Chapter 3

Renewable Energy Trade Potential in South Asia

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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.

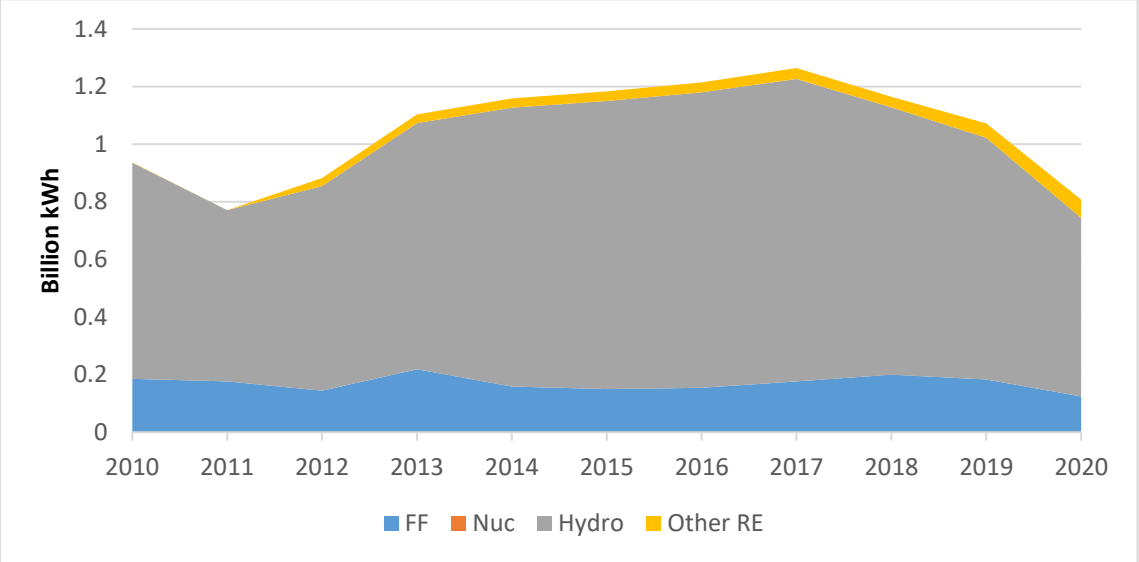
1. Country-specific Energy Transition

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

