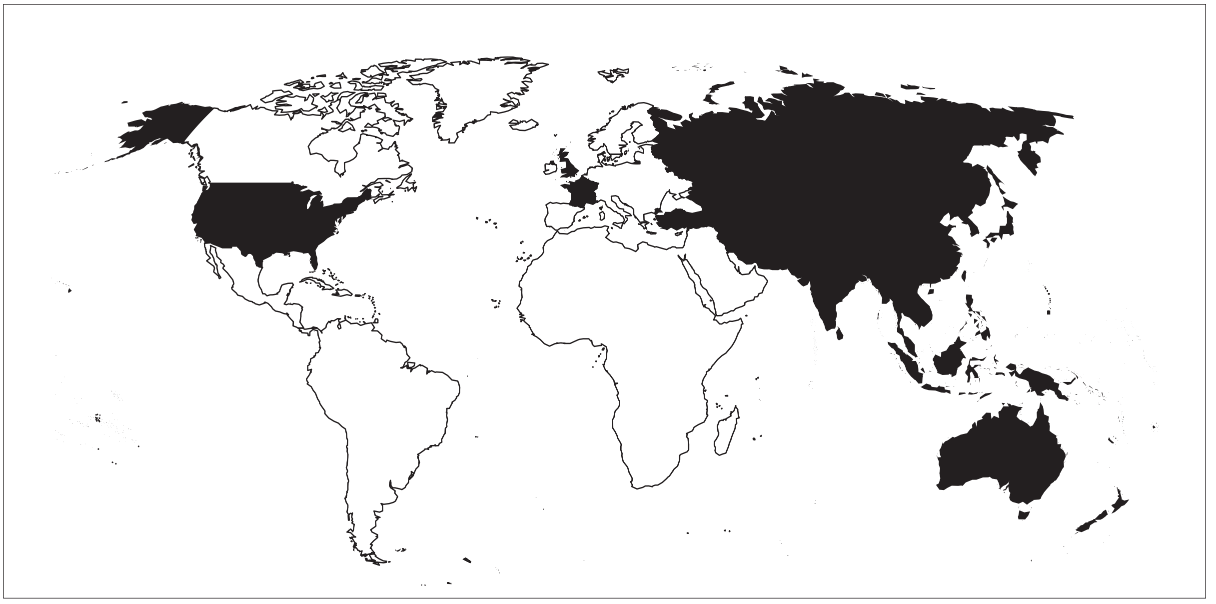
Electricity Connectivity Roadmap

for Asia and the Pacific

Strategies towards interconnecting the region's grids

UNITED NATIONS ESCAP
Economic and Social Commision for Asia and the Pacific



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The Economic and Social Commission for Asia and the Pacific (ESCAP) serves as the United Nations' regional hub promoting cooperation among countries to achieve inclusive and sustainable development.

The largest regional intergovernmental platform with 53 Member States and 9 Associate Members, ESCAP has emerged as a strong regional think-tank offering countries sound analytical products that shed insight into the evolving economic, social and environmental dynamics of the region. The Commission's strategic focus is to deliver on the 2030 Agenda for Sustainable Development, which it does by reinforcing and deepening regional cooperation and integration to advance connectivity, financial cooperation and market integration. ESCAP's research and analysis coupled with its policy advisory services, capacity building and technical assistance to governments aims to support countries' sustainable and inclusive development ambitions.

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Electricity Connectivity Roadmap for Asia and the Pacific:
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Foreword

The transition to sustainable energy is underway in the Asia-Pacific region. However, the speed of this transition and its trajectory varies between countries. The globally adopted 2030 Agenda for Sustainable Development and the Paris Agreement on Climate Change have provided an ambitious framework to develop sustainably and keep global warming within safe limits. Our success in implementing these agendas will rely, to a great extent, on a rapid transition to sustainable energy.

In planning this transition, we must look at the areas of greatest need and opportunity. Electricity is playing an ever-increasing role in all parts of national economies, and the Asia-Pacific region is endowed with remarkable natural resources for the production of electricity. However, these resources are not uniformly distributed and are generally not located in the areas where most development is expected to occur.

While there are many possible pathways to achieving the energy transition, power grid connectivity, coupled with a rapid increase in the use of renewable energy, offers an appealing vehicle that is also compatible with economic and environmental goals. On the subregional scale, work has already commenced on taking advantage of these opportunities. Further and more ambitious interconnection prospects are emerging, and while many scenarios see grid interconnection playing an increasingly important role in the region's power development plans, the potential for interconnection to help accelerate uptake of renewables is, as yet, not fully appreciated.

In response to this potential, member States of ESCAP have asked the secretariat to develop a regional roadmap on energy connectivity. Based on the deliberations of the Expert Working Group on Energy Connectivity, the draft Roadmap was developed and presented to the Committee on Energy in October 2019. This publication has been developed to showcase and provide essential context for the draft Roadmap. It takes stock of the status, benefits and challenges to connectivity that exist across the region, and presents a vision of an integrated Asia-Pacific electricity market based on an interconnected grid.

The draft Roadmap outlined in this report offers an important pathway to achieving the energy transition at reduced cost and with greater benefits. As the regional arm of the United Nations in Asia and the Pacific, ESCAP is ready to work with member States and stakeholders towards achieving this vision. It is hoped that this publication will provide a practical contribution to successfully reaching that goal.

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The draft Roadmap (Chapter 6) was developed by ESCAP's Expert Working Group on Energy Connectivity (EWG EC), chaired by Ms. Wei Xiaowei, Director of the International Cooperation Department at the National Energy Administration, China. Vijay Kharbanda led the roadmap drafting process in support of the EWG-EC. ESCAP secretariat support to the EWG-EC was led by Michael Williamson.

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Executive Summary

The success of the 2030 Agenda for Sustainable Development in the Asia-Pacific region will require a shift in the ways that we source, consume and distribute our energy resources. In the context of the region's rapidly expanding overall energy needs, a growing emphasis on electricity is emerging. As part of the broader energy transition to a future of low carbon energy, the development of the electricity sector is bringing to the fore a range of opportunities and challenges.

Cost reductions in renewables and development of other technological advances – such as the advent of ultra-high-voltage direct current transmission and "smart" grid management – are opening opportunities for the provision of electricity with lower emissions in ways that were previously either not possible or not financially viable. Meanwhile, technology developments in transport and industry, previously the domain of petroleum and natural gas, are creating new markets for electricity.

The Asia-Pacific region's diversity of economic development and political environments provide a complex setting. Over the coming decades, the region is set to continue in its position as the global leader of growth, both in terms of its economic development and increases in its demand for energy. However, this development will not be spread evenly. For example, demand in the two subregions of South-East Asia, and South and South-West Asia is accelerating, while it is levelling off in Central Asia as well as North and North-East Asia. Further diversity is apparent between countries across each subregion and even within each country itself.

The spread of energy resources provides another perspective. These resources are rarely co-located with the areas where demand is projected to grow. With the right approach, power grid interconnection can provide one part of the solution to delivering the region's future power needs as well as help to address the "energy trilemma" of security, affordability and sustainability.

Connectivity enables a range of economic advantages, including least-cost dispatch, price stabilization, and improving the economies of scale for new renewable energy supplies. It brings with it the potential for a range of social and environmental gains. It provides technical benefits, including reinforcement of system stability, opportunities for sharing of ancillary services and optimization of the energy mix, while reducing system vulnerabilities, fuel import dependencies and the impact of resource constraints.

However, it faces challenges in the areas of politics, finance and technical and operational risk. Opportunities can be hampered by a lack of political will, concerns about energy security and difficulties in the alignment of technical regulations across borders. Nevertheless, the relationships developed in overcoming these challenges – in the development of shared infrastructure, harmonization of standards and sharing of information and data on grid operations – can open up further opportunities for regional cooperation in other spheres.

Across the region, various partnerships have already been formed to start taking advantage of the opportunities of cross-border electricity trade. Historically, these have been bilateral arrangements that enabled the resources of one location to feed growing energy demand across the border in a neighbouring country. Examples include projects to build and operate transmission cables connecting hydropower capacity in Nepal to markets in India, and cross-border links to provide coal-sourced electricity from the Russian Federation to Mongolia.

Multilateral arrangements have seen the creation of more integrated solutions on a subregional scale. The ASEAN Economic Community "Blueprint 2025" contains two flagship energy connectivity programmes – the ASEAN Power Grid and the Trans-ASEAN Gas Pipeline – which propose connecting all 10 ASEAN members via 16 separate electrical interconnections.

Intergovernmental institutions supporting subregional scale initiatives include the ministerial-level Asia-Pacific Energy Forum – under the auspices of the United Nations Environmental and Social Commission for Asia and the Pacific (ESCAP) –, the Asia-Pacific Economic Cooperation, ASEAN and the South Asian Association for Regional Cooperation. These institutions can provide platforms for engagement and mechanisms for the development of power connectivity. Their work supports the building of trust and promotion of collective action, the harmonization of policy and regulation, and the facilitation of investment to deliver connectivity infrastructure. They can also provide the necessary frameworks for ongoing management of operating grid interconnections as these arrangements evolve toward full integration.

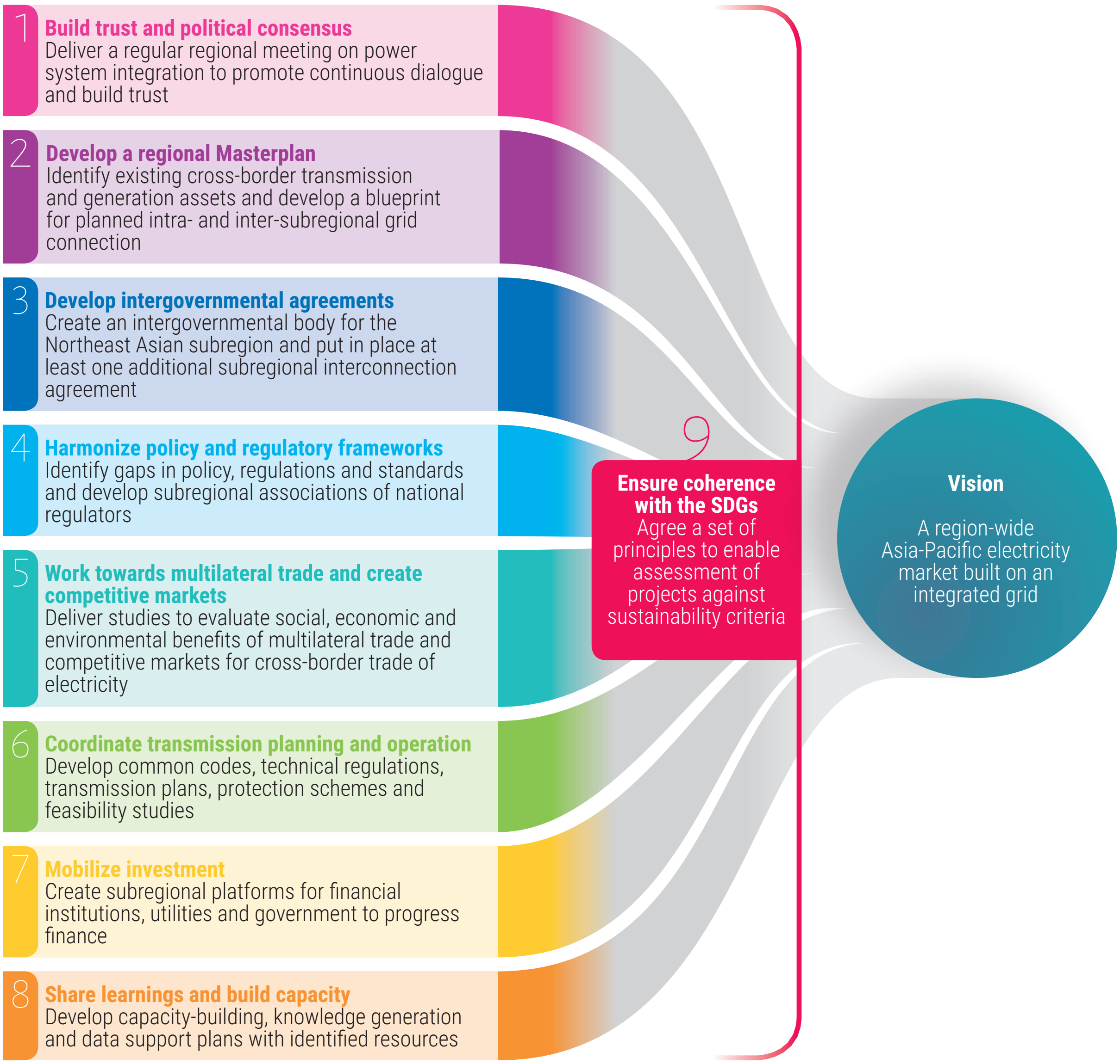
There is an important role for institutions in delivering electricity connectivity. Institutions are essential for generating the political momentum and consensus needed to progress opportunities for grid connectivity and integration. Such institutions can also help to provide the coordination that is required between national Governments to harmonize technical requirements and legal frameworks, and to engage the wide spectrum of stakeholders to ensure optimal outcomes. Importantly, the need for appropriate institutions becomes more important as integration deepens.

Findings on the role of institutions in electricity connectivity note that institutional development will serve to unleash the full benefits from power connectivity. This includes benefits beyond the economic merits of the electricity trade, such as the improvement of technical, social and environmental protection standards. Furthermore, cooperation in the power sector can serve to foster broader collaboration between countries.

As the largest intergovernmental platform for the Asia-Pacific region, ESCAP has been working with its member States towards the vision of an integrated Asia-Pacific electricity market based on an interconnected grid. In 2017, the 73rd Session of the ESCAP Commission adopted a resolution to establish an Expert Working Group on Energy Connectivity (EWG-EC). In 2018, the Second Asian and Pacific Energy Forum adopted a Ministerial Declaration on the development of a draft regional Roadmap on energy connectivity which was subsequently endorsed by the 74th Session of the ESCAP Commission.

Following extensive deliberations, the EWG-EC developed a draft Roadmap consisting of nine integrated strategies for the achievement of this vision. These strategies, outlined in figure 1, describe the roles of the primary stakeholders together with key milestones in their delivery. The draft Roadmap was presented to the Second Session of ESCAP's Committee on Energy in October 2019.

Figure 1 Strategies of the draft Electricity Connectivity Roadmap for Asia and the Pacific



Source: ESCAP.

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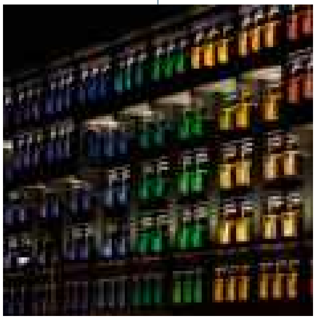

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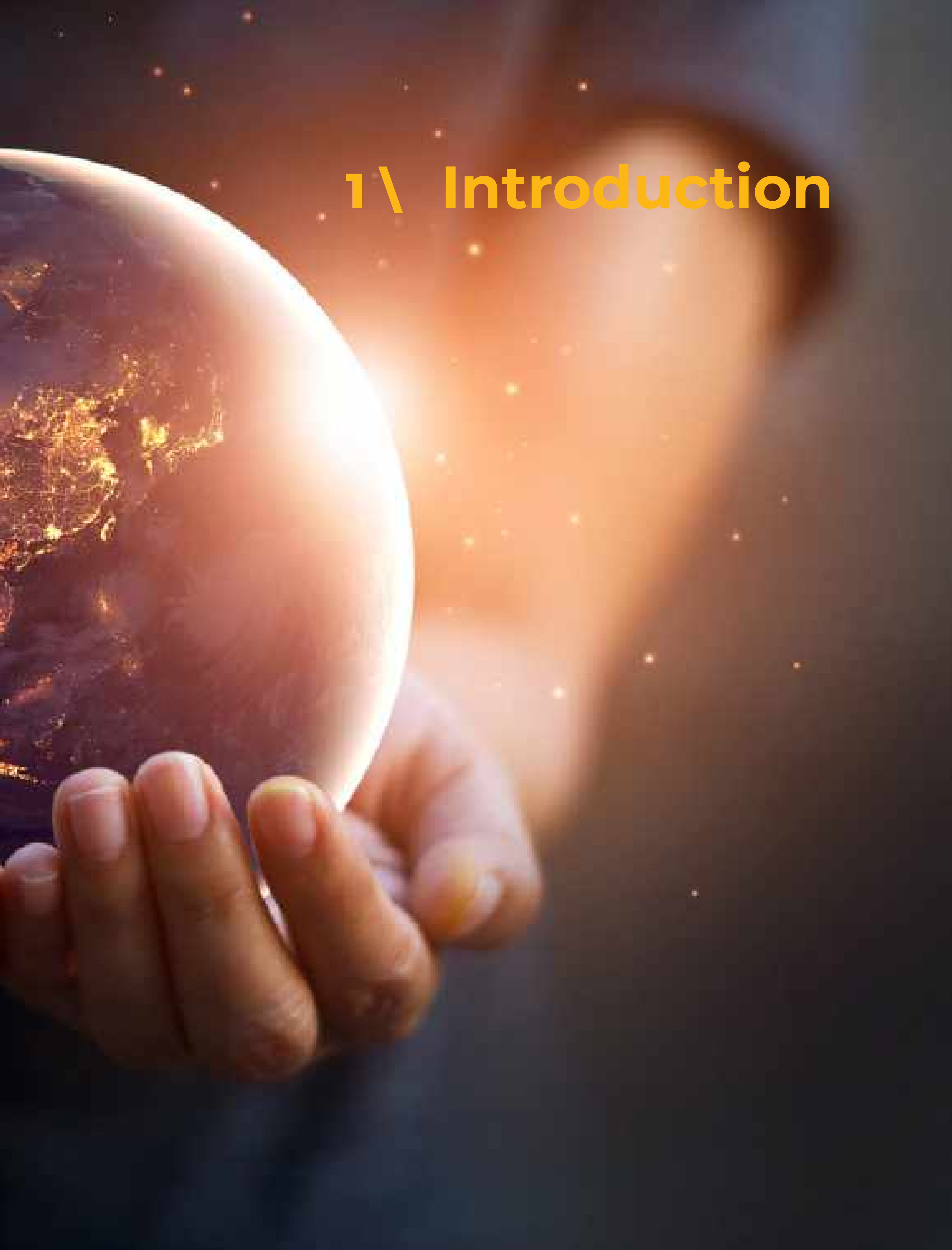
List of acronyms

ADB	Asian Development Bank
AEC	ASEAN Economic Community
AIIB	Asian Infrastructure Investment Bank
APAEC	ASEAN Plan for Action for Energy Cooperation
APG	ASEAN Power Grid
ASEAN	Association of Southeast Asian Nations
AusAID	Australian Agency for International Development
BCIM	BCIM: Bangladesh, China, India and Myanmar
BIMP-EAGA	Brunei Darussalam-Indonesia-Malaysia-Philippines East ASEAN Growth Area
BIMSTEC	Bay of Bengal Initiative for Multi-Sectoral Technical and Economic Cooperation
CAR	Central Asian Republics
CAREC	Central Asian Regional Economic Cooperation
CASA-1000	Central Asia South Asia Electricity Transmission and Trade Project
CASAREM	Central Asia-South Asia Regional Electricity Market
CDC	Coordination Dispatch Centre Energiya
CEC	China Electricity Council
CIS	Commonwealth of Independent States
COI	Corridor of Influence
DABS	Da Afghanistan Breshna-Sherkat

DC	direct current
DFID	United Kingdom Department for International Development
ECO	Economic Cooperation Organization
EEC	Eurasian Economic Cooperation
EGP	Expert Group on Regional Power Trade and Interconnection
EPF	Electric Power Forum
ESCAP	Economic and Social Commission for Asia and the Pacific
EU	European Union
GMS	Greater Mekong Subregion
GMSARN	Greater Mekong Subregion Academic Research Network
GTI	Greater Tumen Initiative
GW	gigawatt
HAPUA	Heads of Power Utilities and Authority
HV	high voltage
HVAC	high-voltage alternating current
HVDC	high-voltage direct current
Hz	Hertz
IEA	International Energy Agency
IMT-GT	India-Malaysia-Thailand Growth Triangle
IPS	Interconnected Power System
IRADe	Integrated Research and Action for Development
km	kilometer
kV	kilovolt
kW	kilowatt
kWh	kilowatt-hour
LTM-PIP	Lao People's Democratic Republic, Thailand and Malaysia Power Integration Project
LTMs-PIP	Lao People's Democratic Republic, Thailand, Malaysia and Singapore Power Integration Project
MER	Central America Regional Electricity Market
MIBEL	Iberian Electricity Market
MOU	Memorandum of Understanding
Mt	million tonnes
MW	megawatt
MWh	megawatt-hour
NAPSI	Northeast Asia Power System Integration
NEARPIC	North-East Asia Regional Power Interconnection and Cooperation
NPS	National Power Systems
PPA	Power Purchase Agreement
PV	photovoltaic
RCI	Regional Cooperation and Integration
RPCC	Regional Power Coordination Center
RPS	Regional Power System
RPTCC	Regional Power Trade Coordination Committee
RPTOA	Regional Power Trade Operating Agreement
SAARC	South Asian Association for Regional Cooperation
SAFIR	South Asia Forum for Infrastructure Regulation
SAPP	Southern African Power Pool
SARI/EI	South Asia Regional Initiative for Energy
SASEC	South Asia Subregional Economic Cooperation
SCO	Shanghai Cooperation Organisation
SDG	Sustainable Development Goal
SEF	Subregional Energy Forum
SIEPAC	System for the Electrical Interconnection of the Central American Countries
TFEC	Total Final Energy Consumption
TSO	Transmission System Operation
TWh	terawatt-hour
UHV	ultra-high voltage
UHVAC	ultra-high voltage alternating current
UHVDC	ultra-high voltage direct current
UN	United Nations
UN-DESA	United Nations Department of Economic and Social Affairs
USAID	United States Agency for International Development
WGPG	Working Group on Performance Standards and Grid Codes

1\ Introduction



Countries in the Asia-Pacific region are confronted by a series of challenges in securing their energy needs into the future. Strong energy demand growth continues as the region's energy needs are expected[1] (Unless noted otherwise, this report uses the IEA's *Stated Policies Scenario*, incorporating today's policy intentions and targets, as the basis for all projections) to grow by 37 per cent between 2018 and 2030. Just as the needs for future energy must be met, the environmental and climate change impacts of energy use require a switch to more sustainable energy sources. The imperative to avoid dangerous climate change and to tackle the immediate challenges of chronic air pollution require an unprecedented response by countries of the region to move away from fossil fuels. In response to these pressures, and aided by rapid technological changes, a global "energy transition" is underway. The energy transition implies a series of shifts in technologies and paradigms for energy production and use. These are being manifested in areas such as the expanding use of low-cost renewables, advanced energy efficiency, decentralized energy, electrification of end-uses, energy storage and electric mobility.

Against this backdrop, the 2030 Agenda for Sustainable Development and the Paris Agreement on Climate Change provide a framework for countries' efforts to adopt sustainable energy approaches and to mitigate the emission of greenhouse gases. Sustainable Development Goal 7 (SDG7) of the 2030 Agenda includes a goal for affordable and clean energy, that is aimed at ensuring access to affordable, reliable, clean and modern energy for all by 2030. It provides targets for universal access to modern energy, increasing the share of renewables and improving energy efficiency. Under the Paris Agreement, countries have pledged to reduce their emissions with varying levels of ambition, with the focus of most commitments placed on energy sector transformations. However, in the Asia-Pacific region, countries are positioned differently in terms of development levels, geography and resource endowments. Each country's approach to sustainable energy development and emission reductions varies accordingly.

"The international community should… reduce the risk of fragmentation by encouraging cross-border, cross-sector and cross-vector strategic partnerships to accelerate progress along net-zero carbon pathways, and to secure new opportunities for global trade in clean electrons and clean molecules (gas and liquids), including hydrogen"(World Energy Council, 2019).]

In progressing the SDG7 targets, the region has a mixed outlook. It has more than halved the population without access to electricity since 1990 and is on track towards almost 100 per cent access to electricity by 2030. However, the goal of providing universal access to clean cooking faces more challenging prospects as current clean cooking access rates are only 56 per cent, with little improvement shown over the past decade. (Asia-Pacific Energy Portal, 2019). In contrast,

1 Unless noted otherwise, this report uses the IEA's ***Stated Policies Scenario***, incorporating today's policy intentions and targets, as the basis for all projections.

indicators of progress related to energy efficiency appear to show better prospects of success. Energy intensity declined steadily across the region by 1.9 per cent from 2000 to 2016 which, if maintained, will narrowly meet the 2030 target under SDG7. The renewable energy sector shows strong growth, but with more progress in the power sector than in the heating, cooling and transport sectors. These factors, combined with the challenge of strong overall energy demand growth, mean that a substantial increase in renewable energy share will not result by 2030 under current policy settings.

Given this context, there is a growing focus on adopting power grid connectivity as a solution to many of the energy challenges experienced by countries of the Asia-Pacific region such as energy decarbonatization, affordability, security and self-sufficiency. The region has abundant renewable energy resources, including hydropower, solar and wind, which are not uniformly distributed. Many of the lowest-cost renewable energy resources are located in sparsely populated areas away from load centres and, in many cases, are situated across international borders from the energy demand centres. Therefore, cross-border electricity trade, enabled by power grid infrastructure connectivity, offers an opportunity to exploit new energy resources and manage the energy surpluses and deficits across the region in an optimal manner.

