INTEGRATING SOUTH ASIA'S POWER GRID FOR A SUSTAINABLE AND LOW CARBON FUTURE

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EXECUTIVE SUMMARY

Since the concept of the SAARC (South Asian Association for Regional Cooperation) Energy Ring – an interconnected electricity system covering South Asia – was first announced in 2004, progress has been made in developing bilateral electricity interconnection and trade in several South Asian countries. However, this progress has not proceeded at the same pace across the subregion, and the vision of a SAARC Energy Ring still seems elusive. Other subregional blocs in the Asia-Pacific region are at varying stages of grid integration, most notably the Association of Southeast Asian Nations (ASEAN) which aims to establish an ASEAN Power Grid. Globally, there are several examples of successful multi-country power systems, principally in Europe, Southern Africa and Central America. For its part, the United Nations Economic and Social Commission for Asia and the Pacific (ESCAP) as the leading intergovernmental body in the Asia-Pacific, recognizes the importance of developing regional power grid interconnections in support of sustainable development. ESCAP promotes Asia-Pacific-wide energy connectivity through its analytical and intergovernmental work. South Asia's interconnection will form a key building block to underpin the broader vision of an interconnected Asia-Pacific power system.

The concept of cross-border power system connectivity has gained increasing support from Governments and international organizations, given the benefits it can offer in lowering costs, diversifying supply, and tapping into renewable and low carbon energy resources. Progress in concluding international agreements on sustainable development and climate change provide a new lens through which to examine South Asia's power grid interconnection. This report examines the progress made to date in integrating the power grids of South Asia as well as the future possibilities of a more integrated power grid covering the subregion. It examines the benefits that can be realized through this process, not only in terms of direct economic benefits, but also in helping countries achieve energy transition, address the Sustainable Development Goals (SDGs) and to fulfill their commitments on climate change through the Paris Agreement.

The benefits of power grid interconnection in South Asia are manifold. National policymakers face an "energy trilemma" of ensuring energy security, affordability and sustainability. Greater connectivity can play a role in solving this trilemma. It can help to (a) deliver an increased supply of electricity, (b) provide enhanced energy security by diversifying supply, (c) reduce costs through arbitrage and economies of scale, (d) tap into under-exploited energy resources such as hydropower and (e) allow greater use of variable renewable energy through balancing generation over larger pooled areas. An interconnected grid covering the subregion is an essential enabler for power generation infrastructure and the development of cross-border electricity trade. With the right mix of national complementary policies, power grid connectivity will form the basis of a subregional delivery system for low carbon energy, facilitating the transition to renewable energy, and as such become a regional public good for South Asia. The direct benefits of full power grid interconnection could reach $9 billion each year in direct savings and reduce GHG emissions by more than 9 per cent per annum compared with business as usual, without accounting for social and environmental benefits. Future analysis is likely to significantly revise upwards the emissions reduction benefits, given rapid declines in renewable energy technology costs and increased estimates of renewable resources in countries such as India and Pakistan.

While these interconnection benefits have been recognized by policymakers in the SAARC countries, there remain a series of political, technical and institutional challenges in realizing them. To help overcome these challenges, a number of subregional initiatives have been mobilized by SAARC, the World Bank, the Asian Development Bank (ADB), the United States Agency for International Development (USAID) and the Department for International Development (DFID) of the United Kingdom of Great Britain and Northern

Ireland. SAARC established the SAARC Energy Centre to drive subregional cooperation and issued the SAARC Framework Agreement for Energy Cooperation (Electricity) in 2014. India issued guidelines with provisions for its cross-border electricity trade (CBET) in 2016.

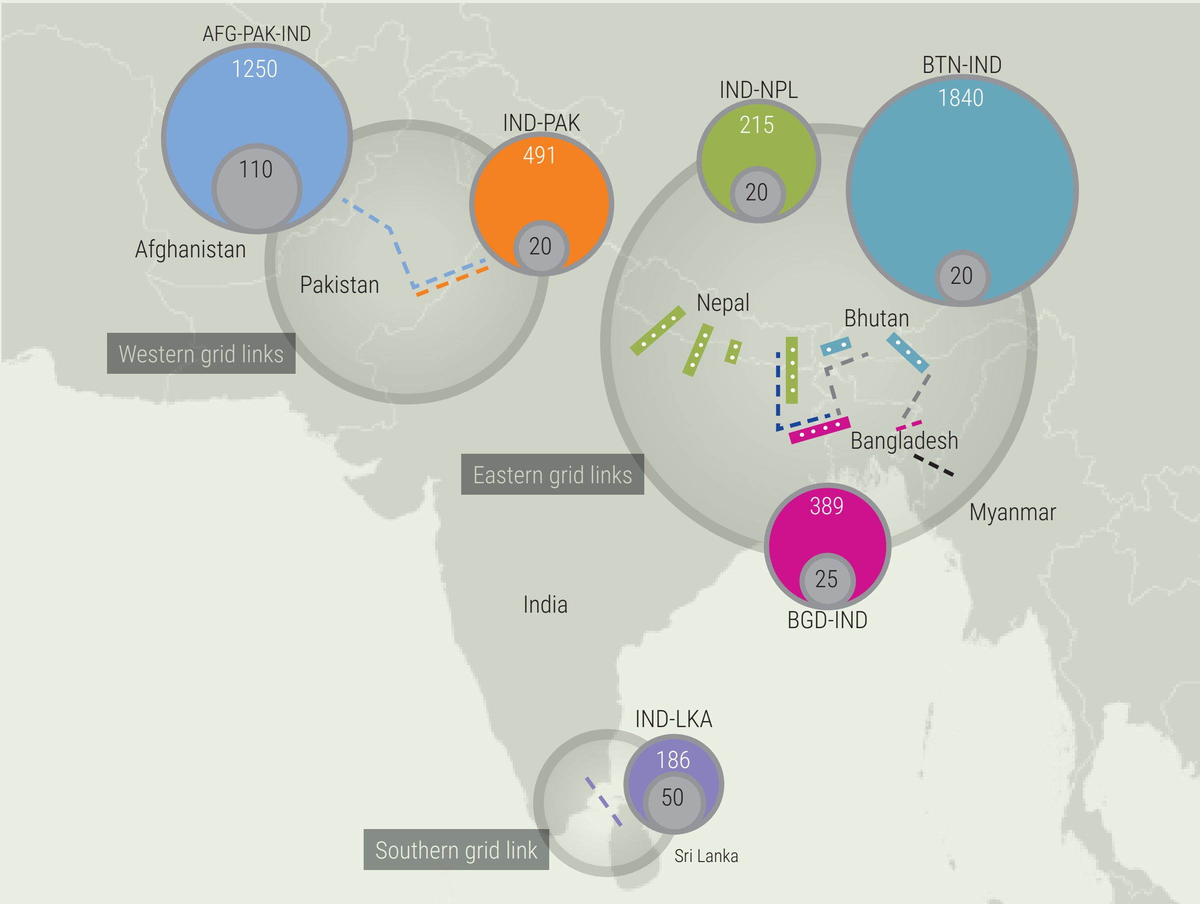
South Asia, with its diversity of energy resources and consumption, presents many positive opportunities for integrating its power grids and promoting CBET. Both renewable and fossil energy sources are unevenly distributed, while electricity shortages and growing demand are pressing problems that need to be solved by energy policymakers. CBET in many cases can offer more viable, affordable and rapid solutions compared to developing domestic generation capacity. In assessing the steps towards power system integration and the optimum level of integration, the participating countries must reconcile issues such as investment requirements, risks, benefits and impacts on their sovereignty.

The geography of South Asia's power grids offers many power connection opportunities at border interfaces, with India located at the centre of many of the power exchange opportunities as an energy supplier, exporter or transit country. To date, the greatest progress in the subregion has been made in bilateral interconnection and power trade between Bangladesh, Bhutan, India and Nepal. These countries have developed a series of interconnections to trade hydropower from Nepal and Bhutan, and to provide support to Bangladesh from India's grid. At the same time progress on interconnection between SAARC's two largest economies, India and Pakistan, is stagnant. The proposed interconnection between India and Sri Lanka is still at the feasibility stage. Figure ES1 highlights the principal interconnection opportunities, and the associated estimated costs and benefits.

The role played by an interconnected power grid for South Asia in boosting renewable energy, enhancing affordability and access while lowering emissions will have a bearing on the subregion's efforts to achieve the SDGs. Given the central role played by energy across the 17 SDGs, the sustainable energy dividends from power grid integration can help achieve many other SDGs in the subregion, including those on poverty, hunger, health, water and sanitation, infrastructure as well as the environmental dimensions of urbanization, climate change, and life under water and on land. Care must be taken to efficiently manage the unintended consequences of subregional electricity integration including the use of land for bioenergy and social impacts from hydropower development.

As a subregion highly exposed to the effects of climate change, the contribution of power grid interconnection to mitigating climate change is of critical importance. The countries in the subregion, through their participation in the Paris Climate Change Agreement, have submitted climate pledges through their Nationally Determined Contributions (NDCs). The majority of these utilize a range of emission intensity reduction targets but ultimately entail a rise in emissions. Given the enormous untapped potential for renewable energy at low cost from hydropower, solar and wind in South Asia, integrating the power systems of the subregion's countries to allow this capacity to be exploited could change the emissions outlook drastically and reframe future climate pledges under the NDCs, allowing greater contribution to the global abatement challenge. The availability under the Paris framework for flexible cooperative means of delivering abatement, through international transfers of mitigation outcomes (ITMOs), provides possible avenues for financing subregional interconnection and renewable energy development. ITMOs enable Parties to negotiate the transfer of some portion of one nation's NDC to another Party's NDC through several mechanisms, including transfers of technology or provisions of climate finance. For implementing the South Asia power grid, ITMOs could provide financing from developed countries outside the region.

Figure ES 1 | Economic costs and benefits of interconnectors in South Asia



Afghanistan-Pakistan-India Jalalabad (AFG)-Peshawar (PAK) via Torkham (HVDV line under construction under CASA 1000 project), with onward connection to Amritsar (IND)	**India-Nepal** Towards Bareilly (IND) from Karmali HEP Towards Muzaffarpur (IND) from Tamakoshi, Anun HEPs
Bangladesh-Nepal Transit possibilities through Siliguri Corridor (IND)	**India-Pakistan** Amritsar (IND) and Lahore (PAK) HVDC line for 500 MW transmission
Bangladesh-India Bheramara (BGD)-Baharapur (IND) (500MV HVDC line) Comilla (BDG)-Pelatana (IND) (100MV), planned)	**India-Sri Lanka** Madurai (IND)-Anuradhapura (LKA) HDVC submarine cable link through the Palk Strait with 500 MW transmission
Bangladesh-Nepal Transit possibilities through Muzaffarpur, Siliguri Corridor (IND)	Annual benefit of interconnection in US$ million
Bhutan-India Towards Siliguri-Alipurduar (IND) from Tala, Chhukha, KurichhuDagachhu and Punatsangchu HEPs Deothang-Rangie (132kV single circuit DC line, eastern Bhutan-NER border)	Annualized interconnection cost in US$ million

Source: ESCAP, with data from ADB, 2017. and Wijayatunga et al. (2015). Abbreviations are; AFG (Afghanistan), BGD (Bangladesh), BTN (Bhutan), IND (India), NPL (Nepal), PAK (Pakistan), LKA (Sri Lanka), and HEP (hydro-electric project).

Grid interconnection in South Asia can generate direct economic benefits for all participating countries through both exporting and importing electricity. For the hydropower-rich least developed countries (Bhutan and Nepal), power exports to their neighbours can generate stable long-term export revenue as well as fast-track their graduation from least developed country status. Larger countries such as India and Pakistan can diversify their generation base and lower overall power costs by utilizing cross-border generation. These two economies may benefit from interconnection that allows optimal exploitation of their wind and solar potential through energy balancing. Under an integrated grid, countries can be both energy producing and energy consuming at different times or seasons, depending on their energy supply and demand situations.

While it will be challenging to implement, there are no reasons why an integrated South Asia power grid is not technically and economically feasible. However, there exists an enormous political and institutional challenge among multiple countries to implement it. A stronger evidence base for assessing its benefits for economic growth, SDG achievement and GHG emissions reductions will help align diverse interests and build support. Galvanizing strong political ownership of the issue at a high level by South Asian leaders is an essential prerequisite. Regional and global cooperation can assist in gleaning the technical, operational and policy lessons available from other successful power system integration cases for stakeholders in South Asia. To engage the private sector further in power grid integration, the Governments of the subregion could collaborate in developing private sector engagement strategies, including through public-private partnerships (PPPs). Capacity-building of South Asia's policymakers, system operators and regulators will play an important role in realizing the vision of the SAARC Energy Ring. The complexity of the integration process and the pace of technology development create knowledge and capacity gaps. Regional cooperation can play a role in bridging these gaps by leveraging the mandates of subregional institutions such as the SAARC Energy Centre.

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ABBREVIATIONS AND ACRONYMS

ASEAN	Association of Southeast Asian Nations
ADB	Asian Development Bank
B2B	business-to-business
CASA-1000	Central Asia-South Asia power project
CBET	cross-border electricity trade
DFID	Department for International Development
ESCAP	Economic and Social Commission for Asia and the Pacific
G2B	government-to-business
G2G	government-to-government
GDP	gross domestic product
GW	gigawatt
IEA	International Energy Agency
IRENA	International Renewable Energy Agency
ITMOs	international transfers of mitigation outcomes
kWh	kilowatt-hours
MW	megawatt
NDCs	Nationally Determined Contributions
PPA	Power Purchase Agreement
PPP	public-private partnership
PTA	Power Trade Agreement
SAARC	South Asian Association for Regional Cooperation
SDGs	Sustainable Development Goals
SME	small and medium-sized enterprise
TWh	terawatt-hours
UNIDO	United Nations Industrial Development Organization
USAID	United States Agency for International Development

INTRODUCTION

CONTEXT

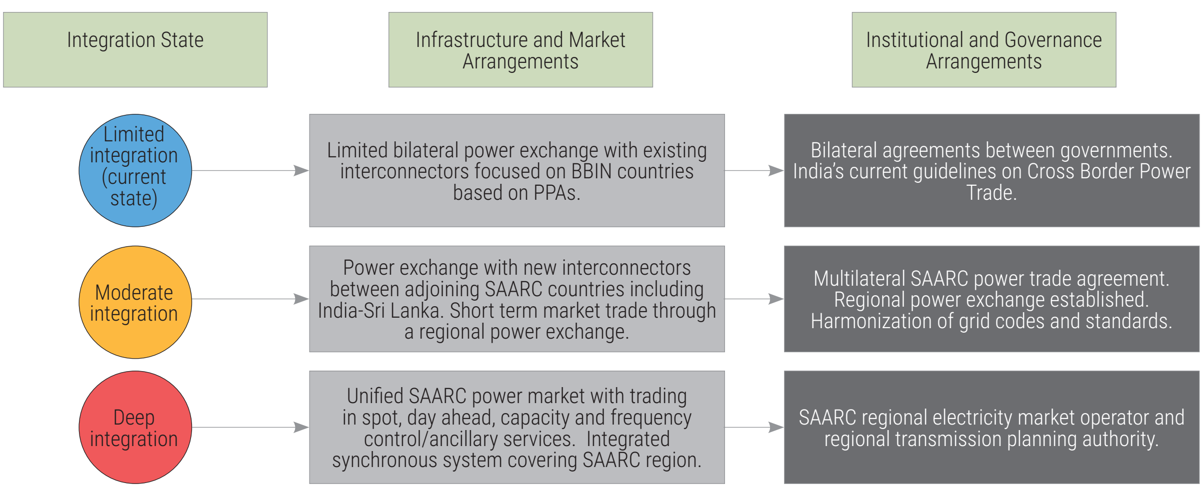
Globally, focus has increased on developing cross-border power interconnection to support the trade of electricity between countries and regions. Governments of many countries have recognized the benefits of regional approaches to power generation. Interconnecting power grids is not an easy process and requires cultural changes, the building of trust between countries and institutional reform over several decades. Interconnected multi-country power grids are increasingly seen as an enabler for renewable energy, and as such a means to help achieve SDG7, the dedicated goal on sustainable energy. An interconnected power grid for the region represents a type of meta-infrastructure – an overarching form of infrastructure that provides the basis for underlying power generation and cross-border power trade to develop. However, creating interconnected grids alone does not guarantee that they will advance sustainable energy. They can provide a conduit for either renewable or fossil-fuelled electricity. However, the analysis in this report examines how, with the right mix of policies in place, power grid connectivity may play a facilitative role in the transition to renewable energy; how it may become a building block in future low-carbon energy systems and evolve as a regional public good for South Asia.

