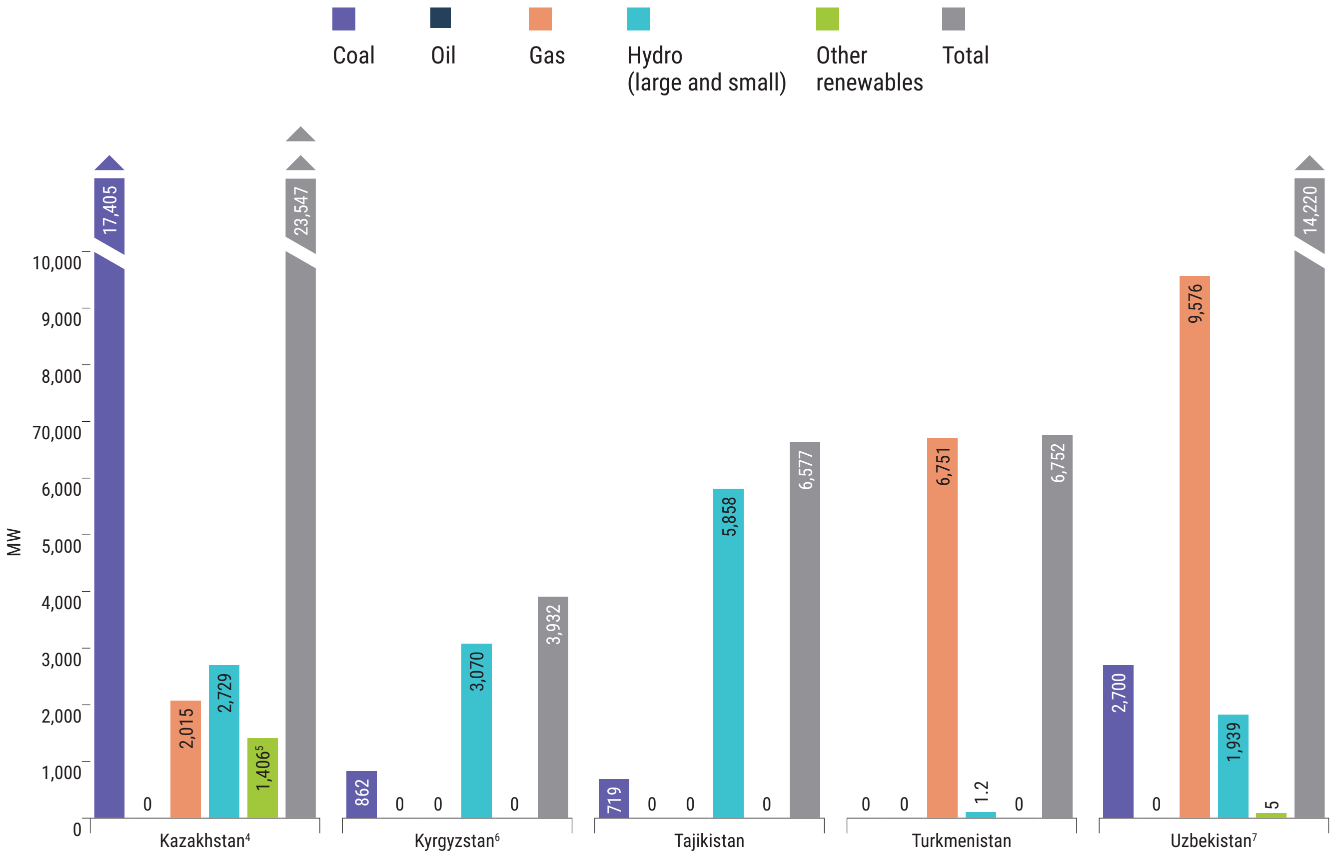
7 For a summary of notable studies, see Regional Power Grid Connectivity for Sustainable Development in North-East Asia, ESCAP, 2020.

2.4. North and Central Asia

The electricity transmission systems of the counties of North Asia and Central Asia are being or have already been interconnected. The exchange of power among those countries, however, is well below the available interconnection capacity. This is mainly due to the fragmentation of previously integrated systems, both in operational terms and, in some cases, because of the explicit decoupling of cross-border interconnections. These factors are a key to facilitating short- and medium-term electricity trade opportunities and the development of new generation projects (World Bank, 2020).

Today, in Central Asia, the Unified Energy System is a legacy of the unified energy system developed under the former USSR to supply power to Kazakhstan, Kyrgyzstan, Tajikistan, Turkmenistan and Uzbekistan (figure 14). The Coordination Dispatch Centre "Energiya", established during the Soviet era but still operational today, coordinates interstate centralized dispatch management of operational and technological activities for electricity supply.

During the Soviet era, the integrated power system closely linked together the consumption of electricity, fuel and water. After the breakup of the Soviet Union, the newly independent countries invested heavily in domestic energy resources to meet demand, which had previously been met through subregional optimized system balancing. Many Central Asian countries have significant fossil fuel reserves, and a number are endowed with hydropower resources. Tajikistan is the largest hydroelectricity producer, and its potential



Source: OSCE Secretariat, 2022.

Figure 14 Installed power generation capacity by country and source in MW, 2019–2021

capacity is three times higher than the current electricity consumption of all of Central Asia (IEA, 2021b). Kyrgyzstan has the second-largest hydropower endowment in Central Asia with a potential generation capacity of 18.5 GW. However, only 10 per cent of its resources are currently being exploited.

Effective and sustainable development and use of these resources could be a significant contributor to balance the region's electricity systems, enabling the integration of renewable energy resources throughout the subregion.

Kazakhstan, Uzbekistan and Turkmenistan currently have sufficient electricity supply to meet domestic demand, using domestically produced hydrocarbon resources. Tajikistan and Kyrgyzstan, on the other hand, suffer from potential deficits to meet peak demand in winter. Tajikistan, in particular, has a higher peak demand in the winter than can be satisfied with national generation, but excess electricity in the summer. Previously these deficits and surpluses were balanced through cross-border trade.

The region's geostrategic location between Asia and Europe means it can become a hub for energy trade between these two blocs. This is already the case with the shared border of the South Asian countries Afghanistan and Pakistan, with rapidly growing electricity demand, where increased opportunities for electricity trade are arising (see CASA-1000, described below).[8]

Gaps and opportunities for North Asia and Central Asia

The historical legacy of power system connectivity in this subregion is a source both of opportunities and obstacles. On the one hand, institutions exist that can and do facilitate collaboration on power system cooperation and development. However, legacy infrastructure and institutions may not be fit for purpose of supporting a transition to the power systems of the future. Most of the existing transmission and distribution lines, for example, and most of the power generation were built during the Soviet era, so modernization and replacements are required.

Discussions are underway to improve the situation. At the two summits of Central Asian countries held in Kazakhstan (2018) and Uzbekistan (2019), leaders called for strengthened cooperation in the energy sector by expanding opportunities for energy trade and promoting the development of modern energy infrastructure.

Several recent reports have reinforced the need and benefits of cross-border electricity trading in Central Asia. The World Bank has shown that the region can reduce operating expenses by as much as US$ 6.4 billion in the next 10 years. Other benefits of power trade include: (a) increased energy security and reliability; (b) more efficient and effective use of infrastructure (including shared planning of reserve margin); (c) fuel cost savings due to a shift from gas to hydro; (d) economies of scale in investments; and (e) greater renewable energy penetration (up to 30,000 MW of solar by 2030) (World Bank, 2020). In addition, as discussed above, the IEA's 2020 connectivity roadmap for Tajikistan assessed the feasibility and extent of electricity trade with Tajikistan's neighbours, and detailed policy recommendations for implementation (IEA, 2021b).

2.5. Inter-subregional **initiatives**

Greater Mekong Subregion (South-East Asia and East Asia)

First established in 1992 by ADB, the Greater Mekong Subregion (GMS) Economic Cooperation Programme involves five South-East Asian countries (Cambodia, the Lao Peoples Democratic Republic, Myanmar, Thailand and Viet Nam) and two provinces in southern China (Yunnan Province and Guangxi Zhuang Autonomous Region). The GMS Regional Power Trade Coordination Committee (RPTCC) was established in 1995.

8 This specific cross-regional power interconnection is detailed in the next section.

Power market integration is one of the top priorities of GMS energy cooperation. The second Strategic Framework (2012-2022) noted that "GMS cooperation in energy aims to establish a competitive and integrated regional power market that will develop, in a sustainable manner, the rich energy resources of the GMS, improving the subregion's energy security and the people's access to modern and affordable energy supplies". The Strategic Framework 2030 has re-affirmed connectivity as a pillar of the subregion. Until this Framework is in place, work will focus on cross-border power trade, establishing regional grid codes, developing regional markets and expanding clean energy investments with a more significant role for the private sector (ADB, 2021b).

Power interconnection in the GMS is seen as progressing in four stages:

- Stage 1: Bilateral cross-border interconnections and ad-hoc PPAs for power trade;
- Stage 2: Limited grid-to-grid power trading between any pair of GMS countries, based on the available capacity of lines, with trading linked to power purchase agreements (PPAs);
- Stage 3: Transmission links are developed for cross-border trading. Third parties other than utilities are allowed to trade;
- Stage 4: a fully integrated GMS regional competitive power market is established.

Currently, GMS countries have reached stage 1, where bilateral trade is ongoing, and are moving towards stage 2. Countries are already interconnected and trade power, albeit to varying degrees and only on a bilateral basis. Recently, China, Myanmar and Bangladesh reached an agreement on trilateral power trading which uses ±660 kV DC interconnector with a capacity of 4 GW, and China and the Lao Peoples Democratic Republic have signed an agreement to build more transmission lines between the two countries (Global times, 2022).

The Mid-Term Review of the Strategic Framework, 2012-2022 (GMS SF-II) concluded that progress in building an integrated regional grid and establishing a regional power market is still constrained by technical, regulatory and institutional challenges, including the need for more operational collaboration under the GMS RPTCC (Shi, 2019). The GMS initiative could benefit from integration with efforts to develop the APG, as five of the 10 ASEAN member States are involved in both initiatives. Aligning overlapping grid development plans for the two initiatives would streamline efforts to build infrastructure and could take advantage of efficiency gains between the initiatives.

Bay of Bengal Initiative for Multi-Sectoral Technical and Economic Cooperation (South Asia and South-East Asia)

The Bay of Bengal Initiative for Multi-Sectoral Technical and Economic Cooperation (BIMSTEC) is an international organization involving five countries across South Asia (Bangladesh, India, Sri Lanka, Bhutan and Nepal) and two in South-East Asia (Myanmar and Thailand), all in the littoral and adjacent areas of the Bay of Bengal.

The "Plan of Action for Energy Cooperation in BIMSTEC" was formulated during the first BIMSTEC Energy Ministers' Conference, held in New Delhi on 4 October 2005. Under the "BIMSTEC Trans-Power Exchange and Development Project" a Task Force led by Thailand developed a draft MoU for grid interconnections. The draft MoU was finalized on 16 March 2015 and signed in August 2018, during the 4th BIMSTEC Summit in Kathmandu.

The MoU provides a general framework for the relevant Parties to cooperate in the implementation of grid interconnections for the trade in electricity, with a view to promoting rational and optimal power transmission in the BIMSTEC region. The MoU facilitates:

- The optimization of using the energy resources in the region for mutual benefits on a non-discriminatory basis, subject to laws, rules and regulations of the respective Parties;
- The promotion of efficient, economic and secure operation of power system needed through the development of regional electricity networks;

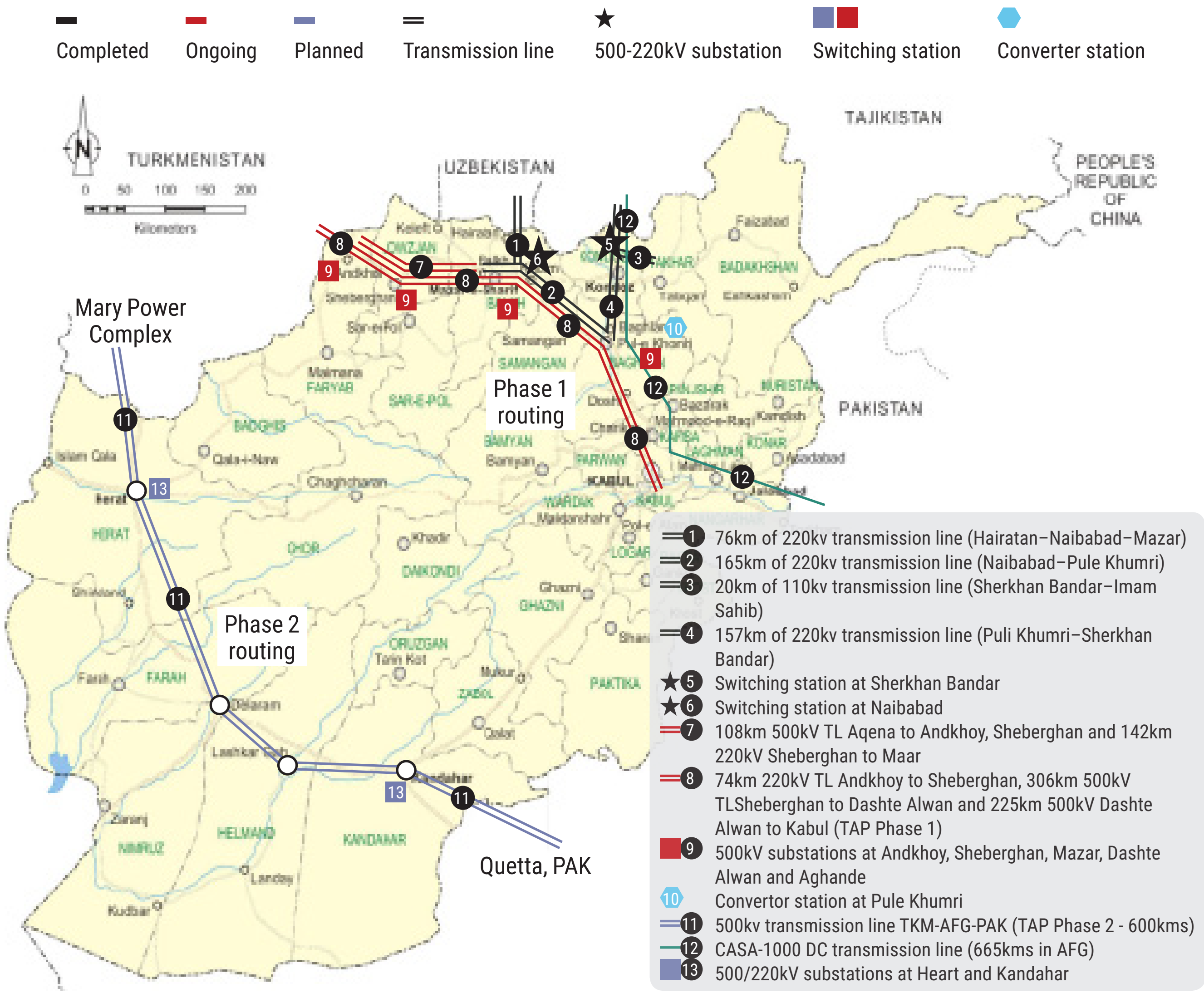
- The necessity of optimization of capital investment for generation capacity addition across the region, and power exchange through cross-border interconnections (BIMSTEC, 2018).

For these purposes, the BIMSTEC Grid Interconnection Coordination Committee (BGICC) was established to coordinate the successful implementation of grid interconnections and trade in electricity.

The first meeting of the BGICC was held on 30 June 2021. The BGICC members, who are mandated to coordinate implementation of grid interconnections and trade in electricity, deliberated on how to undertake the BIMSTEC Grid Interconnection Master Plan Study (BGIMPS). The meeting also touched on the importance of formulating a BIMSTEC Policy for Transmission of Electricity and a BIMSTEC Policy for Trade, Exchange of Electricity and Tariff Mechanism in accordance with the TOR of the BGICC (BIMSTEC, 2021).

CASA-1000, TUTAP and TAP (Central Asia and South Asia)

The South Asia and Central Asia subregions are in the process of interconnecting through the Central Asia South Asia (CASA)-1000 project,



Disclaimer: The boundaries and names shown and the designations used on this map do not imply official endorsement or acceptance by the United Nations.
Source: Energy Charter, 2020.

Figure 15 Proposed Turkmenistan-Afghanistan-Pakistan Power Interconnection Project (TAP)

under development since 2008. CASA-1000 is a 500 kV high-voltage electricity transmission system, which will connect four countries in Central and South Asia, to help alleviate energy shortages and encourage economic growth by facilitating electricity trade.

In 2006, Pakistan and Afghanistan signed agreements with Tajikistan and the Kyrgyz Republic to import electricity through this transmission link project (CASA-1000, 2022).

When completed the 1,222 km CASA-1000 project will enable the transfer south of 1,300 MW of electricity from Tajikistan and the Kyrgyz Republic to Afghanistan and Pakistan. It will also mark an important step towards realizing the proposed Central Asia-South Asia Regional Electricity Market (CASAREM) (CAREC, 2018). The US$ 1.2 billion infrastructure project, which involves the support of several donors and international financial institutions (the World Bank, European Investment Bank, European Bank for Reconstruction and Development, Islamic Development Bank, United Kingdom Foreign and Commonwealth Development Office, and United States Agency for International Development), has an expected commercial start date of 2024.

Under CASA-1000, Afghanistan is primarily a transit, or wheeling, country. However, Afghanistan has a significantly underdeveloped national power system. To address this, the ADB is financing efforts to unify the country's power grid and expand interconnections with neighbours.

The TUTAP (Turkmenistan-Uzbekistan-Tajikistan-Afghanistan-Pakistan) is a project aimed at connecting Afghanistan's currently islanded electrical grids and providing linkages to neighboring countries.

The TAP (Turkmenistan-Afghanistan-Pakistan), another ADB project (figure 15), aims to construct a 500 kV transmission line to export electricity from Turkmenistan to western and southern Afghanistan and on to Pakistan. The project will support Afghanistan's energy needs as well as enable power trade and exchange among the three countries. TAP will be developed in two stages. The first phase – completed in 2021 – linked Turkmenistan to Afghanistan (REGLOBAL, 2022). The second phase – originally projected to be completed by 2022 – will enable the transfer of up to 4,000 MW of power from Turkmenistan to Pakistan, wheeled through Afghanistan (ADB, 2018). However, while discussions are ongoing, due to the political situation in Afghanistan work on this project has been put on hold (Times of India, 2021).

Sun Cable (South-East Asia and Pacific)

The Australia-Asia Power Link (AAPowerLink) is a proposed intercontinental renewable energy generation and transmission project that will supply green electricity from Australia to Singapore, through Indonesia. It includes what would, if built, be the world's largest solar farm (capacity between 36 GWh and 42 GWh), a 5,000 km-long HVDC transmission system (800km-long overhead line to Darwin and 4,200 km undersea cable system from Darwin to Singapore), and the largest battery storage facility to deliver zero carbon electricity from Australia to Singapore.

The Sun Cable project requires an estimated investment of A$ 30 billion (US$ 22.54billion). Anticipating financial closure in late 2023, onshore construction works are planned to start in 2024. Electricity transmission to Darwin and Singapore would commence in 2026 and 2027, respectively. Although facing many commercial and technical challenges related to the integration of a range of technologies and construction activities across three jurisdictions as well as a large geographical footprint, the project is planned to reach full capacity in 2028 (Power Technology, 2021). In addition, the project could benefit from the APG allowing Australia to export electricity to a wider part of South-East Asia.

Conclusion and key messages

From the stock-taking in this chapter, it is clear that in general all subregions have a large number of initiatives focused on cross-border connectivity. For most of the subregions the power system connectivity initiatives started as a response to the benefits of such projects – for example, economic benefits of energy access benefits. Many of the initiatives have also started examining the benefits that connectivity can have on sustainable development. For example, in ASEAN, the AIMS III study takes renewable integration explicitly into account.

Even though many initiatives focus on connectivity from a subregional perspective, most of the development of grid infrastructure is done on a bilateral basis. In the Asia-Pacific region it has been found that while many countries include cross-border transmission in national plans, there is a lack of regional transmission planning to achieve a common vision for transmission development. Again, ASEAN is a notable exception with the ASEAN Power Grid; however, even so, the regional grid is still being developed bilaterally. This means that subregional connectivity initiatives within the Asia-Pacific region still mostly remain at the discussion stage.