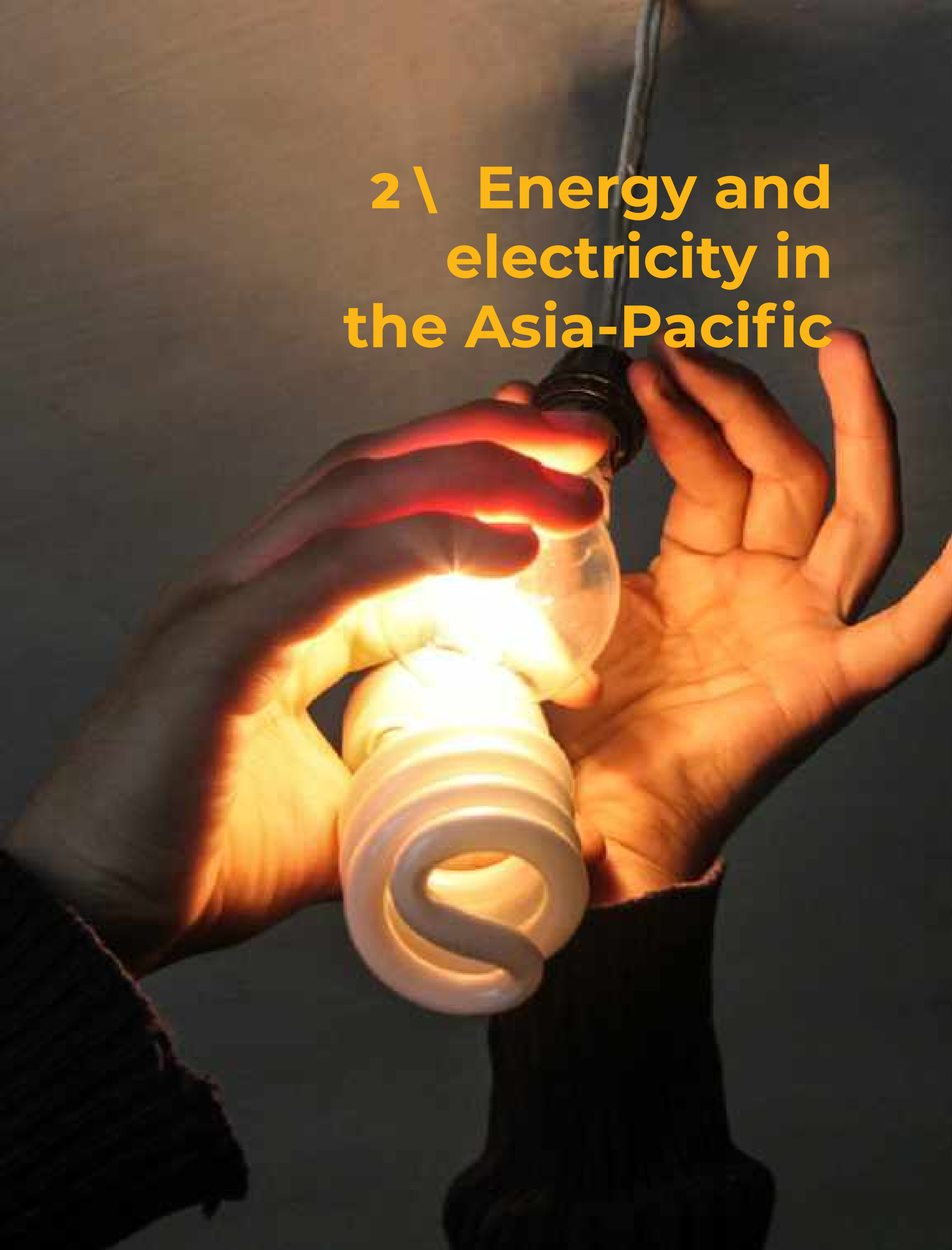
ESCAP places priority on enhancing regional energy connectivity, with a focus on power grids, as a means of enhancing the sustainability and security of the region's energy supply. In this work, ESCAP has drawn on many successful examples of power system integration in other regions of the world, which provide useful reference points and guidance for the region.

In 2017, ESCAP adopted a resolution to establish an Expert Working Group on Energy Connectivity. At the first meeting of the Expert Working Group, held in December 2017 in Bangkok, members proposed the development of a regional Roadmap on energy connectivity. Following this, the region's energy ministers through the Ministerial Declaration of the Second Asian and Pacific Energy Forum, decided to support the work of the Expert Working Group.

With this mandate, ESCAP commissioned a series of subregional studies and other analyses to facilitate the deliberations of the Expert Working Group. During several meetings, the Expert Working Group reviewed the role of interconnectivity across the region and its potential benefits for sustainable development, and considered the challenges to furthering cross-border power interconnectivity. Based on this, the Expert Working Group developed a draft regional Roadmap that delineates the policy, regulatory and institutional arrangements needed to integrate the power grids of the four subregions and the wider Asia-Pacific region.

This report examines the status, benefits and challenges to energy connectivity across the Asia-Pacific region and presents the draft Roadmap. Chapter 2 provides a contextual outline of power demand and supply across the region, while chapter 3 presents a summary of the motivations in support and challenges against increased connectivity. Chapter 4 discusses the current state of connectivity infrastructure together with the status of political and technical alignment across the four subregions where electricity interconnection is viable, while chapter 5, contributed by the University of Tokyo, provides an overview of the functions that institutions are expected to play in promoting regional power connectivity. Finally, chapter 6 outlines a draft Roadmap consisting of nine non-binding strategies for stakeholders to address enabling the region to harness the opportunities of connectivity. It suggests critical milestones, timeframes and responsible entities for delivering each strategy. These strategies were presented in draft form to the Second Session of ESCAP's Committee on Energy in October 2019.

2 \ Energy and electricity in the Asia-Pacific



During the past two decades, countries in Asia and the Pacific have transformed their economies and made remarkable progress in raising incomes and living standards. The region has become a vibrant manufacturing hub for the world, creating millions of jobs and improving access to services.

Rapid economic growth, the demands of a growing middle class and the increased access to modern energy sources are translating into rising energy demand. The latest projections by the International Energy Agency (IEA) predict that energy use in Asia will rise during the next two decades to reach 45 per cent of the global total in 2040 (IEA, 2019c).

Electricity is emerging as an increasingly important energy medium and a highly strategic commodity. Not only is there strong growth in electricity demand, but its share in final energy consumption is also increasing. Figure 2 shows that electricity as a proportion of total energy consumption grew from 17 per cent in 2000 to approximately 24 per cent in 2016. Electricity demand has almost tripled since 2000 and is expected to almost double again between 2018 and 2040. This trend of increasing use of electricity is driven by several factors – overall economic growth, technology changes on the consumption side that favour the use of electrical energy and structural changes in many of the economies of the Asia-Pacific region. The IEA has noted this trend in its projections in the World Energy Outlook, noting that electricity is the fuel the world turns to for its additional energy needs. This trend may accelerate as transport and other end-uses switch to electricity as a principal fuel. This electricity-dependent future not only presents challenges to increase power generation capacity but also offers opportunities to utilize lower-cost renewable energy to deliver against environmental sustainability and growth objectives.

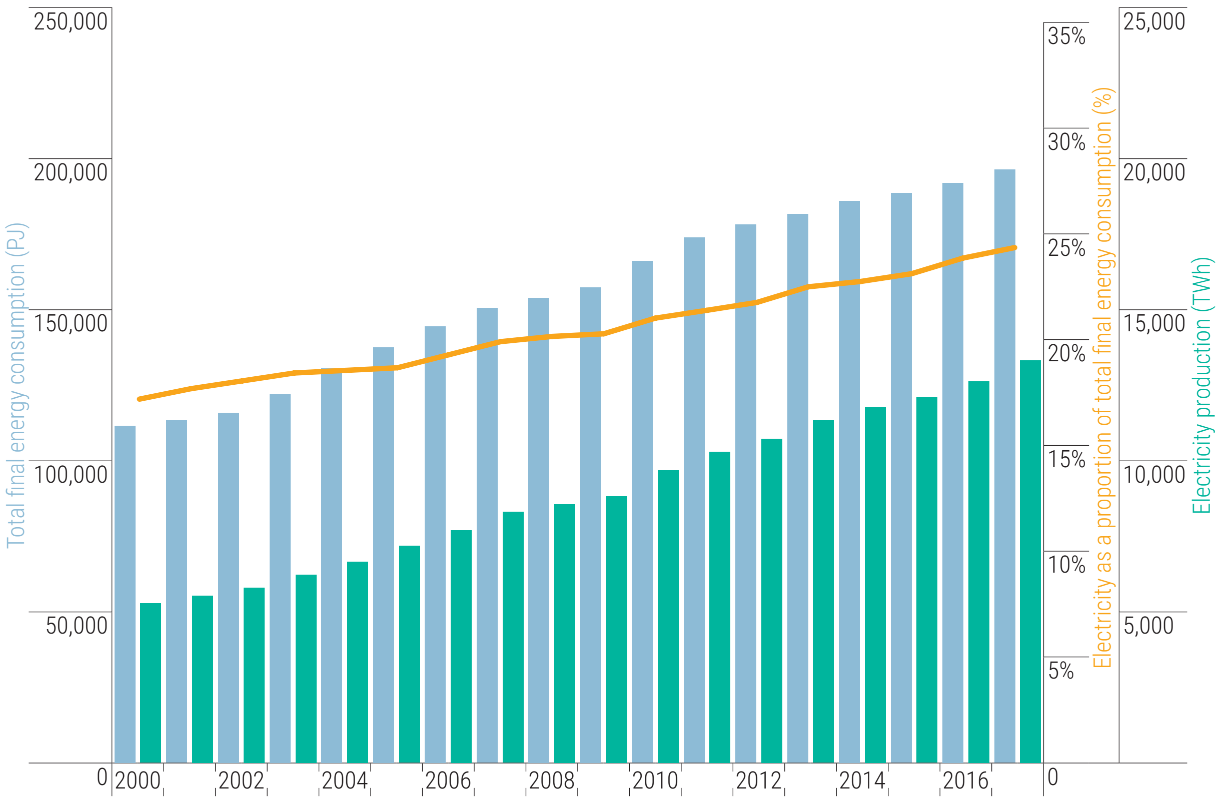
Examining the overall energy consumption picture across the Asia-Pacific, expectations of robust growth in energy demand are driven by countries such as India, where energy demand is expected to double by 2040. China will remain the world's largest energy consumer, but its demand growth is expected to slow considerably and will increasingly be met by low-carbon sources. South-East Asia is another region where energy demand will grow strongly (IEA, 2019c).

Globally, renewable energy will play an increasingly important role as its share of the energy mix grows. Renewables are forecast to increase from 26 per cent of electricity generation capacity in 2018 to 44 per cent in 2040; the IEA's Sustainable Development scenario indicates that it will potentially rise to 67 per cent. Meanwhile, coal demand will remain stable across much of developing Asia (IEA, 2019c).

2.1 Power system outlook for the Asia-Pacific subregions

The South and South-West Asian subregion has experienced a significant and accelerating increase in generation capacity, growing from 203 GW in 2000 to more than 569 GW in 2018. However, this capacity is unevenly distributed, with the major economies of India, the Islamic Republic of Iran and Turkey contributing 90 per cent of the total installed capacity, as of 2018. India alone contributes 60 percentage points of this total, with Turkey and the Islamic Republic of Iran taking the bulk of the remainder (16 and 14 per cent, respectively) (ESCAP, Energy Statistics Database).

Figure 2 Total final consumption and electricity production, 2000-2016[8]



Source: IEA, World Energy Statistics and Balances. Chart generated from the Asia-Pacific Energy Portal at asiapacificenergy.org.

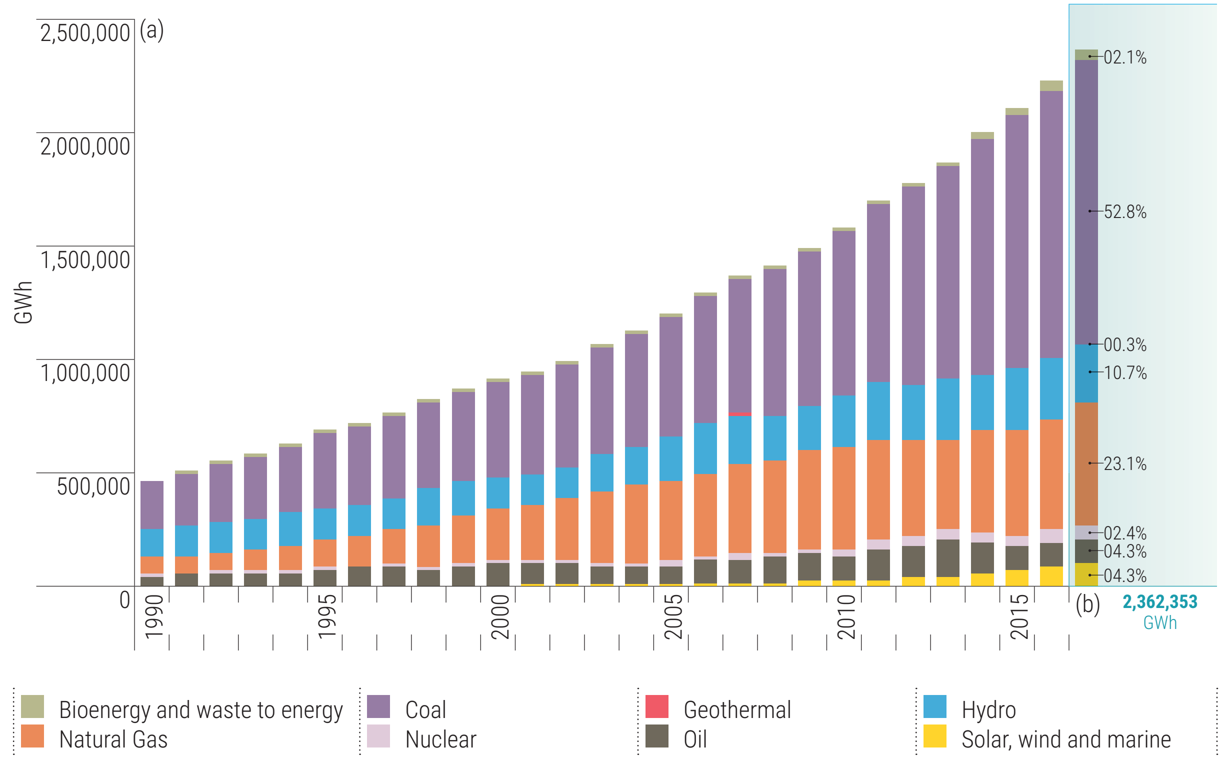
Most of the electricity generated across the subregion is from coal and gas (figure 3), but the subregion's high-quality renewable resources – particularly for hydropower and solar – are expected to be increasingly accessed in the coming years.

In East and North-East Asia, the primary sources of electricity are currently coal, hydropower and natural gas (figure 4). Electricity production by the subregion increased by a factor of almost 5 during 1990-2016. While much of this growth was in fossil fuels and hydropower – a recent study found that China alone added more than 40 GW of new coal capacity in the 18 months up to June 2019 and has more than 120 GW of coal capacity under construction – renewable technologies are rapidly emerging as a significant generation source.

The subregion's power systems are subject to substantial seasonal fluctuations. To manage this inconsistency, countries across East and North-East Asia are working towards sharing their diverse energy sources. The subregion currently has plans for development of interconnections totalling 500 GW, and this is expected to grow more than twofold by 2035.

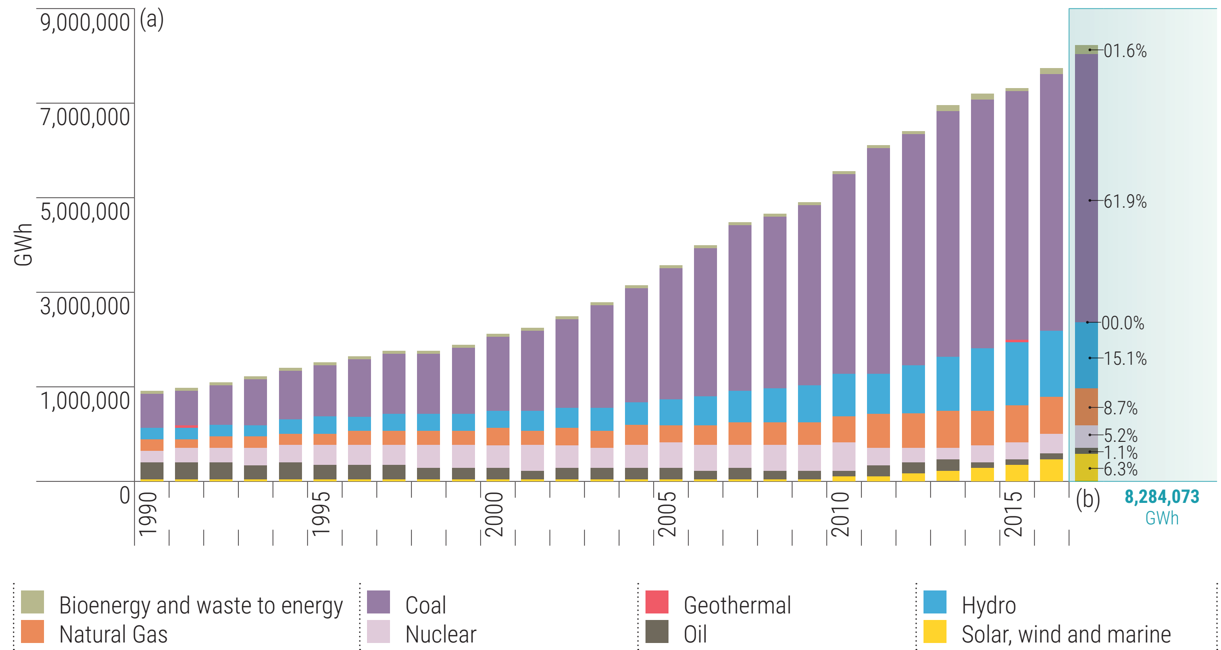
In South-East Asia, electricity production increased from 154 TWh in 1990 to 932 TWh in 2016. Natural gas occupies 41 per cent of all

Figure 3 Electricity production by product in South and South-West Asia: (a) 1990-2016; and (b) 2017.



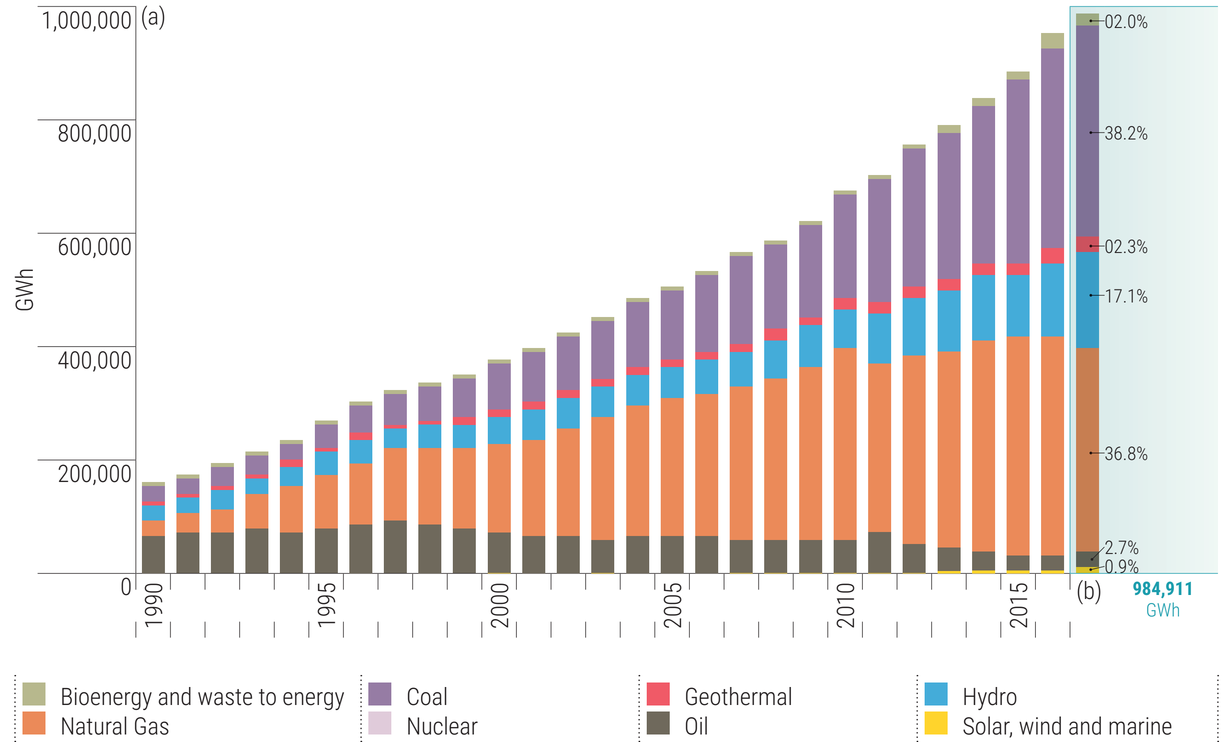
Source: IEA, World Energy Statistics and Balances. Chart generated from the Asia-Pacific Energy Portal at asiapacificenergy.org.

Figure 4 Electricity production by product in East and North-East Asia: (a) 1990-2016; and (b) 2017.



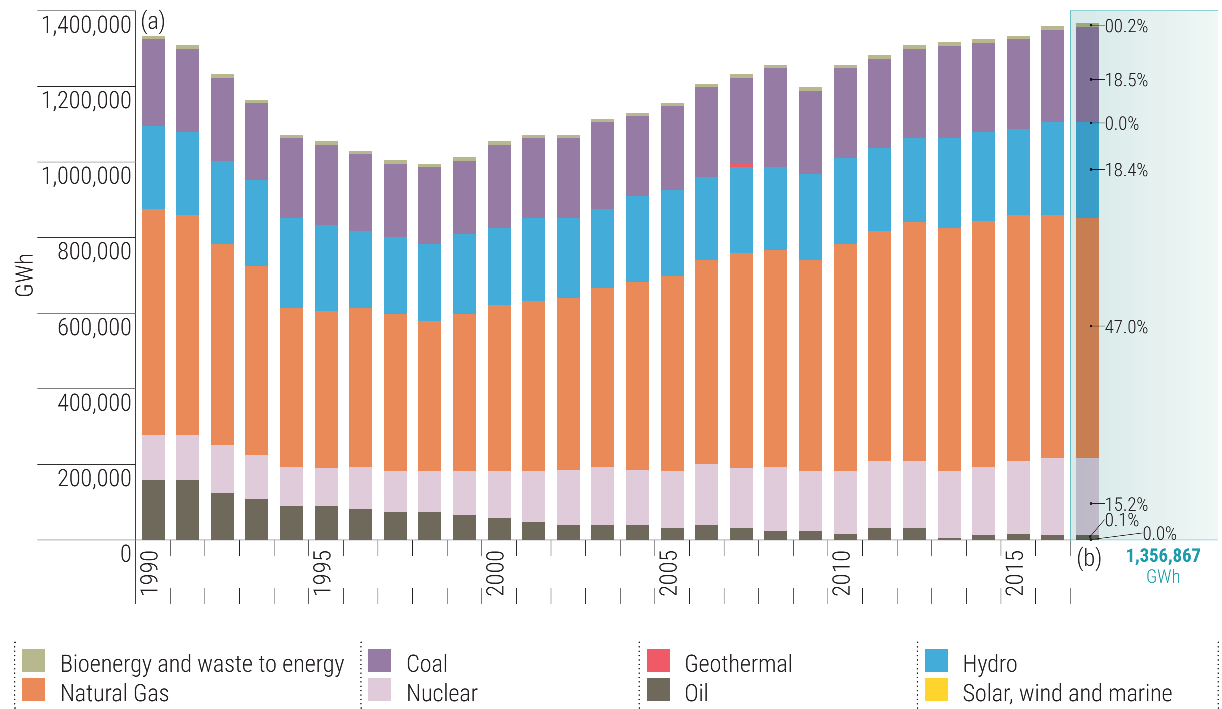
Source: IEA, World Energy Statistics and Balances. Chart generated from the Asia-Pacific Energy Portal at asiapacificenergy.org.

Figure 5 Electricity production by product in South-East Asia: (a) 1990-2016; and (b) 2017.



Source: IEA, World Energy Statistics and Balances. Chart generated from the Asia-Pacific Energy Portal at asiapacificenergy.org.

Figure 6 Electricity production by product in North and Central Asia: (a) 1990-2016; and (b) 2017.



Source: IEA, World Energy Statistics and Balances. Chart generated from the Asia-Pacific Energy Portal at asiapacificenergy.org.

electricity resources (figure 5), slightly more than coal at 36.7 per cent.

Electricity demand in South-East Asia is expected to almost triple between 2015 and 2040, with a shift towards coal set to continue under current policies. Under the business as usual scenario, total installed capacity in 2040 will increase three-fold to 629 GW, at an annual growth rate of 4.6 per cent. Among 424 GW of this new capacity, 42.4 per cent will be from coal (rising from 63 GW in 2015 to 267 GW in 2040) while renewables will contribute 29.2 per cent (50 GW in 2015 to 183 GW in 2040) (ASEAN Centre for Energy, 2017a).