Already, there are several successful global examples of multi-country interconnected power systems that support multilateral power trade. Some have developed varying degrees of market integration as well as physical interconnection. In the Asia-Pacific region, several subregional grid interconnection proposals are at various stages of development, including the ASEAN Power Grid and the Energy Super Ring of North-East Asia. Since the announcement in 2004 of the subregion's own interconnection concept, the "SAARC Energy Ring", progress has been slow and uneven. However, over a decade later, this may be an idea for which the time has come. Advances in power transmission technology and new technologies for renewable generation, together with pressures of demand growth, energy security and sustainability in recent years, have prompted South Asian countries to place greater focus on interconnecting their power grids on a bilateral and multilateral basis. ESCAP promotes Asia and Pacific-wide energy connectivity by undertaking analytical work and providing a platform for dialogue to understand and address the principal barriers to energy connectivity from the national, subregional, and regional perspectives. This report, in focusing on South Asia's potential, recognizes that subregional connectivity initiatives are the building blocks that will underpin the broader vision of an interconnected Asia-Pacific power system.

South Asia offers one of the most compelling opportunities for CBET in the Asia-Pacific region. The subregion faces a combination of uneven distribution of renewable and fossil energy sources, persistent electricity shortages and growing demand, for which CBET can offer solutions. These opportunities are complemented by a desire to move towards a low carbon energy system by among other measures, increasing the share of renewable energy. Varying degrees of power system integration are possible, ranging from bilateral trade to a fully integrated subregional energy market. The optimum level of integration needs to be determined by the participating countries – balancing issues such as investment, risks, benefits and sovereignty. Figure 1 illustrates the steps that can be taken towards a fully integrated market.

Power grid integration provides one tool for helping to address the "energy trilemma" confronting policymakers – that of ensuring security, affordability and sustainability. The diversity of demand profiles in adjoining South Asian countries, and the often-complementary generation profiles of their power sources, provides economic opportunities through, inter alia, avoiding load shedding, price arbitrage, increased economies of scale, reducing transmission losses, pooling reserve margins, cooperation in provision of ancillary services and the coordination of maintenance schedules.

Figure 1 | Steps in Developing an Integrated Power System



If well-implemented, an integrated power grid in South Asia can deliver multiple benefits for participating countries, in terms of affordability, reliability and sustainability of electricity supply, and can trigger positive spillovers outside the energy sector. It can provide a subregional public good in the form of an interlinked grid that can transfer electricity from multiple sources to load centres throughout the subregion as well as form the foundation infrastructure for a future low-carbon electricity system. Other regions have successfully implemented regional power grid interconnection and demonstrated its benefits. These include the synchronous grid covering the European continent, the Southern Africa Power Pool and the Central American Electrical Interconnection System (SIEPAC) linking six countries in Central America (Panama, Costa Rica, Honduras, Nicaragua, El Salvador and Guatemala).

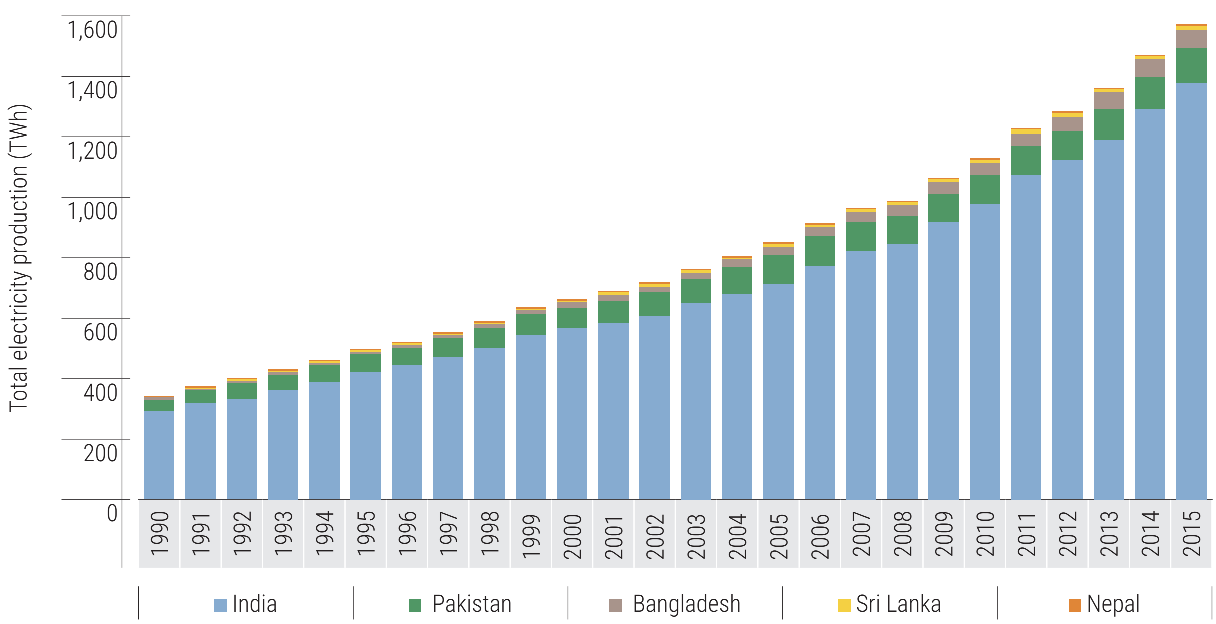
The benefits that can be gained from using CBET as a tool for securing reliable, affordable and sustainable energy are gaining increasingly widespread recognition by Governments and stakeholders in the subregion. A number of dedicated subregional initiatives have been set in place to accelerate CBET in South Asia by SAARC, the World Bank, ADB, USAID, DFID among others. SAARC, after promulgating the concept of the SAARC Energy Ring in 2004, established the SAARC Framework Agreement for Energy Cooperation (Electricity) in 2014. India also issued its own guidelines in 2016 for CBET (Ministry of Power, India, 2016).

THE IMPERATIVE FOR MEETING ELECTRICITY GROWTH IN SOUTH ASIA

South Asia faces a significant challenge in meeting the electricity needs of its population, both today and in the future. Challenges exist in the rapid drivers of energy demand and in the constraints in current and future energy supply options.

Electricity production in South Asia increased rapidly between 1990 and 2015 with further acceleration in more recent years. In 1990, South Asian countries produced more than 340 terawatt-hours (TWh) of electricity. By 2015, this amount had almost quintupled, increasing by 458 per cent to more than 1,500 TWh (figure 2).

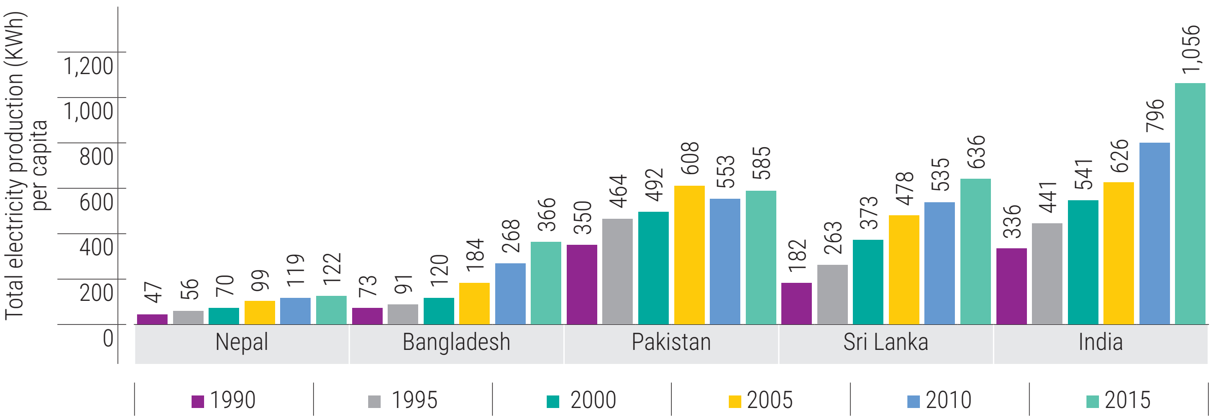
Figure 2 | Total electricity production by selected South Asian countries, 1990-2015



Source: Asia-Pacific Energy Portal, 2018

Significant inequality in per capita electricity production exists across the countries of South Asia (figure 3). In 2015, India's per capita electricity production (box 1) was more than 1,000 kilowatt hours (kWh) per annum. For Sri Lanka and Pakistan, per capita production was far less, while in Bangladesh and Nepal kWh per capita production was only around one-third to one-eighth of that by India. However, electricity production per capita increased significantly for all countries in the subregion.

Figure 3 | Electricity production per capita in selected South Asian countries, 1990-2015



Source: Asia-Pacific Energy Portal, 2018

Box 1 | India's projected electricity demand

CBET is crucial to alleviating the pressure on countries to meet future electricity demand as populations grow and development multiplies per capita electricity consumption. For India, cross-border power trade is crucial. India's peak national planning body, the National Institution for Transforming India (NITI) Aayog in a 2015 report projected that demand for electricity would grow nearly three-fold from 762 TWh in 2012 to 2,239 TWh by 2030, with the fastest increases in residential and industrial sectors as listed below.

Electricity demand in India, by sector (TWh)

Sector	2012	2022	2030	2047
Industry	336	494	703	1 366
Residential	175	480	842	1 840
Commercial	86	142	238	771
Agriculture	136	245	336	501
Others	29	71	121	233
Total	762	1,433	2,239	4 712

Source: NITI Aayog, 2015, p. 10.

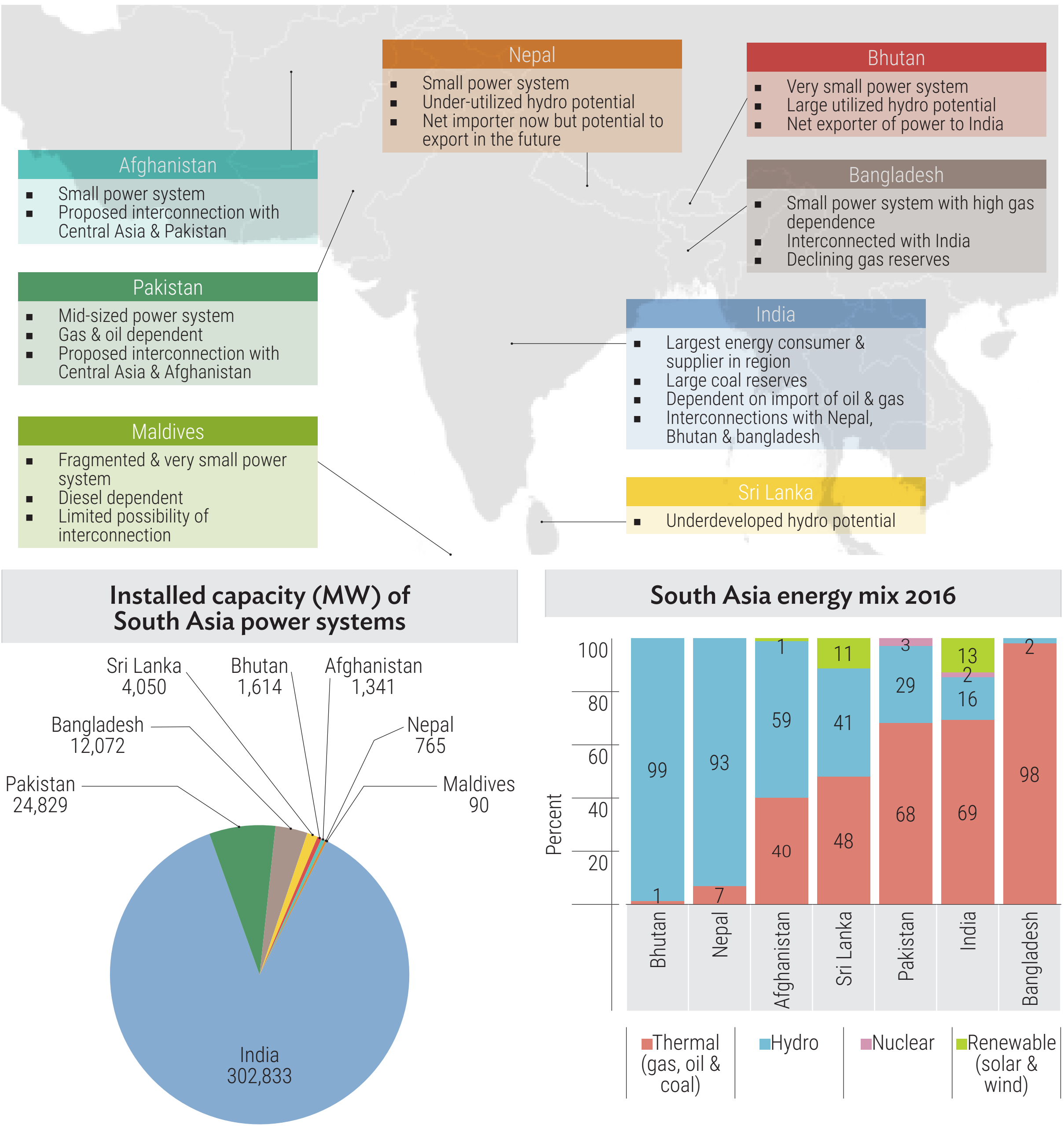
CBET is also crucial to accelerating the potential for an increased renewables share in the energy mix. Without policy intervention, fossil fuel will continue to dominate (85 to 88 per cent) the energy mix with significant adverse impacts on the environment and other SDGs. The NITI Aayog report projects that under current trends, coal with a 52 per cent share (2030) will continue to be the dominant source in the primary energy mix followed by oil at 29 per cent and gas at 8 per cent.

CBET can also substitute for some of the fossil fuel imports that India will need in the future. India's import dependence on fossil fuels is projected to rise from 32 per cent of the primary energy supply in 2012 to 45 per cent in 2030. For oil, import dependence would be more than 80 per cent, while for coal and gas, dependence would be 59 per cent and 40 per cent, respectively.

POWER CORRIDOR GEOGRAPHY IN SOUTH ASIA

The intersecting geography of South Asia through the land borders of Pakistan, India, Nepal, Bhutan and Bangladesh offer extensive possibilities for developing cross-border interconnections of national power grids. To date, interconnections have been developed between India-Nepal, India-Bhutan and India-Bangladesh. With India as a transit country, there are plans for Bangladesh to import electricity from Bhutan and Nepal.

Figure 4 | Power sector profiles of countries in South Asia



Source: South Asia Regional Initiative for Energy Integration, 2016, and Lama, 2017.

While India stands at the hub of South Asia's power corridors, and therefore must be a central actor, each adjoining country also has a critical role to play in ensuring overall success. This particularly the case with Pakistan and Afghanistan in the west, Nepal in the north, Bangladesh, Bhutan, Myanmar and Nepal in the east, and Sri Lanka in the south. Over time, these corridors could be further extended to connect the other adjoining subregions as part of a broader Asia-Pacific energy integration. Each corridor has its own distinctive features in terms of transmission length, its energy resources and demand centres as well as geopolitical and technical challenges. Figure 4 illustrates the energy geography of South Asia.