One of the drivers to push past the discussion stage is political will and enabling institutions, which are lacking in the region. However regional connectivity still represents a significant opportunity to increase the effective utilization of resources across the region and can help produce significant advancements towards achieving SDG 7.

CHAPTER 3

Developing **coordinated frameworks and institutions** for power system connectivity

As noted in chapter 2, many subregions within Asia and the Pacific are undertaking efforts to develop power system connectivity. However, in order to develop regional connectivity, it is helpful to have enabling frameworks that support the integration efforts. Many of these frameworks are highlighted in the roadmap through strategies. For example, strategy 3 points out the importance of developing and implementing intergovernmental agreements on energy cooperation and interconnection. Strategy 4 points out the need to coordinate, harmonize and institutionalize policy and regulatory frameworks. Last, strategies 5 and 6 point out the need for enabling market mechanisms and coordinated power system operations, for which institutional setups will also be needed.

This chapter focuses on the efforts to develop coordinated frameworks and institutions for power system connectivity. The chapter takes stock of the existing enabling institutions and agreements that could provide the foundation for further development of regional connectivity in the Asia-Pacific region.

In the context of the Regional Road Map on Power System Connectivity, the most relevant strategies are:

> Strategy 5. **Move towards multilateral trade and create competitive markets for cross-border electricity;**
>
> Strategy 6. **Coordinate cross-border system operation.**

The main findings of this chapter are:

- Countries in the region face multiple challenges to implementing cross-border power connectivity and trade. Institutions, and/or other coordinating mechanisms present numerous advantages as vehicles to overcome barriers;

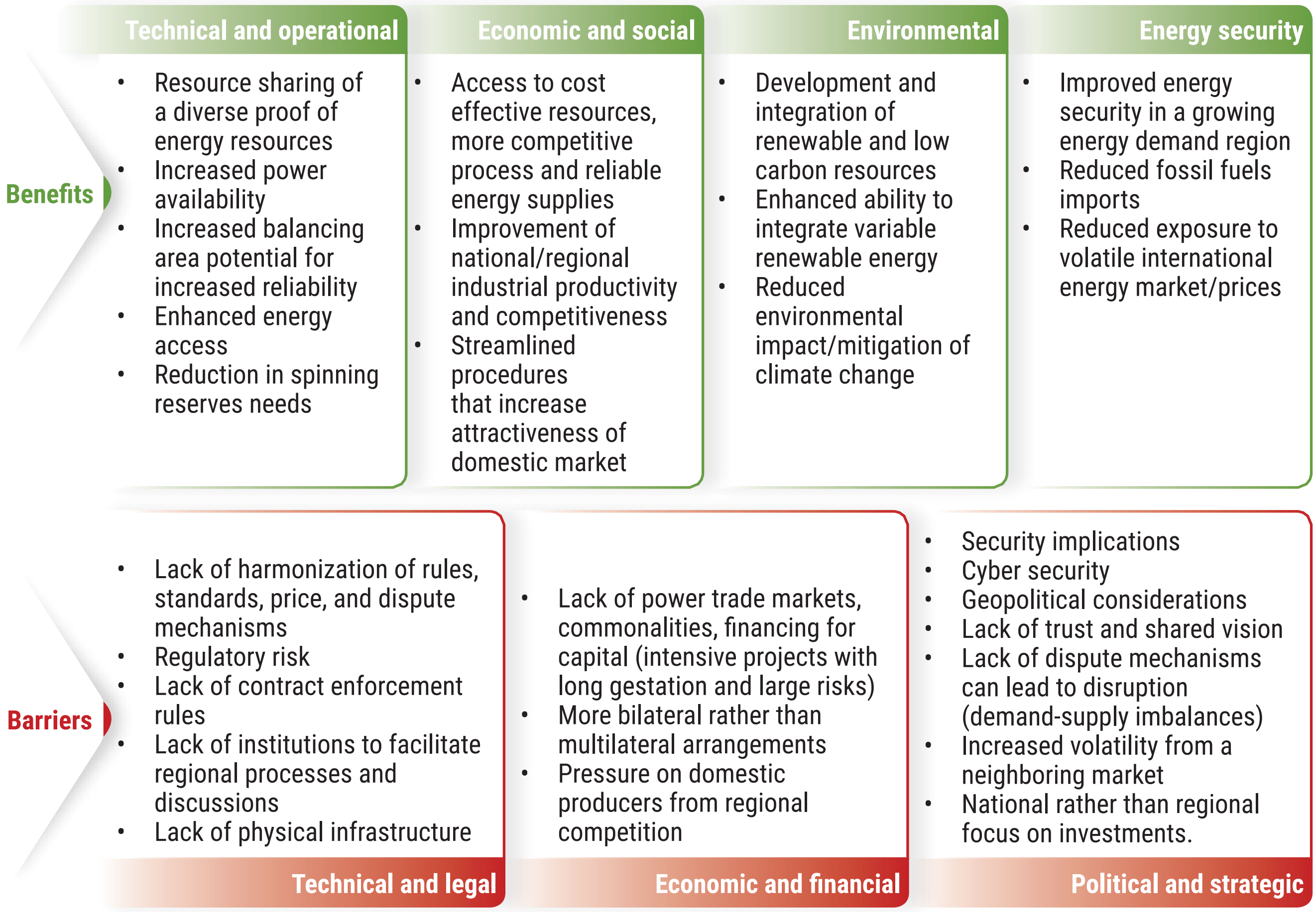
- With the notable exception of North-East Asia, the Asia-Pacific region has several energy/electricity-related cooperation mechanisms. The proliferation of such mechanisms suggests that countries see the benefit of collaborating to meet growing energy demand needs;

- Successful efforts in other regions began through a consensus-building, voluntary, principles-based approach, and evolved to develop harmonized sets of operational and market rules. A soft consensus-based approach can lead to progress when there is sufficient political will and flexibility in approach;

- Before building new institutions, agencies or other mechanisms to address particular connectivity challenges, countries should first assess the role of and potential for existing ones. However, one size fits all institutions and processes are seldom suitable, and the creation of new institutions can make sense when existing institutions are unsuited to delivering required changes or performing specific functions.

3.1. Coordination mechanisms in Asia and the Pacific: **Institutional vs non-institutional approaches**

In the Asia-Pacific region, bilateral connectivity arrangements tend to be the norm. As a result, the operational issues related to these integration efforts are also managed on a



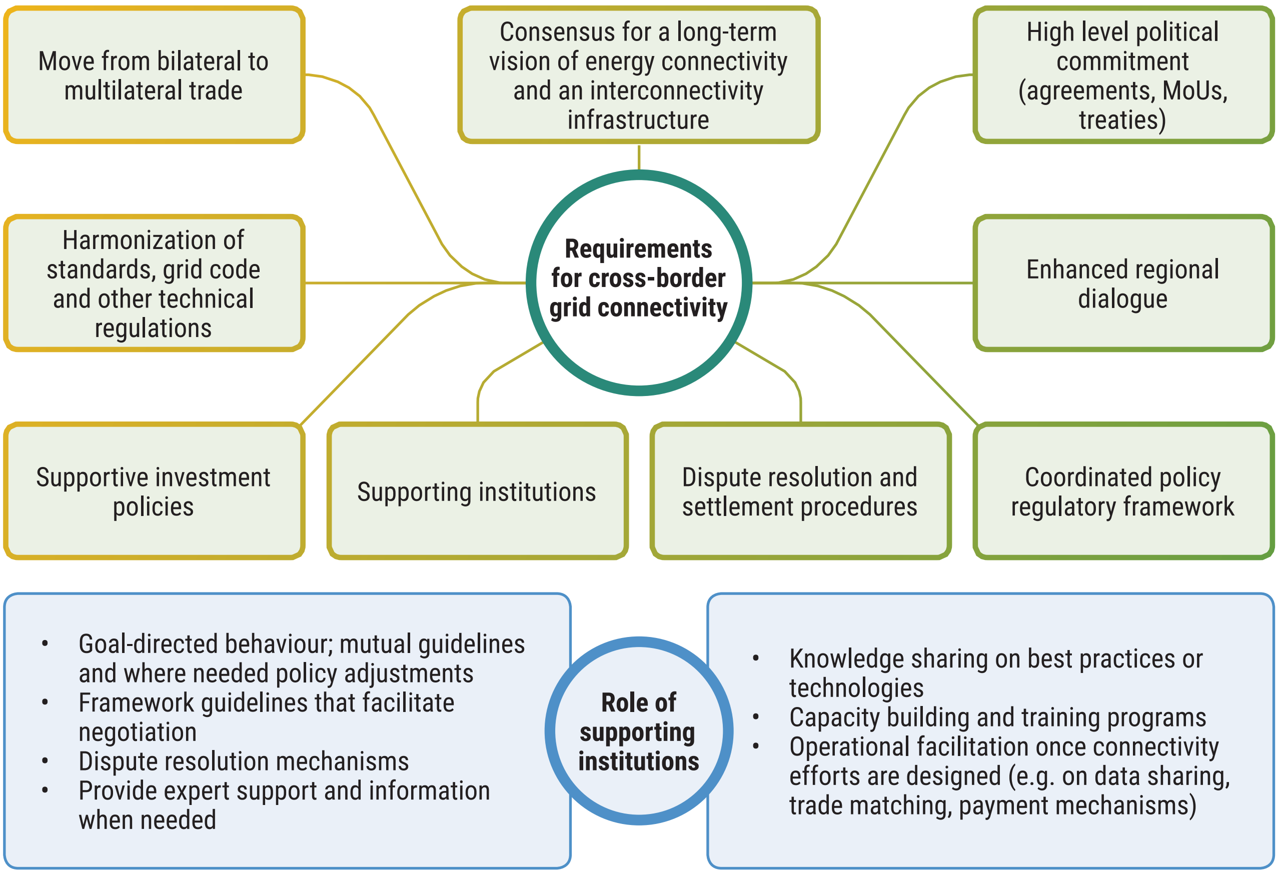
Source: ESCAP.

Figure 16 **Benefits and barriers to cross-border power connectivity and trade** bilateral basis, meaning there is no standard, transparent method for trading and transferring electricity across borders. Progress on more multilateral trading is limited by factors such as a lack of harmonized rules and standards and, in some cases, limited consensus on how power system connectivity should progress. Figure 16 summarizes potential benefits versus obstacles to cross-border power connectivity.

Many conditions must be met to advance cross-border connectivity efforts. These include the mitigation of operational, legal and regulatory discrepancies, finding the economic and financial avenues to expand connectivity projects, and overcoming a potential lack of shared vision and political trust. A common thread among all these areas is the need for increased coordination.

There are signs in Asia and the Pacific that energy, and electricity in particular, has the capacity to become an integrative force among countries, creating a larger sense of shared interests and stakes in cooperation. Precisely because of the strategic socio-economic and national security implications of electricity, the willingness of a nation to voluntarily link its energy plans to others – whether it be in the form of a power grid, a pipeline, or other forms of trade (that is, any other form of interdependence) – requires a degree of trust and confidence. In some respects, this positive economic and energy security-enhancing dimension of electricity integration is already visible in some subregions.

For States seeking to cooperate on subregional and regional connectivity, there are many benefits to using multilateral institutions or other platforms. Because institutions reduce uncertainty, provide expert information and facilitate negotiation, they may have an important role to play in helping to achieve cooperation and stability. The lack of progress in power connectivity and trade in the region is, to a large extent, a result of the absence of multinational markets for electricity which, in



Source: ESCAP.

Figure 17 **Benefits and barriers to cross-border power connectivity and trade** turn, is the result of a lack of commonalities – e.g., standards, guidelines, regulations, pricing and dispute resolution mechanisms. Institutions and other collaborative platforms play an important role in addressing these gaps (figure 17).

The road to cooperation and institutionalization: Levels and approaches

In the Asia-Pacific context, it is possible to recognize different levels of engagement, commitment and approaches to institutionalization. Whereas countries in some subregions have devised intergovernmental arrangements focused on power connectivity, others have not advanced further than the narrative stage.

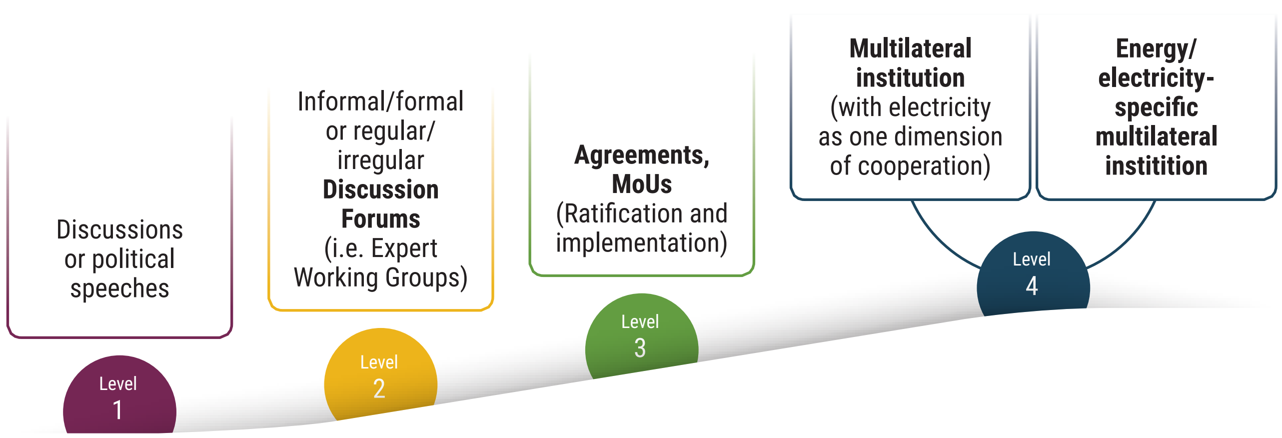
Although the initiation of talks is a necessary departing point, the demonstration of political commitment in signed agreements is critical for enhancing energy connectivity in each subregion. Agreements, MoUs and treaties are essential to building awareness and trust, strengthening cooperation and integration in each subregion, and providing mandates to relevant institutions (including regulators and utilities) to collaborate on connectivity efforts. Equally important is the ratification process and implementation within a given time frame. While progress on power infrastructure projects is, as a general rule, slow continued postponement of projects that have already been devised suggests a need to focus on overcoming fundamental obstacles to progress.

A common factor among successful power system connectivity efforts in Asia-Pacific and beyond is the presence of some type of enabling institution of framework for collaboration.

Institutional frameworks – even loosely defined ones – have clear roles to play in supporting power system integration. Energy-related institutions can support the harmonization regulations or establishment of common regulatory frameworks, data sharing, capacity-building, assessment of renewable energy potential, developing common technical standards, codes and guidelines in the areas of planning and design, and operation and maintenance of cross-border power systems.

Knowledge sharing will help all member countries, improve the efficiency and system operations, and support the interconnection process. Sharing relevant sectoral information and data, and best practices and lessons learnt, particularly with regard to new technologies, can support integration efforts by creating increased awareness and addressing knowledge gaps.

As integration progresses, multilateral platforms can also support conducting joint feasibility studies, aid in dispute resolution, define the model of unified energy market design, and help address energy security concerns (figure 18) (IRENA, OECD, IEA and REN21, 2018).



Source: IRENA, OECD, IEA and REN21.

Figure 18 Different levels of institutionalization of energy/electricity cooperation

Subregional perspective:
South-East Asia

In South-East Asia, cooperation among ASEAN member States in the energy sector extends at least as far back as the creation of the ASEAN Council on Petroleum (ASCOPE), which was established in 1975, in response to the 1973 OPEC oil embargo.

Broader discussions of energy topics have been supported by the ASEAN Ministers on Energy Meeting (AMEM), which began in the 1980s and which has evolved into a permanent forum. The AMEM tackles the issues and concerns of common interest, and sets policy and programme directions pertaining to energy cooperation. Under AMEM, the Senior Officials Meeting on Energy (SOME) has the responsibility for supervising, coordinating and implementing ASEAN's cooperation programmes, policies and decisions about energy affairs.

Another relevant step towards energy cooperation was taken in 1999 with the creation of the ASEAN Centre for Energy (ACE). It facilitates cooperation between ASEAN member States, with non-ASEAN partner countries, and with international organizations, and therefore has a pivotal role in promoting regional energy programmes and activities. Indeed, ACE cooperates with and, when requested, supports the work of the energy bodies, including ASCOPE, the Heads of ASEAN Power Utilities/Authorities (HAPUA), the ASEAN Energy Regulators Network (AERN), the ASEAN Forum on Coal (AFOC), the Energy Efficiency and Conservation Sub-sector Network (EE&C-SSN), the New and Renewable Sources of Energy Subsector Network (NRE-SSN), the Regional Energy Policy and Planning Sub-sector Network (REPP-SSN) and the Nuclear Energy Cooperation Sub-sector Network (NEC-SSN).

With regard to development of APG, three ASEAN bodies other than ACE are of particular importance.

HAPUA is the collaborative body of ASEAN power utilities. Established in 1981, HAPUA has evolved significantly during the past four decades, including a significant restructuring in 2012 that resulted in the creation of five working groups:

- HAPUA Working Group No. 1 – Generation and Renewable Energy;
- HAPUA Working Group No. 2 – Transmission/APG;
- HAPUA Working Group No. 3 – Distribution and Power Reliability and Quality;
- HAPUA Working Group No. 4 – Policy Studies and Commercial Development;
- HAPUA Working Group No. 5 – Human Resources.

HAPUA Working Group 2 has direct responsibility for supporting APG development, although as a practical matter all of the Working Groups also have roles to play. For example, HAPUA Working Group 5 is responsible for capacity-building efforts, including ones related to power connectivity.

The second relevant group is the APG Consultative Committee (APGCC), which is the platform that aids HAPUA's efforts to develop the APG, particularly aspects related to multilateral power trade. The APGCC reports to both HAPUA and SOME, and its membership includes both utility and ministry representatives.

Cognizant of the need to improve coordination among energy bodies, and guided by the need to accelerate cross-border power connectivity and trade, in 2017 member countries established the APG Special Task Force (APG STF) to assist APGCC (ASEAN, 2017). Subsequently, in 2020, APGCC showed the initiative of reviewing its Terms of Reference, considering the region's deepening efforts towards regional power integration, and clarifying the institutional roles and relationships of other multilateral power trade-related bodies (ASEAN, 2020).

Finally, the ASEAN Energy Regulators Network (AERN) is a collaborative body of ASEAN energy regulators. Formed in 2013, AERN is a relatively nascent organization, and its roles and responsibilities are still being defined. It has two working groups – Working Group 1 on Technical and Regulatory Harmonization, and Working Group 2 on Legal and Commercialization – both of which are tasked with supporting the equivalent HAPUA working groups (ASEAN, 2022).

The table in the ASEAN Economic Ministers Meeting on Energy Cooperation (AEMMEC) in support of increased power system integration in ASEAN. It also reflects the development of a growing perception of the role of power connectivity and the willingness to operationalize multilateral power markets in the region, particularly evident in the past five years.

Numerous coordination mechanisms bring together ASEAN member States and its dialogue partners specifically focused on energy, the continued sharing of best practices, and capacity-building activities. A few examples are SOME-EU Dialogue on Energy Cooperation; SOME-IEA Dialogue; ASEAN-China Senior Officials' Consultations; SOME-METI Energy Cooperation; SOME-Russia Consultation; SOME + 3; AMEM + 3; and the East Asia Summit Energy Ministers Meeting (EAS EMM), which formed the EAS Energy Cooperation Task Force (EAS ECTF). Under the ASEAN-US Energy Cooperation Work Plan, led by ACE, progress was made on the third major APG study, AIMS III Phases 1 and 2, which is described in the previous chapter (ASEAN, 2020).

At present, most electricity trade within APG occurs bilaterally, and it is anticipated that further growth in bilateral power trade will continue. However, a pilot for multilateral trading has been established in the form of the Lao Peoples Democratic Republic-Thailand-Malaysia-Singapore Power Integration Project (LTMS-PIP). Initially involving only the Lao People's Democratic Republic, Thailand and Malaysia, this project is seen as a "pathfinder" project to demonstrate that multilateral power trading is possible in an ASEAN context. The LTMS-PIP is a unidirectional power trade where electricity is sold by the Lao People's Democratic Republic to Malaysia (up to 100 MW of supply in the first phase, expanding to 300 MW in the second phase), with Thailand and now Malaysia acting as transit or wheeling, countries (LTMS PIP, 2014)[9] In June 2022 Singapore formally announced the start of imports of 100 MW electricity in the LTMS project (Energy Market Authority, 2022).