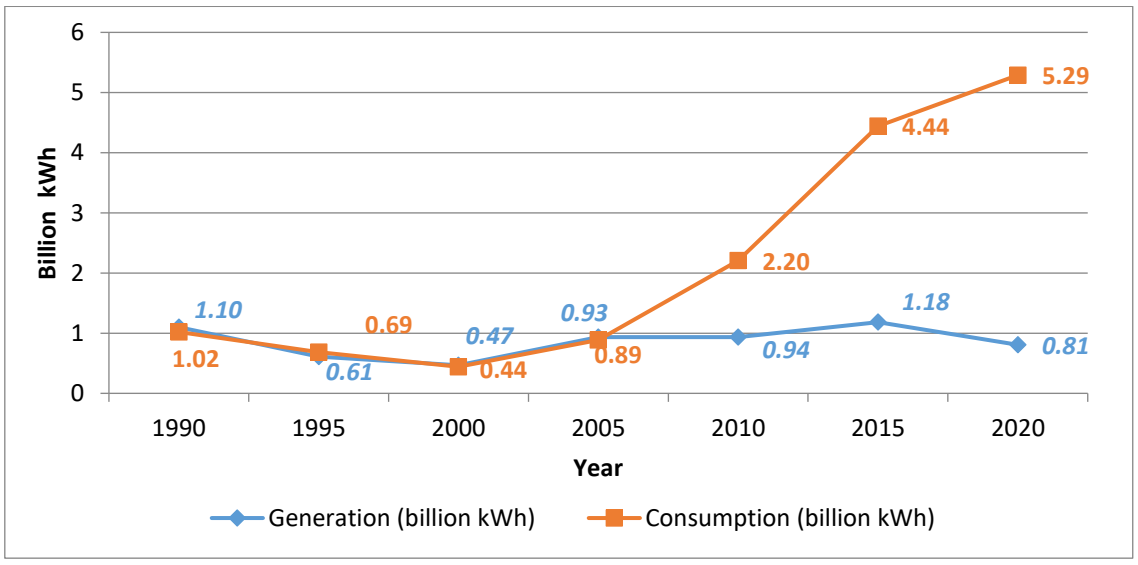


FF = Fossil fuels, Nuc = Nuclear, RE = Renewable energy sources.
Source: International Energy Association, 2022.

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



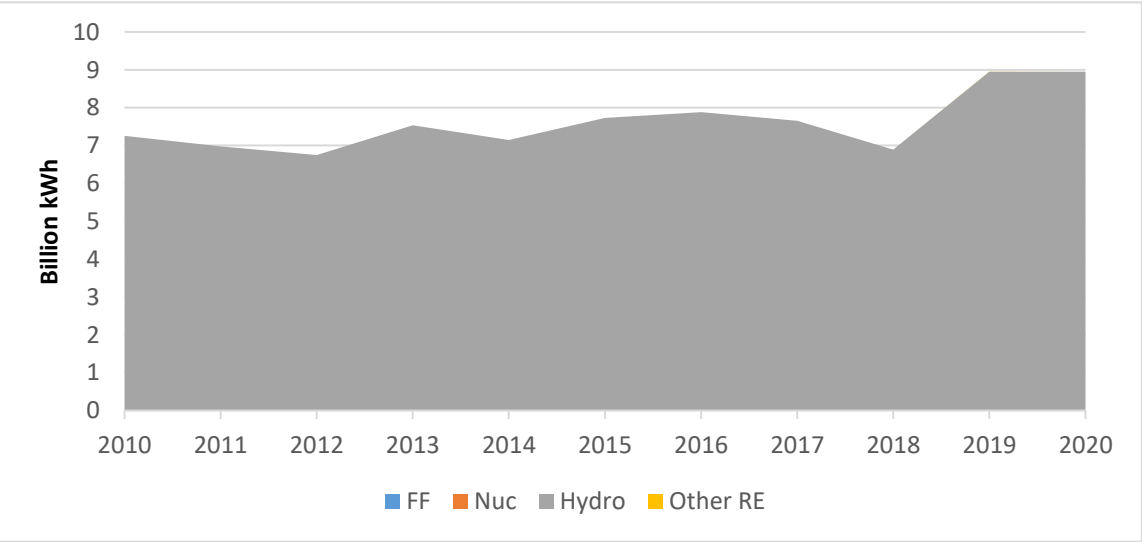
Source: Energy Information Administration, 2022.