Electricity production in North and Central Asia was 1,160 TWh in 2017, with production per capita decreasing from 6,173 kWh per capita in 1990 to 5,017 kWh per capita in 2017. Natural gas is the leading source of electricity production, followed by hydropower, coal and nuclear (figure 6). The subregion is rich in natural resources and is expected to maintain its ability to meet its energy needs locally in the long term.

The analysis of the power systems of each subregion shows several converging trends. Electricity demand is surging and the need for additional generation is largely being met by fossil fuels, thus hampering achievement of the Sustainable Development Goals and commitments under the Paris Agreement. While non-hydropower renewable energy generation is growing strongly, it started from a small base. Thus, efforts to increase the share of renewables are being hampered. Under the business as usual settings it will take considerable time to achieve a high proportion of renewable electricity in the mix. At the same time, the Asia-Pacific region has sufficient renewable energy resource endowments to support a much higher level of penetration. However, these resources are unevenly distributed and generally not located alongside areas of demand growth. Power supplies in many countries are subject to seasonal or more frequent energy shortfalls, and opportunities to harness high-quality renewable energy resources go unrealized. These challenges, among others, are driving a growing regional focus on power connectivity. The following chapter outlines some of the key benefits that power connectivity can bring.

3 \ Power grid connectivity – benefits and challenges

3.1 Benefits

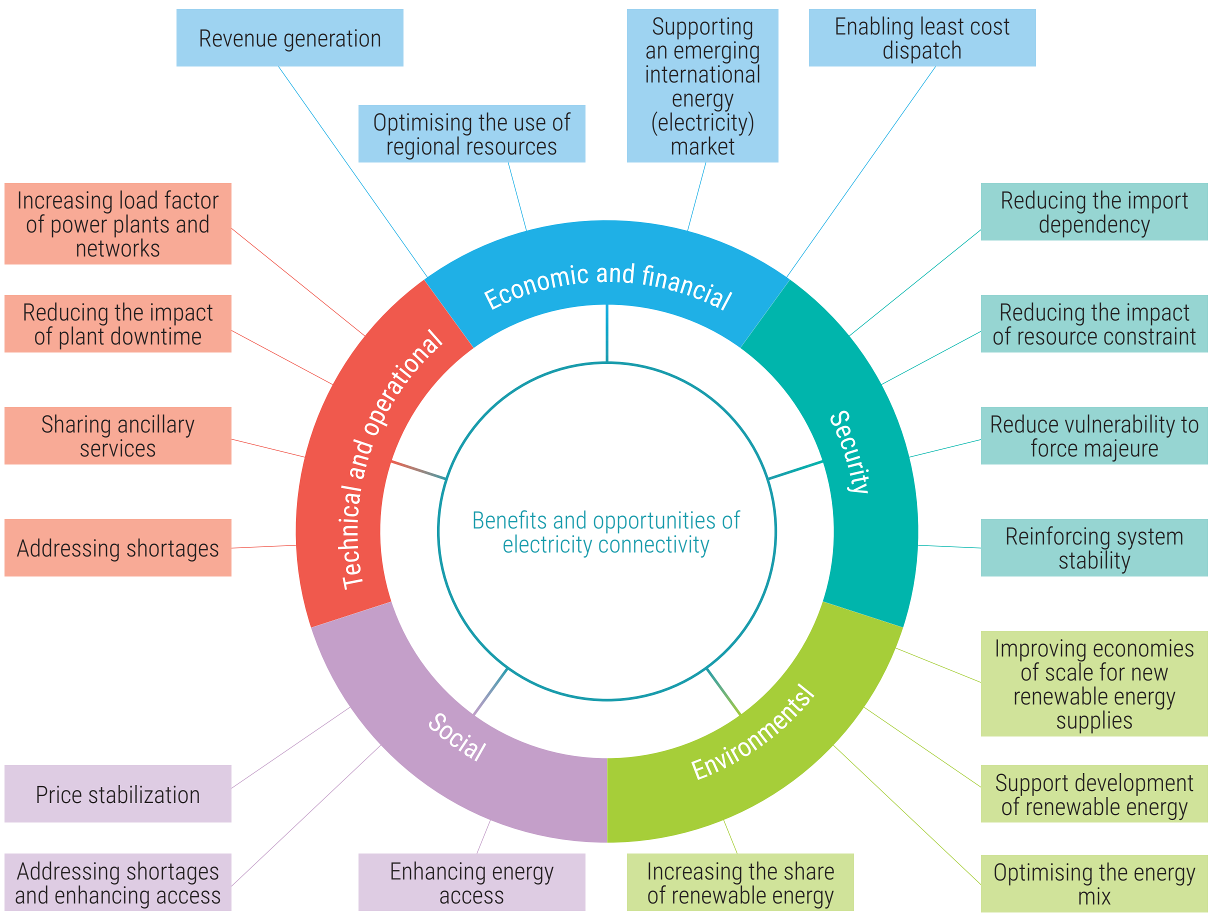
The Asia-Pacific region has diverse political frameworks, market mechanisms, energy resource endowment, and power networks. Economic development contexts also vary greatly, ranging from developed countries to emerging economies with rapidly rising energy demand. Major fossil fuel exporters also exist alongside nations with a high dependence on energy imports. Different forms of cooperation between countries of the region can harness the benefits of diversity, improving economic growth while minimizing the negative environmental impacts of development. Previous research has investigated the benefits of regional energy interconnection, and a wealth of literature is available on the subject (UN-DESA, 2006).

Figure 7 Summarizes some of the benefits stemming from power grid interconnection.

Increasing the share of renewable energy

Despite implementation of renewable energy targets by many countries within their energy

Figure 7 Benefits of regional power trade.



Source: ESCAP.

policies, the increasing use of fossil fuels – particularly coal – is leading to a steep increase in CO_2 emissions.

For example, in the Association of Southeast Asian Nations (ASEAN) region, CO_2 emissions are expected to grow from 1,446 million tons in 2015 to 3,464 million tons in 2040 (ASEAN Centre for Energy, 2017a). However, the ASEAN region has potential for 240 GW of hydropower – more than its total generation capacity in 2015. Indonesia alone has more than 32 GW of geothermal resource potential, while the ASEAN subregion is also highly suitable for solar and biomass energy.

In South and South-West Asia, the wind energy potential across Afghanistan, Bhutan, India, the Islamic Republic of Iran, Nepal, Pakistan, Sri Lanka and Turkey is estimated to be 410 GW, while the hydropower potential is estimated to be almost 1,150 GW (ESCAP, 2018). India alone offers a solar resource potential of 750 GW (National Institute of Solar Energy, India, 2014). Bhutan, Nepal and Pakistan have significant hydropower potential that is expected to exceed their expected future power requirements, while Cambodia, the Lao People's Democratic Republic and Myanmar have sufficient hydropower potential for meet their domestic needs and provide a surplus for export.

Without power interconnection, these potentials will remain under-exploited due to a lack of adequate domestic demand. Development of these resources could replace or offset many planned thermal power plants without an increase in generation costs and, in some cases, even offer a reduction in cost. By providing long-term off-take opportunities, power interconnection can enhance the business case for new renewable energy developments, and economies of scale can then provide further advantages.[2]

2 Sun Cable. Australia-Singapore Power Link. More information is available at the project website. Available at https://www.suncable.sg/.

Connectivity can enhance access to clean energy resources and facilitate further growth of the renewable energy sector in other ways; new linkages to broader consumer bases can open renewable energy developers to alternate financial arrangements, and the reduction of risk can lower the cost of capital. Diversification of both suppliers and consumers can allow larger shares of variable renewables to be integrated into the grid. A recent study on interconnection in the ASEAN region noted that "establishing a scenario of enhanced energy interconnection among ASEAN, China and Bangladesh at a scale of approximately 10 per cent of total power exchange in ASEAN could lead to a 62 per cent share of clean energy in the power generation mix by 2050"(ESCAP, 2018).

The Australia-Singapore Power Link project also known as 'Sun Cable' is a proposal to connect a future 10 GW, battery-supported solar PV array near Tennant Creek in Australia's Northern Territory to Singapore via a 3,000-km undersea cable.[2] If successful, the project would supply up to 20 per cent of Singapore's power needs with "stably priced, dispatchable power" while supporting development of the world's largest solar farm.

Addressing energy shortages and enhancing energy access

Countries across the Asia-Pacific region have enjoyed impressive economic growth during the past decade and have showed progress in reducing poverty; that high growth is expected to continue. Despite this, the power sector has not kept pace with growth in all countries, and chronic problems of shortage of supply and poor quality of service persist in many areas.

The region is home to a very large population of the energy impoverished. In 2017, 232 million people lacked access to electricity. However, energy poverty is not evenly distributed: 182 million of those without access were in South and South-West Asia, a subregion that is itself characterized by a striking difference in per capita electric power consumption between countries.

Separately, at the national, subregional and regional levels, a combination of growing energy demand and a fossil-fuel dominant energy mix will see further challenges emerge over the coming two decades. First, a widening gap between supply and demand will create new risks for energy security and affordability; and second, the supply-demand gap will keep increasing, leading to growing import dependence, particularly for oil and natural gas supplies.

By increasing the uptake of modern renewables for electricity supply, cross-border trade can help in enhancing energy access. It can address shortages, thereby aiding energy security and reducing costs. In some circumstances, cross-border trade can even directly enable regional electrification:

Connectivity for electrification in border zones.

Many countries in the Asia-Pacific have border regions that are far from the county's main economic centres. In some cases, for remote regions with low electrification rates, sourcing electricity from the distribution grid in the adjacent country is more cost-effective than constructing distribution lines to the national power grid.

It should be noted that most cross-border interconnection occurs through high-voltage transmission lines, and connections to these lines require substantial infrastructure support for voltage step-down to the local distribution network. Such infrastructure may be cost-prohibitive for connections to small communities. However, where nearby access is available to a neighbouring country's (lower-voltage) distribution network, cross-border power interconnection at the distribution level can provide new options for electricity access. This type of cross-border power grid connectivity is conducive to improving energy access. This practice is widespread in Asia and the Pacific. For example, the Indian power system supplies many communities in the Terai region of Nepal near the Indian border. Electrification of these rural border areas creates positive impacts on poverty and quality of life, and subsequently builds trust and confidence for other forms of cooperation.

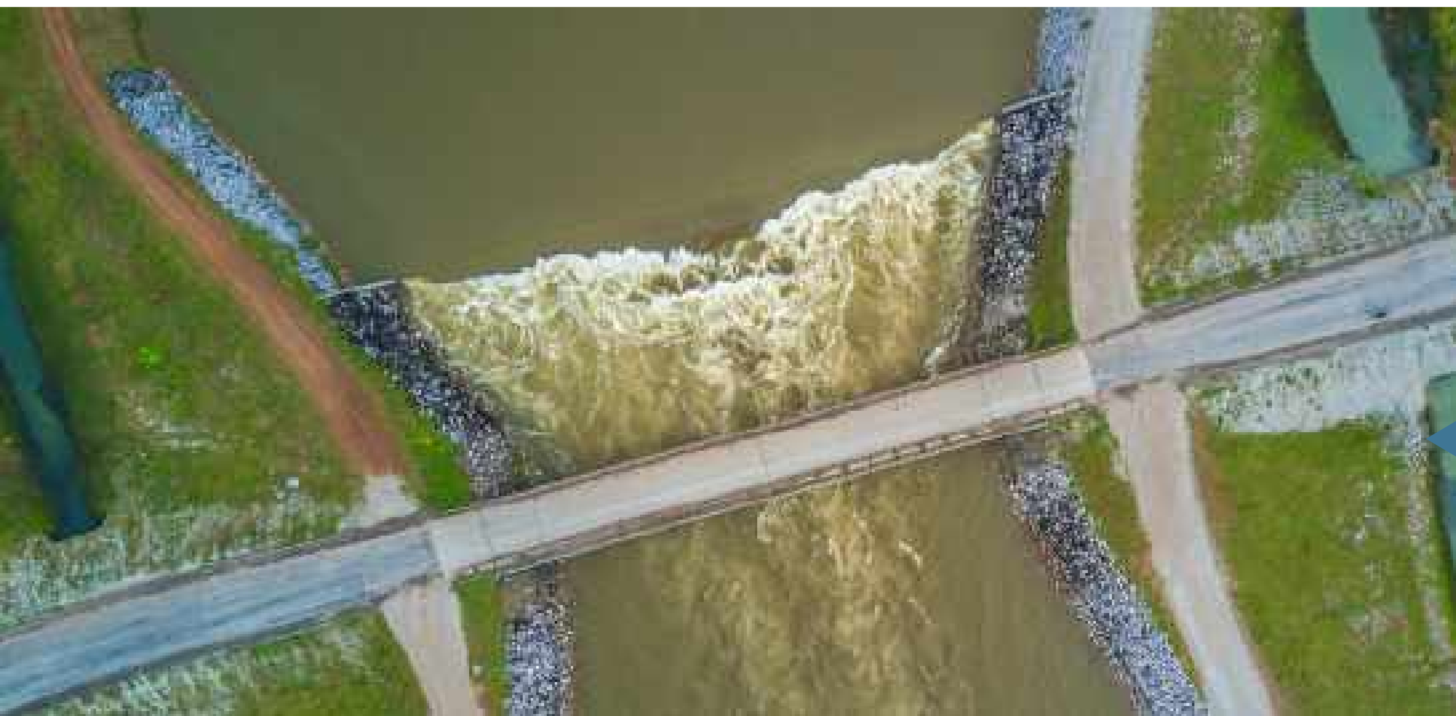
Optimizing the energy mix

Countries across the Asia-Pacific region have tremendous diversity in their generation mix, energy resource endowments, load profiles, climatology and weather patterns. Some countries are rich in fossil fuel resources but not in low-carbon resources; others are resource-poor overall and have limited indigenous energy potential.

In the subregion's power sectors, South-East Asian countries such as Thailand and Viet Nam are largely dependent on imported fossil fuels at present, while Cambodia, the Lao People's Democratic Republic and Myanmar have enough hydropower potential to meet their electricity needs plus a surplus for export. The Lao People's Democratic Republic's estimated potential hydropower capacity of 26 GW is well above the projections of its future domestic total demand (note that in 2015, the total installed capacity in the Lao People's Democratic Republic was only 5.8 GW and the country remains dependent on imports).

Looking at primary resources within the subregion's power sectors, South-East Asian countries such as Thailand and Viet Nam are largely dependent on imported fossil fuels, while their neighbours – Cambodia, the Lao People's Democratic Republic and Myanmar have enough hydropower potential to meet their electricity needs plus a surplus for export. the Lao People's Democratic Republic's estimated potential hydropower capacity of 26 GW is well above the projections of its future domestic total demand (note that in 2015, the total installed capacity in the Lao People's Democratic Republic was only 5.8 GW and the country remains dependent on imports).

Many countries have adopted policies and programmes supporting the development of renewable energy. If renewable energy resources are tapped effectively, South and South-West Asia could become a globally-leading exporter of electricity. Bhutan, Nepal and Pakistan have sufficient hydropower potential to produce well in excess of their forecast future power needs. Further east, in northern China and Mongolia, the Gobi Desert – enormous solar and wind resource, augmented by hydropower in the far eastern region of the Russian Federation – could enable countries in North East Asia to shift the generation mix away from fossil fuels.



Without power export capability facilitated by interconnection, these potentials will remain unexploited. Many countries will continue to import fossil fuels while potential renewable opportunities go untapped.

Economic and technical benefits

A reliable electricity supply must match supply and demand across different timescales – minutes, days and seasons. Many forms of renewable energy are not *dispatchable*: they rely on variable wind, sun and exogenous conditions that are intermittent and cannot be controlled (*scheduled*) to match instantaneous energy demand. (The output of wind and solar power is partly controllable, however, as it can be reduced in response to grid congestion or oversupply in a process known as curtailment. Greater interconnection can reduce the lost economic value from curtailment of renewable energy.) However, under the right circumstances wind, solar and hydropower can reinforce each other by delivering their output based on different weather patterns and timescales. Together with forecasting of wind and solar output, this effect is strengthened when generators and

Large, centralized solar photovoltaic generators with a total capacity of tens of GW are already operating in north-western, northern and north-eastern China. The development and operation of such energy bases cause two interrelated problems: the need to integrate renewable energy into power systems of adequate capacity and the need to compensate for the stochastic fluctuations in the energy these power plants when covering the load schedules of the power systems.

consumption centres are interconnected over larger geographic areas where greater diversity exists.

Stronger and more robust interconnection and trade allow offsetting variability among a more diverse set of generators and consumers. Power interconnection covering large geographic areas can thus accommodate larger shares of wind and solar power at lower cost.

Interconnection also allows the potential for dispatching the least-costly generating units within the larger interconnected area. While this is reliant on the right market frameworks, it provides an opportunity for overall cost savings that can be divided among the component systems.

A related benefit arises from a reduced need for peaking power plants. This is generating capacity that must be built or contracted by the utility and made available to meet peak demand on the system. These power plants are usually designed to ramp up quickly, but they operate only occasionally and may sit idle for much of the time. Their efficiency is not an important design criterion, so they typically operate at

Economic costs and benefits of connectivity.

Previous research work by the Asian Development Bank (ADB) investigated the economic costs and benefits arising from electricity interconnection and trade between the countries of South Asia and between South Asia and the Central Asian region bordering Afghanistan (ADB, 2015). This study evaluated six existing or planned transmission interconnections between India and Bhutan, Nepal, Sri Lanka, Bangladesh and Pakistan as well as between Pakistan and Afghanistan.

The study demonstrated clear benefits, including:

- Assisting the development of hydropower potential, resulting in reduced fossil fuel use, power shortages and carbon dioxide emissions;
- Lowering of the cost of electricity through price arbitrage between countries;
- Lowering of the operating costs of integrated cross-border systems;
- Efficiency gains from increasing the scale of production; and
- Lower levels of required generating capacity due to centralized management and load smoothing.

The study estimated an annualized interconnection cost — which includes estimated capital cost of transmission projects calculated using a weighted average cost of capital of 7.5 per cent and a life of 30 years as well as operation and maintenance costs of 3.5 per cent of capital cost - totalling between $229 million and $243 million, which would realize annual benefits between $3,861 million and $4,127 million.

Separately, it is estimated that electricity market integration in Europe will provide annual savings of €12 billion to €14 billion, or €6.8/MWh of electricity consumed (ESCAP, 2016).

high marginal costs. Although they operate for relatively few hours each year, peaking plants can contribute significantly to the overall system cost. A network's *load factor* (the ratio of average to peak power demand) dictates the required contribution from peaking power plants, and system pooling – by connecting to more diverse areas of both demand and supply – reduces this need.

Similarly, the *spinning reserve* is generation capacity that is held in reserve but ready to respond very quickly if another generator suffers an unexpected outage.

Diversification of the load through interconnection effectively smooths the overall network load profile, increasing the load factor and reducing the requirement for expensive peaking plants. The reduction of imbalances also lessens the need for fast frequency responses and allows for the sharing of spinning reserve across a broader set of consumers, lowering the cost of this service.

The portfolio effect

Interconnection creates a more diverse network by incorporating a larger number of generators and broader consumer base. The technical and economic benefits of this diversification, known as the *portfolio effect*, are apparent in several dimensions:

- The substitution effect enables the system to respond to dynamic fuel prices by substituting lower-cost resources for more valuable resources in the short-term through ramping up and down different types of generating capacity;
- Coordination of scheduled maintenance across a larger number of generators reduces the system impact of generator downtime as well as costs and security risks;
- When operating as an integrated market, diverse supply options can lead to competition, improved efficiency and lower prices for consumers.

Revenue generation

The trade of regional power and ancillary services generates export value for connected countries. It is essential for those less developed countries that are rich in resources and yet require further economic development. Electricity exporters like Cambodia, the Lao People's Democratic Republic and Myanmar could see increased export earnings from export-oriented hydropower projects.

Bhutan in South Asia is earning about 20 per cent of its national revenue from the sale of hydropower to India under a mutually beneficial arrangement.

Energy security

A broad concept of concept of energy security encompasses supply reliability, accessibility, self-sufficiency, diversification of supply and demand, continuity, price stability and environmental impact. Managing these energy security issues requires not only national, but also regional approaches to be successful.

The value of power trade.

The value of trade is at the marginal cost of energy, which is usually higher than the average value of existing energy supply.

The trade is not just energy. Ancillary services — such as frequency control, spinning reserves and operating reserves — provide significant value. The overall costs of grid operation can be reduced when these services are shared across a more extensive network.

The influence of social licence.

A region's geography and history can have a significant positive impact on driving energy integration and connectivity. For example, the long history of the Silk Road has created an extensive reservoir of cross-border social capital, comprising linked histories and cultures. Some remote regions have better linkages with communities in neighbouring countries than with the central Government in their own country. These social and cultural similarities beyond border regions help create comfortable linkages and networks. In this regard, cross-border energy trade linkages can be scaled up, provided that negative impacts are mitigated and positive impacts are supported through a structure of incentives.

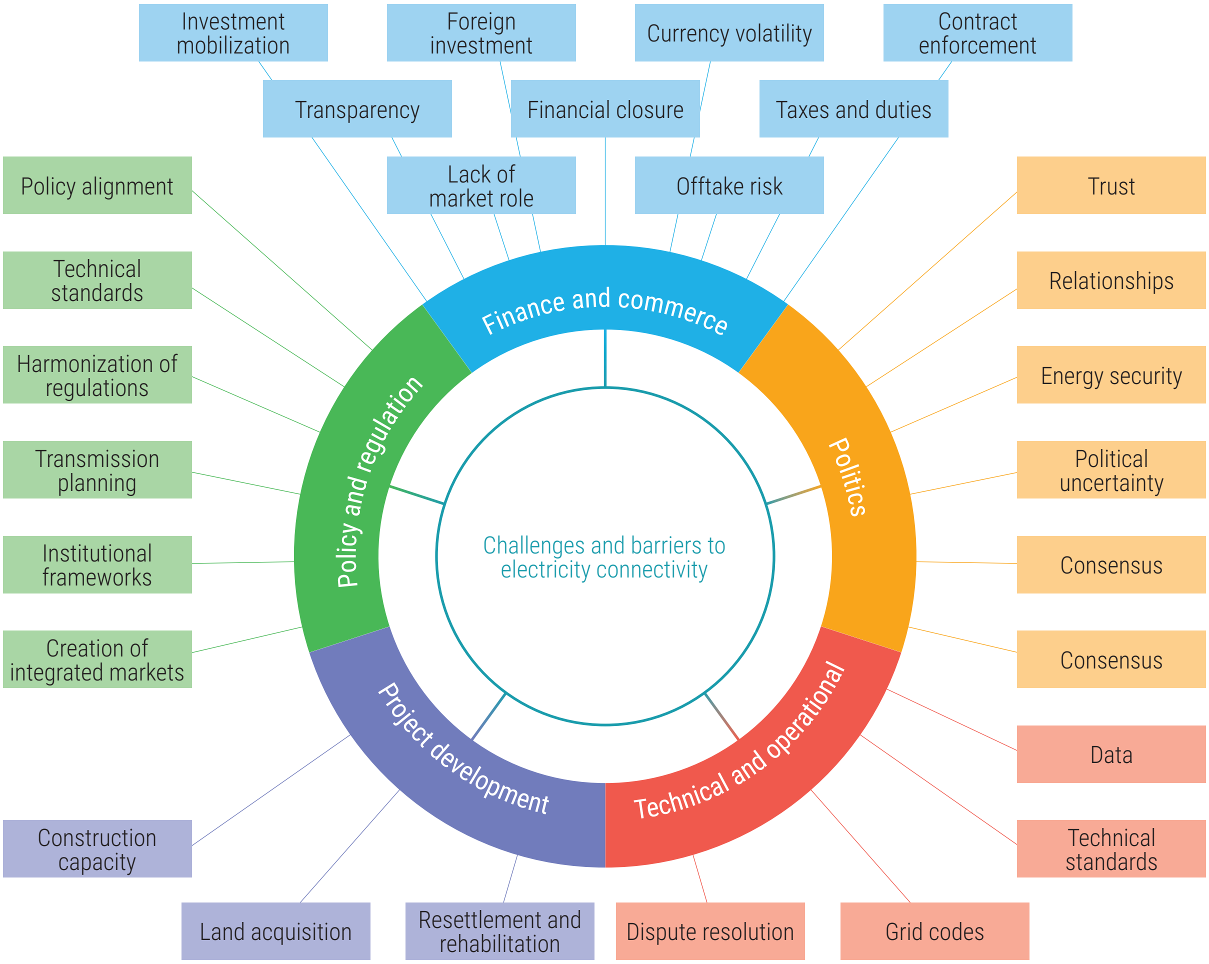
Regional power connectivity can enhance energy security through diversification of the energy supply. This reduces exposure to volatile markets and limits vulnerability to events of *force majeure* (unforeseeable forces preventing normal operations; e.g., manmade or natural disasters). A larger and more diverse generation mix improves reliability through diversity in the types of outages that occur. For variable renewable generation, the increased diversity arising from geographic distribution provides greater security. This effect applies in the event of constrained resources such as reduced hydroelectricity availability during periods of low rainfall, and for short-term variability arising from passing weather systems.

Connectivity also unlocks opportunities for sustainable energy development countries with limited domestic renewable resources can provide market demand for renewables from resource-rich countries. On the other hand, countries with under-utilized resources – such as the hydroelectricity resources of Cambodia, the Lao People's Democratic Republic and Myanmar – can use the demand arising across the border to support development of this potential.