Countries such as Bhutan and Nepal have very high technical potential for hydropower generation, amounting to many multiples of their domestic needs. Other economies, such as Pakistan and India, while possessing large reserves of coal, also have significant potential for wind and solar power. Pakistan is undertaking a significant expansion of its generation fleet by adding coal, hydropower, solar and wind generation as part of the China-Pakistan Economic Corridor development under China's Belt and Road Initiative. India has set implementation targets of a combined 175 gigawatts (GW) of solar, wind, biomass and small hydropower production by 2022.

Integrating increasing amounts of these types of variable forms of power generation can be assisted by the creation of larger multi-country power grids through interconnection. Bangladesh utilizes its declining gas resources for power generation and has limited hydropower. Its power sector needs to be supplemented by other sources in order to meet its growing demand, for which CBET is a key opportunity. Sri Lanka relies on hydropower, oil and coal for its power needs. It has committed to not building any coal plants until after 2037, and to rely on gas and renewables to meet its demand growth. Interconnection with India would help it reduce the need for new capacity additions and to sell surplus power. Table 1 illustrates the bidirectional power exchange opportunities between countries in South Asia.

Table 1 | Summary of power exchange possibilities between South Asian countries

	Exporting countries		
Importing countries	**India**	**Pakistan**	**Bhutan**
India	x	Peak power support possible	Hydropower export
Pakistan	Peak power support possible, particularly in winter	x	Unlikely
Bhutan	Thermal power for dry season support	Unlikely	x
Nepal	Thermal power for dry season support	Unlikely	Unlikely hydropower seasonally correlated
Bangladesh	Two interconnections in operation, 3 more planned	Unlikely	Hydropower export planned via India
Sri Lanka	Thermal power for dry season support	No scope	Unlikely
Afghanistan	Peak power support possible, transit through Pakistan	Peak power support possible	Unlikely

Source: ESCAP compilation, adapted from PTC India

PROGRESS IN DEVELOPING SOUTH ASIA POWER GRID INTEGRATION

In South Asia, progress in developing power grid integration has been uneven. Encouraging progress in the north-eastern portion of the subregion has been made through bilateral interconnections and the ensuing power trade. The power trading arrangements realized to date are between Nepal-India, Bhutan-India and India-Bangladesh. In the near future, Bhutan-Bangladesh power trade will commence through existing interconnections, using India as a transit country. Often these interconnections have been built to connect new hydropower capacity to markets (Nepal and Bhutan to India). In other cases, they have been constructed to transmit energy from specific fossil fuel plants or to provide peak load support (as in the case of India to Bangladesh). These bilateral projects have demonstrated benefits to supplier and consumer countries, i.e., addressing supply shortages, earning export revenue and enhancing domestic energy security. While no electricity trade exists between India and Sri Lanka, a feasibility study has been completed for a submarine connection linking the two countries. This interconnection has a proposed capacity of 500 megawatts (MW), which could be upgraded to 1,000 MW. Owing to the remoteness of Maldives and the small size of its power system, there are no active proposals to connect that country's grid to any nearby country. Chapter 3 outlines in detail the major cross-border interconnection developments.

Significantly, no progress has been made in interconnecting the two largest economies of the subregion, India and Pakistan, where the greatest levels of benefits can be realized. Ongoing political tensions in the subregion prevent the benefits of Pakistan-India power trade from being realized, despite the minimal investment required to connect their grids. However, Afghanistan and Pakistan will be serviced by an interconnection with Central Asia. The Central Asia-South Asia power project (CASA-1000) project, currently under construction with expected completion in 2018, will transfer 1,000 MW of hydroelectricity from Turkmenistan to Afghanistan and Pakistan. An eventual India-Pakistan interconnection would complete the link between India and Central Asia.

Nepal	Bangladesh	Sri Lanka	Afghanistan
Hydropower export	Gas producer but future resource uncertainty	Peak power support possible	Unlikely owing to resource shortage & feasibility of transit via Pakistan
Hydropower export possible via India	Unlikely	No scope	Unlikely owing to resource shortage
Unlikely hydropower seasonally correlated	Thermal power for dry season support, connection via India	No scope	No scope
x	Dry season support, connection via India	No scope	No scope
Hydropower export planned via India	x	No scope	No scope
Unlikely	Unlikely	x	No scope
Unlikely	Unlikely	No scope	x

Much of the activity in bilateral power interconnections in South Asia has been focused on the north-eastern corridor, mostly with regard to connections of new hydropower projects in Bhutan and Nepal with neighbouring India and Bangladesh. The exchange of power may be two-way, based on seasonality. For example, in addition to exporting to India in the wet season, Nepal has also benefitted from India's dry season support for its power grid. In the case of the integration of Sri Lanka's grid with India, the project is at the very early feasibility stage.

Despite the political challenges and institutional complexities that may slow moves towards greater power connectivity, the progress of South Asia's power interconnection may be assisted by two areas of new technology. First, the emergence of new power generation technologies, notably wind and solar power, will supplement the subregion's already abundant hydropower resources. Solar and wind are emerging as the sources of lowest cost in new generation capacity. However, despite the low cost, the locations with these resources may be distant from load centres, while solar and wind output also has daily and seasonal variations that need to be managed with other forms of generation or storage in order to meet demand.

In several countries in South Asia, renewables are emerging at large scale in new capacity additions. India's national policy commitment will see the implementation of 60 GW of wind and 100 GW of solar power generation by 2022. Pakistan has identified a wind corridor in Sindh province with the potential of 43 GW, and it is installing wind and solar projects under the China-Pakistan Economic Corridor programme. With improving renewable technology and policy support, it is possible for the incremental demand in South Asia to be met primarily by renewables.

The second type of technology that may support greater interconnection is high voltage direct current (HVDC) power transmission technology. Advances in the cost effectiveness of HVDC open up possibilities for longer distance power transmission, bringing benefits such as better control of power flow, reactive power management and allowing interconnected grids to work in asynchronous mode, isolating power system faults on each side. Thus, HVDC presents advantages for cross-border interconnection of power systems with different operating parameters. Currently, an HVDC link is in operation between India and Bangladesh, and India has developed internal HVDC links in its domestic grid to optimize internal power flows. For distances exceeding 600 kilometres (km), HVDC offers a more economical solution for power transmission compared to alternating current systems, and is preferred for submarine connections longer than 40 to 50 km.

However, its decreasing cost and other advantages in allowing asynchronous generation are also opening up possibilities for using HVDC for shorter route lengths. There are some hybrid designs for combining an HVDC link with an LNG pipe within the same conduit to allow both power and LNG to be transmitted. There are also synergies between HVDC connectors and ICT connectivity, where fibre-optic links can be co-deployed with HVDC at limited marginal cost, either through hybrid conduits or shared trenching. This opens up possibilities for integrated power and ICT connectivity in the subregion.

Cross-border power interconnection is therefore a critical infrastructure for allowing renewable energy resources to be traded across borders. It can ensure the future success of the renewable energy sector by allowing larger shares of variable renewables to be accepted in national grids. This is because interconnection links diverse loads and generators that may be spread over a wider area, helping to ensure power system balance and stability. New HVDC technologies may also assist in making the economic and technical feasibility of the interconnection process more cost-effective.

It should be noted that a vision of a future South Asia power system based on renewables is not assured under business as usual settings. Estimates are that India will add 40 GW of coal-fired capacity over the next five years to meet demand,[1] despite its ambitious solar and wind expansion. Pakistan in 2017 commissioned two 1,320 MW coal-fired power plants and is planning to use its domestic coal resources to supply additional coal-fired generation capacity. While renewable energy

1 BNEF, New Energy Outlook 2017

is affordable, it may not be applicable at utility scale in all the South Asian countries. For example, the rugged geography of Nepal and Bhutan as well as the pressure on land use in Bangladesh prevent large-scale exploitation of wind and solar power generation.

ENERGY CONNECTIVITY AS A COMPONENT OF REGIONAL ECONOMIC COOPERATION AND INTEGRATION

The ESCAP member States have given the secretariat a mandate to deepen regional economic cooperation and integration (RECI) for the mutual benefit of all countries in the region. ESCAP is working on an approach to RECI that emphasizes four pillars – market integration, seamless connectivity, financial cooperation, and addressing shared vulnerabilities and risks. Within this framework, energy connectivity, together with transport and ICT, has a key role to play in further integrating South Asia (ESCAP, 2017a).

South Asia's integration progress to date has not matched the pace of other blocs. It lags behind the rest of Asia and the Pacific as the least integrated subregion, with a series of barriers to trade, poor overland transport connectivity, low ICT bandwidth as well as limited progress in energy integration. These factors limit the flow of goods, people and information, and restrain economic growth and development. ESCAP estimates that the present $27 billion trade within the subregion amounts to only one-third of its actual potential. Unlocking the barriers that prevent deeper integration of the countries in South Asia will be instrumental in progress in achieving the 2030 Agenda, including addressing poverty, mainstreaming sustainable energy and dealing with climate change. Energy connectivity can make a substantial contribution to the overall integration of South Asia.

SCOPE OF THE REPORT

This report examines the status and prospects of CBET in South Asia, the benefits generated and how they are distributed across the three pillars of sustainable development. It focuses on the potential of CBET to help the countries of the subregion deliver against the Sustainable Development Goals and to reduce GHG emissions in support of the Paris Agreement. In considering the challenges and institutional barriers to CBET, the report highlights some of the steps the subregion needs to take in order to put in place the policy, regulatory and institutional arrangements required to further integrate the power grids of the subregion. It also identifies the gaps in key knowledge and capacity that hinder the development of CBET.

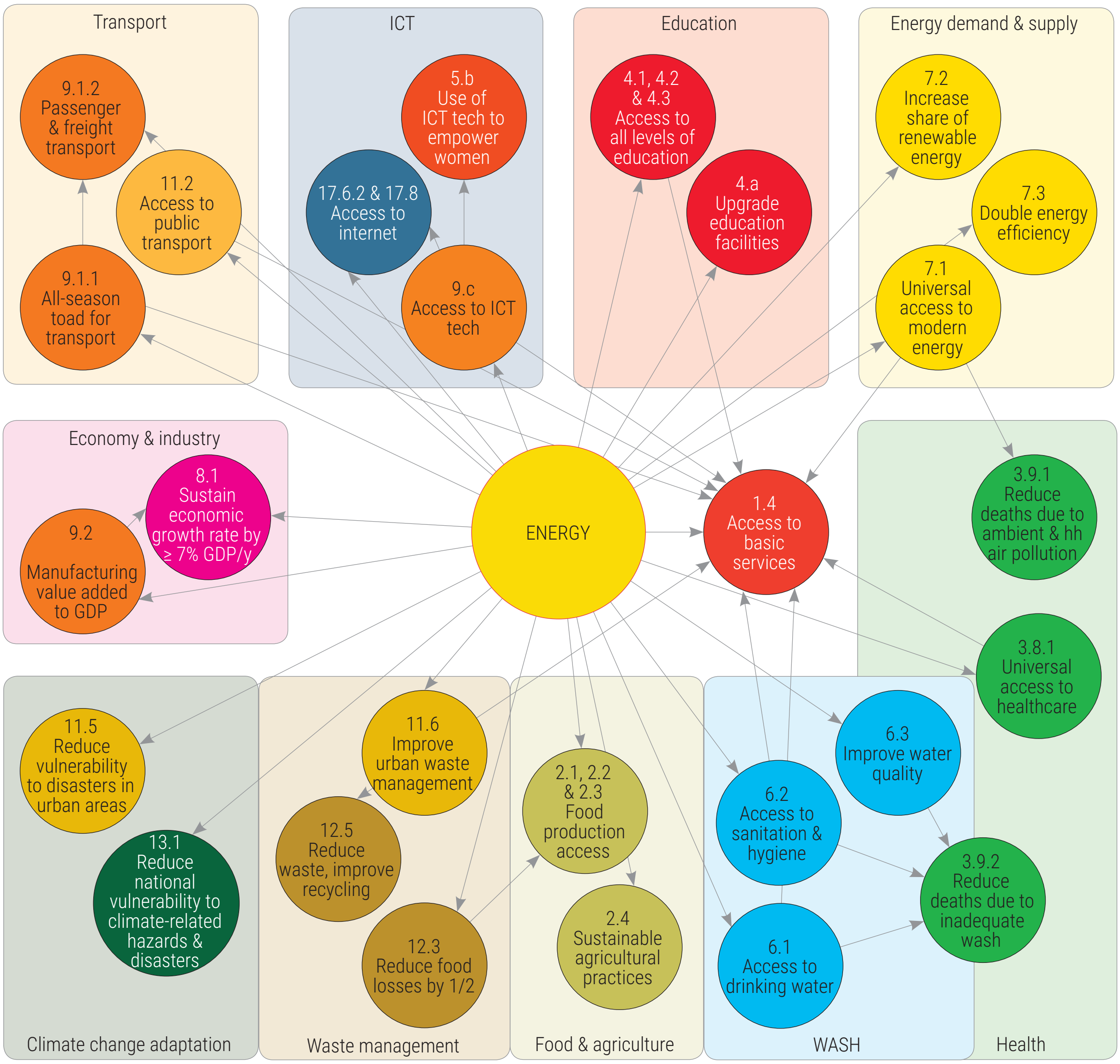
1 SUSTAINABLE DEVELOPMENT BENEFITS FROM AN INTEGRATED SOUTH ASIA POWER GRID

1.1 INTRODUCTION

The success of countries in South Asia in overcoming their energy challenges will be limited if they rely on domestic resources alone and adopt a fragmented approach to developing their electricity sectors. Ensuring a resilient, affordable and sustainable power sector energy requires energy cooperation with neighbours in harnessing synergies and realizing mutual sustainable development gains. Developing an integrated power grid for South Asia, and thereby allowing increased levels of CBET, can be a solution for promoting sustainable growth. This chapter outlines the role that integrating power systems across South Asia could play in improving the affordability, reliability and accessibility of energy as well as tapping into cleaner sources of generation. The chapter outlines the interrelationship between enhanced CBET through regional power connectivity with the achievement of the SDGs and fulfilling the goals of the Paris Agreement on climate change.

CBET can provide direct benefits for sustainable development pathways for countries in South Asia. First, through economies of scale, pooling grids with diverse demand and supply and tapping into cross-border renewable energy resources, CBET can accelerate the transition to sustainable energy, meet growing demand and reduce the cost of supply. Second, CBET can create climate benefits through the provision of cost-effective GHG reduction pathways for South Asia and can assist countries in achieving their NDCs. Third, CBET can play a role in the achievement of the other 16 SDGs beyond SDG7, the dedicated goal of affordable, reliable, sustainable and modern energy for all. CBET can play a role in SDG7 achievement by South Asia, which in turn is linked to the achievement of all other SDGs in the subregion. As South Asia is home to every fifth person in the world, and has multiple development challenges, global SDG success is linked to success in South Asia. Annex A provides an overview of SDG7 and its progress in South Asia. As illustrated in figure 5, multiple interlinkages exist between energy and the economy, society and

Figure 5 | Interlinkages between energy and the SDGs, by thematic sector



Source: *Santika and others, forthcoming.*

environment – all critical to achieving the SDGs. Annex B further describes the linkages between energy and the SDGs.

1.2 CBET AS A DRIVER OF SUSTAINABLE ENERGY PATHWAYS

Based on the uneven distribution of energy resources in South Asia, there is a strong rationale that CBET can provide a critical strategy for bridging current and future energy gaps, and by extension, achieving the Sustainable Development Goals. CBET can help to drive SDG7 directly through increased adoption of renewables and better international cooperation in energy infrastructure. CBET also offers a series of second order benefits for the electricity sector in South Asia as follows::

1. Affordable energy – CBET can reduce the power sector's energy capital capacity requirements and provide access to lower-cost electricity generation, thereby helping to affordably meet the energy needs of a fast-growing population;

2. Reliable energy – CBET can diversify supplies and provide energy options to policymakers outside their borders, thus avoiding seasonal shortages or risk exposure to energy imports with long supply lines;

3. Sustainable energy – CBET can boost renewable energy use by tapping into cross-border renewable energy resources. The integrated power grid underpinning CBET can allow a higher level of penetration of variable renewable energy than each national grid in isolation;

4. Modern energy – CBET can improve electricity delivery, minimize power losses and disruptions for households and businesses, reduce costly and polluting power backup solutions, and inefficient production technologies. minimize power losses and disruptions for households and businesses reduce costly and polluting power backup solutions, and inefficient production technologies.

