ERIA Research Project Report FY2023 No. 10

Renewable Energy Transition in South Asia: Role of Regional Energy Trade

Edited by

Saswata Chaudhury
Raktimava Bose
Debanka Samanta
Venkatachalam Anbumozhi

The Energy and Resources Institute
Creating Innovative Solutions for a Sustainable Future

Energy Research Institute Network

Economic Research Institute for ASEAN and East Asia

Renewable Energy Transition in South Asia: Role of Regional Energy Trade

Economic Research Institute for ASEAN and East Asia (ERIA)
Sentral Senayan II 6th Floor
Jalan Asia Afrika No. 8, Gelora Bung Karno
Senayan, Jakarta Pusat 12710
Indonesia

ERIA Research Project Report FY2023 No. 10
Published in August 2023

Acknowledgements

We would like to express our sincere gratitude to our external project advisor, Dr V Anbumozhi (Director of Research Strategy and Innovations, ERIN-ERIA) and internal project advisor Mr R R Rashmi (Distinguished Fellow, TERI) for their unwavering support and guidance throughout this project. Their expertise, patience, and constructive feedback were instrumental in shaping the direction of this research, and we are grateful for the opportunity to have worked with them.

We are especially grateful to Prof. Selim Raihan (Professor, University of Dhaka and Executive Director, SANEM) for his invaluable guidance in GTAP analysis and Mr Robin Majumder (TERI) for his valuable insights about Indian power trade with neighbouring countries.

We are also grateful to all the distinguished speakers (Dr Vibha Dhawan, Prof. V Anbumozhi, Prof. Selim Raihan, Dr Ritu Mathur, Dr Nitya Nanda, Dr Arpita Mukherjee, Mr R.R Reshmi, Dr Prabir De, Dr Paras Kharel, Prof. P Sengprasong) and all the participants who attended the workshop on 'Renewable Energy Transition in South Asia: Role of Regional Trade and Cooperation,' jointly organised by TERI and EREA on 21 December 2022 for their valuable inputs to evaluate and enrich the study outcome.

We would also like to thank all the members of our research team for their contributions and dedication to this project. Their hard work, collaboration, and diverse perspectives enriched the project in many ways.

In addition, we would specially like to acknowledge the Economic Research Institute for ASEAN and East Asia for its generous funding, which supported this study.

List of Project Members

Project Team

Mr Saswata Chaudhury

Mr Raktimava Bose

Ms Khushi Gupta

Mr Amlan Mishra

Ms Aerica Rishiraj

Mr Debanka Samanta

Mr Kartikey Sharma

Internal Advisor

Mr R Rashmi, TERI

External Advisor

Dr V Anbumozhi, ERIA-ERIN

Special Credit

Dr Selim Raihan, SANEM

Mr Robin Majumdar, TERI

Secretarial Assistance

Ms Lakshmi Subramanium, TERI

Ms Abigail G. Balthazar, ERIA-ERIN

Table of Contents

List of Figures

List of Tables

List of Abbreviations and Acronyms

ADB	Asian Development Bank
ASEAN	Association of Southeast Asian Nations
BBIN	Bhutan-Bangladesh-India-Nepal
BIMSTEC	Bay of Bengal Initiative for Multi-Sectoral Technical and Economic Cooperation
EU	European Union
GDP	Gross Domestic Product
GHG	greenhouse gas
GTAP	Global Trade Analysis Project
HVDC	High-Voltage Direct Current
kV	Kilo-volt
kWh	Kilo-watt-hours
Lao PDR	Lao People's Democratic Republic
MU	Million Unit
NDC	Nationally Determined Contribution
NEA	Nepal Electricity Authority
SAARC	South Asian Association for Regional Cooperation
SADC	Southern African Development Community
SAFTA	South Asian Free Trade Area
SAPP	South African Power Pool
SASEC	South Asia Sub-Regional Economic Cooperation
STEM	Short-Term Energy Market
T&D	transmission and distribution
TWh	Terra-watt-hours

Chapter 1

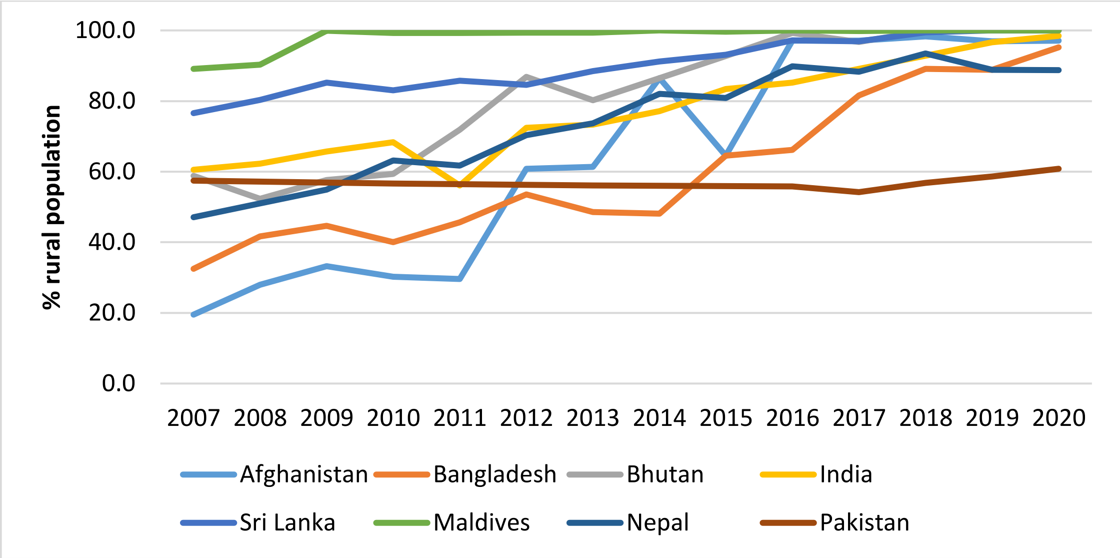
Background

Many South Asian countries, including Afghanistan, Bhutan, Bangladesh, India, Maldives, Nepal, Pakistan, and Sri Lanka, are dependent on fossil fuel energy sources to drive economic growth. However, with the increasing need to limit emissions as emphasized in the Paris Agreement, these countries have committed to decarbonising their economy along with setting their nationally determined contributions (NDCs). In this context, all South Asian countries are reducing their fossil fuel usage and moving toward renewable energy through a faster and more inclusive energy transition.

The South Asian region, one of the fastest growing regions in Asia, is aiming to meet most of its energy requirements through renewable energy (IEA, 2019). With diverse geographical features such as glaciers, deserts, grasslands, and varying climates and proximity to seacoasts, the region has large avenues for growth in renewable energy.

It is also one of the most populated regions in the world with 1.7 billion people and has shown consistent economic growth of 7% (approx.) before the coronavirus disease (COVID-19) pandemic (World Bank, 2020b). However, despite the consistent economic growth, the countries in this region have remained energy-constrained (Murshed, 2021). Though in recent years these countries have witnessed significant improvement in energy access, they are yet to achieve 100% access to electricity in rural areas and access to clean cooking fuel (as indicated in Figure 1.1). As per the same study, most of these countries have failed to meet their energy demand with domestic supply and depend significantly on imports. When increasing energy requirements are met through imports, these cause high dependency that impinges on government budgets, especially if the volume of energy import is very large. Moreover, import dependency for energy products (for example, India’s import dependency of coal from Bangladesh) also compromises the energy security of a country on account of various geopolitical and economic factors (Milina, 2007). Despite the South Asian region having enormous intra-regional trade potential both in energy and in manufacturing products and services, the actual trade in manufacturing products is only one-third of its potential (Kathuria, 2018; Shah, 2020). The energy trade is also abysmally low owing to various regional issues including inappropriate tariff measures, high costs of intra-regional connectivity, geopolitical tension, and lack of infrastructure. Moreover, intra-regional trade in manufacturing goods and energy technology is very low compared to the international trade volume of this region (Kaushik, 2015).

Figure 1.1. Access to Electricity in South Asian Countries, 2007–2020



Source: World Bank, 2022.

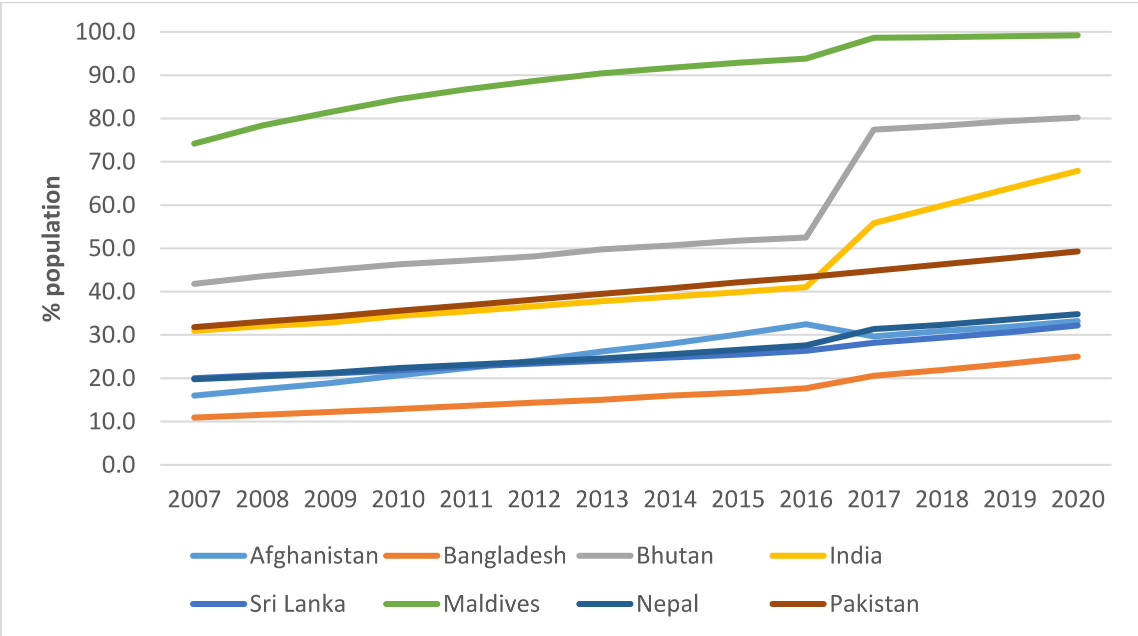
All South Asian countries have infrastructure bottlenecks in the energy sector, which in turn threaten their reliable supply of energy and economic growth potential, as well as achieving United Nations Sustainable Development Goal-7 (affordable and clean energy) (Murshed, 2021; Zhang, 2019). Additionally, fossil fuel dependency for power generation and energy consumption adversely affects the physical environment. In this context, cross-border energy trade, especially renewable energy trade (in terms of electricity), can play an important role in addressing these challenges given there is a demand–supply complementarity and the presence of suitable infrastructure. At present, some progress has been made in bilateral interconnection and power trade among selected countries in the region. The World Bank in June 2022 furnished $1.03 billion to boost trade (in electricity) connectivity in South Asia in two phases to replace the lengthy paper-based trade processes with automated solutions in Bangladesh and Nepal in Phase I and extending to Bhutan in Phase II. However, inducing further collaboration among South Asian economies will not only promote individual interests but also extend spill-over benefits across the entire region. Regional development of infrastructure to promote cross-border trade in South Asia can generate greater returns when it comes to fulfilling the collective interests of the entire region to meet energy needs.

Several pieces of literature like Effendi and Resosudarmo (2020) have analysed the socio-economic and environmental impact of increasing the generation of renewable energy in the context of Association of Southeast Asian Nations (ASEAN) countries using an Inter-Regional Social Accounting Matrix. Based on the empirical analysis, the study concluded that the use of renewable energy not only promotes higher economic growth but also can reduce adverse environmental impact compared to the usage of fossil fuel for power generation in the region. The success story of the ASEAN region in the context of energy cooperation is presented in the annex (Annex 1) along with a few other case studies of regional energy cooperation across the world. Another study by Abrell and Rausch (2016) measured the impact of the expansion of electricity transmission infrastructure and penetration of renewable energy on gains from trade and emissions from power generation in the context of European Union member countries. The study concluded that the expansion of transmission infrastructure leads to significant gains from trade, with the scale depending on renewable energy penetration. Moreover, the expansion of transmission infrastructure along with an increase in renewable energy share ensures more equitable benefit sharing in the region. A similar analysis has not been done for South Asia to date. Thus, it would be interesting to evaluate the relative benefits that can accrue across this region.

1.1. Overview of the current energy sector in South Asia

South Asia continues to depend on fossil fuels to meet its energy demand and electricity generation (as indicated in Figure 1.2). The share of renewables in electricity generation has increased in these countries in recent years, but, due to the increase in the overall demand, the dependency on fossil fuel has not reduced to a large extent. Integration of renewable energy resources into the national energy mix is important for energy sustainability and energy security. This will complement the limited availability of fossil fuel and also address environmental sustainability. But technological backwardness and poor existing networks are the major challenges in the context of switching to renewable energy in South Asian countries. Regional integration including renewable energy trade can facilitate renewable energy transition in the South Asian region.

Figure 1.2. Access to Clean Cooking Fuel in South Asian Countries, 2007–2020



Source: World Bank, 2022.

South Asia has witnessed a growth in energy demand over the past 2 decades, increasing by over 50% since 2000. In particular, electricity demand in Bangladesh, Bhutan, India, Nepal, and Sri Lanka has grown on average by more than 5% annually over the past 2 decades and is expected to more than double by 2050 (World Bank, 2022b).

Approximately two-thirds of the energy usage in South Asia is imported (World Bank, 2022b). The region is still heavily dependent on fossil fuels, which account for about 80% of total primary energy production in the region. Unsurprisingly, greenhouse gas (GHG) emissions from power generation in South Asia are the largest (68%) compared to emissions from other sectors (World Bank, 2022b). All the nations in South Asia, particularly Bangladesh, Afghanistan, India, Maldives, and Sri Lanka, fulfil their energy requirements through oil imports. India is the largest importer after China and the US, and imports 82% of its needs. Moreover, India and Pakistan (the two major economies in South Asia) heavily depend on imports of natural gas from Persian Gulf nations including Qatar and Iran.

Apart from importing oil, the entire South Asian region is also heavily dependent on refined petroleum imports. Some South Asian countries, including Nepal, Bhutan, Afghanistan, and Maldives, depend entirely on importing refined petroleum products as they do not have adequate refining capacity. Most of the countries in South Asia primarily depend on fossil fuels (refer to Table 1.1) to meet their energy demands (IEA, 2021). The exception is Bhutan as its energy supply is largely based on renewable sources. Owing to the country-level decarbonisation strategies, the overall (at the region level) dependency on fossil fuels has reduced in the region (as indicated in Table 1.2). However, the primary energy gap has been increasing sharply (except in Bhutan) due to recent success in rural electrification, increasing urbanisation, increasing penetration of electrical appliances, and increased population. Meeting this energy gap is a big concern for the countries in the region.

Table 1.1. Primary Energy Consumption and Share of Fossil Fuel, 2021

Country	Primary energy consumption (Quad BTU)	Fossil fuel dependency (%)
Afghanistan	0.09	73.61
Bangladesh	1.71	97.99
Bhutan	0.07	16.97
India	31.96	88.95
Maldives	0.03	98.58
Nepal	0.16	61.69
Pakistan	3.35	82.81
Sri Lanka	0.35	84.75

BTU = British thermal units.

Source: Energy Information Administration, 2022.

Table 1.2. Fossil Fuel Dependency Trend in South Asian Countries, 2010–2021
(%)

Country	2010	2015	2016	2017	2018	2019	2020	2021
Afghanistan	88.84	79.83	75.90	74.46	77.70	76.13	74.78	73.61
Bangladesh	99.16	98.57	98.29	98.12	98.07	97.92	97.81	97.99
Bhutan	10.72	13.72	15.50	18.19	20.97	17.23	16.69	16.97
India	92.13	91.62	91.08	90.63	90.31	89.84	88.87	88.95
Maldives	99.87	99.63	99.50	99.33	99.14	99.08	98.79	98.58
Nepal	58.66	58.65	65.80	66.36	67.88	63.39	61.36	61.69
Pakistan	86.53	86.57	87.61	88.22	84.85	85.45	84.50	82.81
Sri Lanka	77.41	82.61	88.04	88.31	82.80	86.55	84.81	84.75

Note: Share of primary energy consumption.
Source: Energy Information Administration, 2022.

Table 1.3. Primary Energy Gap Trend in South Asia, 2009–2021
(Quad BTU)

Country	2009	2010	2015	2016	2017	2018	2019	2020	2021
Afghanistan	–0.07	–0.09	–0.07	–0.05	–0.04	–0.05	–0.05	–0.08	–0.05
Bangladesh	–0.16	–0.19	–0.31	–0.31	–0.40	–0.42	–0.53	–0.57	–0.78
Bhutan	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
India	–7.92	–8.18	–11.69	–11.75	–12.52	–13.35	-13.43	–11.99	–12.97
Maldives	–0.02	–0.02	–0.02	–0.02	–0.02	–0.03	–0.03	–0.03	-0.03
Nepal	–0.05	–0.05	–0.06	–0.10	–0.11	–0.12	–0.11	–0.11	–0.11
Pakistan	–0.82	–0.84	–1.10	–1.38	–1.57	–1.37	–1.39	–1.37	–1.42
Sri Lanka	–0.17	–0.19	–0.28	–0.32	–0.31	–0.31	–0.32	–0.29	–0.29

BTU = British thermal units.
Source: Energy Information Administration, 2022.

As far as the trends in the electricity generation capacity of the region are concerned, Nepal and Bhutan almost entirely depend on renewable sources while most of the other countries are still dependent on fossil fuels and other non-renewable sources (as indicated in Table 1.4). In recent years, overall renewable energy generation has increased significantly (as indicated in Table 1.5) in all South Asian countries (except Afghanistan, due to political turmoil). In spite of existing fossil fuel dependency, all South Asian countries aspire to increase their renewable (non-fossil fuel-based) power generation in their NDCs as indicated in Table 1.6.

Table 1.4. Electricity Generation and Share of Renewables, 2021

Country	Electricity generation	% Non-fossil fuel
Afghanistan	0.83	84.05
Bangladesh	80.57	1.69
Bhutan	9.00	100.00
India	1,702.09	22.59
Maldives	0.66	7.67
Nepal	6.12	100.00
Pakistan	150.17	41.12
Sri Lanka	16.35	36.74

Source: Energy Information Administration, 2022.

Table 1.5. Renewable Energy Generation Trend (Including Hydro), 2010–2021

(Billion kWh)

Country	2010	2015	2016	2017	2018	2019	2020	2021
Afghanistan	0.31	0.59	0.64	0.75	0.54	0.78	0.75	0.60
Bangladesh	0.94	1.29	1.39	0.76	0.96	0.47	0.83	0.98
Bhutan	1.79	2.62	4.47	6.49	6.89	6.93	7.26	6.98
India	76.75	114.98	130.90	127.33	139.15	142.82	148.12	174.54
Maldives	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Nepal	1.62	2.49	2.71	2.76	2.79	3.08	3.18	3.47
Pakistan	17.02	30.55	31.63	28.42	27.51	29.09	32.77	29.68
Sri Lanka	3.18	3.43	3.87	3.93	4.12	3.91	5.68	4.71

Source: Energy Information Administration, 2022.

Table 1.6. NDC Target for South Asian Countries

Country	% of renewable energy generation
Bangladesh	10
Bhutan	100
India	50
Maldives	21
Nepal	100
Pakistan	60
Sri Lanka	70

NDC = nationally determined contribution.

Source: Compilation from country-level government websites, 2022.

Chapter 2

Objectives and Methodology

1. Objectives

Given this background, this study explores the potential of renewable energy trade in South Asia and its challenges. It also wants to quantify the benefits of renewable energy trade at national and regional levels. In brief, the objectives are as follows:

- Mapping of energy surplus/deficit for South Asian countries and estimating energy trade (especially renewable energy) potential in South Asia.
- Identifying barriers and enabling factors for regional cooperation and trade in renewable energy in the South Asian region.
- Estimating the regional and individual country benefits.

The study also seeks to define the research questions corresponding to the above research objectives for proper formulation of the study approach and methodology. The research questions, in the context of renewable energy trade and cooperation in South Asia, will incorporate the regional issues, and the advantages and agreements to satisfy the broad objectives of this study. The research questions are as follows:

A. Is there a significant potential for regional renewable energy in South Asia?

B. What are the major barriers and enablers for regional energy cooperation in South Asia?

C. Can regional renewable energy lead to regional and national economic benefits? Are regional energy cooperation initiatives more beneficial than bilateral energy agreements?

After formulating the objectives and the consistent research questions, the study focuses on designing compatible hypotheses that will simplify the complex issue of cross-border renewable energy trade in South Asia. The hypotheses will test the plausibility and bona fides of the research questions already defined.

The hypotheses are as follows:

Hypotheses corresponding to research question A.

A. H0: There is significant renewable energy trade potential in South Asia.

H1: Renewable energy trade potential in South Asia is not significant.

Hypotheses corresponding to research question B.

B1. H0: Lack of mutual trust and political tension are the major barriers to cross-border renewable energy trade in South Asia.

H1: Lack of mutual trust and political tension are not the major barriers.

B2. H0: Complementarity in demand–supply of renewable energy is the major enabler for cross-border renewable energy trade in South Asia.

H1: Complementarity in demand–supply of renewable energy is not a major enabler for cross-border renewable energy trade in South Asia.

Hypotheses corresponding to research question C.

C1. H0: Regional renewable energy trade leads to regional and national benefits.

H1: Regional renewable energy trade does not lead to national and regional benefits.

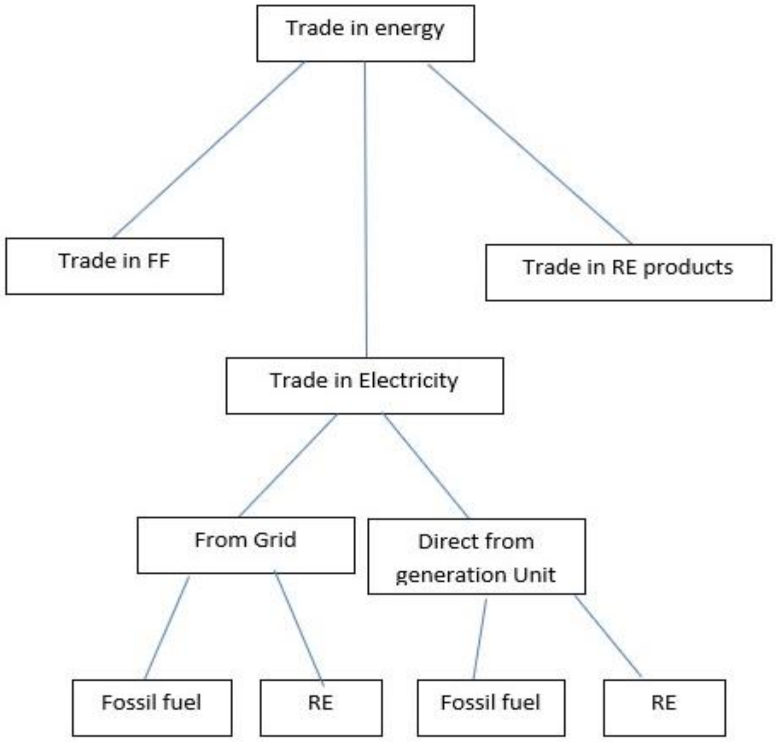
C2. H0: Regional/multilateral renewable energy trade/energy cooperation are more beneficial than bilateral agreements.

H1: Regional/multilateral renewable energy trade/energy cooperation is not more beneficial than bilateral agreements.

The consecutive chapters will explore the above-defined research questions; based on the findings, the validity of the hypotheses will be evaluated.

The study begins with an overview of the renewable energy trade, which is represented in Figure 2.1. In the figure, trade in energy is classified based on generation and has been further subcategorised into the sources of trade in electricity.

Figure 2.1. Classification of Trade in Energy



Note: FF= Fossil Fuel, RE= Renewable Energy.
Trade in FF indicates trade in fossil fuels, for example coal, petroleum products.
Trade in RE products implies trade in renewable energy products, for example solar PVs, batteries, generators, turbines, etc.
Source: TERI, 2022.

2. Trade in Renewable Energy

Renewable energy trade comprises products and green electricity generated by renewable sources. Trade in renewable energy products is not a continuous process and usually occurs as and when required. However, trade in green electricity is somewhat the same as traditional trade in fossil fuels. While trade in both green electricity and fossil fuels is deemed as continuous or regular interval trade, unlike fossil fuels, trade in green electricity cannot be stored for a long period. Moreover, trade in green electricity needs specific infrastructure for the execution of the trade. Thus, for this study, renewable energy trade indicates trade in electricity generated from renewable sources and transmitted through the grid. This renewable energy trade, which is trade in services by nature, is significantly different from any other commercial trade in goods and services, which is already dynamic.

Electricity, despite being a service product, has various characteristics similar to merchandise trade and can be generated, transmitted, and consumed across borders. Countries or regions with surplus electricity can export to those with a deficit, resulting in trade in electricity. However, once electricity is exchanged through grid-based transmission, the ambit and convenience of classifying electricity-generation sources becomes futile because it is not possible to distinguish among electricity produced from various sources. Trade in renewable energy proposed in this study can only be realised through trade in electricity. However, if the electricity generated in the source/exporting country is not fully generated through renewable energy sources, trade in electricity will not be identical to trade in renewable energy. In the context of South Asia, the majority of electricity generation comes from fossil fuel-based sources (except Bhutan and Nepal). However, all countries have their own decarbonisation plans and are accordingly moving their electricity generation away from fossil fuel to renewable energy sources. Once the exporting/source country achieves its decarbonisation target, i.e., 100% of electricity generation through renewable energy, trade in electricity will be identical to trade in renewable energy. In the case of electricity export from Bhutan or Nepal, electricity trade implies trade in renewable energy as a source of generation for electricity, which is almost 100% for these countries. But, for trade in electricity for other source/exporting countries, this study estimates the potential of renewable energy trade.

Next, the study will explore the current and anticipated status and potential of renewable energy trade in South Asia, with a focus on how key factors can be leveraged to foster greater cross-border collaboration in South Asia. To address the research questions, a mixed-method approach (quantitative and qualitative) has been taken, which will provide a more nuanced and detailed understanding of how stakeholders can work together to promote greater cooperation and investment in the same.

3. Methodology

This study employs quantitative research techniques. Moreover, in-depth consultations with relevant experts were conducted to fill the data and information gap in addition to a detailed literature review.

In particular, to address the first objective of the study, the study team undertook a comprehensive review of peer-reviewed research articles and multilateral/bilateral research reports, along with various government reports.

For the second objective, the study undertook a detailed review of the literature. Expert consultation (with a group of experts in energy and trade sectors from government, industry and research, business sector, international organisations, and academia) was conducted for the identification of various factors that influence inter-regional and intra-regional trade and cooperation in energy.

Further, this study has employed the use of Global Trade Analysis Project (GTAP)[1] to estimate the regional and individual country benefits. It is the third and most important objective of the study. GTAP is a global database and modelling framework for quantitative analysis of various global/regional economic policy issues, including trade policy, climate policy, and globalisation linkages to inequality and employment. GTAP is a multi-region, multi-sector, Computable

[1]A brief description of the structure of the GTAP framework has been provided in Annex 3.

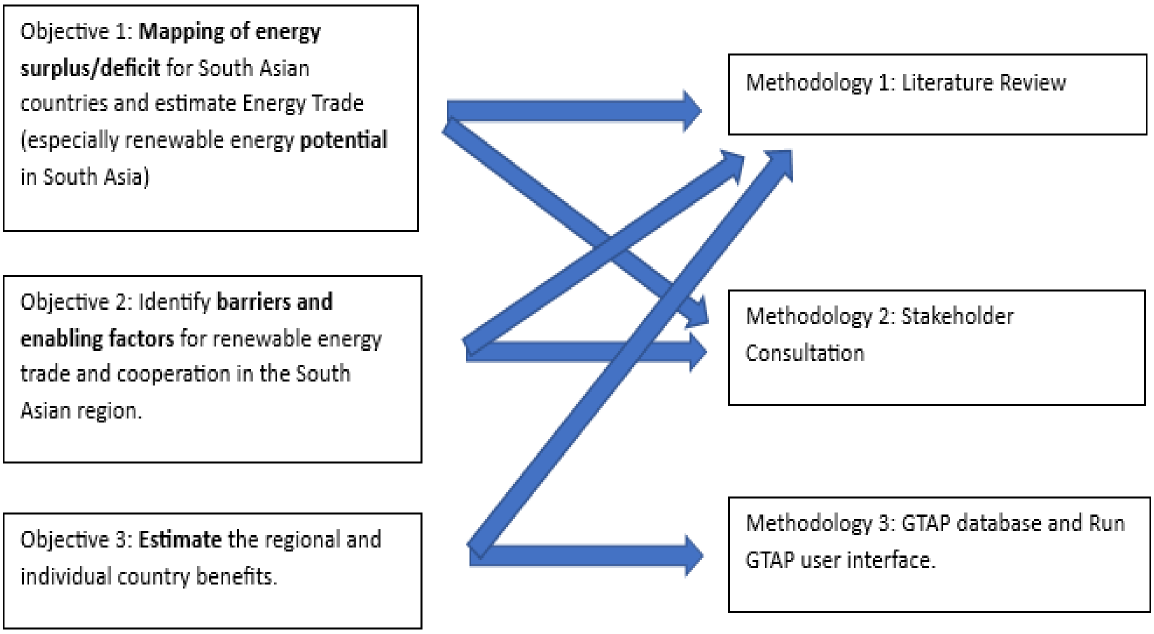
General Equilibrium model, and many recent studies have used GTAP to analyse regional and intra-regional trade issues. Using an inter-regional social accounting matrix, Effendi and Resosudarmo (2020) have analysed the socio-economic and environmental impact of an increased generation of renewable energy in the context of ASEAN countries. The effect was compared with increasing power generation from fossil fuels. Using GTAP-E and GTAP-power database, the study analysed the impact for individual ASEAN member countries. Based on this, the study inferred that the use of renewable energy not only promotes higher gross domestic product (GDP) but also reduces the adverse environmental impact associated with the use of fossil fuel for power generation in the region. The study also measured the impact of higher renewable generation on poverty.

Abrell and Rausch (2016) measured the impact of the expansion of electricity transmission infrastructure and penetration of renewable energy on gains from trade and emissions from power generation in the context of European Union (EU) member countries. The study observed that environmental degradation caused by transmission infrastructure depends on the level of renewable energy penetration. Expansion of transmission infrastructure leads to significant gains from trade, but the level of gains depends on the scale of renewable energy penetration. However, the expansion of transmission infrastructure and an increase in renewable energy share will ensure no adverse impact on regional equity.

In our study, we have used the latest version of GTAP 10 as it provides a database for the world economy aggregated in 141 regions, 65 sectors, and five factors. For each country/region, the database reports production, intermediate, and final uses, international trade and transport margins, and taxes/subsidies (Chepeliev et al., 2019). The values of production, intermediate, and final consumption are all provided in terms of millions of US dollars.

In GTAP 10, out of eight South Asian countries, separate data are only available for Bangladesh, India, Nepal, Pakistan, and Sri Lanka. Data for Afghanistan, Bhutan, and Maldives have been clubbed as the 'Rest of South Asia'. As only Bhutan among the three countries is predominantly engaged in electricity trade, the study assumed that, in the case of renewable energy/electricity trade with Bangladesh, India, and Nepal, 'Rest of South Asia' indicates Bhutan only (as electricity trade for Afghanistan and Maldives are almost negligible). In the case of Pakistan–Afghanistan trade, 'Rest of South Asia' indicates Afghanistan. Figure 2.2 gives a pictorial representation of the broad study approach. In the subsequent chapters, the findings of the study have been discussed at length.

Figure 2.2. The Approach of the Study



Source: TERI, 2022.

Chapter 3

Renewable Energy Trade Potential in South Asia

Renewable energy trade potential refers to the ability of a region or country to generate renewable energy in surplus of their domestic needs and the potential to export the same to neighbouring countries that have higher energy demand and deficit supply. The renewable energy trade can occur through different mechanisms including cross-border transmission lines, energy storage systems, or through regional energy markets or exchanges. The South Asian region has significant potential for cross-border renewable energy trade and huge opportunities for solar, wind, hydro, and biomass energy generation.

In this section, we will focus on the significant opportunities to expand renewable energy generation in South Asia. Different national governments have undertaken various comprehensive policies with forward-looking plans to tackle the growing energy demand and meet their climate-change goals. These have been explored here, individually for each country in the particular region.

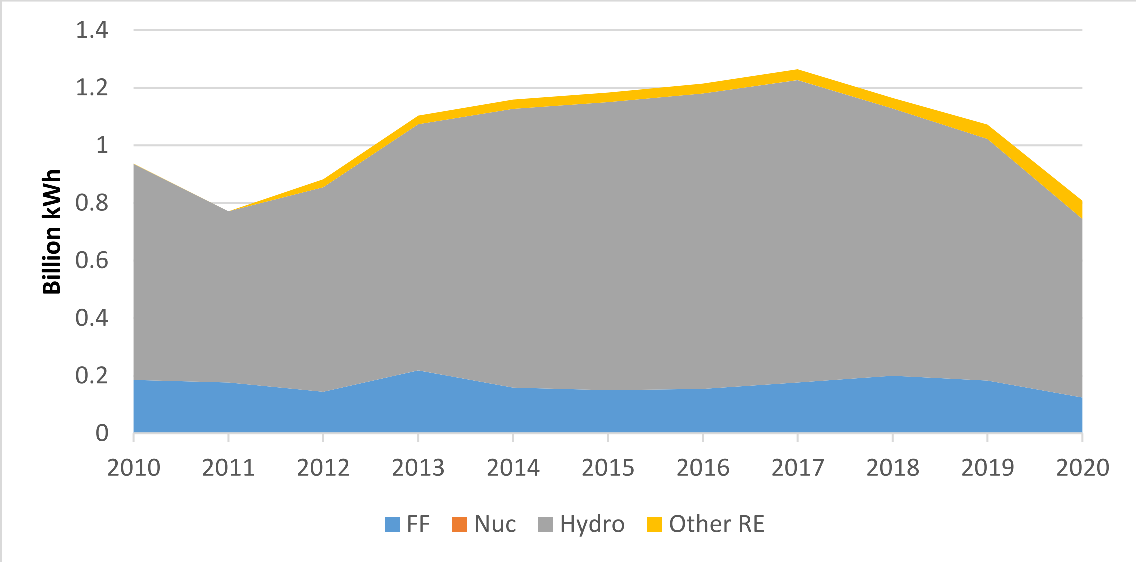
1. Country-specific Energy Transition

1.1. Afghanistan

Despite having $1 trillion or more in mineral deposits, Afghanistan is one of the least developed countries not only in South Asia but also globally. Afghanistan has a significant potential for renewable energy generation, which is estimated at over 300,000 MW. Afghanistan already uses hydro and marine power as a major electricity generation component and has substantial potential for solar power generation as well. The country's huge potential for hydropower generation is due to its abundant rivers and rough topography. Afghanistan's total solar energy potential, based on both solar radiation and suitable area, is estimated at 222,849 MW (ADB, 2019). Based on the average cost, solar is the second-cheapest source for generating electricity after onshore wind in Afghanistan (Mehrad, 2021).