3.2 Challenges and gaps

Cross border trade of electricity faces barriers in areas such as politics, finance, and technical and operational risks. Connectivity requires the

Figure 8   Challenges and barriers to connectivity



Source: ESCAP.

development of infrastructure, harmonization of technical and regulatory standards, coordination of policy, and the sharing of information and data. Electricity trade brings with it a heightened level of strategic importance due to its ties with a range of environmental factors, social and economic considerations, and national energy security concerns. The perceived risks – and the complexity – of electricity interconnection are thus greater than those of most commodity trade. These concerns produce a unique set of challenges and barriers that are outlined in figure 8 and discussed in the following section.

Political factors

Relationships between nations vary across the region and change over time. Where strong relationships do not exist and there is a lack of willingness to cooperate at the highest level, this presents a major barrier for implementing connectivity initiatives. Lack of trust can stem from underlying historical, political and cultural factors. Other regions of the world have demonstrated how these factors can be overcome to develop cooperation on mutually beneficial initiatives such as power grid interconnection.

Political uncertainty and lack of trust impacts energy cooperation and integration in the region in a larger way, delaying and constraining opportunities for development. Some countries hold concerns about their energy security. In others, issues with domestic vested interests create difficulties in obtaining internal consensus. Right-of-way and transit fees for connectivity introduce requirements for complex international negotiations, presenting yet another challenge that is insurmountable without political willingness on the part of the proponents.

Energy security: Many countries aspire to maintaining energy independence from a broader regional energy system, deeming self-sufficiency to be a key indicator of their long-term energy security. The pursuit of higher energy self-sufficiency is an obvious limiting factor in full integration of energy trading, and the process of integration can be perceived as the cession of sovereignty over a strategic sector of the economy.

Technical faults and disturbances can be propagated from one grid to another via their connecting transmission line, potentially resulting in cascading failures from one part of the network to another. This risk can be alleviated with appropriate technical solutions. For example, high-voltage DC transmission can provide stability benefits through direct control of the magnitude and direction of power flow.

Concerns over the security of the power supply are another factor; compared with gas and oil, electricity cannot be stored on a large scale with current technologies. Where a country is reliant on interconnection as a critical supply to its grid, the risk of disruption becomes highly undesirable.

Lack of internal consensus: Political appetite for interconnection is not only attributed to external factors. Low-cost energy resources can be either be exploited for export or retained for future domestic energy demand. Different projections of the future energy need and price lead to different weighing of the gain and cost of electricity exchange.

Domestic vested interests: Despite the potential for overall economic gain from electricity trading, politically powerful utilities – whether state-owned or private – may view a proposal for interconnection as reducing their own economic and/or political standing. These organizations are likely to resist grid interconnections and the resulting risk of diminished market share, electricity revenue or their strategic position.

Transit country motivation: In many cases, electricity connectivity is not exclusively between adjacent countries. Third-party countries may be involved as "transit countries", by providing the right-of-way for transmission lines but not engaging in export or import of electricity. If these crucial partners do not perceive there are sufficient benefits from the project, there may be an absence of political support.

Trust deficits: Despite an overall long-term trend towards globalization and the enhanced

Examples: Successful cooperation.

The European Union and South African Power Pool are two successful examples of energy cooperation and integration. In these cases, participating countries have managed to separate political and economic interests, enabling connectivity to become a key supporter for their economic development and growth.

cooperation and dialogue among countries, trust deficits still remain in many parts of the region. In these cases, there may be a lack of political and public support for proposals to build reliance on their neighbours for significant components of the energy needs. On the other hand, connectivity can be a beneficial tool for building relationships and trust among countries that expands into other spheres of cooperation, as demonstrated by the successful interconnection of power systems in other regions around the world.

High-level decision making: On top of the other challenges listed here, decision-making on connectivity is further complicated by the need for cross-portfolio engagement and negotiation within countries and within government, and a lack of prioritization when contrasted with other political issues. This can mean that high-level decision-making is more difficult than for many other issues, resulting in protracted timeframes and stalling of projects.

Policy, regulation and standards

While the electricity sector is highly regulated in all jurisdictions, each country has its own policies for transmission, expressed in the form of regulations, standards and codes. Differing frameworks can be an impediment to the technical and legal cooperation needed to facilitate connectivity. Furthermore, these variations result in different rules of market operation, and thus different investment environments that present a barrier to financial investment. Gaps in policies, regulations and standards must be identified and addressed through in-depth research and analysis at the outset of any proposition for connection.

Planning and coordination: The development of connectivity infrastructure is complex, requiring long lead times and involving multifaceted planning considerations. The success of any

Example: Political instability.

A lack of political continuity has been a factor in restraining hydropower development in Nepal. The country offers a huge hydro potential of 83 GW; but despite this fact, Nepal was ranked very poorly in terms of the quality of its energy supply until quite recently. The generating capacity of Nepal is currently about 1,200 MW, but the national grid experiences frequent shortfalls, which must be met by electricity imports from India or through load shedding.

The slow progress of hydropower development has been attributed in part to inadequate planning and investment, and delays in project development resulting from legal and regulatory inadequacies.

For example, GMR Group — a private developer from India — is leading development of the upper Karnali Hydropower Project. This single project will increase Nepal's generating capacity by 900 MW. The project was first announced in 2014, but has not yet been able to achieve financial closure due to political uncertainty. Currently, Nepal is importing up to 500 MW of power from India (b) during the dry season to meet its shortfall.

proposed development is dependent on the alignment of technical specifications. Furthermore, project finance and scheduling must be coordinated between proponent countries many months, or in some cases, years in advance.

Consistency of commercial arrangements: National grids often have their own unique commercial arrangements, security mechanisms and approaches to tariff-setting. International, multilateral and multi-directional electricity exchanges create complications, requiring some degree of consistency or agreement to enable trade. Linked to this is the need to create transparent, competitive, and balanced markets with fair pricing mechanisms.

The role of the market in the short term is an important consideration. Difficult questions arise, particularly when the role of markets in existing national grids is not yet apparent.

A pathway towards an integrated power market requires the development of model power purchase agreements, transmission service agreements and payment security mechanisms. Furthermore, model mechanisms and frameworks for the setting and payment security of transit fees are required in order to facilitate agreements for the development and operation of corridors for electricity trade.

Apportionment of costs and benefits: Large public infrastructure projects are often beset by cost over-runs or benefit shortfalls. Related to the commercial issues discussed in this chapter, this implies a need to develop approaches to the apportionment of costs, benefits and risk between participating countries.

Consumer protections: Misalignment of consumer protection policy between participating countries can create an imbalance, with the more-protected consumers receiving greater benefit than those on the other side of the exchange. These will need to be aligned or the benefits apportioned appropriately.

Harmonization of technical requirements: International experience shows the importance for transmission utilities and system operators to engage, discuss and agree on their approach towards harmonization of technical regulations and standards. Such efforts will involve alignment of metering codes, protection schemes, and frequency, voltage and thermal limits, and even information technology systems. Successful international efforts towards this end suggest that multilateral institutions such as the ADB and the World Bank have played key roles in creating platforms and forums for these discussions.

Finance and commerce

Cross-border trading of all commodities faces a range of challenges, from foreign exchange convertibility to government interference, from contract enforcement to concession agreements, and from taxes duties to dispute resolution. ESCAP (2019) has identified a range of risks that must be recognized and addressed for all types of cross-border infrastructure and which apply to electricity infrastructure, including:

- Large investment requirements and lengthy maturation cycles;
- Differing or opaque rationales, and greater political risks;

- Potentially greater foreign currency liabilities;
- Differences in regulatory and policy frameworks;
- Institutional capacity and coordination issues;
- Differing technical standards.

The mobilization of investment is also a challenge. Funding for cross-border power projects is largely sought through international financial institutions (IFIs), multilateral development banks, and contributions from participating countries. With the scale of investment required, there is a need and an opportunity for innovative financial instruments and mechanisms to deliver the funding that is required.

Barriers to investment: Some countries have lifted curbs on foreign and private sector investment on power generation, but investment in transmission infrastructure is often only open to state-owned enterprises. These tend to prioritize investment for domestic transmission line projects and many lack the financial, legal or technical capability for cross-border transmission line development.

Furthermore, the broader economic situation of some countries, and more specifically the performance of their energy utilities, creates difficulties in obtaining capital on competitive terms.

Uncertain payback mechanisms: Transmission grid projects are often capital-intensive, most of which require substantial up-front investments and usually a long construction period. Unlike many power generation projects, which are financially secured by Power Purchase Agreements (PPAs), a well-established long term pay-back mechanism for cross-border transmission lines does not exist. The main reason behind the absence of such a mechanism is that transmission line projects usually have positive externalities, with which the different parties involved have difficulty in reaching agreement on how to reimburse.

Contract enforcement: The abilities of investors and developers to enforce contractual terms – in cases where another party defaults on its contractual obligations – vary between countries. Developers are less inclined to operate where enforcement risk is high, and investors must factor the risk into the cost of financing. However, the risk can be alleviated through the development of strong contract enforcement laws that provide a fair legal framework for all parties.

Arbitration and dispute resolution: Disputes between countries can lead to temporary or permanent discontinuation of electricity supply, resulting in high financial losses and a potential threat to the national grid on one or both sides of a connection.

Considering existing and potential future relationships between participating countries, there is a necessity for strong, clearly-defined and independent dispute resolution procedures.

Currently, sellers and purchasers in cross-border trade can generally resolve their disputes based on the terms of their PPAs. Apart from amicable settlement, these may also provide for arbitration

Intergovernmental institutions, Governments, regulators and appellate tribunals need to develop transparent dispute resolution mechanisms and frameworks, and establish a common institution for resolving any disputes on cross-border electricity trade in each subregion. For example, in South Asia, the SAARC Arbitration Council has been formed to resolve disputes between member countries instead of resolving in a third country. In the long term, a unified Asia-Pacific dispute resolution tribunal may be considered as a means of resolving disputes.

in a third country, which can be very expensive and time-consuming.

Delay in financial closure: Although a project may be economically attractive, the perception of risks associated with country-specific or regional issues constitutes a problem for financial closure. The nature and degree of the risks vary from country to country, but are often related to the financial viability of buyers, land acquisition, foreign exchange convertibility, government interference, breach of contracts, concession agreements and, possibly, the seller's lack of access to transmission lines. These can adversely affect the financial viability of projects and, hence, make financial closure more difficult.

Currency volatility: In many countries in Asia-Pacific region, currency is very volatile and is subject to frequent variation, which is also a challenge. Most commodity trading can be flexibly adjusted according to the currency valuation at the time of trade, but cross-border electricity trade inherits the large sunk cost of transmission lines, bringing long-term contracts that limit this type of flexibility. Hedging instruments are available, including forex and currency swaps, interest rate swaps and forwards options, but these all increase the cost of finance due to the associated risk premium.

In addition, the agreement of a common currency for the sale and purchase of electricity can be a challenge while each country has their own preferred currency.

Taxes and duties: Unfair taxes and duties can have an adverse impact on cross-border power trade. Export tax or transit tax in multilateral trade configurations could pose a further challenge. Achieving the harmonization of relevant taxes and duties, together with minimization of uncertainty due to the potential unilateral imposition of taxes and duties, by participating countries in a cross-border power project remains a challenge.

Government interventions and subsidies: Depending on their design, government interventions can pose a barrier to new entrants across all segments of the energy sector. For example, electricity subsidies often support market incumbents. These generally take one of two forms: (a) a subsidy to end-consumers through low retail prices (consumer subsidy); or (b) subsidies to generators (generator subsidy). While the design intention is to benefit domestic consumers and suppliers, a potential importer would be concerned that a consumer subsidy inevitably transfers wealth to a foreign generator. Likewise, a generator subsidy transfers benefits to foreign consumers. Adverse effects also arise from the price distortions that are entailed, which undermine the fairness of a power market and are unfavourable to those who are unsubsidized. In addition, the presence of subsidies also results in consumer reluctance to enter an open market.

Technical factors

As noted in Section 3.1,successful interconnection requires the alignment of technical standards and grid codes, including metering codes, protection schemes as well as frequency, voltage and thermal limits.

Misalignment of technical standards and codes: Technical standards and codes play a critical role in both the development and in the operation of interconnection transmission systems. In some cases, the standards of countries either side of the interconnection may differ irreconcilably – one example, highlighted in Section 4.3, is the case of the connection between China and DPRK where AC interconnection is not possible because these systems operate at different frequencies (50 Hz in China and 60 Hz in the Democratic People's Republic of Korea) (CEC, 2018). In such situations, alignment can be achieved either through harmonization (agreement on a set of standards to be applied across both jurisdictions) or conversion (retaining different standards but ensuring compatibility and interoperability for all parties).

Weak power grid: The import of bulk electricity usually requires a strong local grid. It must exhibit certain technical characteristics, such as sufficient reactive power, system inertia and contingency reserves, to be able to ride through any transmission line outage. Likewise, the export of bulk electricity also requires strong reactive power support and good connection with the local grid. In countries that lack a strong domestic power support system, these requirements present a major technical hurdle. For example, the power grids in Indonesia and Malaysia are heavily fragmented in part because of their archipelago geography, and this structure constrains their potential for interconnection.

These situations call for investment in ancillary services, adding significantly to the cost of the proposed interconnection.

Sharing of data, learnings and experiences: Asia and the Pacific as a region has rich knowledge and experience in the energy and power sector, but this is not well-managed at the international level. Some countries have successfully implemented projects such as smart grids, energy efficiency projects, hybrid solar and wind power projects, but only share limited knowledge of the factors contributing to this success. Intergovernmental institutions often hold data on the power sector of member countries. However, this information is often incomplete or obsolete as it is not updated in a timely manner. While some national Governments maintain information in the public domain, others lack the willingness or capability to do so.

Project challenges and risk

Beyond the challenges and risk described above, transmission infrastructure projects pose particular challenges related to requirements for land acquisition, and environmental clearances.

Land acquisition: The process of land acquisition is very time consuming and potentially costly. Further, the framework and procedures for acquiring land differ between countries – a consideration that may require accounting for in the apportionment of costs and befits of the

Technology developments.

The transmission industry has delivered substantial technological advancements in the past decade. It is now possible to transmit electricity using transmission lines at an unprecedented scale and across significantly longer distances than was previously feasible.

For a given length and voltage, direct current (DC) transmission lines operate with lower losses than conventional alternating current (AC) lines owing to their different operating principles. As an added benefit, DC interconnection allows the grids on each side to be operated non-synchronously, preventing the spread of system disturbances that can lead to overall failures of the grid.

The DC transmission cables themselves cost less than AC transmission cables for any given length. Further, losses during operation are lower for DC than for AC. However, the cost of conversion stations at each end of the line — providing voltage step-up/down, AC-DC conversion, switching and control — is higher than for AC transmission. As each transmission line requires one conversion station at each end of the line, DC transmission tends to be economically more optimal for longer lines; for transmission distances over a certain "break-even distance", HVDC will provide a lower cost as compared with HVAC. Recent data from technology providers (ABB Group data; CIGRE, 2011) indicates that the break-even distance is approximately 600-800 km for overland lines and far shorter — about 50-100 km — for submarine transmission cables.

The advent of flexible high-voltage direct current (HVDC), maritime HV cable and ultra-high voltage (UHV) technologies brings new possibilities for cross-border power transmission and interconnection.

UHVDC and UHVAC is characterized by high voltages — over 800 kV — which are employed to reduce transmission losses over long distances. The technology has enabled multi-gigawatt scale transmission, a feat previously considered technically infeasible.

Maritime transmission lines, which typically use HVDC or one of its variants, do not require the construction of expensive pylons to support the cable along its length. HVDC transmission system costs are largely dictated by the cost of terminal stations (CIGRE, 2009) (relative to HVAC, which has lower terminal costs but higher marginal costs for the lines), so these lines can run for long distances at lower cost. Due to economies of scale and the technological spillover effect, the maritime solution of interconnection now finds positive prospects for deployment.

Flexible HVDC distinguishes from traditional HVDC by its capacity for active and reactive power control. The technology provides a solution for multi-terminal interconnection across borders while retaining each country's independent control over its own power system.

project, in addition to the impact on development timeframes.

Environmental clearances, rehabilitation and resettlement challenges: Environment approvals can present a significant challenge and a potential risk to the overall project. Likewise, processes for consultation, rehabilitation and resettlement of impacted communities can present a substantial challenge. Large-scale displacement may require social impact analyses/studies to ascertain the nature of interest and estimation of social impact before acquiring land and extending project timeframes, while the costs of rehabilitation and resettlement can be significant in terms of the overall project budget.

Additional challenges in the Asia-Pacific region

Communication and travel restrictions: Poor road connectivity and visa requirements can both present a barrier to worker movements needed to deliver successful connectivity projects.

Similarly, a lack of quality communications infrastructure – or simply the high cost of using the available infrastructure – can prohibit the development of agreements and plans that underpin developments.

Moving from bilateral towards multilateral trade and institutionalization: Across most of the region, electricity trading remains limited and on a bilateral basis. Bilateral experiences and learnings are demonstrating the benefits of electricity trade in terms of economic growth and optimization of energy resources.

The move towards multilateral trade will help countries to gain better access to the advantages of interconnection; this represents a stepping-stone towards an interconnected region-wide system.

Various intergovernmental institutions, donors and multilateral development banks – including the South Asia Association of Regional Cooperation (SAARC), BIMSTEC, the Economic Cooperation Organization (ECO), ASEAN, GMS, Lancang-Mekong Cooperation, World Bank, ADB, the Asian Infrastructure Investment Bank (AIIB) and the United States Agency for International Development (USAID) – are leading the work in promoting energy cooperation and integration on regional basis, while large economies including China, India, the Russian Federation and Thailand are playing a leadership role in developing frameworks for multilateral electricity trade. However, further work is needed to establish effective institutions among the member countries to coordinate policies/regulations/standards for smooth power connectivity and operation of the system. This *Institutional Dimension* of connectivity is addressed in chapter 5 of this report.

Development of an integrated capital market: Integrated capital markets – characterized by transparency and free movement of financial services and capital between countries – encourage competition, enhance innovation, attract wider participants and provide deeper liquidity. These benefits reduce the cost of capital and investment, and enable the development of capital-intensive infrastructure. On the other hand, the absence of an integrated capital market in the region has a negative impact on the ability of developers to raise finance.

As already noted above, the role of markets is an important consideration that is particularly complicated when that role is not yet fully apparent in many economies. The development of an integrated capital market is a crucial step towards financing these major investments.

4 \ Power grid connectivity at the subregional level

At present, interconnectivity and trading of energy in the Asia-Pacific region is largely bilateral. Interconnections are not numerous and are generally of low capacity. These connections were often built for the purpose of near-border trading, not with the intention of integration to create international, subregional- or regional-scale power grids.

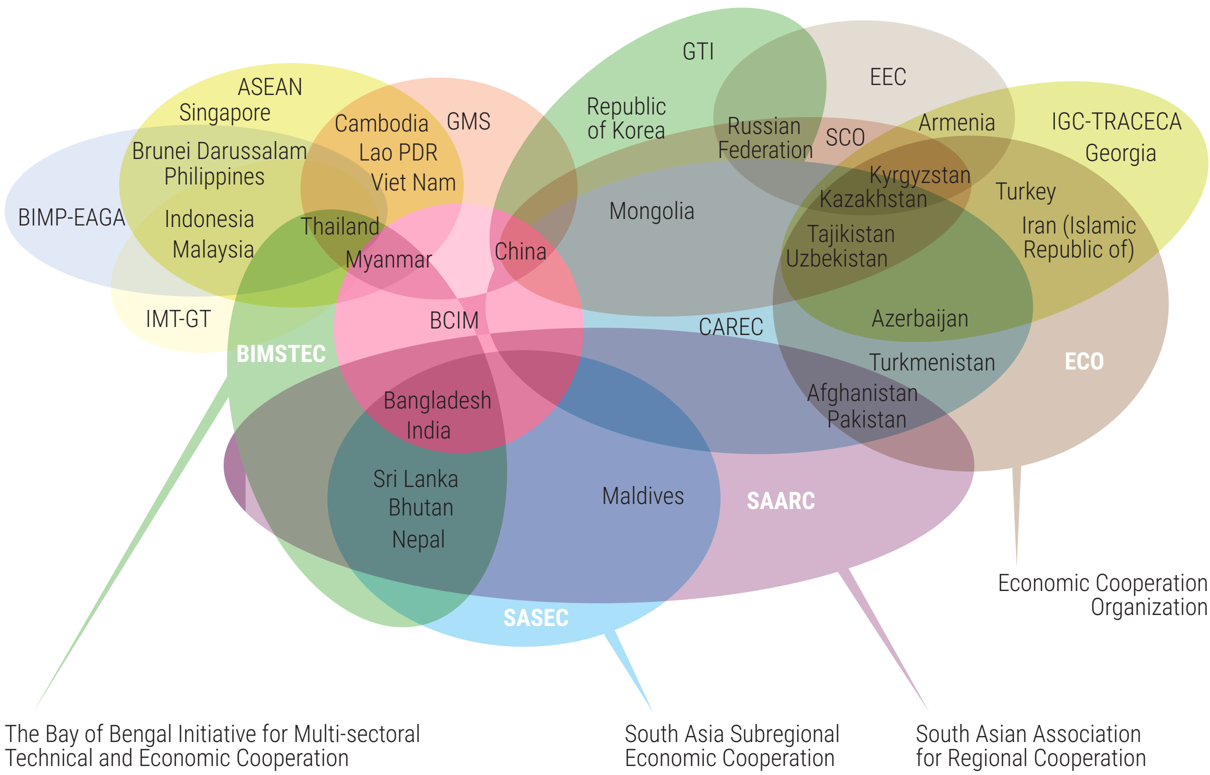
However, countries across the region have recognized the potential benefits of regional energy cooperation and cross-border electricity trade, and are working together to enhance their cooperation through various subregional forums and initiatives (figure 9).

4.1 South and South-West Asia

Despite impressive economic growth, the power sector in the South and South-West Asia subregion has not been able to keep pace, and continues to experience problems of supply shortfalls and poor quality of service. These limitations result in serious economic impacts, as indicated in figure 10, which presents the value lost due to electrical outages (estimated from a sample of affected businesses).

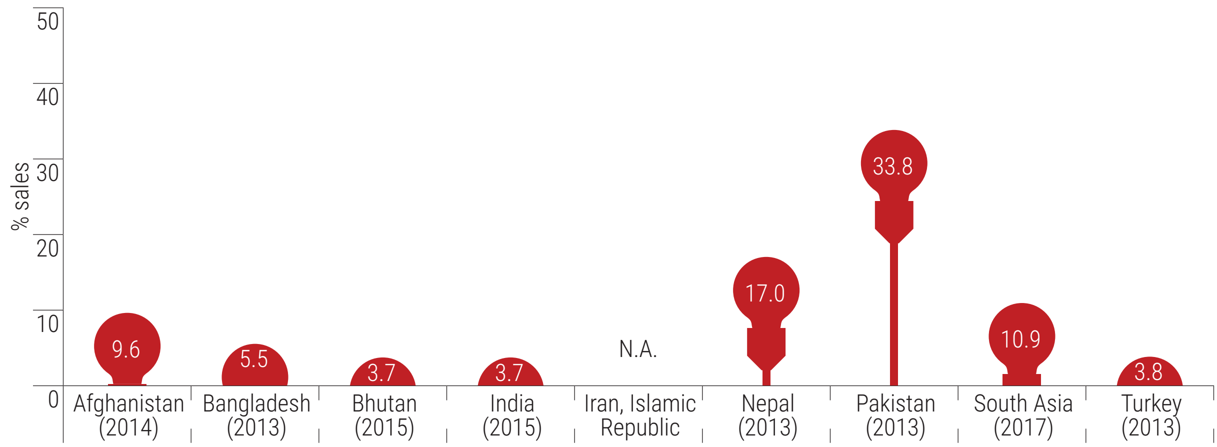
In particular, South Asia, with its diversity of energy resources and development needs, offers

Figure 9 Cooperation initiatives across the Asia-Pacific region



Source: ESCAP, 2016.

Figure 10 Value lost due to electrical outages in South and South-West Asia



Source: World Development Indicators Database, 2017.

one of the most attractive opportunities for an interconnected power system across the Asia-Pacific region. Movements towards this vision commenced as early as 1954 with an agreement to develop the Koshi hydropower project. SAARC, formed in 1985 with the objectives including the promotion of socio-economic development and support productive, has continued to develop the vision with the establishment of a Technical Committee on Energy (2000) and a specialized Working Group on Energy (2004). The SAARC Intergovernmental Framework Agreement on Energy Cooperation was signed in 2014.

South Asian cross-border electricity trade has historically been through bilateral government-to-government agreements based on case-by-case negotiations, and was primarily developed for the purpose of providing electricity to near-border activity, rather than the integration of the grids.

India is now a hub of the subregional power sector. To promote cross-border electricity trade with the neighbouring countries, multiple cross-border interconnections have been established with Bangladesh, Bhutan, Myanmar and Nepal (figure 10), and electricity is now traded with these countries to the extent of up to 3,300 MW. Bangladesh is currently connected to India through two 500 MW HVDC links of 400 kV transmission lines from Bahrampur (India) to Bheramara (Bangladesh), and a third connection with north-eastern India via a 400 kV line from Tripura (India) to Comilla (Bangladesh). Nepal shares about 21 interconnections for electricity exchange with India (mostly through the Indian State of Bihar) through 11 kV and 33 kV distribution lines, and 132 kV and 400 kV transmission lines with a total capacity of up to 500 MW. In 2016, an 11 kV distribution link between Manipur and India was established from which India exports up to 3MW power to Myanmar.