Although more work needs to be done to establish full multilateral, multi-directional power trading in South-East Asia, the LTMS-PIP has served as a useful empirical case study for how such trading could develop, in particular by providing an opportunity to learn from and address technical, legal and financial issues raised by cross-border trade involving multiple countries with different regulatory environments. In addition, it serves as a guiding process, establishing concrete timelines, deliverables and milestones, so that stakeholders can perceive their role in developing the power trade and the progress attained (Han, 2021), (USAID, 2021b).

Subregional perspective: North-East Asia

Progress on power system connectivity in the North-East Asia subregion has been confined to specific bilateral and multilateral agreements and initiatives, with little or no overarching coordination.

In 2016, China (State Grid), Republic of Korea (KEPCO), Japan (Soft Bank) and Russian Federation (Rosseti) signed a memorandum of cooperation to form an interconnected electric power grid in North-East Asia. Such a grid in North-East Asia will connect the bases of renewable energy sources located in Mongolia, north-east and north China, and the Russian Federation Far East with the centres of electricity consumption in northern China, Japan and the Republic of Korea (Ogino, 2020) Interested parties agree that the establishment of this connectivity will boost the large-scale development and utilization of renewable energy sources in the region (the share of these four countries accounts for 78 per cent of Asia's electricity needs) (Silk Road News, 2016).

Also in 2016, the Russian Federation introduced the idea of a North-East Asia Super Energy Ring, and likewise the Republic of Korea in 2017 by proposing to launch discussions among all leaders in North-East Asia to establish a super grid (ESCAP, 2018b). Before that, Mongolia had also shown support for the Gobitec and the Asia Super Grid Initiative in 2013.

9 During the 37th ASEAN Ministers on Energy Meeting (AMEM), during Thailand's Chairmanship, countries welcomed the Joint Statement of the Lao People's Democratic Republic, Thailand and Malaysia (LTM) on the Power Integration Project (PIP) Phase 2. The three countries confirmed an increase in the maximum committed energy capacity trading of the LTM-PIP up to 300 MW (ASEAN, 2021)

The project on the Strategy for North-East Asia Power System Interconnection (NAPSI) by ADB and the Government of Mongolia was established in 2017. Phase 1 of NAPSI focused on developing master plans for renewable generation, market and power trade, and interconnection grid with the target of supporting Mongolia on the multilateral interconnection by using its abundant renewable energy (ESCAP, 2018b), (Ogino, 2020).

In December 2017, China (GEIDCO, SGCC) and the Republic of Korea (KEPCO) signed a Memorandum of Agreement to develop a China-Republic of Korea power grid interconnection project. An MoU between the National Energy Administration of China and the Ministry of Trade, Industry and Energy of the Republic of Korea has been signed to establish a cooperation channel in the energy sector. The first China-Republic of Korea Energy Council Meeting was held in late May 2018 and agreed to conduct joint research on creating a North-East Asian Super Grid for power, including locations and expenses for installing undersea power cables.

In June 2018, KEPCO and Rossetti (Russian Federation) signed an MoU for a joint study on power interconnection between the two countries during the Republic of Korea-Russia Summit. At the same time, the Russian Federation re-emphasized the desire for a “Japan-Russia Power Bridge”, which had been discussed during the Japan-Russian Federation Summit in April 2017.

The lack of coordination among these efforts, and overall limited progress, is due in part to the fact that there are no subregional institutions focused on energy cooperation. Since 2016, however, ESCAP has organized the North-East Asia Regional Power Interconnection (NEARPIC) forum, which provides a platform for discussion on power developments at the national and subregional levels and promote renewable energy development and integration.

Subregional perspective: Central Asia

The member countries of the USSR had a Unified Energy System which originated in 1956, and by 1990 coved two-thirds of the country. During the Soviet era the Central Asia States (Azerbaijan, Armenia, Kazakhstan, Kyrgyzstan, Tajikistan, Turkmenistan and Uzbekistan) all participated in the Unified Energy System.

This mechanism created an energy and water exchange system between Russia and the republics of Central Asia. After the collapse of the Soviet Union, however, the system was disconnected. Re-establishing regional connectivity is being discussed on an ongoing basis in the region, and discussions on regional connectivity are being supported by international and regional institutions. In March 2018, the Tajikistan-Uzbekistan agreement on mutual energy supplies was signed. In April 2018, the ‘Regar-Gulcha’ transmission line that connected power grids of the two countries was commissioned. After a nine-year break, Tajikistan resumed electricity supplies to Uzbekistan in 2018. This event became an important step on the way to restoring the regional energy system (New Eastern Outlook, 2018).

Energy relations in the Central Asia region are developed under the framework of the Commonwealth of Independent States (CIS), the Eurasian Economic Union (EAEU), the Central Asia Regional Economic Cooperation (CAREC) Program, and a number of multilateral and bilateral agreements and treaties.

Electric Power Council of CIS

The Electric Power Council of the CIS was created by the Intergovernmental Agreement on coordination of interstate relations in the CIS electric power industry on 14 February 1992. The key target of the organization is to ensure the sustainable work of the unified energy system of Central Asia, which includes Azerbaijan, Georgia, Kazakhstan, Kyrgyzstan, the Russian Federation and Uzbekistan. The main tasks and functions of the Council include:

- The development of proposals on the principles and directions of integration of the CIS member States in the field of the electric power industry;
- The creation and maintenance of the functioning of the common electric power market of the CIS member States;

- Participation in the preparation of international treaties in the field of energy, and regulation of technical rules for parallel operation of electric power systems of the CIS member States;

- Providing assistance to the CIS member States in the unification and harmonization of regulatory legal acts in the field of electric power;

- The development of international relations in the interests of the CIS member Participation in the work of international energy organizations.

Currently the power systems of a number of Central Asian States, including Kazakhstan, Kyrgyzstan, the Russian Federation and Uzbekistan, are synchronized with many other CIS members. To coordinate parallel operations, the Electric Power Council established the Commission on Operational and Technological Coordination. The Commission has developed regulatory documents defining the main technical requirements for parallel operation of power systems of the CIS and Baltic countries. The countries determined the procedure for providing power reserves and mutual assistance in emergency situations of energy systems, and other agreements to ensure sustainable work of energy systems (Electric Power Council, 2022). Further development of the system includes the restart of electricity trade between Tajikistan and possible integration of Turkmenistan into the system.

Coordination Dispatch Center “Energiya”

Coordination of interstate centralized dispatch management of operational and technological activities for electricity supply is conducted by the Coordination Dispatch Centre (CDC) “Energiya”. Based in Uzbekistan, CDC “Energiya” develops the principles of energy transit distribution based on grid development degree, and works on further improvement of methodology that allows the implementation of involvement of energy systems in the process. The work of CDC “Energiya” is currently supported by international institutions and includes capacity-building and equipment modernization (CAREC, 2019).

Eurasian Economic Union

The Eurasian Economic Union (EAEU) is an international organization for regional economic integration. Created in 2015, its current members are the Republic of Armenia, the Republic of Belarus, the Republic of Kazakhstan, the Kyrgyz Republic and the Russian Federation.

On 29 May 2019, the EAEU members signed an agreement regarding the formation of a common electricity market. At the end of the same year the roadmap of the creation of the common market was approved (Eurasian Economic Commission, 2019). To start the work, however, the countries still need to prepare and approve various regulatory documents. A test run of the common electricity market is planned to be launched in 2024, with the market fully operational by 2025.

Subregional perspective: South Asia

In 2016, India issued the guidelines for CBET, “Guidelines for Import/ Export (Cross-Border) of Electricity.” These guidelines were subsequently updated in 2018. The objectives of the Guidelines are to:

1. Facilitate import/ export of electricity between India and neighboring countries;

2. Evolve a dynamic and robust electricity infrastructure for import/export of electricity;

3. Promote transparency, consistency and predictability in regulatory mechanisms pertaining to import/ export of electricity in the country; and

4. Achieve reliable grid operation and transmission of electricity for import/export (Government of India, 2018).

The guidelines have helped to facilitate the bilateral connectivity efforts between India and Nepal as well as between India and Bhutan.

On a more multilateral basis, several other institutions have been formed to enable the advancement of connectivity in South Asia.

SAARC Energy Centre

The idea of an interconnected electricity system integrating the countries of South Asia was first proposed in 2004 with the concept of SAARC Energy Ring,[10] although progress on this unified vision has been limited (ESCAP, 2018a). In addition, however, there are multilateral efforts among subsets of South Asian countries, in particular the Bangladesh, Bhutan, India, Nepal (BBIN) Initiative.

Several regional cooperation mechanisms have been established to support increased cooperation on energy issues, in particular in the power sector. A Technical Committee on Energy was established in 2000, and in 2004 the Council of Ministers approved the creation of a specialized working group on energy. In addition, the Energy Ministers in 2009 decided to form Expert Groups for different commodities and services, i.e., oil and gas, electricity, renewable energy and technology/ knowledge sharing. The Expert Group on Electricity, led by India, was given a mandate to prepare/finalize the SAARC Inter-Governmental Framework Agreement on Energy Cooperation and other matters pertaining to electricity.

In 2006, the SAARC Energy Centre was established in Islamabad with the mandate of initiating, coordinating and facilitating regional as well as joint and collective activities on energy. Two of its goals are to facilitate energy trade within the SAARC region by establishing a regional electricity grid and natural gas pipelines, and enhancing cooperation in the use of new and renewable energy sources in the region, thereby contributing towards more sustainable development in the SAARC member countries (SAARC, 2022).

The SAARC Framework Agreement on Energy Cooperation (Electricity) was signed during the 18th SAARC Summit in Nepal, 26-27 November 2014. This Agreement has enabling provisions for:

1. Cross border trading of electricity on voluntary basis;
2. Planning of cross border grid interconnection by transmission planning agencies of the Governments through bilateral/trilateral/ mutual agreements based on the needs of the trade in the foreseeable future through studies and sharing technical information required for the same;
3. Building, owning, operating and maintaining the associated transmission system of cross-border interconnection falling within respective national boundaries and/or interconnected at mutually agreed locations;
4. Joint development of coordinated network protection systems incidental to the cross-border interconnection to ensure reliability and security of the grids of the member States;
5. Joint development of coordinated procedures for the secure and reliable operation of the interconnected grids, and to prepare scheduling, dispatch, energy accounting and settlement procedures for cross border trade (SAARC, 2014).

The agreement was signed by all eight countries . It was considered to be a major step to facilitate regional energy connectivity. Since the signing, the SAARC Energy Centre has supported the implementation of the agreement by conducting studies and workshops, for example on mobilizing finances, developing a Smart Grid Road Map, and power pricing for cross-border electricity trade in South Asia.

South Asia Regional Initiative for Energy Integration

The South Asia Regional Initiative for Energy Integration (SARI/EI) is Phase IV and final phase of SARI/EI programme launched by the United States Agency for International Development (USAID) in 2000. This initiative covers all eight countries of South Asia and aims to strengthen energy security in South Asia by focusing on cross-border energy trade, energy market formation and regional clean energy development. The initial phase of the SARI/EI programme (2001-2004) focused on the socio-economic aspects of regional power cooperation by emphasizing information

10 The South Asian Association for Regional Cooperation (SAARC) was established in 1985. SAARC comprises eight member States: Afghanistan, Bangladesh, Bhutan, India, Maldives, Nepal, Pakistan and Sri Lanka.

exchange, capacity-building and the development of pre-feasibility studies (USAID, 2012). Phase II (2004-2007) concentrated on enhancing the policy and regulatory framework for cross-border energy trade, to set a foundation for the market structures and access to cleaner energy sources. This phase also supported several interconnection investments projects and bilateral energy projects from Central Asia to Afghanistan.

The third phase (2007-2012) progressed in two areas: (a) the development of transmission infrastructures guided by technical assistance activities: and (b) market formation activities by providing energy planners and policymakers with modelling techniques and key energy market trends.

Phase IV was launched in 2012 to promote regional power integration and cross-border energy trade. Acting as an enabler for further energy integration in the region, the programme intends to forge a suitable environment to support key stakeholders and the formation of a South Asian electricity market. Through three different task forces, these objectives are achieved by: (a) coordinating policy, legal and regulatory frameworks; (b) advancing transmission systems interconnection in technical and operational areas: and (c) strengthening the South Asia Regional Market by exploring market-driven practices in power trading. Some key accomplishments include supporting the signature of the SAARC Framework Agreement for Energy Cooperation in 2014 and the India-Nepal Power Trade Agreement in 2014 (Ministry of Energy of Nepal, 2014).

Integrated Research and Action for Development

Established in 2002, the Integrated Research and Action for Development (IRADe) is an autonomous and non-profit thinktank that conducts policy analysis and multidisciplinary research. It connects and networks with various stakeholders throughout multiple sectors including Governments, ministries, the private sector, academic experts and NGOs. IRADe's research covers several themes including energy and power systems, urban development, climate change and environment, poverty alleviation and gender, food security and agriculture, and the Asia Center for Sustainable Development.

In 2008, IRADe was registered as a research institution by the Ministry of Science and Technology in India. In areas of gender and energy, it was later selected as the national focal point for India and international networks. As an implementing partner and secretariat of the SARI/EI programme, IRADe supports the promotion of sustainable energy access in the South Asian region. In addition to collaborating with numerous regional forums, IRADe conducts energy policy studies concentrating on technology assessments, pricing policies, global energy scenarios, role of clean energy trade, energy access and long-term energy perspectives to achieve carbon neutrality pledges.

South Asia Forum for Infrastructure Regulation

Established in 1999, the South Asia Forum for Infrastructure Regulation (SAFIR) is an association that promotes information and experience sharing among regulators in South Asia. The Forum plays a significant role in disseminating best practices. SAFIR members meet every year during the Annual General Meeting (AGM) to seek the views of members or discuss trends and challenges in the process of the reforms.

SAFIR has numerous Working Groups including one overviewing the South Asian power sector and SARI/EI programme activities. In collaboration with SARI/EI, USAID and IRADe, the SAFIR Working Group aims to enhance regulatory cooperation to facilitate knowledge sharing, address cross-sectoral energy regulatory challenges, and develop a transparent regulatory framework to promote investment in the region (USAID, 2020). Key activities include providing inputs on regulatory guidelines, undertaking research on issues relevant to energy sector regulations, developing roadmaps and regulatory interventions for South Asia's effective energy cooperation, and creating a data bank on energy issues.

3.2. **Learning** from experiences in other regions

In considering how institutional frameworks can support increased power system integration, it is worth examining efforts in other parts of the world. In many cases these efforts are also relatively nascent, and so their experiences may offer parallel views to those in the Asia-Pacific region. Others are far more advanced, and therefore may be useful in guiding the evolution of efforts in Asia and the Pacific (figure 19).

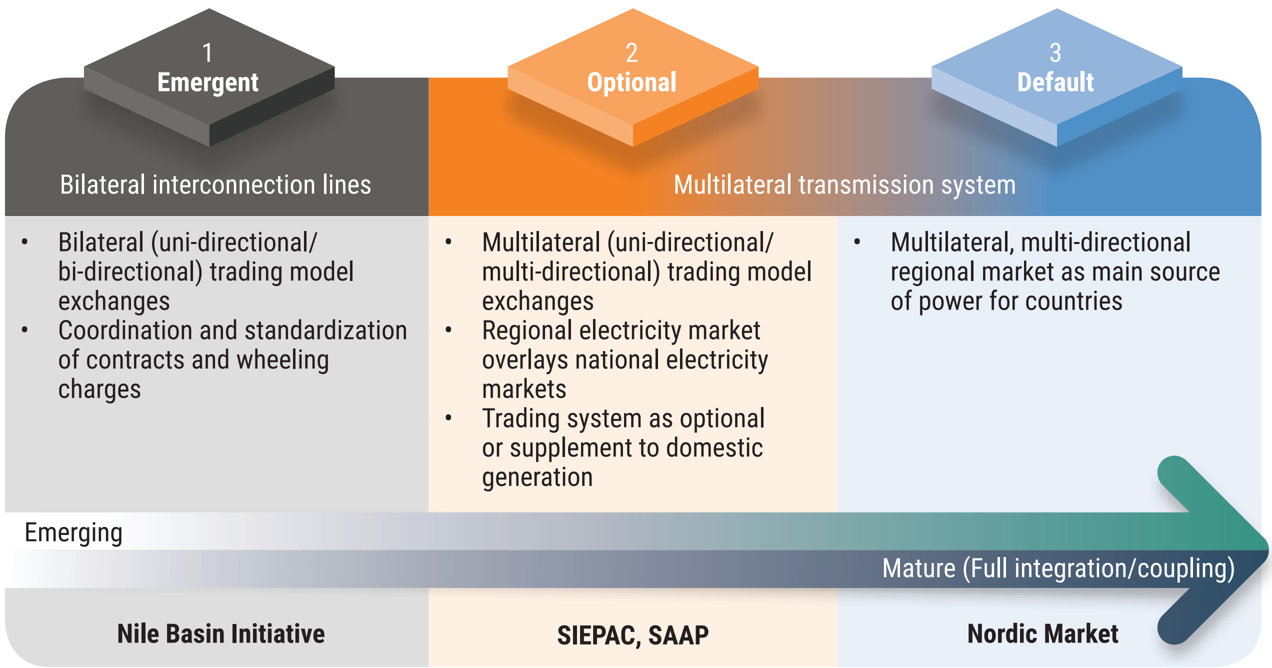
The idiosyncrasies of each power connectivity initiative demonstrate that there is no single, uncontested model to follow. Hence, there are many market design options and different routes to follow. States can mimic or avoid a particular course of action, eventually leapfrogging the process towards establishing cross-border power connectivity and trade.

Nile Basil Initiative

The Nile Basin Initiative (NBI) is an intergovernmental partnership established in 1999 with the objective of a shared vision: "To achieve sustainable socio-economic development through the equitable utilization of, and benefit from, the common Nile Basin water resources". It is comprised of 10 Nile Basin countries – Burundi, Democratic Republic of the Congo, Egypt, Ethiopia, Kenya, Rwanda, South Sudan, Sudan, Tanzania and Uganda. Eritrea participates as an observer. This institution functions as a platform for the Basin States to coordinate the sustainable management and development of the shared Nile Basin water and related resources for mutual benefit (Nile Basin Initiative, 2022).

The development of the Nile and its resources is essential for this set of countries, which are characterized by low per capita incomes, high poverty levels, low electrification rates and low electricity consumption. The power sector is one of the NBI's main priority areas under its agenda for development and natural resource management.

The region is marked by substantial spatial and temporal variability of water resource availability.



Source: ESCAP.

Figure 19 Levels of regional power connectivity and trading arrangements

Nile Basin Initiative (NBI) at a glance	
Population (total)	**Around 561 million (World Bank, 2021)**
Electric power consumption (total)	2,587 kWh per capita (Statista, 2020; WB, 2014)*
Countries involved	10 Burundi, DR Congo, Egypt, Ethiopia, Kenya, Rwanda, South Sudan, Sudan, Tanzania, Uganda
Projects	Interconnection of the Electric Grids of the five Nile Equatorial Lakes countries (Burundi, DR Congo, Kenya, Rwanda and Uganda) project. Through four interconnections, it will cover around 1000 km, transmitted via 220 kV and 400 kV lines: • Kenya-Uganda – 254 km • Uganda-Rwanda – 172 km • Rwanda Burundi – 200 • Burundi-DRC-Rwanda – 545 km Ethiopia-Sudan interconnection Project – 296 km of line with a transmission capacity rating of 1200 MW. Backbone Zambia-Tanzania-Kenya Project - Through several components, this will link the EAPP countries to the Southern Africa Power Pool (SAPP), enabling power sharing across the region. Uganda-DRC transmission line Study preparing to build a high-voltage transmission line (353 km) in North Eastern DRC to complete the Nile equatorial lakes regional power grid (Nile Basin Initiative, 2015). Regional Rusumo Hydroelectric Project - joint development by the Governments of Burundi, Rwanda and Tanzania. It will generate approximately 80MWs to be shared equally between the three countries, each benefiting about 26MW directly connected to the national grid through 372 Km of 220Kv transmission lines (Nile Basin Initiative, 2021). Feasibility of the 170-kilometre 400kV Nimule-Juba power transmission line. The Nimule-Juba high voltage transmission line will also connect the Eastern Africa Power Pool (EAPP) countries through various interconnections, forming part of the western arm of the North-South electricity superhighway (Nile Basin Initiative, 2021a)
Traded volumes	220 MW in 2013, rising to 620 MW by 2030 (ECA, 2009)

Data for Egypt, Ethiopia, Kenya, Sudan from Statista, 2020. Data for DR Congo and South Sudan: World Bank, 2014. There is no available data for Burundi, Rwanda and Uganda.
Source: World Bank, 2021, 2014; Statista 2020; Nile Basin Initiative, 2015, 2021, 2021a, Economic Consulting Associates, 2009b.