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

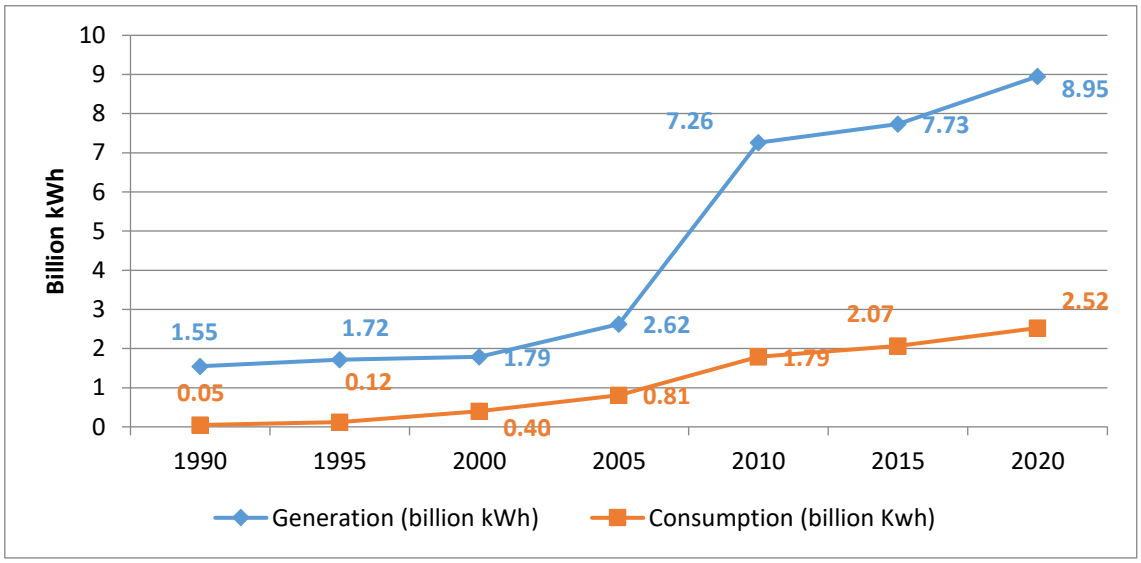


FF = Fossil fuels, Nuc = Nuclear, RE = Renewable energy sources.
Source: International Energy Agency, 2022.

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.

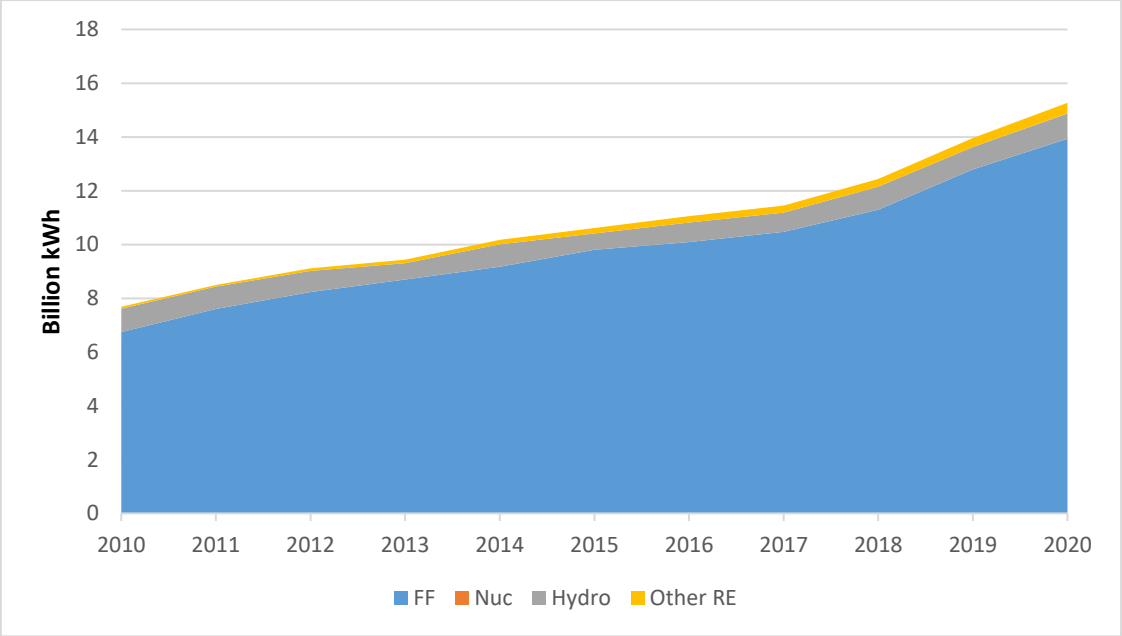
The excess electricity production capacity over the consumption demands of Bhutan is an impressive feat and showcases its commitment to sustainable energy production. Furthermore, Bhutan's ability to export surplus electricity to neighbouring countries provides a significant boost to its economy.

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.