The distribution of solar resources in Afghanistan indicates that its technological capacity is highest in the southern and western provinces of Helmand, Kandahar, Herat, Farah, and Nimroz, as these areas have an overall capacity of 142.568 MW or 64% of the total potential of the country (Mehrad, 2021). Recently, the Asian Development Bank (ADB) approved a $44.76 million grant to develop Afghanistan's first 20 MW on-grid solar plant and boost the country's renewable energy generation and supply. Figure 3.1 illustrates the electricity generation mix and the importance of hydropower and solar energy in Afghanistan.

Figure 3.1. Afghanistan's Electricity Generation Capacity, 2010–2020

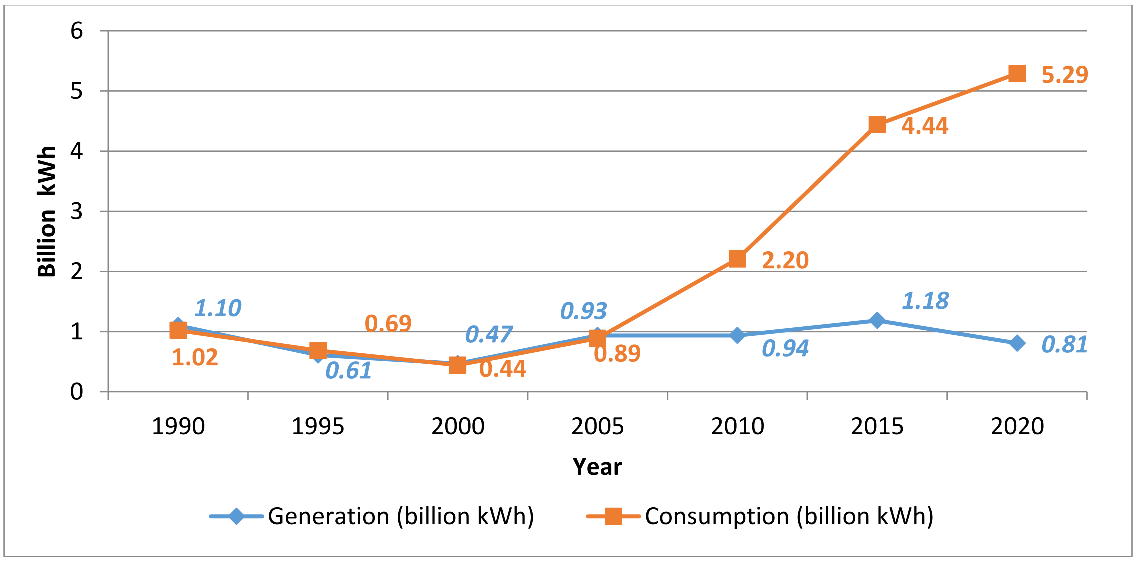


FF = Fossil fuels, Nuc = Nuclear, RE = Renewable energy sources.
Source: International Energy Association, 2022.

From Figure 3.1 we can observe that the major source of electricity in Afghanistan comes from renewable energy (almost 88%) and the remaining 12% comes from non-renewable energy. As mentioned, Afghanistan has a large hydropower generation capacity; it also has solar power capacity that can be harnessed to produce electricity in the long run.

Based on these supply and renewable energy generation capabilities, we will look at the demand side. Using Figure 3.2, the study will illustrate Afghanistan's electricity generation and consumption trends over the years.

Figure 3.2. Afghanistan's Electricity Generation and Consumption Trends, 1990–2020



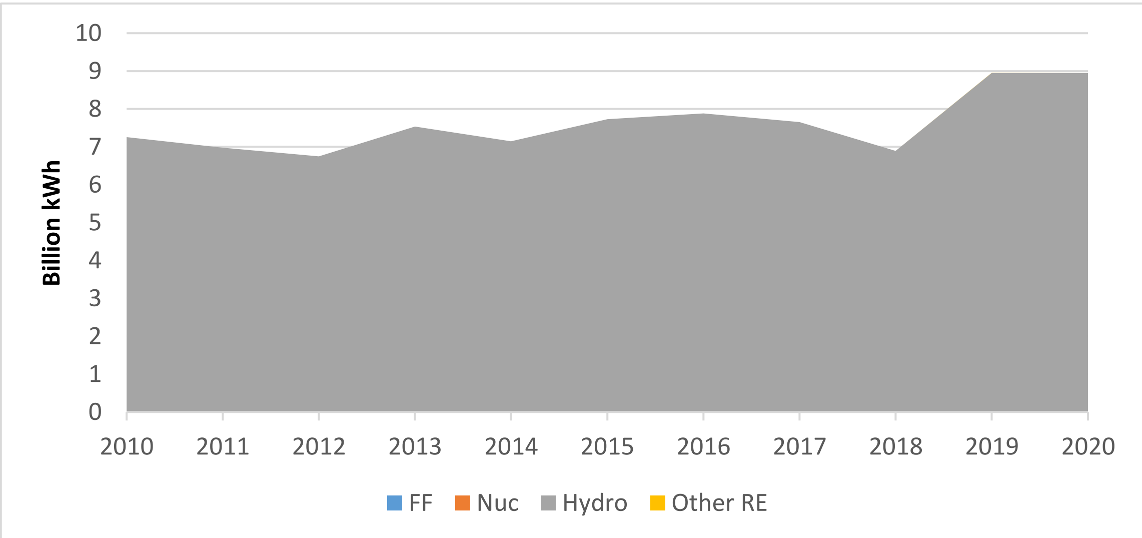
Source: Energy Information Administration, 2022.

One remarkable aspect is that Afghanistan's increase in electricity consumption has far exceeded its generation capacity. The country's electricity sector has faced numerous challenges over the years, such as political instability, lack of infrastructure, and limited investment in the energy sector (McDonald, 2016). As a result, its electricity generation capacity has remained relatively low, hovering around 1 billion kWh, while electricity consumption has skyrocketed, increasing approximately by five times since 2005. This situation has resulted in a significant electricity deficit, with Afghanistan struggling to meet its energy demands. The country has had to resort to importing electricity from neighbouring countries, which has placed a significant strain on its economy.

1.2. Bhutan

Bhutan is situated on the southern slope of the Eastern Himalayas and is among the richest countries by GDP per capita in South Asia ($3,491 in 2022). But it is still among the poorest in the world and ranked 178th (nominal GDP) by the International Monetary Fund. Bhutan has the potential to be self-sufficient with indigenous energy sources. Its total electricity generation is estimated at 8 billion kWh. This constitutes energy production, which is 361% of the country's own usage. Bhutan's energy supply is largely based on renewable sources, primarily from its various hydropower projects. However, as per the estimation of the Bhutan Renewable Energy Master Plan, the country can produce 12 GW of solar energy and 760 MW of wind energy. The country has pilot projects in solar, wind, biogas, and small hydropower (Rangjhung, Zhemgang small hydropower plant) along with mega-hydropower projects. It has also joined the International Solar Alliance, an action-oriented, member-driven, collaborative platform for increased deployment of solar energy technologies. In the next 2 years, Bhutan plans to harness 300 MW of solar energy. Its first project, under construction, is a 17.38 MW solar plant in Wangduephodrang district financed by ADB. Figure 3.3 shows the country's electricity generation mix from different sources.

Figure 3.3. Bhutan's Electricity Generation Capacity, 2010–2020



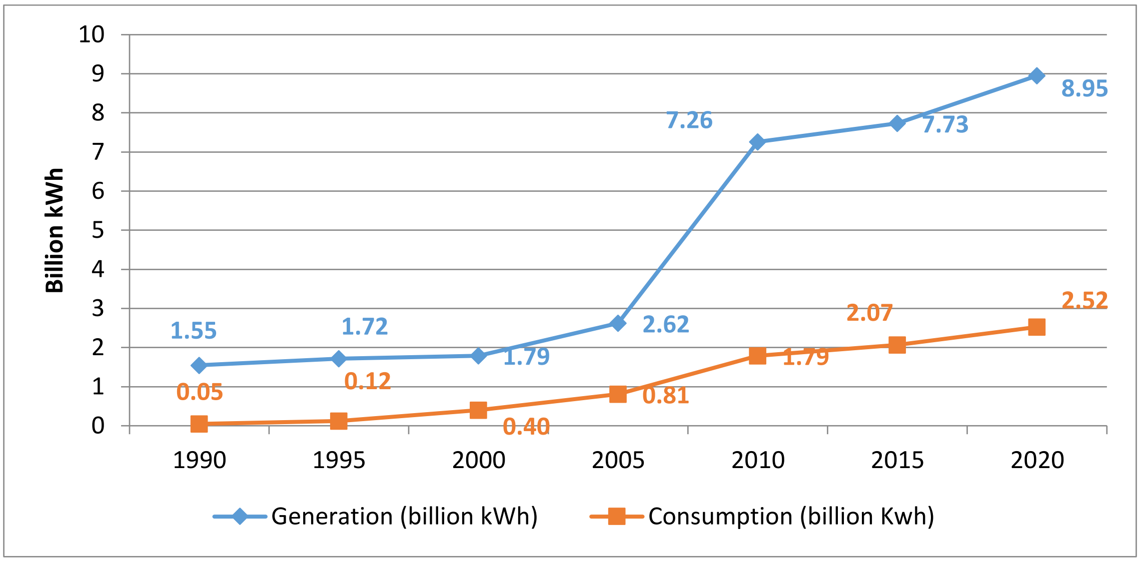
FF = Fossil fuels, Nuc = Nuclear, RE = Renewable energy sources.

Source: International Energy Agency, 2022.

Figure 3.3 shows that almost 100% of Bhutan's electricity comes from its vast hydropower reserve. Although optimistic, the country will still require diversifying the renewable sources of energy by means of imports or alternative generation.

Even though Bhutan has a strong electricity generation capacity, the study also analysed the general trends of consumption alongside generation so that insights can be provided on the hydropower exports of Bhutan to South Asia (mainly India).

Figure 3.4. Bhutan's Electricity Consumption and Generation, 1990–2020



Source: Energy Information Administration, 2022.

Figure 3.4 illustrates Bhutan's impressive electricity generation and consumption trends. Its energy sector has experienced impressive growth, with electricity production capacity increasing by almost 5 billion kWh between 2005 and 2020. In contrast, the country's consumption has remained relatively constant, i.e. between 1 and 2 billion kWh.

This indicates that Bhutan's energy sector is well-developed and capable of meeting its energy demands while simultaneously producing surplus energy to export to other countries. The country's impressive electricity generation capacity can be attributed to its significant investment in hydropower infrastructure, which has been a crucial factor in its economic development.

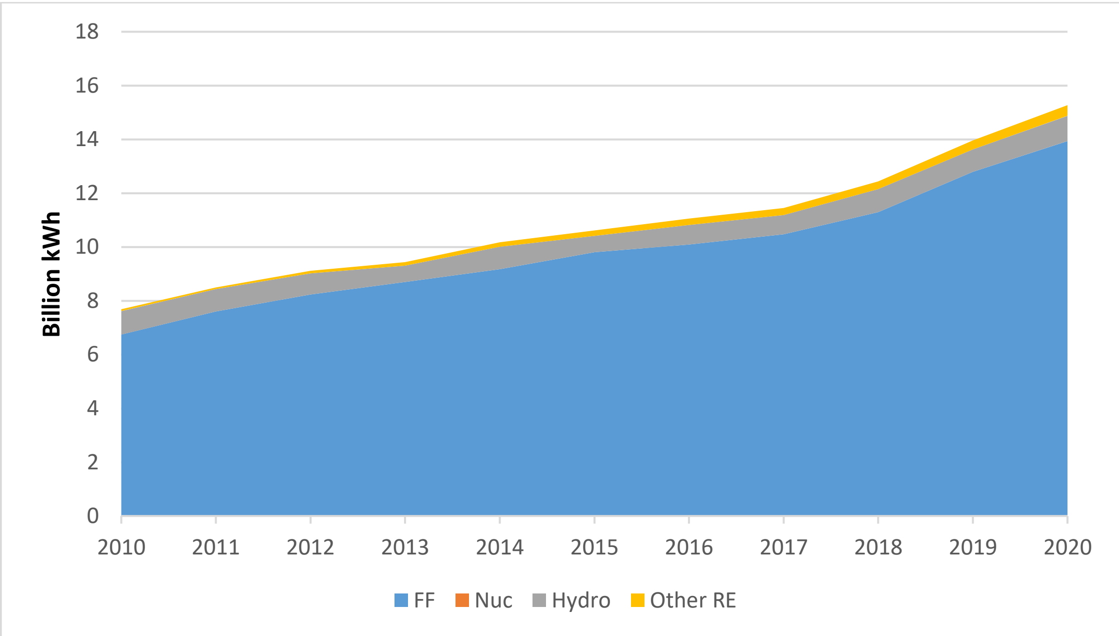
The excess electricity production capacity over the consumption demands of Bhutan is an impressive feat and showcases its commitment to sustainable energy production. Furthermore, Bhutan's ability to export surplus electricity to neighbouring countries provides a significant boost to its economy.

1.3. Bangladesh

With a population of more than 165 million, Bangladesh is one of the most densely populated countries in the world and the second-largest economy in South Asia after India (Hossen, 2021). Bangladesh is gradually shifting toward a green economy and has one of the largest off-grid solar power programmes in the world, which is benefitting 20 million people. In Bangladesh, the programme '100% Renewable Energy for Bangladesh – Energy Access for All within One Generation' was launched in 2019, and the country envisages almost 40 GW of renewable energy generation capacity by 2041.

Even with such ambitious targets, Bangladesh still derives most of its electricity from fossil fuel. The 2022 national grid collapse plunged the entire country into a nationwide blackout and showed the importance of grid expansion going hand-in-hand with the expansion of electricity generation. Figure 3.5 shows the generation of electricity and a hike in the sectoral consumption of electricity in the country.

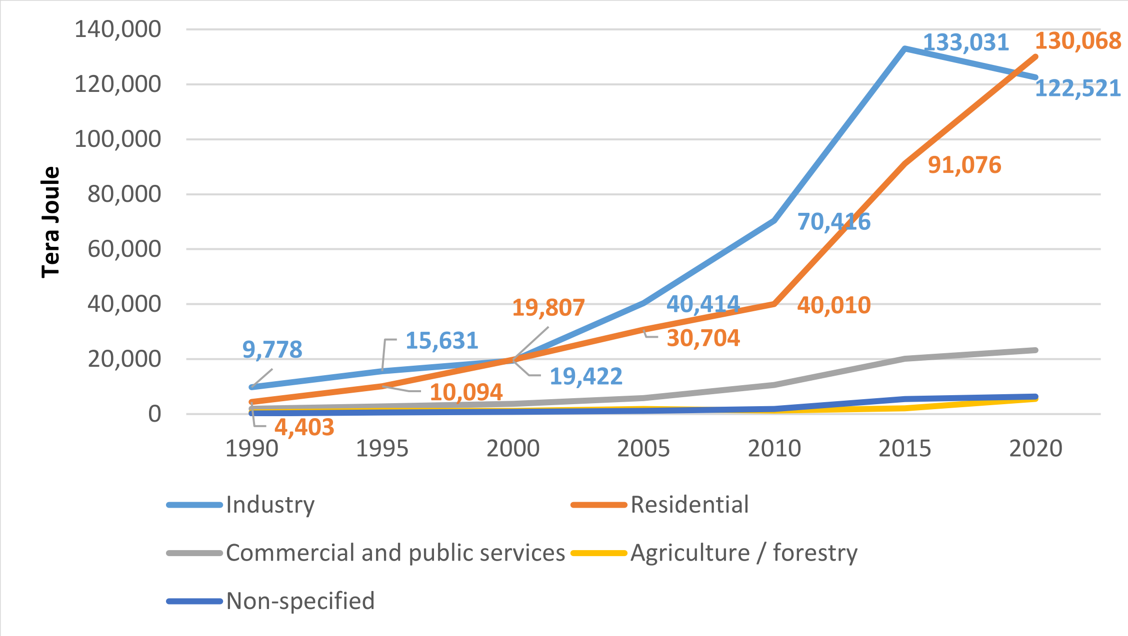
Figure 3.5. Electricity Generation Capacity of Bangladesh, 2010–2020



FF = Fossil fuels, Nuc = Nuclear, RE = Renewable energy sources.
Source: International Energy Agency, 2022.

From the figure, we can observe that the major source of electricity in Bangladesh comes from non-renewable sources (almost 99%) and a mere 1% comes from renewables. This implies that Bangladesh has yet to undergo a mass clean energy transition that will substitute fossil fuel sources of generation.

Figure 3.6. Bangladesh's Electricity Consumption by Sector, 1990–2020

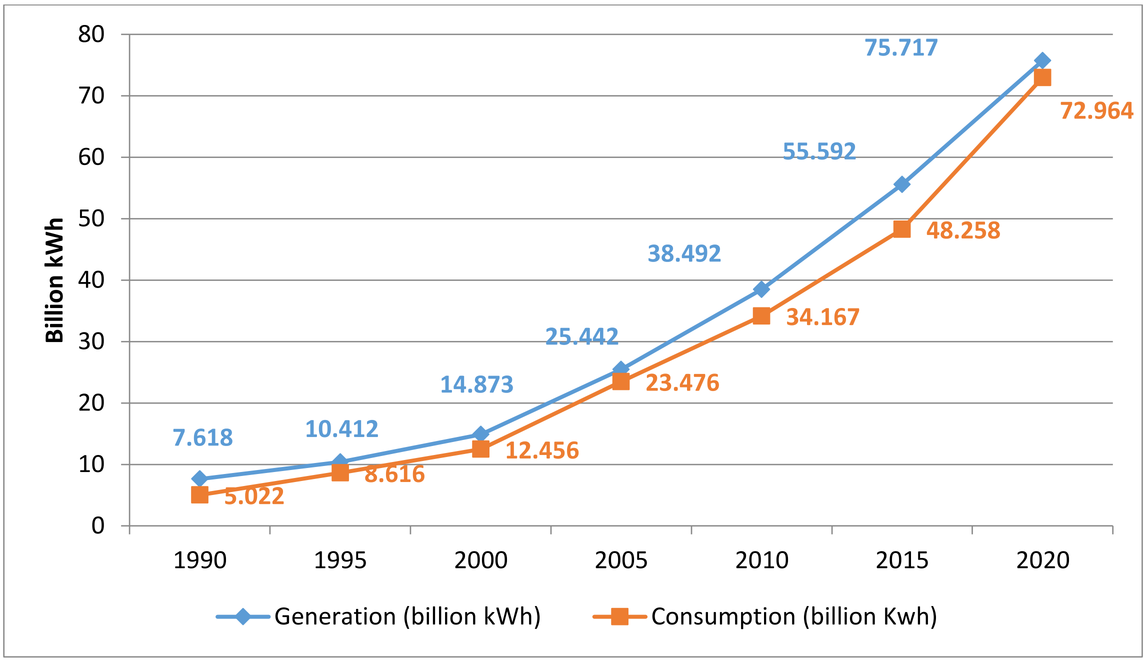


Source: International Energy Agency, 2022.

In Bangladesh, the residential sector is the largest consumer of electricity (over 45%) followed by the industrial sector (over 40%). In the last 5 years, the electrification of the residential sector has surpassed the industrial sector. This is because of the policies adopted by the Bangladesh government to electrify its rural areas. This has ultimately led to 100% electrification of the country. Moreover, the adoption of various energy efficiency measures in the industry sector has also helped to economise energy consumption in the sector.

The following figure shows the trends in consumption and generation of electricity over time, to gain insight into the overall expansion of the electricity sector for Bangladesh. Figure 3.7 considers a period of 30 years (1990–2020).

Figure 3.7. Bangladesh's Electricity Consumption and Generation, 1990–2020



Source: Energy Information Administration, 2022.

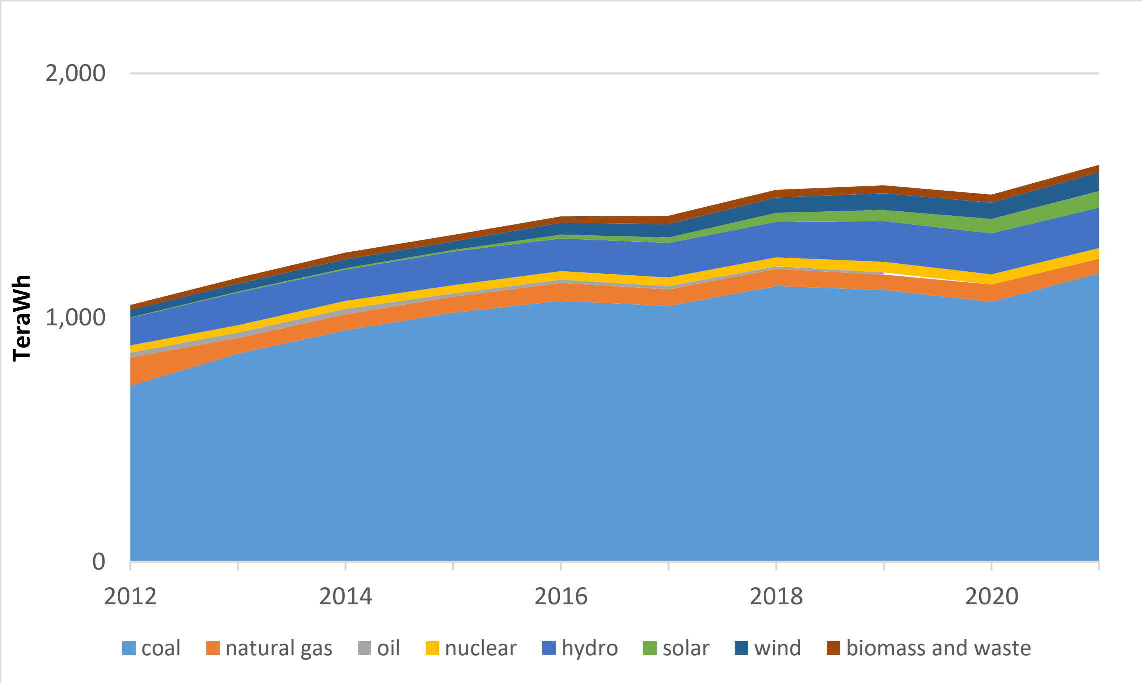
Bangladesh's electricity sector has seen impressive growth over the years, with both electricity generation and consumption increasing at a steady pace. This growth in consumption can be attributed to several factors, such as its rapidly growing population, urbanisation, and industrialisation. Despite this increase in consumption, Bangladesh's electricity generation capacity has been able to keep pace and continues to produce surplus electricity. Over the last 3 decades, electricity generation has increased from 7.6 billion kWh to 75.7 billion kWh whereas consumption has increased from 5.02 billion kWh to 72.97 billion kWh.

1.4. India

India is the largest country in South Asia and the seventh-largest country in the world (by area). Globally, it holds the fourth position in renewable energy installed capacity, including large hydro and wind power and solar power capacity (REN21, n.d.). India has already set an ambitious target of fulfilling half of its energy requirements through non-fossil fuel sources by 2030 and even increased the target in COP26 to 500 GW of non-fossil fuel-based energy by 2030. Moreover, it is seeking to replace natural gas with green hydrogen. The commitments toward the Paris Agreement, including the NDCs, coupled with the country's recent goal of carbon neutrality by 2070, is a huge step in the global diaspora for it to emerge as an energy leader in the region. India is also planning to set up a carbon credit trading scheme, while the world's largest renewable energy park of 30 GW capacity solar–wind hybrid project is under installation in Gujarat. The country is pursuing bilateral engagements with many countries and also permitting foreign direct investment up to 100% under the automatic route. The recent central government budget has announced production-linked incentives for solar manufacturers and Green Bonds, while it published the Green Hydrogen and Ammonia policy to provide incentives to its renewable energy transition plan. It has also established its first and the largest ever energy exchange called the Indian Energy Exchange, which facilitates the physical delivery of electricity through an automated trading platform. In this regard, two new products have been launched to facilitate power exchange: Real-Time Market and Green Term Ahead Market. The Real-Time Market enables distribution companies to buy power at the last moment and avoid load shedding. This will help manage the variability of renewable energy whereas the Green Term Ahead Market is a lucrative basis to procure it on a flexible basis with the scope of hedging against price volatility in the short-term power market. The volume of electricity traded in the Real-Time Market through November 2021 was 22,713 MU (Ministry of Power, 2022).

To understand the segregation of electricity generation, we have categorised the fuel source type, and used this in the net generation graph in Figure 3.8.

Figure 3.8. India's Net Electricity Generation by Fuel Type, 2012–2021



Source: U.S. Energy Information Administration, International Energy Statistics and Estimates, 2022.

The following are the observations based on Figure 3.8:

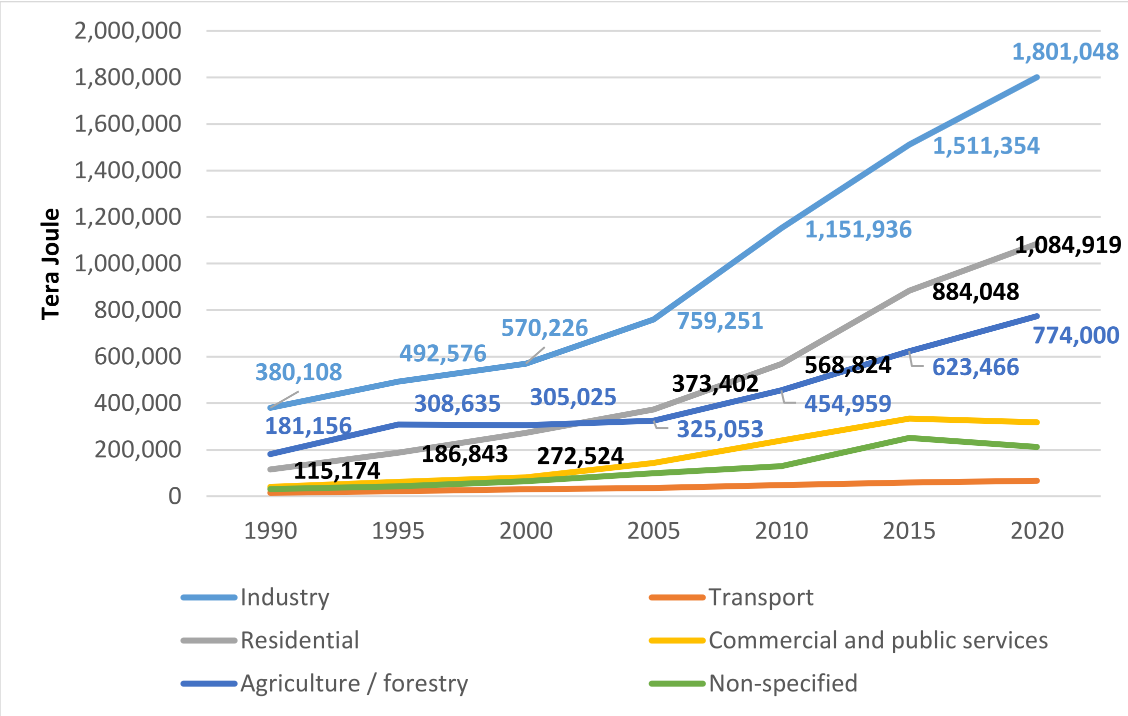
- In 2021, India generated around 1,628 TWh of net electricity, a rise of 8% over 2020. This increase came after a 2% reduction in demand by 2020 for the first time in at least 39 years, due to strict lockdown measures imposed in response to the COVID-19 pandemic (Reuters, 2021).
- In 2021, fossil fuel accounted for 76% of India's net power generation. Coal accounted for the bulk of all energy sources (73% of total generating). Coal-fired power stations produced 1,243 TWh, exceeding the previous high of 1,208 TWh set in 2018. Natural gas,

oil, and nuclear power accounted for less than 7% of India's total power supply (International Energy Statistics, 2022).

- Renewable energy occupied the second-largest share of electricity generation (21%), with hydropower comprising 10%, solar 4%, wind 5%, and biomass 2% (International Energy Statistics, 2022).
- Solar energy generation reached 16% in 2021, following 2 years of average growth of 26%. Wind energy generation increased by 15% in 2021 (International Energy Statistics, 2022).

This study has also considered the demand for electricity and the consumption rate across all sectors, which is depicted in Figure 3.9. It depicts the usage and relative importance of electricity in industry, agriculture, and other economic activities.

Figure 3.9. India's Electricity Consumption by Sector, 1990–2020

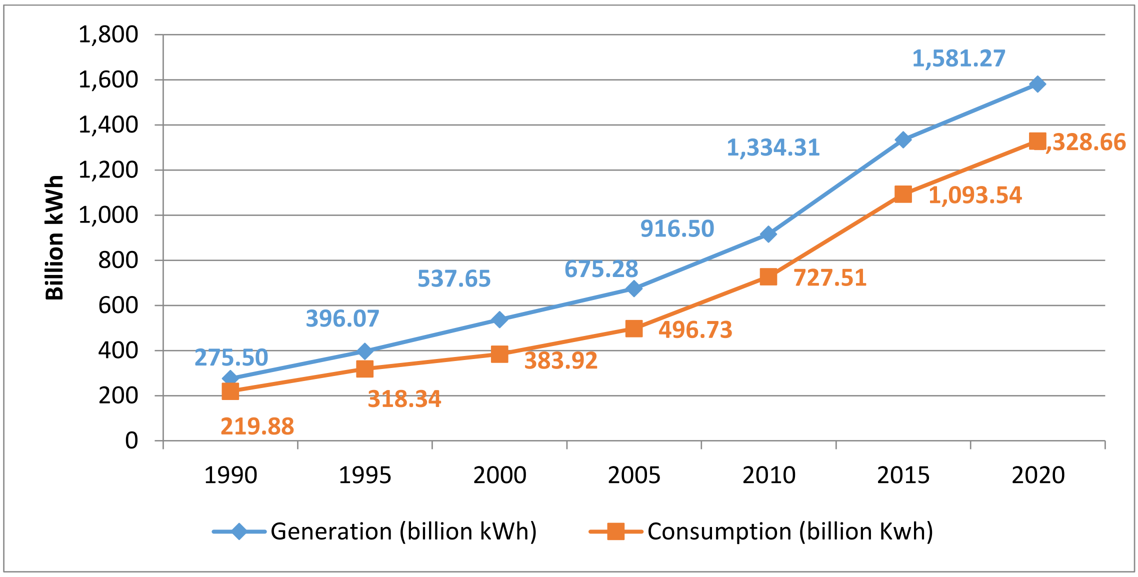


Source: International Energy Agency, 2022.

As per the figure, there has been an increase in demand for electricity and hence an increase in consumption across all sectors. In India, the industry sector is the main consumer of electricity, with a 40% share of total electricity consumption in 2020. This is followed by the residential sector (25%) and the agriculture sector (19%). The share of electricity in the industry sector rose nearly four times (0.38 million TJ in 1980 to 1.8 million TJ in 2020) in the last 30 years, which is an indication of the growing industrialisation in the country. There has been a steady increase (0.18 million TJ to 0.77 million TJ) in electrification in the agriculture sector, which indicates the modernisation and mechanisation of agriculture with more electric-intensive technology.

As demonstrated for other countries, this study has also graphically analysed the trends of electricity generation and consumption over the past 3 decades to deconstruct the emerging relevance of electricity over the past years (refer to Figure 3.10).

Figure 3.10. India's Trend in Electricity Generation and Consumption, 1990–2020



Source: Energy Information Administration, 2022.

The graph indicates that India produces more electricity than the other countries, generating almost 1.580 trillion kWh. One can also see that India has the potential to produce enough electricity to meet its domestic demand. The country's electricity production capacity has been growing consistently over the years and has maintained a steady pace of generating electricity to meet the country's rising demands.

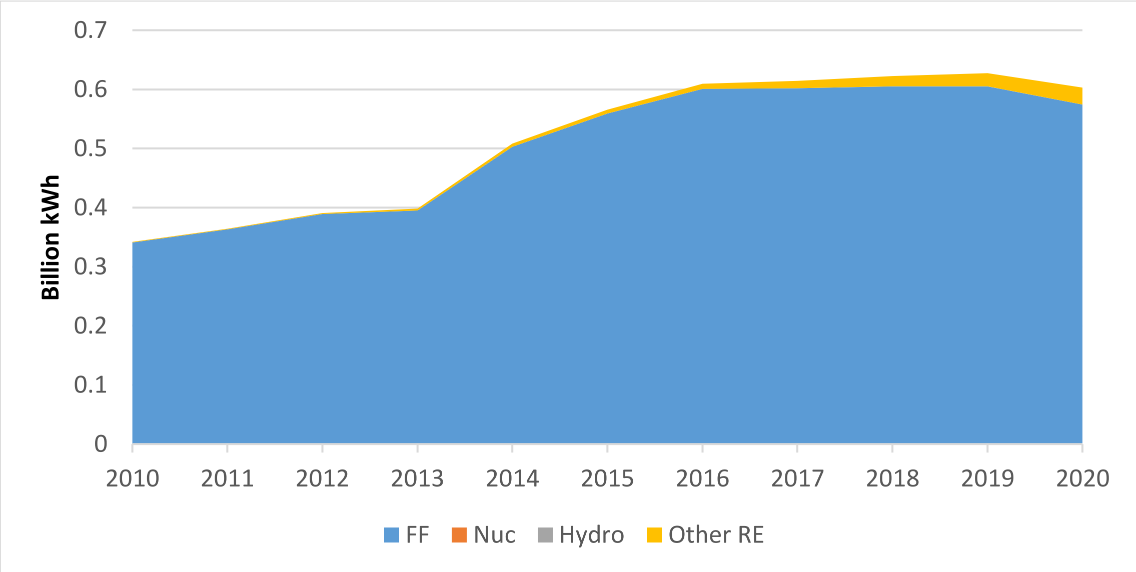
India's ability to produce such a vast amount of electricity is a testament to its rapidly developing energy sector, which has been able to meet the energy needs of the country's growing population and economy.

In conclusion, the analysis indicates that India has the necessary infrastructure and capacity to produce enough electricity to meet the needs of its people. The data suggest that the country's energy sector has been able to keep pace with the growing demand for electricity, and it is likely to continue to do so. Therefore, India's electricity production capacity is a significant strength and a critical factor in its continued economic growth and development.