1.3 CBET AS AN ACCELERATOR OF THE ENERGY TRANSITION TO RENEWABLES

Renewables are likely to play a central role in the future energy mix in South Asia. While a substantial shift towards renewables is taking place globally, driven by rapid technology advances, South Asia's energy future depends on how it leverages its advantages in renewables and takes part in the global trend.[2] This is especially so because today renewables are seen not only as an alternate source of energy, but also as tools to address other pressing needs, such as reducing the health and environmental impacts associated with fossil energy, mitigating greenhouse gas emissions and delivering socio-economic benefits.

Renewable energy production, both in total energy consumption and in electricity, has increased in absolute terms in South Asia during the past two decades. However, its overall share has decreased as its growth has been outpaced by faster growth in non-renewable energy sources. The share of renewables in the electricity mix had declined to about 15 per cent by 2014, down from 27 per cent in 1990 (Asia Pacific Energy Portal, 2018). Reversing this trend is critical for South Asia, and cross-border power trade capitalizing on the subregion's hydropower offers an important solution.[3]

The installed capacity of renewables is only a fraction of the total potential renewable energy resources that could be utilized (table 2). However, better policies are required to accelerate transitions to renewables and avoid exploiting economically cheap but unsustainable carbon-based fuels. CBET-based incentives to transition away from carbon-based fuels can better distribute the country-based renewable capacity to

2 Large gaps are expected between the potential of fossil fuel supply and the energy demand to achieve the South Asian countries' new social and economic development targets, making a growing use of renewables in the subregion (Shukla and others, 2017).

3 In the medium term, hydropower generation, primarily from Bhutan, is expected to displace about 10,000 GWh of thermal generation in India by 2016/17 and 40,000 GWh of thermal generation in India by 2020/21. See Wijayatunga, Chattopadhyay and Fernando (2015).

Table 2 | Potential generation capacity and energy reserves in South Asia

	Generation capacity			Reserves			
Country	Wind (MW)	Utility-scale solar (MW)	Hydropower (MW)	Coal (million tonnes)	Oil (million barrels)	Natural gas (trillion cubic feet)	Biomass (million tonnes)
Afghanistan	67 000	220 000	23 000	440	-	15	23
Bangladesh	-	-	4 000	884	12	-	-
Bhutan	4 825	-	263 000	2	-	8	27
India	102 778	750 000	150 000	90 085	5 700	39	139
Maldives	-	-	-	-	-	-	-
Nepal	3 000	-	733 000	-	-	-	27
Pakistan	131 800	169 000	60 000	17 550	324	33	-
Sri Lanka	24 000	-	21 000	-	-	-	12
Total	333 403	1 139 000	1 254 000	108 961	6 036	95	228

Source: Author's compilation, based on IRADe, 2013, Farooq and Kumar 2013, Shukla and others 2017, and Water and Power Development Authority, 2013

consumers across the region, while still meeting the needs of consumers within countries that enjoy natural renewable resource endowments.

The scope of diversification into other renewable sources beyond hydropower, such as solar and wind energy is higher than ever before, given that the cost gap between electricity generated from renewables and that from fossil fuels is narrowing quickly.[4] There are several advantages South Asia offers in adopting renewable energy.

First, in addition to hydropower, the subregion offers some of the world's highest quality and most extensive wind and solar resources. The wind energy potential across Afghanistan, Pakistan, India and Sri Lanka may be in the region of 320 GW. The hydropower potential, concentrated in India, Bhutan, Nepal and Afghanistan, is estimated to be almost 1,300 GW.[5] Reliable estimates of solar resource potential are difficult to ascertain, but the Government of India's official calculation of its solar resource potential stands at 750 GW.[6] Exploiting the full renewable energy potential of all the countries in the subregion collectively would yield an annual generation of approximately 9500 TWh, about six times the current subregional demand. Figure 6 illustrates the renewable energy resource potential across South Asia focusing on three key technologies of utility scale solar, wind and hydro.

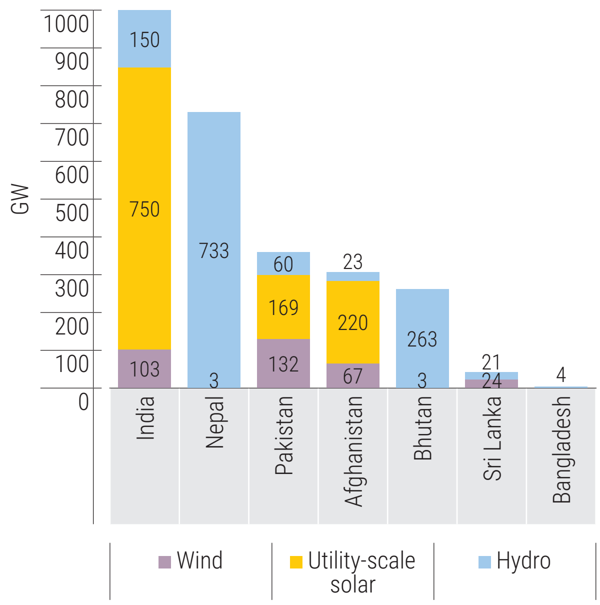
Secondly, renewable energy costs in the subregion are highly competitive, offering some of the lowest installed costs of renewable energy systems globally (IRENA, 2018). India in 2016/2017 achieved the lowest average installed cost for PV and wind power, at $1,100/kW and $1,120/kW respectively, which was slightly lower than China. These costs are expected to further decline in line with the global learning curve on renewables. A further advantage is the fact that much of the energy consumption or production infrastructure that will exist in in 2030 has yet to be built, allowing South Asian countries to leapfrog to more advanced technologies, both on the generation and the demand side. For example, India has committed to a 100 per cent electric vehicle target by 2030, which could have a major impact on transport emissions with the right generation mix in place.

4 This is a key finding of IEA (2015).

5 Based on data from IRADe, 2013, Farooq and Kumar, 2013, Shukla and others 2017, and Water and Power Development Authority, 2013 and capacity factors typical for the region.

6 http://mnre.gov.in/file-manager/UserFiles/Statewise-Solar-Potential-NISE.pdf

Figure 6 | Estimated renewable energy potential in South Asia



Source: Author's compilation, based on IRADe, 2013, Farooq and Kumar, 2013, Shukla and others, 2017, and Water and Power Development Authority, 2013.

1.4 IMPACTS OF SDG7 ON OTHER SDGS

As introduced earlier in this chapter, advancing sustainable energy through SDG7 can provide strong beneficial net effects for all other SDGs. At the same time, planning for the energy transition and meeting SDG7 requires anticipating the possible trade-offs and constraints it may pose to the achievement of other SDGs. Externalities can be organized by their type of impact on other SDGs (Annex B).[7] Positive impacts can be: (a) enabling by creating better conditions for SDG achievement; (b) reinforcing, by increasing achievement directly; and (c) indivisible, where the goals are inextricably linked. Negative impacts can be: (a) constraining by limiting options for other goals; (b)counteractive by clashing with another goal; or (c) cancelling by making achievement impossible.

Using this organization framework, figure 7 shows a summary of the positive and negative impacts of SDG7 and energy on other SDGs.[8] In terms of positive impacts, SDG7 is an enabler for all other SDGs, as described above. However, it can also reinforce SDG achievement of goals related to poverty, hunger, health, water and sanitation, infrastructure as well as environmental dimensions of urbanization, climate change, and life under water and on land. For SDG11 in particular, energy sustainability is indivisible with the achievement of sustainable urbanization.

At the same time, SDG7 has the potential for negative impacts on several other SDGs, although it does not cancel out the potential to achieve any other goal. Progress on SDG7 has potential constraining impacts on SDGs related to slowing the pace of gains in poverty, hunger and health, water and sanitation, growth, infrastructure and inequality as well as life under water and on land. The downsides in these cases relate to the need to pursue efficiency gains and more costly energy technologies and methods for achieving SDG7 compared to faster but unsustainable gains using polluting and more traditional energy sources. In addition, constraints may occur when there are uneven and unequal gains in SDG7 achievement and energy access for all.

Other greater potential downsides that policymakers must address are the potential counteracting effects of SDG7 achievement on SDGs 2 and 15, hunger eradication and life on land, respectively, which principally stem from bioenergy projects and the land-use requirements of other renewables. Faster SDG7 achievement could partially counteract SDG2 achievement, given the common demand of bioenergy and agriculture for limited land resources; however, this impact may be small. Renewable energy expansion in projects including hydropower and other sources could potentially clash with environmental considerations, including forest cover, ecosystems and biodiversity. Again, smart policy and inter-jurisdictional and cross-border environmental governance can provide the best mechanism for countries to maximize the pace at which they accelerate towards these goals.

7 For a description of the categorization of interlinkages, see Nilsson, et. Al. (2016).

8 A full analysis and literature review of possible impacts of SDG7 on other SDGs is available in (McCollum and others, 2018)

Figure 7 | Interlinkages between SDG7 and other SDGs

Source: McCollum and others, 2018.

1.5 ROLE OF CBET IN SOUTH ASIA'S CLIMATE CHANGE GOALS

The introduction to this report notes the role that an integrated South Asian power grid could play in increasing the subregion's ability to deliver on the Paris Agreement. The issues of energy and climate change are deeply interlinked. Energy is the key driver of global climate change, accounting for almost 80 per cent of GHG emissions. For South Asia, the effects of unmitigated climate change will be serious, including those on its ability to access water resources and hydropower. The subregion is host to many climate sensitive areas and biodiversity hotspots. As South Asia is one of the principal subregions with large reserves of untapped hydropower, the impact of climate change on the water cycle has great significance. The Himalayan Hindu Kush area, which is the source of most of South Asia's rivers, stretches across six countries of the subregion. Climate change is already having an impact on the Hindu Kush in the form of receding glaciers, flash floods and glacial lake outbursts. The coastal belts of Bangladesh and India are highly susceptible to climate risks such as sea level rises and storms.

All countries in the subregion have signed the Paris Agreement and have submitted climate pledges through their NDCs, which contain varying levels of

Nilsson and others, (2016), proposes categories of interaction between one SDG and other SDGs Interaction, separated into positive and negative for the respective interactions. The categories are: (+3 Indivisible) - Inextricably linked to the achievement of another goal, (+2 Reinforcing) - Aids the achievement of another goal, (+1 Enabling), Creates conditions that further another goal, (0 Consistent) - No significant positive or negative interactions, (−1 Constraining) - Limits options on another goal, (−2 Counteracting) - Clashes with another goal, (−3 Cancelling) - Makes it impossible to reach another goal.

ambition. Almost all of these NDCs foresee growth in national emissions before an eventual peak and decline, and hence propose reductions in carbon intensity of the economy or in business as usual emission forecasts as their basis.[9] The NDCs are to be resubmitted every five years, with the intention of increasing aspirations over time to meet the required aggregate global emission reductions. Table 3 summarizes the subregion's NDC commitments. .

Currently, South Asia accounts for 8 per cent of global emissions, but according to some forecasts, this share could rise to 12 per cent by 2030[10] as the subregion's countries develop. However, an alternative view of the future could be that South Asia becomes a driver of climate change mitigation as it capitalizes on its natural opportunities for GHG emissions reductions.

A World Bank study (Timilsina and others, 2015) estimated that CBET in South Asia could reduce

9 Converting intensity based targets into annual GHG abatement quantities is difficult given the uncertainty over future business as usual emissions growth.

10 Based on business as usual scenario under the Global Change Assessment Model see https://www.climatewatchdata.org/pathways/models/3

Table 3 | NDCs of SAARC member countries

Country	Mitigation target	Baseline	Target year	Reduction coverage
Afghanistan	13.6 per cent	BAU	2030	Economy-wide
Bangladesh	5 to 15 per cent	BAU	2030	Sectoral
Bhutan	Remain carbon neutral	2000	N/A	Economy-wide
India	33 to 35 per cent carbon intensity reduction	2005	2030	Economy-wide
Maldives	10 per cent unconditional – 24 per cent conditional	BAU	2030	Economy-wide
Nepal	50 per cent reduction in dependency on fossil fuels	n/a	2050	n/a
Pakistan	20 per cent	BAU	2030	Economy-wide
Sri Lanka	7 per cent unconditional, 23 per cent conditional	BAU	2030	Sectoral

Source: Author's compilation, based on NDCs.

emissions by 9 per cent compared to the baseline during 2015-2040. The same study also indicates that in the case of the implementation of a regional emissions trading scheme, power grid connectivity increases the level of abatement achieved for a given carbon price, as it provides access to lower cost mitigation options. However, the study pointed to the sensitivity of these results to the capital costs of wind and solar power. As these costs are reduced, the modelling predicts greater deployment of these technologies and larger flows of zero emission electricity across borders.[11] As the capital costs of solar and wind power have decreased considerably in South Asia from the values used in the study – for example, in India by 41 per cent and 50 per cent, respectively (IRENA, 2018) – these emission reduction estimates should be considered as lower-bound. The true quantum of GHG abatement that could be realized through CBET has not been comprehensively estimated. Given the dynamic nature of renewable power pricing, it would be beneficial to undertake modelling of GHG reductions from CBET in South Asia with up-to-date assumptions.

11 The model predicts a doubling of installed solar power if the costs reduce by 32 per cent and an increase in wind generation of 32 per cent with wind installed cost reduction of 24per cent. These cost benchmarks have already been surpassed since the study was published in 2015.

CBET is also a highly prospective area for deepening international climate cooperation. The Paris Agreement is notable for its success in engaging all counties in a bottom-up effort to reduce emissions in line with the 2°C target. However, beyond this achievement it also offers the possibility of using flexible cooperative means of delivering abatement through ITMOs. Articles 6.2 and 6.3 of the Paris Agreement provide the foundation for ITMOs between Parties to achieve their NDCs. ITMOs involve a negotiated transfer of some portion of one nation's NDC to another party's NDC, potentially including bilateral, regional or multilateral emissions credit trading schemes, linked networks of carbon pricing mechanisms, transfers of technology, or provisions of climate finance.

In the context of the South Asia power grid, ITMO schemes could provide a source of finance from developed countries outside the region. Countries such as India or Bangladesh, which can exploit hydropower potential in neighbouring countries through cross-border connectivity, could transfer the emission savings from these projects to other countries outside the subregion in order to achieve their NDCs. The carbon accounting that must be applied by countries that choose to use an ITMO is rigorous and will need to be applied to determine the GHG savings that new energy interconnections or energy project will create.

However, these standards build confidence in ITMOs that can spur new partnerships between Governments, the private sector, development agencies, financial institutions and civil society to harness low-cost abatement opportunities that can be realized through connectivity and CBET. This could encompass capacity-building, knowledge-sharing and technology transfer practices.

Even with existing technologies, evidence supports the claim that creating multi-country power systems for South Asia will promote electricity trade, increase the use of renewable energy and reduce emissions compared to the case without interconnection. The abundant renewable resources, the intersecting geography of the South Asian countries and the short transmission interconnection distances offer greater opportunities than in many other regions. The renewable energy resource potential of the region outlined in this chapter indicates that eventually South Asia could meet up to 100 per cent of its electricity needs through renewables,[12] helped by declining costs, interconnection and supportive policies. This is despite expected demand growth and the use of electricity in a broader range of applications such as mobility. Realizing the full renewable potential would offer enormous potential for GHG abatement, allowing countries to dramatically increase the ambition of their NDCs or to transfer the abatement to other parties via flexibility mechanisms.

1.6 SPILLOVERS FOR PEACE AND DEVELOPMENT IN THE SUBREGION

CBET can provide additional multiplier effects on reducing inequality, addressing key drivers of demographic and technological change and lower drivers of instability that can have an impact on peace and development.