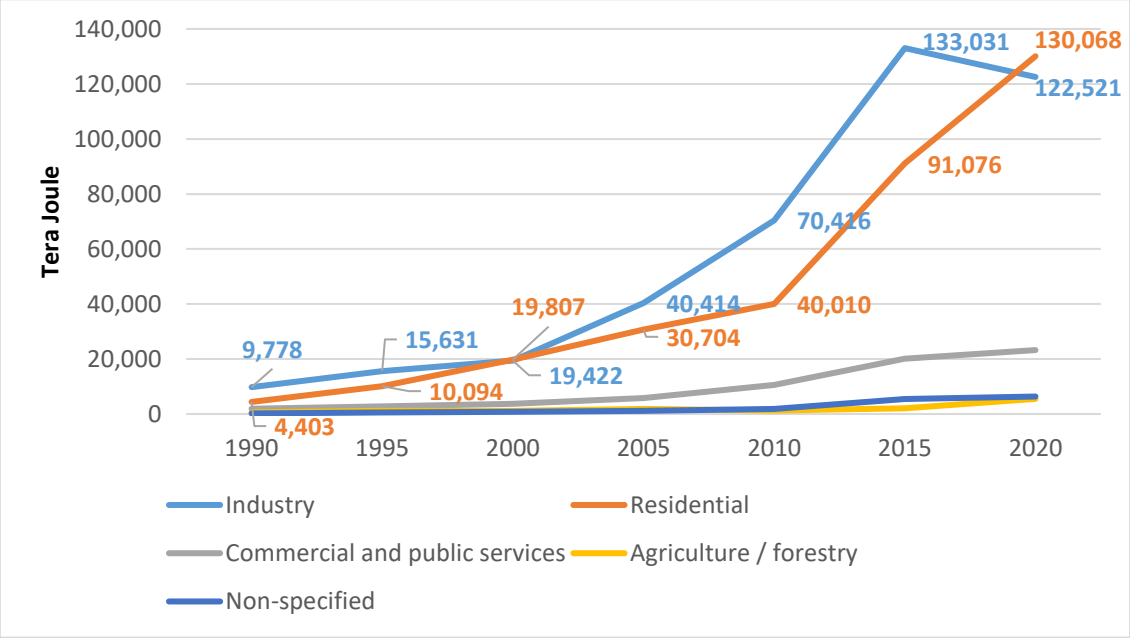
Figure 3.5. Electricity Generation Capacity of Bangladesh, 2010–2020