1.5. Maldives

Maldives was one of the poorest economies in the world in the 1970s. However, its development has been marked by the largely successful economic programme in the 1980s and a boost in tourism. In addition, its 5 MW solar project has amply benefitted Maldives. Under the UN Climate Action Summit (2020), Maldives has strengthened its commitments toward climate change and renewable energy targets to achieve its carbon neutrality targets by 2030. Assistance has been provided by the World Bank for this. Maldives has no proven fossil fuel reserves but has abundant renewable energy sources, with the potential to produce green hydrogen fuel (ADB, 2020). Maldives has also undertaken the Accelerating Private Investments in Renewable Energy programme, funded by the Green Climate Fund and the World Bank. By 2023, the nation of islands aims to more than triple its renewable energy capacity to 85 MW, of which 75 MW would be solar. It is also seeking to set up an 8 MW waste-to-energy plant with assistance from ADB. The electricity generation mix from various sources has been shown in Figure 3.11.

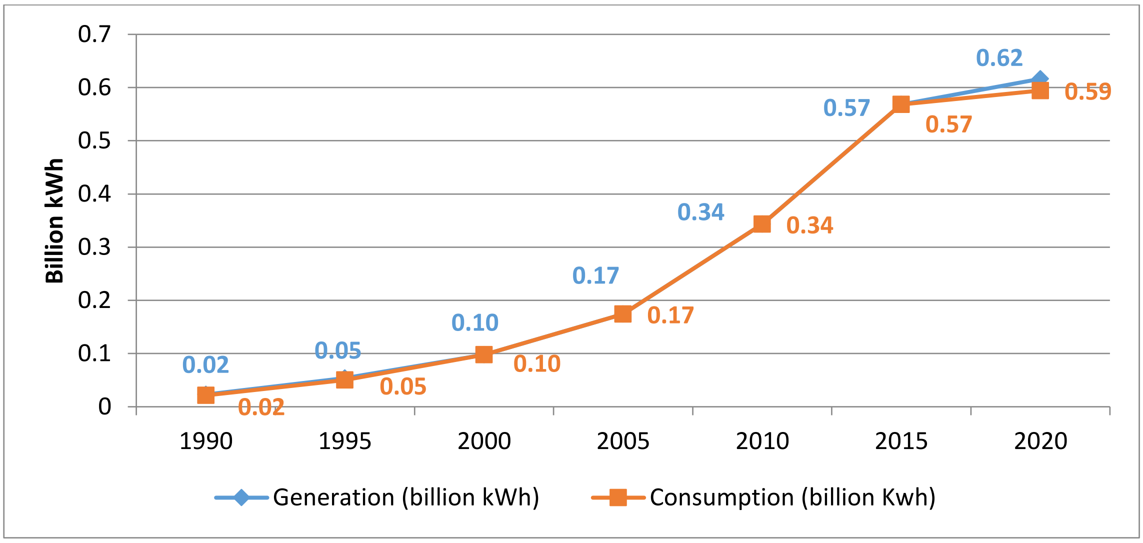
Figure 3.11. Maldives' Electricity Generation, 2010–2020



FF = Fossil fuels, Nuc = Nuclear, RE = Renewable energy sources
Source: International Energy Agency, 2022.

Almost 94% of electricity in Maldives comes from non-renewable sources, with the remainder stemming mainly solar energy. We have analysed the trends of consumption and generation of electricity for Maldives in Figure 3.12.

Figure 3.12. Maldives' Electricity Generation and Consumption Trends, 1990–2020



Source: Energy Information Administration, 2022.

Maldives has been able to balance electricity generation and consumption until recently. In recent years, it has increased its generation capacity, thus enabling it to meet the country's growing energy demands.

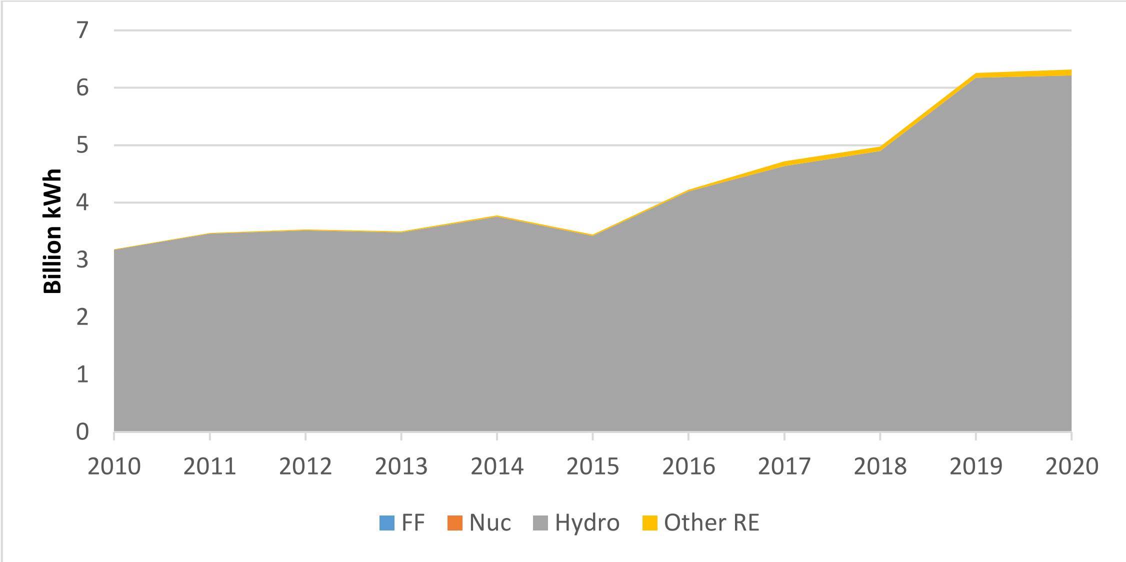
Furthermore, Maldives has been focusing on renewable energy, which has played a significant role in the country's energy sector development. Renewable energy has not only enabled Maldives to reduce its carbon footprint but also provided a sustainable source of energy, reducing the country's dependence on imported fossil fuels.

In conclusion, the analysis indicates that Maldives' energy sector is developing, with the country investing in its energy infrastructure and focusing on renewable energy. Its focus on renewable energy and investment in its energy sector is likely to provide a sustainable source of energy and contribute to the country's economic growth.

1.6. Nepal

Nepal is one of the developing nations in South Asia with vast hydropower reserves. It has set extensive NDCs; these include 80% electrification through renewable energy sources with an appropriate energy mix (4,000 MW hydro and 2,100 MW solar energy) by 2030. The World Bank has approved a Strategic Climate Fund grant of $5.61 million and a Strategic Climate Fund loan of $2 million to help Nepal diversify its energy sources. This is also in line with Nepal's Renewable Energy Subsidy Policy and its existing Renewable Energy for Rural Areas programme that aims to develop a framework for the participatory and demand-led promotion of small-scale renewable energy. Figure 3.13 shows the electricity generation mix of Nepal from different sources and the sectoral spread of the same across agriculture, industry, transport, etc.

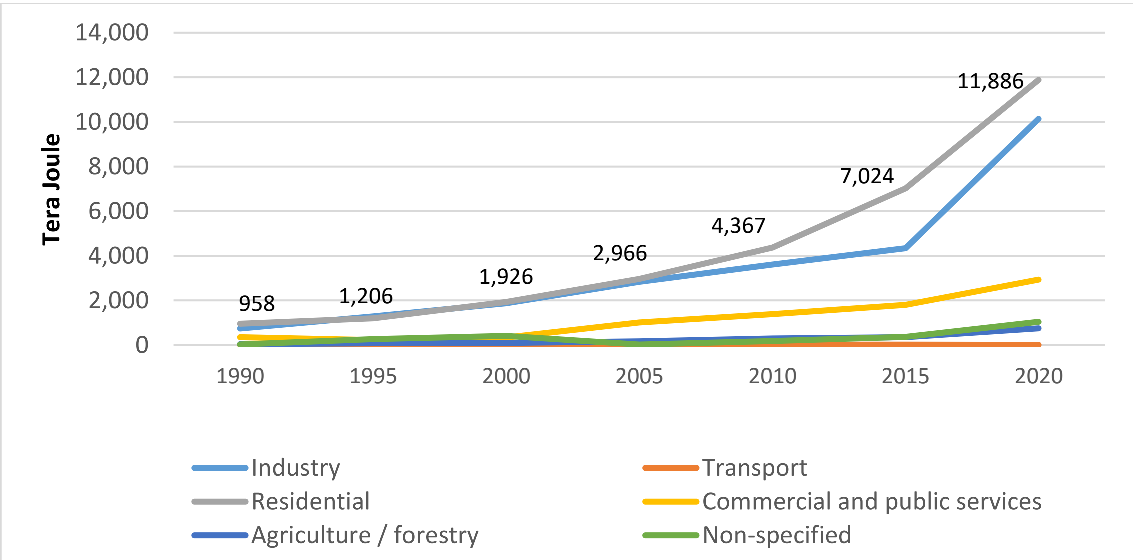
Figure 3.13. Electricity Generation Mix of Nepal from Different Sources, 2010–2020



FF = Fossil fuels, Nuc = Nuclear, RE = Renewable energy sources
Source: International Energy Agency, 2022.

From Figure 3.13 we can see that almost 100% of Nepal's electricity comes from renewable sources. Moreover, almost the entire renewable source comes from its vast hydropower reserve, with the remainder coming from solar power.

Figure 3.14. Nepal's Electricity Consumption by Sector, 1990–2020

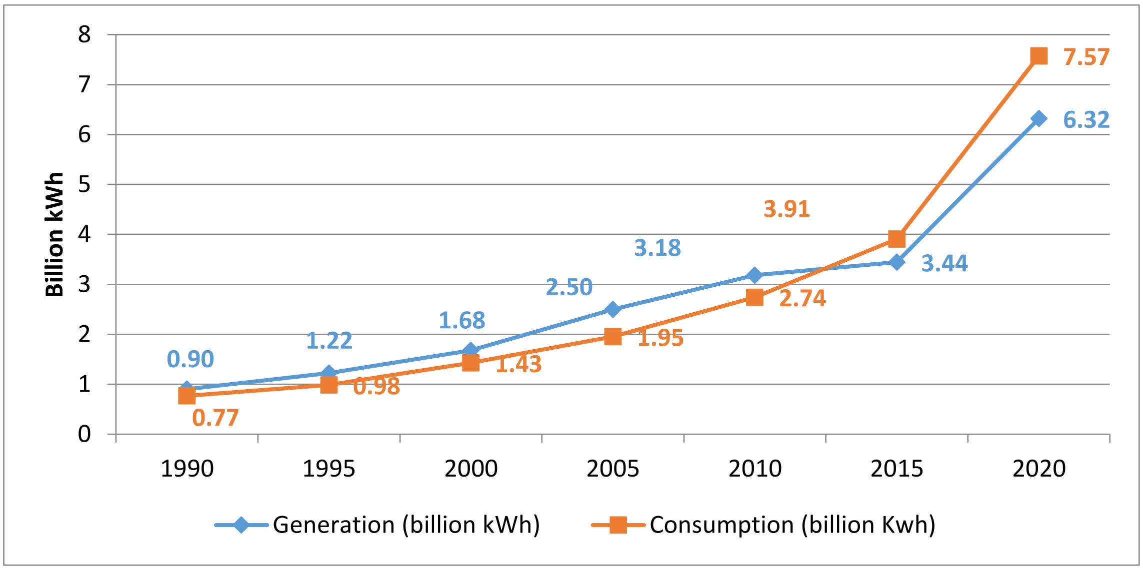


Source: International Energy Agency, 2022.

Figure 3.14 shows the increase in demand for electricity and hence the increase in consumption across all the sectors. In Nepal, the residential sector is the largest consumer of electricity, with over 40% in 2020. It is followed by the industry sector, which is around 38% and the commercial sector at around 11%. The share of electricity in the residential sector rose more than 10 times over the last 30 years, which indicates that quality of life improved in the country. Over the last 5 years, there has been a steep increase in electrification in the industry sector.

To show the changes in the electricity sector in Nepal, the study analysed the trends of electricity consumption and generation over the past 3 decades with the help of Figure 3.15.

Figure 3.15. Nepal's Electricity Consumption and Generation, 1990–2020



Source: Energy Information Administration, 2022.

This graph clearly indicates that Nepal was self-sufficient in the generation and consumption of electricity till the early 2010s and even had a surplus over consumption in these years. However, since 2010 consumption has been consistently higher than the generation, with a significant gap arising from 2012 onward.

From 1991 to 2012, Nepal had a remarkable generation profile for electricity, producing approximately 0.3186 billion kWh more than its requirement. However, the scenario changed after 2012, with the country facing a demand-supply deficit in electricity. This has made the country susceptible to either importing electricity from other countries or expanding its domestic generation.

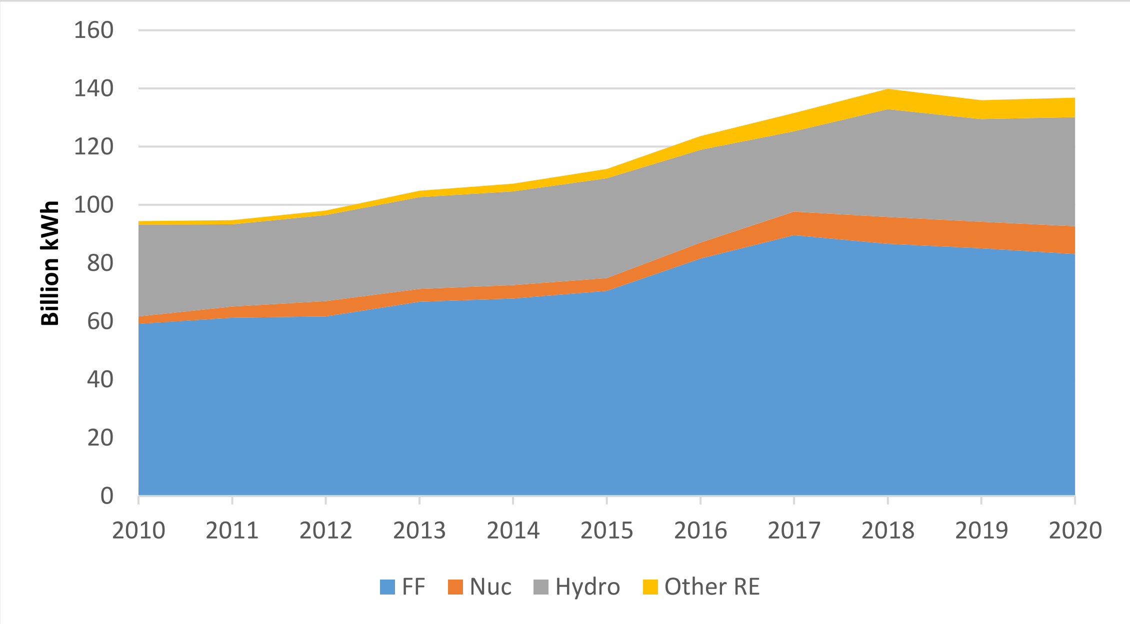
As of 2019, Nepal's electricity consumption stood at 7.574 billion kWh, while its electricity generation was only 6.318 billion kWh. This indicates that the country has a shortage of electricity, with inadequate generation to meet the increasing demand.

This analysis highlights the evolution of Nepal's electricity consumption and generation, from being self-sufficient to facing a deficit in electricity requirements. Given the limited domestic resources, electricity import from neighbouring countries could be an important strategy for Nepal, especially in the winter season when domestic hydro generation is almost negligible.

1.7. Pakistan

Pakistan is the second-largest country (by area) in South Asia and one of the world's largest consumers of gas in the region. While it has a strong potential for generating renewable energy, it is still far behind the world in terms of developing such resources. The Government of Pakistan aims to derive 60% of its energy from renewable sources and is adding 13,000 MW of hydropower through 2030. To expand renewable energy in Pakistan's energy mix, the World Bank has provided $100 million financial assistance to Sindh Solar Energy Project to support independent power producers develop 400 MW of new solar power projects. The electricity generation capacity of Pakistan from various sources is shown in Figure 3.16.

Figure 3.16. Pakistan Electricity Generation Capacity, 2010–2020

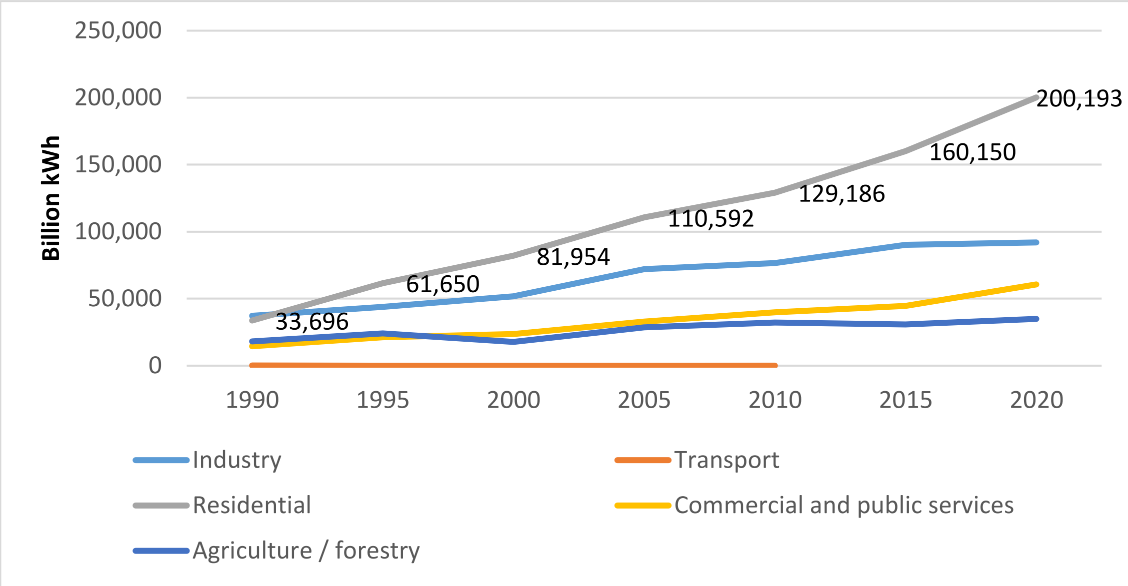


FF = Fossil fuels, Nuc = Nuclear, RE = renewable energy sources

Source: International Energy Agency, 2022.

From the figure, it can be observed that the major source of electricity in Pakistan is from non-renewable fossil fuel (almost 67%) and the remaining 33% is from renewable sources, mainly hydropower. Figure 3.17 depicts the consumption of electricity by different sectors.

Figure 3.17. Pakistan's Electricity Consumption by Sector, 1990–2020
(TJ)



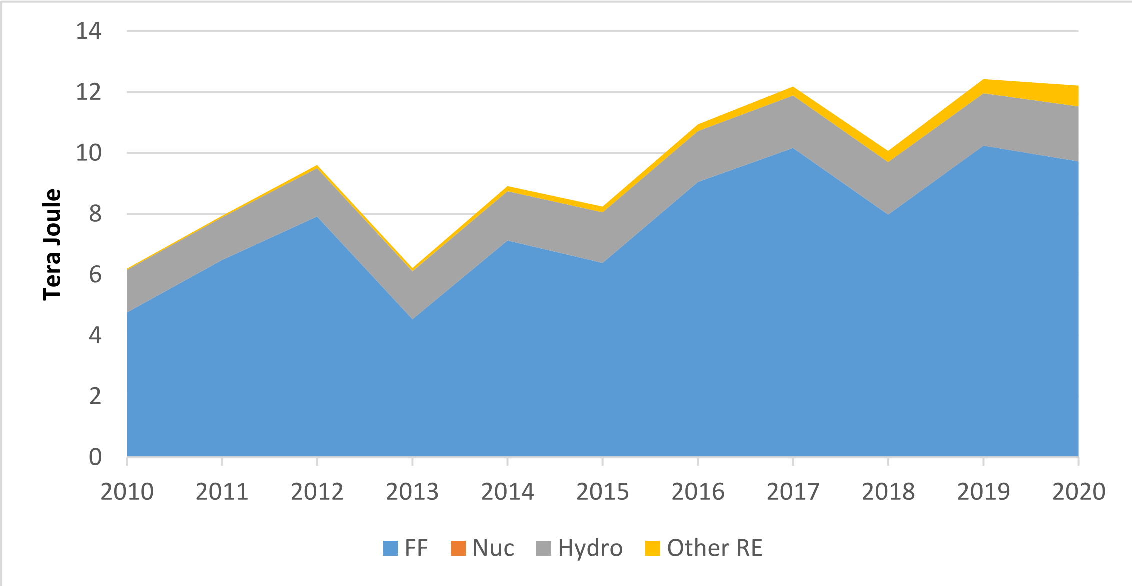
Source: International Energy Agency, 2022.

In Pakistan, the residential sector is the major electricity consumer, accounting for more than half of total electricity consumption in 2020. It is followed by the industry sector at around 25% and the commercial sector at around 16%. The share of electricity in the residential sector rose nearly five-fold in the last 30 years, an indication of the urbanisation of the country. Non-electrification of the transport sector, as shown in the figure, depicts that Pakistan suffered from a huge cost of entry to the market of electric vehicles and clean energy. This, along with a nearly stagnant electrification of the industrial sector, shows that the sector is still hugely labour-intensive and energy-inefficient.

1.8. Sri Lanka

Sri Lanka is an important transhipment hub for South Asia. In Sri Lanka, the State Ministry of Solar Power, Wind, and Hydro Power Generation Projects Development has added 2,700 MW of renewable energy-based electricity to the national grid. The Ministry has prepared a Renewable Energy Strategic Plan, which is updated every 5 years, in line with the power generation plan of the Ceylon Electricity Board (CEB). It plans to feed 70% of the national grid with renewable electricity by 2030. Figure 3.18 illustrates the electricity generation from different sources and their consumption by sector.

Figure 3.18. Sri Lanka's Electricity Generation by Sector, 2010–2020

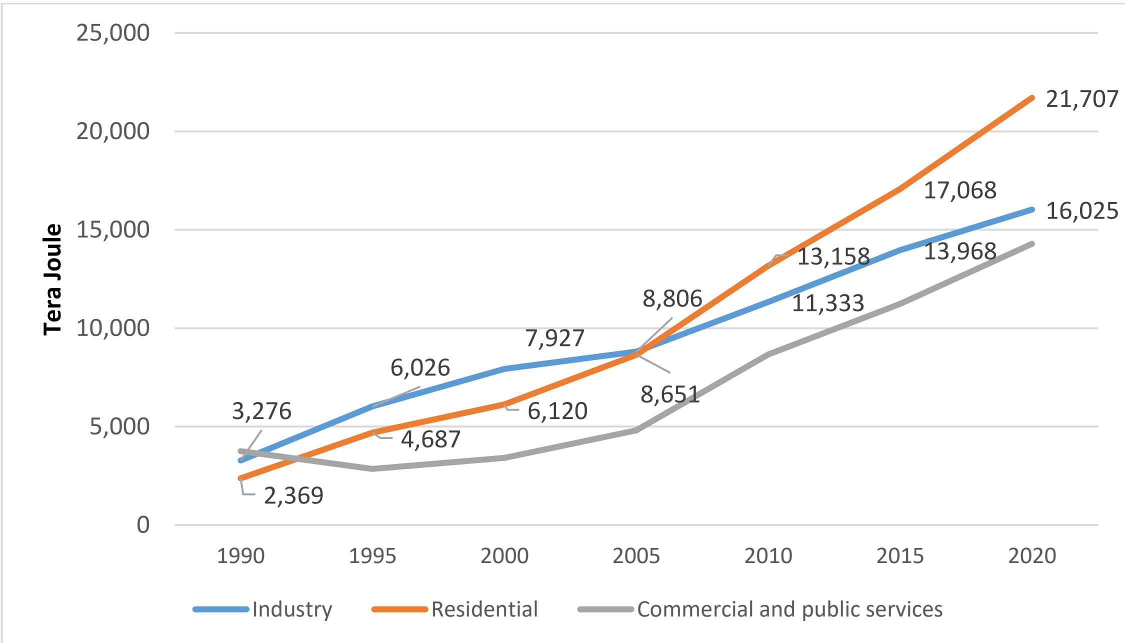


FF = Fossil fuels, Nuc = Nuclear, RE = Renewable energy sources.

Source: International Energy Agency, 2022.

In Figure 3.18, it is observed that the major source of electricity in the country is from non-renewable fossil fuel (almost 63%) and the remaining 37% comes from renewable sources.

Figure 3.19. Sri Lanka's Electricity Consumption by Sector, 1990–2020



Source: International Energy Agency, 2022.

The residential sector is the largest consumer of electricity, with over 40% share in the total electricity consumption in 2020. It is followed by the industry sector at over 30% and the commercial sector at around 25%. The graph shows an increase in electrification spill-over across all sectors and a steady transition toward electricity utilisation across space and time.

2. Energy Transition in the South Asia Region

The World Bank's South Asia Regional Electricity Markets (SAREM) programme is progressively strengthening inter-country transmission connectivity, supporting energy markets, and better aligning legislative and regulatory frameworks to enable greater electricity trade across South Asia. South Asia's electricity grids of India, Bhutan, Bangladesh, Nepal, and Sri Lanka are separated by limited physical interconnections and separate governing structures. While India, Bhutan, Nepal, and Bangladesh are physically interconnected, the degree to which they trade electricity is limited. An evolving electricity market in India along with a shift toward renewable energy generation could increase the opportunities for cross-border trade in the region. Additionally, the growth of renewable energy in India and Sri Lanka exposes some benefits to the interconnection of the grids between these countries, which may not have existed in the past.

Northeast India is a vital link to Bangladesh, Bhutan, and Nepal. Thus, energy trade between India and Southeast Asia, using India's Northeast region, could be a feasible option for all South Asia (Anbumozhi, Kutani, and Lama, 2019). Alama et al. (2018) suggest that Bangladesh, Bhutan, India (northeast), and Nepal (Bhutan–Bangladesh–India–Nepal) must engage in facilitating oil and gas exploration and processing in Northeast India and Bangladesh through Chittagong seaport as their energy hub for cross-border energy trading. Furthermore, the current power grid locations in South Asia imply a large potential for power exchange/trade across neighbouring country borders. An interconnected grid across the South Asian region can be a crucial facilitator for power generation infrastructure, as well as the development of cross-border electricity trade (UNESCAP, 2018). Due to India's central location and economic size (as an importer, exporter, or transit country), it can play a very important role in these potential power exchange dynamics in South Asia. Moreover, India's geographic location also facilitates cross-border energy trade even with Southeast Asia and can benefit both regions (Anbumozhi, Kutani, and Lama, et al., 2019). India already has a power exchange (export) network with Myanmar and regular power exchange takes place through an agreement. As of now, there is significant progress in bilateral interconnection and power trade among Bangladesh, Bhutan, India, and Nepal. An interconnected power transmission network was already developed among these countries to trade hydropower from Nepal and Bhutan to India and Bangladesh. While interconnection between India and Sri Lanka is still at the feasibility stage, the interconnection between India and Pakistan is stagnant. Other than renewable energy trade, a cross-border pipeline for natural gas has huge potential in the South Asian region. Regional cooperation in developing an integrated pipeline system for importing natural gas to South Asia will not only meet the demand for natural gas in households and electricity generation but also be of great help in the transition of the transport and industry sectors. Such interconnected works are also progressing in Southeast Asia (Kutani and Li, 2014). It is observed that Bhutan, Sri Lanka, and Nepal have enormous potential in hydropower that can also be exported after meeting domestic requirements.

2.1. Potential of Renewable Energy Trade in South Asia

Though all South Asian countries have huge potential for renewable energy generation, their focus on resources varies. However, focusing on renewable energy at the country level has various challenges, including import dependency on renewable energy manufacturing, ensuring grid stability and power quality, and cost reduction through scaling up of generation. Another important challenge is efficient utilisation of renewable energy generation, without much application of energy storage, which makes the overall generation cost significantly high. Moreover, financing of renewable energy transition and related socio-economic issues also poses severe challenges. Renewable energy trade, being a potential alternative strategy to most of challenges above, provides an opportunity for intra- and inter-regional trade within and across the regions.

Relatively large-scale renewable energy generation can ensure a lower cost of production (economies of scale) but has the issue of proper utilisation of supply. Export to neighbouring countries (assuming there is a demand for it) through a grid network will address the challenge of integrating expensive energy storage and marketability/proper utilisation of generation. Moreover, when a country is importing renewable energy, it helps to not only reduce domestic use of fossil fuel, but also to save on the import of renewable energy manufacturing (like solar module/energy storage). India's model of 'One Nation One Grid One Frequency' as a part of the National Electricity Policy aims for equity-based transmission of electricity across the entire country while minimising infrastructure damage and creating demand-supply matching the electricity market. Moreover, a similar type of grid network and power exchange mechanism can be extended to the Far East through Myanmar and the Far West through Oman.

Rather than the national-level renewable energy targets, meeting the regional renewable energy goal is relatively easy if regional trade in renewable energy can be ensured. The renewable energy trade potential in South Asia is high because of the complementarity in renewable energy resource and demand patterns. For example, in terms of the abundance, Bhutan and Nepal have huge hydro potential while India has solar and wind potential. On the other hand, in terms of demand complementarity, power/energy demand is relatively low in India during winter but relatively high in Nepal and Bhutan. By contrast, demand peaks in summer in India, while it is the opposite scenario in Bhutan and Nepal. During winter, hydropower production is less owing to water resources freezing in hilly areas of Nepal and Bhutan. But the demand for electricity is higher owing to heating requirements. This forces the two countries to become electricity importers in the winter season and exporters in the summer season. Connecting different types of renewable energy (solar and wind with hydro) in the grid will also address the stability of the grid issue to a large extent.

Table 3.1 shows that Bhutan, Nepal, and India import and export electricity to their neighbouring countries while Bangladesh, Pakistan, and Afghanistan are net importers of electricity. Due to the large geographical size and the varied topography of India, there is a significant demand-supply gap across various regions in the country. Rather than arranging electricity from other regions of the country, it is more economical to trade with neighbouring countries to meet the demand-supply gap. On the other hand, Sri Lanka and Maldives have been unable to trade electricity to date owing to a lack of physical connectivity.

Table 3.1. Export and Import of Electricity in South Asian Countries, 2010–2021

(Billion kWh)

Country		2010	2015	2016	2017	2018	2019	2020	2021
Afghanistan	Import	1.57	3.78	4.33	4.61	4.99	4.91	5.15	5.40
	Export	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Bangladesh	Import	0.00	3.38	3.82	4.66	4.78	6.79	6.67	6.60
	Export	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Bhutan	Import	0.13	0.13	0.09	0.09	0.13	0.10	0.10	0.10
	Export	5.58	5.72	5.76	5.70	4.58	6.15	6.00	5.30
India	Import	5.61	5.24	5.62	5.07	4.40	6.35	9.32	7.40
	Export	0.06	5.15	6.71	7.20	8.49	9.49	9.43	9.30
Nepal	Import	0.69	1.78	2.18	2.58	2.81	1.73	2.83	2.80
	Export	0.03	0.00	0.00	0.00	0.04	0.11	0.04	0.06
Pakistan	Import	0.27	0.46	0.50	0.56	0.49	0.51	0.51	0.50
	Export	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Source: Energy Information Administration, 2022.

India has already established grid connectivity and power exchange mechanisms with Bhutan, Bangladesh, and Nepal (BBIN network) in South Asia and Myanmar in Southeast Asia on a bilateral basis.[2] While Bhutan, India, and Nepal export and import electricity as per the domestic demand-supply gap, Bangladesh and Myanmar only import electricity. Due to energy shortages, electricity import from India is an effective strategy for Bangladesh to meet its increasing demand. As per Table 3.2, India's net import from Bhutan was 9,318 MU in 2020–21 while net exports to Bangladesh and Nepal were 7,552 MU and 1,865 MU, respectively. Compared to 2020–21, the net import in 2021–22 from Bhutan has reduced to 7,597 MU while net export to Bangladesh has declined to 7,302 MU and to Nepal has increased to 1,921 MU. In January and February 2022, India exported 62 MU and 52 MU of electricity to Bhutan (as indicated in Figure 3.20 and in all other months, imported from Bhutan. Similarly, from September to November 2021, India imported from Nepal while in all other months, it exported electricity to Nepal. This relative demand–supply complementarity creates huge renewable energy trade potential in South Asia. Moreover, Bangladesh made an agreement

[2] Details of the electricity trade within BBIN network are referred to in Annex 2.

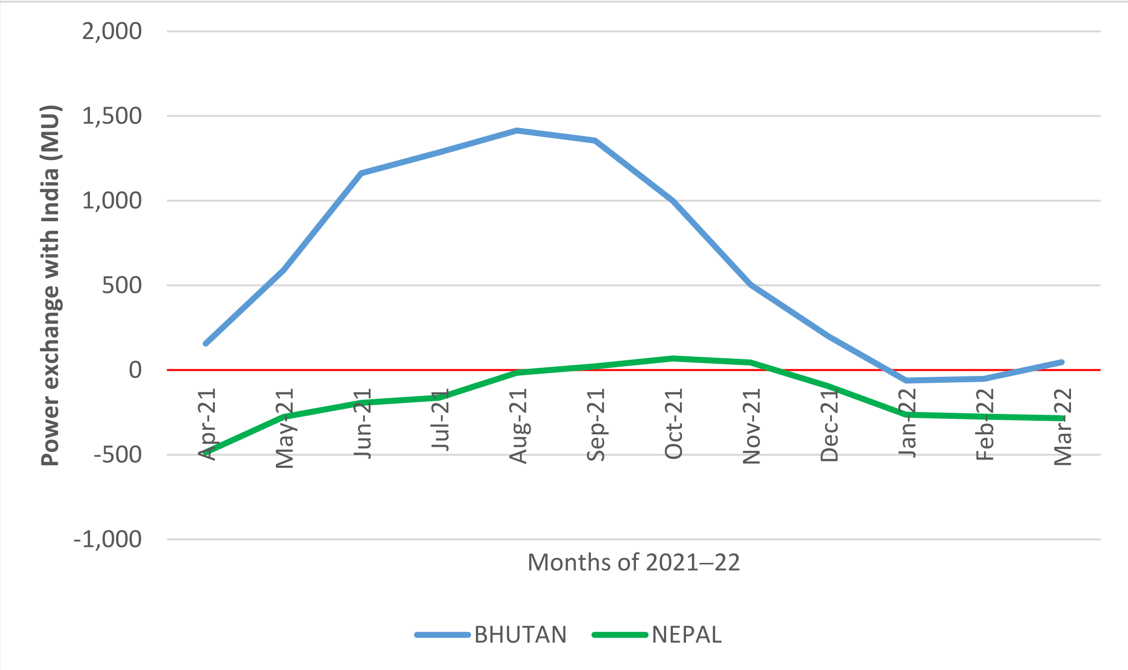
with Nepal for power exchange through India. However, to make the renewable energy trade more effective and efficient, it needs to go beyond a bilateral basis to a multilateral agreement.