Several proposals for additional interconnection projects to augment those already in operation are being explored by India-Bangladesh Joint Technical Committees.

This interconnected system is expanding with expectations that its capacity will be doubled by 2023, while becoming more market-oriented and focused on the integration of participating grids. Estimates are that the region will require

43.2 GW of additional cross-border transmission capacity by 2036. Achievement of this goal will require further effort across the political, legal, regulatory, policy, technical, operational and market dimensions.

Recently, Bangladesh signed an MOU with Bhutan and Nepal to enable trilateral power trading, and another trilateral MOU between Bangladesh, Bhutan and India is expected to be signed soon.[3] Bangladesh has also signed MOUs with Bhutan and Nepal, opening further prospects for interconnection.

A masterplan for the transmission of power from hydropower projects in Arunachal Pradesh in the north-east salient region to other parts of India foresees the construction of a number of HVAC and HVDC lines. In view of the Right of Way constraints in the narrow Siliguri Corridor, the possibility of routing the line through Bangladesh is being explored. Bangladesh may import up to 2,000 MW as part of this arrangement.

Further afield, a feasibility study has shown the technical and financial viability of interconnecting Madurai (India) and Anuradhapura (Sri-Lanka) through a 400 kV HVDC submarine cable with a capacity of up to 1,000 MW. Another feasibility study that investigated linking India to Pakistan from Amritsar (India) to Lahore (Pakistan) is also under consideration by both Governments.

In the western part of South Asia, Pakistan and Afghanistan are connected through Central Asia and import power from the Islamic Republic of Iran, Tajikistan, Uzbekistan and Turkmenistan.

Pakistan and Afghanistan have signed agreements with Tajikistan and Kyrgyzstan to import electricity through the Central Asia-South Asia Electricity Transmission and Trade Project titled CASA-1000. The project will put in place the commercial and institutional arrangements as well as the infrastructure for 1,300 MW of electricity trade. Financial closure of this $1.16 billion transmission link has already been completed, signifying an important step toward realizing the planned Central Asia-South Asia Regional Electricity Market (CASAREM).

As a part of ECO, Turkey is well-connected to Bulgaria, Greece, Syria, Georgia, the Islamic Republic of Iran, Iraq, Armenia and the European system of transmission networks. The Islamic Republic of Iran is also connected to Pakistan and Afghanistan.

3 India-Bangladesh Joint Statement, 2017.

In Afghanistan, the Government-owned utility Da Afghanistan Breshna-Sherkat (DABS) is responsible for generation, transmission and distribution across the country. The transmission system is connected to Uzbekistan, Turkmenistan and Tajikistan though 220 kV and 110 kV transmission lines.

4.2 South-East Asia

In the South-East Asian energy sector, the coming decades will be dominated by challenges in managing the growth of energy consumption and moving away from a fossil-fuel reliant energy mix. A widening gap between supply and demand will create new risks for security of supply and affordability, leading to growing import dependence. It is estimated that ASEAN oil import dependency will increase from 44 per cent in 2011 to 75 per cent in 2035. All ASEAN members are expected to become net importers of fossil fuels by 2030, with the exception of Brunei Darussalam and Indonesia (IEA, 2019a).

Increases in the use of fossil fuels will lead to CO_2 emissions to be grown from 1446 million tons (Mt) in 2015 to 3464 Mt in 2040. (ASEAN Centre for Energy, 2017a).

The development of the subregion's vast low-carbon energy resources could address these two challenges simultaneously. Previous work has identified more than 241 GW of feasible hydropower potential, amounting to more than ASEAN's total generation capacity in 2015. Indonesia alone has more than 29.5 GW of geothermal resource potential, while South-East Asia is also highly suited for exploitation of solar and biomass energy resources, including in countries such as Singapore. Development of the subregion's low carbon energy resources could replace many planned thermal power plants without increasing generation costs. Yet even the cost-effective hydropower and geothermal resources are presently underdeveloped.

ASEAN has established itself as a pioneer in regional energy connectivity due to its political integration architecture. Strategies building on the successful realization of the ASEAN Economic Community (AEC) in 2015 envision a well-connected system driving an integrated, competitive and resilient subregion to address challenges, including energy security and a sustainable growth agenda (APAEC, 2015). The AEC Blueprint 2025 consists of five interrelated and mutually reinforcing pillars (ASEAN Secretariat, 2015):

- A highly-integrated and cohesive economy;
- A competitive, innovative, and dynamic ASEAN;
- Enhanced connectivity and sectoral cooperation;
- A resilient, inclusive, people-oriented and people-centred ASEAN; and
- A global ASEAN.

Energy connectivity is a key instrument supporting these goals. Two energy connectivity programmes – the ASEAN Power Grid (APG) and the Trans-ASEAN Gas Pipeline – are flagships in the AEC Blueprint 2025 and have been placed among the top priorities of the regional integration agenda. The ultimate goal for of the APG is interconnection across all 10 ASEAN members, with an ASEAN Plan of Action for Energy Cooperation (APAEC) 2016-2025 proposing 16 interconnection systems with the following three priority projects:

Figure 11   Interstate power grid interconnections in South-East Asia[4]

Data source: World Bank.

- System A (North System), located in the Cambodia, the Lao People's Democratic Republic, Myanmar, Thailand and Viet Nam.
- System B (South System), located in Thailand, Indonesia (Sumatra, Batam), Malaysia (Peninsular), and Singapore.
- System C (East System), located in Brunei Darussalam, Malaysia (Sabah, Sarawak), Indonesia (west and north Kalimantan) and the Philippines.

Transboundary power trade is already quite common between countries in ASEAN (see Figure 11), and in 2016 the power trade capacity reached 5.5 GW, amounting to around 2.3 per cent of the total installed generation capacity (APAEC, 2015).

Further extensions of the ASEAN Power Grid to neighbouring countries are under development or active consideration. The subregion is also connected to China under the Greater Mekong Subregion (GMS) power framework. In 2017,

4 Note that transmission lines displayed in figure 11 are those for which precise geographic data were available at the time of publication. There may exist additional interconnections, which are not presented here.

ASEAN exchanged about 51.7 TWh with Yunnan and Guangxi provinces in China via cross-border transmission lines to Myanmar, the Lao People's Democratic Republic and Thailand. Australia is actively investigating the potential of exporting solar electricity via a submarine HVDC cable to Singapore, and countries in South Asia are seeking to enhance cooperation – with energy as a priority – through the Bay of Bengal Initiative for Multi-Sectoral Technical and Economic Cooperation (BIMSTEC).

Within ASEAN, progress has so far been focused on bilateral interconnections, but the first phase of a new strategy, the ASEAN Plan of Action for Energy Cooperation (APAEC) 2016-2025, targeted development of the first multilateral connection and initiation of multilateral electricity trade in at least one subregion by 2018 (APAEC, 2015). The pilot Lao People's Democratic Republic, Thailand, Malaysia, and Singapore Power Integration Project (LTMS-PIP) will enable Malaysia to purchase up to 100 MW of electricity power from the Lao People's Democratic Republic using Thailand's existing transmission grid. It is a stepping-stone for multilateral electricity trade towards realizing the APG beyond neighbouring borders (ASEAN Centre for Energy, 2017b). For the pilot multilateral electricity trading, the Lao People's Democratic Republic, Thailand and Malaysia signed a cross-border power and transmission agreement in September 2017 (ASEAN Centre fo Energy, 2017b); on 1 January 2018, the Lao People's Democratic Republic began electricity trading with Malaysia, with Thailand as a "power wheeler" – sharing its transmission network but not purchasing or selling power as part of the arrangement.

Particular interest has been shown in tapping the hydropower potential in Cambodia, the Lao People's Democratic Republic and Myanmar for domestic use and cross-border interconnections in order to supply growing demand in Thailand, southern China, Malaysia, Singapore and Viet Nam, as a means of facilitating trade and underpinning development of a regional power market.

4.3 East and North-East Asia

Much of the North-East Asia region is rich with conventional energy resources. Looking forward, there are abundant prospects for renewable energy resource development – particularly wind, solar and hydropower potential in China, hydropower potential in the Russian Federation, and solar and wind in Mongolia. The region exhibits excellent prospects for connectivity, with a combination of local seasonal resource excesses and shortfalls together with potential for development of flexible generation capacity.

For example, flexible hydropower generation in the Russian Federation could balance variable wind and solar generation in Mongolia and northern China. During winter, a generation surplus in north and north-east China (due to a combination of strong wind, low demand and the excess generation arising from servicing of thermal demand by combined heat and power generators) could make up for the power shortage produced by Russian hydropower outage due to frozen rivers.

At present, electricity trade is primarily bilateral between the Russian Federation-Mongolia, Russian Federation-China and Mongolia-China. These interconnections were generally intended for near-border trading of electricity and most are of relatively low capacity. Most electricity trade is undertaken through bilateral arrangements and a range of bilateral intergovernmental commissions on economic and technical cooperation exist, providing reliable and government-supported cooperation channels.

A 500 kV transmission line with DC back-to-back facility connects the Russian Federation and China. The electrical interconnection between the Russian Federation and Mongolia was established more than 40 years ago as part of a larger system of interconnection, named Mir, between the Soviet Union and East European countries. The first transmission line between the Russian Federation and China came into operation in 1992 (Gotvanskij and Simonov, 2012).

Cooperation between Mongolia and the Russian Federation first commenced under the former Soviet Union when USSR-Mongolian electric power cooperation was regulated within the framework of the Council for Mutual Economic Assistance. The Council comprised East European countries, the former USSR, Mongolia and some other socialist countries. The current Russian Federation-Mongolia intergovernmental commission on trade, economic, scientific and technical cooperation now determines bilateral cooperation and regulates activities in power trading between the countries. Electric power cooperation and trading are now based on an a bilateral agreement signed in 1999, with subsidiary agreements between state-owned power companies – including an agreement between Russian Federation and Mongolian System operators on parallel operation, dispatching and technical data exchange (2008), and between Inter RAO (Russian Federation) and the Power Grid Company of Mongolia (2015). New Agreements between both government and non-government companies (Eurosibenergo, Russian Federation, and Just Group, Mongolia, 2010) consider development of Russian Federation-Mongolia power trading and power export to other countries, particularly to China.

There is a special interconnection between China and the Democratic People's Republic of Korea. In fact, this is not an interconnection in the true sense because there are no physical electric lines between two countries. Four transborder generating plants are owned jointly by China and the Democratic People's Republic of Korea. The power units are divided between the countries and are connected to operate separately — AC interconnection is not possible because these systems operate at different frequencies (50 Hz in China and 60 Hz in the Democratic People's Republic of Korea) (CEC, 2018).

Mongolia's interconnection with the Russian Federation, first established in the 1970s, includes two 220 V transmission lines, one 110 kV line and eight 10 kV lines. These are of relatively low capacity and intended for near-border trading of electricity, mostly for export of Russian electricity to Mongolia but also with capability for bi-directional power flow during periods of low demand in Mongolia.

The Russian Federation and China cooperate closely on power sector activity under the auspices of the Russian Federation -China Intergovernmental Commission on Energy Cooperation, which oversees a joint working group on cooperation in electric power. An intergovernmental agreement between these two countries on trade and economic cooperation, signed in 1992 and backed by an intergovernmental agreement on energy cooperation in 1996, forms the legal foundation of their power interconnection and trade. This was followed by agreements between power companies which now regulate technical details of power export from the Russian Federation to China.

Figure 12 Interstate power grid interconnections in North East Asia[5]

AC 110 kV | AC 220 kV | AC 500 kV

Data source: World Bank.

5 Note that transmission lines displayed in figure 12 are those for which precise geographic data were available at the time of publication. There may exist additional interconnections, which are not presented here.

The transmission network between the Russian Federation and China currently includes 110, 220 and 500 kV transmission lines: Two lines of 110 kV, one of 220 kV and one of 500 kV. The latter was put in place in 2011 with back-to-back facility (enabling independent, asynchronous management of the two grids) constructed on Chinese territory.

The Russian Federation has also formed intergovernmental commissions that oversee cooperation on electric power with the Democratic People's Republic of Korea, the Republic of Korea and Japan.

Connections between Mongolia and China have been established during the past decade and are intended for power export from China to the mining and processing facilities in the south of Mongolia. These consist of two 220 kV power lines, two 35 kV power lines and four 10 kV power lines.

Four joint China-Democratic People's Republic of Korea transborder hydropower generators, with total installed capacity of 1.6 GW have been in operation for several decades (CEC 2018). Capacity and power generation are equally divided between countries, with each country receiving 0.8 GW of capacity and approximately 3 TWh/year of electricity from the considered transboundary electric power cooperation.

Multilateral arrangements are beginning to develop among industrial, government and international partners. Institutes in Mongolia, the Republic of Korea, Japan, the Russian Federation and China have all signed MOUs and supported the completion of studies on the prospects of a North-East Asia-wide grid, Gobitec and the Asian Supergrid. (The Gobitec concept proposes production of renewable solar and wind energy in the Gobi Desert – which holds potential of around 2,600 TWh – and delivering electricity to high-demand regions via the planned Asian Supergrid connecting the Russian Federation, Mongolia, China, the Republic of Korea and Japan.) The North-East Asia Regional Power Interconnection and Cooperation (NEARPIC) forum, initiated by the China Electricity Council in 2016 and held annually in different countries of the subregion, provides an important platform for discussion of approaches and actions in promoting and developing power interconnection across the subregion.

In September 2018, President Khaltmaagiin Battulga of Mongolia proposed the establishment of an organization to formulate a comprehensive policy and prepare relevant agreements and negotiations on the North-East Asian Supergrid project with the appropriate involvement of Mongolia, the Russian Federation, China, Japan, the Republic of Korea and the Democratic People's Republic of Korea (Batmunkh, 2018). The ADB in 2019 has concluded detailed technical studies under Strategy for North-East Asia Power System Integration (NAPSI). The technical work under NAPSI examined the potential for developing large-scale solar and wind power and the interconnection needed to neighbouring countries to export this energy. These studies indicate that renewable energy capacity of up to 100 GW could be developed for export to the neighbouring counties at a lower cost than that of current supplies. To realize this project the study recommended that a subregional coordination body be established to oversee the process of interconnection.

4.4 North and Central Asia

The power systems of the Central Asian Republics (CAR) were largely designed under the former Soviet Union, taking into account the natural advantage of available fuel and energy resources and seasonal electricity exchange across the subregion. As a result, they feature a high degree of cross-border interconnection (figure 13).

Climate and natural conditions of the region provide ample opportunities for the use of renewable sources, which play an important role in diversifying the energy balance, energy security and reducing harmful emissions into the atmosphere.

Uzbekistan has good solar, hydropower, wind and geothermal energy resources as well as biomass. Assessments indicate that the technical potential of renewable energy sources in the Republic of Uzbekistan is 180 million tons of oil equivalent, or more than three times its annual need for energy

Kazakhstan has created a legislative framework and designated target indicators to develop a green economy. The total installed renewable generation capacity will be 1,700 MW in 2020, of which wind farms account for 933 MW and solar power plants 467 MW.

In Tajikistan, hydropower dominates the power generation mix at 95 per cent of domestic generation. Together with the Kyrgyzstan, Tajikistan will export surplus capacity to Afghanistan and Pakistan, using the Central Asia-South Asia power project (CASA-1000) once completed.

Kyrgyzstan has a high potential of renewable energy sources, which is estimated at 840 million tons of oil equivalent. The main sources are solar energy, small river energy, wind energy and geothermal energy.

In Armenia, the economically feasible wind energy potential is estimated at 450 MW with electricity generation of 1.2 billion kWh per year.

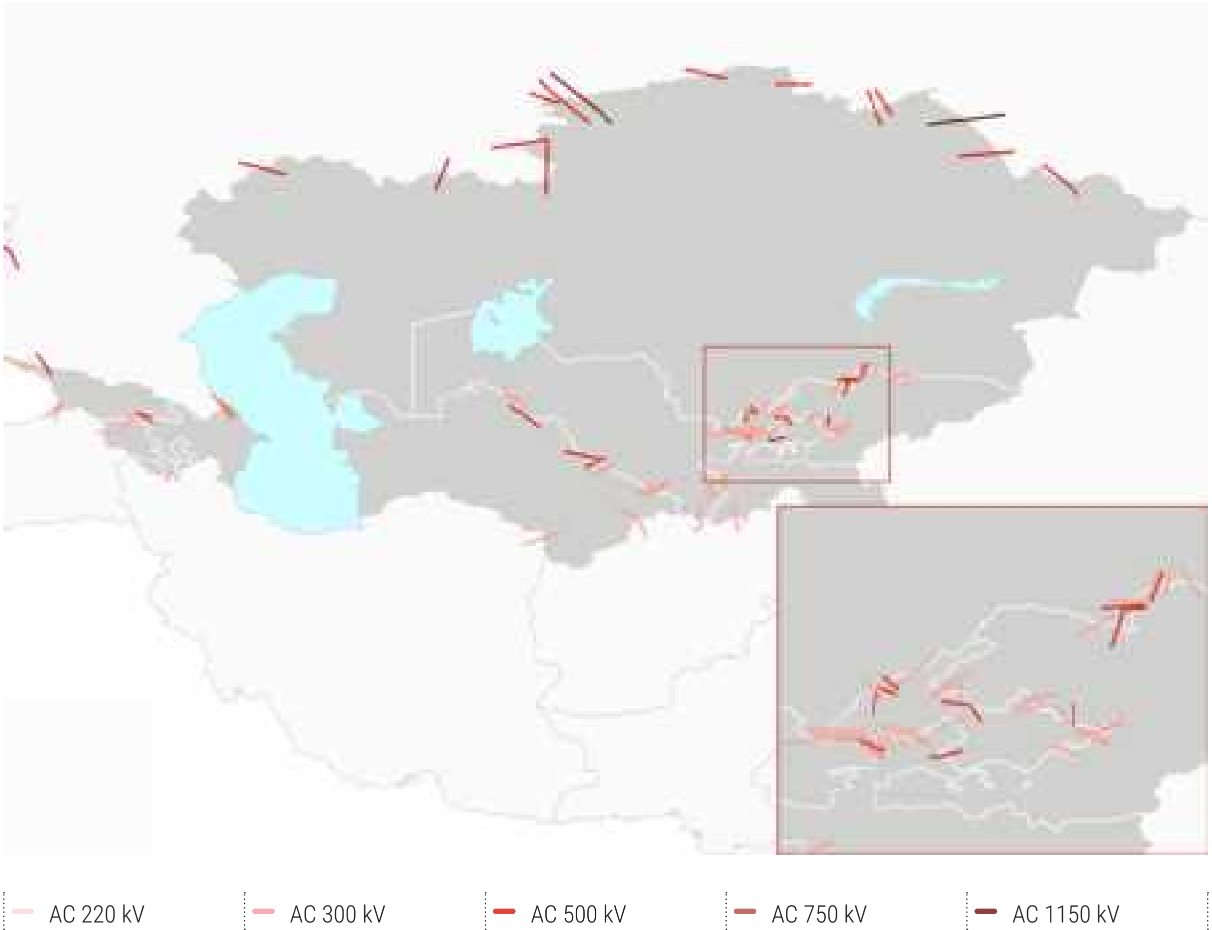
In Georgia, the total potential of solar energy is estimated at 108 MW, and about 300 rivers have been identified as having hydropower potential. One study has identified the technical feasibility of a single hydropower plant with a total capacity of 15 GW.

Turkmenistan, which has large hydrocarbon reserves, has plans for the development of renewable energy, mainly solar.

The bulk of Afghanistan's domestic electricity needs are supplied by connections with Tajikistan, Turkmenistan, Uzbekistan and the Islamic Republic of Iran. Afghanistan is connected to the Central Asia power system according to an island scheme; standards and codes are not yet harmonized, so the islanding arrangement ensures the stability of electrical conditions with minimal risk to the supplying side. A major infrastructure project is planned for the construction of a Surkhan Puli-Khumri transmission line, which will connect Afghanistan to the UPS of Central Asia. This will increase the supply of electricity from Uzbekistan to Afghanistan by 70 per cent.

In the regional United Energy System, built using 220-500 kV electrical networks, the thermal power plants of Kazakhstan, Turkmenistan and Uzbekistan are combined with hydropower

Figure 13 Interstate power grid interconnections in North and Central Asia[6]



Data source: World Bank.

stations of Tajikistan and Kyrgyzstan. Historically, this allowed Tajikistan and Kyrgyzstan to export electricity in the summer when their hydropower systems operated with maximum load, and to import electricity in the winter, when there was a shortage of energy. Output from hydropower stations in Tajikistan and Kyrgyzstan was coordinated in accordance with the primary task of meeting the irrigation needs of the downstream countries (Uzbekistan, Turkmenistan and Kazakhstan). As a result, electricity output from these generators was of secondary consideration to irrigation needs.

Following the achievement of independence with the dismantling of the Soviet Union in 1991, the CAR countries began to pursue a policy of energy self-sufficiency. Rising energy prices led to a commercial push to export fossil fuels outside the CARs, leading to a collapse of the earlier energy exchange schemes. This, along with the introduction of national currencies, led to an initial stage of barter-based energy exchange schemes. The intervening period has seen situations in which individual countries produced electricity using domestic fossil

6 Note that transmission lines displayed in figure 13 are those for which precise geographic data were available at the time of publication. There may exist additional interconnections, which are not presented here.

fuel resources instead of mutually beneficial imports from neighbouring countries. Under these conditions, the volume of electricity trade decreased from 25 TWh in 1990 to 6.5 TWh in 1995.

In more recent years, Tajikistan has frequently discharged large quantities of water for irrigation purposes in the summer during periods of low demand for electricity, resulting in electricity supply shortfalls in Tajikistan and Kyrgyzstan during winter. System operators in Tajikistan and Kyrgyzstan are now working to improve and move their focus away from irrigation and towards hydropower, and to align the energy regime with the prevailing power demand during winter.

Another recent shift has been seen in Uzbekistan, where changes in the banking sector in 2017 have radically changed relations with neighbouring countries. The intervening period has seen an increase in energy trade due to Uzbekistan's importing cheaper hydropower from Tajikistan and Kyrgyzstan, in order to prevent idle discharge of water, and in energy supplied from Turkmenistan to Uzbekistan.

Intergovernmental relationships in the subregion are primarily bilateral. Bilateral commissions on economic and technical cooperation provide reliable and state-supported channels of cooperation, creating a legal framework for cooperation on the basis of which several MOUs and agreements have been made between countries of the subregion. Intergovernmental commissions on trade, economic and scientific and technical cooperation are also prominent supporters of bilateral cooperation in the energy sector. These commissions support harmonization of regulations together with cooperation on power plant and transmission infrastructure development, fuel supply, energy conservation, equipment procurement and environmental protection.

The Coordination Dispatch Center Energiya (CDC) is a multilateral institution that was established in 2003 as a non-governmental, non-profit organization overseeing power transmission activities of Kazakhstan, Uzbekistan, Kyrgyzstan and Tajikistan.

Another multilateral arrangement is the Electric Power Council of the Commonwealth of Independent States (CIS), consisting of all Central Asian countries and Armenia. The Electric Power Council was established in 1993 with key functions including supporting the integration of the electric power industries of CIS members. Its work includes the harmonization of standards and codes across the subregion together with making sure that appropriate legal and commercial conditions are in place to ensure the success of power system cooperation. The strategic objectives of this cooperation are defined by regulatory acts, and about 50 subsidiary documents have been adopted that regulate the parallel operation of the power systems within the framework.

The Electric Power Council of the CIS and the United Nations Economic Commission for Europe have signed an MOU providing for cooperation in the development of interregional collaboration on energy, energy security and sustainable energy development.

New perspectives are emerging for the development of energy cooperation in the region, and a wide number of interconnection activities are currently in play:

- The power grids of Uzbekistan and Tajikistan have agreed on a scheme for connecting the networks with the creation of another 500 kV ring through the power system of Tajikistan, which will significantly increase the opportunities for regional power trade;

- The connection of the Turkmenistan power system will also provide opportunities for the expansion of electricity transit services through the electrical networks of the countries of the region;

- Taking into account the potential for generating electricity by hydropower stations of the Tajik energy system and eliminating idle discharges from reservoirs, it is expedient for Kazakhstan, Uzbekistan and Turkmenistan to actively participate in the decision-making process on electricity supply in the framework of the CASA-1000 project together with the World Bank, USAID and other beneficiaries

- In accordance with the agreement on the construction of a connecting line between Armenia and Georgia, signed on 26 January 2010, Georgia will build part of the 500 kV line to the state border, in turn, Armenia – the rest of the OHL from the state border to Ayrum with DC injection (back-to-back) at 700 MW in Ayrum. During 2023-2028 cross-border links between the Georgian and neighbouring energy systems will be significantly expanded, which will allow exchanging the capacity of 1,400 MW with Turkey, 1,600 MW with the Russian Federation, and 700 MW with Armenia. There is already an opportunity for the exchange of 700-1,000 MW capacity between the energy systems of Georgia and Azerbaijan

- Kazakhstan's power sector specialists see the possibility of further strengthening the connection between the north and the south by building a direct-current line, which, by injecting power directly into the deficient part, will significantly improve the reliability of energy supply to consumers in the south of the country

Looking forward, the bilateral arrangement structure will be strengthened and will provide a reliable and state-supported channel for cooperation in the energy sector. In some cases, the transition from a bilateral form to a multilateral form of cooperation and agreements will allow the countries of the subregion to increase the reliability and economy of the energy systems.