It can also slow down the process of rural to urban migration and the socio-political instability emanating from that process. Socio-political instability, tension and insurgencies that have constrained the South Asia subregion have mostly been attributed to resource disparity, poverty and economic inequalities.[13] Regional inequality and underdevelopment have been a major source of internal conflicts. Removal of regional disparity mediated through electricity supply reduces internal stress and promotes better governance, as it energizes the entire socio-economic process.

A study by the World Bank (2016), citing experiences of cross-border power trading arrangements from various subregions of the world, showed that trust building through electricity trading is possible even between countries with a history of conflict. Broader free trade arrangements among countries can generate the trust required to expand regional power cooperation. Traditionally disparate localities within countries that are linked together by power grids can also experience such trust-building and its positive consequences.

CBET can provide the potential for using regional cooperation and common markets to address cross-border development challenges peacefully across countries. CBET in South Asia, and related sectoral priorities – such as the development of hydropower resources, and the environmental impacts of various energy production alternatives – could support the development of policies and forums for tackling other cross-border issues (e.g., subregional water resources, and other external environmental spillovers and effects). Other cross-border impacts such as natural disasters illustrate the benefits of CBET in the provision of resilient power supply as well as access to other production and grid sources when disasters have a negative impact local power production. CBET, through regional cooperation, can be a good practice for trust building through the establishment of norms and standards towards an integrated electricity market in South Asia. Chapter 2 provides an overview of pathways for countries to consider moving towards greater grid integration.

12 Complete penetration of renewables would however require advanced technology approaches including storage, advanced demand side management and some degree of surplus energy to be curtailed.

13 Security threats, terrorism induced disruptions can in turn hamper investments in energy as is observed in South Asia (ESCAP 2016).

2 | THE ECONOMIC CASE FOR POWER GRID INTERCONNECTION IN SOUTH ASIA

2.1 INTRODUCTION

This chapter describes the pivotal role that energy plays in driving socio-economic progress, including achieving the SDGs. By focusing on the economic pillar of development, direct economic benefits can be realized through power grid integration. Power shortages and the growing import of fossil fuels impose a heavy economic cost on South Asia. Countries in the subregion face resource constraints to mobilizing investments in modern energy sources on a scale needed to meet increasing energy demand. This investment deficit is not in energy generation capacity but also in transmission and distribution infrastructure. At the same time, limitations on access to clean, reliable and affordable energy have had a detrimental effect on economic growth and prosperity, which in turn has imposed resource constraints in terms of mobilizing sufficient investments for the energy sector.[14] Breaking this deadlock is vital for South Asia. This chapter argues that one solution to this dilemma can be found through increasing cross-border energy trade, which would enable better and more efficient production and distribution of energy (World Bank, 2016).

14 It has been estimated that primary commercial energy demand in South Asia will increase from primary commercial energy supply of 655 million tons of oil equivalent in 2011 to more than 2,200 million tons of oil equivalent by 2030. See ESCAP, 2016.

South Asia can find a collective solution by harnessing domestic energy endowments, including the large unexploited hydro-electric potential, which are dispersed across the subregion. Intraregional differences in resource endowments, together with variation in the load curves across South Asia, offer opportunities for a subregional approach to power generation and its efficient use. This requires joint investments for power generation and joint management of power distribution through cross-border grid interconnections and allied infrastructure. As well as the "hard" infrastructure of physical power grid interconnection, there is a need to: (a) develop the "soft" infrastructure for interconnection – the power trade agreements, harmonization of laws, regulations and standards – necessary for connecting adjoining power systems; and (b) strengthen the capacity of the institutions involved.

A regional approach with optimal use of a diverse generation mix and trade can bring enhanced operational efficiency, economic gains and environmental benefits.[15] There are, however, tradeoffs between gains in power system performance with issues such as national sovereignty and energy policy independence. High levels of trust and cooperation, the formation of new institutions, and harmonization of the rules and standards of different national power systems are necessary prerequisites for integrating the power systems of South Asia.

2.2 BENEFITS OF REGIONAL ELECTRICITY TRADE: EVIDENCE FROM SOUTH ASIA

Regional electricity trade enabled through enhanced power grid connectivity is a key strategy for overcoming South Asia's energy sector challenges and delivering economic benefits for all participating countries. Interconnected systems deliver multiple benefits to linked countries across several dimensions. These include:

1. Lower costs of electricity through more efficient utilization of subregional energy endowments and price arbitrage between countries;
2. Lower operating costs of cross-border integrated systems;
3. Input efficiency gains from greater scale of production; and
4. Lower levels of required generating capacity due to centralized management of reserves and the smoothing of variations, both in generation and in load profiles.

Beyond these direct benefits, interconnected grids may also offer investors an improved investment climate and attractive investment opportunities for private capital from efficiency gains in production and distribution chains, through enhanced reliability and stability of the shared power generation installations and by way of equitable distribution.[16] At a broader level, it is also argued that pursuit of a best energy mix by a country is fulfilled in the ideal way when the energy baskets of a subregional group of countries are optimized, based on cooperation between consumers and suppliers.[17] The relatively short distance of the transmission links required, complementarities in energy resources – particularly in hydropower and thermal power endowments – diverse demand profiles and differing seasonal power requirements offer ideal conditions for regional electricity cooperation in South Asia.

Cross-border power trade also has the potential to make importing countries less vulnerable to volatile electricity prices. Lower costs of power will play an important role in increasing access, affordability and per capita energy usage. In addition to direct economic benefits, regional cooperation and joint ownership can

15 Efforts for building energy infrastructure have mostly remained confined to national level so far in the Asia-Pacific, partly because in the past self-reliance rather than connectivity used to be seen as the main way to ensure energy security. See ESCAP, 2017 b.

16 IRADE (2013) notes from the experience of linked power grids in India that even if all subsystems suffer from power shortages, there are still opportunities to trade electricity as it provides appropriate signals for the more economic utilization of existing capacities and utilizes change in consumption behavior to suit the market conditions.

17 See comments on pursuit of energy diversification in Ito, Zhidong and Komiyama (2008).

be expected to deliver important spillovers. First among these would be a default mechanism for mutual support of national power systems during contingencies, which could bring about substantial transformation in the geopolitical relations in the subregion. Joint investments in hydropower projects can act as the single most effective confidence-building measure through the participation of multiple stakeholders (World Bank, 2016).

2.3 SUMMARY OF THE ECONOMIC COSTS AND BENEFITS OF SOUTH ASIA'S POWER CORRIDORS

A number of studies have examined the economic costs and benefits of establishing interconnections for power trade between South Asian countries. The most authoritative analysis was prepared by the Asian Development Bank (Wijayatunga and others, 2015). which accounts for the economic and relativity benefits of interconnection. The results of the analysis are summarized in figure 8. The analysis highlights the high benefit cost ratios arising from all the interconnection elements, highlighting the strong returns from the yet to be realized India-Pakistan interconnection. Figure 8 also summarizes the costs and benefits of the various interconnections between countries in South Asia.

2.4 ALLOCATIVE EFFICIENCY AND ENHANCED POWER AVAILABILITY

One key advantage offered by CBET is the opportunity to exploit daily and seasonal variations in power demand and generation. In a regional power grid, inter-regional differences in daily load curves due to variations in time zone and seasonal power demand, differing urban-rural or industry demand patterns, and holidays are served with better supply management between surplus-deficit localities. In addition to maximizing the utility of each unit of energy resource, contingencies such as the loss of a generating unit or a transmission line are better addressed by a larger interconnected network of power plants and power grids. There are technical benefits from pooling demand and generation over larger areas such as greater system inertia, reduced frequency fluctuation and lower incidence of blackouts. Larger interconnected networks also reduce complexities associated with land procurement for setting up power infrastructure and minimizing the issues of asset management, while giving greater location choices to new power projects.

Recent estimates show that CBET could lead to substantial reductions of capacity investments required to meet a given demand. Compared with the baseline, the required installed generation capacity in South Asia could be lowered by 35 GW in India, 13 GW in Pakistan and 11 GW in Bangladesh during 2015-2040, while reductions of 52 GW, 9 GW and 4 GW could be expected in Nepal, Bhutan and Afghanistan, respectively.[18] These shifts are projected against a three-fold increase by 2040 in South Asia's total generation capacity. The simulation results indicate that regional electricity cooperation and trade could reduce total undiscounted electricity supply costs in the region by $222 billion, or more than $9 billion per year during the period studied, compared with the baseline.[19]

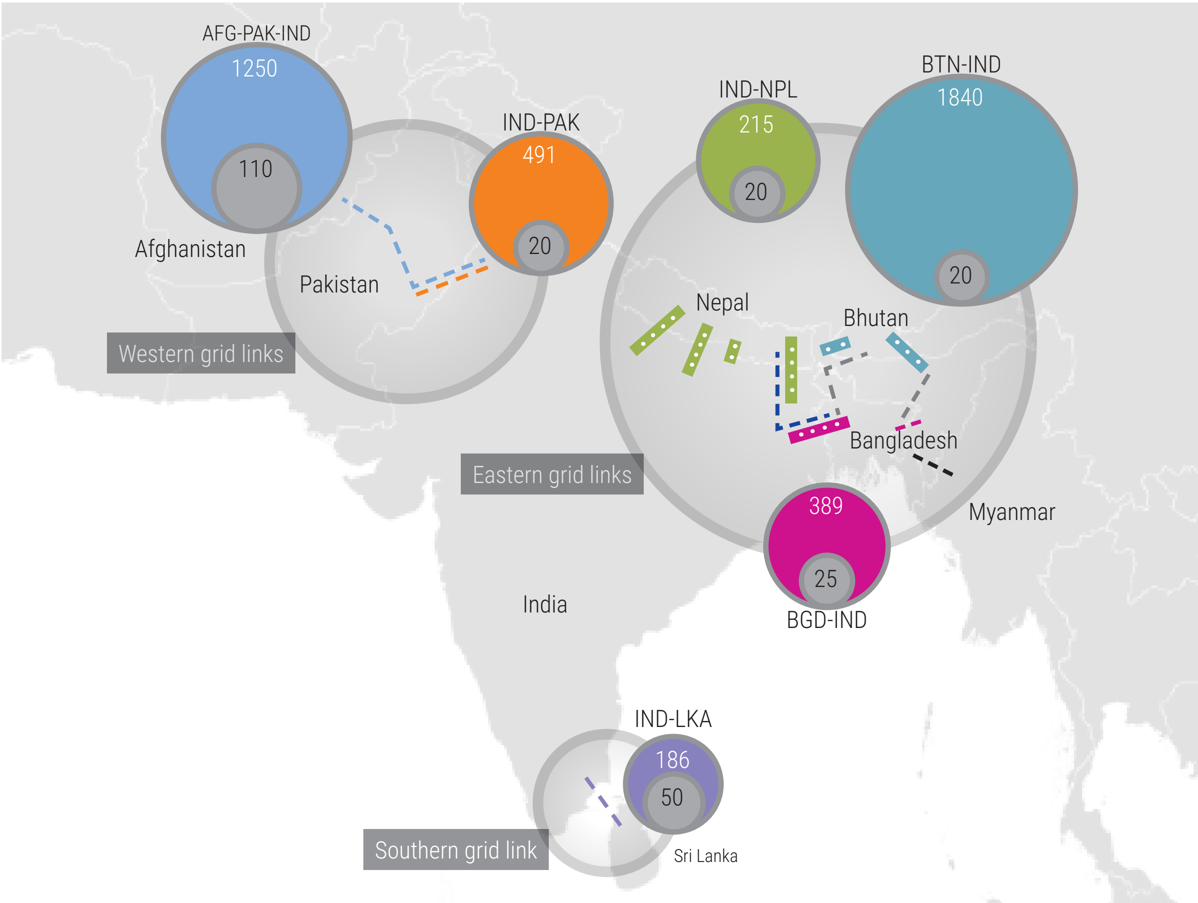
The case of bilateral electricity trade between India and Nepal shows evidence of potential gains in terms of faster growth in renewable energy installed capacity. Some studies have demonstrated that economically feasible electricity export from Nepal to match peak load requirement in India could lead to quicker mobilization of capital investments in the hydropower sector in Nepal.[20] One such simulation projects a substantially higher growth of installed hydropower generation capacity in Nepal under a regime of accelerated bilateral power trade with India compared to the status quo (figure 9). Accordingly, installed hydropower capacity in Nepal with liberal electricity trade could be as much as four times higher compared with capacity without open trade.

18 See Timilsina and others, (2015). This study uses an electricity planning model that produces optimal expansion of electricity generation capacities and transmission interconnections in the long-term to quantify the benefits of unrestricted cross-border electricity trade in the South Asia during 2015–40.

19 Ibid. These gains are mainly attributed to the savings in operational costs, which would be (in undiscounted terms) $270 billion lower under regional cooperation.

20 See IRADE, 2016b for a recent exposition

Figure 8 | Economic costs and benefits of interconnectors in South Asia



Afghanistan-Pakistan-India
Jalalabad (AFG)-Peshawar (PAK) via Torkham (HVDV line under construction under CASA 1000 project), with onward connection to Amritsar (IND)

Bangladesh-Nepal
Transit possibilities through Siliguri Corridor (IND)

Bangladesh-India
Bheramara (BGD)-Baharapur (IND) (500MV HVDC line)
Comilla (BDG)-Pelatana (IND) (100MV), planned)

Bangladesh-Nepal
Transit possibilities through Muzaffarpur, Siliguri Corridor (IND)

Bhutan-India
Towards Siliguri-Alipurduar (IND) from Tala, Chhukha, KurichhuDagachhu and Punatsangchu HEPs
Deothang-Rangie (132kV single circuit DC line, eastern Bhutan-NER border)

India-Nepal
Towards Bareilly (IND) from Karmali HEP
Towards Muzaffarpur (IND) from Tamakoshi, Anun HEPs

India-Pakistan
Amritsar (IND) and Lahore (PAK) HVDC line for 500 MW transmission

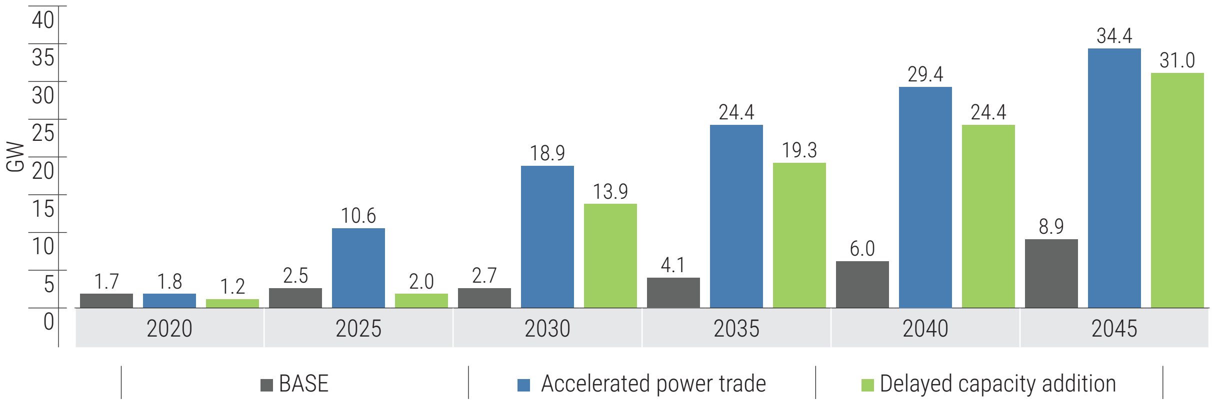
India-Sri Lanka
Madurai (IND)-Anuradhapura (LKA) HDVC submarine cable link through the Palk Strait with 500 MW transmission

Annual benefit of interconnection in US$ million

Annualized interconnection cost in US$ million

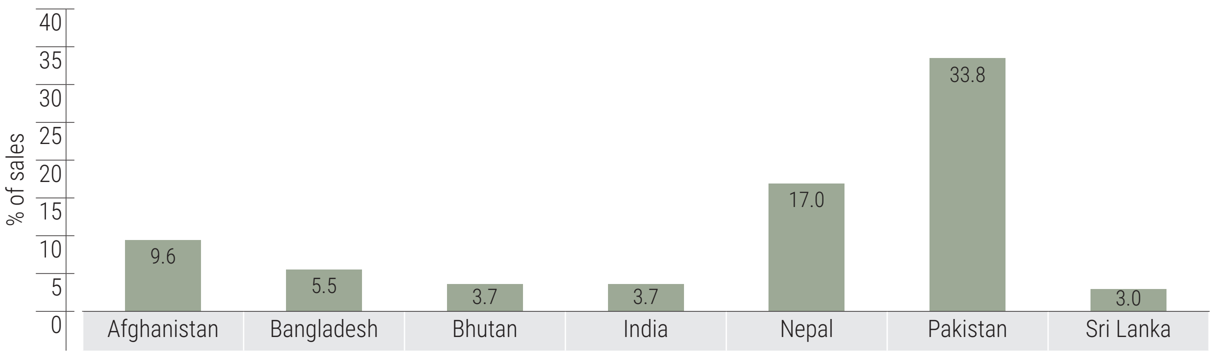
Source: ESCAP, with data from ADB, 2017. and Wijayatunga et al. (2015). Abbreviations are; AFG (Afghanistan), BGD (Bangladesh), BTN (Bhutan), IND (India), NPL (Nepal), PAK (Pakistan), LKA (Sri Lanka), and HEP (hydro-electric project).