NBI members recognize that unilateral development of water resources can lead to conflict and sub-optimal utilization of the shared water resources as well as complementarities between diverse needs for, and access to water, and the diverse development and availability of electricity (Nile Basin Initiative, 2016). Given these imbalances and the potential for complementarity, integration of the electricity sector is seen as a strategy for addressing power needs and supporting economic development.

The strategic directions for NBI during 2017-2027 are identified in the NBI Strategy document. Goal number 2 is: "Enhance hydropower development in the basin and increase interconnectivity of electric grids and power trade". The document's starting point is an acknowledgement that energy supply in the Nile Basin countries remains inadequate, unreliable and expensive. Unlocking the full potential of the Nile Basin requires transboundary cooperation in hydropower development and grids to ensure a more comprehensive approach to the river basin context, enhance regional cooperation and trust, reduce financial risks as well as open future sustainable development opportunities (Nile Basin Initiative, 2016).

At present, however, there is very limited cross-border power trade between these countries. In fact, the Nile Basin remains the only region on the African continent without a functional regional power grid. Moreover, the limited amounts of trade are not supported by common frameworks, but rather primarily bilateral and trilateral agreements.

It is, therefore, this region's goal to tap into the huge hydropower potential that the basin offers by (a) facilitating the identification, preparation and implementation of power generation and transmission infrastructure projects, and (b) enhancing capacity for systems management, including operation guidelines, in the region. For countries to move from trade based primarily on bilateral contracts towards a competitive regional market, investment in the transmission backbone is required, and an institutional and regulatory framework should be developed. This could ultimately result in the establishment of a regional regulator and regional dispatch centre.

SIEPAC (Central American Electrical Interconnection System)

The SIEPAC was created in 1996 by the six countries in Central America: Nicaragua, Costa Rica, Guatemala, Panama, Honduras and El Salvador. However, the first interconnection (between Honduras and Nicaragua) dates back to 1976. Since its creation SIEPAC has evolved into a competitive electricity market in which all Central American countries participate (Echevarría, 2017).

SIEPAC is underpinned by the Framework Treaty for the Central American Electricity Market ("Tratado Marco", or Marco Treaty), which contains two components: the creation of the MER (Mercado Eléctrico Regional), and the development and construction of the first regional transmission system.

The objective of SIEPAC is to enable potential gains from integration while respecting national sovereignty. The original idea stemmed from the region's untapped energy reserves, particularly in hydropower, which were difficult to develop because of relatively small national markets. Achieving economies of scale in generation was only possible in the context of a multinational market. SIEPAC will also bring efficiency gains through economic dispatch, shared reserve margins and exploitation of complementarities in demand and supply. The drivers for the creation of the regional market focus on the following objectives: to improve operational efficiency; reduce dependence on fossil fuels; improve national and international competition; reduce electricity prices; and attract private investment (Economic Consulting Associates, 2010c).

MER's design was approved in 2000, establishing it as a seventh market that overlays the six national systems. The design allows individual countries to develop national power sectors at their own pace while also enabling trade within the region. The focus on gradualism is explicitly required in the Marco Treaty.

The MER is supported by an institutional framework composed of the Regional Commission for Electricity Interconnection (CRIE), the Regional Operating Agency (EOR) and the MER's Steering Committee (CDMER). These institutions, provided for in the Marco Treaty, have a supranational legal status which grants them independence from any of the six national legal systems (Economic Consulting Associates, 2010c). In addition, it has a Council

SIEPAC at a glance	
Population (total)	Around 50 million (World Bank, 2021)
Electricity consumption (total)	7,316 kWh per capita (Statista, 2020)
Countries involved	6 Nicaragua, Costa Rica, Guatemala, Panamá, Honduras and El Salvador
Projects	Development and construction of a 1.793 km international transmission line, from Panama in the south to Guatemala in the north (Guatemala – 283km; El Salvador – 286 km; Honduras – 274 km; Nicaragua - 307 km; Costa Rica – 493 km; Panama – 150 km). It is a 230 kV power line with a circuit capacity of 300 MW and provision for second circuit of the same capacity, as well as their respective bays and substations. Development of a regional electricity market (MER) based on a standard set of trading rules at the regional (supranational) level (Echevarria et al, 2017).
Installed capacity	19 GW in 2020 (Renewable energy accounts for 81.9% of total installed capacity) (Barrera, 2021).
Traded volumes	345 GWh in January 2022 (new record), surpassing the previous maximum recorded in April 2019, 323 GWh (CRIE, 2022) (CRIE, 2022)

Source: Echevarria, 2017; Barrera, 2021; CRIE, 2022.

of Ministers of Energy (to develop guidelines for the regional energy policy), and a Regional Operations Entity.

The infrastructure currently includes 1,800 km of transmission lines with a capacity of 300 MW. The project was completed in 2014, and MER was launched at the same time. Most trade is settled based on real-time conditions. There is a contracts market allowing for forward trading, but this is also relatively short term: under a year in nearly all cases and mostly running weeks to months. Progress is being made towards allowing for firm transactions of up to one year. The level of energy exchanges has grown steadily, from 688 GWh in 2013 to 2,182 GWh in 2019.

SIEPAC's main infrastructure is also integrating with neighbouring countries through links between Mexico and Guatemala (already fully operational), and a link between Panama and Colombia that is in the design phase.

All in all, it should be noted that this case emerged from a diverse set of countries in Central America, raising possibilities for other regional contexts such as the ones in Asia and the Pacific. There is structural variation across markets translated, for example, into differentiated actors participating in MER at the national level, which depends on national-level laws and regulations.[11] The case study shows that countries do not need fully integrated and aligned markets to reap the benefits of regional connectivity.

Southern African Power Pool

Southern African Power Pool (SAPP) was created in 1995, SAPP connects 12 countries in southern Africa and allows for multilateral, multi-directional trading among multiple countries in the region (figure 20). Most of the generation and transmission infrastructure of SAPP precedes the formation of the power pool. The founding agreements of SAPP were, in fact, inspired by bilateral and multilateral agreements that were already in place. The trading arrangements between members have continued to operate predominantly under the pre-SAPP–type bilateral and multilateral contracts. SAPP's focus has thus been to:

11 To illustrate this point, Honduras and Costa Rica participate in MER through their vertically integrated national utilities, while the remaining four countries participate directly through generators, marketers, distributors and large-sized customers (IEA, 2019).

SAAP at a glance	
Population (total)	Around 341 million (World Bank, 2021)
Electricity consumption (total)	Approx. 10,239 kWh per capita (Statista, 2020; WB, 2014) *
Countries involved	12 members: Angola, Botswana, DRC, Lesotho, Malawi, Mozambique, Namibia, South Africa, Swaziland, Tanzania, Zambia, Zimbabwe
Projects	Generation projects: Batoka (Zambia and Zimbabwe) – 2,400 MW in 2023 Mphanda Nkuwa (Mozambique) - 1,500 MW in 2028 Devil's Gorge (Zambia and Zimbabwe) - 1,200 MW in 2032 Inga 3&4 (DRC) - 4,800 in 2030, 9,426 MW in 2032, rising yearly to 11,654 MW in 2034 Stiegler's Gorge (Tanzania) - 1,048 MW in 2036 2,096 MW in 2039. Transmission projects: Inga-Angola - 3 x 400 kV HVAC - 1,100 MW in 2020 (2 lines), 1,600 MW in 2034 (with third line); Inga-Luano (Zambia) - 500 kV HVDC, 2,000 MW in 2029; Inga-Limpopo (Gauteng) - 600 kV HVDC 3,000 MW in 2032; STE (Mozambique) - 2 x 400 kV HVAC, 500 kV HVDC Phased development over 2023–2028 (SAPP, 2017a).
Installed capacity	67,266 MW (SAPP, n.d.)
Traded volumes	133.5 GWh in July 2022 (SAPP, 2022)

Data for DRC refers to 2014. No available data for Lesotho, Malawi and Swaziland.
Source: World Bank, 2021, 2014; Statista, 2020; SAPP, 2017a; SAPP, n.d.; SAPP, 2022.

1. Improve the reliability and security of the existing regional grid;

2. Facilitate the expansion of the grid to connect nonoperating members; and

3. Introduce a short-term energy market (STEM) to facilitate the trading of surplus energy not committed under existing contracts (Economic Consulting Associates, 2009a).

The SAPP has evolved since the establishment of the Short-Term Energy Market in April 2001. In January 2004, SAPP started the development of a competitive electricity market for the Southern African Development Community (SADC) region. It intends to provide a forum for regional solutions to electric energy problems to be a fully integrated, competitive energy market, and a provider of sustainable energy solutions for the SADC region and beyond.

Disclaimer: The boundaries and names shown and the designations used on this map do not imply official endorsement or acceptance by the United Nations.
Source: SAPP

Figure 20 Southern African Power Pool Grid Map

The Day-ahead Market (DAM) was established in December 2009, replacing STEM; however, most of the electricity trade in the region continued to be via long-term bilateral contracts. In 2015, the SAPP Trading Platform was upgraded with Forward Physical Markets and the Intra-Day Market. Participants maintain their own national power systems and use SAPP as an optional, secondary resource to sell excess power. SAPP operates as a multilateral platform for trading electricity surplus close to real-time alongside other arrangements, which preserves the domestic price-setting approach of the participants and remains rather independent from neighbouring countries for electricity security.

An executive committee manages SAPP with a subsidiary committee under SADC's Directorate of infrastructure. Trading volumes are only a fraction of the total electricity sales in the region, in part due to transmission constraints. Although the initial SAPP trading activities were based on excess generation capacity available for various historical reasons, it was recognized from the outset that the major benefits would come from coordinated investment in new generation and transmission facilities.

The most recent SAPP Pool Plan, released in 2017, aims to "identify a core set of generation and transmission investments of regional significance that can provide adequate electricity supply to the region under different scenarios in an efficient and economically, environmentally and socially sustainable manner, and support enhanced integration and power trade in the SAPP region." National power system master plans are the basis for the Pool Plan. Contrary to a regional cooperative strategy, countries in SAPP plan to be self-sufficient in capacity from their own generation resources to match maximum power demand and reserve obligations. The more common reasons for this inward focus of the country plans are: (a) the fact that importing countries have suffered more than exporting countries during recent periods of power shortages; (b) there are no guarantees that the generation development of each country will proceed as planned; (c) there is no price transparency, and therefore imports may not be advantageous in terms of cost for countries with no alternative options; and (d) the need to develop local industry and skills (SAPP, 2017b).

Although this Pool Plan is purely indicative and does not create an obligation on members to comply, it was produced in the hope that its perspectives might be incorporated into national development planning. It intends to represent a guide for the development and review of national plans to maximize the synergistic benefits over the upcoming decades (SAPP, 2017b).

A critical feature of SAPP is that the national markets have not been deregulated. In each participating country, national incumbent power companies act as single buyers (and sellers) of electricity. However, this has not hindered the development of a market model from supporting the better utilization of power resources on a regional basis. In some countries, IPPs have been allowed to participate directly in SAPP.

Similar to the SIEPAC, under the SAPP market framework, only excess generation is traded. In other words, member States first ensure that they are able to cover their own demand before offering generation capacity to the SAPP regional market. In addition, power can also be traded through SAPP on an emergency basis to help meet unexpected shortfalls (IEA, 2019). In short, SAPP helps to facilitate regional connectivity and shows the value of gradual implementation in order to harvest synergies between power systems.

The integrated European power market

The European electricity market has developed over a long period and at different paces in different parts of Europe. One of the early efforts of integration happened in the Nordic countries. Established in 1993, the Nordic market and the establishment of the Nordic power exchange, Nord Pool, was initially the product of the Norwegian approach to liberalization and new Energy Act of 1991. In 2000, it moved from being a Norwegian power market to becoming the Nordic power market. As further integration has happened in the European Union Nord Pool expanded its services to include the Baltic States and the United Kingdom.

European legislation has further allowed for competition between exchanges in Europe, which means that exchange services are no longer a monopoly function in the European market. Market participants are free to choose between exchanges operating in the price zones they trade in. For the Nordic subregion this means, for example, that the Paris-based exchange EPEX spot also offers its services in the Nordic price zones (Bredesen, 2015).

The Nordic subregion is part of the larger European day-ahead coupling, which happened in 2014, when the first single-day ahead coupling mechanism in Europe was launched. Since 2014 the European market has steadily increased harmonization as well as included markets and timeframes, which means that currently a single intra-day market also exists, and platforms for balancing resources at a pan-European level are under development.

The European power market is highly integrated with implicit day-ahead auctions. The implicit auctions means that when power is traded on the exchange, there is no need to separately book transfer capacity between price zones. The available transfer capacity is taken as an input to the auction together with bids and asks. One algorithm for the entire European market then solves the optimization problem of lowest generation cost to meet demand, and which turns into a dispatch schedule.

The European market is governed by a set of documents known as "network codes". The network codes include topics such as congestion management, cost sharing, capacity allocation in several timeframes, security analysis and more. The transmission system operators (TSOs) are obliged to develop methodologies to support implementation of the network codes. These methodologies can be developed by a subset of TSOs or all TSOs, depending on their scope. When methodologies are developed among a subset of TSOs, it is a reflection of continued differences among European Union member States. Harmonizing within subsets of TSOs is a step towards harmonization across the entire region. In this way the European market takes incremental steps towards full harmonization, which can be a useful tool when harmonizing very complex rules, regulations and methodologies.

Once methodologies have been developed by the TSOs, they submit them to the regulators for approval. Regulators, like the TSOs, work together to either approve the methodologies or suggest changes.

In case there are disagreements, either between the TSOs, or between the regulators or the regulators and the TSOs, the methodologies will be referred to the Agency for the Cooperation of Energy Regulators (ACER). ACER has the jurisdiction to finally decide on methodologies and enforce them in the national power systems. ACER is a very important institution for the development and operation of the European power system, since it acts as a dispute resolution mechanism and ensures that there is progress on the agreed developments and that operational procedures are implemented within the single market for power.

The European power connectivity and trade experience is commonly presented as one of the most advanced and successful power trade models. In addition to the brief evolution presented above, several explanations underpin this assessment. Compromise became one of the basic criteria for the success in the market. A solution based on economic principles that lay the foundation for a reliable power system operation was – and still is – the main reason for its success.

Conclusion

Countries in Asia and the Pacific face multiple challenges to implementing cross-border power connectivity and trade. Institutions and/or other coordinating mechanisms present numerous advantages as vehicles to overcome barriers. The analysis of regional and non-regional successful initiatives suggests that regional markets require some degree of regional institutions. Institutions are the key to (a) developing common policies, regulations and standards; (b) a growing sense of trust and commitment; and (c) developing power system operations.

With the notable exception of North-East Asia, the Asia-Pacific region has several energy/electricity-related cooperation mechanisms. The proliferation of coordination mechanisms – closer to or away from the classic structuring of intergovernmental organizations – suggests that countries acknowledge their potential role in achieving power connectivity and trade. However, it is also noted that most of the institutions still focus on the preliminary efforts of regional integration with analysis and experience-sharing, Institutions that implement processes and detailed market design are still largely lacking in the Asia-Pacific region with the exception of Central Asia, which has several institutions focusing on power system operation, and which has historical roots in the integration of the Soviet Union.

Despite slow progress, South-East Asia (through ASEAN) remains an interesting example of cross-border (and cross-subregional) power connectivity. ASEAN has a long, evolutive process around energy cooperation. Institutions have served as the primary platform for regional energy activities as well as contributing to creating a uniform approach to energy among member countries, assisting in energy governance and infrastructure, collecting and disseminated access to information on energy, all of which are vital for regional energy planning and other prominent roles.

However, ASEAN energy-related institutions lack, by design, the authority to set and enforce rules for ASEAN member States. Their limited authority combined with a lack of consensus among ASEAN member States for a common approach to APG development has limited progress. The example of the successful European experience unveiled the importance of a consensus-building, voluntary, principles-based approach. Hence, it is possible for a soft consensus-based management system to support progress, when there is sufficient political will and flexibility in the approach.

Bearing in mind the role of cooperation mechanisms, before building new institutions agencies or other mechanisms to address particular connectivity challenges, countries should first assess the role of, and potential for existing ones. That said, one size fits all institutions and processes are seldom suitable, and the creation of new institutions can make sense when it is clear that existing institutions are unsuited to delivering required changes or performing specific functions.

In order to operationalize cross-border power connectivity and trade, regardless of the 'model', strategies can/should create institutions – both at the technical level (Association of Regulators/ Association of Transmission Utilities/system operators) and more in the political realm (ministerial meetings, senior official meetings, working groups).

CHAPTER 4
Cross-cutting issues

Among the strategies contained in ESCAP's Road Map for Power System Connectivity in Asia and the Pacific, several strategies do not easily fall in the categories of planning or operational issues. Instead, these strategies address cross-cutting issues that are either foundational in nature, such as the need for political trust, or are applicable in many different contexts, such as the need for capacity-building, or data sharing, requiring harmonization.

In the context of the Regional Road Map on Power System Connectivity, the most relevant strategies are:

Strategy 1. **Build trust and political consensus for cross-border electricity trade;**

Strategy 3. **Develop and implement intergovernmental agreements on energy cooperation and interconnection;**

Strategy 4. **Coordinate, harmonize and institutionalize policy and regulatory frameworks;**

Strategy 7. **Mobilize investment in cross-border grid and generation infrastructure;**

Strategy 8. **Build capacities and share information, data, lessons learnt and best practices;**

Strategy 9. **Ensure coherence of energy connectivity initiatives and the Sustainable Development Goals.**

The key findings of this chapter are:

- Cross-border electricity connectivity projects are complex endeavours. However, obstacles to progress may often be overemphasized, while potentially positive economic and environmental impacts of connectivity garner less attention;

- Because initiatives in the region are primarily still bilateral, practical experience with the impacts of multilateral connectivity is still limited;
- Examples of positive impacts from energy connectivity policy initiatives do exist such as, for example, improving energy access and reducing power system reserve requirements;
- Concerns about energy security, while understandable, should not dominate the agenda. In practice, limiting power system connectivity can actually expose energy importing countries to disruptions, given the uncertainty and vulnerability of supply chains and energy markets, by reducing the overall diversity of the energy system;
- Properly developed, power system connectivity linked to renewable energy deployment can enhance energy security through greater diversification of energy supplies and reduced exposure to volatile global commodities markets.

4.1. Exploring the relationship between power system connectivity and sustainable development: **From theory to evidence**

Many studies have shown that more interconnected power systems offer a number of potential benefits. These include: economic and financial benefits, such as lower costs; security benefits, including increased reliability and resilience; technical and operational benefits; and social and environmental benefits.