5 \ The institutional dimension of power grid connectivity

5.1 Introduction: Institutional frameworks for regional power connectivity

There is a broad consensus on the need for the development of institutional frameworks able to overcome the challenges and gaps for regional power connectivity (Estevadeordal, Frantz, and Nguyen, 2003). These regional institutions can be of different types of "arrangements and organizations, ranging from ad hoc and informal forums that lack an organizational core, to formal standing bodies that serve a particular purpose" (ADB, 2010). Including informal discussion groupings and fora, or more established ad hoc working groups and inter-country meetings, and even supranational organizations with authority in specific areas. In general, these institutions serve as a bridge between national and regional interests, so as to ensure a solution satisfactory to all participating countries.

Regional power connectivity together with other types of transboundary infrastructures, such as transport and telecommunications, constitutes a new type of regional cooperation. This builds upon broader experiences in political and economic integration. In contrast to these two forms, cooperation in the infrastructure sector is considered to be better placed to endure the arising discrepancies between countries (Tomassian, 2009). However, the development of institutional frameworks is still required to

Table 1 Overall stages of the institutional development for regional power connectivity

Stage 1	Stage 2	Stage 3	Stage 4
Limited integration	Moderate integration		Deep integration
Only country-to-country trade is possible.	Power trade including also the possibility of utilizing a third country network.	Interconnectors for cross-border trade are built. Actors other than national utilities can participate.	Regional competitive market.
GMS, SAARC, CAREC	Lao People's Democratic Republic, Thailand and Malaysia Power Integration Project (LTM-PIP).	Central America Regional Electricity Market (MER), Southern African Power Pool (SAPP).	Nord Pool, Iberian Electricity Market (MIBEL).

Sources: ADB, 2008 and ESCAP, 2018.

drive and operationalize agreements between different Governments.

The institutional development must adapt to a gradual process of integration (table 1), from cooperation or coordination to integration (World Bank, 2011). Regional power connectivity usually starts without the creation of new formal institutions. In many cases, the expansion of national power grids to the borders of countries will allow utilities to establish small-scale interconnections, often at the distribution level for the mutual support in cases of necessity. There are also cases of transboundary power trade to supply electricity to border towns isolated from their national grids (China-Myanmar, Myanmar-India and Lao People's Democratic Republic-Thailand provide good existing examples). The development of large-scale hydropower dams is also one of the starting points for power trade. This can be in the form of bi-national power plants on shared rivers (e.g., the Itaipu dam between Brazil and Paraguay) or jointly developed projects with an electricity trade agreement (e.g., hydropower projects in the Lao People's Democratic Republic with an export contract with Thailand). As the integration deepens, the need for regional institutions becomes more urgent. In order to support this gradual process, institutional arrangements are "important for formulating strategies, defining goals, developing processes, implementing plans, measuring progress, making mid-course corrections, bringing together and managing resources, and building capacity" (ESCAP, 2016).

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5.2 Institutional functions for regional power connectivity

The analysis of regional power connectivity as a type of regional public good helps to create a better understanding of the role that institutions play in the cooperation process (Andrews-Speed, 2011; Perry, 2014; and Holzinger, 2000). However, it is also important to note how the contribution from each party or country affects the overall level of good provided; that is, the production function or aggregation technology (Hirshleifer, 1983). These can be a summation, weighted sum, weakest link, or best shot as explained in table 2 (ADB, 2018; Sandler, 1998; and Arce and Sandler, 2001). Hence, the role of institutions is to help in increasing that level and consensus-building approaches are required.

As noted in chapter 3, a lack of political will is a common issue highlighted as the main obstacle for the development of regional power connectivity. Governments commonly consider the security of the electricity supply as a strategic policy target. The process of integration can be perceived as a sovereignty cession over a critical sector. The need for a shift from national to regional mindset is one of the pre-requisites for functional regional power trade (Olmos and Pérez-Arriaga, 2013). For that, institutions are also important in the process for aligning regional and national goals.

On the other hand, regional power connectivity has also been pointed out as a promising element to foster cooperation between countries (Kammen, 2015). Indeed, there are cases where the power trade was possible even though the political climate was adverse (Oseni and Pollitt, 2016). In Asia and the Pacific, the GMS is a paradigmatic example of a regional integration initiative effectively seeking peace dividends (World Bank, 2008). Similarly, in Latin America, the SIEPAC project was launched in the aftermath of the Esquipulas Peace Agreements, at a time when political division and confrontation in Central America was at a very high level. Building on the success of the SIEPAC project, Central American countries have expanded this cooperation to other areas through the Mesoamerican Project. All these experiences have led to the conceptualization of a silent physical integration that continues even when political and economic cooperation is not possible (Tomassian, 2009). While not in the power sector, the Indus Water Treaty between Pakistan and India represents another example of cooperation in infrastructures that endures political and economic conflicts (Alam, 2002).

Table 2   Typologies of regional public goods problems

Aggregation technology	Definition
Summation	The overall level of public good equals the sum of country contributions
Weighted sum	Each agent's contribution can have a different additive impact on the overall level
Weakest link	The smallest effort determines the public good level
Best shot	The largest effort determines the public good level

Source: Arce and Sandler, 2002

Table 3 Overview of institutional functions for regional power connectivity

Aspect	Institutional functions
Political	Mobilizing and granting long-term political commitment.
	Coordination with other regional initiatives.
	Trust building among member countries.
	Development of interfaces between political and technical levels.
	Balancing regional and national interests.
Policy and regulatory	Coordination and harmonization of policies and regulations.
	Facilitation the development of a common set of regulations (regional regulatory guidelines).
	Facilitation of data and knowledge sharing.
	Coordination with national regulators.
Technical	Information-sharing mechanisms.
	Ensure smooth coordination between regional and national rules.
	Regional harmonization of grid codes and technical standards.
	Security of systems, such as cybersecurity.
Economic and financial	Assessment and sharing of benefits/costs and pricing arrangements (e.g. wheeling charges/transit fee mechanism).
	Investment-friendly framework for construction and operation.
	Facilitation of transboundary PPAs (including the development of model PPA/TSA) and/or electricity markets.
	Preparation of regional power development plans.
	Promoting open market access.
Social	Benefit-sharing with and protection of affected local communities.
	Promotion of spillover cooperation initiatives.
Environmental	Special consideration to transboundary impacts and sharing of benefits.
	Addressing environmental impacts in natural borders.
	Facilitating the development of common set of environmental standards.
Legal	Securing rights of way.
	Enforceability contracts and conflict resolution mechanisms.
	Coordination of all related regional agreements with national legal systems.

Sources: Author, based on dimensions from (UN-DESA, 2006), and expert insights.

The ability to secure a robust and reliable transboundary transfer of electricity and its smooth integration into national mixes is an essential element. In Section 3.2 noted the risk of fault propagation across interconnections; in cases of deep integration, the failure of a power plant in one country could have snowball effects on other countries, affecting their supply and even ending in a regional blackout. In 2019, a nation-wide blackout in Argentina affected neighbouring Uruguay as well as some parts of Paraguay and Chile (BBC, 2019; Politi and Krauss, 2019). In 2003, a failure in an interconnection between Switzerland and Italy triggered a cascade effect that ended in causing a nation-wide blackout in Italy (UCTE, 2004). Coordination between national electricity operators and regulators is essential to addressing the possible weaknesses that can come from international interconnections.

Regional power connectivity is intrinsically multi-dimensional. Hence, institutional functions must cover multiple dimensions. Table 3 provides a summary of the findings from a desk-based literature review as well as inputs from regional experts and policymakers. The following subsections provide further details of each.

Political

The most immediate role for institutions is to convey to political actors the merits of cooperation so as to maintain the required support. Progress of the connectivity will be stagnant if Governments perceive the cooperation as a zero-sum game rather than a win-win situation (Ghate, 2011). Regional fora and summits also provide opportunities to highlight the benefits of the cooperation programmes in relevant matters for member countries.

1. Mobilizing political will and granting long-term political commitment. Regional power connectivity is a long process that is likely to require commitment from different national administrations. For that to occur, broad

Examples of high level government commitment at the subregional level:

- Countries in South and South-West Asia and South-East Asia are following a strategic approach of creating intergovernmental institutions and associations, facilitating high-level commitment towards energy cooperation and electricity connectivity. The agreements have resulted in the strategic enhancement of connectivity and trade of electricity;
- The ASEAN Plan of Action for Energy Cooperation (APAEC) is an agreed plan proposing 16 cross-border interconnections; in 2019, ASEAN countries already have a trading capacity of more than 5.5 GW (APAEC, 2015);
- In South and South-West Asia, more than 3,500 MW is already being traded, and this is expected to double by 2021-2022.

Example: Building consensus and trust.

To promote energy cooperation in the South Asia region, the South Asia Association of Regional Cooperation (SAARC) established a technical committee on energy in 2000. In 2004, SAARC published its vision for the SAARC Energy Ring and Market for Electricity, which proposed connecting India, Pakistan, Bangladesh, Sri Lanka, Nepal, Maldives and Bhutan.

In November 2014, member countries signed the Agreement for Energy Cooperation (Electricity). Despite these efforts, this agreement has still not been ratified by all member countries.

However, four countries within SAARC — Bangladesh, Bhutan, Nepal and India — have developed successful cross-border electricity trading arrangements in the eastern part of the South Asia subregion, almost exclusively under bilateral arrangements. The development of mutual trust among the member countries is a key step in promoting energy cooperation and integration in the region.

support is needed to be fostered in each member country. National utilities and other technical bodies, which are likely to be more consistent across the time, are important to ensuring the national benefits from the project and to keeping the commitment from new Governments to extend their support to the integration process. Therefore, keeping regional ownership is essential through participation by member countries' organizations.

2. Coordination and trust-building. Power connectivity in Asian subregions has usually been under the umbrella of broader initiatives for regional cooperation. Transport, together with energy, is the most common, but can also include others such as trade, telecommunications, health, food, environment, education and tourism. Furthermore, there are cases in which a country is participating in more than one initiative. For that, it is important that participants in ad hoc groups can ensure the coherence between the actions being promoted.

Neighbouring countries' relations can be strained for a variety of reasons. From historical rivalry to more recent economic or political disagreements, these may affect the evolution of cooperation agreements in other areas. For

International organizations as honest brokers for regional power connectivity and a role for academia on track II diplomacy channels.

The need for a change from national to regional mindset is commonly considered as one of the key barriers to regional power connectivity. Indeed, the robustness and resilience of the regional interconnection will greatly depend on that. However, countries may find it difficult to make such a move towards regionally-oriented investments and policies.

International organizations can play such a role, as honest brokers. Without doubt, the financing provided by global and regional development banks and partners is essential for many countries in the Asia-Pacific region. However, these stakeholders can play an even more central role in building trust and promoting effective coordination based on their accumulated social capital from member countries and communities (ADB, 2018). Likewise, international institutions such as ESCAP can be instrumental as "neutral and honest broker that facilitates effective negotiations between the large and small economies based on the emerging architecture for new corridors of prosperity; and fosters consensus and legal agreements for regional connectivity" (Akhtar, 2014).

The ADB has been the spearhead in promoting regional infrastructures in Asia and the Pacific, and the organization's role as an honest broker is widely acknowledged. The promotion of Regional Cooperation and Integration (RCI) became a core specialization under the ADB's 2020 strategy, and the most recent 2030 strategy also includes RCI as a key operational priority. This has clearly been the case under the GMS Programme, in which the support from ADB was instrumental in fostering collective action in a time of complex relations between participating countries.

International organizations as honest brokers for regional power connectivity and a role for academia on track II diplomacy channels.

Furthermore, ADB is the secretariat of several regional initiatives that include power connectivity as a key objective. This includes the Central Asian Regional Economic Cooperation (CAREC) Programme, the GMS Programme, and the South Asia Subregional Economic Cooperation (SASEC) Initiative. The ADB also plays major role in the Indonesia-Malaysia-Thailand Growth Triangle (IMT-GT), and the Brunei Darussalam-Indonesia-Malaysia-Philippines East ASEAN Growth Area (BIMP-EAGA).

This role of honest broker is played by many other institutions. For example, the World Bank has incorporated regional integration as a key pillar for numerous strategies across the globe. In the Asia-Pacific region, the World Bank has been collaborating with countries and other donors to support most of the regional power connectivity actions to date. The CASA-1000 project is a good example of such collaboration with others including the Islamic Development Bank, USAID, United States State Department, United Kingdom Department for International Development (DFID), and the former Australian Agency for International Development (AusAID).

In addition, academic and research communities provide alternative mechanisms for track II diplomacy. In North-East Asia, the Asia International Grid Connection Study Group — established by the Renewable Energy Institute in Japan — has been conducting research on how regional power connectivity could bring benefits to Japan (Renewable Energy Institute, 2018 and 2019). In South Asia, USAID initiated the South Asia Regional Initiative for Energy (SARI/EI) programme in 2000 with scope on Afghanistan, Bangladesh, Bhutan, India, Maldives, Nepal, Pakistan and Sri Lanka. The current phase of this initiative is being conducted by Integrated Research and Action for Development (IRADe). There are also several examples of purely academic networks that conduct research on regional power connectivity and their conferences, such as the Greater Mekong Subregion Academic Research Network (GMSARN), which provide platforms for knowledge sharing between academic and policy makers.

that, it is important for member countries to ensure that regional power trading will not be affected. However, electricity trading is relatively different from other energy trading (Renewable Energy Institute, 2019). For example, electricity is difficult to store, so (unlike fossil fuels) it cannot be easily traded-on; transmission lines represent substantial sunk costs, so stakeholders are reluctant to reduce their utilization. Regional institutions must develop appropriate mechanisms to reduce such concerns.

Regional optimization is a basic rationale for promoting the integration of electricity systems on a regional scale. However, regional optimization does not necessarily provide a similar marginal gain for all participating countries. Indeed, it can also be possible that they will find it less advantageous than the status quo.

However, in order to avoid the creation of such a situation, it is important to consider a balance between "winners" and "losers", and to allow for the development of nationally acceptable solutions for every country.

3. Development of interfaces between political and technical levels. Connectivity agreements between countries necessarily involve political and technical discussions. These will be in parallel most of the time. The coordination between those two levels is, therefore, an essential element. The development of fora and other opportunities for science/policy communication can facilitate this process.

Policy, regulation and standards

The regional regulatory process may require numerous changes and interferences in national regulatory frameworks. The consequences of this at all levels (political, economic, legal and social) increase the complexity and is likely to delay progress. For these reasons, regional regulatory fora can have an important role in driving the process over long periods.

1. **Coordination and harmonization**. Technical standards and regulatory frameworks usually differ between countries. This is particularly true for the Asia-Pacific region, where the electricity sectors of countries are at very different stages of development and deregulation. The most basic role for these fora is to facilitate the sharing of this information and foster the development of coordination mechanisms between countries.

2. **Facilitating the development of a common set of regulations** (regional regulatory guidelines). A common set of regulations will be needed in order to realize a truly regional electricity market. This is not necessarily the near-term or even medium-term goal for every subregion. Nevertheless, this process for designing common regulations from within the region can bring other benefits in terms of transfer of best practices.

A supranational regional regulator with oversight capacities over the national systems can increase the security for all actors involved in electricity trade through higher clarity of rules and sanctions. However, this may not be a politically acceptable solution in many situations. Even without that, national regulators require timely information on the developments in the power trade and changes at the country level that may have broader implications regionally. Associations of regulators foster the harmonization of the actions between all the national regulators.

3. **Sharing knowledge and data**. The development and operation of the regional power trade rely on effective mechanisms for sharing the data of the systems. A regional centre can be established with

Examples: European, South African and Western African Power Pools.

The European Power Pool, South African Power Pool and Western African Power Pools are good examples of successful alignment of policies, regulations and standards through the creation of forums to enable discussion among policy makers and regulators across the participating jurisdictions. These cases demonstrate the potential that arises from cross-cutting of regulations for smooth regional interconnectivity.

Examples: Associations of Electricity Regulators.

Each country has its own system for the regulation of electricity, based on domestic requirements. For multilateral electricity trade, it is important to institutionalize the process of coordination of regulations by enabling regulators to develop a harmonized set of regulations for cross-border electricity trade. International experience has shown that the formation of an association of regulators in the region could be a successful pathway to achieving this alignment.

In South and South-West Asia, countries have taken the important decision to constitute a working group of national regulators under the South Asia Forum for Infrastructure Regulation (SAFIR). Similarly, ASEAN has created the Heads of Power Utilities and Authority (HAPUA). These forums have facilitated discussions around the cross-cutting of regulations, capacity-building and knowledge sharing, resulting in a move towards a common understanding of, and approach to connectivity and electricity trade.

this responsibility. However, in some cases, this might include further complexities due to the sensitivity of the information; therefore, alternative approaches should be developed through regional discussions. A simple solution in such cases is to split the responsibilities of regional institutions between different countries as a means to increasing interdependence. This approach was successfully applied in Central America, where the operator, regulator and owner of the system are each in a different country.

GMS institutional development.

The GMS is one of the most advanced examples of regional power connectivity in the Asia-Pacific region and, as such, it provides a good perspective of the long process required and the institutional development associated. The multi-sector programme was launched under an initiative of the ADB in the early 1990s and has received support from ASEAN. Indeed, it is one of the most representative world cases of interlinkage between regional cooperation and infrastructures development. A key initial objective for the programme was indeed to foster collaboration and mutual support between countries in a region emerging from the Indochina and Cold Wars.

Energy has been one of the priority areas for the programme since its inception. The programme has evolved to include several areas for cooperation, but the 45 MW Xeset project was the precursor of the GMS programme. The relatively small project was the first realized with ADB support in the Lao People's Democratic Republic and included a power trade agreement with Thailand. Then, at the first and second GMS ministerial meetings or conferences, the countries outlined a list of priority interconnection projects that will serve the foundation for the first regional indicative master plan.

A breakthrough was achieved in 1999 with the adoption of the Policy Statement that led to the signing of the Inter-Governmental Agreement (IGA) during the first GMS Summit of Leaders in Phnom Penh. This reinvigorated the cooperation process at the region-wide level. The Regional Power Trade Coordination Committee was established soon after, with the task of supervising the further developments. It was also in charge of drafting the Regional Power Operating Agreement that set the well-known four stages process for the GMS power connectivity:

- Stage 1: One-way power sales under a power purchase agreement from an independent power producer in one country to a power utility in a second country, using a dedicated transmission line;

- Stage 2: Trading between two countries, initially using spare capacity in dedicated stage 1 transmission lines, and eventually using other third-country transmission facilities;

- Stage 3: All countries interconnected with 230-500 kV lines will introduce centralized operations with a regional system operator that will facilitate third-party participation in trading (entities other than generators/sellers and utilities/purchasers); and

- Stage 4: All countries accept legal and regulatory changes to enable a free and competitive electricity market, with independent third-party participation.

Since then the nearly three decades of experience in regional power connectivity in the GMS has shown an evolving institutional framework (figure 14). The main institutions created in this time have been:

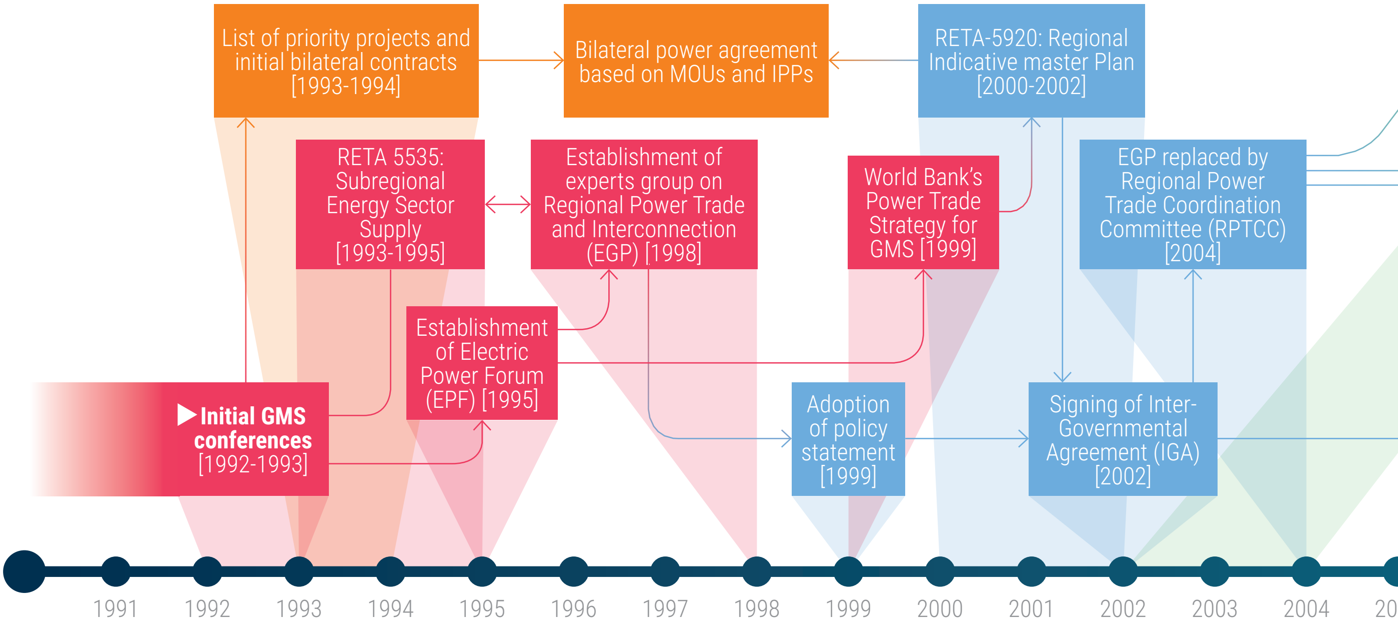
- **Electric Power Forum** (**EPF**). Established in April 1995, this body oversaw the initial works to foster regional power connectivity in the GMS. Each country was involved with two representatives, a senior official from each Government and another from the national utilities. The EPF adopted the Policy Statement on Regional Power Trade in the GMS in October 1999, that led to the signing of the intergovernmental agreement in November 2002. The EPF met eleven times until its replacement by the SEF in 2004;

- **Expert Group on Regional Power Trade and Interconnection** (**EGP**). Established in 1998 by the EPF. The EGP met nine times until it was dissolved and replaced by the RPTCC in 2003 after the signing of the IGA;

- **Subregional Energy Forum** (**SEF**). Established in 2004 with the intention of expanding energy cooperation in the region. This roadmap was approved in a special SEF session in 2009, including four strategic objectives for the sector up to 2022: (a) enhancement of access to modern energy to all sectors/communities; (b) development/utilization of low carbon, renewable domestic resources while reducing oil dependency; (c) improvement of regional energy cooperation and security; and (d) promotion of private participation in GMS energy development.

- **Regional Power Trade Coordination Committee** (**RPTCC**). Established in 2004, it has become the main institution for GMS power connectivity. The RPTCC is composed of representatives from ministries and energy departments of each country. It has met

Figure 14 Overall view of the GMS Power Group process



Sources: ADB, 2012 and 2016; Chen and Zhu, 2016; Del Barrio-Alvarez and Horii, 2017.

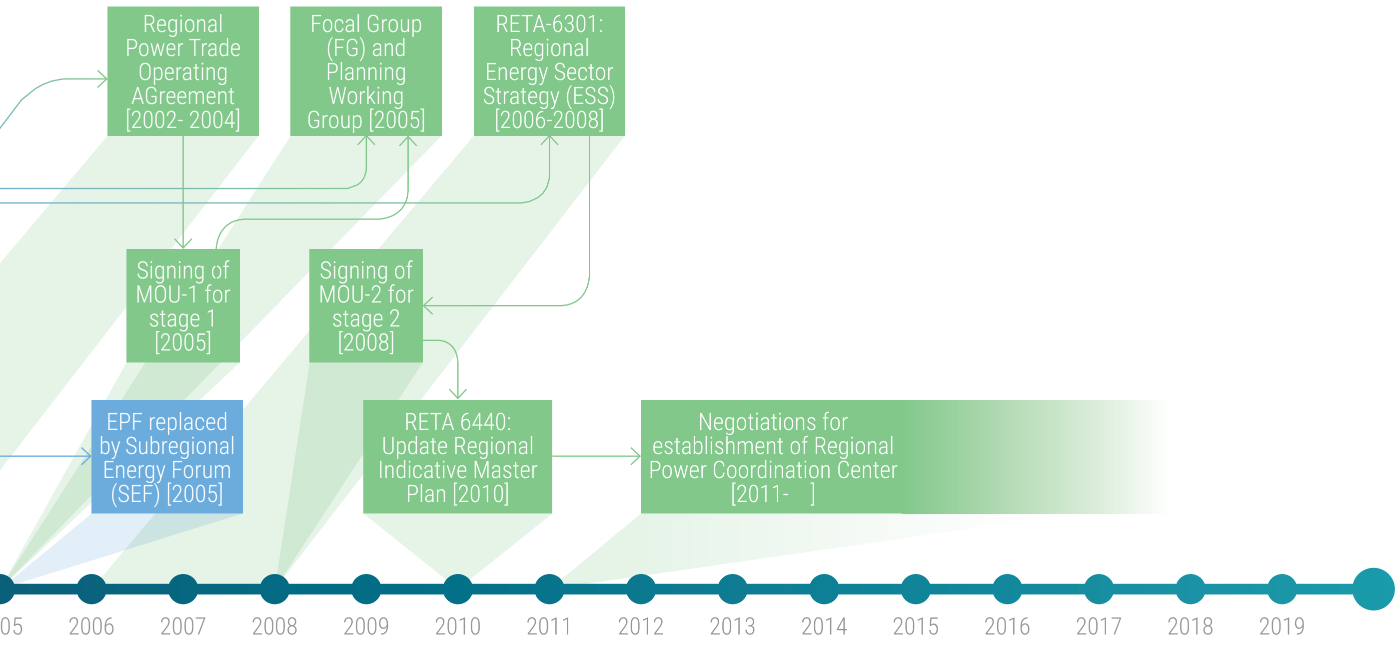
consistently twice a year, totalling 26 times (25 ordinary meetings and one special in 2012). The RPTCC is assisted by the Working Group on Performance Standards and Grid Codes (WGPG) and the Working Group on Regulatory Issues (WGRI). RPTCC was in charge of preparing the Regional Power Trade Operating Agreement (RPTOA) and the updating of the GMS Regional Master Plan. It has been leading the discussions for the establishment of the Regional Power Coordination Centre.