Table 3.2. Existing Trade in Electricity with India in Bangladesh, Bhutan, and Nepal
(MU)

Year	Bhutan	Nepal	Bangladesh
2017–18	5,611.1	–2,389.0	–4,808.8
2018–19	4,657.1	–2,798.8	–5,690.3
2019–20	6,310.7	–2,373.1	–6,987.9
2020–21	9,318.2	–1,865.1	–7,552.0
2021–22	7,596.7	–1,921.1	–7,301.7

Source: Power System Operation Corporation Limited (POSOCO) monthly reports, 2017–18 to 2021–22.

Figure 3.20. India's Monthly Power Exchange with Bhutan and Nepal



Source: Power System Operation Corporation Limited (POSOCO) Monthly Reports, 2021–22.

As per Table 3.3, India wants to upgrade its inter-country cross-border electricity network from the existing 4,233 MW to 8,253 MW to facilitate more power exchange with neighbouring countries. Other than the network development plan, India also has plans for various high-capacity (400 kV and 765 kV) cross-border interconnections, which are in the planning and implementation stage.

Table 3.3. Cross-border Network Development Plan of India with Neighbours

Between countries	Present capacity	Future capacity
India–Bhutan	2,070	4,290
India–Bangladesh	1,160	1,160
India–Nepal	1,000	2,800
Total (incl. India–Myanmar)	4,233	8,253

Source: Ministry of Power Annual Report (2021–2022), 2022.

Based on the above analysis, we found that there is demand and supply complementarity across the countries in South Asia that is consistent with the variability and seasonality of renewable energy generation in the region. Thus, the null hypothesis (A H0) proposed in Chapter 2 corresponding to research Question 1 can be accepted and we can conclude that there is huge potential for renewable energy trade and cooperation in South Asia.

Chapter 4

Key Barriers and Enablers

1. Trade Barriers

Regionalism is defined as inter-governmental cooperation to attain common interests through socialisation and institutionalisation (Sridharan, 2007). The economic growth of member countries can be enhanced through regional integration, which will facilitate trade, technology, and investment prospects, as well as increase opportunities and scope for economic development and welfare gains (Javed, 2019). Examples of regional trade agreements include the North American Free Trade Agreement, Central American-Dominican Republic Free Trade Agreement, the European Union, and Asia-Pacific Economic Cooperation.

South Asia is often described as the world's least-integrated sub-region. Intra-regional merchandise trade in South Asia is less than one-third of its potential. It was at $26.8 billion in 2014 against a potential of $81.2 billion, as estimated by the UNESCAP South Asia Gravity Model (2017). Moreover, the intra-regional trade share in total merchandise trade of South Asian economies is merely about 5% as compared to more than 20% of Southeast Asia (UNESCAP, 2017). The potential of intra-regional trade in services, as well as investments, also remains untapped. Due to insufficient domestic reserves, intra-regional trade in fossil fuel also remains negligible. However, the focus on non-fossil fuel energy sources has opened intra-regional trade potential due to the complementarity in demand and supply.

Therefore, South Asia has significant potential for improvement in terms of renewable energy trade integration. Countries such as Bangladesh, Bhutan, Nepal, and Sri Lanka are yet to achieve their bilateral renewable energy trade potential, while there is great scope of improving the trade within the region.

Due to obstacles to regional cooperation, countries are rather more interested in bilateral cooperation than regional cooperation. The air trade corridor between India and Afghanistan is a classic example of bilateral cooperation in South Asia, which was not otherwise possible in regional cooperation where Pakistan is involved. Huda (2016) found that cooperation is held back by security issues, concerns about relative gains, and mistrust, along with a lack of communication and problematic implementation.

South Asian countries have established several institutional frameworks for developing regional economic integration, such as South Asian Association for Regional Cooperation (SAARC), as well as the South Asia Free Trade Agreement (SAFTA), to enhance the volume of trade. SAFTA was signed on 6 January 2004 at the 12th SAARC Summit and came into force on 1 January 2006.

SAFTA is driven by the principles of the World Trade Organization, espousing reciprocity, and awareness of the needs of least-developed SAFTA countries (Bangladesh, Nepal, Bhutan, and

Maldives) (Maqbool, Chattha, and Azeem, 2007). The agreement also targets the elimination of tariffs, para-tariffs, and non-tariff barriers (USAID, 2005). Studies by Srinivasan and Canonero (1995) and Srinivasan (1994) also indicate that, although there can be substantial potential gains from regional trade liberalisation, these gains are larger for smaller economies. Srinivasan also argues that gains for South Asia are substantial when dealing with other collective regional arrangements rather than the individual establishment.

However, SAFTA has only been a limited success and has been hampered by its narrow scope. Because of the narrow export base of these countries, there has been more competition than cooperation in this region and, thus, very low complementarity. The SAARC-envisioned progressive trade liberalisation programme has not been sufficient to ensure the full implementation of the SAFTA, due to the existence of non-tariff barriers, while SAARC's focus has remained tariff reduction alone.

Furthermore, the trade liberalisation objectives of SAARC are not achieved due to the slow finalisation of schedules of specific commitments in South Asia. Banik and Bhaumik (2014) pointed out that, due to high barriers to trade, including domestic regulations, mainly services trade is occurring informally. Various obstacles in the form of exorbitant transportation costs and a dearth of regional transit trade agreements and cross-border infrastructure are also adversely affecting the volume of trade for goods and services in the South Asian region (Manzoor et al., 2019). Jayaram (2016) comments on the negligible impact of SAFTA on the various trade barriers in the region, which are largely driven by political and social issues.

Trade and regional economic integration can provide critical and transformative support in terms of sustainable development. It can also improve economic and social welfare. While economic cooperation and integration at the sub-regional level have worked as a powerful tool in empowering neighbourhoods in many parts of the world, the South Asia sub-region has lagged in harnessing its full potential due to the discussed barriers and challenges. Therefore, the region continues to underperform in poverty reduction and other indicators of development.

1.1. Trade Barriers to Electricity/Renewable Energy

Trade in electricity can be considered as trade in renewable energy if the entire generation of power is from renewable energy sources. Trade in renewable energy (considered to be trade in services), which cannot be stored for a long time and has severe fluctuations in generation patterns across time and season has a somewhat different nature (compared to conventional trade in products). The absence of suitable infrastructure is one of the most important challenges for trade in electricity. Proper network connectivity needs to be ensured for electricity trade. Trade in electricity is only possible when there is an exportable surplus after meeting domestic demand. To increase exportable electricity, the technology needs to be upgraded, which can enable higher generation capacity as well as proper demand management (to meet domestic demand through the surplus generation and better export surplus). Generation capacity can be arranged if technology and financing are available, but in the case of South Asian countries, there is a lack of indigenous manufacturing capacity in renewable energy generation. Solar panels, windmills, and their components along with energy storage need to be imported primarily from China. India has taken various initiatives (e.g.

regulatory and financial incentives including loans, grants, tax rebates, and usage of biogas recovery systems other than production-linked incentives) to develop indigenous renewable energy manufacturing capacity. But the raw material (rare earth material) required for renewable energy manufacturing is not available domestically; rather, the international market is monopolised by China.

Transmission and distribution (T&D) loss is also another challenge for such infrastructure development to facilitate renewable energy trade. T&D loss in South Asian countries is relatively high (as indicated in Table 4.1) compared to the global standard.

Table 4.1. T&D Loss in South Asian Countries, 2010–2021

(% of Generation)

Country	2010	2015	2016	2017	2018	2019	2020	2021
Afghanistan	32.47	44.12	48.57	48.65	54.94	62.46	82.99	80.81
Bangladesh	11.24	19.27	16.23	16.56	17.26	11.99	12.45	11.67
Bhutan	0.26	0.86	3.37	0.76	2.68	5.88	5.88	5.55
India	21.23	18.05	17.65	17.41	17.03	16.75	15.97	15.10
Maldives	0.00	0.00	0.00	3.23	3.32	3.29	3.57	3.40
Nepal	34.60	38.02	33.95	30.60	22.39	18.91	24.15	26.16
Pakistan	16.21	15.32	19.07	16.04	11.99	12.78	13.15	11.99
Sri Lanka	14.24	7.27	7.28	5.63	9.41	8.64	9.60	9.17

T&D = transmission and distribution.

Source: Energy Information Administration, 2022.

Dense forests exist between India and Bhutan/Nepal and deep sea between India and Sri Lanka/Maldives, making a connectivity network a real challenge for effective renewable energy trade between these countries. Even if the technology is available, the network needs to be cost-effective and eco-friendly.

Political issues also hinder renewable energy trade. For example, it is difficult for India to import power from Nepal or Bhutan as part of a renewable energy plan if it is developed by China. Moreover, the sovereignty of natural resources (such as land and water) is also an issue; for example, River Brahmaputra water-sharing issues between India and China impede the construction of hydropower projects.

Different countries have their own norms and regulations for renewable energy generation and distribution. The absence of a common protocol also poses challenges to effective multilateral renewable energy trade. Without such a protocol, it is beneficial for the countries to engage in bilateral agreements instead of having a multilateral arrangement, even though that could be more beneficial.

Moreover, trade in renewable energy has its own challenges like generation variability (across time and season) and frequency variability, which can have a severe impact on grid stability. Trade in renewable energy, if based on single/limited renewable energy sources, cannot be sustainable.

Although the South Asian region is endowed with various renewable energy sources, cross-border investment and cooperation in renewable energy trade still lag. Based on the above paragraphs, the barriers to renewable energy trade in South Asia can be briefly categorised as follows:

Economic barriers

- High front-end capital and project development costs per kW of installed electricity generating capacity, although the operation and maintenance costs are low.
- Higher cost of investment in renewable energy projects compared to conventional energy projects.
- Longer payback period and a lower rate of return in initial phases.
- Lack of cost-reflective pricing with a regional disparity in generation capacity and lower operational efficiency.
- Limited involvement of the private sector.

Technical and capability barriers

- Discrete and non-integrated supply chain for energy and energy-based services.
- Lack of flexibility in renewable energy knowledge and technology transfer in the region that would require well-defined area-specific protocols and agreements.
- In the initial phases, the knowledge of specific skills, technicality, and cost-effective operations far outweigh the benefits of first mover advantage.
- Lack of sufficient infrastructure (insufficient grid network and high T&D loss) to enhance renewable energy electricity trade across countries within the region.

Financial barriers

- Lack of sustainable mechanism for subsidy in the context of investment in cross-border renewable energy projects.
- Lack of flexibility in finance by commercial banks and international organisations, even though there has been a recent rise in different financial initiatives by the World Bank, ADB, and national governments.

Regulatory, legal, and institutional barriers

- Lack of proper regulation in the planning, execution, and operation of renewable energy projects.
- Under-utilisation of the positive externalities arising out of varied natural regional advantages such as rough terrain, proximity to coasts and tides, and offshore-onshore mix of generation opportunities.
- Information barriers in renewable energy services and generation.

2. Enablers for Renewable Energy Trade in South Asia

Although the South Asian region is unique in its energy resource diversity, renewable energy trade and cooperation are still limited to some inter-governmental bilateral negotiations. Proper political will and indigenous involvement are required to extend the spill-over benefits over the region and move forward from a bilateral to a multilateral arrangement. The key enablers in the current situation can be identified as follows:

- The geography of South Asia's power grids offers many power connection opportunities at border interfaces, with India as the centre of many power exchange opportunities as an energy supplier, exporter, or transit country (ESCAP APEF, 2018).
- Regional renewable energy trade through a common pool of power with diversified renewable energy sources can help to reduce the risk of grid instability arising out of variable generation patterns.
- An integrated regional power market with quality renewable energy supply availability and trade infrastructure can enable cooperation in the region (Chen, 2022). For example, energy cooperation is the main focus of South Asia Sub-Regional Economic Cooperation (SASEC).
- Significant complementarity in renewable energy supply potential and demand pattern for the region.
- Facilitating a decentralised structure of regional grids (the US model of energy cooperation) rather than a centralised one (the EU model of energy cooperation) as it would allow individual countries to maintain their control over respective grids (isolation in the case of emergencies) while enhancing higher coordination and information sharing for renewable energy trade and cooperation (S&P Global, 2021).
- Improving investment environment and ease of doing business for the private sector for both renewable energy generation and transmission by flexible approval and regulation.
- Harmonising legal and regulatory frameworks for cross-border renewable energy transfer and transaction along with the possibility of a Renewable Energy Charter Treaty for the region.
- Individual commitments toward climate change and decarbonisation targets can enable renewable energy cooperation across the region while facilitating surplus renewable energy export to other countries.
- Because of diversified renewable energy resource endowments, national investment in renewable energy infrastructure becomes expensive in some countries and environmental commitment can be alternatively fulfilled by imports from neighbouring countries.
- Counterintuitively, global oil price shocks can also act as the key enabler of renewable energy trade and regional cooperation for energy security requirements.
- The 'One Sun One World One Grid' (OSOWOG) initiative of India to develop trans-national grid across the globe to transport solar power to different load centres all over the world, can also enable regional renewable energy trade. While another Indian initiative, 'One Nation One Grid One Frequency', integrates grids within the country, OSOWOG envisages to integrate grids across the countries.

The detailed discussion on barriers and enablers of renewable energy trade in South Asia based on literature review and stakeholder consultation suggests that, due to a lack of mutual trust in the region, the countries are mostly engaged in bilateral agreements for renewable energy/energy cooperation. However, factors such as lack of proper infrastructure and unutilised renewable energy potential can also act as important barriers. Thus, the null hypothesis B1 H0 proposed in Chapter 2 can be partially accepted. This helps the study to conclude that ensuring political trust is necessary but not sufficient for effective regional renewable energy trade and cooperation. Even in the presence of mutual trust, without a proper arrangement of infrastructure, cross-border renewable energy trade and cooperation cannot be enhanced. On the other hand, the presence of complementarity in electricity demand and the source of renewable energy supply are not the only important enablers for regional renewable energy trade and cooperation. Additional factors such as national climate commitment and secure sustainable energy supply resistant to global geo-political shock can also play an important role as an enabler for the global renewable energy trade and cooperation. Thus, the null hypothesis (B2 H0) corresponding to research Question 2 can be accepted because the demand–supply complementarity cannot be completely substituted by the premise of national climate commitment.

Chapter 5

Regional and Country Benefits

1. Impact of Renewable Energy Trade at National and Regional Levels

On the basis of the existing bilateral electricity trade agreements within the BBIN network, the study has the following propositions:

(1) The impact of bilateral trade on trading partners and other neighbouring countries in the region when there is:
   a. change in electricity trade only; and
   b. change in electricity trade backed by technology improvement in the exporting country. This is a very important proposition because when we propose a change in electricity trade from an exporting to an importing country, it requires an increase in exportable electricity in the exporting country, which can be ensured only through technology improvement. Exportable electricity can be enhanced through demand-side management (including efficient end-use applications) and supply augmentation with additional capacity development and generation plan. However, a reduction in T&D loss, which is relatively high in South Asian countries, can also be a strategy to increase exportable electricity. All these measures are necessary for the enhancement of exportable electricity through technology improvement.

(2) Study the impact of multilateral trade on trading partners and the entire region.

Given the existing capacity and demand-supply scenario (in terms of mutual complementarity in renewable energy source potential and demand variability), bilateral electricity trade is already in place for India with Bhutan, Bangladesh, and Nepal. While Bangladesh is only an importing country, Bhutan and Nepal export and import electricity with India as per the demand-supply gap. Based on this, the following cases were analysed to estimate the impact of bilateral trade in terms of GDP and welfare (a more normative measure and defined as 'utility from GDP').

A. Bhutan to India
B. Nepal to India
C. India to Nepal
D. India to Bhutan
E. India to Bangladesh
F. Nepal to Bangladesh
G. Bhutan to Bangladesh

On the basis of India's One Sun One World One Grid initiative and recent developments, the following cases were also analysed:

H. India to Sri Lanka

Another case study was also analysed based on expert consultation conducted during the course of study (2021–22):

I. Pakistan to Afghanistan

The impact (in terms of GDP and welfare) of Bhutan to India electricity trade on Bhutanese and Indian economies (based on GTAP analysis) is as follows:

1.1. Case 1: Electricity Export from Bhutan to India: Without any technology change

Table 5.1. Bilateral Electricity Trade Benefits (GDP and Welfare) from Bhutan to India Electricity Trade

(million US$)

Country	Change in Welfare			Change in GDP		
	5%	10%	20%	5%	10%	20%
Bhutan	8.66	18.5	41.77	4.68	10	22.55
Sri Lanka	0.05	0.12	0.27	0.02	0.03	0.06
Pakistan	0.44	0.93	2.11	0.08	0.17	0.38
Nepal	–0.27	–0.57	–1.25	–0.06	–0.14	–0.3
India	3.74	8.07	18.69	3.5	7.63	17.63
Bangladesh	–0.01	–0.02	–0.04	0	0.02	0.03

GDP = gross domestic product.

Note: Due to data limitation, except for Pakistan–Afghanistan trade, 'Rest of South Asia' (which includes Afghanistan, Bhutan, and Maldives) includes Bhutan only in all other bilateral/multilateral cases.

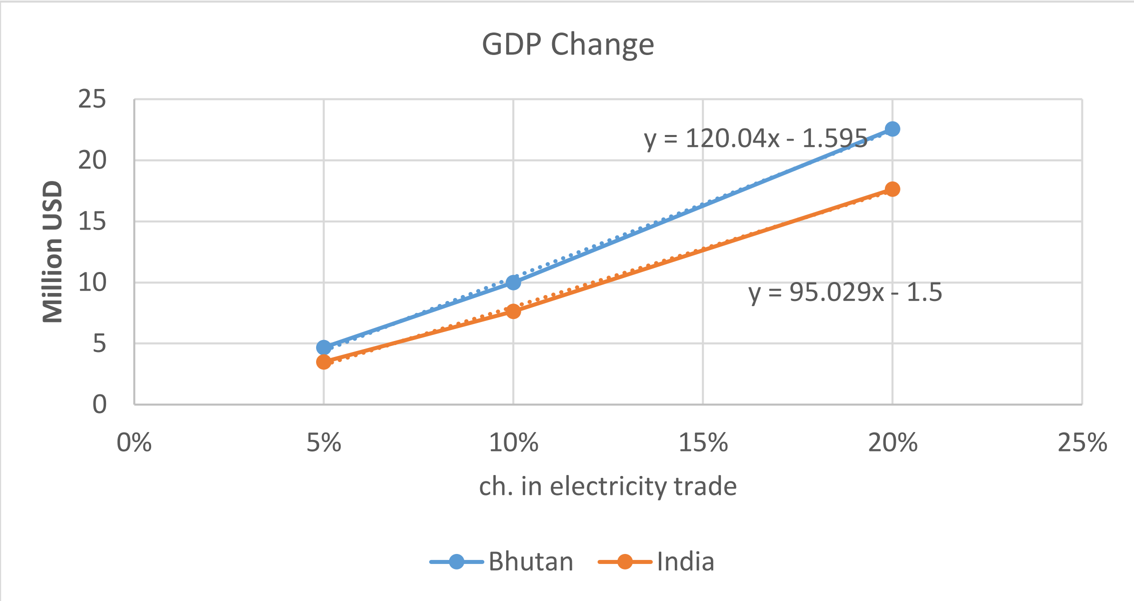
Source: TERI Estimations, 2022.

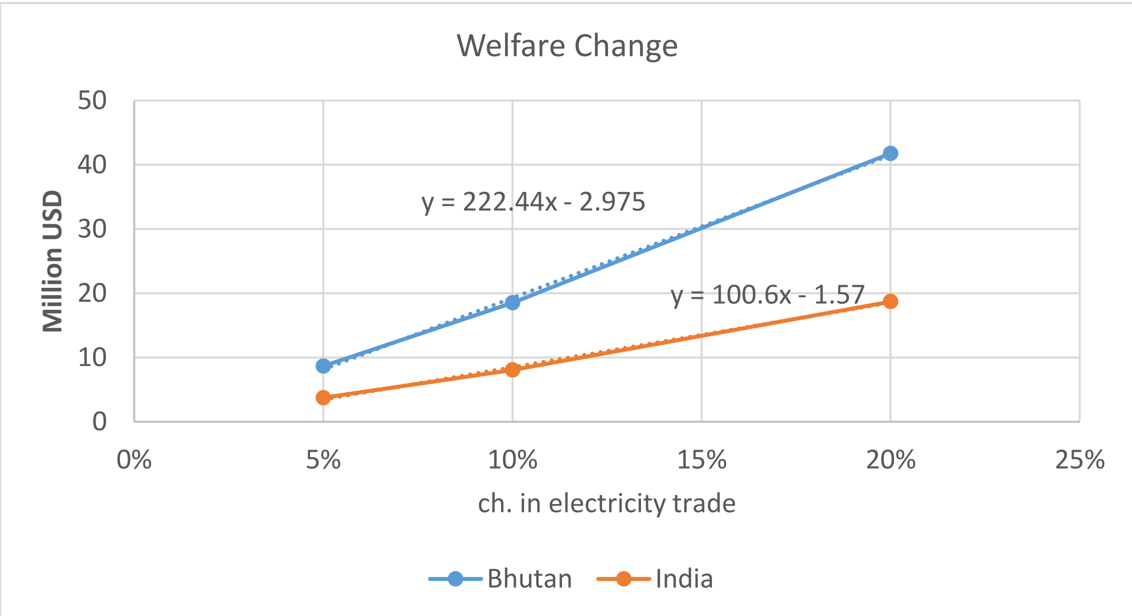
As indicated in Table 5.1, if electricity exports from Bhutan to India increased by 5% (over the existing trade level), the GDP in Bhutan and India will be $4.68 million and $3.5 million, respectively. Thus, bilateral electricity trade from Bhutan to India will have a positive impact on the GDP of both trading partners but it will be relatively higher for the exporting country. Similarly, the welfare of both trading partners will increase as a result of an increase in electricity trade with relatively higher benefits for the exporting country. This bilateral electricity trade agreement may have some adverse impact on the neighbouring partners who are already/potential trading partners with either/both of them.

If electricity trade from Bhutan to India increased by 10%, we can see that the scale of positive impact (for both GDP and welfare) is relatively higher (more than doubled) for both the trading partners, while the relative gain for the exporting country is even more. In the case of a 20% increase in existing electricity trade, the scale of impact is even higher for both the trading partners and for both GDP and welfare.

Grounded on the above concept of the potential growth path of bilateral trade in electricity, this study has developed a trade benefit trajectory based on the change in bilateral electricity trade. This trajectory (Figure 5.1) will help to measure the expected level of change in benefits (doubling/tripling or many-fold increase) from enhanced potential trade in electricity.

Figure 5.1. Trajectory of Trade Benefits for Bhutan and India Based on Bhutan to India Electricity Trade. (a) GDP and (B) Welfare





GDP = gross domestic product.

Source: TERI Estimations, 2022.

1.2. Case 2: Electricity Export from Bhutan to India: With Technology Upgradation in Bhutan

Table 5.2. Benefits (GDP and Welfare) from Bilateral Electricity from Bhutan to India

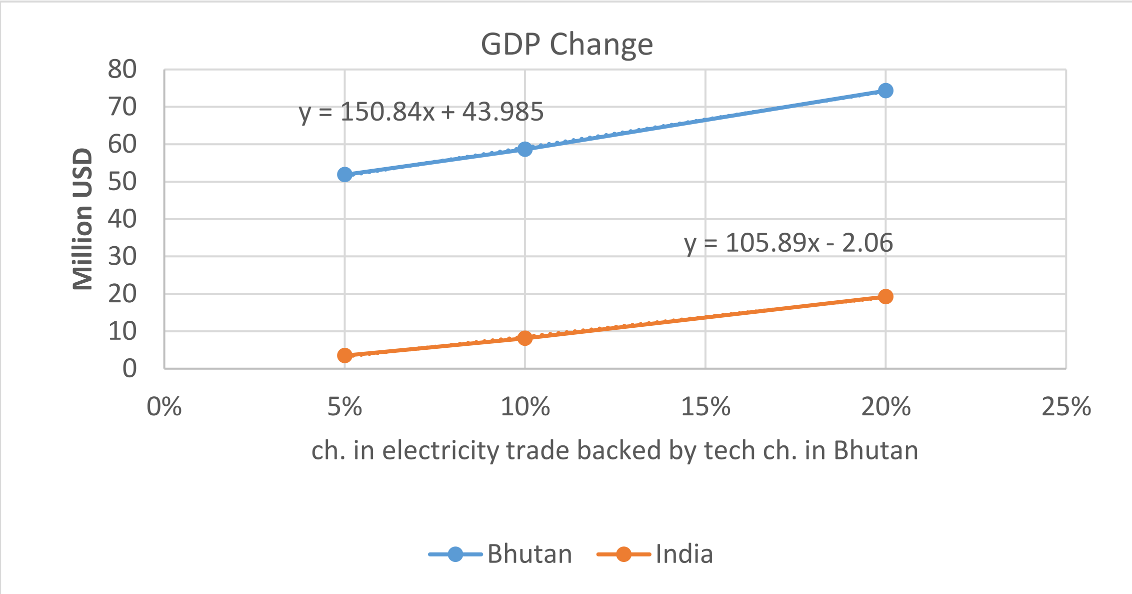
Country	Change in Welfare				Change in GDP		
	5%	**10%**	**20%**		**5%**	**10%**	**20%**
Bhutan	68.8	80.55	107.95		51.84	58.6	74.31
Sri Lanka	0.27	0.35	0.53		0.06	0.09	0.13
Pakistan	3.15	3.75	5.15		0.41	0.52	0.77
Nepal	–0.13	–0.47	–1.25		–0.06	–0.15	–0.33
India	8.17	13.47	26.35		3.5	8.13	19.25
Bangladesh	–0.07	–0.08	–0.11		–1.08	–1.08	–1.05

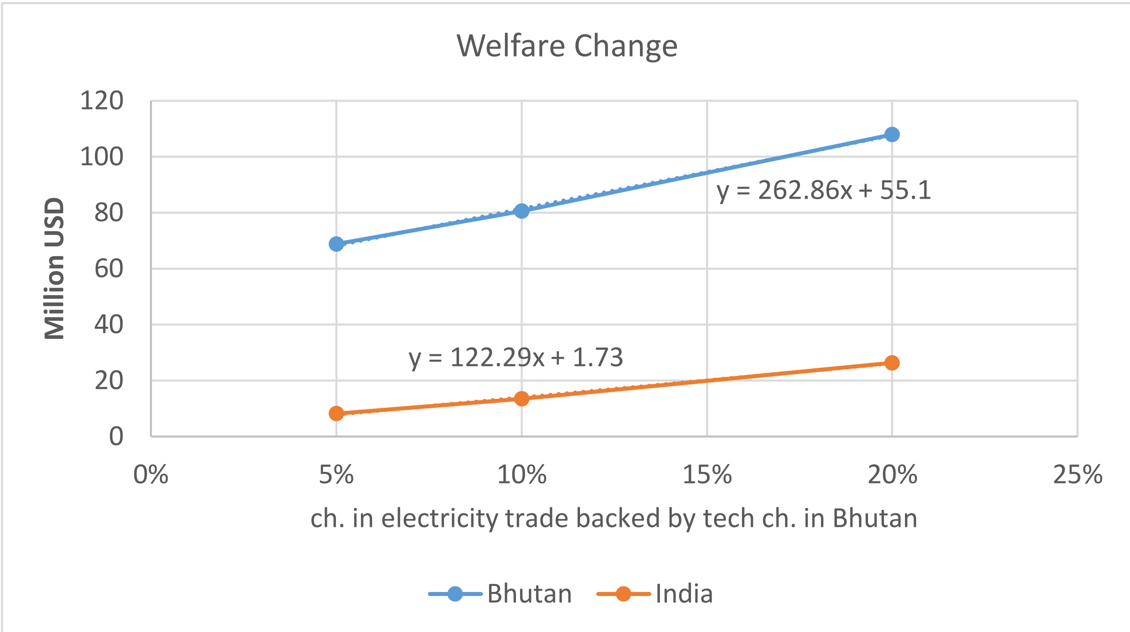
GDP = gross domestic product.
Source: TERI Estimations, 2022.

Table 5.2 indicates that when existing electricity exports from Bhutan to India increase by 5% accompanied by relevant technology improvement (required to ensure a 5% increase in exportable electricity) in Bhutan, both Bhutan and India benefit, with relatively higher benefits for Bhutan (exporting country) in terms of both GDP and welfare. Moreover, the level of benefits in this case (increase in export backed by technology improvement in the exporting country) is comparatively higher than the potential benefits from a 5% increase in the export of electricity only.

These features remain true for a 10% and 20% increase in export also. However, when the study prepares the benefit trajectory (as indicated in Figure 5.2) from an increase in electricity trade with technology upgradation in the exporting country, it reveals that, while the level of benefits is higher, changing the scale (from 5% to 10% or 10% to 20% or similar change) will flatten compared to benefit trajectory of increase in trade only.

Figure 5.2. Trajectory of Trade Benefits for Bhutan and India from Bhutan to India Electricity Trade Backed by Technology Upgradation in Bhutan: (a) GDP and (b) Welfare





GDP = gross domestic product.

Source: TERI Estimations, 2022.

Similar analyses were done for all the above bilateral trade possibilities (Case B to Case I) and the detailed results are provided in the Annex.

1.3. Case 3: Electricity Export from India to Bhutan: Without Any Technology Change

Table 5.3. Benefits (GDP and Welfare) from Bilateral Electricity from India to Bhutan

	Country	Change in Welfare			Change in GDP		
		5%	10%	20%	5%	10%	20%
Change in Electricity	Bhutan	0.38	0.82	1.93	0.18	0.64	1.09
	Sri Lanka	0	–0.01	–0.01	0	0	0
	Pakistan	–0.02	–0.03	–0.08	0	–0.02	–0.05
	Nepal	0	–0.01	–0.01	0	0	0
	India	0.32	0.68	1.58	0.21	0.49	1.18
	Bangladesh	0	–0.01	–0.01	0	0	0
	Rest of World	–0.57	–1.23	–2.87	0	0	0

GDP = gross domestic product.
Source: TERI Estimations, 2022.

As indicated in Table 5.3, if electricity exported from India to Bhutan increases by 5% (over the existing trade level), the change in GDP of India and Bhutan will be $0.21 million and $0.18 million, respectively. Thus, bilateral electricity trade from India to Bhutan will have a positive impact on the GDP of both trading partners, with higher relative benefits for the exporting country. Similarly, the welfare of both trading partners will increase as a result of an increase in electricity trade. As mentioned previously, Bhutan's electricity generation almost entirely depends on hydropower, which reduces during the winter season. Due to a lack of generation diversity, Bhutan primarily imports electricity from India during this period. Without importing power, Bhutan will be unable to manage its economic activity during this time. Thus, the increase in India's electricity export to Bhutan (which is entirely during the winter) results in relatively higher utility for Bhutan. This enhanced bilateral electricity trade may have some adverse impact on neighbouring countries due to their potential electricity trade relationship with either of these two trading partners.

When the existing electricity trade from India to Bhutan increases by 10%, we can see from Table 5.3 that the scale of positive impact (for both GDP and welfare) is comparatively higher for both the trading partners and the relative gain for the exporting country is even more. Similarly, in the case of a 20% increase in the existing electricity trade, the scale of impact is even higher for both partners in terms of GDP and welfare.

1.4. Case 4: Electricity Export from India to Bhutan: With Technology Upgradation in India

Table 5.4. Benefits (GDP and Welfare) from Bilateral Electricity from India to Bhutan Backed by Technology Upgradation

Change in Electricity with Technology Improvement in Exporting Country	Country	Change in Welfare 5%	Change in Welfare 10%	Change in Welfare 20%	Change in GDP 5%	Change in GDP 10%	Change in GDP 20%
	Bhutan	0.37	0.82	1.93	0.21	0.45	1.07
	Sri Lanka	–0.01	–0.01	–0.02	0	0	–0.01
	Pakistan	–0.01	–0.03	–0.07	0	–0.02	–0.05
	Nepal	0	0	–0.01	0	0	0
	India	13.22	13.59	14.48	11.38	11.49	11.62
	Bangladesh	–0.01	–0.01	–0.02	0	0	–0.02
	Rest of World	–2.48	–3.14	–4.78	0	0	0

GDP = gross domestic product.
Source: TERI Estimations, 2022.

Table 5.4 indicates that when the existing electricity export from India to Bhutan is increased by 5% accompanied by relevant technology improvement in India, benefits are positive for both Bhutan and India, with relatively higher benefits for India (exporting country) in terms of GDP and welfare. Even if electricity export leads to economic benefits, due to infrastructural bottlenecks, the exporting country may not have sufficient exportable surplus of electricity. Hence, technology upgradation is essential for an exporting country so that it can produce surplus electricity.

Moreover, the level of benefits in this case (increase in export backed by technology improvement in the exporting country) is comparatively higher than potential benefits from the same 5% increase in the export of electricity only. Here the benefit for India is much higher compared to Bhutan because technology upgradation provides other positive externalities also in the exporting countries. Similarly, 10% and 20% increase in electricity trade in presence of technology upgradation will result in higher levels of economic benefits for the trading partners with relatively more benefits available to the exporting country (India).

1.5. Case 5: Electricity Export from India to Bangladesh: Without Any Technology Change

Table 5.5. Benefits (GDP and Welfare) from Bilateral Electricity from India to Bangladesh

	Country	Change in Welfare			Change in GDP		
		5%	10%	20%	5%	10%	20%
Change in Electricity	Bhutan	–0.45	–0.84	–1.48	–0.24	–0.46	–0.8
	Sri Lanka	–0.01	–0.03	–0.06	0	–0.01	–0.01
	Pakistan	–0.03	–0.05	–0.1	0	0	–0.02
	Nepal	–0.51	–0.95	–1.68	–0.13	–0.24	–0.42
	India	0.97	1.96	4.01	0.24	0.86	2.02
	Bangladesh	0.09	0.52	1.04	0.56	2.02	5.06
	Rest of World	–0.74	–1.61	–3.69	0	0	0

GDP = gross domestic product.
Source: TERI Estimations, 2022.