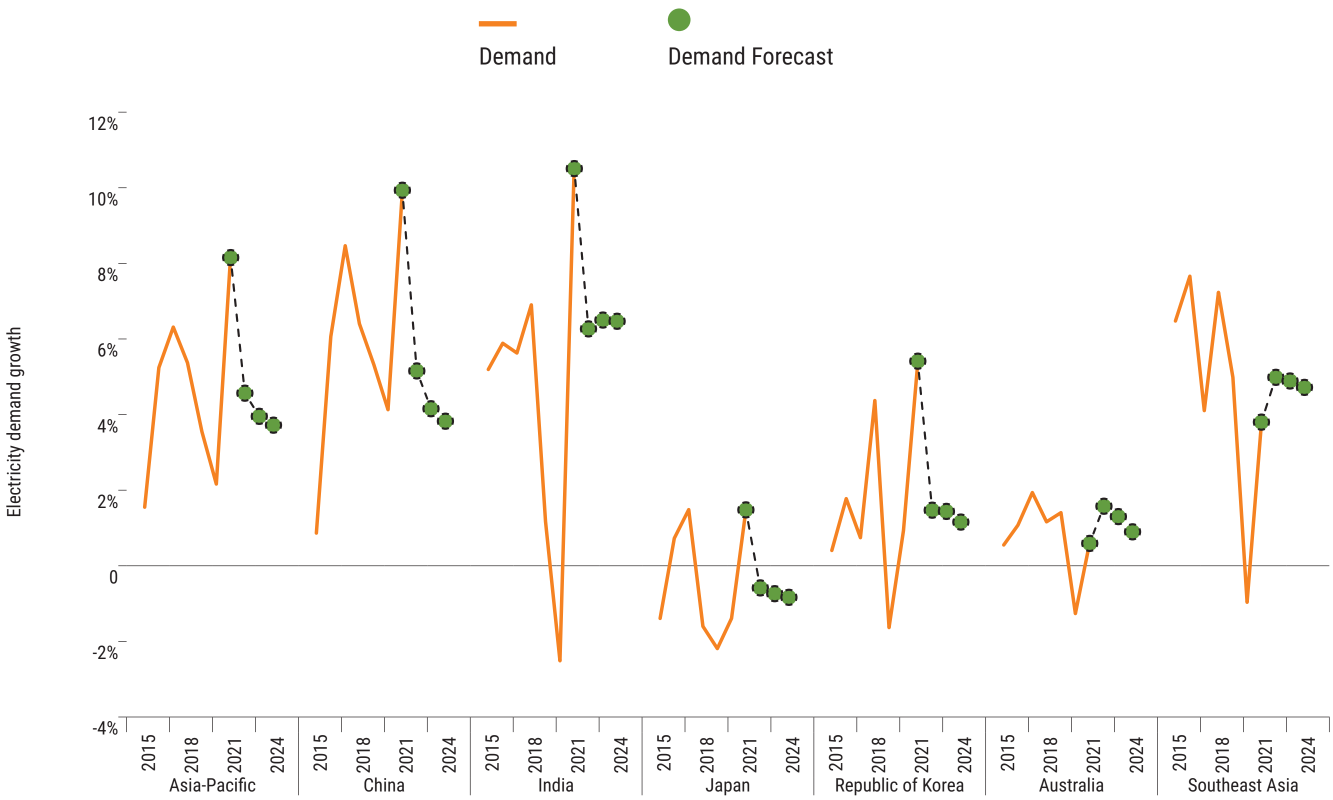
However, cross-border electricity projects are complex endeavours that have risks associated with them, including the potential that these benefits will not be fully realized, or that they will not be equitably distributed.

Previous chapters of this report have focused on the practical aspects of planning and operating interconnected grids. This section will focus on relevant cross-cutting issues, including potential social and environmental impacts of power connectivity, illustrated with concrete examples.

Connectivity, energy access and the reduction of energy poverty

According to IEA projections, the primary driver of global energy demand growth is the Asia-Pacific region, with growth particularly concentrated in emerging and developing Asia (figure 21). Most countries in the region are expected to see continued demand growth up to 2024, with the regional growth rate stabilizing at around 4 per cent per year on average, slightly below pre-pandemic levels but above the global average of below 3 per cent (IEA, 2022a).

Energy access and economic growth are closely intertwined, and increased access is a necessary condition for economic development. During the past two decades, economic growth in Asia and the Pacific has lifted millions of people out of poverty, and in the process the



Source: IEA, 2022a.

Figure 21 Historical and projected electricity demand in the Asia-Pacific region and select countries, 2015-2024

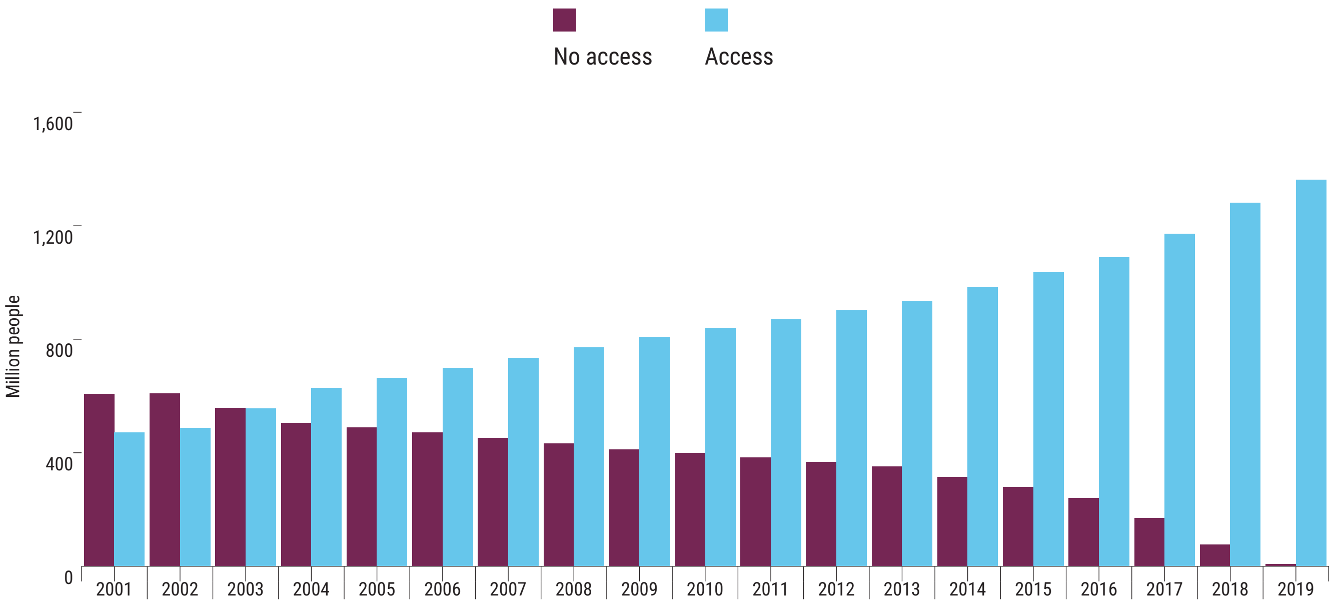
region has achieved near universal access to electricity. However, energy poverty has not been fully eliminated, and even in contexts where universal access has been attained, there is room to improve the quality of supply, for example, by reducing the number or length of interruptions.[12]

Connectivity in border zones is one important example. Cross-border trade can help to meet growing demand, enhance energy access and help address power shortages, thereby improving energy security while potentially reducing costs. In certain cases, it can be easier or more cost-effective to import electricity from a neighbouring country's distribution grid to improve low electrification rates rather than constructing distribution lines to the national power grid (ESCAP, 2018a).

South Asia provides a useful case study. In this subregion, several countries have not been able to keep pace with growth in energy demand, experiencing chronic problems of supply shortage and poor quality of service, including frequent and extended power outages.[13] For populations served by off-grid systems, power may be limited in quantity, subject to seasonal fluctuations and vulnerable to fuel availability. The direct benefits of full power grid interconnection could reach US$ 9 billion each year in direct savings and reduce GHG

12 East Asia and South-East Asia approached universal access, exceeding 98 per cent access to electricity by 2019. Central and South Asia displayed the most significant drop in access deficit, with Afghanistan, Bangladesh, India and Nepal driving the decline. However, overall regional progress in access to electricity rates masks unequal progress across subregions, where energy poverty still exists. Of the world's top 20 countries with access deficits in 2019, four are in the Asia- Pacific region: Pakistan (56 million), India (30 million), Myanmar (17 million), Bangladesh (13 million) and the Democratic People's Republic of Korea (13 million) (IRENA, 2021a), See also chapter 1 of this Report.

13 According to the World Bank, the value lost in South Asia due to electrical outages in 2020 was 10.9% of sales for affected firms (in East Asia and the Pacific, excluding high income, the value lost was 2.9).

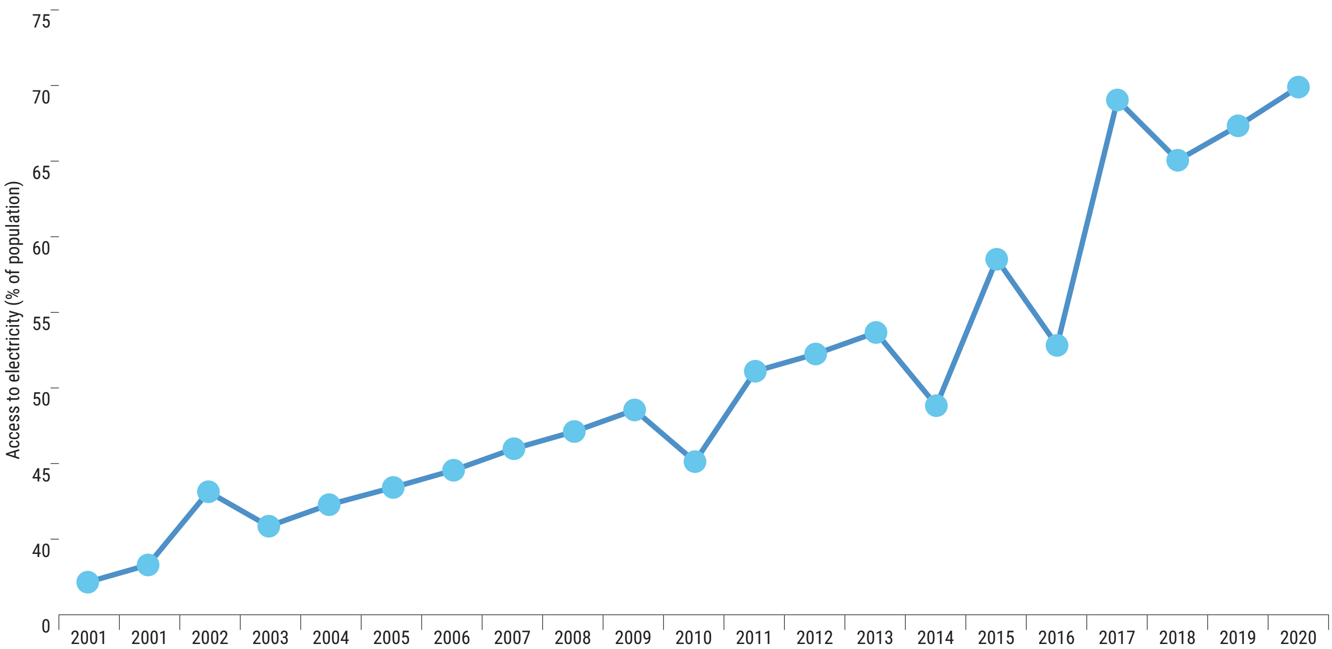


Source: IEA, 2021e.

Figure 22 Access to electricity in India

emissions by more than 9 per cent per annum compared with business as usual, without even accounting for social and environmental benefits (ESCAP, 2018a).

India has made considerable improvements in access to electricity as a result of an aggressive strategy to increase power supply and expand national grid connectivity, while also investing



Source: World Bank Global Electrification Database.

Figure 23 Access to electricity in Myanmar (in %)

in off-grid solutions. Near-universal household access to electricity was achieved in 2019, meaning that more than 900 million citizens have gained an electrical connection in less than two decades (IEA, 2021e).

Cross-border power connectivity and trade have allowed neighbouring countries to benefit from India's progress. For example, the Indian power system serves many communities in the Terai region of Nepal (ESCAP, 2019a). On the other hand, cross-border connectivity is a major contributor to Bhutan's economy, with the Government earning about 25 per cent of its total revenues from the export of hydropower to India.

The situation in Myanmar offers another illustrative example. In 2011, only 13 per cent of Myanmar's population had access to the national electricity grid, and in the rural context, the national power grid network covered only 7 per cent of the country's villages (UNDP, 2013). By 2020, after a concerted effort by the Government, 70 per cent of the population had access to electricity (World Bank, IEA, IRENA, UN and WHO, 2022).

However, Myanmar has been less successful in increasing the supply of electricity to match rising demand, and the country still struggles with annual blackouts, especially in the summer. To help meet its supply gap, Myanmar has agreed to import 1,000 MW of power from southern China, which has an excess of hydroelectric generation (Lim, 2020).

Proposals have been made to extend this type of collaboration to link southern China, South-East Asia and South Asia. Research by the Global Energy Interconnection Development Cooperation Organization (GEIDCO) suggests that cross-border interconnection between Bangladesh, India and Myanmar could reduce power shortages and increase access by allowing more deployment and optimal use of hydropower, solar and wind (Lim, 2020).

Renewables and the contribution of connectivity to climate change mitigation

Energy is a key driver of global climate change, accounting for almost 80 per cent of GHG emissions (ESCAP, 2018a). The Asia-Pacific region accounts for more than half of global energy consumption, with 85 per cent of that consumption coming from fossil fuels.

Cross-border power grid connectivity does not, by itself, guarantee the advancement of sustainable development. However, cross-border connectivity can help to support the integration of higher shares of renewable energy by providing additional sources of flexibility, and through natural resources smoothing and increased balancing areas. Therefore, cross-border power connectivity in combination with renewable energy deployment can contribute to the mitigation of climate change and social issues.

For example, cross-border connectivity can allow generating units with lower environmental impacts to replace units with higher environmental impacts. Countries that rely heavily on coal- and gas-fired generation can import cleaner sources of electricity from neighbouring countries that have excess domestic supply, thereby reducing their reliance on fossil-fuels without having to first build additional renewable generation domestically. In many cases this strategy would not increase overall import dependence, as power imports would be offsetting fossil fuel imports.

For countries where environmental and land-use constraints limit the potential to develop new renewable generation, interconnections can allow new plants to be built in less sensitive areas further away (Kharbanda, 2019). More generally, connectivity can allow countries with an overabundance of renewable energy resource potential to develop renewable energy resources for export, earning revenue from the sale of electricity while also creating other economic opportunities domestically.

The proposed Gobitec and the Asian Super Grid are examples of how renewable energy deployment could take a central role in enabling connectivity in North-East Asia (figure 24). The concept is to develop 100 GW of renewable energy in the Gobi Desert for export to China, the Republic of Korea and Japan by 2030. Under this proposal, interconnections would link Irkutsk in the Russian Federation with Beijing, Shanghai and Seoul in the south as well as Japan through a northern line via the Sakhalin peninsula. Infrastructure costs were estimated

Disclaimer: The boundaries and names shown and the designations used on this map do not imply official endorsement or acceptance by the United Nations.
Source: Renewable Energy Institute Japan, 2014, *Gobitec and Asian Super Grid for Renewable Energies in Northeast Asia*.

Figure 24 Map of proposed Asian Super Grid interconnections

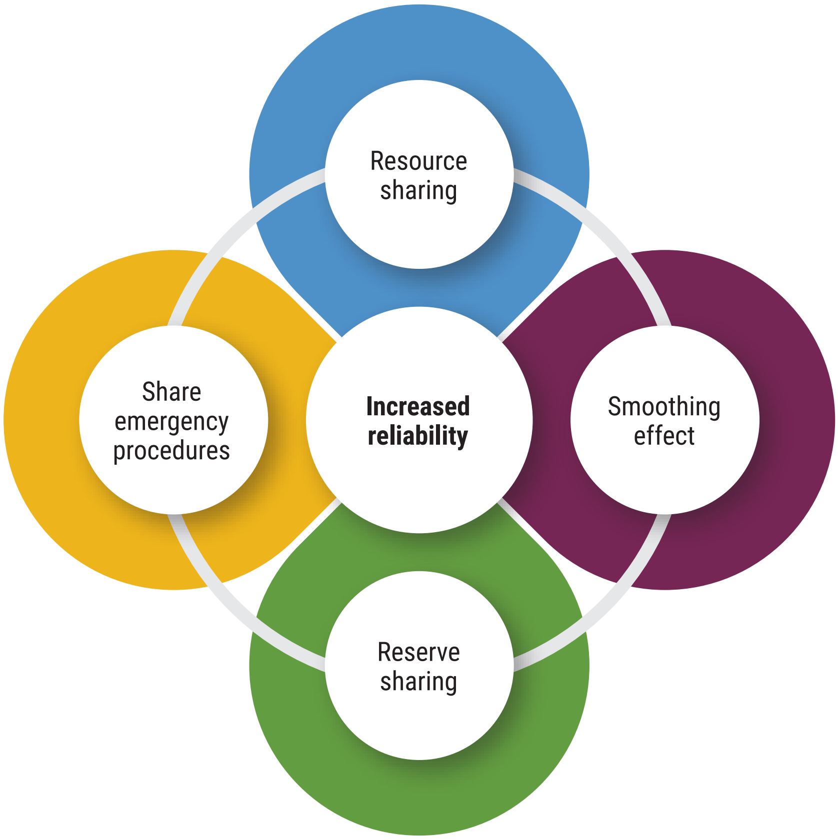
to be US$ 294 billion, and annual operation and maintenance costs at US$ 7.3 billion. The total unit cost of supply was therefore estimated to be US$ 0.10/kWh to US$ 0.13/kWh. Moreover, these estimates are likely conservative, as since the time of the study, the technical performance and costs of associated technologies – such as point-to-point high voltage DC lines, onshore wind turbines and solar PV – have also improved significantly. The study offered a holistic approach covering technologies, costs, financial benefits and the necessary legal frameworks. It clearly highlighted the environmental and social benefits – such as job creation – and the risks and opportunities associated with such a megaproject (IRENA, 2021c).

A study by IRENA described previous modelling work by the Asia-Pacific Energy Research Centre (APERC), estimating the economic and environmental benefits of an interconnected system for North-East Asia. In a scenario with the Russian Federation and Mongolia renewable energy resources included, CO2 emissions are estimated to fall by 149 Mt CO2, i.e., 5.3 per cent (IRENA, 2021c).

The linkage between power connectivity and energy security

To fully achieve SDG 7, access to energy must be both sustainable and reliable. Figure 25 highlights some of the primary ways that connectivity helps to increase power system reliability, including the share of variable renewable energy increases.

A core characteristic of variable renewable energy sources, like wind and solar PV, is their weather dependence. While in any specific location weather patterns can vary significantly, over large geographic areas natural variations average out, resulting in a so-called "smoothing" effect. Therefore, it is easier to integrate variable



Source: ESCAP.

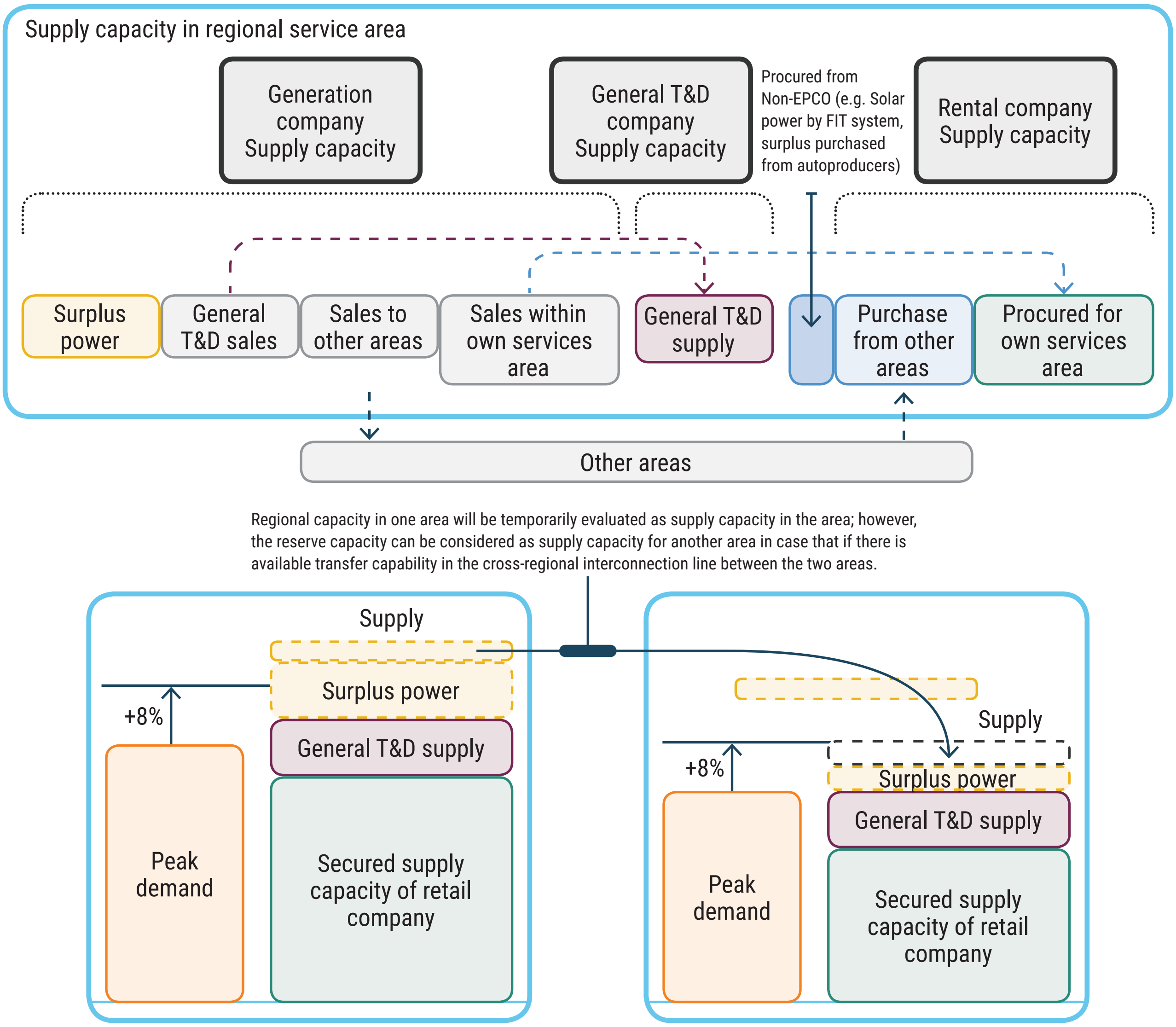
Figure 25 Operational benefits of connectivity

renewables over larger "balancing areas" than smaller ones.