- **Regional Power Coordination Centre (RPCC)**. Discussions for its establishment started in 2011.

Economics and finance

The ability to increase the security of supply at a lower cost is one of the key drivers for regional power connectivity. However, the complexities of transboundary investments may also add additional financial costs. The certainty of payment and enforceability of agreements is essential for the bankability of the projects. The guarantees and financial creditworthiness that parties will be able to provide is another aspect to consider for transboundary projects (even if the generation plant is located only in a single country). This becomes even more complex when the trade involves more than two countries (e.g. transit territories) and as the development of regional electricity markets start to emerge. Regional institutions can help to address these concerns by establishing the frameworks to increase the guarantees to transboundary projects and those dependent on the power trade.

1. **Assessment and sharing of benefits and costs**: The decision of "who pays what" is an immediate concern that needs to be



addressed. Different options exist to evaluate a "fair" price to be covered by each country. These can vary from economic to technical gains. This becomes gradually more complex as more countries and other stakeholders become involved. The power trade can impact to all member countries, not only to the exporting and importing. Therefore, balancing the distribution of the benefits is needed to reach a politically acceptable solution.

The construction of regionally oriented projects is likely to be financed and built in a different manner to national projects, thus requiring consideration of a unique investment framework to service these needs. For example, the power purchase agreement (PPAs), as explained below, will involve actors from different countries, regulatory frameworks to allow for this will be needed. Furthermore, especially as the integration deepens, to grant non-discriminatory access to the electricity infrastructure, such as national interconnected systems. The Renewable Energy Institute in Japan identified four different types of business models for the building of interconnections, namely: generators / suppliers dedicated model, regulated grid tariff model, transmission rights sales model, and congestion charge model (Renewable Energy Institute, 2018).

2. **Power Purchase Agreements (PPAs) and electricity markets**: Attraction of private finance for transboundary projects is very complex, particularly between countries with very different levels of creditworthiness. In such cases, the "richer" country will be likely to give more guarantees to investors, independently of the estimation of gains from each country. There is also the risk that national contracts will be preferred over transboundary projects, both from government and investor perspective.

Regional planning contributes to more optimized investments. It is also a positive signal to investors by increasing transparency to secure that transboundary social and environmental impacts are also considered in the analysis. Furthermore, this can bring additional investment saving from regional economies of scale (IEA, 2018).

The level of unbundling and liberalization of power sectors is different across Asia. This can become an obstacle to promote "fair" access to some markets. This can create unbalances in some regions. Gradual movements towards increasing competitiveness and openness need to be balanced with the conditions of each individual country.

Technical factors

Regional power trade adds new technical requirements that need to be considered through adequate institutional mechanisms. In order to establish multilateral trade, harmonized grid codes, wheeling charge methodologies, and third party access are required (IEA, 2019a). At the technical level, regional institutions can be created combining senior officials and representatives from national companies. These can establish under them several working and ad-hoc expert groups for specific issues, such as:

1. **Information sharing**: Smooth grid interconnection is intensive in data needs. There can be challenges from largely different levels of data availability for each country. In the absence of regional transmission system operation (TSO), national TSOs will need to establish the mechanisms for information sharing between them. Whilst TSO responsibilities are usually limited to one country, or even subnational division, experiences with power failures and blackouts across-borders show the importance of smooth communication. (Wittenstein, M. and others, 2016). The level of information sharing increases as the integration continues. However, this information can be considered as confidential or risk to be shared. For that, it is important to first secure an agreement of which information will be shared, under which mechanisms, and the necessity of that. The group or institution formed will need to have the appropriate mandate from the member countries.

2. **Coordination and harmonization of standards, codes and rules**: Compatibility between national and regional grid codes and operation rules is a common need for smooth operation when moving up from limited to moderate integration. Each country is likely to have followed a different process in the development of its own internal rules.

A further step after the compatibility is to proceed to a harmonization, so similar rules will apply with the independence of the country. This process can create synergies since similar systems will become regional standard. A more robust integrated regional electricity system would be possible. Mechanisms for the evaluation of the security, such as N-1 criterion*, should be implemented. In some other cases, standards might not be compatible with each other, requiring one or all the countries to establish new set of rules.

3. **Security**: The increasing digitalization and decentralization of the electricity systems make them more vulnerable to cyberattacks. The increase in the connectivity of power systems can increase the likelihood of cascade effects due to external attacks (European Commission). On the other hand, this interdependence can be also a trigger to promote more effectively coordinate actions and to be an incentive for more advanced

The case of a superposed regional electricity market, SIEPAC project and the Regional Electricity Market (MER) in Central America.

The System for the Electrical Interconnection of the Central American Countries or SIEPAC Project ("*Sistema para la Interconexion Electrica de los Paises de America Central*" in Spanish) aims for the realization of a fully integrated regional electricity market in Central America (including Guatemala, Honduras, El Salvador, Nicaragua, Costa Rica, and Panama). The project consists of physical and institutional components. The first is the construction of a trunk transmission line crossing all the countries, including interconnections with each national system at several points. The latter includes regional institutions for the management, operation and regulation of the regional system. The project operates with support from the Inter-American Development Bank and the Government of Spain (particularly Endesa, the national utility at that time).

The Framework Treaty ("*Tratado Marco*") officially launched the SIEPAC project in 1996, after having been discussed at different times since the early 1980s. The Framework Treaty foresees an integration process based on three principles — gradualism, reciprocity and competition. It also includes the establishment of three pillar institutions — the owner of the infrastructure, the regional operator and the regional regulator.

Pre-feasibility studies have been conducted to analyse different options for the integration and to assess the economic returns to each country. Discussions between member countries found difficulty in realizing a direct transition to a fully integrated regional electricity market (the best-option). However, the second-best option was positively viewed by all member countries. This consists of the development of a superposed regional electricity market for the regional power trade, while maintaining the national electricity market for internal markets. This leads to the conceptualization of a gradualism approach from which the success of the superposed regional market will lead to full integration, in what has become known as "6+1=1" (six national markets plus one superposed regional are equal to one regional market).

The main institutions in the SIEPAC project are described below. Figure 15 shows the institutional framework for the superposed MER.

- "*Empresa Propietaria de la Red*" (EPR): Special-purpose company for the construction and ownership of the infrastructure. It is a private law enterprise created by the national utilities from each member country and (at-that-time) Spain's national utility Endesa (currently Enel). Later, Mexico CFE and Colombia ISA also became equal shareholders, in line with the interest in the interconnection of both countries to the SIEPAC system. Currently, interconnection between Mexico and Guatemala is already in operation. The interconnection between Panama and Colombia has faced more difficulties and has not been developed yet. The headquarters is in San Jose (Costa Rica), with representative offices in each in country.

The case of a superposed regional electricity market, SIEPAC project and the Regional Electricity Market (MER) in Central America.

- "*Ente Operador de la Red*" (EOR): The regional operator board members are two representatives from each state-owned company in the region and a rotatory presidency. Its first main task was the drafting of the regional regulatory framework (RMER). For the rapid progress in the interconnection between the two still not unconnected countries (at that time El Salvador and Nicaragua), a transitory regulation (RTMER) was approved to facilitate the power trade (even though without a regional market). EOR also established the Central American Market Operator (OMCA) to take care of these. The EOR currently is in charge of the regional dispatch, and is headquartered in San Salvador (El Salvador).
- "*Comision Regional de Interconexion Eléctrica*" (CRIE): The regional regulator has one commissioner selected by each country. The decisions have been traditionally based on consensus. It soon became clear that the CRIE needed to strengthen its capabilities and that a new more political body was required. The Second Protocol to the Framework Treaty in 2011 approved the RMER, as well as the strengthening of the CRIE and creation of the CDMER (explained below). CRIE headquarters are in Guatemala City (Guatemala).
- "*Consejo Director del MER*" (CDMER): The steering committee was created under the Second Protocol with the purpose of facilitating the commitments made and to coordinating the relations between the regional entities. The CDMER is integrated by one representative from each Government, who has the authority to coordinate the national policies related to MER. Currently, the CDMER is leading the efforts to draft a Third Protocol to the Framework Treaty. Contrary to the others, CDMER does not have an headquarters, independent budget or personnel.

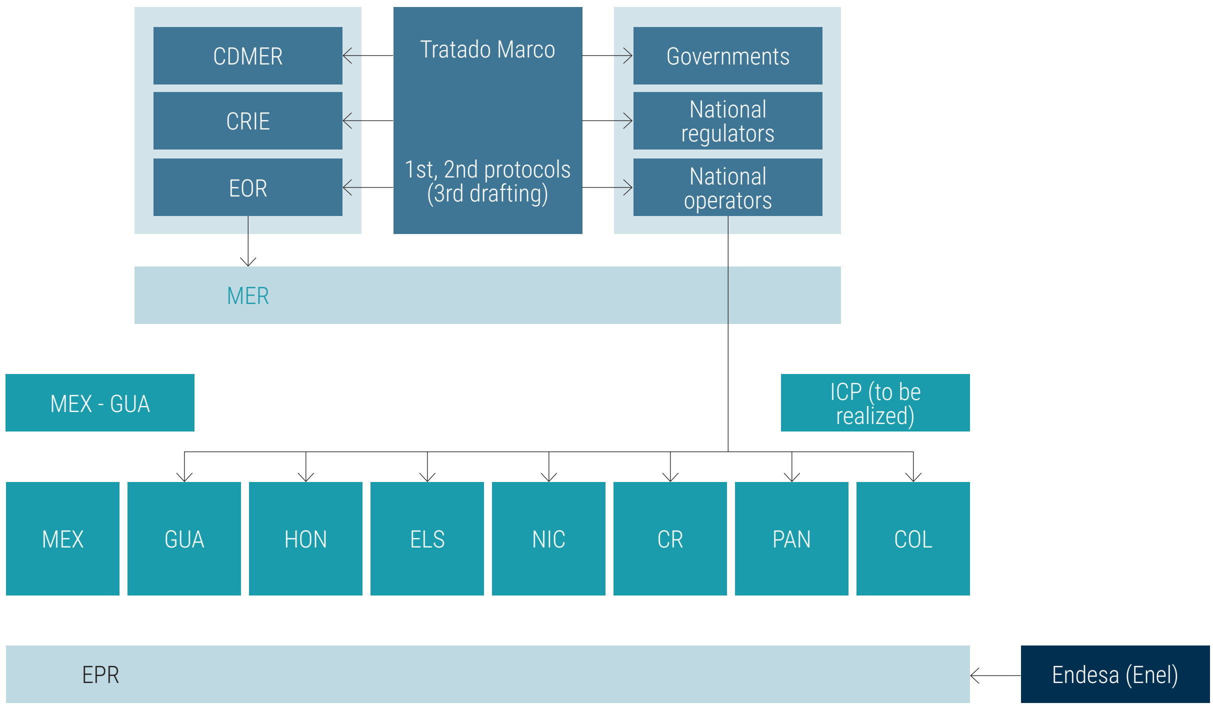
"N-1" is a security criterion which means that the grid must be capable of experiencing outage of a single key asset (transmission line, transformer or generator) without causing losses in electricity supply. N-1 takes does not account for the probability or the magnitude of impact of such outages.

economies to support the strengthening of the others' systems.

Social factors

Regional power connect is expected to have a direct impact on a more robust supply of electricity. In that sense, there are several social benefits directly derived from this in the areas connected to the national grid. Furthermore, there are several examples of borders areas for which electrification is simpler by directly importing from the neighboring country (see breakout in Section 3.1.2). On the other hand, regional power connectivity can lead also to the

Figure 15 The institutional framework for the superposed electricity market (MER) in Central America



Sources: Del Barrio-Alvarez, Komatsuzaki, and Horii, 2013; Echevarria, Jesurun-Clements, Mercado, and Trujillo, 2017; EOR, 2018; Rivas, 2019; Robinson, 2010

construction of large infrastructure for generation and transmission, with a direct impact in the people and ecosystems. In the case of large-scale hydropower dams, this impact can spread to all the downstream areas and countries. For national projects, countries have mechanisms to address the burden faced by the infrastructure development. Similar mechanisms need to be put in place by regional institutions or through international negotiations. This section focuses on the social dimension, whilst the next one focuses on the environmental aspects.

1. **Benefit-sharing and community protections**: In some cases, those people or communities that are most affected by development projects do not duly benefit from the electricity generated and/or traded. People displaced by generation projects or those affected by the crossing of transmission lines might not get similar benefits from the electricity in the regional system. Moreover, these communities are likely already living in vulnerable situations. It is important for governments and investors to protect those rights. In addition, the scales of the investments can make important

CASA-1000 Community Engagement Programme.

The Central Asia-South Asia power project, commonly known as CASA-1000, aims to interconnect hydropower-rich Kyrgyzstan and Tajikistan to the energy hunger Afghanistan and Pakistan that is being developed with strong support from the World Bank. This is a mutually beneficial power trade for the countries involved. However, there are also communities that are affected by the construction of the infrastructure and may be excluded from the benefits of the same (especially those not connected to nationally interconnected power systems).

The Community Support Project (CASA-CSP) is designed to share the benefits created through the project with the entire population affected by the infrastructure in the corridor of influence (COI). For that, CASA-CSP channels part of the revenue generated from the power trade agreements towards community-driven development projects in the corridors of influence in each country.

Specific CASA-CSPs have been approved for Afghanistan in 2014, the Kyrgyz Republic in 2018, and Tajikistan in 2019. The one for Pakistan is still under preparation.

Table 4 Overview of the CASA-Community Support Project (CASA-CSP)

	Afghanistan	Tajikistan	Kyrgyz
Approval date	2014	March 2019	2018
Corridor of influence (COI)	562 km long, 4 km wide	170 km long, 3 km wide	450 km, 3 km wide
Funding approved	USD 40 million	USD 26 million	USD 10 million
Provinces affected	6 provinces (Parwan, Kunduz, Baghlan, Laghman, Nangarhar, Kabul)	from Sughd region in the north bordering the Kyrgyz Republic, to Khatlon region in the south, and covers eight districts and 24 Jamoats (subdistricts)	3 oblasts (Batken, Jalal-Abad and Osh Oblasts) and an estimated 22 inhabited Aiyl Aimaks (AAs).
Affected population	700 communities spread over 23 districts (152,000 families)	60 villages 130,000 people live within the CoI, and the project population of the target areas in Isfara district in Sughd region is 73,000. At the institutional level, BT, ESPMU, NSIFT, and 26 local administrations (24 Jamoats and two townships) will benefit from the project through capacity building aligned with their institutional responsibilities.	37 villages with a combined population of 87,500 within the Corridor of Impact. Within the 22 AAs, there are an estimated 132 villages with a total population of about 330,000. The Transmission Line is expected to directly cross approximately 10 villages.
Components	Community grants for sub-projects Community mobilization Project implementation support Communications and outreach	Rural electricity supply improvements Community-led investments in socio-economic infrastructures Community mobilization, capacity building, and local governance Project management, monitoring and evaluation, and communications	Community led investments in social and economic infrastructure Community mobilization, youth engagement and communications Project management, and monitoring and evaluation

Source: World Bank, 2014b, 2014a, 2018 and 2019.

contributions to the development and well-being of the affected communities.

Regional power connectivity can be a mechanism for fostering greater interconnection between the people from neighbouring countries. In that sense, the required level of cooperation between governments can trigger cooperation at the societal levels. Social and cultural exchanges can promote a better understanding between societies and even generate more trust and willingness to collaborate in broader issues in the long run.

Environmental

Regional power connectivity can bring various environmental benefits, but these come also with other possible negative externalities that need to be addressed. The possibility to develop large-scale hydropower dams with power exporting purpose has been one of the drivers for regional power connectivity. Institutions can play an important role in ensuring these risks and benefits are managed optimally.

1. **Transboundary impacts and sharing of benefits**: Regional power connectivity in Asia is commonly associated with the construction of large-scale power projects, particularly dams. The impacts in the ecological system of the river need to be included in the analysis (Schmitt and others, 2019). Support to the development of basic-wide strategic environmental assessments will clarify the impacts and become a supporting tool for the dam development in the mainstream and tributaries. The Mekong River Commission (MRC)'s Prior Notification Process provides an example of a non-binding mechanism aimed at foster improvements in mainstream projects based on inputs from downstream communities.

2. **Environmental impacts in natural borders**: In addition to transboundary rivers, other environmental ecosystems such as forests, lakes, and migration patterns of birds that can be negatively affected by the development of regional power connectivity projects. There can be also transboundary negative effects from generation projects developed near to national borders, which may be the case when two countries have very different standards. In all these case, regional organizations with a strong presence from local communities and subnational governments can facilitate the addressing of concerns in the countries' borders. The Trifinion Plan in the Lempa River between Guatemala, El Salvador, and Honduras provides a good example (Artiga, 2003). The growth triangles in Southeast Asia are an example of cooperation including only parts of the countries (Tang and Thant, 1994).

3. **Development of a common set of environmental standards**: Regional power connectivity can be a driver towards improving standards through the process of revision and agreement. Past experience has shown how supranational environmental regulation in the European Union (EU) has led to an upward movement (Holzinger and Sommerer, 2011). The development of regional power connectivity in Asia-Pacific will require also efforts to improve the standards from nations that can learn from more advanced neighbouring countries.

Institutions and agreements should be made in order to foster this process.

Legal

Regional power connectivity requires the development, signing, ratification, implementation, and monitoring of many legal agreements. In that sense, these do not differ much of other types of international agreements. However, energy security is commonly a key priority in national political agendas. In many ways, these are closely related to policy and regulatory issues.

1. **Securing rights of way**: The construction of long-distance transmission lines is intrinsic to the development of transboundary power trade. These transmission lines will likely affect new areas of high environmental and/or cultural value. The design of the infrastructure will need to take into consideration the most adequate alternatives. It can also happen that the most complex areas fall into a single country, affecting the entire project. The member countries should be ready for such circumstances.

2. **Enforceability and conflict resolution**: Conflicts between parties are likely to appear, as it is the case in national electricity markets. However, contrary to national systems, the establishment of a supranational regulator or tribunal will not acceptable in most of the cases. Even if a regional regulation can be created, its actual enforcement could be perceived by some as an invasion of national sovereignty. Hence, it is needed to find alternative arbitration mechanisms that will be accepted by all the parties.

3. **Coordination of all related regional agreements with national legal systems**: Once an agreement has been reached at the regional level, it is required to "translate" it into the national legal system. In cases, this can require some modifications and therefore a harmonization process. Different countries will probably be able to conclude that at different paces. This can create also tensions that need to properly be addressed.

5.3 Policy findings: Developing institutional mechanisms for a regional roadmap on Asia's power connectivity in the era of Sustainable Development

Many lessons can be derived from the analysis of the functions for institutions in regional power connectivity initiatives. Regional power connectivity is still in early the integration phases in most parts of Asia. Nonetheless, there is broadly political, technical, and financial support for the expansion of electricity trading. In the coming years, it can be expected that countries will increase the number of interconnections and the volume of electricity trade. New links between subregions are likely to be built too.

Regional institutions are to play a vital role in promoting the collective action in the regional power connectivity process. This chapter provides a broader look at specific functions from institutions in a multi-dimensional manner. At political level, institutions will need to facilitate the trust building between governments so they will be able to approach the cooperation as a win-win. The process of shifting policies and technical systems towards more regionally oriented will required also active involvement of regional institutions to move and monitor the process. Mechanisms for the promotion of investment, and facilitation an open use of common infrastructure are to require extensive discussions and negotiations. The social and environmental impacts are also to not be overlooked in this process. Regional institutions are in best position to make sure to both expand the benefits of the project to affected communities that do not gain profit directly from the project, and to address transboundary negative externalities. Finally, supporting the establishment of adequate legal arrangements region-wide will help the interconnection to move towards integration, maximizing the benefits from the connectivity process.

There are several policy findings derived from this chapter to be considered in the institutional development of regional power connectivity in Asia-Pacific:

1. The design of institutions must be flexible to be able to adapt to varying needs within a long, gradual process that will likely face complex decision-making processes, while serving to assist with working towards a consistent, long-term goal. As one example, the experience at the GMS has seen the creation of institutions for a specific purpose that, after being this fulfilled, were replaced by new ones to seek for the revised (medium-term) goals.

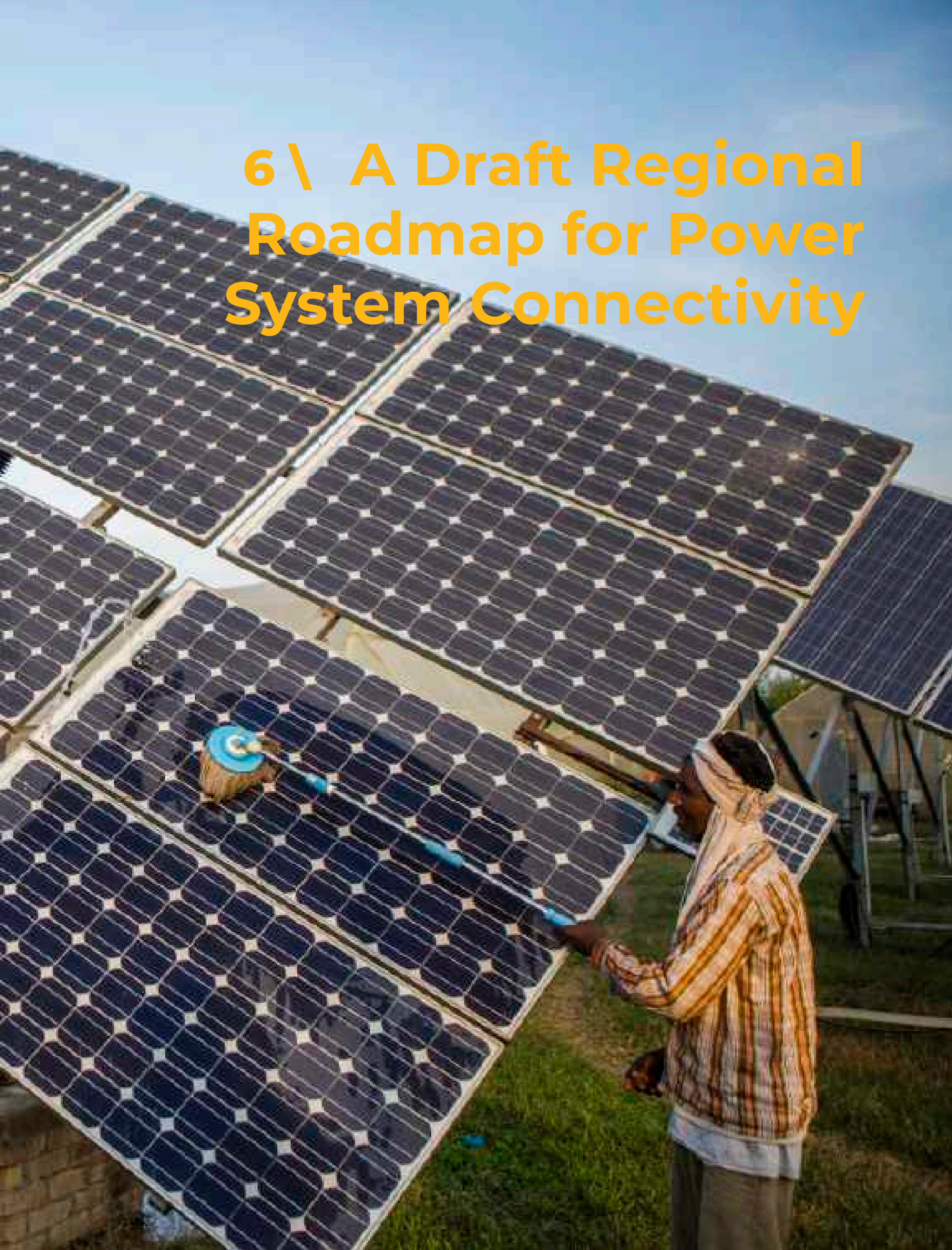
2. Actions should be taken towards granting the long-term political commitment, so to facilitate the transition towards regionally oriented systems. The shift from purely national oriented systems to regional mindset is always a long process. Even under the most favorable political environmental, the modification, adaptation, and harmonization of standards, systems, and regulations is time consuming. This process is therefore prone to be affected by changes on governmental priorities and agendas. Regional organizations can help to keep the commitments and to better express the benefits of the cooperation, even under shifting priorities and agendas.