As indicated in Table 5.5, if electricity export from India to Bangladesh increases by 5% (over the existing trade level), the change in the GDP of India and Bangladesh will be $0.24 million and $0.56 million, respectively. Thus, bilateral electricity trade from India to Bangladesh will have a positive impact on the GDP of both trading partners. Similarly, the welfare of both trading partners will increase as a result of an increase in electricity trade. Bangladesh is currently struggling with a power crisis and the import of electricity from India is essential for its economic development. Due to the importance of reliable electricity import from India, the trade impact in Bangladesh is relatively high. When electricity trade between India and Bangladesh increases by 10%, it suggests that the magnitude of the positive impact (on both GDP and wellbeing) is comparably greater for both trading partners. The relative gain for the exporting country is significantly greater; and this holds true when trade increases by 20%.

1.6. Case 6: Electricity Export from India to Bangladesh: With Technology Upgradation in India

Table 5.6. Benefits (GDP and Welfare) from Bilateral Electricity from India to Bangladesh Backed by Technology Upgradation

		Change in Welfare			Change in GDP		
Change in Electricity with Technology Improvement in Exporting Country	**Country**	**5%**	**10%**	**20%**	**5%**	**10%**	**20%**
	Bhutan	–0.65	–1.05	–1.69	–0.36	–0.57	–0.92
	Sri Lanka	–0.19	–0.20	–0.23	–0.08	–0.08	–0.09
	Pakistan	0.1	0.07	0.03	0.02	0.02	0.02
	Nepal	–0.44	–0.88	–1.61	–0.1	–0.21	–0.39
	India	516.24	517.23	519.29	455.12	455.78	455.98
	Bang	0.56	0.88	1.52	4.91	9.83	20.39
	Rest of World	–76.84	–77.72	–79.81	–16	–16	–16

GDP = gross domestic product.
Source: TERI Estimations, 2022.

Table 5.6 indicates that when existing electricity export from India to Bangladesh is increased by 5% accompanied by relevant technology improvement in India, the benefits are positive for both the countries with higher benefits for India (exporting country) in terms of GDP and welfare. The level of benefits, in this case, is relatively higher than a 5% increase in the export of electricity only. Here the change in GDP and welfare for India is much higher compared to Bangladesh because of positive externality of technology improvement in India. For both a 10% and 20% increase in electricity trade, technology improvement in India results in more economic benefits for Bangladesh, with marginally higher benefits for India.

1.7. Case 7: Electricity Export from India to Sri Lanka: Without Any Technology Change

Table 5.7. Benefits (GDP and Welfare) from Bilateral Electricity from India to Sri Lanka

	Country	Change in Welfare				Change in GDP		
		5%	10%	20%		5%	10%	20%
Change in Electricity	Bhutan	0	0	0		0	0	0
	Sri Lanka	1.46	1.52	1.58		0.69	0.76	1.08
	Pakistan	0	0	0		0	0	0
	Nepal	0	0	–0.01		0	0	0
	India	2.67	2.77	2.98		2.25	2.28	2.48
	Bangladesh	0	0	–0.01		0	0	0
	Rest of World	–0.88	–1.03	–1.34		0	0	0

GDP = gross domestic product.

Source: TERI Estimations, 2022.

As indicated in Table 5.7, if electricity export from India to Sri Lanka increases by 5% (over the existing trade level), the change in GDP of India and Sri Lanka will be $2.25 million and $0.69 million, respectively. Thus, bilateral electricity trade from India to Sri Lanka will have a positive impact on the GDP of both trading partners, with higher relative benefits for the exporting country. The welfare of both trading partners will also improve as power trade increases.

When electricity trade from India to Sri Lanka increases by 10%, the scale of positive impact (for both GDP and welfare) is comparatively higher for both the trading partners and the relative gain for the exporting country is even more. This holds true even when the increase is 20%. India–Sri Lanka electricity trade may not have much implication for the neighbouring partners due to the absence of electricity trade (actual/potential) relationship of Sri Lanka with other neighbouring partners. However, a large increase in India–Sri Lanka trade (e.g. 20%) can have marginally adverse implication for India’s trading partners (like Nepal or Bangladesh).

1.8. Case 8: Electricity Export from India to Sri Lanka: With Technology Upgradation in India

Table 5.8. Benefits (GDP and Welfare) from Bilateral Electricity from India to Sri Lanka Backed by Technology Upgradation

		Change in Welfare			Change in GDP		
Change in Electricity with Technology Improvement in Exporting Country	**Country**	**5%**	**10%**	**20%**	**5%**	**10%**	**20%**
	Bhutan	–0.02	-0.03	-0.02	-0.02	-0.02	-0.07
	Sri Lanka	43.34	49.02	51.62	36.01	40.26	45.56
	Pakistan	0.1	0.12	0.02	0.02	0.02	-0.05
	Nepal	0.03	0.04	0.01	0.01	0.02	-0.02
	India	77.4	103.17	156.08	68	90.63	114.81
	Bangladesh	–0.03	-0.04	-0.05	-0.03	-0.05	-0.04
	Rest of World	–22.29	-27.49	-8	-8	-8	30

GDP = gross domestic product.
Source: TERI Estimations, 2022.

Table 5.8 indicates that when existing electricity export from India to Sri Lanka increased by 5% accompanied by relevant technology improvement in India, the benefits are positive for both nations, with higher benefits for India (exporting country) in terms of both GDP and welfare. The level of benefits, in this case, is higher than the potential benefits from the same percentage of increase in the export of electricity only. Due to positive externality of technology advancement, the scale of economic benefits is higher. Moreover, for actual realisation of electricity trade from India to Sri Lanka, a technological upgrade is required, namely the use of a high-voltage direct current (HVDC) connecting line through the sea.

1.9. Case 9: Electricity Export from India to Nepal: Without Any Technology Change

Table 5.9. Benefits (GDP and Welfare) from Bilateral Electricity from India to Nepal

	Country	Change in Welfare			Change in GDP		
		5%	10%	20%	5%	10%	20%
Change in Electricity	Bhutan	–0.01	–0.03	–0.06	–0.01	–0.01	–0.03
	Sri Lanka	0.0	–0.01	-0.01	0.0	0.0	0.0
	Pakistan	0.0	0.0	0.0	0.0	0.0	0.0
	Nepal	0.73	1.59	3.76	0.38	0.83	1.95
	India	0.25	0.54	1.25	0.45	0.92	2.09
	Bangladesh	0.0	–0.01	–0.01	0.0	0.0	0.0
	Rest of World	–0.71	–1.55	–3.64	0.0	0.0	0.0

GDP = gross domestic product.

Source: TERI Estimations, 2022.

As indicated in Table 5.9, if electricity exports from India to Nepal increases by 5%, the change in the GDP of India and Nepal will be $0.45 million and $0.38 million, respectively. Thus, bilateral electricity trade from India to Nepal will have a positive impact on the GDP of both trading partners, with higher relative benefits for the exporting country India. Similarly, the welfare of both trading partners will increase as a result of the increase in electricity trade. Nepal's electricity is generated almost entirely from hydropower and there has not been any other diversified option for generation. For this reason, Nepal is very much dependent on India during the winter season when hydropower generation is limited. Thus, electricity imports from India results in higher level of welfare in Nepal. When electricity export from India to Nepal increases by 10%, the table indicates that the scale of positive impact is comparatively higher for both trading partners. In the case of a 20% increase in existing electricity trade, the scale of impact is even higher for both the partners for both GDP and welfare.

1.10. Case 10: Electricity Export from India to Nepal: With Technology Upgradation in India

Table 5.10. Benefits (GDP and Welfare) from Bilateral Electricity from India to Nepal Backed by Technology Upgradation

	Country	Change in Welfare			Change in GDP		
Change in Electricity with Technology Improvement in Exporting Country		**5%**	**10%**	**20%**	**5%**	**10%**	**20%**
	Bhutan	–0.22	–0.23	–0.27	–0.13	-0.13	–0.15
	Sri Lanka	–0.18	–0.18	–0.19	–0.08	–0.08	–0.08
	Pakistan	0.12	0.12	0.13	0.03	0.03	0.03
	Nepal	10.81	13.68	17.86	8.41	10.86	11.99
	India	515.52	515.81	516.53	455.25	455.78	455.98
	Bangladesh	–0.30	–0.30	–0.31	–0.25	–0.25	–0.25
	Rest of World	–76.81	–77.65	–79.76	–16	–16	–16

GDP = gross domestic product.
Source: TERI Estimations, 2022.

Table 5.10 indicates that when existing electricity export from India to Nepal is increased by 5% accompanied by relevant technology improvement in India, benefits are positive for both Nepal and India, with relatively higher benefits for India in terms of GDP and welfare. Technology improvement in the exporting country leads to a higher exportable surplus of electricity, along with other positive externalities. Thus, export backed by technology improvements leads to higher level of economic benefits. For 10% and 20% increase in electricity trade backed by technology upgradation in exporting country led to even higher levels of benefits.

1.11. Case 11: Electricity Export from Nepal to Bangladesh: Without Any Technology Change

Table 5.11. Benefits (GDP and Welfare) from Bilateral Electricity from Nepal to Bangladesh

	Country	Change in Welfare			Change in GDP		
		5%	10%	20%	5%	10%	20%
Change in Electricity	Bhutan	–0.02	–0.05	–0.11	–0.01	–0.03	–0.06
	Sri Lanka	0	0	0	0	0	0
	Pakistan	0	0	0	0	0	0
	Nepal	1.08	2.35	5.51	0.27	0.59	1.38
	India	0.02	0.04	0.09	0	0.13	0.13
	Bangladesh	0.74	1.66	4.01	0.19	0.42	1.0
	Rest of World	–0.88	–1.91	–4.48	0	0	0

GDP = gross domestic product.
Source: TERI Estimations, 2022.

Table 5.11 shows that if Nepal's electricity exports to Bangladesh increase by 5% (over the current trade level), the change in GDP for Nepal and Bangladesh will be \$0.27 million and \$0.19 million, respectively. Hence, bilateral energy trade from Nepal to Bangladesh will enhance both the trading partners' GDP, with greater relative gains for the exporting country. Similarly, the well-being of both trading partners will improve as electricity trade enhanced. Electricity trade between Nepal and Bangladesh is very important for Bangladesh. It is because Bangladesh not only suffers from an electricity deficit but it also is struggling to generate electricity from renewable sources. The electricity imported from Nepal is primarily renewable power (generated by hydro in Nepal). Thus, this electricity trade helps Bangladesh not only to meet its power demand but also meet its renewable target. The level of benefit increases with increase in electricity trade.

1.12. Case 12: Electricity Export from Nepal to Bangladesh: With Technology Upgradation in Bangladesh

Table 5.12. Benefits (GDP and Welfare) from Bilateral Electricity from Nepal to Bangladesh Backed by Technology Upgradation

Change in electricity with technology improvement in exporting country	Country	Change in Welfare			Change in GDP		
		5%	10%	20%	5%	10%	20%
	Bhutan	–0.29	–0.32	–0.39	–0.14	–0.16	–0.20
	Sri Lanka	–0.04	–0.04	–0.04	–0.01	–0.01	–0.01
	Pakistan	0.07	0.07	0.07	0	0	0
	Nepal	90.84	92.41	96.3	50.16	50.56	51.56
	India	3.45	3.48	3.55	1.13	1.13	1.25
	Bangladesh	0.99	2.09	3.56	0.47	0.85	1.50
	Rest of World	–49.52	–50.8	–53.98	–8	–8	–8

GDP = gross domestic product.
Source: TERI Estimations, 2022.

Table 5.12 indicates that when existing electricity export from Nepal to Bangladesh is increased by 5% accompanied by relevant technology improvement in the export country, benefits are positive for both Nepal and Bangladesh, with higher benefits for the former. This is because technology improvement leads to more exportable surplus electricity for Nepal. Nepal can reap a huge benefit even from the positive externality of infrastructure development and export more electricity to its neighbouring countries (like India), who also benefit, as depicted in the table. The scale of benefits increases with increasing levels of electricity trade backed by technology upgrades in Nepal.

1.13. Case 13: Electricity Export from Bhutan to Bangladesh: Without Any Technology Change

Table 5.13. Benefits (GDP and Welfare) from Bilateral Electricity from Bhutan to Bangladesh

	Country	Change in Welfare			Change in GDP		
		5%	10%	20%	5%	10%	20%
Change in Electricity	Bhutan	0.93	1.99	4.53	0.5	1.08	2.45
	Sri Lanka	0.01	0.01	0.03	0	0	0.01
	Pakistan	0.05	0.1	0.22	0.02	0.02	0.05
	Nepal	–0.07	–0.16	–0.35	–0.02	–0.04	–0.09
	India	–0.19	-0.4	–0.9	0	0	0
	Bangladesh	0.22	1.03	2.77	0.4	1.47	3.44
	Rest of World	–0.28	–0.6	–1.38	0	0	0

GDP = gross domestic product.
Source: TERI Estimations, 2022.

As shown in Table 5.13, if Bhutan's electricity export to Bangladesh increases by 5% (over existing trade), the change in GDP for Bhutan and Bangladesh will be $0.5 million and $0.4 million, respectively. Hence, bilateral energy trade from Bhutan to Bangladesh will enhance both trading partners' GDP, with greater relative gains for the exporting country. Similarly, the well-being of both trading partners will improve as electricity commerce expands. Electricity trade between Bhutan and Bangladesh is very important for Bangladesh because, as noted, it suffers by not only from an electricity deficit but it is also struggling to generate electricity from renewable sources. The electricity imported from Bhutan is primarily renewable power (hydropower). Thus, this electricity trade helps Bangladesh not only to meet its power demand but also meet its renewable target. The level of benefit increases with any electricity trade increase.

1.14. Case 14: Electricity Export from Bhutan to Bangladesh: With Technology Upgradation in Bhutan

Table 1. Benefits (GDP and Welfare) from Bilateral Electricity from Bhutan to Bangladesh Backed by Technology Upgradation

Change in Electricity with Technology Improvement in Exporting Country	Country	Change in Welfare			Change in GDP		
		5%	10%	20%	5%	10%	20%
	Bhutan	59.5	60.78	63.79	46.47	47.2	48.93
	Sri Lanka	0.21	0.22	0.24	0.05	0.05	0.05
	Pakistan	2.68	2.74	2.89	0.33	0.34	0.36
	Nepal	0.1	0.01	-0.22	–0.01	–0.03	–0.09
	India	3.35	3.09	2.51	–0.38	–0.38	–0.38
	Bang	3.06	5.02	8.66	1.97	3.0	5.48
	Rest of World	–22.49	–22.89	–23.85	0	0	0

GDP = gross domestic product.
Source: TERI Estimations, 2022.

Table 5.14 indicates that when existing electricity export from Bhutan to Bangladesh is increased by 5%, accompanied by relevant technology improvement in Bhutan, benefits are positive for both Bhutan and Bangladesh, with higher benefits for the exporting country. This is because, technology improvement leads to more exportable surplus electricity for Bhutan. Bhutan can reap a huge benefit even from the positive externality of infrastructure development and export more electricity to its neighbouring countries (like India), who also benefit, as depicted in the table. Scale of benefits increases with increasing levels of electricity trade backed by technology upgradation in Bhutan.

1.15. Case 15: Electricity Export from Pakistan to Afghanistan: Without Any Technology Change

Table 5.15. Benefits (GDP and Welfare) from Bilateral Electricity from Pakistan to Afghanistan

	Country	Change in Welfare			Change in GDP		
		5%	10%	20%	5%	10%	20%
Change in Electricity	Afghanistan	0.56	1.22	2.84	0.33	0.72	1.69
	Sri Lanka	0	0	–0.01	0	0	0
	Pakistan	0.63	1.35	3.09	0.11	0.25	0.58
	Nepal	0	0.01	0.01	0	0	0
	India	–0.02	–0.04	–0.09	0	0	–0.13
	Bangladesh	–0.01	–0.01	–0.02	0	0	–0.02
	Rest of World	–0.89	–1.93	–4.43	0	0	0

GDP = gross domestic product.
Source: TERI Estimations, 2022.

Table 5.15 indicates that if electricity export from Pakistan to Afghanistan increases by 5% (over the existing trade level), the change in the GDP of Afghanistan and Pakistan will be $0.33 million and $0.11 million, respectively. Thus, bilateral electricity trade from Pakistan to Afghanistan will have a positive impact on the GDP of both trading partners. Scale of economic benefits increases with increasing level of electricity trade for both partners and for both GDP and welfare.

1.16. Case 16: Electricity Export from Pakistan to Afghanistan: With Technology Upgradation in Pakistan

Table 5.16. Benefits (GDP and Welfare) from Bilateral Electricity from Pakistan to Afghanistan Backed by Technology Upgradation

Change in Electricity with Technology Improvement in Exporting Country		Change in Welfare			Change in GDP		
	Country	**5%**	**10%**	**20%**	**5%**	**10%**	**20%**
	Afghanistan	8.66	9.33	10.98	6.84	7.22	8.18
	Sri Lanka	0.08	0.08	0.07	0.03	0.02	0.02
	Pakistan	147.42	148.15	149.92	126.42	126.56	126.92
	Nepal	0.07	0.07	0.08	0.01	0.01	0.01
	India	1.44	1.42	1.37	–0.38	–0.50	–0.50
	Bangladesh	–0.23	–0.24	–0.25	–0.22	-0.22	–0.22
	Rest of World	–31.43	–32.49	–35.04	–8	–8	–8

GDP = gross domestic product.
Source: TERI Estimations, 2022.

Table 5.16 indicates that when existing electricity export from Pakistan to Afghanistan is increased by 5% accompanied by relevant technology improvement in Pakistan, benefits are positive for both countries. However, Pakistan will witness higher benefits due to positive externality of technology improvement. Moreover, scale of benefits will increase with higher levels of electricity trade.

2. Regional Integration

In terms of renewable energy resource and demand pattern complementarity, the scope of electricity trade is more in the case of multilateral or regional arrangements compared to the bilateral trade agreement. Here, the study explored two different scenarios:

(1) Bhutan-India-Nepal
(2) Bhutan-Bangladesh-India-Nepal (BBIN)

Due to limited data availability, regionalisation potential with all eight members could not be explored.

2.1. Regional Integration: Electricity Trade Only

Table 5.17. GDP and Welfare Impact of Bhutan–India–Nepal Trilateral Trade in Electricity Only

Country	Welfare	GDP Change
Bhutan	18.76	10.11
Sri Lanka	0.11	0.02
Pakistan	0.96	0.17
Nepal	9.78	4.07
India	9.83	8
Bangladesh	-0.04	0.03

GDP = gross domestic product.
Source: TERI Estimations, 2022.

Renewable energy generation resource and demand pattern complementarity are most pronounced in the case of Bhutan, India, and Nepal. India is already engaged in huge electricity trade with these two countries on a bilateral basis. But Bhutan and Nepal have also become part of the India Energy Exchange with the aim to trade power from a common pool as and when required. This case will indicate the change in benefit level and sharing when the bilateral trade of India with Bhutan and Nepal is upgraded to trilateral trade between Bhutan-India-Nepal. Table 5.17 indicates that trilateral electricity trade results in higher benefits (compared to bilateral trade benefits from Bhutan to India, India to Bhutan, Nepal to India, and India to Nepal) for participating countries in terms of both GDP and welfare. Moreover, more countries get benefitted from such trade arrangements.

2.2. Regional Integration: Electricity Trade Backed by Technology Upgradation in Exporting Countries

Table 5.18. Bilateral Trade versus Multilateral Trade: Benefit Sharing across Countries

Country	GDP				Welfare			
	BBIN	**BBIN+P**	**BBIN+SL**	**BBIN+P+SL**	**BBIN**	**BBIN+P**	**BBIN+SL**	**BBIN+P+SL**
Bhutan	49.59	49.57	49.57	49.57	62.74	62.7	62.7	62.7
Sri Lanka	–0.23	10.98	–0.21	10.98	–0.25	14.38	–0.22	14.37
Pakistan	0.38	79.5	79.88	79.88	3.14	94.95	95.32	95.35
Nepal	53.19	53.2	53.20	53.20	98.62	98.64	98.63	98.64
India	1137	1136.63	1136.75	1136.63	1295.47	1296.23	1296.67	1296.79
Bangladesh	21.09	21.05	21.05	21.06	37.45	37.32	37.31	37.31

BBIN = Bhutan-Bangladesh-India-Nepal.
BBIN+P = BBIN + Pakistan.
BBIN+SL = BBIN + Sri Lanka.
BBIN+P+SL = BBIN + Pakistan + Sri Lanka.
GDP = gross domestic product.
Source: TERI Estimations, 2022.

Table 5.18 indicates that when electricity trade increases backed by technology improvement in exporting countries, benefit sharing across countries is more profound in multilateral/regional arrangements, as compared with all previous cases,[3] especially bilateral trade.

Based on these two results (refer to Tables 5.17 and 5.18), it can be expected that larger benefits will be available when more countries join the energy cooperation framework/electricity trade network for effective and efficient utilisation of available power supply. Moreover, technology upgradation in the exporting country will increase the level of benefits for participating countries. In the case of multilateral/regional arrangement, more countries are getting benefitted who were not part of benefit sharing from a bilateral agreement between the two other countries.

Tables 5.17 and 5.18 also indicate that India is going to reap huge benefits from such multilateral/regional trade arrangements. In regional cooperation in energy, due to economic size and central location, India will play the most important/pivotal role. It has already proposed to create the 'One Sun One World One Grid' network to connect its neighbours and exchange power among the common grid-connected countries. In the case of regional

[3] i.e. bilateral trade with an increase in electricity export, bilateral trade with an increase in electricity export backed by technology upgradation in exporting country, and multilateral trade in electricity.

electricity trade with technology improvement in exporting countries, the level of benefit will be significantly higher for India because of its central role in this initiative and its economic size. However, benefits shared by other participating countries are also significant, especially when compared to their respective economic size, infrastructure, and market bottlenecks.

The major findings of the study are as follows:

- Bilateral trade in renewable energy leads to GDP as well as welfare gain for both trading partners.
- Benefit is higher when renewable energy trade is backed by technology improvement in the source/exporting country.
- Regional trade is more beneficial than bilateral trade.

The above empirical analysis indicates that bilateral renewable trade/cooperation provides economic benefits to the participating countries as well as the entire region. However, the benefit scale can be enhanced for the participating countries and the entire region if multilateral renewable energy cooperation can be arranged. Thus, the null hypotheses C1H0 and C2H0 corresponding to research Question 3 can be fully accepted. Bilateral energy cooperation already exists between India and Bhutan, India and Nepal, and India and Bangladesh. But BBIN regional cooperation is in progress through cross-border grid integration and electricity trade via the India Energy Exchange. Bhutan and Nepal are already part of the India Energy Exchange. The realisation of this BBIN network will help Bangladesh to import power supply even from Nepal and Bhutan. Thus, BBIN will not only help increase the level of benefit but also widen the scope of spill-over benefits to a larger number of countries. India's One Sun One World One Grid initiative is expected to integrate other South Asian countries into the regional energy cooperation and provide more benefits. However, the initiative can be further extended to Southeast and East Asia and West Asia in the near future.

Chapter 6

The Way Forward

1. General Remarks on Renewable Energy Trade and Cooperation Policy

Every region in the world has its own renewable energy policies. The South Asian region is no different. Each country has its own policy instruments with various targets and commitments. Before any new policies are formulated, it is advisable that the existing policy instruments are identified and categorised under the umbrella framework. This has been the practice followed during peer review of existing literature. The policymakers choose the instruments to be adopted based on their area of implementation.

- Regulatory instruments
  a. Unified, yet decentralised laws and regulations.
  b. Codes and standards pertaining to institutional, strategic planning, sectorial standards, vehicle-fuel economy, and emission standards.
  c. Parliamentary resolutions.
  d. Monitoring and auditing.
- Economic instruments
  a. Direct investment in infrastructure, procurement, and generation.
  b. Fiscal/financial stimuli in the form of loans, grants, aids, subsidies, and even feed-in tariffs/premiums.
  c. Market-based impetus (tradable certificates) such as Green Certificates and GHG Certificates.
  e. Liability mechanisms in the form of renewable energy trade contracts.
- Voluntary instruments
  a. Research and development.
  b. Technology development, deployment and distribution.
  c. Public voluntary schemes.
  d. Negotiation in public-private or only private initiatives.
- Information and education instruments
  a. Comparison label to induce a healthy spirit of competition.
  b. Information sharing to promote healthy renewable energy trade.
  c. Endorsement.
  d. Transnational awareness and training and aid-in-implementation.

The above-identified policy instruments should be assessed to address the barriers and accelerate the enablers of cross-border renewable energy trade and cooperation. The analysis can be based on certain criteria that could decode the feasibility and viability of such instruments in the context of South Asian regional renewable energy cooperation. These are as follows:

- **Economic Criteria** based on past regional or other countries' policy experience.
- **Environmental Effectiveness**, whether such policies have the actual ability to achieve such vision.
- **Fiscal/Budgetary criteria** based on the depth of the Exchequer.
- **Policy Effectiveness** based on other region's experience with policy changes.
- **Policy Implementation** based on the interaction between policy existence and the government effectiveness index (World Bank, 2018).
- **Stakeholder Support.**

It is necessary to identify the areas of implementation and execution along with associated renewable energy cross-border trade infrastructure. The protocols for renewable energy generation and trade also need to be defined for the fulfilment of renewable energy targets. This had to be done not only for individual countries but collectively for the entire region. This report recommends a policy mix of different instruments, along with the opening of avenues for new policy suggestions. This is because a single policy cannot address the issues of regional renewable energy cooperation, especially in the context of South Asia, as every country in the region has a diverse energy economy.

2. Risks Associated with Renewable Energy Trade and Cooperation in South Asia

Cross-border renewable energy trade in South Asia has the potential to foster significant benefits in the region. This includes increased access to green and affordable energy, improved energy security, and reduced GHG emissions. However, a few associated risks should be carefully considered by policymakers and stakeholders:

(1) Political risks: The South Asian region is known for its history of political disputes and unrest. These can be a huge negative externality in their renewable energy projects and infrastructure. Therefore, they have to be effectively dealt with when considering cross-border renewable energy trade and cooperation.

(2) Regulatory risks: Lack of harmonised and consistent regulatory frameworks can cause uncertainty and information asymmetry for investors and infrastructure developers. No umbrella framework exists; hence, different national policies involving land acquisition and disputes over tariffs can cause delays and disruption in the critical path of cross-border projects including prospective renewable energy trade.

(3) Environmental risks: The cross-border renewable energy trade has both positive and negative impacts, depending on its location and design. Renewable energy cooperation can address such adversities. However, the vulnerable ecosystems can cause a crisis in one area, which can spill over to the entire region if not protected properly beforehand.

(4) Financial risks: The renewable energy trade and cooperation are marked by medium- and long-term contracts. These require a proper business-conducive environment for the investors. When it comes to cross-border involvements of multiple investors and stakeholders, financing such projects is a huge commitment.

(5) Technical risks: Renewable energy trade and projects require complex technologies and sophisticated infrastructure. The lack of technical expertise and renewable energy awareness can create cross-border renewable energy cooperation challenges, particularly

in areas with lesser T&D infrastructure. These include grid instability and interoperability that can even transmit crises across the entire region.

Grid operation in the context of transnational renewable energy trade in South Asia requires attention and is associated with country-specific risks that can adversely affect the stability and reliability of the power system and future renewable energy projects. Here are some country-specific risks associated with cross-border grid operability and renewable energy trade in the South Asian region.

(1) India: India has a large and rapidly growing renewable energy sector that has the potential to drive the development of cross-border renewable energy trade initiatives. However, India's power grid faces technical challenges such as limited transmission capacity, high transmission and distribution losses, and frequency fluctuations. For example, in 2020, grid instability in the Southern states of India caused power disruptions affecting millions of people. The country faced challenges in maintaining grid stability due to the integration of intermittent renewable energy sources, such as wind and solar. During the COVID-19 lockdown, the demand for electricity reduced significantly. The reduced demand was addressed by less generation from coal due to the 'must run' status of renewable plants and the low cost of production. The major challenge against the complete reliability on renewable generation is its variability and seasonality in generation. Unless the renewable basket is appropriately diversified and properly integrated, generation only from renewables can lead to grid instability. In its long-term strategy, India thus wants to focus on non-conventional (nuclear in addition to renewable) sources rather than only renewable sources.

(2) Bangladesh: In Bangladesh, the main risk associated with grid operation is system overload. Rapid economic growth and urbanisation have enhanced the demand for electricity, leading to the overloading of the power grid. Further overloading can create voltage fluctuations, resulting in equipment damage and blackouts. For example, in 2020, a transformer failure caused a major power outage in Dhaka. Other than the lack of significant progress in energy transition, there is the possibility that grid instability may persist even in renewable energy-based electricity generation.

(3) Nepal: Nepal faces grid stability challenges owing to its mountainous terrain and inadequate transmission infrastructure. The integration of intermittent renewable energy sources, such as hydropower, can create challenges for grid stability, particularly during the dry season when hydropower generation is low. In 2019, Nepal faced power outages due to a decrease in hydropower generation during the dry season. Unless diversity in the renewable basket is ensured, this problem will persist.

(4) Bhutan: Bhutan has inadequate grid infrastructure and transmission mechanisms, along with disputes over ownership of hydropower projects. This can act as an obstacle to regional renewable energy cooperation.

(5) Sri Lanka: Sri Lanka has ambitious renewable energy targets but faces technical issues such as integrating grid-based intermittent renewables while minimising technical losses. In Sri Lanka, the main risk associated with grid operation is the greater cost of electricity generation. The reliance on fossil fuels for electricity generation has led to higher

generation costs, which are passed on to consumers through high electricity tariffs. The high cost of electricity can impact the competitiveness of Sri Lankan businesses and the affordability of electricity for households. Along with the progress in energy transition, this issue needs to be addressed.

(6) Pakistan: Pakistan faces significant challenges in consistently maintaining grid stability due to a lack of transmission infrastructure and high levels of electricity theft. These challenges can impact the credibility, reliability, and quality of the power supply, particularly in rural areas. For example, in 2019–20, Pakistan experienced widespread power outages due to a breakdown in the transmission system. As a result of limited domestic financial capability, public–private partnerships and/or foreign funding are required to address such infrastructural issues. China is already taking advantage of this issue. For a successful South Asian regional energy initiative, this issue should be addressed properly.

Managing these country-specific risks requires careful planning, risk management, investment in transmission infrastructure, minimising T&D losses, and adoption of advanced grid management technologies. Stakeholders can choose to invest in transmission and distribution infrastructure, energy storage facilities, grid modernisation, and demand-side management to tackle grid instability. Countries in the region need to collaborate and develop mutually beneficial frameworks for cross-border renewable energy trade to tackle grid operability and ensure reliable and affordable renewable energy supply for businesses and households.

3. Conclusion

With growing concerns over climate change, countries across the world have given their individual targets and commitments to achieve net-zero carbon emissions. Thus, this is a joint effort to combat the huge usage of fossil-fuel sources of energy and substitute the same with clean energy sources. The countries in the South Asian region, being rich in diversified and scattered sources of renewable energy, have the scope of making the most of their indigenous advantages while depending on cross-border cooperation to reconcile with their comparative disadvantages. However, the current legal framework and incentive mechanisms are not properly developed to minimise the barriers to renewable energy cooperation and accelerate their enablers.

This study has identified the different barriers and enablers of renewable energy trade in the South Asian region and tried to assess whether there is significant regional renewable energy trade potential and whether such potential is affected by bilateral or multilateral or any region-specific characteristics. Other than that, the risks identified in the previous section also need to be addressed for the effective success of regional renewable energy trade and cooperation.

The following conclusions can be inferred from the results of the study:

- Although the actual intra-regional trade of renewable energy is low in South Asia, it has significant renewable energy trade potential. The region is endowed with untapped renewable energy resources that can be utilised on a need basis to generate a greater scale of benefits for the entire region.

- It seems that political unrest and lack of credibility in the region are the major barriers to trade because of which renewable energy trade and cooperation are also affected. Rational analysis has shown that even after the ideal resolution of the issue of cross-border turmoil and trust deficit, there is no sufficient cross-border infrastructure to integrate the entire region for regional renewable energy trade and cooperation.
- The seasonality and variability of the renewable energy demand–supply complementarity of the South Asian region is a key enabler of renewable energy trade and cooperation. However, seasonality has to be supplemented by individual NDCs and climate commitments. Various regional energy cooperation case studies show the importance of such complementarity for regional cooperation.
- The already existing energy trade agreements in the South Asian region have rendered national and regional benefits but limited to participating nations. Such negotiations can be eventually extended to trilateral and multinational agreements, which are not only capable of generating greater economies of scale (in terms of GDP and welfare) but also fostering a much greater degree of energy cooperation, security, and interregional relations in South Asia.

4. Recommendations and Lessons Learned

On the basis of GTAP-based empirical analysis, identified barriers, and enablers and stakeholder consultation (both during the study and from the final dissemination event held on 21 December 2022), the study has the following recommendations:

- **Electrification of end-use applications and greening of power generation is the primary requirement for renewable energy trade in every country:** Electrification of end-use applications and generating that electricity from renewable sources are the two most important and almost necessary conditions for decarbonisation. Except for a few end-use applications (such as furnaces in industries) and a few hard-to-abate activities (such as air transport), the above two strategies can help ensure low-carbon green transition, as well as enable green electricity trade across borders.

- **Effective grid integration with all types of renewable generation to reduce renewable generation variability and intermittent supply issue:** Grid integration of renewable energy is necessary for effective utilisation of available supply. However, due to the inherent nature of generation (variable and intermittent generation), grid integration with renewable energy supply makes grid operation unstable. However, integrating various renewable energy sources in the grid can reduce such issues of intermittent supply and help ensure the stability of the grid. For example, when solar supply is not available, wind or bioenergy can continue to feed into the grid to keep it operational.

- **Strengthening of grid infrastructure within and across countries to ensure absorption of flexible renewable energy supply:** Upgradation and strengthening of grid infrastructure are of utmost importance to enable renewable energy trade within and across regions. For example, to enable renewable energy trade between India and Sri Lanka/Maldives, under-sea network development is necessary. Similarly, to strengthen the network infrastructure between India and Nepal/Bhutan, a network needs to be developed in dense forest. In either case, the network needs to be cost-effective and eco-friendly. Moreover, existing grid systems are mostly prepared for thermal and hydro generation. But, integrating renewable energy supply, which is characterised by variable and intermittent supply, grid infrastructure within and across border needs to be upgraded to accommodate renewable energy supply to maintain grid stability.

- **Reduce T&D loss and promote effective demand management (through efficiency) for effective utilisation of available power supply:** Reducing T&D loss is an important step for effective utilisation of supply. On the other hand, promoting effective demand management (for example through the adoption of energy-efficient appliances) can also help to reduce domestic demand and enhance exportable electricity.

- **Promote manufacturing of renewable generation to reduce import dependency on renewable machineries:** All South Asian countries are heavily dependent on the import of renewable machineries/manufacturing (for example, solar module and its components including battery storage). However, globally, renewable energy manufacturing is concentrated (mostly in China), which can have severe energy security issues. To address this problem, the development of indigenous renewable energy manufacturing capability is important.