Connectivity also improves power system resilience through resource complementarity, in particular by allowing for aggregation of resources whose availability is less correlated. Take, for example, two interconnected systems, one with a high share of solar PV and the other with a high share of hydroelectric power. During normal conditions, the hydropower could be used to balance the variability of solar PV, generation from which is reduced when there is cloud cover and, of course, goes to zero at night. During extended dry periods, however, solar PV could be used to offset the reduction in hydrogeneration, as the likelihood that solar generation in a dry year will be available during the day is relatively high.

In addition, connectivity allows the sharing of reserve generation capacity, or generation that is kept on standby in case of unplanned outages or unexpected spikes in demand. The ability to share lowers the total amount of reserve capacity required, and therefore the same level of reliability can be met at lower cost. In case an emergency or an outage occurs, coordinated emergency procedures can help to avoid black outs or help black start the system more effectively. An example of connectivity reducing the need for generation reserves can be seen in Japan (figure 26).

In Japan, one of the responsibilities of the Organization for Cross-regional Coordination of Transmission Operators (OCCTO) is evaluating the reserve margin levels across the 10 utility service areas of the Japanese power system. The target reserve margin of a service area is 8 per cent (i.e., an additional 8 per cent of available generating capacity above the projected peak load). However, if one service area has a reserve margin higher than 8 per cent, the excess capacity can be counted toward the reserve margin requirements in



Source: OCCTO, 2020.

Figure 26 Supply-Demand balance evaluation

another area, as long as there is available transfer capacity.

Resource and reserve sharing through connectivity does have implications for energy security, particularly as the energy situation in one country could potentially spill over into interconnected systems. An outage in one system, for example, can also result in outages in interconnected systems. This relative inter-dependence can be politically undesirable, and therefor acts a barrier to increased connectivity.

However, it is also the case that the security implications of energy connectivity are considered in too narrow a context. Increased power system connectivity, if viewed from the perspective of the energy system as a whole, can reduce or at least mitigate the impact of dependency on imported energy overall. For example, a country that is a significant importer of coal or natural gas for power generation could reduce its dependence on (and therefore exposure to) global markets for those fuels by tapping into renewable energy resources located across their border.

4.2. **Financing** power system connectivity

Scaling up cross-border connectivity requires investments in infrastructure, human capacity and institutions, all of which require access to finance. Therefore, understanding options for unlocking different sources of financing is crucial.

According to IEA, to achieve SDG 7 by 2030 emerging and developing countries will need to invest US$ 85 billion in transmission infrastructure (IEA, 2021f). Currently, most of network investments in the Asia-Pacific region are done by State-owned, vertically integrated utilities, with a few notable exceptions including Australia, India and the Philippines (ESCAP, 2022). This puts a significant burden on government resources, which must make decisions on allocating resources across a range of sectors beyond just energy. To increase grid investments to the required scale, additional sources of capital will need to be found, including private investments and climate finance.

While physical infrastructure requires the most investments in dollar terms, it is equally important that countries investment in the national and regional institutions that support cross-border connectivity. In many parts of Asia-Pacific, institutions exist (for example, ACE in South-East Asia), but resources and therefore their ability to function effectively are limited. In some cases, new institutions may need to be established to take on functions that do not easily fit into the mandates or structures of existing institutions – for example, organizing a multilateral power market or acting as an authority to resolve disputes.

It is important that institutions such as these be financed sufficiently and through sustainable sources such as, for example, fees paid by participants. It is equally important, however, to consider the capacity of participating countries to bear these costs as well as the potential for perceived "free-riding" by stakeholders who benefit from these institutions to a degree that is significantly out of proportion to their contribution. To address this and related issues it is important that stakeholders agree up front on the level and modality of financing as well as a mechanism for reviewing and revising this over time, as the economic situation of participants evolves and new members are added.

Once connectivity initiatives have been established, additional financial considerations become relevant. For example, wheeling charges, or transit fees, may need to be paid to an intermediary which enables the transfer of electricity between two other countries. It is important that the method for calculating these charges as well as how the fees will be collected and disseminated be agreed upon in advance in a transparent manner. It is particularly important that these be designed in a collaborative manner between regulators and utilities, to ensure that the fees are reflective of actual system costs and that they do not impose an undue burden on consumers or third-parties utilizing the grid.

4.3. Data-sharing **practices**

Data challenges: Generating and sharing data

Although energy data availability has significantly improved in recent years, information is not equally reliable and not evenly shared across the region. Having access to transparent and up-to-date datasets is a fundamental building block for connectivity (figure 27).

As can be seen in figure 27, access to transparent and trustworthy data is important in each step of cross-border connectivity. In the "building the vision" phase, data are critical for effectively modelling the benefits and costs of increased connectivity. This helps technical decisions, but is also important for building political will, as these initiatives should contribute to overall economic development and energy security.

Source: ESCAP.

Figure 27 The role of data in energy connectivity

During the design phase, data are necessary to evaluate the specific investments required as well as to identify and develop an appropriate market model. Finally, after power systems are interconnected, data are vital to daily operations, to ensure system stability and to incentivize the involvement of market participants.

Data provision has been singled out as one of the success factors of the European power market. Comprehensive libraries store more than a decade's worth of data on prices, capacity, power flows and other relevant factors. Such data are readily accessible to all interested stakeholders, including market participants and analysts, thereby improving overall transparency and enabling a level playing field for market participants (Bredesen, 2015).

During the past decade, national agencies and international multilateral organizations have deepened efforts to improve the quality and dissemination of information. However, data quality and frequency are not consistent across countries in the Asia-Pacific region. For example, statistics on renewable energy use in rural areas of developing countries are not being collected systematically (ESCAP, 2021b).

Subregionally focused organizations such as the ASEAN Centre for Energy collect and disseminate data to their members and, in some cases, make that data available publicly. There are also a growing number of free-access institutional data sources including, for example, ESCAP's Asia-Pacific Energy Portal. The IEA, which collects energy data both from member and non-member States, makes some data available on its website for free, and potentially will do so more in the future (IEA, 2022b).

While these efforts are commendable, it is important to emphasize that, in the context of power system connectivity, there is no one-size-fits-all solution to data sharing. Historical data and data that are not considered sensitive should ideally be shared as widely as possible. When it comes to the daily operation of connectivity efforts in particular, though, sensitive data can and should be shared in a secure manner only among participants that require access; the collection and dissemination of this data should be done by relevant entities at the national, subregional and regional levels.

4.4. Capacity-building, learning and best practices

Planning, developing and operating power systems are complex activities. Introducing an additional dimension of bilateral or even multilateral connectivity requires even more specific expertise. The absence of these skills and the need for capacity-building are a consistent obstacle to effective electricity cooperation on energy issues in general, and power system connectivity, in particular.

At the subregional level in Asia and the Pacific, some existing institutions address this need through knowledge sharing, joint research, and training and capacity-building. In South Asia, for example, the SAARC Energy Centre, has been working to build capacity across technical areas related to cross-border electricity trade as well as foster subregional dialogue on the SAARC Power Grid. The SAARC Framework Agreement encourages cooperation on project financing, settlement mechanisms, harmonization of grid codes, load forecasting techniques and storage integration in networks. The South Asia Forum for Infrastructure Regulators performs a similar function for regulators in the subregion, including energy regulators.

In South-East Asia, ACE functions, among other things, as a knowledge hub for its member States, providing a repository of data and analysis. Other entities in the subregion have more direct roles in capacity-building, often with the support of ACE. The HAPUA, for example, has a working group focused on human resources which helps to identify and meet capacity-building needs, including those related to power system connectivity, while the more nascent ASEAN Energy Regulator Network performs a similar role for energy regulators.

The APEC Energy Working Group has also embarked on many activities addressing a range of energy issues from exploration and production to fuel use, power generation, energy end-use, and environmental and regulatory policies. Its knowledge-sharing platform aims to document and share case studies, best practices and innovations in the field of smart energy. In addition, it has been conducting capacity-building workshops for APEC developing economies every year since 2000 including, for example, increasing capacity to collect and disseminate energy statistics (APEC, 2015).

The ADB is yet another important stakeholder in the region. Energy is one of its main areas of focus, and it has financed power and energy connectivity projects in different Asia-Pacific subregions. Among many other activities, ADB organizes knowledge collaboration through its Development Asia platform. Together with various subregion programmes, this platform promotes the sharing of development experience and expertise, best practices and technology relevant to the SDGs.

Although not exclusively orientated to Asia-Pacific, other energy-related institutions have a specific stake in this region, producing knowledge products and capacity-building mechanisms orientated to assist in specific issues. Such is the case of IEA, IRENA, the Energy Charter, Energy Council and Sustainable Energy for All (SEforALL). In addition, international financial institutions such as the World Bank and the International Monetary Fund have specific mechanisms for dealing with different challenges in Asia and they closely follow this region's needs and prospects.

For the sustained development of the region, countries must possess and share sectoral information and data, share best practices and lessons learnt, most notably in what pertains to new technologies. All these platforms have also been critical for conducting joint feasibility studies, exploring the options of a multilateral dispute settlement mechanism, elaborating models of unified energy market design, technical interconnection blueprints and stipulating the security guarantees address energy security issues (IRENA, OECD, IEA and REN21, 2018).

Conclusion and key messages

The potential role of power system power connectivity in the Asia-Pacific region is widely recognized, as is evidenced by the number and variety of subregional initiatives – discussed in more detail in the preceding chapters. However, there remains no consistent view of the how power system connectivity should progress in the region, and therefore only limited progress of initiatives on the ground. Cross-border electricity connectivity projects are complex endeavours, and it is not surprising that progress has been relatively slow. However, Governments tend to overemphasize the obstacles to power system connectivity initiatives while not fully appreciating their direct socio-economic and environmental impacts.

There are many examples of positive transformations that originated from energy connectivity policy initiatives. The facilitation of energy access through regional power interconnection and the utilization of neighbouring networks has benefitted many populations across the Asia-Pacific region. However, because most initiatives are still bilateral, empirical evidence of the benefits of multilateral connectivity in the region is still limited.

Concerns about energy security, while understandable, should be put into appropriate context. Some countries have a preference at the national level for self-sufficiency rather than interdependence. However, limiting power system connectivity can expose energy importing countries to disruptions rather than mitigate, particularly given the uncertainty and vulnerability of supply chains and energy markets. Power system connectivity therefore should be seen as supportive of overall energy security, including through greater diversification of energy resources and reduced exposure to global markets for fossil fuels as well as having the potential to maintain high levels of system security at lower costs.

Financial flows are central to connectivity. During the development stage, connectivity needs financing both of assets and institutions. Allowing private finance to participate in the development of grids can be a way to unlock greater sources of finance, thereby helping to bridge the investment gap. Once connectivity efforts are made, operational institutions become central to a well-functioning market. Creating trustworthy and efficient settlement institutions is a critical step towards increased connectivity.

Transparent data underpins the entire process of connectivity. It is important that stakeholders harmonize data standards and establish well-functioning platforms to increase data sharing. While such efforts exist, these must be accelerated and amplified to make more data available to more stakeholders, while also enabling the secure sharing of data among relevant market participants.

CHAPTER 5

Emerging issues

Key messages

The previous chapters have focused on a range of topics related to power system connectivity projects as they currently exist, including planning and operating integrated systems, and relevant cross-cutting issues. A number of emerging topics, however, could potentially impact power system connectivity – both positively, by making these efforts easier, and negatively, by disrupting them or offering alternative paths to sustainable development. These include technological advancements in storage and, on the demand-side, blockchain-based trading platforms, digitalisation of the power sector, sustainable energy connectivity beyond the power sector (including for example hydrogen), and connectivity issues for island States where cross-border power system integration is not an economically viable option.

The main findings of this chapter are:

- Emerging topics deserve the attention of policymakers, practitioners and researchers, given the potential to be disruptive, including in the context of cross-border connectivity;
- Sector coupling can help to drive the expansion of low-emissions generation, but it will also require a vast build-out of electricity infrastructure and the ability for system operators to leverage all forms of system flexibility. Policymakers should consider the role of increased cross-border connectivity to meet increasing and changing demand;
- Renewable gases, with particular emphasis on hydrogen, are attracting a great deal of attention in the Asia-Pacific region and beyond. Policymakers should consider the potential role of hydrogen and other zero-carbon fuels in their decarbonization strategies, including the potential for regional

trade and impact on demand for renewable energy;

- Island nations are particularly vulnerable to the impacts of climate change and the volatility of global commodity. While cross-border power system connectivity makes less economic sense in this context, there are still many opportunities for increased collaboration and cooperation.

Policymakers and other stakeholders must carefully ponder how electricity is produced, how robust systems are against cyber security threats and extreme weather events, and how to reduce the vulnerability of island States. The strategies that States adopt to meet the challenge of provision of electricity will, to a large extent, determine the economic resilience and sustainability of the whole region.

5.1. **Implications** of technological innovation

During past decades, new technologies have been assisting the Asia-Pacific region in responding to the growing sustainable energy needs. Technological advancements such as low carbon technologies, UHVDC transmission, smart grids, storage and energy efficiency solutions have opened up an array of economic, social, security and environmental benefits.

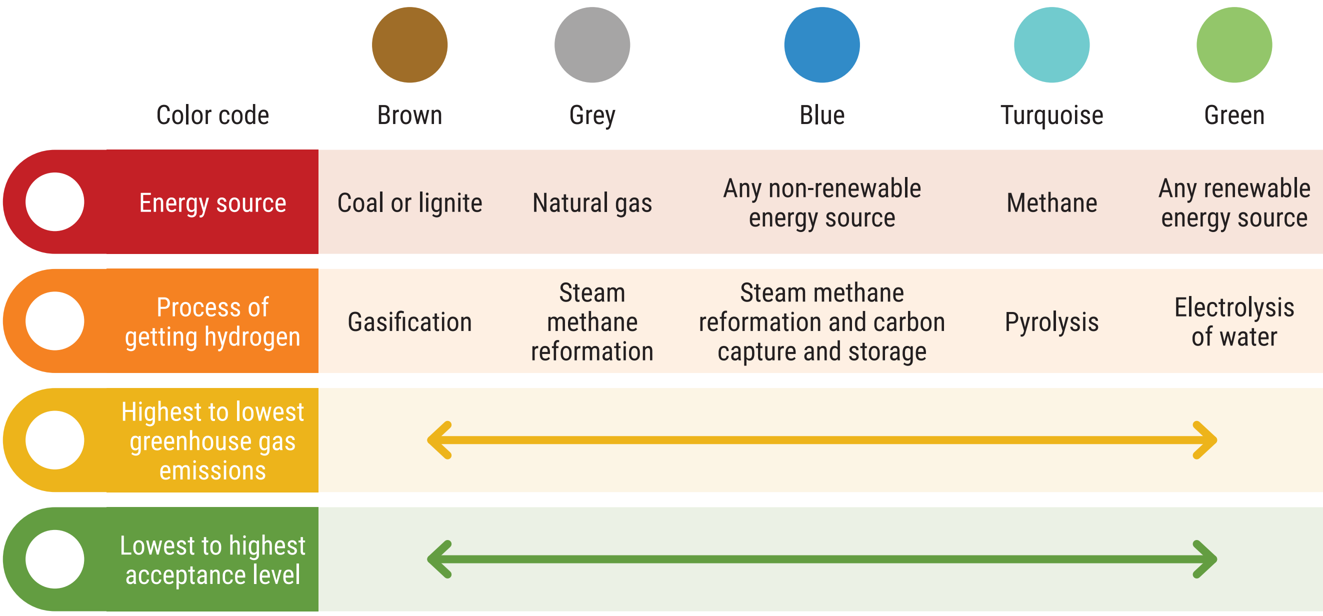
IRENA's analysis of the innovation landscape highlights 11 technologies that will have a significant impact on the development of power systems around the world:

- Utility-scale batteries;
- behind-the-meter batteries;
- Electric-vehicle smart charging;
- Renewable power-to-heat;
- Renewable power-to-X (e.g., renewable gases, hydrogen);
- Internet of Things;
- Artificial intelligence and Big Data;
- Blockchain;
- Renewable mini-grids;
- Super Grids; and
- Flexibility in conventional power plants (IRENA, 2019).

While these technologies cover many different aspects of the power system, a common element among them is that they are enablers of innovative business models, improved market design, and efficient and secure system operations. In addition, all have roles to play, either as drivers or beneficiaries of increased connectivity.

Take, for example, renewable power-to-X. Within the commitment to transition to a lower-carbon economy, the inclusion of renewable gases, with particular emphasis on hydrogen, has been presented as an environmentally-friendly fuel for the future, assuming relevance in some countries' decarbonization strategies. It is an efficient and clean energy carrier that can be utilized in new applications and integrated into existing industrial processes in place of fossil fuels.

How clean hydrogen is, however, depends on the production method used (figure 28). Brown hydrogen, for example, is produced through a thermochemical reaction called coal gasification, a process that results in significant levels of CO_2 as a by-product. Grey and blue hydrogen are both produced through natural gas steam methane reforming, the difference being for hydrogen to be considered "blue" the associated CO_2 emissions must be captured and securely stored. Finally, green hydrogen is produced exclusively from processes that use energy from renewable origin sources, with zero or close to zero GHG emissions. Green hydrogen can be produced from the electrolysis of water, from biomass, through processes of gasification, biochemical conversion or biogas reformation,



Source: Iunera.

Figure 28 The "colors" of hydrogen

provided that the sustainability requirements are met.

Local conditions, including the relative carbon intensity of the existing generation mix and the availability of inexpensive coal and natural gas as a fuel stock, will largely dictate the type of hydrogen production in each particular national context. This is particularly relevant to Asia and the Pacific and that region's variety of conditions. Countries like China, India and Australia, for example, are already experimenting with the production of brown hydrogen, because of their abundant domestic coal resources. However, as technology advances and production costs decrease, countries in the region seeking to position themselves as hydrogen producers will ideally seek to transition to cleaner production methods (DLA Piper, 2021).

Already, green hydrogen is attracting a great deal of attention in the Asia-Pacific region. China, for example, has set a target of up to 200,000 tonnes of renewable H2 by 2025 as part of the new Medium and Long-term Plan for the Development of Hydrogen Energy Industry (2021-2035). China's National Development and Reform Commission (NDRC) has declared hydrogen to be an important component of the energy transition, a key component of the future national energy system and an important strategic emerging industry (Nakano, 2022).

Some countries are seeking to encourage hydrogen use while enabling supply through a combination of imported and domestic production. For example, Japan, in addition to import initiatives (like the Japan-Brunei Darussalam supply chain), is supporting domestic green hydrogen production as a future core component of its energy transition (DLA Piper, 2021). Japan has opened the world's largest green hydrogen plant near Fukushima, using a 20 MW solar array and renewable power from the grid to test the mass production of green hydrogen to fuel hydrogen cars and buses.