Figure 9 | Projected growth in installed hydropower generation capacity in Nepal



Source: *IRADE (2016)*

Figure 10 | Value lost due to electrical outages (percentage of sales for affected firms)



Source: *World Development Indicators, 2017.*

Note: *Latest data available for each country (Afghanistan, 2014; Bangladesh, 2013; Bhutan, 2015; India, 2014; Nepal, 2013; Pakistan, 2013; Sri Lanka, 2011). Data unavailable for Maldives.*

2.5 DIRECT IMPACTS ON ECONOMIC GROWTH

Enhanced CBET is expected to result in direct economic benefits, both for importing and for exporting countries. While the net importers are set to benefit through greater industrial output due to enhanced access and continuity of electricity supply, benefits through growth in national income will accrue to exporting countries through export revenue. For example, recent studies of India-Nepal power trade report gains for both countries. Nepal, as the exporting country, is projected to gain through export earnings as well as enhanced consumption.

Under an accelerated bilateral power trading arrangement between both countries, Nepal's GDP is expected reach $85 billion by 2040 from $21.14 billion in 2016, registering a fourfold increase (IRADe, 2016b).[21] In this scenario, the ability to meet the growing domestic demand for power in India through imports is expected to result in huge welfare gains in terms of higher

21 Figures have been converted to US$ from Nepali Rupees at current exchange rates (December 2017). Under the scenario considered here, Nepal's installed capacity is projected to grow from 1.8 GW in 2020 to 29.4 GW in 2040. Rapid rise in Nepal's electricity generation capacity would accrue by tapping into the country's hydropower resources, wherein the percentage of value added by hydropower to the total GDP of Nepal is estimated to reach 4.21 per cent by 2027 (See USAID 2004).

industrial as well as private household consumption, and subsequently translating into sustained GDP growth rate in India.

The costs imposed by non-availability of electricity are an important aspect to consider. The high rates of direct economic losses inflicted by electricity outages in South Asia is already of concern (figure 10). Such estimated losses calculated as forgone value of sales range from 3 per cent in Sri Lanka to almost 27 per cent in Nepal.

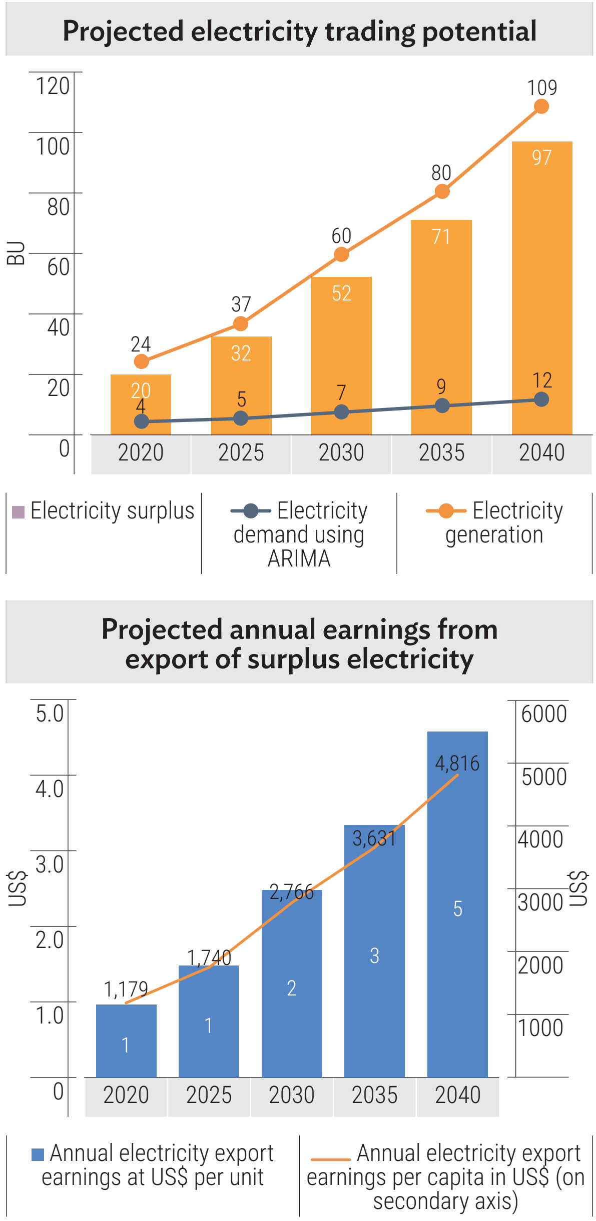
2.6 EXPORT REVENUE AND CONSUMPTION DRIVEN GROWTH

As outlined in the preceding section, power exporting countries of South Asia stand to gain both from revenues and enhanced energy consumption. Case studies of Bhutan's hydropower potential illustrate the fact that export possibilities would open avenues for meeting growing domestic demand as well as offering huge surpluses for export (IRADe, 2016a). Some estimates show possibilities of a four-fold growth in exportable surplus of hydropower for Bhutan between 2020 to 2045 (figure 11). Achieving such a growth path in hydropower generation could translate into growth in per capita export earnings from $1,179 in 2020 to $4,816 by 2045 (figure 11). High growth of export revenue can significantly boost domestic economic expansion and diversification in Bhutan and accelerate the process of least developed country graduation. Revenue from power exports already contributed 14 per cent of total GDP of Bhutan in 2015, through projects such as the export-oriented Tala Hydroelectric Power Plant.[22]

2.7 TRADE, INDUSTRIAL GROWTH AND EMPLOYMENT

For electricity surplus countries, CBET will become an important source of foreign exchange revenue, while deficit countries will have opportunities to revitalize their manufacturing sectors through improved affordability, availability and security of supply. The manufacturing capacity of South Asia, typically scattered over a large number of SMEs in the unorganized sectors, will be supported through better access to electricity. The most notable and direct economic benefits will accrue from improvement in overall industrial productivity and competitiveness. In addition to enhancing their operational efficiency through a reliable and steady supply of electricity,

Figure 11 | Projected electricity trading potential and annual earnings of Bhutan up to 2040



Source: IRADe, 2016a.

22 http://www.nsb.gov.bt/publication/files/pub1rt4291ni.pdf

the lower cost of supply will enable SMEs to advance their price competitiveness. Better market penetration, export earnings and job growth can therefore be triggered by CBET.

Another important effect is the structural changes of the economy with CBET. The scenario of enhanced power trade between India and Nepal forecasts a rise in the share of industry in GDP for both countries, indicating prospects for higher employment, technological advancements and improvement in labour productivity (IRADe, 2016b). A major impediment to trade within South Asia is the lack of supporting infrastructure, which substantially increases trading costs. Information, communications, banking, financial exchanges and other trade facilitation mechanisms are important infrastructure requirements for regularizing trade. If these systems are improved through better power availability, the resulting enhanced service sector activities could reduce overall transaction costs, and thus improve trade potential (USAID, 2004).

2.8 DEVELOPMENT OF THE AGRICULTURE SECTOR

A large segment of the labor force in South Asia is still dependent on the agriculture sector, which remains energy starved. The potential benefits of enhanced electricity availability to this sector will have significant subregional implications for the subregion in diversifying livelihood options of vulnerable rural communities. With over 75 per cent of South Asia's population concentrated in rural areas where agriculture has been the mainstay of livelihood, food security and poverty vulnerability has been critical. A study by the World Bank (2009) showed the per capita agriculture productivity growth of South Asia, at 2 per cent, has lagged behind other regions. In contrast, East Asia and the Pacific grew at 3.1 per cent, while Latin America increased by 2.8 per cent. In Bangladesh, by 2050, rice and wheat yields may drop by 8 per cent and 32 per cent, respectively (Faisal and Parveen, 2004). However, where there is easy accessibility to electricity such as in India's Punjab and Haryana districts, along with other critical inputs, the yield per hectare has been much higher. Electricity access could therefore help bridge the yield gap (Lama, 2010).

2.9 CBET FOR RURAL ELECTRIFICATION IN BORDER ZONES

In addition to the large-scale interconnection of high voltage networks, several countries of South Asia cooperate in supplying electricity by extending their distribution networks to reach communities living along the border regions of the neighbouring country. This approach in many border interfaces reflects the reality that extending the grid from an adjoining country may be a lower cost option than extending the supplying country's own national grid to those areas. This practice is widespread, particularly on the Nepal/India border where communities in the Terai region of Nepal are supplied by the Indian power system. While not considered as part of the mainstream CBET initiatives, electrification of these rural border areas creates positive impacts on poverty and quality of life

for the communities, and subsequently builds trust and confidence in other forms of energy cooperation.

2.10 SAVINGS AND GAINS FROM REINVESTMENT IN THE SOCIAL SECTOR

While availability of power can potentially trigger enhanced industrial activity, the income for such activities – coupled with additional revenue generated by electricity exports – opens up possibilities for increased investment in social or physical infrastructure. A comprehensive study conducted by USAID (2005) in the context of electricity trade between India and Pakistan revealed a huge chain of benefits cutting across various sectors and issues driven by reinvestment. The study estimated that if Pakistan were to sell 3,000 MW of power to India, it could earn an annual net profit of $160 million at a selling price of Indian Rs. 2.86/unit (after deducting fixed and transmission costs) and gain an additional $300 million through a parallel 10 per cent decrease in defence expenditure, due to improved international relations. Thus, the direct savings to Pakistan would be in the order of $460 million per year. India also would benefit from gaining access to lower-cost power and improved system reliability. The reinvestment scenarios considered by the study offered insights into the indirect social spillovers of power trade. For example, even if Pakistan were to spend only half of the savings of $460 million on education, it could radically transform its educational sector. By spending these funds on primary education, an estimated 27,600 new schools could be built, and 5.52 million more children enrolled annually.

3 | MODALITIES OF REGIONAL COOPERATION FOR TRANSBOUNDARY POWER TRADE IN SOUTH ASIA

3.1 INTRODUCTION

The previous chapters have outlined how CBET can deliver benefits in multiple dimensions for participating countries in South Asia. In order to realize these benefits, South Asian countries will have to navigate a number of policy choices. Decisions must be made on (a) legal frameworks for market integration, (b) pricing, (c) harmonization of regulatory arrangements, (d) national and regional institutional architecture, (e) investment cooperation, (f) modalities of private sector involvement, (g) ownership and management of common energy infrastructure, (h) development of codes for coordinated grid operations, and (i) trading mechanisms as well as numerous other issues. Other global interconnection experiences have shown that the gradual evolution of legal and institutional frameworks –from bilateral cross-border arrangements to shared generation capacities, and to the formation of apex institutions – are needed for a comprehensive approach to the governance of regional energy cooperation.[23]

23 For example, see ECA (2010) for an exposition on the evolution of formal institutional arrangement in Southeast Asia with the intervention of multilateral bodies such as ADB, following a number of bilateral power trading projects that took place in the initial phases.

As discussed in the preceding chapters, most of the essential building blocks of an eventual region-wide electricity grid in South Asia are now developing, in the form of several commissioned and ongoing bilateral electricity trading arrangements, with a focus on the north-eastern part of the subregion. Integration of the existing fragmented trading infrastructure would pave the way for a SAARC Power Grid. The same principle would apply to the process of regulatory harmonization that needs to complement the infrastructural integration. Current bilateral trading arrangements include PTAs that cover pricing distribution, tariffs, ownership and a host of regulatory issues, and which can form the basis for greater regulatory harmonization and regional institutional architecture. Since the adoption of the SAARC Framework Agreement for Energy Cooperation (Electricity) in 2014, new possibilities have emerged for making progress along these lines. These initiatives now have to move to the next step through advanced policy frameworks and new infrastructure investments.

This chapter examines the priorities of regional cooperation for electricity trade and possible modalities to target such priorities. It lays out the major areas of policy interventions that are best carried out through regional cooperation and discusses the prospects for South Asia in each of those areas.

3.2 AREAS OF REGIONAL COOPERATION

The principal requirements of CBET can be broadly divided into infrastructural and regulatory facilitation, both of which require close coordination and partnership between participating countries. These two categories are often referred to as "hard" (infrastructural) and "soft" (regulatory) reforms, respectively. For the first category, a series of technical and financial cooperation modalities must be adopted in order to establish fully functional cross-border transmission lines. Cooperation requirements include sourcing of initial investment as well as institutional and managerial arrangements for the day-to-day operation of the grid. The second category, regulatory cooperation, is more difficult to achieve as it addresses the issues of harmonization of laws and regulations, and the alignment of diverse governance systems of the power sectors across countries. A third category of regional cooperation is the facilitation of private sector participation in various stages of power generation and cross-border trade. Although regional cooperation for infrastructure and regulatory harmonization predominantly alludes to government-to-government (G2G) cooperation, the increasing role of the private sector necessitates government-to-business (G2B) and even business-to-business (B2B) partnerships. However, given the overarching regulatory environment for CBET, effective private sector involvement implies a level of intergovernmental cooperation. Private sector involvement in CBET is steadily increasing in the South Asia, with several contracts being undertaken for setting up hydropower generation and transmission units facilitated by G2B Power Purchase Agreements (PPAs) (see examples in the following section).

South Asia's prospects of realizing greater regional cooperation in support of CBET primarily are supported by several developments underway. Foremost of these is a consensus achieved under the SAARC process by way of the SAARC Framework Agreement for Energy Cooperation (Electricity) signed in 2014. While the Framework Agreement by itself is insufficient to meet all the legal requirements of a regional power grid, it is an important gateway to deeper regulatory alignment. Other subregional building blocks are constituted by various bilateral Power Trade Agreements (PTAs) and PPAs. In addition, examples are emerging of private sector participation in generation and cross-border transmission projects that can be built on and replicated. The principal areas in which regional cooperation is required are:

1. Infrastructure financing – setting up of common resource pools and/or sourcing of finances from multilateral development banks and donors for multi-country power projects;

2. Regulatory harmonization – the SAARC Framework Agreement can serve as an overarching facilitator, with PTAs and PPAs as building blocks;

3. Promotion of private sector participation – regulatory reforms to enable the private sector to engage in and execute contracts with public and

private entities from partner countries, including through PPPs;

4. Sharing of best practices and capacity building – creation of an intergovernmental platform, constituted by group of experts and institutions currently engaged in energy research, for regular training and knowledge sharing.