3. Mechanisms to involve honest brokers and track II diplomacy can have important positive impacts, like in trust building and finding commonly agreeable solutions. The coordinative action between the multiple international financing institutions (i.e. global and regional development and donor countries). The involvement of academic and research community through studies and science and policy dialogues can help to identify areas of concern misrepresented in the integration process and highlight opportunities.

4. Local and other subnational governmental bodies are to play a fundamental role, many times overlooked, particularly to address concerns of communities in border areas. As experience with other common pool public goods (i.e. transboundary lakes), subnational authorities have a closer and tight relation with the affected communities and their concerns. Similar involvement is being important in the implementation of social programmes such as in the CASA-1000.

5. Institutional development shall serve to unleash full benefits from the power connectivity, beyond the economic merits of the electricity trade, such as improvement of technical, and social and environmental protection standards. Furthermore, the cooperation in the power sector can serve to foster collaboration between countries in other areas.

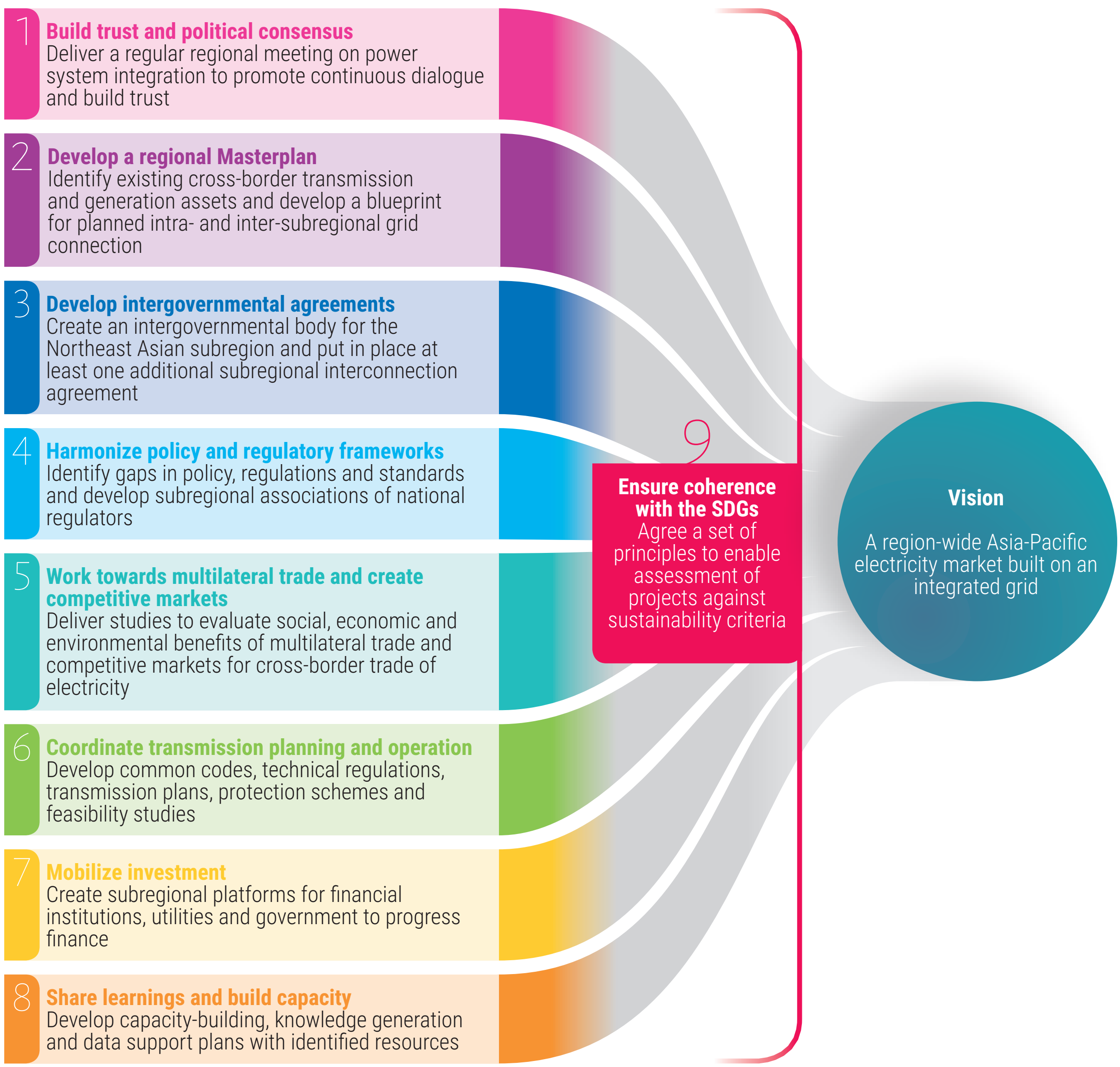
6 \ A Draft Regional Roadmap for Power System Connectivity



Following extensive deliberations, the ESCAP Expert Working Group developed the following draft regional Roadmap on power system connectivity. The draft Roadmap was presented to the Second Committee on Energy who agreed with the draft and recommended the document be submitted for endorsement by ESCAP member States at the seventy-sixth session of the Commission.

Member States recognized the role of the draft Roadmap in accelerating power system connectivity, based on a set of nine reference strategies. The overall objective of the roadmap is to eventually create a pan-Asian interconnected grid that offers a more reliable, affordable and

Figure 16 Strategies of the draft Electricity Connectivity Roadmap for Asia and the Pacific



sustainable electricity supply. The draft Roadmap also aligns power system connectivity with the Sustainable Development Goals, in particular in meeting the SDG7 targets.

The draft Roadmap (summarized in figure 16) proposes the nine detailed strategies for regional stakeholders to address, suggesting key milestones, timeframes and responsible entities for realizing each element. The timeframes for each strategy are defined as short term (1 to 3 years), medium term (4 to 7 years) and long term (7 to 15 years).

The roadmap acknowledges that energy policy is affected by the circumstances of each country and subregion, and leaves room for each country's discretion. It is intended as a guideline and is therefore non-binding. Careful consideration should be given to the respective circumstances of countries during its implementation. Many countries in the region are archipelagic, presenting major challenges to power grid integration. However, in these areas, where fuel is often transported to service power needs, connectivity can offer great benefits. It is important to understand these unique issues and to seek the best policies, regulations and business models to address power grid connectivity in these circumstances.

6.1 Strategy 1

Building trust and political consensus for cross-border electricity trade

Geopolitical issues and lack of trust among many of the countries in Asia and the Pacific is a major challenge to enhancing connectivity and establishing cross-border electricity trade. Overcoming this is a process of continuous trust building, which must be supported by independent intergovernmental organizations such as ESCAP, subregional cooperation organizations and multilateral banks. There is a need to build consensus among member States for the long-term vision of energy connectivity in the Asia-Pacific region and for overcoming the principal barriers to energy connectivity.

To create trust and to promote political consensus, it is important to promote continuous dialogue among the decision makers and stakeholders of member countries in each subregion. ESCAP and subregional Intergovernmental institutions, such as the South Asian Association for Regional Cooperation (SAARC), the Bay of Bengal Initiative for Multi-Sectoral Technical and Economic Cooperation, the GMS, ASEAN, the Eurasian Economic Community, the Shanghai Cooperation Organization, the Greater Tumen Initiative, the Lancang-Mekong Cooperation and the Eurasian Economic Cooperation Organization (EECO), can play a vital role in building trust and political consensus. This can be done by utilizing their platforms to convene stakeholders such as policy makers, decision makers, think tanks, regulators, financing organizations and private developers. To progress this strategy, these intergovernmental institutions need to develop coordinated action plans on power grid connectivity.

Building trust for cross-border energy connectivity should also be pursued with countries regardless of whether they are export, import or transit countries. This process is needed to promote understanding of the benefits among different sectors of society and ensure support for the interconnection process.

For building trust and political consensus with the objective of enhancing grid connectivity in the Asia-Pacific region, ESCAP must play a central role by organizing focused regional meetings – which may be held as part of ESCAP's Committee on Energy – for promotion and coordination of region-wide connectivity efforts. Furthermore, multilateral Institutions such as the World Bank, ADB, the IEA and the International Renewable Energy Agency working in different subregions as well as specialized institutions also need to coordinate and align their activities with those of ESCAP and the subregional intergovernmental institutions in order to avoid duplication and to maximize impact.

Key milestones	A regional meeting on grid integration convened regularly from 2021.
Timeframe	Short, medium and long term.
Key implementers	Member States, with support from ESCAP secretariat, sub regional organizations, intergovernmental institutions, and multi-lateral development banks.

6.2 Strategy 2 Development of a regional cross-border electricity Grid Masterplan

Today, grid interconnectivity in the Asia-Pacific region operates on a bilateral basis and is limited in its extent. To promote connectivity for the broader Asia-Pacific region, it is important to develop and agree upon a Grid Masterplan for interconnection of the region's power grids. The Grid Masterplan is envisaged as an agreed reference blueprint for the intra- and inter-subregional interconnections, identifying current and planned cross-border transmission and generation assets. It will build upon and integrate existing or future subregional grid masterplans. The development of the Grid Masterplan should adhere to the principle of inclusiveness, by reflecting the concerns and demands of relevant stakeholders. It will not be a legal document; it will be voluntary in nature, and will take into account each country's energy policy and power system.

To support this, there should be greater networking of subregional intergovernmental institutions including multilateral institutions. This will enable member States to identify and enhance the economic, social and environmental benefits of the cross-border electricity trade, and agree on the architecture of a regional cross-border grid.

ESCAP can convene meetings of member States and the subregional intergovernmental institutions working in the subregions to develop a Grid Masterplan for interconnection of the region's power grids. ESCAP can provide technical support though mapping high-voltage transmission lines near borders. Multilateral institutions such as the World Bank and ADB can also support ESCAP in these efforts.

Key milestones	A regional Grid Masterplan agreed by member States by 2025; mapping of the region's existing high-voltage transmission network by 2022.
Timeframe	Medium term.
Key implementers	Member States, with support from the ESCAP secretariat and subregional institutions.

6.3 Strategy 3 Develop and implement intergovernmental agreements on energy cooperation and interconnection

Political commitment in the form of various treaties, agreements or Memorandums of Understanding among the member States in each subregion is critical for enhancing energy connectivity. International experiences of successful power pools highlight the importance of signing agreements among the participating countries in order to signal each country's political commitment to promoting energy cooperation and integration within a specific time frame.

In North-East Asia, there is no intergovernmental institution and no existing agreement between the member countries on interconnection. The current trade is limited and is based on bilateral agreements. In SAARC, ASEAN and the GMS groupings, member countries are following strategic processes such as signing of agreements on energy cooperation and grid connectivity, and establishing ministerial committees and working groups to promote energy cooperation and integration. The Bay of Bengal Initiative for Multi-Sectoral Technical and Economic Cooperation countries have also recently signed an agreement on grid interconnection.

Where agreements are already in place, it is important that member countries ratify and expedite their implementation. For subregions where the process of signing of these agreements has yet to be initiated, it is important to learn from the experiences of SAARC, ASEAN, the GMS and other successful power pools elsewhere in the world, and to enhance collaboration with these institutions. This will help in adopting a strategic approach to enhance energy cooperation and connectivity in their subregions.

Intergovernmental institutions such as SAARC, the GMS, the Bay of Bengal Initiative for Multi-Sectoral Technical and Economic Cooperation, EECO, the Greater Tumen Initiative and the Shanghai Cooperation Organization working in each subregion of Asia and the Pacific need to develop action plans for making concerted efforts to sign and implement agreements among member countries for power grid interconnection within a specified time frame. For North-East Asia, ESCAP should facilitate the creation of a subregional body dedicated to realizing interconnection with the support of multilateral financial institutions.

ESCAP, with the support of intergovernmental institutions and multilateral development institutions such as the World Bank and ADB, needs to support member States in developing and formalizing grid connectivity integration agreements in order to enhance energy connectivity in the region.

Key milestones	Subregional body for North East Asia connectivity established by 2022; at least one additional subregional interconnection agreement is in place by 2025.
Timeframe	Short and medium term.
Key implementers	Member States, with support from the ESCAP secretariat and subregional organizations.

6.4 Strategy 4 Coordinate, harmonize and institutionalize policy and regulatory frameworks

Policies, regulations and standards for power grids may differ between countries in each subregion. As the electricity sector is highly regulated, with grid stability a critical priority, aligning policies, regulations and standards with regard to cross-border electricity trade is vital.

It is important to identify such gaps in policies, regulations and standards in each subregion by conducting in-depth research and analyses, and to identifying where these need to be amended through notification by the regulators of each country.

Moreover, efforts need to be made to develop model or common frameworks for policies, regulations and standards in support of cross-border electricity trade.

Integrated markets require integrated institutions for transparent, smooth trade of electricity in each subregion and for a unified Asia-Pacific region.

Regulators in each subregion, with the support of intergovernmental institutions and/or multilateral institutions should establish forums or associations of national regulators in each subregion to enable harmonization of regulations, capacity-building and knowledge sharing. International experience also suggests that multilateral institutions such as ADB and the World Bank have played key roles in creating these structures.

A forum or association of regulators, in subregions where these have not already been formed, can also facilitate in developing a common set of regulations for cross-border electricity trade such as licensing, open access, harmonization of grid codes, transmission pricing framework at the subregional level, but eventually covering the entire region.

Key milestones	Analysis of gaps in grid policies, regulations and standards in each subregion by 2023; subregional associations of national regulators formed by 2025.
Timeframe	Short and medium term.
Key implementers	Member States, with support from the ESCAP secretariat and subregional organizations.

6.5 Strategy 5

Move towards multilateral power trade and creation of competitive markets for cross-border electricity

Transitioning electricity trade from a bilateral to multilateral basis is a challenge in the Asia-Pacific region. Existing cross-border electricity trade remains limited and on a bilateral basis. Moving this to a multilateral mode will help the countries to optimize overall regional energy resources, enhance economic growth, expand the use of renewables, strengthen reliability, lower costs and contribute to the environmental sustainability of the power sector. It is important to continue promoting power grid connectivity on a bilateral basis as a building block of a multilateral system. However, there is a need to encourage member States to make a transition to multilateral trade in order to realize the full benefits of connectivity.

Linked to this is the need to create transparent, fair, competitive and balanced electricity markets with fair pricing mechanisms. This is vital for the success of regional power connectivity. Market integration can take advantage of diversity between countries, enhance competitiveness and reduce costs for consumers. In other regions, experience with cross-border electricity markets has been positive but highlights the need for strong institutional frameworks. With each country having its own tariff-pricing mechanism, differing commercial agreements and payment security mechanisms, a secured payment mechanism is critical for enhancing cross-border trade of electricity.

The development of model power purchase agreement templates, transmission service agreements and payment security mechanisms acceptable to member countries would be an important enabling step for electricity trade. Furthermore, implementing transparent and attractive mechanisms for a transit fee framework for all the member countries, which will allow corridors for wheeling of electricity between countries, will help to expedite cross-border interconnection and trade.

The forums of subregional regulators can support the development of an integrated electricity market by facilitating contractual document templates such as power purchase agreements, transmission service agreements, transit fee frameworks, subregional pricing frameworks, payment security mechanisms, competitive bidding and market rules for electricity trade on power exchanges. The experience of international power pools also highlights the importance of comprehensive, well-drafted standard contracts that fully incorporate the consequences of contractual defaults and emergency events.

Intergovernmental institutions and multilateral institutions working in subregions should make concerted efforts, together with Governments, regulators and decision makers, to promote a move of cross-border electricity trade to a multilateral basis as well as the development of competitive markets for cross-border electricity. Large countries such as China, India, , the Russian Federation and Thailand can play a leading role for promoting this shift.

The economic, social and environmental benefits of the electricity trade and relevant international experiences, including regional examples, need to be shared with relevant stakeholders, including national policymakers, to build the case for multilateral trade of electricity.

Key milestones	Development of subregional and Asia-Pacific studies to evaluate the social, economic and environmental benefits of multilateral electricity trade and competitive markets by 2023
Timeframe	Short, medium and long term.
Key implementers	Member States, with support from the ESCAP secretariat and subregional organizations.

6.6 Strategy 6

Coordinate cross-border transmission planning and system operation

The transmission of electricity across different national grid networks requires transmission systems to be physically interconnected. To interconnect two different national power systems, it is important to harmonize technical standards and grid codes such as frequency, voltage and thermal limits. Furthermore, metering connection, protection schemes, transmission planning and scheduling need to be coordinated among the technical institutions and power utilities of member countries in each subregion to ensure safe and reliable flow of electricity.

To encourage the development of cross-border generation power projects, power utilities should plan and develop adequate transmission infrastructure for the transmission of electricity, to allow open access for developers to transmit power.

System operators, transmission utilities and technical institutions in each country – with the support of ESCAP, subregional institutions, national governments and multilateral institutions – should create associations in each subregion for coordinated transmission planning and system operation of the interconnection system network. It is important that national transmission plans and cross-border transmission plans should be compatible with each other.

These bodies can facilitate the development of common sets of grid codes and technical regulations, master grid plans, protection schemes and scheduling, together with feasibility studies for smooth interconnection of power systems in each subregion.

Key milestones	Development for each subregion of common grid codes, technical regulations, subregional grid plans and feasibility studies for interconnection completed by 2025.
Timeframe	Short, medium and long term.
Key implementers	Member States, with support from the ESCAP secretariat, subregional organizations, multilateral development banks and specialized institutions such as the International Renewable Energy Agency and the International Energy Agency.

6.7 Strategy 7

Mobilize investment in cross-border grid and generation infrastructure

As the power sector is capital intensive and associated with large risks and long gestation periods, mobilizing investment is a challenge. Funding for cross-border power projects is largely being done through IFIs, multilateral development banks and national contributions. Considering the scale of investment required to realize large-scale integration of the Asia-Pacific region's power grids, there is a need to develop innovative financial instruments and mechanisms in each subregion to mobilize financing.

To attract investment, it is therefore important that investment-friendly policies, guidelines and frameworks are in place. These include removal of barriers to private sector and foreign investment, smooth process of land acquisition, resettlement and relocation process, and planning clearances. These policies, guidelines and frameworks need to be developed in each subregion to attract developers and investors for the infrastructure underpinning interconnection.

To lower risk and facilitate investment, it is necessary to have strong, swift and clearly defined dispute resolution procedures to support electricity trade agreements. The repercussions of such disputes can lead to discontinuation of electricity supply temporarily or permanently, resulting in high financial losses and demand-supply imbalance. At present, sellers and purchasers in cross-border electricity trade need to resolve their disputes based on Power Purchase Agreements. Apart from amicable settlement, these also provide provision for arbitration in a third country. Government, intergovernmental institutions, regulators and appellate tribunals need to develop transparent dispute resolution mechanisms and frameworks, and establish a common institution for resolving any disputes on cross-border electricity trade in each subregion. In South Asia, the SAARC Arbitration Council has been formed to resolve any disputes between the member countries instead of resolving them in a third country.

Uncertain taxes and duties also deter investment. In Asia and the Pacific, currency is very volatile, which presents a challenge for developers to invest in cross-border power projects and associated transmission infrastructure.

To encourage investment, ESCAP in association with other intergovernmental institutions should organize focused group meetings, workshops and conferences, and invite various financial institutions, private and public developers, governments and policymakers in one platform for each subregion to discuss investment-related issues, and to address barriers to investment in the power sector.

The finance sector in its own right can make a contribution to unlocking finance, and designing for prudent and efficient risk allocation. The creation of associations of financial institutions and multilateral institutions is proposed, representing members from the chambers of commerce of member countries, multilateral financial institutions and think tanks in each subregion. The objective would be to the development of investor-friendly policies and frameworks by policy makers of member countries to encourage private investment. These bodies may facilitate the development of transparent policies and regulations on taxes and duties as well as adopt a common currency acceptable to all member countries to encourage developers to invest in the sector.

These forums or associations can also facilitate research studies on issues such as renewable energy financing instruments, developing capital markets, and energy investment risk assessment. They can facilitate tapping funds at competitive rates from the New Development Bank, the Asian Infrastructure Investment Bank, the ADB or the World Bank for cross-border generation and energy connectivity infrastructure projects.

In addition, instruments such as green bonds, blended financing or renewable energy certificates can be tailor-made for financing of specific cross-border projects, including the development of renewable energy projects.

Key milestones	Subregional platforms convening financial institutions, utilities and government created to progress financing of cross-border connectivity projects by 2023.
Timeframe	Short, medium and long term.
Key implementers	Member States, with support from the ESCAP secretariat, subregional organizations, multilateral development banks and specialized institutions such as the International Renewable Energy Agency and the International Energy Agency.

6.8 Strategy 8

Capacity-building, sharing of information, data, learning and best practices

The Asia-Pacific region has rich knowledge and experience in the energy and power sector. Some of the intergovernmental institutions have data and information on the power sector of member countries in their subregion, but it is often not adequate and not updated regularly. National Governments are also maintaining some data in the public domain on the power sector, whereas some countries lack public data on the power sector. In addition, the subregions have limited sharing of data, information, learning, best practices and new technologies.

Some countries in Asia and the Pacific have successfully implemented projects such as smart grids, energy efficiency projects, and hybrid solar and wind power projects, but offer limited sharing of best practices and capacity-building. If the power sector is to grow and integrate more effectively across the region, it is important that there should be sharing of information, data, learning and best practices through capacity-building programmes among the member countries.

Intergovernmental institutions in each subregion as well as ESCAP should work together to develop and maintain data and information together with utilization of lessons learnt and the best practices relevant to power grid interconnection. Together they can create a Centre of Excellence covering knowledge on renewable energy, power markets and cross-border electricity connectivity. Intergovernmental institutions can develop and maintain data for their subregions, whereas ESCAP can cover the wider Asia-Pacific region. The existing Asia-Pacific Energy Portal operated by ESCAP can be reinforced for this purpose, with more geospatial data on cross-border power infrastructure and energy data.

Intergovernmental institutions, national Governments, power utilities and multilateral financial institutions can develop plans for capacity-building and sharing information and expertise in areas such as new technologies, energy efficiency, smart grid activities, EV charging infrastructure, large solar power and competitive bidding to enable all the member countries to successfully implement them and improve efficiency and system operations.

Key milestones	Capacity-building, knowledge generation and data support plans developed, and resources identified to support member States undertake grid interconnection by 2021.
Timeframe	Short, medium and long term.
Key implementers	The ESCAP secretariat, with support from member States, subregional organizations, multilateral development banks, universities, research institutes and specialized institutions such as the International Renewable Energy Agency and the International Energy Agency.

6.9 Strategy 9

Ensure the coherence of energy connectivity initiatives with the Sustainable Development Goals

In addition to economic gains, enhancing energy connectivity can lead to many other positive externalities related to sustainable development, such as reducing greenhouse gas emissions, improving energy accessibility in remote areas and job creation. To ensure that a strong synergy exists between energy connectivity projects and sustainable development, more focused attention should be placed on the social and environmental influences of these projects over a long-term timescale. Proactive and consistent measures countering social dislocation, biodiversity loss, and climate change impacts should be introduced. In addition, it should be ensured that the economic gains of energy connectivity are evenly distributed to all participating countries, and are translated into tangible benefits for all sectors of society within each country and between genders.

The Sustainable Development Goals provide an agreed framework for countries to pursue national development that measures progress in social, economic and environmental terms. Developments in cross-border energy connectivity will offer more comprehensive benefits if they are aligned with the Sustainable Development Goals in the planning, implementation and operational phases.

Hence each interconnection proposal should be developed in an inclusive manner that ensures an overall positive societal impact and environmental protection as well as meeting economic criteria, with emphasis placed on stakeholder consultation and engagement. ESCAP can support its members in following this principle and the implementation of cross-border connectivity initiatives in a manner that supports the Sustainable Development Goals through its intergovernmental work and its research and analytical capacity.

Key milestones	A set of principles to enable the assessment of interconnection projects against sustainability criteria, to ensure coherence with the Sustainable Development Goals, agreed by member States by 2023.
Timeframe	Short, medium and long term.
Key implementers	Member States, with support from the ESCAP secretariat, subregional organizations, multilateral development banks, universities and research institutes.

7 \ Conclusions

The potential for enhanced power grid connectivity and cross-border electricity trade in the Asia-Pacific region is significant. Connecting power grids of adjoining countries and subregions can capitalize on complementarities between countries in terms of energy demand and energy resource availability, particularly wind, solar and hydropower potential. Achieving power grid connectivity can enhance the availability and affordability of electricity, and accelerate the utilization of renewables. It therefore contributes to environmental sustainability of the energy sector, while advancing Sustainable Development Goal 7 and the broader 2030 Agenda for Sustainable Development.

This requires an evolutionary process through the augmentation of connectivity infrastructure, the leveraging of existing bilateral exchanges of electricity to build up to multilateral trade and, eventually, the creation of an integrated power market. This will require the development of a regional framework and appropriate institutions to support and coordinate it.

Experience from other regions has underscored the central role that institutions play in the process of interconnection. Regional and subregional institutions can play a vital role in promoting collective action. At the political level, institutions can help to facilitate trust-building between Governments so that they will be able to cooperate in the approach to taking advantage of the opportunities. Regional and subregional institutions can also support enhanced cooperation on the creation of appropriate architectural and governance structures in order to guide the process of legal and regulatory cooperation.

The process of developing interconnection has already begun. Across the Asia-Pacific region, several good examples of subregional interconnection are already operating, while many more are under development. By building upon and providing impetus to existing initiatives, the draft Roadmap is intended to enable coordination among various institutions and serve to progressively remove barriers to energy interconnection.

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