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

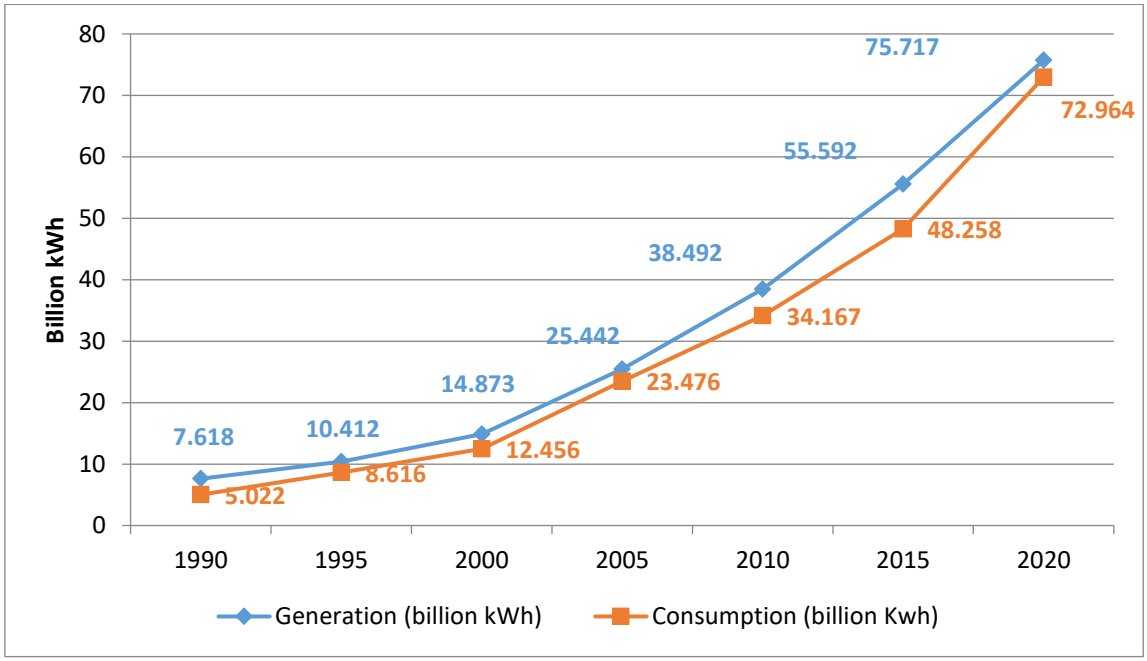


Source: International Energy Agency, 2022.

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.

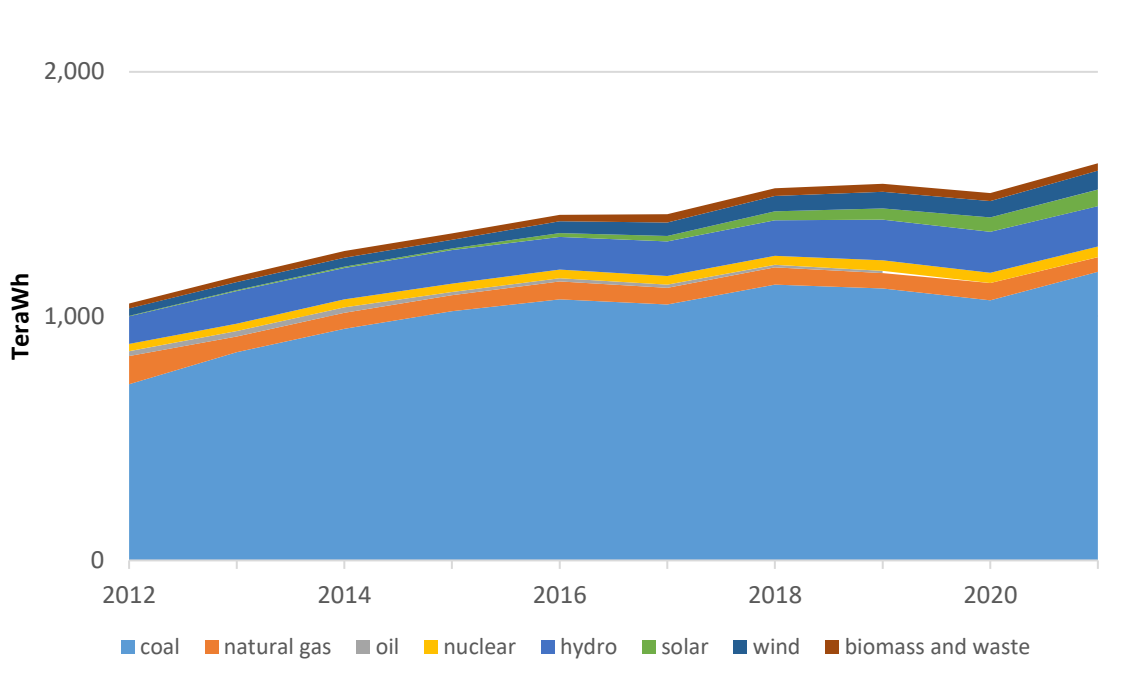
1.4. India

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:

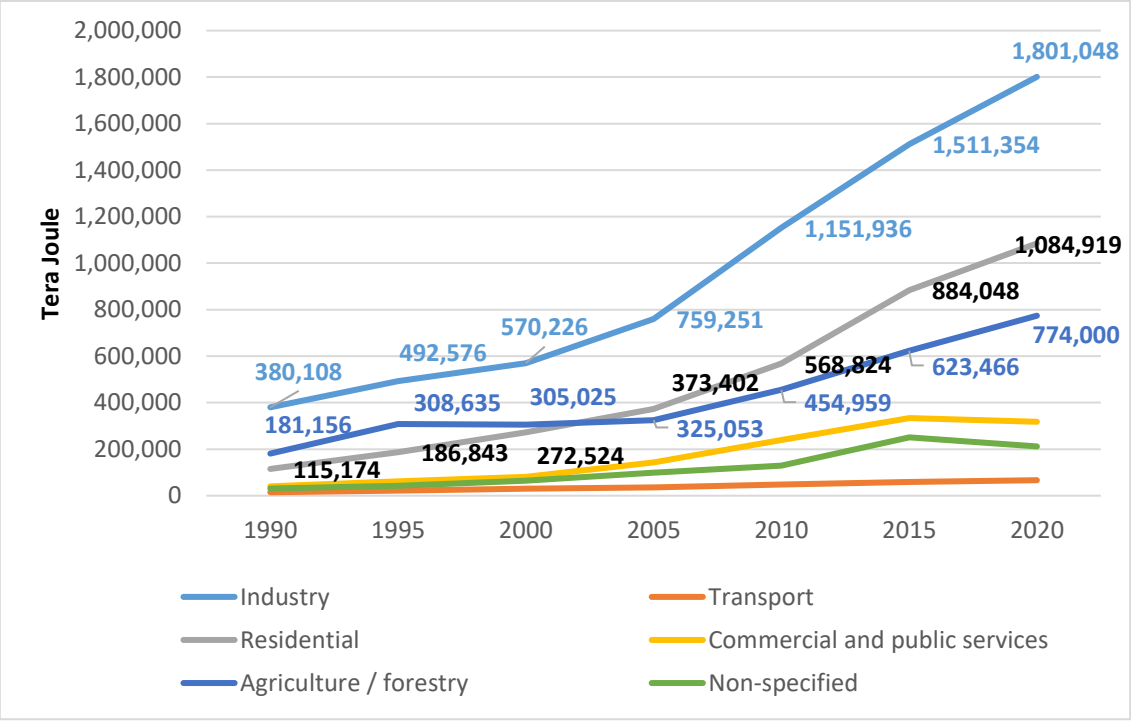
- In 2021, India generated around 1,628 TWh of net electricity, a rise of 8% over 2020. This increase came after a 2% reduction in demand by 2020 for the first time in at least 39 years, due to strict lockdown measures imposed in response to the COVID-19 pandemic (Reuters, 2021).
- In 2021, fossil fuel 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