The measures under these four areas of cooperation have overlap and cross-cutting impacts. For example, one of the objectives of facilitation of private sector participation is to supplement public financing of infrastructure. More importantly, infrastructure and regulatory harmonization should progress together for achieving any meaningful results. This particularly so in the South Asian context, where several export-oriented hydropower project development agreements are being executed, with accompanying PPAs. There is also a dynamic and mutually reinforcing relationship between these areas of cooperation; greater regional energy market integration will make it easier to mitigate risk as well as help to develop a predictable and reliable regulatory environment, thereby creating profitable trading opportunities, and attracting further investments. The following sections of this chapter examine the prospects and challenges for South Asia in these areas of regional cooperation.

3.3 ROLE OF THE SAARC FRAMEWORK AGREEMENT

Various bilateral arrangements for CBET in South Asia have emerged out of necessity induced by severe power shortages and growing demand. The past practice has been of scattered project-based and localized CBET, under bilateral agreements, given the lack of a platform for integrating these components into a regional grid. With the signing of the SAARC Framework Agreement for Energy Cooperation (Electricity), the platform now exists. However, the Framework Agreement contains only broad-based provisions for cooperation, with a call to adapt the prevailing electricity laws, regulations, and policies of member States for promoting cross-border electricity trade (box 2).

The Framework Agreement entitles authorized public and private entities – power producers, transmission or distribution utilities, trading companies, or any other institution established and registered under the laws of any one of the member States – to voluntarily engage in CBET on the basis of bilateral, trilateral, or multilateral agreements. The main provisions of the Framework Agreements are aimed at:

1. Enabling the respective transmission agencies to build, own, operate and maintain the associated transmission system of cross-border interconnection;

Box 2 | Laying the foundations for the SAARC power grid: SAARC Framework Agreement for Energy Cooperation (Electricity)

The SAARC Framework Agreement for Energy Cooperation (Electricity), signed at the eighteenth SAARC Summit held in November 2014, was a major step towards developing a SAARC market for electricity, and laid the legal and regulatory foundations for the SAARC Power Grid. In its preamble, the agreement recognizes: (a) the importance of electricity in promoting economic growth and improving the quality of life; (b) the common benefits of cross-border electricity exchanges and trade; (c) the need for increased economic cooperation and creation of new opportunities in the electricity sector; and (d) the need to promote regional power trade, energy efficiency, energy conservation, and the development of labelling and standardization of appliances, and sharing of knowledge.

The Framework Agreement contains guiding provisions for infrastructure building and management of cross-border power interconnections, a transmission services agreement, electricity grid protection system, transmission access, trading arrangements including pricing and duty structure, and overall intergovernmental regulatory requirements. As the first step, the working details of the mandate for these provisions will have to be framed through further mutual consultations. The SAARC member States need to initiate the process for making necessary amendments to their national policies as well as existing laws and regulations.

Source: Source: ESCAP 2017 b

2. Facilitating authorized buying and selling entities to enter into transmission service agreements with the transmission service provider;

3. Enabling non-discriminatory access to transmission grids as per laws, rules, regulation, and applicable intergovernmental bilateral trade agreements; Joint development of coordinated procedures for secure and reliable operations of interconnected grids;

4. Exemptions from export/import duty/levies/fees for cross-border trade and exchange of electricity between buying and selling entities;

5. Enabling knowledge sharing and joint research, and exchanges between experts and professionals related to, among other things, power generation, transmission, distribution, energy efficiency, reduction of transmission and distribution losses; and

6. Joint development of the structure, functions and institutional mechanisms for regulatory issues related to electricity exchange and trade.

The provisions clarify the respective roles of apex national electricity regulatory authorities and other stakeholders and participants. The usage of the broad definition of authorized entities to include public regulatory agencies, state-owned corporations and private enterprises enlarges the scope of possible cross-border trading arrangements. While the responsibilities for creating enabling laws and providing non-discriminatory access lies with regulatory authorities, flexibility in the nature of participation by other stakeholders is endorsed. The principal focus of the Framework Agreement is therefore on enabling national laws and regulations.

An assessment conducted by the ADB (2017) on the status of enabling national laws and regulations among SAARC member States, as necessitated by the Framework Agreement, shows significant progress made in this regard. Except for Afghanistan, all SAARC member States have provided for CBET together with parameters for licensing in one or more of their respective national laws where applicable.[24] The National Energy Policy (1996) of Bangladesh, the Electricity Act (1992) of Nepal and the guidelines of the National Electric Power Regularity Authority of Pakistan are examples of national policies with these provisions. Some countries have brought in recent amendments to existing enabling provisions. CBET and licensing norms are contained in the Electricity Act, 2003 of India. In 2016 India introduced its Guidelines on Cross-Border Trade of Electricity to promote "cross-border trade of electricity with greater transparency, consistency and predictability in regulatory approaches across jurisdictions and minimize perception of regulatory risks" (Ministry of Power, India, 2016).

Progress made by South Asian countries in terms of regulatory reforms following enabling clauses is, however, uneven. For regional power exchanges, harmonization of fees, tariff structures, mechanisms for third-party access and necessary exemptions from cumbersome compliance procedures, most countries have yet to make transparent regulatory amendments. In terms of technical progress, such as the development of grid codes for coordinated system operation with neighbouring countries, the SAARC member States have some way to go. Similarly, aspects of common institutional arrangements for system operation and management have yet to be fully developed. However, certain bilateral cases as well as localized or project-based successful examples of CBET in the subregion provide the foundation for substantial progress in these areas of cooperation.

3.4 EXISTING SUBREGIONAL INFRASTRUCTURE DEVELOPMENT AND INSTITUTIONAL ARCHITECTURE

As discussed in the preceding chapters, the leading examples of existing CBET in South Asia are those of Bangladesh, Bhutan and Nepal with India. They are governed by respective PTAs and or PPAs and are facilitated by established transboundary interconnections. These projects together form

24 Maldives is not included in the study as a non-participant in the regional grid owing to limited feasibility.

the basis for a regional power grid, provided the directives under the SAARC Framework Agreement are translated into agreements for larger-scale transmission. Enhanced CBET in the subregion will depend on the expansion of the existing links and regulatory arrangements.

At present, there are several completed and ongoing projects for bilateral exchange of hydropower, the integration of which would form the basis of a SAARC Power Grid (table 4). India has been assisting Bhutan and Nepal in the development of relatively small hydropower projects such as Pokahra (1 MW), Trisuli (21 MW), Western Gandak (15 MW) and Devighat (14.1 MW). Much larger hydropower projects, such as Pancheshwar (5,600 MW), Saptakoshi (3,300 MW) and Karnali (10,800 MW), are planned, with the engagement of leading Indian private companies and multinational corporations. The grant of hydropower projects in Nepal, such as Arun-3 (900 MW) to Sutlej Jal Vidyut Nigam Ltd. and Upper Karnali (300 MW), to a consortium of GMR Group companies and Italian-Thai Development, on the basis of a build-own-operate-transfer arrangement are the main examples.

India and Bangladesh took a major step towards fostering CBET by commissioning South Asia's first ever cross-border HVDC interconnection in 2013. This interconnection links India's eastern electrical grid at Bahrampur to Bangladesh's western grid at Bheramara with a capacity of 500 MW in support of the India-Bangladesh power exchange programme. The Power Grid Company of Bangladesh and the ADB have provided the majority of the finance for the Bangladesh portion of the line while the Power Grid Corporation of India Limited built and financed the infrastructure in India. India's state-run generator NTPC Ltd. power trading arm, Vidyut Vyapar Nigam Ltd, and the Bangladesh Power Development Board signed a G2G electricity purchase agreement for 250 MW in 2012. A PPA was signed between (the Power Trading Corporation of India) and the Bangladesh Power Development Board in November 2013, and power supply to the Bangladesh Power Development Board started with effect from December 2013 at a levelized tariff of R. 4.45/kWh. In addition to the two countries enjoying benefits of seasonal complementarity, this initiative has benefitted Bangladesh by assisting it to reduce its peak demand deficit of 1,000-1,500 MW and its dependence on less efficient and more expensive power plants.

The role of bilateral intergovernmental PTAs in facilitating these partnerships between state-owned enterprises as well as public-private joint ventures in the subregion is critical. The bilateral agreement between India and Nepal was extended in 2014 and enables the two neighbours to "develop transmission interconnections, grid connectivity, power exchange and trading through governmental, public and private enterprises on mutually acceptable terms." Following the provision of the SAARC Framework Agreement, it also allows licensed electricity producers, buyers and traders from both countries to engage in cross-border electricity trading, including via power exchanges, and to seek cross-border transmission access as per the laws of the respective countries. For transmission infrastructure, the increase in projects implied that additional transmission lines needed to be established. Accordingly, new transmission lines need to be promoted and right-of-way provided through land acquisition by States, particularly for transit purposes.

Experiences of other subregional power trading arrangements suggest that coordination between operators of national or subnational/localized grids that can be potentially linked together, can lead to effective integration of cross-border power market, in the absence of a unified multi-country grid and an empowered regional institution to govern it. Gradual expansion and integration is possible for cross-border power sector cooperation and trade, which started based on a few isolated projects. In the case of Nord Pool, the facilitator of the leading integrated power market in northern Europe, each participating country can continue to maintain its own national grid code, implying that complete conversion to uniform grid codes may not be a prerequisite.

As a near-term objective, the countries supporting the South Asian power grid can therefore focus more on better coordination among national grid operators for efficient operation, including commonly agreed timelines for dispatch schedules and modalities for financial settlements. However, the challenge of rapid expansion in the long term may have to be

Table 4 | Major cross-border transmission developments towards a SAARC regional power grid

Countries	Progress of Cross-border Interconnections
Bhutan-India	Bhutan signed a Framework Agreement with India in 2009, committing to develop 10000 MW of installed capacity in Bhutan by 2020 and import half of this. Grid reinforcement to evacuate power from various HEPs are in progress. About 1500 MW currently being imported. A string of 132kV, 220kV and 400kV lines in the Southwestern border regions of Bhutan are currently used to evacuate power from Tala, Chhukha, Kurichhu, Dagachhu and Punatsangchu HEPs towards the Silliguri-Alipurduar corridor in India. A 132kV single circuit DC line serves the Deothang – Rangia interconnection in the Southeastern border region.
Bangladesh-India	A 400kV, 30 km double-circuit HVDC line from Bheramara (Bangladesh) to Baharampur (India) and a 500 MW 400/230 KV back-to-back HVDC substation established in 2013. The link carries 500 MW of power in the short run and will subsequently have capacity of 1000 MW. Other bilateral connections are being planned including a 400kV DC line between Surjyamaninagar (India) and Comilla (Bangladesh) for transfer of 100MV from Palatana power project in Tripura, India.
India-Nepal	About 12 interconnections through 11kV, 33kV and 132 kV lines connect the Southern Terai region of Nepal with bordering Indian states, enabling access to several existing and developing hydropower projects in Nepal. These include connections towards Bareilly (IND) from Karnali HEP, towards Gorakhpur (IND) from Marsyangdi HEP, and towards Muzaffarpur (IND) from Tamakoshi, Arun HEPs. Dhalkebar-Muzaffarpur 400kV line project is expected to add 1000 MW of cross-border transfer capability. An integrated Master Plan envisions power evacuation from about 280 hydropower projects in Nepal to India, totaling 45GW installed capacity, through high capacity cross-border links. Upgradation of existing lines, along with construction of new lines are proposed in phased manner till 2035.
India-Pakistan	Cross-border interconnection to support import of 500 MW electricity from India to Pakistan via the Amritsar-Lahore interconnection has been under consideration.
India-Sri Lanka	The proposed India-Sri Lanka 400kV HVDC grid interconnection involves construction of a HVDC connection between Madurai (India) to Anuradhapura (Sri Lanka). The link has a proposed length of 387 km including 127 km of submarine cables with an initial capacity of 500 MW and has future potential of 1000 MW.

Source: Source: Author's compilation

met with the establishment of a single cross-national regulatory body. Ongoing reforms in the subregion will have to factor in the requirements of such long-term aspirations.

3.5 PROMOTION OF PRIVATE SECTOR PARTICIPATION

Greater involvement of the private sector in energy generation and transmission is essential to promoting enhanced CBET due to several reasons. Private sector participants bring in the means to overcome resource deficiencies, greater operational flexibility compared to public sector entities, research and development capabilities, a broad range of partnerships and dynamism in management practices. International experience, such as in the case of the Southern African Power Pool, provides successful examples of various forms of PPPs as well as various levels of engagement of the private sector in generation and transmission projects of regional importance.

Recognizing the importance of partnerships, the SAARC Framework Agreement broadly defines buying and selling entities as "any authorized public or private power producer, power utility, trading company, transmission utility, distribution company, or any other institution established and registered under the laws of any one of the member States." This also entails various categories of private entities to engage in almost all aspects of CBET. However, various provisions of the Framework Agreement clearly lay out the role of Governments in providing the necessary policy, legal, and regulatory frameworks for private sector involvement, and thereby underscore the significance of achieving complementarities in public-private partnerships.

In addition to enabling laws and regulations, one of the most important areas of public sector support for private sector participation is that of financial guaranteeing. Most of the projects, particularly hydropower projects, require huge initial investments and are sourced under various co-financing arrangements. A major concern of private lenders is that of debt servicing in the eventuality of project failures, and they therefore require sovereign guarantees against commercial

risks. Public-private partnerships are often necessary for favourable risk assessments and for addressing the environmental and social impacts of a project.[25] Gradual liberalization of the energy sector has already led to a rapid rise in private sector operations in most of the South Asian countries. The share of the private sector in total installed capacity for electricity generation increased from 10 per cent in 2001 to 43 per cent in 2016 (Ministry of Power, India, 2017).

This trend is also permeating into cross-border operations. Currently, there are several examples and formal partnership models for private-public partnerships in cross-border electricity generation and transmission in South Asia. One of the prominent examples is the signing of a Power Development Agreement by GMR Upper Karnali Hydropower Ltd., a subsidiary of an Indian company, with the Government of Nepal in 2014. The agreement paved the way for developing a 900 MW hydropower project in Nepal (Upper Karnali Hydro Electric Project). This was made possible under the G2G framework of the Power Trade Agreement (PTA) between India and Nepal, a Power Purchase Agreement (PPA) as well as a 30-year licence to import power from the Government of India, which have been instrumental in ensuring the feasibility of the project.

Following these examples of state-led regulatory facilitation as well as the G2B legal framework, GMR Upper Karnali Hydropower Ltd. is negotiating a grid connection agreement with the Bangladesh Power Development Board with the objective of commencing power trade to Bangladesh from the project with transit via India. In order to secure transit rights, another G2G agreement in the form of a Memorandum of Understanding was signed in April 2017 between the Bangladesh Power Development Board and India's Vidyut Vyapar Nigam.

These existing project development agreements, PTAs and PPAs that are focused on the north-eastern part of the SAARC subregion provide useful templates to follow for further emerging PPPs. They are also laying the foundations of legal arrangements for transit, taking countries several steps closer to an eventual subregional power grid. However, in the continuing absence of formal modalities for broader private sector involvement, Governments need to fortify these efforts by formulating a comprehensive plan on private sector participation. Such a plan should be developed through a joint evaluation of the first-generation public-private projects, with the objective of developing model templates, in the light of the experiences so far. Such common frameworks can be developed as a part of a regional cooperation exercise.

3.6 REGIONAL COOPERATION FOR CAPACITY-BUILDING

Enhancing CBET requires regional cooperation in capacity-building. Developing a multi-country knowledge management system covering expertise and best practices in financial sourcing, business models and technological know-how would be of great benefit. The SAARC Framework Agreement also envisages knowledge sharing and joint research among participating countries, given the fast-paced technological advancements taking place in power generation, transmission and distribution. Topics such as project financing, settlement mechanisms, harmonization of grid codes, load forecasting techniques and integration of storage in networks are some relevant examples. Regional cooperation in these areas can pay dividends, given the differences in technological capabilities across the subregion. Addressing the high losses in subregional transmission and distribution systems is an area that can benefit from knowledge sharing, thus complementing cooperation on CBET.

The SAARC Energy Centre, established by SAARC member countries to foster cooperation on energy, has been working to build capacity across technical areas related to CBET as well as foster subregional dialogue on the SAARC Power Grid. Several specialized agencies are also working to build capacities in South Asia in support of CBET. For example, the South Asia Regional Initiative for Energy Integration (SARI/EI) has conducted training and capacity-building sessions under a multi-year programme supported by USAID.