- **Development of a regional database to carry out proper economic cost of power trade in the region:** The creation and updating/maintenance of a regional database (for cross-border power trading) is an important step for estimation of economic cost and benefit and its cross-border sharing. This is important to increase awareness and promote regional integration and cooperation in renewable energy in the South Asian context.

- **Effective regional integration and inter-regional power trade can effectively address the following issues:**

  - **Diversified and complementary renewable energy generation potential:** One of the advantages of renewable energy trade among South Asian countries is its diversified renewable sources. While Bhutan and Nepal have enormous hydropower generation potential, India is endowed with solar and wind energy; and Pakistan has considerable potential for wind power generation in the coastal belt of Sindh and Baluchistan. Similarly, Sri Lanka is blessed with biomass, solar, and wind. With these vast variations and complementarity in renewable energy generation sources, regional renewable energy trade can address the problem of intermittent and variable supply of renewables. For example, during the winter season when hydro (due to freezing of water resources) and solar (due to low radiation) are not effective, wind or bioenergy can provide power supply. Owing to India and Pakistan's nuclear capability, power generation through nuclear source can also help to meet the decarbonisation target of non-fossil fuel generation during this season.

  - **Intra- and inter-regional demand variation:** There is a wide intra-regional demand variation across countries within South Asia. Bhutan and Nepal have excess power generation during summer and monsoon seasons, but deficit during the winter season and as a result have to import electricity from India. On the other hand, during summer, India experiences excess demand while relatively lower demand during winter. The countries can work toward expanding the cooperation and trade in renewable energy with their nearby countries/regions (like ASEAN) to explore and improve this trade potential.

- **Regional trade in power is an alternative to the application of expensive energy storage:** Renewable energy generation is intermittent while demand is continuous along with the possibility of demand-supply mismatch existing. To address this issue, one alternative is the utilisation of energy storage. But that would make the total cost of supply significantly high. The alternative to energy storage integration is regional integration. Across the region, demand and supply mismatch can be traded through a common power exchange mechanism, which will effectively address the above issue.
- **Energy trade needs to be accompanied by technology development in both trading countries to reap more benefits:** Either demand or supply or upgradation of technology in both countries can only ensure more exportable electricity through demand-side management or supply enhancement. However, technology and infrastructure improvement are also important for the effective utilisation of imported supply by the importing country and reducing T&D loss.
- **Realisation of cross-border energy trade agreement through bilateral/multilateral initiatives:** Though there has been an existing framework for energy cooperation, such as SAARC, it has failed to generate sufficient benefit at bilateral or multilateral levels. The Myanmar-Bangladesh-India gas pipeline, the Bangladesh-Bhutan-India-Nepal sub-regional framework for energy cooperation, and the Turkmenistan-Afghanistan-Pakistan-India are some examples of bilateral and multilateral power trade agreements that have failed due to the absence of suitable dialogues between the stakeholders and appropriate inter-governmental intervention. For any such regional initiative to be fruitful (for instance, the 'One Sun One World One Grid' initiative by India), strong inter-governmental actions and intentions are required. In this context, the ASEAN Plan of Action for Energy Cooperation or Lao PDR-Thailand-Malaysia-Singapore Power Integration Project initiatives could provide important lessons to South Asian countries.
- **Estimate operational viability of technologies for intra-regional transmission through sea-route (for Sri Lanka and Maldives) and dense forests (for Nepal and Bhutan) through eco-friendly and sustainable technology and low-cost/cost-effective (relative to benefits) technology.**
- **Multilateral trade is more beneficial than bilateral trade, but multilateral arrangement can start with bilateral and trilateral arrangements.**
- **Financing is always an issue, hence public-private partnership and private initiatives can be effective alternatives:** Private sector investment is crucial for a secure energy framework. In Bangladesh, India, and Pakistan, private funding contributed 44%, 48.5%, and

53% respectively, in the distribution sector, especially for residential consumers.[4] Many countries including Nepal and Bangladesh are welcoming private investment even in renewable energy generation to expedite the decarbonisation journey. Hence, one can conclude that private investment is required over and above conventional financing methods of government and public-private partnership funding.

- **Being related to renewable energy in the context of developing countries, international funding (e.g. climate fund, clean energy fund) for the promotion of renewable generation and transmission can play an important role:** Given the financial crunch of most South Asian countries, international and multilateral funding is also required for successful implementation and development of regional renewable energy trade and cooperation. ADB is already providing relevant financing in this regard. Thus, one can conclude that there is a need to increase the awareness about potential benefits of regional integration in renewable energy trade at both government and industry levels.
- **Need to learn from the successful implementation of regional energy trade in other economic regions (such as ASEAN, the EU):** Strong inter-governmental intention and proactive dialogue and actions (as seen in other successful regional energy cooperation, including between ASEAN and the European Union) can be utilised to modify and expedite the regional renewable energy trade initiative in the South Asian context, e.g. the Lao PDR-Thailand-Malaysia-Singapore Power Integration Project in ASEAN, which already includes a wheeling charge methodology that is applicable for a harmonised regional energy trade framework.
- **Preparation of common regional protocol for power exchange**: Due to diversified domestic regulations on renewable energy generation, renewable purchase obligation and distribution, cross-border power exchange may be difficult unless there is a common regional protocol. Such a protocol is currently missing in the South Asian context. However, recently the landmark Motor Vehicles Agreement for the Regulation of Passenger, Personnel and Cargo Vehicular Traffic among the four South Asian neighbours (that is Bhutan, Bangladesh, India, and Nepal) has been signed. Similar regional protocols are required to promote and facilitate regional renewable energy trade in South Asia.

[4] Details available at https://www.thehindu.com/opinion/op-ed/the-goal-of-an-energy-secure-south-asia/article65354570.ece

Lesson Learned

Learning for South Asia from Southeast Asia

Southeast Asia has already shown remarkable progress in regional energy cooperation, whereas South Asia has just started the journey. Despite several differences in the geopolitical situation and the nature of energy and economic structure between these two regions, South Asia can learn from Southeast Asia on many aspects of regional energy cooperation. The most important aspects are in infrastructure development, arrangement of financial resources, and development of the appropriate regulatory framework. These three aspects are very important to enable regional energy cooperation; in particular, the development of a common energy protocol is a necessary requirement for the success of regional energy trade/cooperation. South Asia already has similar protocols in place for transport movement in the BBIN network. To develop such an energy protocol, the Southeast Asian experience can provide valuable input for South Asian countries. Moreover, despite having bilateral political trust issues between the two neighbouring countries, they can engage in energy cooperation to reap the economic benefits, keeping aside the distribution of benefits among the partners. This initiative can open the channel for further collaboration in other fields also.

Learning for Southeast Asia from South Asia

Southeast Asia is already much ahead of South Asia in terms of regional energy trade and cooperation. The region has already successfully implemented multilateral energy cooperation by progressing from bilateral agreements. However, the identification of demand complementarity, which is more pronounced in South Asia, can be useful even for Southeast Asia. For example, Lao PDR, Myanmar, and Viet Nam are primarily agriculture-based economies, while Thailand is service sector-oriented. The main source of electricity demand in Indonesia is mining and related industries, while Singapore and Malaysia are primarily industry-based countries. So, it may be possible that even demand complementarity may be present in Southeast Asian countries. The effective tapping of such an opportunity could add value and further interest in the enhancement of energy cooperation. Moreover, for the sustainability of energy cooperation with a targeted transition from fossil fuel, the development of supply complementarity (in the South Asian context) in renewable energy sources will be important in the near future. Once the Southeast Asian region moves away from fossil fuel-based energy cooperation, diversification of renewable energy sources will be the key aspect of grid stability and reliability of power supply.

References

Aalto, P. (2014), 'Energy Market Integration and Regional Institutions in East Asia', *Energy Policy*, 74: pp.91–100.

Abrell, J. and S. Rausch (2016), 'Cross-Country Electricity Trade, Renewable Energy and European Transmission Infrastructure Policy', *Journal of Environmental Economics and Management*, 79, pp.87–113.

Alama, F., S. Khondkar, A. Quamrul, M. Israt, C. Harun, and R. Jazara (2018), 'Dependence on Energy in South Asia and the Need for a Regional Solution', *Energy Procedia*, 160, pp.26–33.

Andrews-Speed, P. (2016), 'Applying Institutional Theory to the Low-Carbon Energy Transition', 9 April 2022. https://doi.org/10.1016/j.erss.2015.12.011.

Andrews-Speed, P. and A. Hezri (2013), 'Institutional and Governance Dimensions of ASEAN Energy Market Integration', 2 March, 2022. http://www.asean-aemi.org/wp-content/uploads/2013/09/AEMI-Working-Paper-Institutional-and-governance-dimensions-of-ASEAN-Energy-Market-Integration.pdf.

Anbumozhi, V., I. Kutani, and M.P. Lama (2019), *Energising Connectivity between Northeast India and its Neighbours*. 17 March 2022.

https://www.eria.org/uploads/media/ERIA_Book_Energising_Connectivity_Northeast_India (NER)_2019.pdf.

Asian Development Bank (ADB) (2017), *Bhutan Green Power Development Project*. 8 June, 2022. https://www.adb.org/sites/default/files/project-documents/37399/37399-013-pcr-en.pdf.

Asian Development Bank (ADB) (2018), *South Asia Subregional Economic Cooperation Regional Energy Cooperation: Technical Assistance Report*. 9 June, 2022. https://www.adb.org/projects/documents/reg-52070-001-tar.

Asian Development Bank (ADB) (2019), *Sri Lanka Energy Sector Assessment, Strategy and Road Map*. 13 September, 2022. https://www.adb.org/sites/default/files/institutional-document/547381/sri-lanka-energy-assessment-strategy-road-map.pdf.

Asian Development Bank (ADB) (2020), *A Brighter Future for Maldives Powered by Renewables: Roadmap for energy sector 2020-2030.* 15 September 2022. http://dx.doi.org/10.22617/TCS200355-2.

ANI (2022), 'Nepal Plans to Buy 365 MW Power from India to Meet Winter Demands,' *ANI*. 15 November. 14 December, 2022. https://www.aninews.in/news/world/asia/nepal-plans-to-buy-365mw-power-from-india-to-meet-winter-demands20220922183245/.

ASEAN Centre for Energy (2017), *The 5th ASEAN Energy Outlook 2015-2040 (AEO5).* 19 July 2022. https://asean.org/wp-content/uploads/2021/08/5th-ASEAN-Energy-Outlook-AEO5.pdf.

ASEAN Centre for Energy (2020), *ASEAN Plan of Action for Energy Cooperation (APAEC) 2016-2025 Phase II*. 20 July 2022. https://aseanenergy.org/asean-plan-of-action-for-energy-cooperation-apaec-phase-ii-2021-2025/

Banik, A. and P.K. Bhaumik (2014), '*Assessing the Barriers to Trade in Services in South Asia*'. 21 April 2022. https://www.researchgate.net/publication/228240991_Assessing_the_Barriers_to_Trade_in_Services_in_South_Asia

Chen, G. (2022), 'An Integrated Electricity Market in South Asia is Key to Energy Security,' 22 November, 2022. https://blogs.worldbank.org/endpovertyinsouthasia/integrated-electricity-market-south-asia-key-energy-security#:~:text=A%20more%20deeply%20integrated%20power,importers%20and%20revenues%20for%20exporters

Chepeliev, M. (2019). *GTAP-Power 10 Data Base: A Technical Note*. 3 August 2022. https://www.researchgate.net/profile/Maksym-Chepeliev/publication/340285613_GTAP-Power_10a_Database_a_Technical_Note/links/5e827c1d299bf1a91b8d082d/GTAP-Power-10a-Database-a-Technical-Note.pdf

Central Electricity Authority (CEA) (2021), *Annual Report 2020-21*. 14 September, 2022. https://cea.nic.in/wp-content/uploads/notification/2021/12/CEAAnnualReport_final.pdf.

ECA (2009), 'Economic Consulting Associates. 2009. The Potential of Regional Power Sector Integration: South African Power Pool Transmission and Trading Case Study,' Energy Sector Management Assistance Program (ESMAP). Brief note 004/10. Washington, DC: World Bank. 10 November, 2022. https://openknowledge.worldbank.org/entities/publication/1770b484-20d3-59ca-8f79-09143ba9e8d9 License: CC BY 3.0 IGO.

ECA (2010), 'Economic Consulting Associates. 2010. The Potential of Regional Power Sector Integration: South East Europe Transmission and Trading Case Study,' Energy Sector Management Assistance Program (ESMAP). Brief note 004/10. Washington, DC: World Bank. 15 July 2022. https://openknowledge.worldbank.org/entities/publication/aa61b66f-c3e9-5e08-8de6-16d1ad61ca71 License: CC BY 3.0 IGO.

Effendi, Y. and B. Resosudarmo (2020), 'Development of Renewable Energy in ASEAN Countries: Socioeconomic and Environmental Impacts', 11 April, 2022. *Asia-Pacific Journal of Regional Science*, 6, pp.247–66.

ESCAP (2018), *Integrating South Asia's Power Grid for a Sustainable and Low Carbon Future.* 21 September, 2022. https://www.unescap.org/resources/integrating-south-asia-s-power-grid-sustainable-and-low-carbon-future.

ESCAP (2022), *Energy Pathways for the 2030 Agenda, SDG 7 Roadmap for Bhutan*. 29 September, 2022. https://www.unescap.org/sites/default/d8files/knowledge-products/0512SDG7%20Roadmap%20for%20Bhutan_Web_Final%2013%20May%202022.pdf

Huda M.S. and M. McDonald (2016), 'Regional Cooperation on Energy in South Asia: Unravelling the Political Challenges in Implementing Transnational Pipelines and Electricity Grids'. 9 May, 2022. https://www.researchgate.net/publication/307878639_Regional_cooperation_on_energy_in_South_Asia_Unraveling_the_political_challenges_in_implementing_transnational_pipelines_and_electricity_grids.

Hossen, A. (2021), *Circular Economy: A Potential Pathway to a Sustainable Bangladesh*. 16 February, 2022. *The Daily Star*. https://www.thedailystar.net/opinion/news/circular-economy-potential-pathway-sustainable-bangladesh-2045333.

IAEA (2021), *Planning for a Sustainable Future: Energy Experts in Latin America and Caribbean Analyse Future Demand, with IAEA Support*. 8 December, 2022. https://www.iaea.org/newscenter/news/planning-for-a-sustainable-future-energy-experts-in-latin-america-and-caribbean-analyse-future-demand-with-iaea-support.

IEA (2019), *International Energy Agency Southeast Asia Energy Outlook 2019*. 12 December, 2022. https://www.iea.org/reports/southeast-asia-energy-outlook-2019.

IEA (2022), *International Energy Agency South-East Asia Energy Outlook 2022*. 12 December, 2022. https://www.iea.org/reports/southeast-asia-energy-outlook-2022/key-findings.

IRENA (2013), *Regional Initiatives West Africa Clean Energy Corridor (WACEC)*. 14 December, 2022. https://www.irena.org/Energy-Transition/Country-engagement/Regional-Initiatives/West-Africa-Clean-Energy-Corridor.

Jayaram, N. (2016), *Failure of Institutionalised Cooperation in South Asia*. 11 November, 2022. https://mantraya.org/failure-of-institutionalised-cooperation-in-south-asia/.

Javed, A. (2019), *South Asia's Services Trade: Barriers and Prospects for Integration*. 15 November, 2022. https://www.ijmae.com/article_114651_fb0c0c544c46ca6ae6c83babca57e8fa.pdf.

Kathmandu Post (2022), *Electricity authority may scrap bid to buy power from India under six-month deal.* 6 November, 2022. https://kathmandupost.com/national/2022/11/06/electricity-authority-may-scrap-bid-to-buy-power-from-india-under-six-month-deal

Kathuria, S. (2018), *A Glass Half Full: The Promise of Regional Trade in South Asia.* South Asia Development Forum. Washington, DC: World Bank. 18 February, 2022. https://openknowledge.worldbank.org/entities/publication/3a4a1a79-a5bb-52e5-bee4-8073bbf4f80f License: CC BY 3.0 IGO.

Kaushik, S. (2015), *Picture Trade: How We Can Visualise Intra-Regional Trade in South Asia and Beyond*. 12 May, 2022. https://blogs.worldbank.org/trade/picture-how-we-can-visualize-intra-regional-trade-south-asia-and-beyond.

Kuensel (2022), 'Infrastructure Development in Jigmeling Industrial Estate to Complete by December.' 4 October, 2022. https://kuenselonline.com/infrastructure-development-in-jigmeling-industrial-estate-to-complete-by-december/.

Kutani, I. and Y. Li (2014), 'Investing in Power Grid Interconnection in East Asia,' *ERIA Research Project Report,* No. 23. Jakarta: ERIA.

Manzoor, R., A. Maken, V. Ahmed, and A. Javed (2019), 'Reforming Trade and Transport Connectivity,' *Sukkur Journal of Management and Business,* 6(1), pp.45–65.

Maqbool, A., M.W.A. Chattha, and M. Azeem (2007), *Challenges and Opportunities for Pakistan under SAFTA*. 28 March 2022, https://www.gtap.agecon.purdue.edu/resources/download/2977.pdf.

McCartney, M. and J. Brunner (2020), 'Improved Water Management Is Central to Solving the Water-Energy-Food Trilemma in Lao-PDR', *International Journal of Water Resources Development*. 21 July, 2022. https://www.researchgate.net/publication/342189770_Improved_water_management_is_central_to_solving_the_water-energy-food_trilemma_in_Lao_PDR.

Mehrad, A.T. (2021), 'Assessment of Solar Energy Potential and Development in Afghanistan', *E3S Web Conf. 239 00012*. 10 August, 2022. https://www.e3s-conferences.org/articles/e3sconf/pdf/2021/15/e3sconf_icren2021_00012.pdf.

Milina, V. (2007), 'Energy Security and Geopolitics,' *Connections* 6(4), pp.25–44.

Ministry of Power (MoP) (2022), *Annual Report 2021–22*. New Delhi: Government of India.

Montmasson-Clair, G. and B. Deonarain (2017), *Regional integration in South Africa: A platform for electricity sustainability*. 21 September, 2022. https://unctad.org/system/files/non-official-document/unda1617ld02_electricity_SA_en.pdf.

Murshed, M. (2020), *An empirical analysis of the non-linear impacts of ICT-trade openness on renewable energy transition, energy efficiency, clean cooking fuel access and environmental sustainability in South Asia*. 28 September, 2022. https://link.springer.com/article/10.1007/s11356-020-09497-3.

Murshed, M. (2021), 'Can Regional Trade Integration Facilitate Renewable Energy Transition to Ensure Energy Sustainability in South Asia?', *Energy Reports,* 7, pp.808–21.

Nangia, R. (2019), 'Securing Asia's Energy Future with Regional Integration', *Energy Policy,* 132, pp.1262–73.

National Bureau of Asian Research (NBR) (2022), *Transforming Regional Electricity Markets in South and Southeast Asia for a Greener and More Sustainable Future*. 4 January, 2023. https://www.nbr.org/wp-content/uploads/pdfs/publications/panda-dec22.pdf.

Nayek, S. (2022), Harnessing the potential of Indo-Nepal partnerships in hydropower; ORF. 26 November 2022 https://www.orfonline.org/research/harnessing-the-potential-of-india-nepal-partnerships-in-hydropower/.

Power System Operation Corporation Limited (POSOCO) Monthly Reports, Various Months 2018-19 to 2022-23. 21 March, 2023. https://posoco.in/reports/monthly-reports/

REN21 (n.d.), *Renewables 2022 Global Status Report*. 12 August 2022 https://www.ren21.net/gsr-2022/.

Reuters (2021), 'India Power Demand Falls for First Time in 35 Years,' *Reuters*, April 1. 23 February, 2023. https://www.reuters.com/article/india-electricity-idUSKBN2BO49Z.

S&P Global (2021), *South Asia regional power market: Moving towards market-based electricity trade*. India-Nepal: Commodity Insights. 9 February, 2023. https://www.spglobal.com/commodityinsights/en/ci/research-analysis/south-asia-regional-power-market-moving-towards-marketbased.html.

SAPP (2021), *South African Power Pool 'Energising the SADC region for economic development' 2021 Annual Report*. 14 September, 2022. https://www.sapp.co.zw/sites/default/files/Full%20Report%20SAPP.pdf.

Schmitter, P.C. (1970), 'Central America Integration: Spill-Over, Spill-Around or Encapsulation', *Journal of Common Market Studies,* 9(1), pp.1–48.

Shah, M.I. (2020), 'Investigating the Role of Regional Economic Integration on Growth: Fresh Insights from South Asia' *Global Journal of Emerging Market Economies*, 13(1), pp.35–57.

Singh, S. (2022), 'India Keeps Renewables Target Flexible, Goal of 500 GW Green Energy by 2030 Dropped,' *The Economic Times*, August 5 2022, https://economictimes.indiatimes.com/industry/renewables/india-keeps-renewables-target-flexible-goal-of-500-gw-green-energy-by-2030-dropped/articleshow/93357477.cms.

Sridharan, K. (2007), *Regional Cooperation in South Asia and Southeast Asia*. Singapore: ISEAS.

Srinivasan, T.N. (1994), 'Regional Trading Arrangements and Beyond: Exploring Some Options for South Asia, Theory, Empirics, And Policy'. *Report No. IDP-142*, Office of the Chief Economist, South Asia Region, World Bank.

Srinivasan, T.N. and G. Canonero (1995), *Preferential Agreements in South Asia: Theory, Empirics and Policy*. Yale Growth Centre, Yale University.

Straits Times (2022), *Singapore begins importing renewable energy from Laos via Thailand, Malaysia*. 30 June 2022. https://www.straitstimes.com/singapore/environment/singapore-begins-importing-renewable-energy-from-laos-via-thailand-malaysia.

Surendra, K.C., S.K. Khanal, P. Shrestha, and B. Lamsal (2010), 'Current Status of Renewable Energy in Nepal: Opportunities and Challenges,' *Renewable and Sustainable Energy Reviews,* 15(8), pp.4107–17.

UNESCAP (2017), *Unlocking the Potential of Regional Economic Cooperation and Integration in South Asia Potential, Challenges and the Way Forward*. 22 June 2022. https://www.unescap.org/sites/default/files/publications/UNESCAP_RECI%20Report_0_Sep2018.pdf.

UNESCAP (2018), *Integrating South Asia's Power Grid For a Sustainable and Low Carbon Future*. 25 June 2022 https://www.unescap.org/sites/default/files/Integrating%20South%20Asia%E2%80%99s%20Power%20Grid%20for%20a%20Sustainable%20and%20Low%20Carbon%20Future_WEB.pdf.

USAID (2005), *South Asian Free Trade Area: opportunities and challenges*. Washington, DC: USAID.

U.S. Energy Information Agency (2020), *International Energy Statistics*. 2 December 2022. https://www.eia.gov/international/data/world.

VIF (2022), *Future of Hydropower Cooperation in Bhutan*. 22 September 2022. https://www.vifindia.org/print/10159.

Wijayatunga, P. and P.N. Fernando (2013), 'An Overview of Energy Cooperation in South Asia', *South Asia Working Paper Series.* 22 July, 2022. https://www.adb.org/sites/default/files/publication/30262/overview-energy-cooperation-south-asia.pdf.

World Bank (2018), *Regional Power Trade in West Africa Offers Promise of Affordable, Reliable Electricity*. 20 November 2022. https://www.worldbank.org/en/news/feature/2018/04/20/regional-power-trade-west-africa-offers-promise-affordable-reliable-electricity.

World Bank (2020a), *Regional Electricity Trade, Key to Unleashing West Africa's Power*. 18 November 2022. https://blogs.worldbank.org/energy/regional-electricity-trade-key-unleashing-west-africas-power?cid=eae_tt_energy_en_ext.

World Bank (2020b), *The Economic Impact of Covid-19 on South Asia*. World Bank. 18 November 2022 https://www.worldbank.org/en/news/press-release/2023/02/16/covid-19-s-impact-on-south-asia-s-youth-could-last-generations#:~:text=The%20World%20Bank's%20pandemic%20response,for%2015%20health%20projects%2C%20%242.80.

World Bank (2022a*), Putting Africa on the Path to Universal Electricity Access*. 19 November 2022. https://blogs.worldbank.org/energy/putting-africa-path-universal-electricity-access.

World Bank (2022b), *An Integrated Electricity Market in South Asia Is Key To Energy Security*. 24 November 2022. https://blogs.worldbank.org/energy/putting-africa-path-universal-electricity-access.

Zhang, F. (2019). *In the Dark*. Washington, DC: World Bank.

Annex 1

Case Studies on Regional Energy Cooperation

Case Study 1: Regional Energy Trade and Cooperation in Southeast Asia

The Association of Southeast Asian Nations (ASEAN) is a strong and active regional cooperation consisting of Brunei Darussalam, Cambodia, Indonesia, Myanmar, Lao People's Democratic Republic (Lao PDR), Malaysia, the Philippines, Singapore, Thailand, and Viet Nam. The World Bank estimates that ASEAN is expected to grow collectively by over 5% per year to become the world's fourth-largest economy by 2030. Similarly, the ASEAN Centre of Energy (2017) has predicted that energy demand in the region will increase by more than 70% between 2020 and 2040. The demand will be largely driven by the growing ownership of household appliances and air conditioners. Of the region's 10 countries, the four largest by electricity consumption are Indonesia (26%), Viet Nam (22%), Thailand (19%), and Malaysia (15%). They make up more than 80% of the total demand in the region.

ASEAN has been working toward regional electricity interconnectivity through an ASEAN Power Grid (APG) since 1997. The development of the APG was planned to commence with cross-border bilateral connections and subsequently expand to greater levels of multilateral integration. The ASEAN Plan of Action for Energy Cooperation 2016–2025 (ASEAN Centre for Energy, 2020) sets objectives for moving toward regional connectivity. It prioritises the expansion of multilateral power trade as part of the ASEAN Economic Community 2025 agenda. As of 2020, the ASEAN region had 282 GW of power-installed capacity. The three dominant economies (Indonesia, Viet Nam, and Thailand) accounted for much of the total coal (31.4%), gas (30.9%), and hydro (20.9%), and contributed more than 80% of the total power-installed capacity of all ASEAN countries (NBR, 2022). The largest net importer is Thailand, with net electricity imports of 23.4 TWh in 2017, while the largest current electricity exporter is Lao PDR, which exported 21.3 TWh in 2017, which is 80% of its overall electricity generation (US Energy Information Agency, 2020). Thailand has the potential to become a major regional electricity trading hub by transmitting electricity from Lao PDR and Myanmar to Malaysia and Singapore.

In ASEAN, both bilateral and multilateral approaches to trade have been undertaken. Most cross-border electricity trade has been based on bilateral contracts involving unidirectional flows. Only one multi-country project has commenced: a still relatively small pilot involving Lao PDR, Thailand, and Malaysia that started at 100 MW in 2018 and was expanded to 300 MW in 2020. Under this arrangement, Lao PDR exports electricity to Malaysia via Thailand, with a wheeling method being used for determining the revenues going to Thailand. In 2022, this project was extended to include Singapore, which plans to commence 100 MW of power imports from Lao PDR (Straits Times, 2022).

Under a bilateral approach, trade occurs between two jurisdictions. Bilateral trade can be unidirectional (such as Thailand importing from Lao PDR) or bidirectional (such as the two-way power trade that exists between Lao PDR and Viet Nam). ASEAN has a long history of facilitating cross-border electricity transmission, with imports by Thailand from Lao PDR starting in 1971, while imports by Lao PDR from Thailand date back to the 1990s. Cambodia has been importing from Lao PDR since 2010, from Thailand since 2009, and from Viet Nam since 2008.

Multilateral trade involves several or more jurisdictions. The Lao PDR-Thailand-Malaysia-Singapore Power Integration Project is currently serving as a 'pathfinder' project for multilateral trading. Malaysia purchases power from Lao PDR under set terms on price and quantity, and Thailand acts as a wheeling country that allows the use of its energy grid for transmission between Malaysia and Lao PDR. This project has shown that energy trading among Southeast Asian countries is possible but can be expanded to be multidirectional and involve more than three countries. The Lao PDR-Thailand-Malaysia-Singapore Power Integration Project already includes a wheeling charge methodology that is applicable for a harmonised regional model. Over the last 15 years, trade has increased five-fold, and power exports from Lao PDR to Thailand have contributed a share in the trade of about 79% in 2019 (ASEAN Energy Outlook, 2020). Grid interconnection exists between Lao PDR and Thailand, Lao PDR and Viet Nam, Lao PDR and Cambodia, Thailand and Cambodia, Viet Nam and Cambodia, Peninsular Malaysia and Singapore, Thailand and Peninsular Malaysia, and Sarawak (Malaysia) and West Kalimantan (Indonesia). Myanmar, Lao PDR, and Viet Nam all have grid interconnections with China, which is a part of the Greater Mekong Subregion. As on April 2020, the ASEAN Power Grid had 7.7 GW of cross-border transmission interconnection CBTI capacity and in the future, its capacity is expected to increase to around 26–30 GW (NBR, 2022).

Most exported power from Lao PDR to Thailand, Cambodia, Myanmar, and Viet Nam is generated using coal and hydro sources (IEA, 2019). About 50 hydro dams were functional in Lao PDR during 2005–20 and about another 50 potential dams are in the pipeline (McCartney & Brunner, 2020). ASEAN has a high potential for solar and wind power generation for both domestic use and cross-border trade. The ASEAN region's renewable energy potential is 37.7 GW of biomass, 240 GW of hydro, 33.3 GW of geothermal, 8,119 GW of solar, and 342 GW of wind sources. There are also sizeable offshore and floating solar and wind opportunities (World Bank, 2019). ASEAN's electricity cooperation has followed its mode of governance, which is characterised by largely informal institutional cooperation with non-binding consequences (Aalto, 2014; Andrews-Speed & Hezri, 2013; Andrews-Speed, 2016). At meetings, governments often discuss and agree on general and easy points. Because regional power integration is viewed as a long-term process that goes far beyond the typical political cycle, complex issues about long-term projects are frequently delayed or remain unresolved (Nangia, 2019). Another situation, 'Spill-around', i.e. where little progress is accomplished through somewhat disorganised efforts, has been observed as opposed to substantial regional integration (Schmitter, 1970).

Case Study 2: Regional Energy Trade and Cooperation in South African Region

Lack of availability and access to electricity supply is one of the most significant challenges faced by most of South African countries. This is likely to hinder the economic and industrial development of the region. Regional economic collaboration such as the Southern African Development Community (SADC), which comprises 16 member states, has been trying to enhance the level, scale, and distribution of fuel- and electricity-based infrastructure projects across the member states in Southern Africa. The Energy Sector Plan as part of the SADC Regional Infrastructure Development Master Plan, aims to define the infrastructure requirements and conditions to facilitate the growth of energy, electricity, and other sectors by 2027 (Montmasson-Clair and Deonarain, 2017). Unfortunately, the traditional technique of electrification through grid expansion has not been effective in tackling the issue of energy poverty in rural areas of the Sub-Saharan Africa (SSA)/SADC region. Grid expansion involves high expenditures and long implementation times, indicating that remote locations would have to wait a longer time to get access to energy electricity. Because of SADC members' high suppressed demand and low electrification rate, strategies such as integration with other country grids, complementarity between various renewable sources, and distributed generation are seen as more appropriate to speed up regional rural electrification.

In this background, the South African Power Pool (SAPP) was created in August 1995 at the SADC summit held in Kempton Park, South Africa with the member nations (except Mauritius) signing the Memorandum of Understanding for the formation of a common electricity pool and a common regional market for electricity. The SAPP is a cooperation of the national electricity companies in Southern Africa under the purview of SADC. It has the vision of a fully integrated, competitive energy market and a provider of sustainable energy solutions for the SADC and beyond.

The SAPP also believes that it can be an initiative to improve the bilateral and multilateral relationships among the member nations. Through SAPP, the regional members can collaborate on sustainable development priorities, as well as coordinate the planning of thorough development of an electric power network. The need for the SAPP can be seen by the fact that only 5% of rural areas in Southern Africa have access to electricity. SAPP has the potential to significantly improve the existing status quo of energy access in the region, which has been fundamentally energy deficient, especially in the rural areas of the region. The SAPP was further integrated with the SADC's Regional Energy Access Strategy and Action Plan. It has commissioned a total of 22,907 MW of new generation capacity in the past 10 years from 2010 to 2020 against the planned new generation capacity of 30,092 MW for the same period, thus commissioning 8,168 MW less than what was planned. This is likely to address the lack of energy access by 50% in the next 10 years through the effective utilisation of regional energy resources as a means to reduce the proportion of people in the region without access to energy (SAPP, 2021). At present, SAPP comprises all twelve SADC member countries in the subcontinent, which includes Angola, Botswana, Democratic Republic of Congo, the Kingdom of Eswatini, the Kingdom of Lesotho, Malawi, Mozambique, Namibia, South Africa, Tanzania, Zambia, and Zimbabwe (the other SADC members are the island states of Comoros, Madagascar, Mauritius, and Seychelles). Nine of these countries are operating members that are part of the interconnected grid that carried out around 97% of the energy produced by the SAPP countries (ECA, 2009).

The bulk of the power is generated from coal-based capacity, which is concentrated in South Africa's Northern provinces, eastern Botswana, and western Zimbabwe. South Africa also has a nuclear power plant in the Western Cape and hydro in the Drakensberg Mountains. Electricity generation in the rest of the SADC countries is predominantly hydro-based, with power stations being located in the Zambezi Basin countries of Zambia, Zimbabwe, Mozambique, and Malawi, at Inga in the Congo, in central Angola, Northern Namibia, and Tanzania. The existing operational statistics (2009) give the following generation mix for SAPP: 74.3% coal, 20.1% hydro, 4% nuclear, and 1.6% diesel and gas (ECA,2009).

The trading arrangements between member countries have continued to operate predominantly under the pre-SAPP–type bilateral and multilateral contracts. SAPP's focus has thus been:

1. To improve the reliability and security of the existing regional grid.

2. To facilitate the expansion of the grid to connect non-operating members.

3. To introduce a short-term energy market (STEM) to facilitate the trading of surplus energy not committed under existing contracts.

4. To integrate the functionality of regulatory agencies (such as Renewable Energy for Rural Areas of Southern Africa, which includes eight regional operating members including ECB Namibia and ERB Zambia), with trans-national agencies (such as the World Bank, USAID, EU-ACP Energy Facility) for capacity building, information sharing, and facilitation of electricity sector policy, legislation, and regulation.