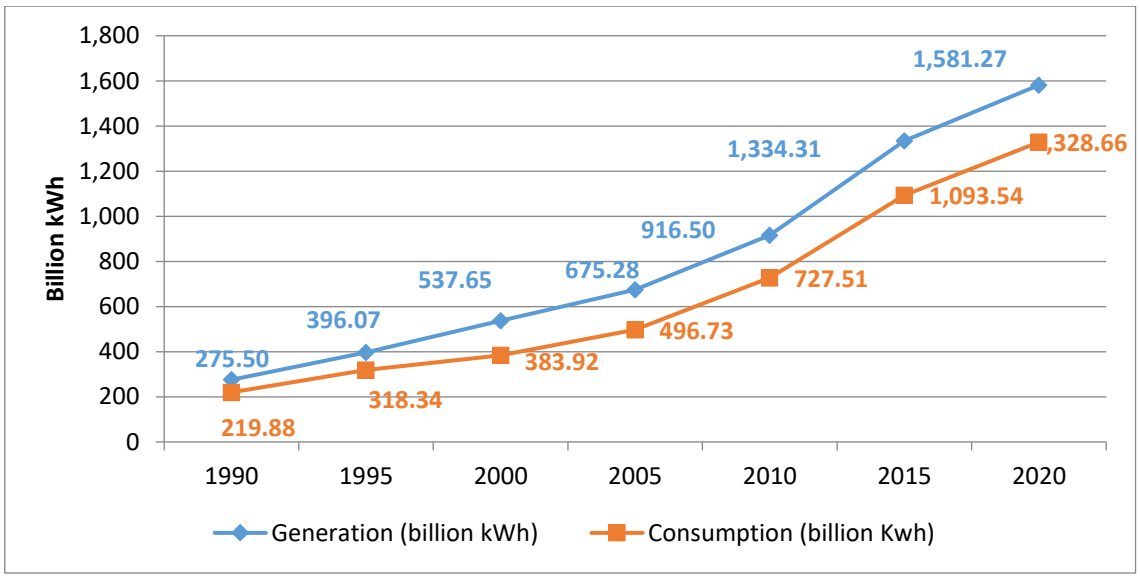


Source: International Energy Agency, 2022.

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.

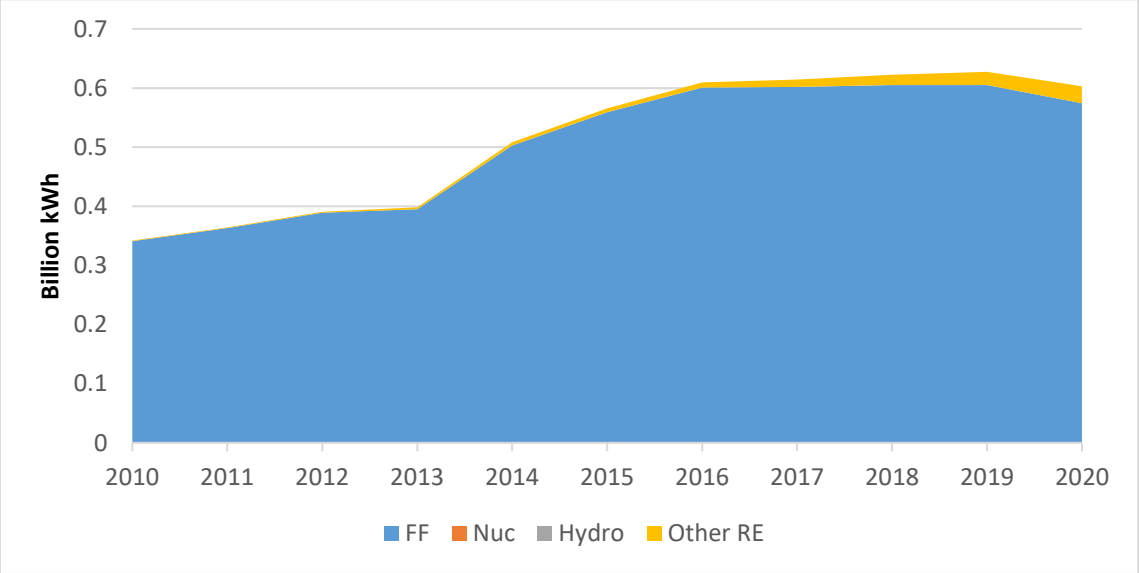
In conclusion, the analysis indicates that India has the necessary infrastructure and capacity to produce enough electricity to meet the needs of its people. The data suggest that the country's energy sector has been able to keep pace with the growing demand for electricity, and it is likely to continue 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.