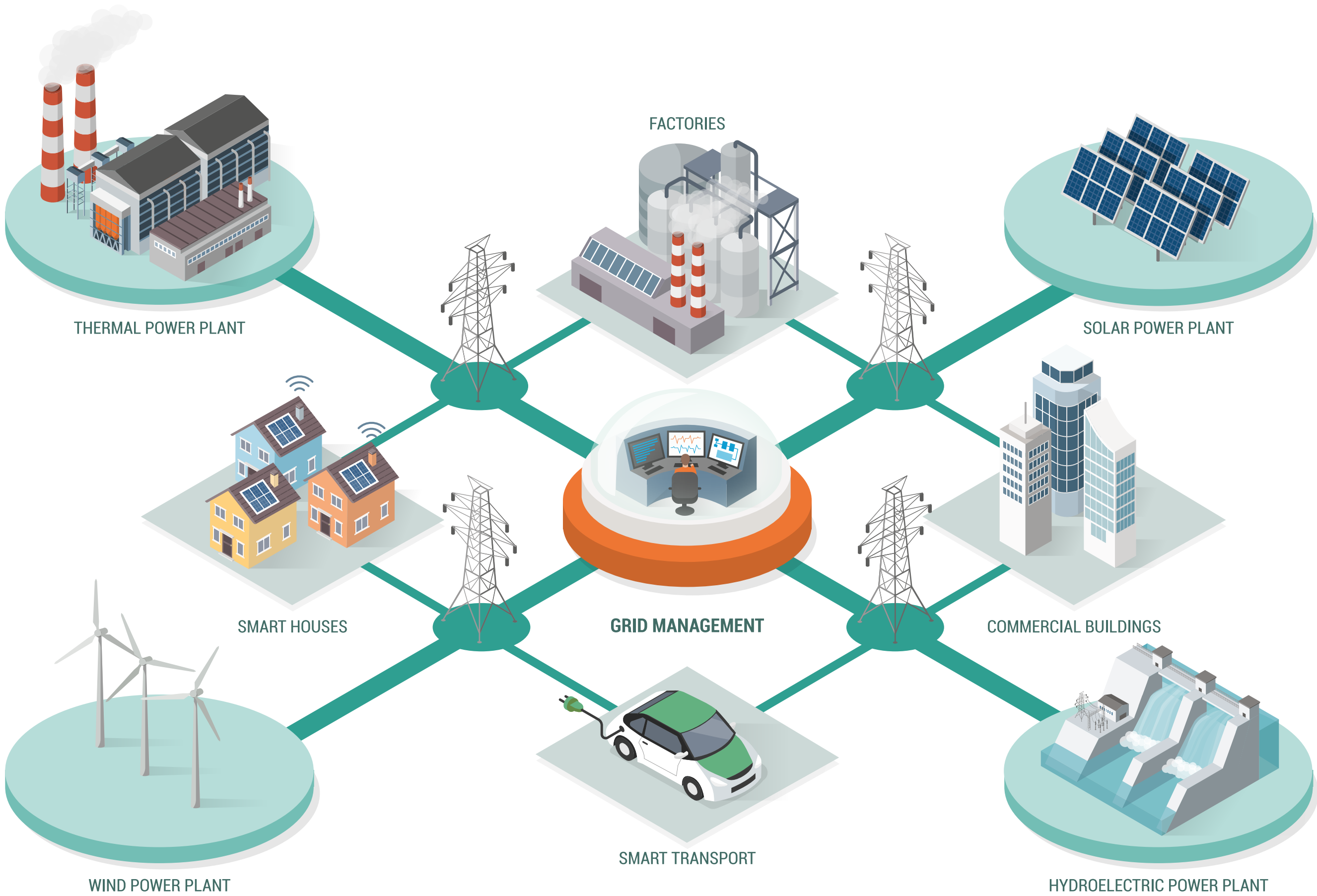
In Australia, several green hydrogen projects are being developed. Clean hydrogen is a priority low emissions technology under Australia's Technology Investment Roadmap and part of the plan to reach net-zero emissions by 2050. Australia's National Hydrogen Strategy sets an adaptive pathway for a clean, innovative and safe hydrogen industry, positioned to be a major global player by 2030. A key element of the approach will be to create hydrogen hubs – clusters of large-scale demand. These hubs will make infrastructure development more cost-effective, promote efficiencies from economies of scale, foster innovation and promote synergies from sector coupling. The plan is that these will then be complemented by other early steps to use hydrogen in transport, industry and gas distribution networks, and integrate hydrogen technologies into electricity systems in a way that enhances reliability (COAG Energy Council, 2019).

New Zealand, too, will focus on developing exportation hubs in combination with blue and green hydrogen production. Other nations like the Republic of Korea and China are likely to focus on manufacturing and exporting hydrogen technology applications, particularly in the transport sector, betting on FCEVs to facilitate the introduction of hydrogen technologies into the region.

Regardless of the strategies pursued across the region, significantly reducing hydrogen production costs is expected to have a substantial impact on the interests of States and investors . At present, green hydrogen is still far from being an economically and technically viable option, and the future potential for a green hydrogen market is tightly linked to reducing the cost of its production (ERIA, 2019).

Sector coupling

Sector coupling refers to the integration of the power supply sector and end-uses that have traditionally, or are typically served by non-electricity-based energy sources (heating/ cooling, transport and industry). While this could, in many cases, mean the electrification of end-uses, in practice it could also involve more bi-directional coupling, for example the production of low-carbon fuels or the production of electricity from non-traditional sources. The underlying driver of sector coupling



Source: EURACTIV (2021); elenabs/iStockphoto.

Figure 29 The use of sector coupling (end-use integration) is the notion that tighter linking of electricity and other energy-related processes would improve the efficiency, flexibility, reliability and adequacy of energy systems, while also enabling cross-sectoral decarbonization (EURACTIV, 2021) (figure 29).

As IRENA puts it, when coupled to a power grid, supply-side applications work like an interface, becoming components of the power system. They provide additional flexibility by (a) adjusting their demand profile based on price signals, and (b) making any integrated electricity, gas or heat storage a source of energy storage for the power system, thereby decoupling the timing of demand for final energy from the availability of energy supply.

Cost-efficient sector coupling would require incentives to ensure system-friendly demand as well as increased monitoring of the power system. Aggregated electric heat pumps and vehicles, for example, could participate in the wholesale and system services markets (IRENA, OECD, IEA and REN21, 2018). Therefore, digitalization of these sectors is an important element of sector coupling.

Sector coupling may align demand better with VRE production periods if proper demand profile strategies are adopted. However, this endeavour raises difficult questions about the energy sector's design and system costs, and it is particularly challenging when cross-border connectivity is at stake. The complexity of power systems' planning requires technical capacity, a coordinated market and an institutional framework in which roles and responsibilities are clearly defined. To foster the full potential of sector coupling in several end-use and supply applications, it is important that existing techno-economic, policy and regulatory barriers are removed to work towards a more integrated approach to energy systems planning.

5.2. The **security** of interconnected systems

Energy demand in the Asia-Pacific region is expected to double by 2030 (ADB, 2021a). Meeting this rising demand is often beyond the capacity of existing energy systems. The strategies that States adopt to meet this challenge will dictate their future development. That is, how electricity is produced, transmitted, distributed and consumed will largely determine the economic resilience and sustainability of the whole region.

The IEA estimates that installed electricity-generating capacity will increase by about 7 per cent annually in the Asia-Pacific region, from 3,386 gigawatts in 2019 to 6,113 gigawatts in 2030. However, in order to meet rising demand and decarbonize the power system, solar, wind and hydropower will need grow at 11 per cent per year (ADB, 2021a).

During the COVID-19 pandemic, and in contrast with sharp declines seen in other parts of the energy sector – such as oil, gas and coal – renewable energy deployment continued to increase. In 2020, China, India and the European Union drove auctioned renewable power capacity worldwide 15 per cent higher than in 2019. India, in particular, is expected to have been be the largest contributor to the renewables upswing in 2021, with the country's annual additions doubling from 2020, according to IEA (IEA, 2020c).

By 2030, investments in renewable energy generation in the Asia-Pacific region could reach US$ 1.3 trillion per annum, double the rate of investment in the previous decade, while investments in the region's electricity grid total about US$ 1 trillion per annum (ADB, 2021a).

The challenges of RE integration and distributed generation

Increased use of renewable energy poses significant technical challenges for grid operators. The intrinsically variable nature of renewables, for example, means it is difficult to predict their availability well in advance and over long time horizons. Planning and system operation methods designed around so-called "dispatchable" generation, which can be turned up and down essentially at will, were not designed with this level of supply-side volatility in mind.

On the demand side is the issue of increasing deployment of distributed renewables, which come into conflict with the power system's traditional, one-way economic model. Behind-the-meter distributed generation competes with grid integration by reducing net demand and, where it is allowed, directly providing power to distribution grids. Solar power production, including home installations, has grown during the past decade, and the trend is expected to continue. Under favourable policy conditions, IEA has forecast that solar PV global annual additions could reach a record level of 150 gigawatts by 2022 – an increase of almost 40 per cent in just three years (IEA, 2020c). Utilities and regulatory policy thus need to handle a large influx of distributed energy resources, which may conflict with long-established utility business models based on electricity demand growth.

Falling prices are a main driver of these investments in solar PV, but there is also growing interest in seeking energy independence at a personal level. This has already been the case in countries that suffer from significant reliability problems, where diesel generators have long been used by households that can afford them. However, grid defections are not exclusive to emerging or developing countries. In the United States, for example, events like the 2021 winter storm that caused blackouts for millions of Texas households, and the transmission-triggered wild fires and related outages in California, have increased interest in the role that distributed resources play in enabling resilience (Council on Foreign Relations, 2021).

This trend will be further amplified as the cost of batteries declines (Frankel, 2017). The combination of low-cost solar PV and batteries can drastically reduce the need for customers to have access to the grid at all (Coren, 2017). Companies like Tesla[14] and Ford (Bloomberg, 2022) are actively seeking to transform homes into distributed power plants. This raises concerns over the ability of utilities to maintain their traditional business and operation models, which rely on revenue from customers to cover their investment costs. Grid modernization and investments to meet sustainability goals come at a significant capital expense. As a larger share of electricity is sourced from renewables, utilities must ensure enough system flexibility to maintain reliability when the supply of renewables is intermittent or low (McKinsey, 2019). These investments are easier to justify in a context of rising demand, and therefore increasing future revenues. However, if net demand declines because an increasing number of consumers produce and consume their own electricity, the cost burden on customers who only purchase their power from the grid increases. This increases the incentive to invest in behind-the-meter generation, ultimately leading to the so-called 'utility death spiral' (Coren, 2017).

Overall, this is the present and future scenario that policymakers need to face proactively. The stance taken will largely determine whether consumers/producers will have an economic incentive to embark on a "full grid defection"', a "partial defection" or no defection in the medium term. In some instances, some utilities have imposed new fees or restrictions on solar users to make up for lost revenue. Another option has been for utilities to get into the renewable business themselves – in such cases, much of the increase in solar power capacity has been driven by utilities rather than homeowners/ independent power producers.

A McKinsey study has suggested that customers can contribute to grid operations in multiple ways with the right prices as incentives, including demand-response, flexibility and distributed generation. Over time, customers can be integrated into an on-grid market that prices energy, capacity and flexibility in real-time based on system needs. In that future, the utility could function as a platform that facilitates transactions – for a fee – between itself and customers, between third parties and customers, and between customers. Rate-based compensation for these services is a potential first step towards such a grid-based market (McKinsey, 2019).

14 Tesla's business approach sells battery systems and solar panels packaged together as an alternative to the traditional grid. According to Elon Musk: "This is a prosperous future both for Tesla and for the utilities. If this is not done, the utilities will fail to serve their customers. They won't be able to do it." (Alamalhodaei, 2021)

Underpinning the debate and the national-specific decisions is the awareness of the technical, institutional and economic challenges behind low-carbon electrification and the need for policymakers to address them in an integrated way. Challenges – but also opportunities – will stem from the interplay of these dimensions. Clearly, so will the prospects of cross-border power connectivity in the region.

Digitalization and cyber security

One of the main trends in the power sector has been digitalization and smart grids – in essence, smart grid technology integrates sensors and data-sharing into grid technologies enable greater situational awareness and responsiveness. A smart-grid system can increase reliability. Special meters in houses and businesses, and sensors along transmission and distribution lines, can constantly monitor demand and supply, while small-sized devices (synchrophasors) measure the flow of electricity through the grid in real-time, allowing operators to foresee and avoid, or identify and manage, disruptions. On the consumer side, smart appliances can communicate with the grid and, for example, shift electricity use to off-peak times, easing the burden on the grid while also saving consumers money. However, countries must have procedures and institutions that effectively collect and integrate the smart grid data into system operations, in order for benefits to be realized; in many cases, this would need to be developed (ESCAP, 2021b).

Digitalization efforts have a significant impact on end-use energy efficiency, therefore reducing energy demand. Energy efficiency can lead to greater economic productivity, and provide social and environmental benefits such as increased energy affordability, avoided infrastructure construction, improved air quality, reduced pollution and global climate change mitigation (ADB, 2021a). Energy efficiency has shown significant improvements in Asia and the Pacific, but this is a region where energy intensity remains above the world average, with considerable subregional variations.

Notwithstanding the potential benefits of smart grid infrastructure, these investments also carry potential vulnerabilities. In truth, a growing reliance of the grids on digital systems means that generation, transmission and distribution systems are all increasingly exposed to cyber intrusions. Grid operators all over the world are generally unsecured against newly developed malware. Therefore, plans to build new power infrastructure in Asia and the Pacific should consider these new threats to power supply security to make it future proof- resilient.

Extreme weather events and power infrastructure resilience

One of ADB's Energy Policy 2021 principles is to build a sustainable and resilient energy future by, among other things, increasing the climate resilience of energy infrastructure (ADB, 2021a). In fact, power systems tend to be debated as a source of emissions and a cause of climate change. Much less attention is given to the consequences of climate change on the power sector, i.e., the exposure and vulnerability of this sector to the changes in climate within the region (ADB, 2012), (ADB, 2013).

However, extreme weather is a growing concern, including hurricanes, changes in rainfall and river discharge patterns, rising sea levels, flooding, heatwaves and even solar flares, which can overwhelm ageing power lines. In addition, most of the grid infrastructure is built above ground, which is cheaper to construct but more vulnerable. Increased variability due to climate change will increase energy demand, and reduce production and transmission efficiency. Again, this is a concern for developing as well as developed countries. Existing power systems were designed for different climatic circumstances. As climate change makes extreme weather events more frequent and severe, power systems need to be designed for resilience under different kinds of vulnerabilities. Technological solutions can also be combined to meet some of these challenges. For example, separable microgrids that incorporate smart-grid technologies and batteries can increase the resilience of local power systems by supplying power to communities, even when severe weather or other outages affect the broader power system (Council on Foreign Relations, 2021).

Case study: Power Ledger P2P BCPG at T77 Precinct – Thailand

The Power Ledger project in Thailand involves a total of 1.2 MW of solar PV developed in a private mixed-use property development called the T77 precinct. A peer-to-peer platform provider, Power Ledger first piloted its technology in Australia to support renewable energy trading in neighbourhood-scale residential communities running small-scale rooftop solar PVs, within an embedded network with a shared sub-utility scale battery storage facility.

The key defining feature for this project is in the form of shared sub-utility scale battery storage. The trading mechanism provided by Power Ledger's peer-to-peer platform is similar to other blockchain-enabled energy trading marketplaces, where energy is sold to peers through private smart contracts. This model is simpler to deploy in newer property developments which do not require significant grid modernization to support net metering; however, in contrast, there are challenges in scaling up the technology in established urban neighbourhoods because of retrofitting and investment needs.

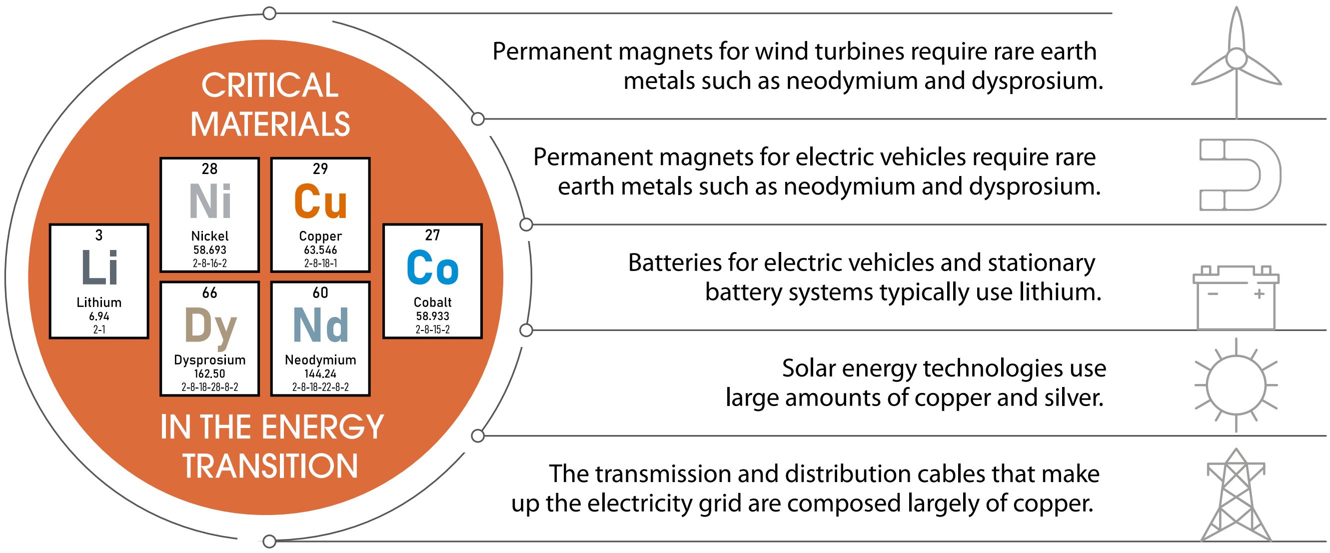
While the project has received support from the local grid managed by Bangkok's Metropolitan Electricity Authority, it is largely a private initiative, and regulatory obstacles make it difficult to see the potential for replicability. For example, Bangkok does not currently have a feed-in tariff or other regulatory rules for the participation of behind-the-meter generation with the grid.

Case study: Marketplace 2.0 by Electrify – Singapore

In comparison to the previous project by Power Ledger in the T77 Precinct of Bangkok, the regulatory framework in Singapore has been liberalized to enable competition for the production and delivery of electricity. As in the Bangkok case study, this project uses smart meters to log energy produced into a blockchain. The Electrify project is designed to operate across the city-wide power grid in Singapore to enable residential rooftop PV owners to trade energy in the marketplace. Electrify partners with Senoko, a local energy retailer, to enable customers to trade energy on its platform. While this project is designed for real-time power trading, it is less clear whether it is supported by an energy management trading and dispatch system built into the existing grid infrastructure; as power is not stored in batteries, the technology appears, to be primarily a virtual trading platform at present. In order to scale up to a city-wide level, the project would require significant buy-in from grid owners and operators as well as investments in net metering technology at the prosumer level, where relevant.