25 "The risk perceptions are often influenced by the nature and extent of governmental involvement. For an example using the case of the Theun-Hinboun Hydropower Project in Lao People's Democratic Republic (Lao PDR), see Rahman and others, 2011.

4 | CONCLUSION

South Asia, like many other subregions, is working to deepen its integration in trade, infrastructure connectivity and financial cooperation. As part of this effort, the integration of the power grids of the countries in South Asia is a major component of overall subregional integration that can realize benefits across the social, environmental and economic pillars of development. South Asia offers a unique example for the application of a regional approach to electricity. It faces current electricity deficits, with a strong demand growth outlook, but at the same time has enormous unexploited generation potential. Since the concept of the SAARC Energy Ring was advanced in 2004, several factors have emerged that can help to positively shape this endeavour; concerns over GHG emissions, the emergence of low-cost solar and wind power generation, and advances in HVDC technology are just some of these factors.

It has been estimated that through economies of scale, expansion of the renewable contribution and optimization of generation, it will be possible to yield up to $9 billion each year in direct savings and reduce GHG emissions by more than 9 per cent per annum. The cost savings estimates do not consider the additional positive spillovers in the social and environmental realms that would accrue from more affordable, accessible and sustainable energy. The calculated emissions savings may be much higher as the modelled results are sensitive to the input costs of wind and solar power, which have been dramatically revised downwards in recent years. Depending on the complementarity of policies enacted by participating countries, integrating the subregion's power systems to enable CBET can make major contributions to the SDGs and to developing a low-carbon energy system.

Grid interconnection is not a zero-sum game of transactions between countries. There are benefits for all participating exporting and importing countries. For South Asian least developed countries rich in hydropower resources, such as Bhutan and Nepal, connecting their grids with larger neighbours can provide a valuable source of long-term export revenue and play an important role in least developed country graduation. In the case of larger countries, such as India and Pakistan, diversifying their generation base and accessing lower-cost power from cross-border sources can help underpin industrial growth and reduce domestic GHG emissions. It may also support these countries in scaling up their wind and solar power generation through energy balancing provided by interconnection. There may not be a clear demarcation between energy producing countries and energy consuming countries. At different times of the day or during different seasons countries may alternately be importers or exporters of energy, depending on their generation profiles. The geography of the subregion places India as the central actor in power grid integration. India is the largest economy in South Asia and can play the role of electricity supplier, consumer and transit country in an integrated grid. Its commitment to the vision of a subregional power grid will be instrumental to the success of this proposal.

An integrated South Asia power grid is both technically and economically feasible. The major complexity is in aligning the policy and institutional arrangements among multiple countries. The narrative of South Asia's grid interconnection to date is one of uneven progress. The north-eastern part of the subregion has witnessed remarkable progress in grid integration through bilateral cooperation involving Bangladesh, Bhutan, India and Nepal. However, progress in connecting India with Pakistan and Afghanistan, potentially one of the most viable energy corridors of the subregion, has not been realized. Similarly, the possibility of connecting India with Sri Lanka is at a nascent stage and will be essential to supporting Sri Lanka's energy expansion and commitment to adding no new coal capacity until 2037. The largest unrealized opportunity in the subregion is establishing an interconnection between India and Pakistan, given the low level of required infrastructure investment, the complementarity of the two power systems and the size of their economies. Studies have shown the return on investment in this interconnection will be among the highest in the subregion. Moving the

cooperation on power grids to a multilateral basis, with strong political ownership at a high level by South Asian leaders, is essential.

Building support for this multilateral engagement requires a strong evidence base to assess the benefits of an integrated South Asian power system across the three dimensions of sustainable development. In particular, understanding how it could support SDG achievement and reduce GHG emissions will enable more ambitious NDCs to be formulated. The development of policies on national climate change and renewable energy will also need to be linked to the development of the South Asian power grid in order to take advantage of opportunities afforded by interconnection, especially as renewables gain a higher share of generation. This is a complex and evolving field involving multiple disciplines, in which the experiences of other Governments and power system operators with experience in the integration challenge can assist.

A detailed study on the emissions reduction potential of an integrated SAARC power grid could be undertaken to help increase the understanding of this area. This is particularly important, given the rapidly evolving energy market dynamics and renewable energy pricing. Earlier research has shown the strong influence of renewable energy cost reductions on regional deployment of energy, the volume of energy traded and, therefore, the viability of different interconnectors (Timilsina and others, 2015). Given the significant GHG reduction potential of CBET, opportunities to leverage the flexibility mechanisms available under the Paris Agreement, including ITMOs and climate finance to support grid interconnection and renewable energy projects, should be sought. The technical, operational and policy lessons available from other successful power system integration cases can be shared with stakeholders in South Asia. The full renewable energy potential of South Asia is several multiples of its projected demand even in 2040. Exploiting this potential with the support of interconnection would reframe the GHG emissions trajectories of countries in the subregion and assist the Paris Agreement to reach its goals.

Recognizing the essential role of the private sector in CBET, the Governments of the subregion could collaborate in developing modalities for enhancing private sector engagement, including through PPPs. This should be based on a review of the existing public-private collaboration to date in power projects and interconnections between countries.

Enhancing the capacity of South Asia's policymakers, system operators and regulators in the power sector across a number of technical, operational and policy areas is essential to the acceleration of grid integration. Knowledge and capacity gaps, together with emerging technologies and systems, pose challenges. Regional cooperation between Governments of the subregion is critical to bridging these gaps. Opportunities to learn from successful subregion power grid integration examples in the Greater Mekong Subregion, Europe, Africa and Central America will also be highly beneficial. The SAARC Energy Centre, formed by the member States and the key institution with a mandate on power grid connectivity, should be supported in undertaking these efforts.

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ANNEX A

SDG7 PROGRESS IN SOUTH ASIA

The 2030 Agenda for Sustainable Development was adopted by United Nations member States in September 2015. It comprises 17 Sustainable Development Goals (SDGs) to be achieved by 2030, covering all aspects of social, economic and environmental development for all countries. SDG 7 has the specific objective of ensuring access to affordable, reliable, sustainable and modern energy for all. Its targets include achieving universal access to modern energy such as electricity, ensuring access to clean technologies for cooking and other uses, boosting renewable energy in the global energy mix and doubling the rate of energy efficiency. It also highlights the means of implementation for achieving sustainable energy security, including better international cooperation and sustainable energy infrastructure (figure A1).

Figure A1 | Goal 7: Ensure access to affordable, reliable, sustainable and modern energy for all

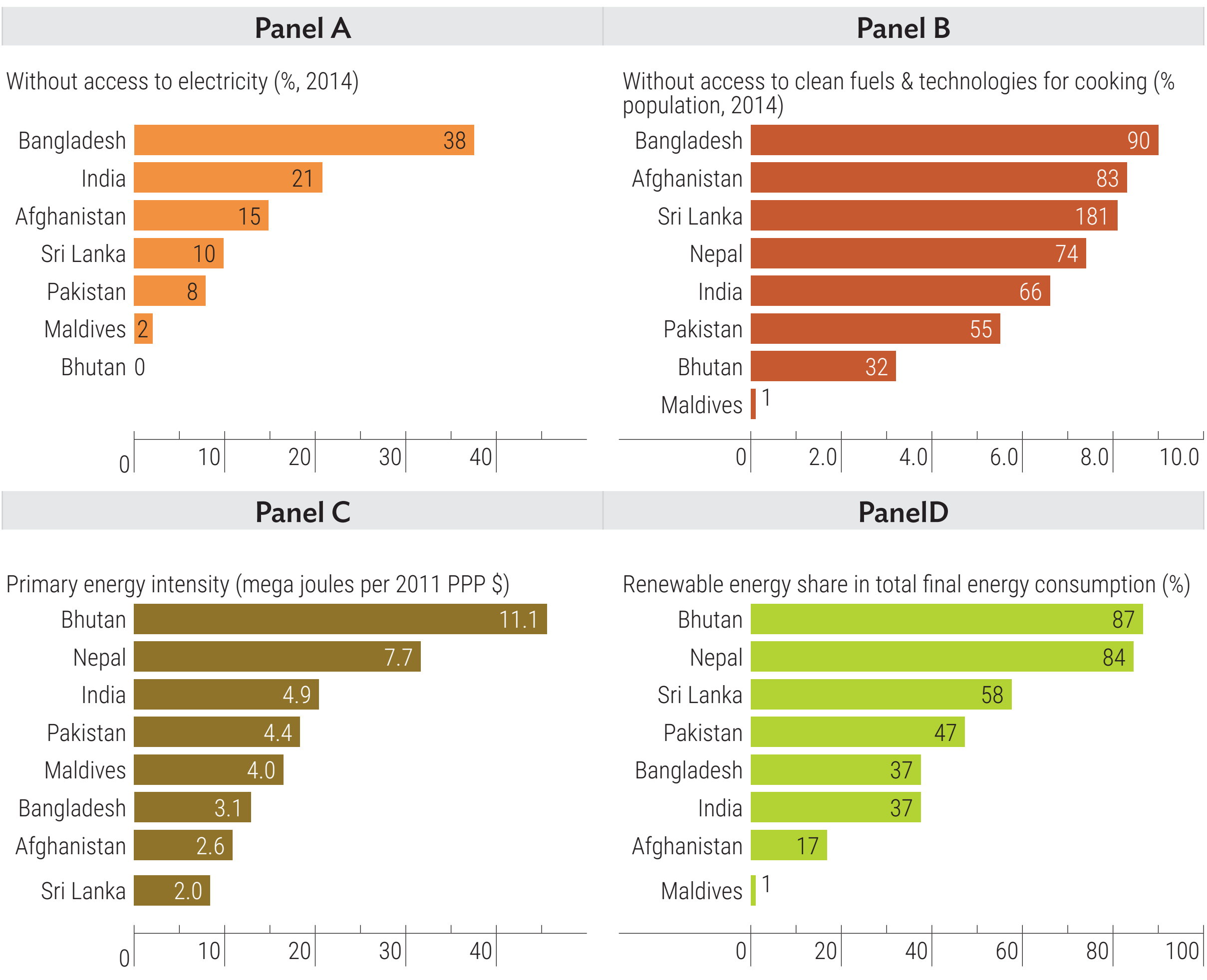
Target 7.1 By 2030, ensure universal access to affordable, reliable and modern energy services.	Indicators 7.1.1. Proportion of population with access to electricity, and 7.1.2. Proportion of population with primary reliance on clean fuels and technology.
Target 7.2 By 2030, increase substantially the share of renewable energy in the global energy mix.	Indicator 7.2.1. Renewable energy share in the total final energy consumption.
Target 7.3 By 2030, double the global rate of improvement in energy efficiency.	Indicator 7.3.1. Energy intensity measured in terms of primary energy and gross domestic product (GDP).
MOI 7.a By 2030, enhance international cooperation to facilitate access to clean energy research and technology, including renewable energy, energy efficiency and advanced and cleaner fossil-fuel technology, and promote investment in energy infrastructure and clean energy technology.	MOI Indicator 7.a.1. International financial flows to developing countries in support of clean energy research and development and renewable energy production, including in hybrid systems.
MOI 7.b By 2030, expand infrastructure and upgrade technology for supplying modern and sustainable energy services for all in developing countries, in particular least developed countries, small island developing States and landlocked developing countries, in accordance with their respective programmes of support.	MOI Indicator 7.b.1. Investments in energy efficiency as a proportion of GDP, and the amount of foreign direct investment in financial transfer for infrastructure and technology to sustainable development services.

Source: General Assembly resolution 70/1, the future we want.

South Asia still faces significant gaps in achieving the SDG7 targets. More than one-fifth of the population lacks access to electricity (figure A2, Panel A). In Bangladesh, more than one-third lack access, but universal access has been met in Bhutan and Maldives. Most of the population in South Asia lacks access to clean cooking fuels and technologies, including the vast majority of people in Bangladesh, Afghanistan, Sri Lanka, Nepal and India (figure A2, Panel B). Primary energy intensity varies across the subregion from as low as Sri Lanka's rate of 2 megajoules per international dollar of GDP (2011, PPP), to as high as Bhutan's rate of 11 megajoules per international dollar of GDP. However, energy efficiency has improved for the subregion. Hydropower resources in Bhutan and Nepal have helped to ensure that more than 80 per cent of their energy is renewable, while it is around half the energy mix for Sri Lanka and Pakistan. Renewable energy contributes more than one-third of energy for Bangladesh and India.

At the same time, the 2030 Agenda emphasizes the crucial importance of the interlinkages and integrated nature of the SDGs. SDG7 and energy security have significant interlinkages and interdependencies with other SDGs, in some cases with positive spillovers and in other cases where trade-offs have to be considered and addressed.

Figure A2 | South Asia SDG7 progress



Source: ESCAP, 2017c.

Note: Panel A shown as share of population without access to electricity, which complements the SDG7 target indicator of the share of population with access to electricity.

ANNEX B

SELECTED INTERLINKAGES BETWEEN ENERGY AND OTHER SDGS

SDG	Selected energy interlinkages
1 NO POVERTY	Lower energy costs and better access can raise incomes and alleviate poverty
2 ZERO HUNGER	Energy efficiency and access drive benefit agriculture productivity, access to food and food utilization
3 GOOD HEALTH AND WELL-BEING	Better energy intensive health services can be delivered and negative health impacts from energy externalities, like air pollution, can be reduced
4 QUALITY EDUCATION	Higher human capital development by increasing time for education at night, increasing efficient education infrastructure, and access to remote/online energy intensive education delivery solutions
5 GENDER EQUALITY	Energy access can save time and resources in the household in removing barriers to empowering women's participation in the workforce, business and control of resources.
6 CLEAN WATER AND SANITATION	Energy efficiency and availability is critical for core water and sanitation infrastructure and ensuring reliable access.
8 DECENT WORK AND ECONOMIC GROWTH	Better energy solutions increase GDP in energy sectors, and higher productivity spillovers to other parts of the economy boosting capital intensity in production. Energy sector technologies create new markets and jobs, for example in renewables infrastructure, installation and service delivery
9 INDUSTRY, INNOVATION AND INFRASTRUCTURE	Energy intensive transport benefits from efficiency gains and movement to renewables, enabling ICT connectivity, including more efficient and zero emissions vehicles
10 REDUCED INEQUALITIES	Access to energy supports greater economic, social and environmental equality through opportunities for participation and voice
11 SUSTAINABLE CITIES AND COMMUNITIES	Energy is strongly linked and interdependent with urbanization and responsible production and consumption. Sustainable urbanization depends on sustainable energy as population centres increase in size and number.
12 RESPONSIBLE CONSUMPTION AND PRODUCTION	Responsible production and consumption relies on energy transformations towards renewables, high efficiency and low energy solutions, especially in energy intensive solutions for waste management and recycling
13 CLIMATE ACTION	Energy efficiency and a renewables transition are also essential for adapting to the impacts of climate change and limiting the anthropogenic impact of people on the environment including lowering carbon emissions.
14 LIFE BELOW WATER 15 LIFE ON LAND	Energy is also linked to solutions for improving life under water and life on land by lowering the environmental footprint of energy production and consumption by populations and ensuring an energy transition can preserve sustainability of land and water resources.
16 PEACE AND JUSTICE STRONG INSTITUTIONS	Energy has important interlinkages with peace, justice and rights as a basis for providing energy intensive ICT resources for information and citizenship inclusion in society and decision making and access to information. Ensuring government service delivery and fulfilling social obligations to countries are increasingly delivered through online solutions and electronic devices
17 PARTNERSHIPS FOR THE GOALS	For the purpose of implementing the SDGs, energy is interlinked with international cooperation in finance, data, technology and policy for energy sustainability. In South Asia, cooperation and partnership is a principle for energy sustainability and SDG achievement through regional cooperation opportunities including CBET.

Source: Author's compilation.

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