SAPP has made creditable strides in establishing mechanisms to encourage short-term trade. STEM that was developed and used over the period 2001–07 is a notable achievement. However, the statistics involved in STEM were always a small proportion of the region's total annual energy consumption, which is about 300,000 GWh in the interconnected grid. The reduction in STEM trading activities in 2007 and 2008 was due to power shortages and transmission constraints. STEM is currently being replaced by a fully competitive day-ahead market. But most of the electricity trade in the region will continue to be via long-term bilateral contracts. The introduction of the day-ahead market has been delayed because even before the implementation, there is an utmost need to ensure that all the members fully understand the way the market operates including details of market operation and how it will affect the long-term contracts.

The 2007 electricity crisis in South Africa triggered a new stage for regional energy cooperation with the transition of the regional hegemony from an exporter of low-cost electricity to an importer of power (Trade and Industrial Policy Strategies, UNCTAD). However, SADC has enormous renewable energy potential, and in the short term, it is critical to examine off-grid alternatives based on renewable energy system to increase electricity access throughout the member states. Hybrid systems that use more than one source of energy, such as diesel and solar or wind and solar, would improve the communities' energy capacity. To achieve the intended integration of the Renewable Energy System, SADC member states must investigate certain ways of dealing with variable renewables. Energy storage (e.g. reservoirs, batteries), demand-side management, grid interconnectivity and interoperability, and complementarity between renewable energy sources and distributed generation are among the techniques that need to be taken into consideration. Because of SADC members' high suppressed demand and low electrification rate, strategies such as integration with other grids, and complementarity between the renewable energy system and distributive generation are seen as more appropriate for creating short- and medium-term impact, which will enhance the region's electrification.

Case Study 3: Regional Energy Trade and Cooperation in West African Region

West Africa is mostly characterised by a rapidly expanding and scattered population with persistent poverty levels and a lack of access to affordable and clean energy. However, the provision of affordable clean energy can have a positive externality of economic growth, poverty reduction, and a general improvement in the quality of life of millions of people. Globally, West Africa has one of the lowest rates of power access including a lack of reliable electricity supply and even affordable cooking oil, with only around 42% of the total population and 8% of the rural population having access to electricity (World Bank, 2022a). The West Africa UN sub-region comprises the following countries: Benin, Burkina Faso, Cape Verde, Côte d'Ivoire, Gambia, Ghana, Guinea, Guinea-Bissau, Liberia, Mali, Mauritania, Niger, Nigeria, Senegal, Sierra Leone, and Togo. The energy sector in the area is characterised by unreliable and overpriced power supplies, limited rates of access to electricity, and an inability to recover the unbelievably high cost of supplying electricity. Access to electricity in West Africa is at 52% with shortages of up to 80 hours per month and yet electricity here remains among the costliest in the world (World Bank, 2018). West Africans pay nearly twice as much for energy as their neighbours on the eastern side of the continent, and costs can be as high as $0.40/kWh for those residing in the area's unstable countries (World Bank, 2020a).

West Africa has abundant energy resources. Over one-third of Africa's gas and oil deposits are located in this area, together with more than 23,000 MW of hydropower. However, distribution has been a serious issue because the primary electrical supply sources are not in the periphery of the major consumption areas. Different initiatives have been taken to increase the share of renewable energy in the region's overall electricity mix to around 48% in 2030; these include the West African Clean Energy Corridor coupled with Renewable Energy Policy (IRENA, 2013). The World Bank estimates that the integrated power trade in the region could save up to $5–8 billion per year by enabling countries to import cheaper electricity and increase affordable, reliable, and modern energy.

To solve the issues, the Economic Commission of West African States has been targeting a goal of a fully integrated regional power market, i.e. the West African Power Pool. Trade within the West African Power Pool might cut energy costs and boost power system resilience and reliability in the region by integrating nearby power systems and pooling energy resources. It is a vital component for enhancing energy availability in a region where many people rely on firewood and charcoal to meet their energy needs.

Phase I of the Inter-Zonal Transmission Hub Project of the West African Power Pool was supported by the International Development Association. The International Transmission Hub Project aims to enhance Ghana's energy export capacity and lower the cost of electricity supply to Burkina Faso. This was achieved through the installation of a transmission line connecting Bolgatanga, Ghana, Ouagadougou, and Burkina Faso. As a result, Ghana's capacity to export electricity has significantly increased. In Burkina Faso, electricity costs have decreased from $0.26/kWh to $0.20/kWh, and power disruptions have been reduced (World Bank, 2021). Access to electricity has also been improved in rural regions. The capacity to export electricity from Ghana can be further extended to Mali and Niger which can be greatly benefitted.

In future, IDA will continue to assist in the expansion of electrification across the West African Power Pool sub-region. This will facilitate improving energy access in the region and uplifting the livelihood of the households.

The economic benefits of the regional power market have been projected at $665 million per year, and the reduction in regional power outages would be equivalent to Togo's whole electricity usage (World Bank, 2018). The initiative has the potential to reduce the average cost of power generation in the region by one-third, along with a reduction of electricity cost disparity across countries. The region's small and energy-constrained states, particularly Liberia, Sierra Leone, Gambia, Guinea-Bissau, Burkina Faso, Niger, and Mali, would be among the biggest beneficiaries of the regional energy market.

Case Study 4: Regional Energy Trade and Cooperation in Latin America

From 1980 to 2000, South America pioneered the reform of the power sector and the creation of competitive electricity markets. The process started in Chile, which introduced an electricity sector framework in 1982 to increase competition in generation and encourage open access to transmission. Argentina incorporated similar reforms with a new electricity law that came into force in 1992, followed shortly thereafter by similar moves in Peru, Colombia, and Bolivia. Brazil and Venezuela took longer to follow this model and only made initial regulatory changes in 1997.

The Garabi project, planned during the 1990s as a part of this movement in South America, was influenced by the liberalisation of economies, reform of electricity sectors, and the movement toward the promotion of energy exchanges driven by market rules. The energy reforms were also driven by a need to maintain the momentum of economic growth while easing the pressure on government resources. Private investment in electricity took place not just in generation and distribution, but also in transmission, including three private regional interconnector projects: Argentina-Chile, Bolivia-Brazil, and Argentina-Brazil (Garabi Project).

The Garabi project connects the 50 Hz Argentine system to the 60 Hz Brazilian network via two 1,000 MW transmission lines and inverter stations. With the support of the two governments, the Garabi project was planned, promoted, and implemented by private-sector interests led by the Spanish-based electricity company: Endesa. In April 1997, the Governments of Argentina and Brazil signed an agreement to facilitate cross-border energy trading between the two countries. In early 1998, Endesa registered a special-purpose company called Companhia de Interconexão Energética (CIEN) in Brazil. In May 1998, the Brazilian Ministry of Mines and Energy and the Argentine Government signed a 20-year contract with CIEN. As per the contract, Brazil will import 1,000 MW from the wholesale energy market in Argentina. At the time, it was estimated that Argentina had nearly 7,000 MW of surplus capacity that could be exported to Brazil if appropriate transmission systems were in place (ECA, 2010).

The Garabi project was designed to solve the problems of electricity supply in Brazil during the drought months. In the late 1990s and through 2001, Brazil was facing a serious electricity supply crisis due to low rainfall. It was reducing water availability in reservoirs and, thus, limiting the hydro potential of the country. In 2001, rainfall was less than 75% of expected levels, which led to the imposition of an energy rationing system. While hydroelectricity is an excellent source of affordable electricity, it is subject to fluctuations in hydrological flow. The situation in Brazil highlighted the internal shortcomings of the energy market in which the government still owned about 75% of generating assets but had not adequately invested in the sector. To overcome the shortfall, Brazil decided to import power from Argentina during this phase. As Argentina was powered mostly by gas-fuelled power plants, the fluctuations in the hydrological flows had a negligible effect on its power generation potential. It could, thus, cater to the power needs of Brazil during the dry months.

Similarly, Argentina's power sector contains fuelled plants, which are immune to seasonal problems induced by hydrological fluctuations. However, the cost of power generation through gas-fuelled plants, compared to hydroelectric plants, is significantly higher. During the winter months, the energy demand in Argentina is much higher, and importing hydroelectric power during these periods is more viable and efficient than ramping up expensive gas-fuelled energy production. The timing of the high hydro season in Brazil coincides with these colder winter months in Argentina; thus, it is beneficial for Brazil to export hydroelectricity at a time when Argentina would welcome means to reduce the gas demand. If the full capacity of Garabi were to be used, Brazil could export 2,000 MW during the four winter months, thereby displacing about 10 million m^3/day of gas in Argentina. Brazil in turn would be able to import 1,000 MW during the remaining 8 months (ECA, 2010).

Imports from Argentina via Garabi helped alleviate Brazil's energy shortfall in the first few years after it was operational. Counterfactually, rather than fulfilling the regional role of being a major exporter of gas and gas-based electricity, Argentina became an energy-deficit country. The government first restricted gas exports to both Chile and Brazil and later (in 2004) introduced a regulation that forbade the export of electricity generated in Argentina with Argentine gas. As a result, the surplus gas and electricity capacity in Argentina eroded after the crisis and the underlying rationale for Garabi became redundant and then formally stopped when Argentina banned exports of domestically produced electricity to its neighbours. Instead, Argentina has sought to import power to supplement its inadequate domestic supplies. As a result, the power flows through the Garabi system have predominantly been from Brazil to Argentina, and not in the reverse direction, as had originally been planned. Power has also been routed from Brazil via Garabi to Uruguay, taking advantage of the high-capacity 60 Hz-to-50 Hz converter station.

The Garabi hydropower project is one of a series of potential projects that Brazil is studying to increase its electrical generation capacity. Two problems are likely to keep the Garabi project relatively low-priority. The first relates to the strenuously articulated objections of environmental groups, which are concerned that up to 33,000 hectares of inhabited land may be inundated and that the water supply downstream of the dam may be severely compromised. The second relates to the undermining of confidence in regional schemes resulting from the Argentine institutional default. Further complicating the issue is the fact that Garabi is not a Brazilian project, but a bi-national initiative that needs to be jointly developed by both countries.

The Garabi project is reflective of the South American region as a whole, which illustrates that the electricity sector in the region does not have any regional integration and is instead characterised by a series of bilateral generation and transmission projects. For the longer term, there is hope that the bilateral projects existing between Argentina, Brazil, Bolivia, Uruguay, Paraguay, and Chile will eventually evolve into the formation and establishment of a MERCOSUR regional energy market. Projections by the United Nations Department of Economic and Social Affairs state that by 2030, the Latin American and Caribbean region's population will increase to approximately 721 million, which would produce a corresponding growth in energy demand while ensuring conditions for sustainable development (IAEA, 2021). The growth in energy demand amid security concerns and trepidations for reducing climate impacts have made the Latin American and Caribbean countries rethink their energy policy.

Annex 2

Details of BBIN Electricity Trade

India, because of its large economy and central location, will play the most important role in the energy trade and cooperation in South Asian region. Due to the same reason, India is the major exporter and importer in the Bangladesh-Bhutan-India-Nepal (BBIN) network. In the BBIN network, electricity export from Bhutan and Nepal represents renewable energy trade while electricity export from India will also indicate renewable energy trade with full decarbonisation of Indian power sector. Recent monthly electricity trade though bilateral contracts and India Energy Exchange within the BBIN network through various routes are shown in Table A2.1 (import to India) and A2 (export from India).

Table A2.1. India's Monthly Electricity Import from Neighbouring Countries through Various Routes

		Bhutan									Nepal			
		400 kV Tala Binaguri I,II & IV	400 kV Binaguri Malbase	220 kV Birpara Chuka D/C	220 kV Birpara Malbase	400 kV Punat-sanchu Alipurd-war D/C*	400 kV Jigmeling Alipurd-war D/C	132 kV Rangia Motanga	132 kV Salakati Gelephu	Bhutan	132 kV Tanak-pur Mahendra -nagar	400 kV Muzaffar-pur Dhalke-bar	From BIHAR Source	Nepal
2022-23	Dec-22	81.46	36.6	2.42	0	0.03	0.06	1.88	0.15	122.6	0	14.61	0	14.61
	Nov-22	246.91	7.54	16.16	0.19	16.84	25.61	8.01	2.27	323.53	0	163.84	0	163.84
	Oct-22	408.39	128.76	95.59	15.32	79.84	206.45	24.97	12.65	971.97	0	264.98	0	264.98
	Sep-22	553.64	156.5	113.64	29.34	110.81	330.7	26.04	11.17	1,331.8	0	261.99	0	261.99
	Aug-22	542.26	191.03	118.66	20.79	127.23	324.77	26.03	9.93	1,360.7	0	240.44	0.07	240.51
	Jul-22	389.73	266.65	92.47	14.84	92.27	275.24	23.7	8.48	1,163.4	1.25	243.32	0	244.57
	Jun-22	276.65	265.3	100.82	11.04	100.51	254.78	9.69	1.98	1,020.8	0	189.03	0	189.03
	May-22	104.73	93.67	42.38	2.5	60.76	91.43	19.31	2.59	417.37	1.45	0	0	1.45
	Apr-22	112.56	92.93	35.66	1.4	52.13	94.01	11.47	1.96	402.12	0	0	0	0
2021-22	Mar-22	38.61	36.63	18.3	0.21	31.56	47.61	6.75	1.34	181.01	0	0	0	0
	Feb-22	0	0	0.45	0	10.89	8.7	0.74	0	20.78	0	0	0	0
	Jan-22	0.79	0	0	0	8.96	14.25	1.07	0	25.07	0	0	0	0
	Dec-21	85.48	55.66	9.98	0	23.91	37.44	2.41	1.54	216.42	0	0	0.9	0.9
	Nov-21	319.38	14.89	51.86	1.69	55.22	83.35	8.47	5.76	540.62	0	0	0	0

		Bhutan									Nepal			
		400 kV Tala Binaguri I,II & IV	400 kV Binaguri Malbase	220 kV Birpara Chuka D/C	220 kV Birpara Malbase	400 kV Punat-sanchu Alipurd-war D/C*	400 kV Jigmeling Alipurd-war D/C	132 kV Rangia Motanga	132 kV Salakati Gelephu	Bhutan	132 kV Tanak-pur Mahendra -nagar	400 kV Muzaffar-pur Dhalke-bar	From BIHAR Source	Nepal
	Oct-21	353.58	179.82	119.66	31.31	80.64	230.35	26.57	10.29	1,032.2	0	0	33.87	33.87
	Sep-21	403.68	202.21	136.97	39.93	125.89	376.52	31.19	17.72	1,334.1	0	0	6.75	6.75
	Aug-21	457.6	212.16	145.71	40.88	127.83	382.51	32.09	16.46	1,415.2	0	0	4.54	4.54
	Jul-21	377.44	192.17	150.69	45.24	116.29	348.13	33.45	18.77	1,282.2	0	0	0	0
	Jun-21	393.58	174.99	124.56	32.66	277.73	122.52	30.67	16.72	1,173.4	0	0	0.98	0.98
	May-21	164.46	97.49	63.54	8.28		245.47	20.95	3.12	603.31	0	0	0	0
	Apr-21	41.79	24.98	8.52	0.01		91.05	4.81	0.03	171.19	0	0	0	0
2020-21	Mar-21	38.49	24.12	2.94	0		88.59	3.77	0	157.91	0	0	0	0
	Feb-21	31.36	21.48	5.56	0		64.55	0.42	0	123.37	0	0	0	0
	Jan-21	44.96	34.36	7.54	0		83.33	0.83	0	171.02	0	0	0	0
	Dec-20	69.79	56.58	31.66	0		102.16	2.33	0	262.52	0	0	0.18	0.18
	Nov-20	239.16	5.58	47.49	0.73		142.38	14.28	5.16	454.78	0	0	0.13	0.13
	Oct-20	378.75	112.91	142	38.93		284.47	36.12	25.29	1,018.5	0	0	0.21	0.21
	Sep-20	573.63	179.94	175.56	59.01		470.22	37.94	35.55	1,531.9	0	0	0.1	0.1
	Aug-20	592.61	189.87	183.31	60.98		542.93	36.01	39.21	1,644.9	0	0	2.88	2.88

		Bhutan									Nepal			
		400 kV Tala Binaguri I,II & IV	400 kV Binaguri Malbase	220 kV Birpara Chuka D/C	220 kV Birpara Malbase	400 kV Punat-sanchu Alipurd-war D/C*	400 kV Jigmeling Alipurd-war D/C	132 kV Rangia Motanga	132 kV Salakati Gelephu	Bhutan	132 kV Tanak-pur Mahendra -nagar	400 kV Muzaffar-pur Dhalke-bar	From BIHAR Source	Nepal
	Jul-20	596.86	189.06	180.67	53.9		531.37	39.64	33.85	1,625.4	0	0	0.19	0.19
	Jun-20	466.61	158.35	126.93	26.72		432.5	19.49	8.55	1,239.2	0	0	0	0
	May-20	295.75	88.83	98.13	7.7		307.28	25.45	11.33	834.47	0	1	0	1
	Apr-20	88.05	31.55	56.37	0		135	5.73	0	316.7	0	0	0	0
2019-20	Mar-20	31.66	18.35	11.21	0		81.81	1.09	0	144.12	0	1	3.5	4.5
	Feb-20	22.28	9.55	0	0		61.76	0	0	93.59	0	0	0	0
	Jan-20	41.55	23.65	0.73	0		75.46	0.55	0	141.94	0	1	0	1
	Dec-19	80.68	28.9	8.14	0		95.71	0.03	0	213.46	0	1	1.66	2.66
	Nov-19	130.62	55.93	44.54	0.29		126.69	7.08	4.57	369.72	0	0.29	0.27	0.56
	Oct-19	456.77	36.78	103.34	8.63		256.79	27.98	20.52	910.81	0	0.85	4.47	5.32
	Sep-19	544.14	161.85	127.37	35.17		339.36	29.92	34.04	1271.9	0	0	4.35	4.35
	Aug-19	558.74	161.99	144.06	48.08			39.1	30.8	982.77	0	0	0	0
	Jul-19	514.26	154.06	158.5	45.96			36.84	31.21	940.83	0.64	0	24.93	25.57
	Jun-19	182.76	65.6	64.33	5.01			27.17	7.38	352.25	0	0	0	0
	May-19	190.23	81.51	66.62	0			21.89	2.77	363.02	0	0	0	0

		Bhutan									Nepal			
		400 kV Tala Binaguri I,II & IV	400 kV Binaguri Malbase	220 kV Birpara Chuka D/C	220 kV Birpara Malbase	400 kV Punat-sanchu Alipurd-war D/C*	400 kV Jigmeling Alipurd-war D/C	132 kV Rangia Motanga	132 kV Salakati Gelephu	Bhutan	132 kV Tanak-pur Mahendra -nagar	400 kV Muzaffar-pur Dhalke-bar	From BIHAR Source	Nepal
	Apr-19	132.5	81.46	44.4	0			10.82	0.36	269.54	0	0	0	0
2018-19	Mar-19	47.67	30.88	10.17	0			2.28	0	91	0	0		0
	Feb-19	28.61	17.6	9.43	0			0.47	12.59	68.7	0	0		0
	Jan-19	32.91	20.54	0	0			0.1	0	53.55	0	0		0
	Dec-18	78.63	6.83	2.6	0			1.47	0	89.53	0	0		0
	Nov-18	154.55	11.71	14.88	0.03			11.81	1.81	194.79	0	64.42		64.42
	Oct-18	175.68	74.63	67.07	8.85			20.23	15.58	362.04	0	72.06		72.06
	Sep-18	461.05	156.9	157.13	48.34			37.46	31.89	892.77	0	0		0
	Aug-18	584.73	175.01	170.69	48.73			37.32	31.07	1,047.6	0	0		0
	Jul-18	558.23	185.63	163.49	48.59			39.3	29.4	1,024.6	0	0		0
	Jun-18	241.25	96.4	96	14.63			0	12.18	460.46	0	0		0
	May-18	148.44	74.67	58.4	5.29			0	3.14	289.94	0	0		0
	Apr-18	47.99	17.08	4.87	0			11.16	0.14	81.24	0	0		0

Source: POSOCO Monthly Reports, Various Months, 2018–19 to 2022–23.

Table A2: India's Monthly Electricity Export to Neighbouring Countries through Various Routes

		Bhutan									Bangladesh			Nepal			
		400 kV Tala Binaguri I,II & IV	400 kV Binaguri-Malbase	220 kV Birpara-Chuka D/C	220 kV Birpara-Malbase	400 kV Punat-sanchu Alipurd-war D/C*	400 kV Jigme-ling Alipurdwar D/C	132 kV Rangia Motan-ga	132 kV Salakati Gelephu	Bhutan	400 kV Behram-pur Bhera-mara D/C	132 kV Surjyam ani-nagar Comilla D/C	Bangla-desh	132 kV TanakpurMahendranagar	400 kV MuzaffarpurDhalkebar	From BIHAR Source	Nepal
2022-23	Dec-22	0	7.38	4.01	25.92	9.26	13.76	1.35	5.04	66.72	591.98	67.04	659.02	30.37	52.48	7.8	90.65
	Nov-22	0	38.73	0.03	25.29	0	0	0.11	0.07	64.23	594.43	77.84	672.27	0	0	0	0
	Oct-22	0	0	0	0	0	0	0	0	0	663.92	98.04	761.96	2.21	0	0.01	2.22
	Sep-22	0	0	0	0	0	0	0	0.14	0.14	654.02	96.8	750.82	10.95	0	0.2	11.15
	Aug-22	0	0	0	0	0	0	0	0	0	677.47	105.75	783.22	25.01	0	1.29	26.3
	Jul-22	0	0	0	3	0	0	0	0	3	596.52	91.1	687.62	27.91	0	4.3	32.21
	Jun-22	0	0	0	1.03	0	0	0.01	0	1.04	660.29	84.17	744.46	43.18	0	11.28	54.46
	May-22	0	0	0	3.99	0	0	0	0.58	4.57	658.48	73.5	731.98	40.82	90.63	12.41	143.86
	Apr-22	0	0	0	8.42	0	0	0.49	2.42	11.33	661.79	101.39	763.18	37.49	124.95	88.92	251.36
2021-22	Mar-22	0	21.33	2.43	19.26	0	0	0.34	3.26	46.62	563.73	85.72	649.45	44.25	141.91	110.58	296.74
	Feb-22	0	41.75	8.95	33.16	0	0	2.69	6.34	92.89	474.79	59.06	533.85	46.17	177.66	67.45	291.28
	Jan-22	0	51.99	3.41	36.17	0	0	0.8	4.34	96.71	478.27	62.21	540.48	49.22	162.22	56.39	267.83
	Dec-21	0	0	0.01	12.4	0	0	0.72	0.2	13.33	396.73	57.64	454.37	6.12	65.8	25.11	97.03

		Bhutan									Bangladesh			Nepal			
		400 kV Tala Binaguri I,II & IV	**400 kV Binaguri-Malbase**	**220 kV Birpara-Chuka D/C**	**220 kV Birpara-Malbase**	**400 kV Punatsanchu Alipurdwar D/C***	**400 kV Jigmeling Alipurdwar D/C**	**132 kV Rangia Motanga**	**132 kV Salakati Gelephu**	**Bhutan**	**400 kV Behrampur Bheramara D/C**	**132 kV Surjyamaninagar Comilla D/C**	**Bangladesh**	**132 kV TanakpurMahendranagar**	**400 kV MuzaffarpurDhalkebar**	**From BIHAR Source**	**Nepal**
	Nov-21	0	19.86	0	16.17	0	0	0	0	36.03	476.96	65	541.96	0.01	–43.09	0	–43.08
	Oct-21	0	0	0	0	0	0	0	0	0	533.52	89.3	622.82	1.71	–37.95	0.07	–36.17
	Sep-21	0.02	0	0	0	0	0	0	0	0.02	518.83	86.53	605.36	5.2	–24.56	2.93	–16.43
	Aug-21	0	0.07	0	0	0	0	0	0	0.07	505.82	92.36	598.18	15.51	–13.81	14.22	15.92
	Jul-21	0.01	0.04	0	0	0	0	0	0	0.05	581.48	84.34	665.82	37.14	82.43	43.73	163.3
	Jun-21	0	0	0	0	0	0	0	0	0	638.44	83.14	721.58	35.67	120.15	39.32	195.14
	May-21	0	0	0	7.3	0	0	0	7.31	14.61	627.17	98.81	725.98	43.01	158.26	77.02	278.29
	Apr-21	0	0	0.46	12.8	0	0	0.13	7.35	20.74	570.53	96.66	667.19	45.46	239.19	200.8	485.45
2020-21	Mar-21	0	0.25	1.01	19.83	0	0	1.47	15.19	37.75	564.27	98.42	662.69	43.05	235.18	162.36	440.59
	Feb-21	0	0	0.47	16.89	0	0	6.88	12.46	36.7	455.63	60.62	516.25	47.81	190.03	145.5	383.34
	Jan-21	0	0	0	18.88	0	0	3.41	12.26	34.55	473.26	62.06	535.32	49.73	196.41	134.86	381
	Dec-20	0	0	0	15.93	0	0	0.88	6.41	23.22	374.89	60.81	435.7	36.61	155.86	55.75	248.22
	Nov-20	0	0.82	0	10.47	0	0	0	0.41	11.7	473.68	68.87	542.55	7.62	21.63	32.05	61.3

		Bhutan									Bangladesh			Nepal			
		400 kV Tala Binaguri I,II & IV	400 kV Binaguri-Malbase	220 kV Birpara-Chuka D/C	220 kV Birpara-Malbase	400 kV Punat-sanchu Alipurd-war D/C*	400 kV Jigme-ling Alipurdwar D/C	132 kV Rangia Motan-ga	132 kV Salakati Gelephu	Bhutan	400 kV Behram-pur Bhera-mara D/C	132 kV Surjyamani-nagar Comilla D/C	Bangla-desh	132 kV TanakpurMahendranagar	400 kV MuzaffarpurDhalkebar	From BIHAR Source	Nepal
	Oct-20	0	1.34	0	0	0	0	0	0	1.34	679.17	96.75	775.92	9.06	23.29	8.77	41.12
	Sep-20	0	0	0	0	0	0	0	0	0	669.35	106.46	775.81	12.68	37.32	8.3	58.3
	Aug-20	0	0	0	0	0	0	0	0	0	691.26	97.62	788.88	20.94	52.9	9.46	83.3
	Jul-20	0	0	0	0	0	0	0	0.95	0.95	681.64	98.59	780.23	15	19.59	14.06	48.65
	Jun-20	0	0	0	0	0	0	0	0	0	655.5	94.06	749.56	5.67	23.55	13.87	43.09
	May-20	0	2.57	0	17.11	0	0	0	0.47	20.15	494.78	88.84	583.62	2.57	7.95	10.27	20.79
	Apr-20	0	0	0	45.16	0	0	0.26	6.76	52.18	338.97	69.43	408.4	8.27	43.32	8.97	60.56
2019-20	Mar-20	0	0	2.68	34.7	0	0	6.24	7.05	50.67	385.56	79.23	464.79	28.26	147.47	62.25	237.98
	Feb-20	0	0	8.65	25.39	0	0	6.14	7.15	47.33	294.09	60.54	354.63	35.64	172.41	90.17	298.22
	Jan-20	0	0	2.96	22.34	0	0	5.36	8.63	39.29	229.48	61.66	291.14	37.04	180.72	75.37	293.13
	Dec-19	0	0	0.58	29.05	0	0	5.23	9.76	44.62	214.2	60.72	274.92	17.93	150.54	26.47	194.94
	Nov-19	0	0	0	20.61	0	0	0.14	1.66	22.41	401.71	74.52	476.23	6.51	11.32	19.13	36.96
	Oct-19	0	10.72	0	0.9	0	0	0	0	11.62	625.71	98.5	724.21	2.81	17.39	14.38	34.58
	Sep-19	0	0	0	0	0	0	0	0.75	0.75	641.9	108.11	750.01	7.39	122.08	20.89	150.36

		Bhutan									Bangladesh			Nepal			
		400 kV Tala Binaguri I,II & IV	400 kV Binaguri-Malbase	220 kV Birpara-Chuka D/C	220 kV Birpara-Malbase	400 kV Punat-sanchu Alipurd-war D/C*	400 kV Jigme-ling Alipurdwar D/C	132 kV Rangia Motan-ga	132 kV Salakati Gelephu	Bhutan	400 kV Behram-pur Bhera-mara D/C	132 kV Surjyamani-nagar Comilla D/C	Bangla-desh	132 kV TanakpurMahendranagar	400 kV MuzaffarpurDhalkebar	From BIHAR Source	Nepal
	Aug-19	0	0	0	0	0	0	0	0.75	0.75	639.21	110.09	749.3	10.55	129.63	40.58	180.76
	Jul-19	0	0	0	0	0	0	0	0	0	669.47	95.17	764.64	8.41	140.52	28.81	177.74
	Jun-19	0	0	0	2.45	0	0	0	0.02	2.47	603.77	104.09	707.86	15.09	157.12	93.68	265.89
	May-19	0	0	0	1.74	0	0	0	2.21	3.95	665.85	107.88	773.73	18.72	162.46	109.22	290.4
	Apr-19	0	0	0	11.76	0	0	0.1	5.7	17.56	567.5	85.55	653.05	17.91	153.04	75.03	245.98
2018-19	Mar-19	0.26	0.07	4.72	24.63	0	0	1.11	10.53	41.32	546.87	84.68	631.55	25.36	166.85		192.21
	Feb-19	0.31	0	1.98	34.58	0	0	1.31	0	38.18	425.45	64.13	489.58	23.4	159.89		183.29
	Jan-19	0.49	0	4.42	33.96	0	0	3.84	11.57	54.28	360.23	67.3	427.53	12.9	184.11		197.01
	Dec-18	0.41	8.35	2.84	33.58	0	0	0.86	11.8	57.84	353.32	63.65	416.97	12.9	152.09		164.99
	Nov-18	0	43.01	0	21.35	0	0	0.01	2.34	66.71	420.93	67.75	488.68	4.8	0		4.8
	Oct-18	0	0	0	1.93	0	0	0	0	1.93	525.96	85.94	611.9	6.73	0		6.73
	Sep-18	0	0	0	0	0	0	0	0	0	498.5	97.53	596.03	6.76	122.35		129.11
	Aug-18	0	0	0	0	0	0	0	0	0	363.86	101.08	464.94	6.86	55.01		61.87
	Jul-18	0	0	0	0	0	0	0	0	0	345.94	95.93	441.87	11.04	71.52		82.56

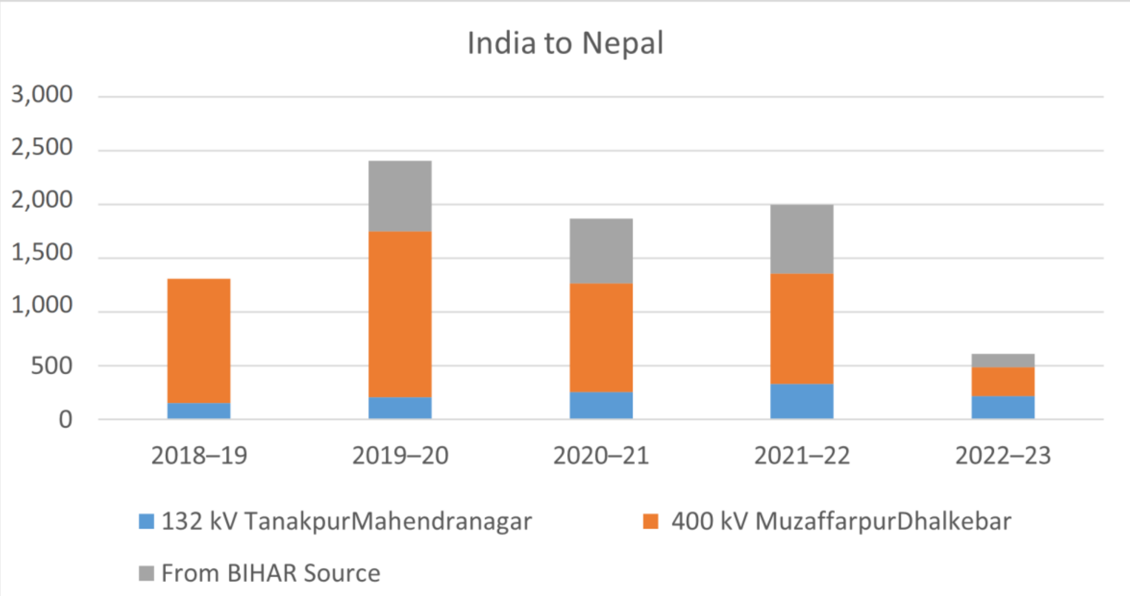
		Bhutan									Bangladesh			Nepal			
		400 kV Tala Binaguri I,II & IV	400 kV Binaguri-Malbase	220 kV Birpara-Chuka D/C	220 kV Birpara-Malbase	400 kV Punatsanchu Alipurdwar D/C*	400 kV Jigmeling Alipurdwar D/C	132 kV Rangia Motanga	132 kV Salakati Gelephu	Bhutan	400 kV Behrampur Bheramara D/C	132 kV Surjyamaninagar Comilla D/C	Bangladesh	132 kV TanakpurMahendranagar	400 kV MuzaffarpurDhalkebar	From BIHAR Source	Nepal
	Jun-18	0	0	0	0.61	0	0	29.65	0	30.26	326.04	100.13	426.17	12.35	72.63		84.98
	May-18	0.03	0	0	6.3	0	0	22.41	1.73	30.47	351.85	90.43	442.28	15.05	83.66		98.71
	Apr-18	0.29	0.49	0.96	20.97	0	0	0	6.78	29.49	198.54	86.13	284.67	17.62	84.91		102.53

Source: POSOCO Monthly Reports, Various Months, 2018–19 to 2022–23.

India-Nepal

Nepal is already involved in cross-border exchange of electricity, which includes both export and import with other South Asian countries, especially India. The annual electricity exports and imports between India and Nepal through various sources are shown in Figures A2.1 and A2.2, which indicate that, even though there is a necessity for expanding trade routes, Nepal has the potential to grow as a major export player in South Asia.