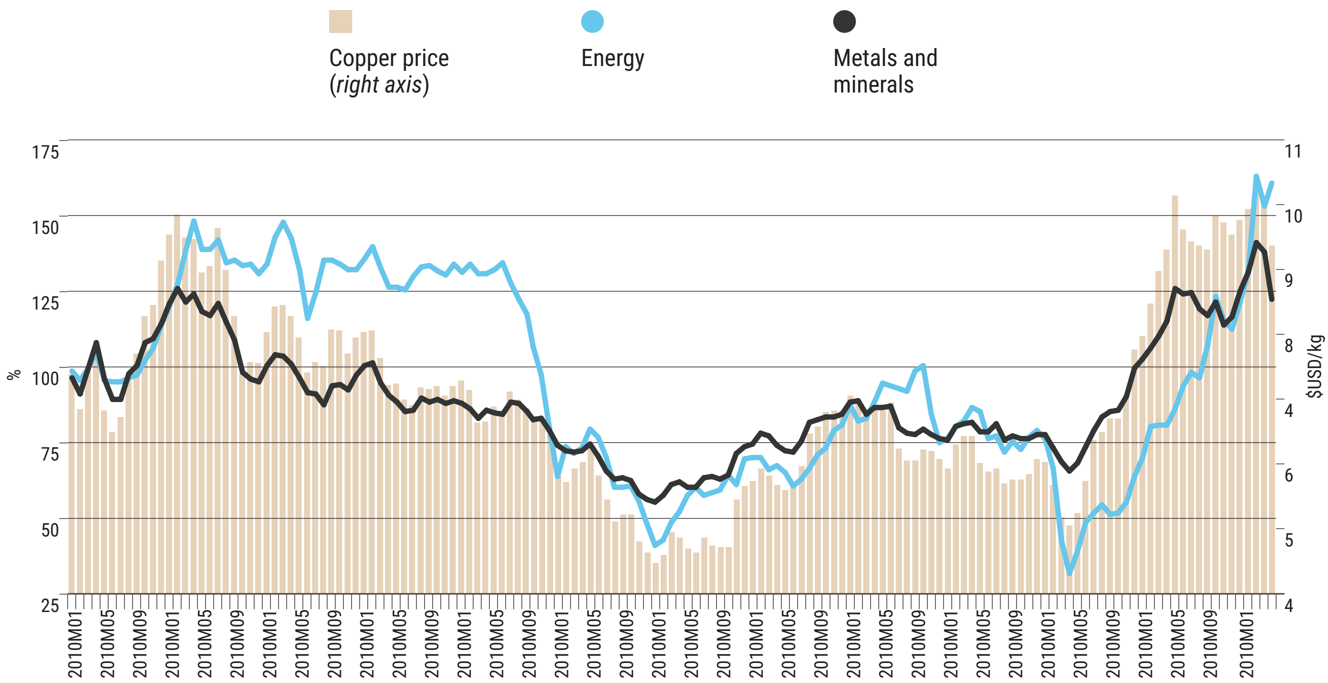
Microgrids and peer-to-peer trading

While the preceding chapters of this report focus on large-scale, cross-border power system connectivity, technological innovations could also drive connectivity at the local distribution level. Integrating power system planning with urban development plans is important, especially taking into account municipal electric vehicle and charging infrastructure deployment policies. Urban mini-grids could, for example, supplement main grids to seamlessly integrate local and distant renewable power generation for consumption at the neighbourhood and community levels. Solutions for fully integrating renewable energy with the power consumption of households and commercial users could include integrating sub-utility scale generation technologies (e.g., building integrated PVs and urban wind turbines) into urban planning and design. This could also include socio-economic policy interventions such as the design and development of neighbourhood-scale power markets that enable communities to simultaneously produce renewable energy, trade, schedule and dispatch renewable



Source: IRENA, 2022.

Figure 30 **Main technologies using critical minerals**



Note: Prices are based on nominal US dollars, 2010=100; Copper price US$ 1,000/mt; January 2010-May 2022.
Source: World Bank.

Figure 31 **Monthly prices and indices for selected energy sources, metals and minerals, 2010-2022** energy on-demand through smart mini-grid infrastructure.

Supply chains

Key technologies such as solar panels, wind turbines and batteries require critical materials such as nickel, copper, lithium and rare earth elements (figure 30). Copper is a crucial component of power lines connecting generators with end-users. Lithium and nickel are used to produce rechargeable batteries. Rare earth elements such as neodymium and dysprosium play key roles in the permanent magnets found in wind turbines and electric vehicles. None of these elements can easily be replaced by alternatives, and there is growing concern over their availability and affordability (IRENA, 2022).

Currently there is a growth in critical materials prices due to the increased demand. In 2015-2020, the copper price was in the range of US$ 5 to US$/kg, while in 2021 it exceeded US$ 10/kg (figure 31). The main reason for this change was the economic recovery after the COVID-19 pandemic and increased energy infrastructure projects, plus lower copper concentration and deeper resources, which increase the price of mining. Experts forecast that the prices will continue to grow to US$ 15/kg for the next two years due to the increased demand for electric vehicles and renewable energy projects, which account for about 72 per cent of total copper consumption growth (IRENA, 2022).

One of the solutions for meeting the increasing demand could be the concept of circular economy, by conserving resources after they are used and reintroducing them to the life-cycle of a certain product. Recycling solar PV modules, wind turbines and batteries are all feasible from a technical viewpoint; however, the cost-effectiveness of the processes still needs to be improved, and circular economy practices on their own cannot meet new demand for these materials. As a result, during the near-term, primary materials will continue to play a primary role. In the long-term, however, advanced technologies for recycling may become a game changer in energy transition. Strengthening research and cooperation among countries as well as energy connectivity will help to increase productivity and cost-effectiveness.

According to World Bank data, the total change in nominal prices during the 23-month period from April 2020-March 2022 resulted in the largest increase in energy prices since the 1973 oil embargo. The current crises and increased energy prices may influence the energy transition in the short period. The current high cost of energy and other commodities, plus a higher interest rate environment, may reduce the availability of capital for renewable energy projects. Several countries have already announced plans to increase fossil fuel production. China, for example, intends to increase its coal production by 300 million tons (World Bank, 2022a). Renewable energy projects, however, have proven to be resilient so far, and investments in these technologies will likely continue, in particular because they offer an opportunity to reduce reliance on high-cost fossil fuels.

5.3. Energy connectivity and the **Pacific Islands**

The above chapters focus on connectivity efforts and opportunities in Asia, where the potential for cross-border power system integration is highest. When considering the role of energy connectivity in the Pacific subregion, the context is quite different. The relatively limited populations and long distances between the numerous Pacific islands makes cross-border power system interconnection an uneconomic option for meeting energy needs.

The Pacific Island Countries and Territories (PICTs) make up a heterogenous subregion including 14 countries and territories with a total population of 2.4 million people.[15] Among their vulnerabilities are geographic remoteness and

15 The Cook Islands, Federated States of Micronesia, Fiji, Kiribati, Marshall Islands, Nauru, Niue, Palau, Samoa, Solomon Islands, Tokelau, Tonga, Tuvalu and Vanuatu. See United Nations (UNDP, 2017)

isolation, limited resources, political instability as well as heavy dependence on ODA, overseas remittances and imported goods, despite large distances to major markets. These features imperil the implementation of SDGs, and SDG 7 in particular.

The Asia-Pacific region still presents some of the lowest rates of access to electricity globally, although there has been an improvement during the past decade.[16] In an energy power system where mini-grids and microgrids are predominant, electricity prices are also among the highest in the region and the world, mainly due to heavy reliance on high-cost diesel-based generation. In addition, because the region is located in the Ring of Fire, it is among the most vulnerable in the world to the impacts of climate change and natural disasters. In a region where economic growth is already residual, the economic costs of disasters continue to detract from growth.

Against this setting, the energy sector is highly vulnerable, requiring adequate attention to these issues in the specific design of energy production and distribution infrastructure. Increasing energy security needs are becoming paramount and are leading to increasing investments in renewable energy technologies. Renewable energy potential is high; however, issues related to infrastructure resilience to climate change events remain.

Transforming the energy sector in PICTs into an economically viable and environmentally-friendly system requires a comprehensive approach to designing the appropriate policy framework to integrate RE technologies fully. Political support is the key to facilitating the implementation of strategies to achieve national energy policy goals. The barriers encountered in implementing energy and renewal energy policy include: limited human capacity; financial and market hindrances; lack of data and access to information; various technical, regulatory and institutional barriers; obstacles to deploying infrastructure in remote areas; and social issues (IRENA, 2012).

Nevertheless, the PICTs are actively working together to address their collective energy challenges. The Framework for Energy Security and Resilience in the Pacific (FESRIP) 2021-2030 is the latest reading of the emerging energy sector issues and opportunities that the region needs to effectively address through an integrated regional/national approach: (a) climate change impacts; (b) inadequate data and energy security indicators; (c) petroleum dependence; (d) progress in energy technologies and their cost; (e) renewable electricity progress; (f) energy efficiency progress; (g) energy for transport; (h) gender and energy; (i) pandemic impact; and (j) proliferation of regional energy centres (Pacific Community and CROP, 2021).

The Pacific Power Association (PPA), an intergovernmental agency and member of the Council of Regional Organizations in the Pacific (CROP), promotes the direct cooperation between Pacific Island power utilities, and works as an interface between these and international organizations. During the past few years, the Sustainable Energy Industry Development Project (SEIDP), supported by the World Bank, has been implemented with the aim of increasing the data availability as well as the capacity of the region's power utilities to enhance their ability to incorporate and manage renewable energy technologies and long-term disaster risk planning. Structured in three components, the project provides support to the PPA to assist regional utilities through: (a) the increase of publicly available information on renewable energy resources; (b) the improvement of technical and institutional capacity for planning and management of power systems with higher levels of renewable energy; and (c) the strengthening of planning capacity for disaster recovery and risk reduction (World Bank, 2017)

During COP 26 in Glasgow, IRENA signed an agreement with the Alliance of Small Island States (AOSIS), including the Pacific islands. The agreement aims to mobilize climate finance and advance the deployment of renewable energy across Small Island Developing States (SIDS). In September 2021, AOSIS and IRENA, through the SIDS Lighthouse Initiative, committed to achieving a total of 10 GW installed renewable energy capacity in all SIDS by 2030 under a joint energy compact submitted to the United Nations. At the end of 2020, around 6 GW of renewables were operational in SIDS (IRENA, 2021a).

16 Fiji, Kiribati, Nauru, Palau, Samoa and Tuvalu have 100 per cent electrification.

KEY MESSAGES

Emerging topics deserve the attention of policymakers, practitioners and researchers, given their potential to be disruptive, including in the context of cross-border connectivity.

Renewable gases, with particular emphasis on hydrogen, are attracting a great deal of attention in the Asia-Pacific region and beyond. Several countries have developed hydrogen strategies. Policymakers should consider the potential role of hydrogen and other zero-carbon fuels in their decarbonization strategies, including the potential for regional trade. Policymakers should also keep in mind the fact that, if demand for green hydrogen takes off, it will become both a driver of, and a competing use for, increased deployment of renewable energy.

More generally, sector coupling is providing additional impetus for clean electrification. Increased linkages between electricity and other sectors significant will also help drive the expansion of low-emissions generation, but it will also require a vast build-out of electricity infrastructure and all forms of system flexibility. Policymakers should consider how increased cross-border connectivity can help to meet this potentially significant increase in demand.

Policymakers and other stakeholders must carefully ponder how electricity is produced, how robust the systems are against cyber security threats and extreme weather events, and how to reduce PICT's vulnerability. The strategies that States adopt to meet the challenge of provision of electricity will, to a large extent, determine the economic resilience and sustainability of the whole region.

Annex

Chronology of ministerial support for power system integration in ASEAN

Date	Event	Location	Description/reference to
Oct 1981	3rd AEMMEC	Manila, The Philippines	The Meeting agreed on a wide range of ASEAN cooperation in the power utility sector, namely in interconnection.
Jan 1983	4th AEMMEC	Singapore	Adoption of the recommendation made by HAPUA on cooperation in interconnection, *inter alia*.
Jun 1989	8th AEMMEC	Kuala Lumpur, Malaysia	The Minister of Works of Malaysia highlighted the electric power system interconnection as one of the specific areas of energy cooperation.
Nov 1990	9th AEMMEC	Manila, The Philippines	The Ministers approved the Programme of Action for the Enhancement of ASEAN Cooperation on Energy, which identified electricity as one of the nine energy sectors for closer and enhanced cooperation in ASEAN. The Ministers agreed that the Trans-ASEAN Power Grid project be expanded and its implementation expedited to allow a greater exchange of power among all the ASEAN member countries
Aug 1991	10th AEMMEC	Singapore	The Ministers noted the progress achieved in the Interconnection Project where the feasibility studies of four interconnection projects have been completed and compiled in one document, and is ready for submission to potential sources for technical assistance.
Apr 1994	12th AEMMEC	Bandar Seri Begawan, Brunei Darussalam	The Ministers noted the significant progress achieved in the implementation of energy cooperation projects in the areas of coal, power utilities/authorities, new and renewable sources of energy, and energy conservation. In this respect, emphasis would be given towards the realization of the ASEAN Power Grid and also on regular information exchange on power supply and demand situation among member States.
Dec 1995	5thASEAN Summit	Bangkok, Thailand	ASEAN Medium-Term Programme of Action on Energy Cooperation – 1995-1999 (3.1. a) Strengthening interconnection development leading to the realization of the ASEAN Power Grid)
Dec 1997	2nd ASEAN Informal Summit	Kuala Lumpur, Malaysia	ASEAN Vision 2020 We resolve, *inter alia*, to (…) establish interconnecting arrangements in the field of energy and utilities for electricity, natural gas and water within ASEAN through the ASEAN Power Grid and a Trans-ASEAN Gas Pipeline and Water Pipeline, and promote cooperation in energy efficiency and conservation as well as the development of new and renewable energy resources.
			Hanoi Plan of Action (1999-2004) 2.10.3 Energy B. Institute the policy framework and implementation modalities by 2004 for the early realization of the trans-ASEAN energy networks covering the ASEAN Power Grid and the Trans-ASEAN Gas Pipeline Projects as a more focused continuation of the Medium-Term Programme of Action (1995-1999).
Aug 1998	16th AMEM	Singapore	The Ministers were pleased to note the proposal to prepare a Masterplan for the ASEAN Power Grid Interconnection, as this is a timely initiative to move forward the ASEAN vision of electricity interconnection.
Jul 1999	17th AMEM	Bangkok, Thailand	ASEAN Plan of Action for Energy Cooperation 1999-2004 Programme Area No. 1. ASEAN Power Grid
Jul 2003	21st AMEM	Langkawi, Malaysia	The Ministers agreed that the Final Report of the ASEAN Interconnection Master Plan Study (AIMS) to be the reference document for the implementation of the electricity interconnection projects in the ASEAN region.
Jun 2004	22nd AMEM	Makati City, Philippines	ASEAN Plan of Action for Energy Cooperation 2004-2009 Programme Area No. 1. ASEAN Power Grid
2004			Memorandum of Understanding between the Heads of ASEAN Power Utilities/ Authorities

Date	Event	Location	Description/reference to
Aug 2007			Memorandum of Understanding on the ASEAN Power Grid
Nov 2007	13th ASEAN Summit	Singapore	ASEAN Economic Community Blueprint: 54. Expedite the development of the ASEAN Power Grid (APG) and the Trans-ASEAN Gas Pipeline (TAGP)
Jul 2009	27th AMEM	Mandalay, Myanmar	ASEAN Plan of Action for Energy Cooperation (APAEC) 2010-2015 Programme Area No. 1. ASEAN Power Grid
Jul 2010	28th AMEM	Da Lat, Viet Nam	Acknowledgement of the completion of Phase II of the ASEAN Interconnection Master Plan Study, optimization of energy sources indigenous to the region, and recommended guidelines to speed up implementation of the ASEAN Power Grid, notably on the reliability of operation, safety standards and procedures in generation, transmission, and guidelines on a model framework for investment of the interconnection projects and for the cross-border sale and transmission of electricity.
Sept 2011	29th AMEM	Jerudong, Brunei Darussalam	Acknowledgement of a "Golden Opportunity for ASEAN Energy Connectivity". Ministers welcomed regional efforts in the finalization of the guidelines to speed up the implementation of the ASEAN Power Grid. The Ministers noted that bilateral and sub-regional arrangements would play a key role in realizing the ASEAN Power Grid. The Ministers further acknowledged that private sector involvement would catalyze the implementation of the ASEAN Power Grid.
Sept 2012	30th AMEM	Phnom Penh, Cambodia	Ministers welcomed HAPUA's efforts to accelerate work on the harmonization of regulatory framework and technical standards for the operation of the APG. The Ministers welcomed the new developments in the implementation of the ASEAN Power Grid (APG) project, particularly the signing of the MoU between Indonesia and Malaysia on the Interconnection Project No.4 Peninsular Malaysia-Sumatra (with its commercial operation date (COD) expected in 2017), and the agreement that the two member States would start power exchanges of the Interconnection Project No. 6 West Kalimantan-Sarawak in 2015.
Sept 2013	31st AMEM	Bali, Indonesia	Ministers commended the Heads of ASEAN Power Utilities/Authorities (HAPUA) on their efforts in moving forward on the harmonization of the technical, legal and regulatory framework and identification of financial modalities for the realization of the ASEAN Power Grid (APG). Ministers welcomed the recommendations of the project on "Harmonisation of the Technical Standards, Codes and Guidelines in the area of Planning and Design, System Operation and Maintenance for the APG" (assistance ADB). To accelerate the realization of the APG, the Ministers tasked HAPUA to develop an efficient and effective framework for taxation and customs tariff in order to accelerate investments in the development of APG projects. Ministers also noted the progress of the six interconnection projects that are currently under construction, particularly the new interconnection projects between Viet Nam and the Lao People's Democratic Republic; and between Sarawak in Malaysia and West Kalimantan in Indonesia.
Sept 2014	32nd AMEM	Vientiane, Lao People's Democratic Republic	The Ministers welcomed the new initiative to undertake a pilot project to explore cross-border power trade involving four ASEAN Member States. The pilot project, entitled "Lao PDR, Thailand, Malaysia, Singapore (LTMS) Power Integration Project (PIP)", will serve as a pathfinder to enhance multilateral electricity trading beyond neighbouring borders towards realizing the APG.
Oct 2015	33rd AMEM	Kuala Lumpur, Malaysia	Ministers reiterated their support for the Lao People's Democratic Repub lic-Thailand-Malaysia-Singapore Power Integration Project (LTMS-PIP) as a pathfinder to complement existing efforts towards realizing the ASEAN Power Grid and the ASEAN Economic Community. The Ministers commended the efforts of the LTMS Working Group (LTMS-WG) and LTMS Technical Taskforce (LTMS TTF) in examining the feasibility of cross border power trade of up to 100MW from the Lao People's Democratic Republic to Singapore using existing interconnections. Ministers looked forward to the possible signing of a LTMS Memorandum of Understanding on Power Integration when the parties are ready.

Date	Event	Location	Description/reference to
			ASEAN Plan of Action for Energy Cooperation (APAEC) 2016-2025. Phase I: 2016-2020) Programme Area No.1 – ASEAN Power Grid. Strategy: To initiate multilateral electricity trade in at least one sub-region by 2018.
Sept 2016	34th AMEM	Nay Pyi Taw, Myanmar	On the development of the ASEAN Power Grid (APG), the Ministers welcomed the achievements made by HAPUA in implementing the APG, including the successful completion of more than 1,700 megawatts of new interconnection capacity for 2015/2016 which involves the completion to date of eight (8) cross-border transmission links/projects under the umbrella of the sixteen (16) APG projects identified under the APAEC. The Ministers noted HAPUA's plans to conduct studies to ascertain the APG institutions needed to support further implementation of the APG and to help policymakers determine the feasibility of various options to establish the mechanisms of multilateral power exchange in ASEAN. The Ministers also welcomed the signing by the Lao People's Democratic Republic, Thailand and Malaysia of an MoU to pursue the initial phase of the Lao People's Democratic Republic, Thailand, Malaysia and Singapore Power Integration Project (LTMS-PIP). The Ministers commended the efforts of the four countries in examining the feasibility of power trade beyond neighbouring countries and reiterated their support for the LTMS-PIP as a pathfinder to complement existing efforts towards realizing multilateral electricity trade in the ASEAN Power Grid (APG) and the ASEAN Economic Community.
Sep 2017	35th AMEM	Pasay City, The Philippines	Establishment of the APG Special Task Force (APG STF) and the adoption of its Terms of Reference to assist the APGCC in accelerating the realization of APG multilateral power trade. The Ministers noted the outcomes of HAPUA Council's commitment to pursue multilateral power trade in the APG and to update the APG Interconnection Master Plan Study (AIMS)
Sep 2019	37th AMEM	Bangkok, Thailand	"AIMS III will set out the interconnection infrastructure needed to enable expanded power trade as well as integrate higher shares of renewables into the APG.
Nov 2020	38th AMEM		The Ministers appreciated the continuing efforts to expand multilateral electricity trading in the region, noting the actions collectively pursued in 2020 to advance this. LTMS-PIP countries announced their commitment to initiate up to 100 MW of cross-border power trade from the Lao People's Democratic Republic to Singapore via Thailand and Malaysia using existing interconnections from 2022 to 2023. Initiative of the ASEAN Power Grid Consultative Committee (APGCC) to review its Terms of Reference, considering the region's deepening efforts towards regional power integration and clarifying the institutional roles and relationships of other MPT (multilateral power trade) related bodies.
Sept 2021	39th AMEM		On the ASEAN Power Grid (APG), the Meeting appreciated the continuing efforts to expand multilateral electricity trading in the region, strengthen grid resilience and modernization, and promote clean and renewable energy integration. The second Joint Statement of LTMS-PIP by the Lao People's Democratic Republic, Thailand, Malaysia and Singapore, in which the four countries reaffirmed their commitment to advancing multilateral cross-border power trade in ASEAN.

Source: ESCAP (based on textual analysis of ASEAN reports, agreements and declarations) (www.asean.org).

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