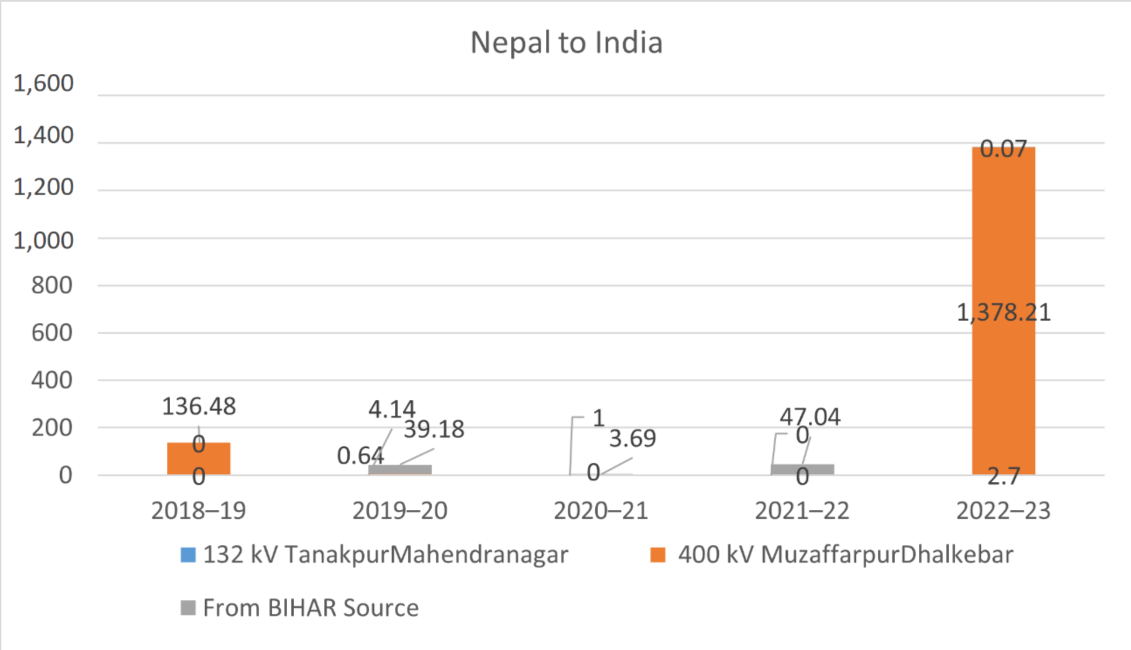
Figure A2.1. Annual Electricity Export from India to Nepal through Various Routes



Note: From BIHAR Source: Bihar being India-Nepal border state, in addition to 132 kV TanakpurMahendranagar and 400 kV MuzaffarpurDhalkebar lines, India-Nepal electricity trade is also conducted through Raxaul-Birgunj 33kV line to meet the load of Raxaul-Ramnagar and Birgunj areas.

Source: TERI Estimation based on POSOCO Monthly Reports, Various months, 2018–19 to 2022–23.

Figure A2.2. Annual Electricity Import of India from Nepal through Various Routes



Note: From BIHAR Source: Bihar being India-Nepal border state, in addition to 132 kV TanakpurMahendranagar and 400 kV MuzaffarpurDhalkebar lines, India-Nepal electricity trade is also conducted through Raxaul-Birgunj 33kV line to meet the load of Raxaul-Ramnagar and Birgunj areas.
Source: TERI Estimation based on POSOCO Monthly Reports, Various months, 2018–19 to 2022–23.

In 2014, India and Nepal signed an agreement on 'Electric Power Trade, Cross-border Transmission Interconnection and Grid Connectivity'. The two countries agreed to explore the development of a hydropower project in Nepal with a focus on storage. According to Nepal Electric Board, Nepal has had surplus power ever since the 456 MW Upper Tamakoshi Hydropower project became functional (July 2021). Nepal's power market is largely dependent on hydropower, with the country having the potential to generate up to 83,000 MW, of which only a fraction has been harnessed to date (NBR, 2022).

Expanding the electricity sector has contributed significantly to economic growth in many countries, highlighting the crucial role that the energy sector plays in development. However, the electricity sector in Nepal has been underperforming. Insufficient and unreliable supply of low-quality electricity has been a significant development constraint. Although some improvements have been made, the basic energy needs of the country's citizens are still only partially being met, and the energy sector remains dominated by traditional sources, with over three-quarters of the total energy consumption coming from fuel wood. Nepal does not have any known oil or gas resources, forcing the country to import all its fossil fuel needs. While around 89% of the population has access to electricity as of 2019, the supply is still of poor quality and unreliable. Despite an increase in per capita electricity consumption from 63 kWh per annum in 2000 to 177 kWh per annum in 2018, Nepal's per capita electricity consumption is still among the lowest in the world. It is one-twentieth of the global average (ADB, 2020).

The power producers in Nepal include the Nepal Electricity Authority (NEA), independent power producers, and small-scale community-based micro-hydropower plants. The NEA is the government-owned monopoly responsible for electricity generation, transmission, and distribution in the country. The independent power producers operate independently of the NEA and have the license to produce and sell electricity to the NEA. The small-scale community-based micro-hydropower plants generate electricity for local communities and are often supported by non-governmental organisations and development agencies.

In terms of distribution, the NEA is responsible for the distribution of electricity in most of the country. However, in some areas, the distribution is managed by local distribution companies. Nepal's hydroelectric power plants are located along its major rivers, including the Sapta Koshi, Sapta Gandaki, Karnali and Mahakali, and southern rivers (ADB, 2020). The hydropower potential of these major river systems is given in Table A2.2. Several of its large-scale hydropower projects are under construction, including the Upper Karnali (900 MW), Arun III (900 MW), and Upper Marsyangdi (600 MW) projects (CEA, 2021).

Table A2.2. Major River Systems of Nepal and their Hydropower Potential

Major River Basin	Theoretical Potential	Technical Potential		Economic Potential	
	Megawatts	Project Sites	Megawatts	Project Sites	Megawatts
Sapta Koshi	22,350	53	11,400	40	10,860
Sapta Gandaki	20,650	18	6,660	12	5,270
Karnali and Mahakali	36,180	34	26,570	9	25,125
Southern Rivers	4,110	9	980	5	878
Total	83,290	114	45,610	66	42,133

Source: Surendra et al., 2010.

In the fiscal year 2018–19, Nepal's maximum electricity demand was 1,320 MW, but the country's total installed generation capacity was only 1,182 MW. Out of this capacity, 621 MW was owned by the NEA (Nayek, 2022). It generated 34% of the total electricity sold. The private investors, on the other hand, owned 560 MW and generated 29% of the total sold electricity. The remaining demand was met by importing electricity from India, which accounted for 38% of the total electricity sale, with a maximum import of around 596 MW (ADB, 2020).

Nepal is primarily an agricultural country, and its energy demand is highly dependent on hydropower. During the winter season, the energy demand in Nepal increases due to the cold weather, resulting in higher electricity consumption. However, the hydropower capacity in Nepal is not sufficient to meet the rising energy demand during this period. Due to the dry winter season, the water level in the river drops, causing many hydropower projects to generate less than 60% of their installed production capacity, as reported by the NEA (Rising Nepal Daily, 2020). As a result, Nepal needs to import electricity from its neighbouring countries, primarily India, to bridge the gap between demand and supply. According to the NEA, Nepal's electricity import from India during the winter season has been increasing steadily over the years. Nepal bought 365 MW of power from India to meet its demand during winter in September 2022 (ANI, 2022).

This marked the first instance of Nepal purchasing electricity on a long-term basis through competitive bidding from India, according to a report by the *Kathmandu Post*. Nepali authorities are seeking a 6-month contract for power supply from India, starting from 1 December 2022 to 31 May 2023.

During the monsoon season, hydropower projects in Nepal generate more electricity than the country needs, and they even export the surplus. As per the NEA, the total installed capacity of power projects in Nepal is around 2,200 MW, while the peak electricity demand stands at 1,866 MW (ANI, 2022).

<u>Present Power Transfer</u>

The total export of the existing interconnection network between India and Nepal has the potential of 1,000 MW (approx.) power transfer. About 350 MW can be transferred through 132 kV and below radial lines and about 650 MW of power can be exported through the first high-capacity link, i.e. 400 kV D/c Dhalkebar (Nepal)–Muzaffarpur (India) line (MoP, 2022).

<u>Under-construction Interconnections</u>

According to the Ministry of Power, Government of India, an additional 1,800 MW interconnection line between Nepal and India are under construction stage; these include Sitamarhi (Power Grid)–Dhalkebar (Nepal) 400 kV D/c (Quad) line (associated with Arun-3 HEP, Nepal): The Nepal portion will be developed by M/s SAPDC (developer of Arun-3 HEP) and the Indian portion will be undertaken by POWERGRID for M/s SAPDC. The project is expected to be ready by April 2023. The Gorakhpur (India)–New Butwal (Nepal) 400 kV D/c (Quad) line is also under-construction. The requisite approvals from various relevant authorities are being obtained to take up the actual implementation.

<u>Future interconnections</u>

Other than the existing and under-construction networks between India and Nepal, there are a few expansion plans that, as suggested by the Ministry of Power, Government of India, may be realised in the near future. These are as follows:

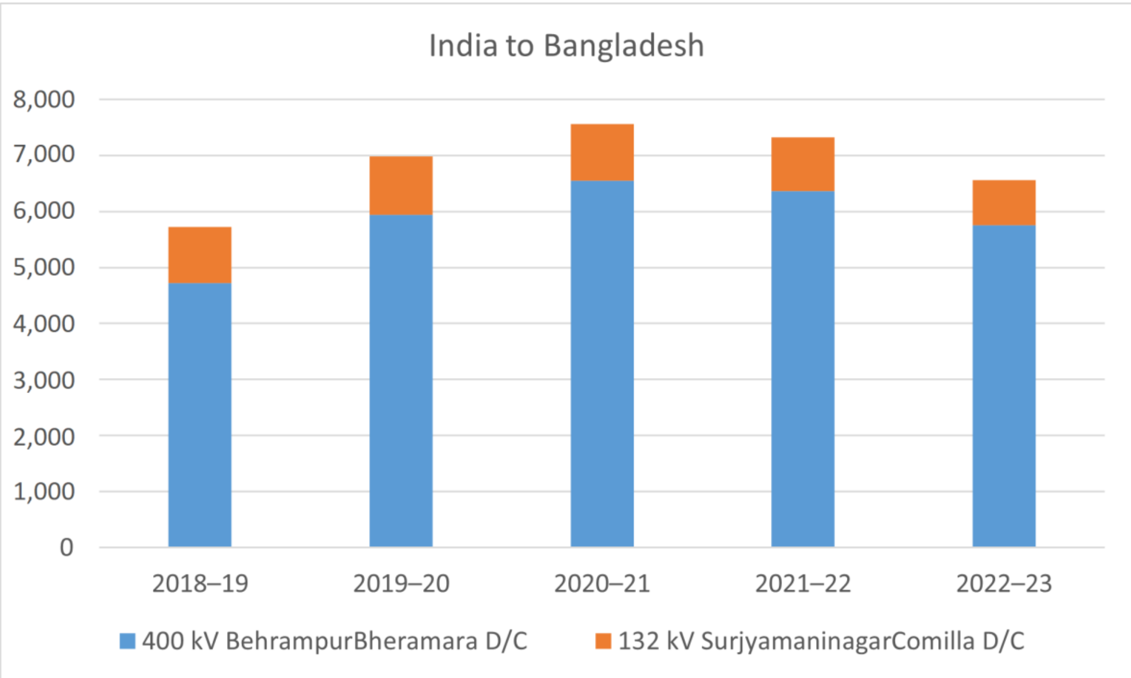
- Gorakhpur (India)–New Butwal (Nepal) 400 kV D/c (Quad) line
- Second circuit of Kataiya–Kusaha and Raxaul–Parwanipur 132 kV lines
- New 132 kV radial lines from Uttar Pradesh to Nepal
- Transmission system of Arun-III HEP

- Requirement of New Lumki (Nepal)–Bareilly (India) and New Duhabi (Nepal)–New Purnea (India) 400 kV interconnections and status of associated hydro generation projects in Nepal
- India–Nepal Interconnection Master Plan

India–Bangladesh

India and Bangladesh have been cooperating in the power sector for several years. Both countries have signed multiple agreements to facilitate the cross-border trade of electricity and improve energy security in the region. On 11 January 2010, the Governments of India and Bangladesh signed a Memorandum of Understanding to collaborate on the power sector. As a result of this agreement, they established a joint working group and joint steering committee. The 19th meeting of the joint working group and joint steering committee was held in Dhaka, Bangladesh on 21 and 23 January 2021. However, due to the COVID-19 pandemic, the next joint working group/joint steering committee meeting was not held as scheduled. Both parties are currently working on finalising mutually convenient dates for the meeting.

Figure A2.3. Annual Electricity Export from India to Bangladesh through Various Routes



Source: TERI Estimation based on POSOCO Monthly Reports, Various months, 2018–19 to 2022–23.

Present Power Transfer and Future Interconnection

Bangladesh acts as a major importer of electricity from India. The different routes available for annual electricity export from India to Bangladesh are indicated in Figure A2.3. The present power transfer capacity between India and Bangladesh is around 1,160 MW, with 160 MW coming from the Surajmaninagar–North Comilla interconnection and 1,000 MW passing through the Baharampur–Bheramara interconnection. A 1,600 MW generation facility is being built by M/s Adani, India. It would deliver power to Bangladesh in a radial mode without connecting to the Indian grid beginning in 2022–23.

A 765 kV D/C cross-border link between Katihar (Bihar), Parbotipur (Bangladesh), and Bornagar (Assam) is expected to be built by India in March 2021. The link would require the construction of new 765/400 kV substations at Bornagar and Katihar and a 765 kV switching station at Parbotipur. A coal-based power station called 'Maitree Super Thermal Power Plant' with a 1,320 MW capacity is being built in Rampal by Bangladesh India Friendship Power Company Limited, a joint venture between NTPC and BPDB. The project is being executed by BHEL and financed by Indian EXIM Bank for $1.6 billion.

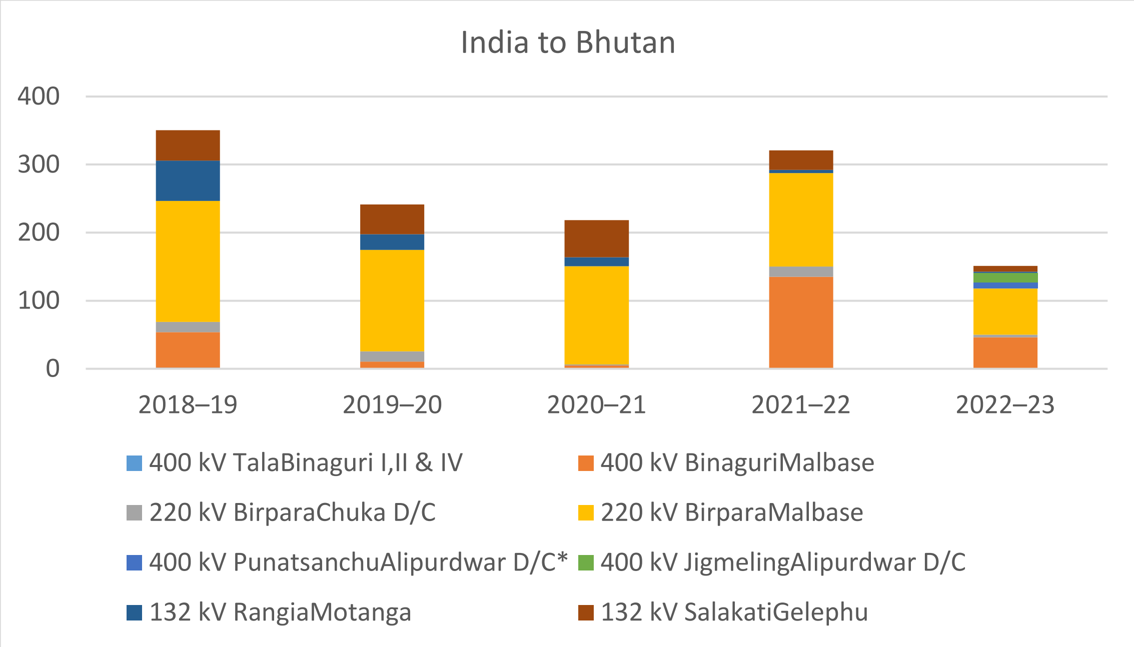
The Government of India has also chosen NTPC Vidyut Vyapar Nigam (NVVN) to serve as the nodal organisation for cross-border power trading with Bangladesh. NVVN and BPDB signed a power purchase agreement in October 2013 for the provision of 250 MW of electricity from NTPC units over a 25-year period. They also signed two additional PPAs in March 2016 and April 2017 for the supply of 100 MW and 60 MW of power from Tripura, respectively. In February 2018, NVVN was awarded an international contract to supply 300 MW of round the clock power to BPDB for a period of 15 years. As of 31 December 2021, NVVN had provided Bangladesh with 3,962 MUs (provisional) of power for the current fiscal year.

India–Bhutan

There are four major rivers in Bhutan, namely Torsa, Wangchu, Sankosh, and Manas. All these rivers have high snow-fed continuing water flow that has huge potential for hydroelectric power generation. The demand for electricity in Bhutan is estimated to be significantly less in the near future compared to the hydroelectric power generation potential. The total hydropower projects expected to be commissioned in Bhutan by 2025, 2030, and 2040 are 10,000 MW, 14,000 MW, and 23,500 MW, respectively (Ministry of Power Annual Report 2021–22, Government of India). This massive hydroelectric power generation is expected to reap huge benefits for India and also other South Asian countries.

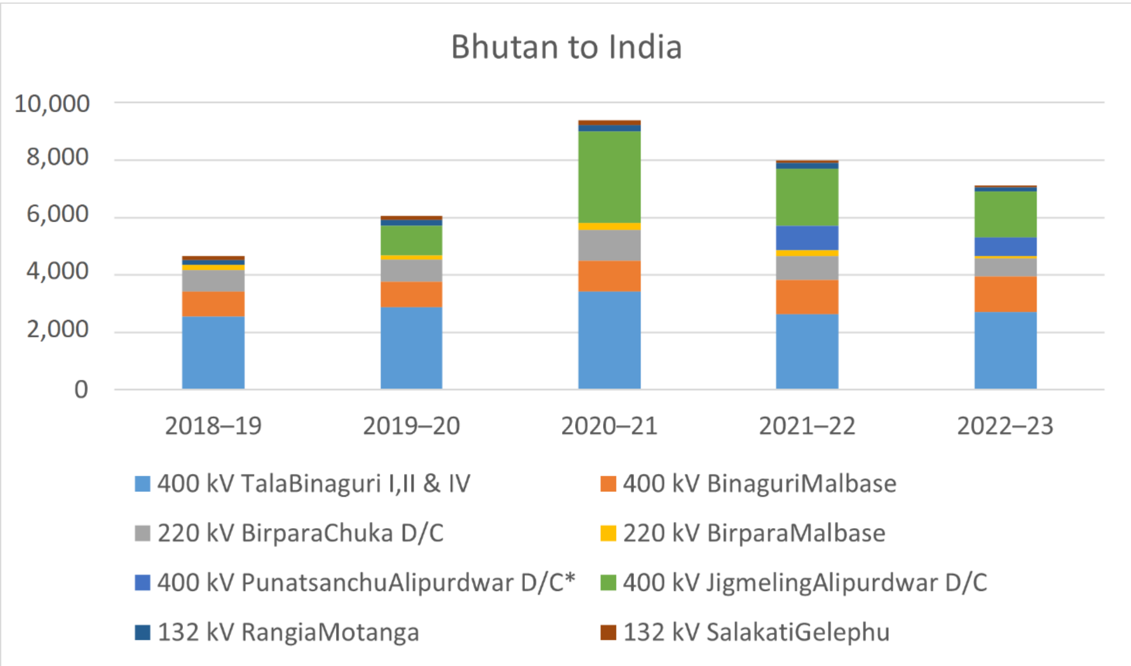
Additionally, Bhutan currently exports about 75.5% of electricity generated in the country to India. According to Bhutan's 'Richness Experiences in Cross Border Electricity Trade, 2022' report, this is about 117,715.31 GWh of the total power generation of 155,925.81 GWh. The report states that electricity is also exported to India via 15 transmission lines, including 10 400 kV transmission lines used for bulk export. These lines are operated under various types of power purchase agreements. The annual electricity exports and imports between India and Bhutan are shown in Figures A2.4 and A2.5 respectively, which indicate the various routes of electricity trade and the consequent growing exports of Bhutan in the region.

Figure A2.4. Annual Electricity Export from India to Bhutan through Various Routes



Source: TERI Estimation based on POSOCO Monthly Reports, Various months, 2018–19 to 2022–23.

Figure A2.5. Annual Electricity Import of India from Bhutan through Various Routes

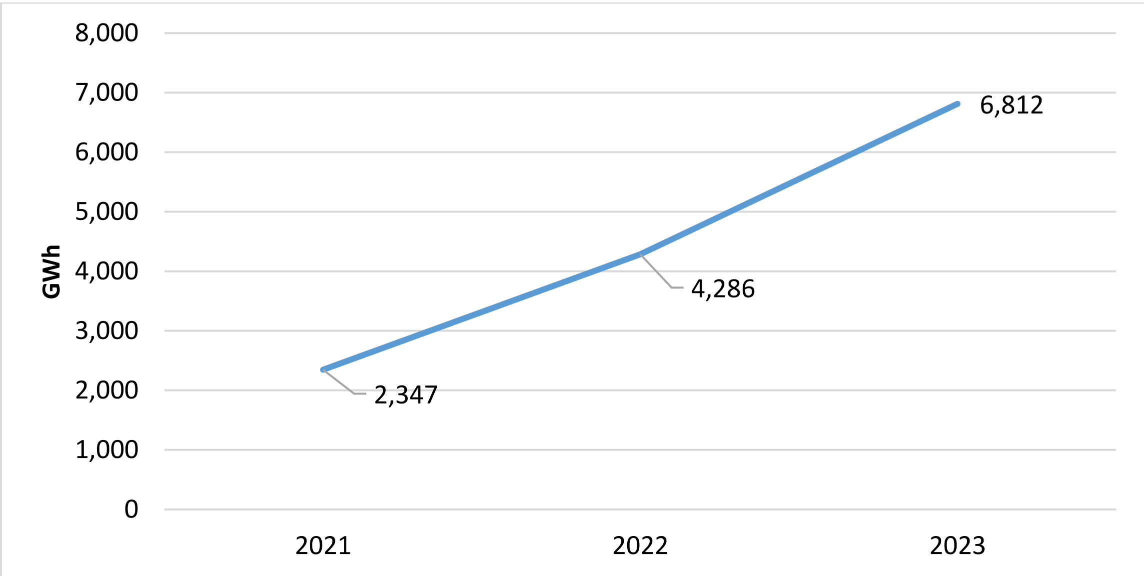


Source: TERI Estimation based on POSOCO Monthly Reports, Various months, 2018–19 to 2022–23.

Bhutan is known for its abundance of hydropower, which can generate large amounts of electricity for both domestic consumption and export to neighbouring countries. The hydroelectric power capacity of the area is evaluated to be more than 30,000 MW. However, it is only commercially and technologically possible to harness around 23,760 MW of that total capacity (VIF, 2022). The country's electricity generation is dominated by two main power producers: the Bhutan Electricity Authority (BEA) and the Druk Green Power Corporation (DGPC). BEA is responsible for the transmission and distribution of electricity within Bhutan, while DGPC functions as the main hydropower producer in the country (ADB, 2017).

Bhutan's domestic demand for electricity has been increasing steadily over the years and is expected to continue to do so. In fact, according to the proposals for revising electricity tariffs submitted by the power sector to the BEA, Bhutan's domestic energy requirement is predicted to double within the next 2 years. Bhutan Power Corporation, DGPC, and Mangdechhu Hydroelectric Project Authority, which collectively form Bhutan's power generation, transmission, and distribution companies, have suggested revising the tariff to ensure efficient business operations and expand and upgrade infrastructure. The demand for energy will be further driven by the establishment of several new power-intensive industries, including numerous high-voltage and medium-voltage industries in the Jigmeling and Motanga industrial parks located in Gelephu and Samdrup Jongkhar. Additionally, the Jigmeling industrial estate, which began building 10 factories in November of 2021, will become the largest industrial estate in Bhutan (Kuensel, 2022). Bhutan's domestic energy demand is expected to rise from 2,437 GWh in 2021 to 6,812 GWh in 2023 due to the emergence of numerous industries that require high- and medium-voltage power. Figure A2.6 shows the anticipated growth in domestic load for electricity over 2021–23 that can be connected to the rising energy demand and the increasing number of electricity-intensive industries in Bhutan.

Figure A2.6. Projected Domestic Load Growth for Electricity in Bhutan from 2021 to 2023



Source: Kuensel, 2022.

Bhutan's power constraint is getting worse as a result of increasing domestic demand, particularly from enterprises. As a result, an effective mechanism needs to be created for the high-voltage industries during winter for electricity import from India, such as through power purchase agreements between Bhutanese organisations and Indian distributors.

Increasing firm power capacity with the inclusion of additional generation capacity would help to fulfil the growing domestic energy demand. Yet, this will also raise the issue of how to sell the summertime overcapacity. Bhutan can build hybrid solar or mini-hydropower plants to meet its demand. It is also considering building storage or pondage plants in the long run. Moreover, in the future, industries might be permitted to build captive power plants.

Bhutan generates surplus energy throughout the year and is also a net exporter of electricity on an annual basis. However, during the winter season, the country's domestic hydropower production is restricted. This is due to the hydrology and design of the current hydropower plants, which causes a drop in electricity generation to approximately 20% of its installed capacity. As a result, Bhutan needs to import a considerable amount of electricity from India during the winter months to meet its domestic energy needs.

However, on the supply side, capacity addition has not taken place, and it is unlikely to gain momentum. The domestic peak demand for Bhutan was 450 MW in the winter of 2021, but the firm power capacity of the generating plants was 400 MW.

DGPC began importing electricity from the Indian Energy Exchange for the first time in the winter of 2021. However, there have not been any sizable imports yet. During this time, Bhutan also participated in the Indian Energy Exchange Day-Ahead market to purchase power from India. Bhutan has been concentrating on developing renewable energy sources such as solar and wind power to reduce its dependence on imported electricity and promote self-sufficiency in energy production. With the reopening of the economy post-pandemic, hydropower development in the country is expected to accelerate, aided by the availability of Indian workers.

The Punatsangchhu II and Nikachhu hydropower projects are scheduled to be commissioned in 2023. In the Bay of Bengal Initiative for Multi-Sectoral Technical and Economic Cooperation (BIMSTEC) ministerial meeting, held in April, regional grid connectivity was discussed. If a shared regional grid is established, Bhutan will be able to sell its summer overcapacity to its neighbouring countries. Also, it will make winter imports easier.

In conclusion, Bhutan's import of electricity from India in the winter season is a crucial aspect of its energy strategy. This enables the country to maintain a reliable and consistent supply of electricity. However, the country's growing focus on developing renewable energy sources suggests a shift toward greater self-sufficiency and sustainability in the future (Kuensel, 2022).

Bhutan–Bangladesh as power trade potential

According to the Hydropower Committee Report, Bangladesh incurs electricity supply deficits. This deficit is expected to continue as demand is projected to almost triple from 11,405 MW in 2016 to 33,708 MW in 2030. As per the report, Bangladesh has very few options for generation capacity addition due to limited energy resources. The projections are that Bangladesh will have an installed generation capacity (gas, oil, and coal) of only 25,000 MW by 2040.

A large percentage of the capacity addition is to be through coal-fired thermal power stations for which Bangladesh will depend largely on imported coal. While generation from domestic gas works out to be the cheapest, Bangladesh has limited onshore gas reserves while the offshore gas reserves remain largely unexplored.

The report also says that from the various options, the import of power works out to be the cheapest option for the country. Bangladesh is already cooperating with India to establish transmission links and import electricity from India. According to the report, hydropower from Bhutan could play a very important and competitive role in the Bangladeshi power market due to two important factors: the presence of such an existing demand-supply gap, which is expected to keep widening in the future, and projected power tariffs in Bangladesh.

The report also highlighted that the 1,125 MW Dorjilung project can be developed in Bhutan through the collaboration of Bangladesh, Bhutan, and India, which will facilitate the export of electricity specifically to Bangladesh. This proposal could also open a market opportunity for Bhutan with a market-based tariff regime denominated in foreign exchange.

Nepal as Competitors

The report indicates that Nepal can emerge as a future competitor for Bhutan in the South Asia's hydropower export market. As Bhutan and Nepal have similar geographical and climatic conditions, both countries have huge hydropower-generation and export potential. Nepal presently has several hydropower projects aggregating 1,300 MW under construction (through the Nepal Electricity Authority, and through private–public partnerships) and Independent Power Producers' routes. The following are the few other mega-projects under consideration:

- 900 MW Arun-3
- 750 MW West Seti
- 4,800 MW Pancheshwar projects.

Nepal and India are strengthening the transmission connectivity between the two countries to facilitate trade in electricity. The energy market potentials in India and Bangladesh are huge and increasing over time. But Bhutan and Nepal, in spite of their huge hydropower potential, have not been able to meet the entire demand of the Indian and Bangladeshi energy markets. The report has highlighted that Nepal could turn out to be Bhutan's competitor for the Indian and Bangladesh energy markets. The report recommends that in order to satisfy its own interest, Bhutan should maintain a competitive edge over Nepal.

India–Sri Lanka

According to the Ministry of Power, Government of India (2021) report, the present installed capacity of the Sri Lanka grid is about 4 GW, and the peak demand is about 2.5 GW. The annual energy demand of the country is about 14.5 BU. The installed capacity and peak demand of the Sri Lanka grid are expected to reach about 6 GW and 3.4 GW respectively, in the next three to four years.

The electricity industry and the petroleum industry are both managed largely by state-owned corporations. Private sector participation in the electricity industry is limited to power generation; while in the petroleum industry the private sector is engaged in petroleum distribution, bunker supplies, gas distribution, and oil exploration.

Sri Lanka used 12.8 million tonnes of oil equivalent energy in 2017. At $7.50 of economic output per kg of oil equivalent in 2014, Sri Lanka ranks high among countries that report similar per capita economic output. Petroleum, imported as crude oil and finished products, provides the highest share (43% in 2017) of energy to the national economy, followed by biomass (37%), coal (11%), hydro (6%), and renewable energy (3%). The country has succeeded in delivering modern energy sources to its whole population; petroleum products and bottled liquefied petroleum gas are widely available. The electrification of households reached 100% in 2017. Energy end-users are households and commercial (40%), transport (36%), and industries (34%). Sri Lanka's per capita electricity consumption was 626 kWh/person in 2017, lower than India and many of the developing countries in Southeast Asia (ADB, 2019).

Future Interconnections

During the fourth joint working group meeting held on 27 June 2019, it was decided that the Joint Technical Team may prepare the Detail Project Report for New Madurai to New Habarana 2x500 MW VSC-based overhead HVDC line. As per the report, the work would be carried out in two phases as follows:

- Phase-1: 1,000 MW Madurai-New (India) to New Habarana (Sri Lanka) HVDC (overhead) line (about 397 km) along with 500 MW VSC-based HVDC terminals at both ends by 2025.
- Phase-2: Second 500 MW VSC-based HVDC terminals at Madurai-New and New Habarana by 2030.

Trincomalee Power Company Ltd. (TPCL) is a joint venture between NTPC Ltd. and Ceylon Electricity Board, Sri Lanka (CEB) incorporated in Sri Lanka on 26 September 2011. NTPC and CEB each hold 50% equity share capital of the company. TPCL shall develop a 50 MW solar power project at Sampur, Sri Lanka. Further, a Joint Venture & Shareholders' Agreement for incorporating a new joint venture company in Sri Lanka has been signed between NTPC and CEB on 25 October 2019, with an objective to develop a 300 MW LNG Power Project at Kerawalapitiya. Project Agreements, in this regard, are under finalisation (MoP, 2021)

Annex 3
Details of the GTAP Model Used in the Study

1. GTAP Introduction

The standard GTAP Model is a multi-region, multi-sector, computable general equilibrium model, with perfect competition and constant returns to scale. The innovative aspects of this model include the following:

- The treatment of private household preferences using non-homothetic Constant Difference of Elasticity functional forms.
- The explicit treatment of international trade and transport margins. Bilateral trade is handled via the Armington assumption.
- A global banking sector that intermediates between global savings and consumption.

The GTAP model also gives users a wide range of closure options, including unemployment, tax revenue replacement, and fixed trade balance closures. It also furnishes a selection of partial equilibrium closures (facilitating comparison of results to studies based on partial equilibrium assumptions).

2. Database

The GTAP database is a consistent representation of the world economy for a pre-determined reference year. Underlying the database there are several data sources, including national input–output tables, trade, macroeconomic, energy, and protection data. The underlying input–output tables are heterogeneous in sources, methodology, base years, and sectoral detail. Thus, to achieve consistency, substantial efforts are made to make the disparate sources comparable. For these reasons, the objective of the GTAP database is not to provide input–output tables, but to facilitate the operation of economic simulation models that ensure a consistent set of economic facts. Some users interested in particular social accounting matrices use utilities written by researchers in the network to extract them. Users building input–output tables based on this information do so at their own risk and are assumed to understand the limitations imposed by the process of database construction.

GTAP is not a relational database of economic variables. Users interested in economic data only for comparative purposes are better served by sources such as the World Bank Development Indicators, the International Monetary Fund financial statistics, or the Food and Agriculture Organisation statistics, to name a few. GTAP data accurately depict the magnitudes of economic variables. However, they are presented in terms of the aggregates that serve Computable General Equilibrium modelling.

To carry out the analysis, the study used the latest version of the GTAP 10. It provides a database for the world economy aggregated in 141 regions, 65 sectors, and five factors. For each country/region, the database reports production, intermediate and final uses, international trade and transport margins, and taxes/subsidies (Chepeliev et al., 2019).

3. Assumption

In GTAP 10, 141 regions were mapped into 10 new regions, i.e. Oceania, East Asia, Southeast Asia, South Asia, North America, Latin America, the European Union, Middle East and North Africa, and Sub-Saharan Africa. All other remaining countries are mapped in the 'Rest of the World' category. In our study, we have changed the country specification according to our study objective and made the country classification of all South Asian countries individually, i.e. India, Pakistan, Nepal, Bangladesh, Sri Lanka, and the remaining three countries (Afghanistan, Bhutan, and Maldives) have been included as a single entity called 'Rest of South Asia'. We have classified all other countries into 'Rest of the World'. As, out of Afghanistan, Bhutan, and Maldives, only Bhutan is predominantly engaged in electricity trade, the study assumed that in the case of renewable energy/electricity trade with Bangladesh, India, and Nepal, 'Rest of South Asia' indicates Bhutan only (as electricity trade for Afghanistan and Maldives are almost negligible). Only in the case of Pakistan–Afghanistan trade, the 'Rest of South Asia' indicates Afghanistan.

In sectorial aggregation, 65 sectors are mapped together into 10 new sectors. As we wanted to see the energy trade, we have classified all the sectors that are related to the energy sector. Coal, oil, gas, petroleum products, electrical equipment and electricity are categorised in the energy sector and all the remaining sectors are distinguished as 'primary services', 'secondary services', 'tertiary services' and 'other services' based on the nature of economic activities and services and how they are derived.

In the factorial aggregation, only land and natural resources are mapped into LAND and other factors, i.e. skilled, unskilled labour, and capital are kept unchanged.