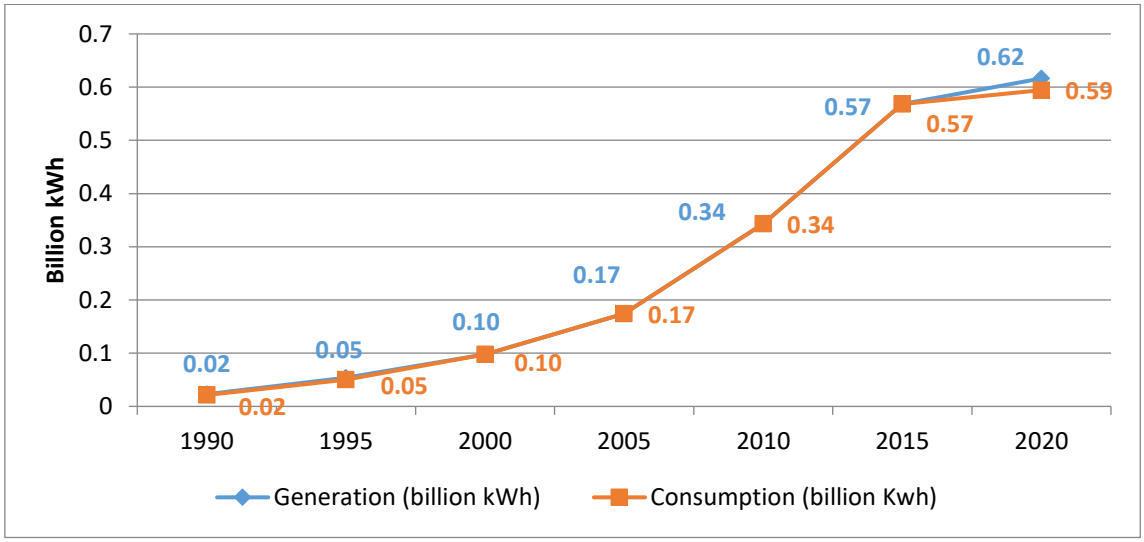
Figure 3.11. Maldives' Electricity Generation, 2010–2020



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.

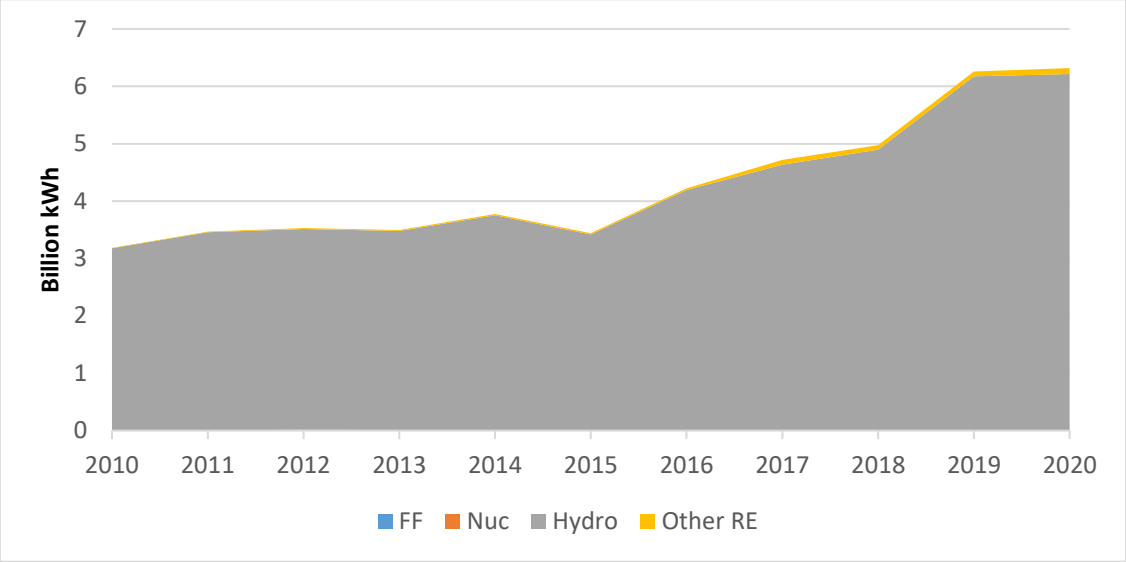
Furthermore, Maldives has been focusing on renewable energy, which has played a significant role in the country's energy sector development. Renewable energy has not only enabled Maldives to reduce its carbon footprint but also provided a sustainable source of energy, reducing the country's dependence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

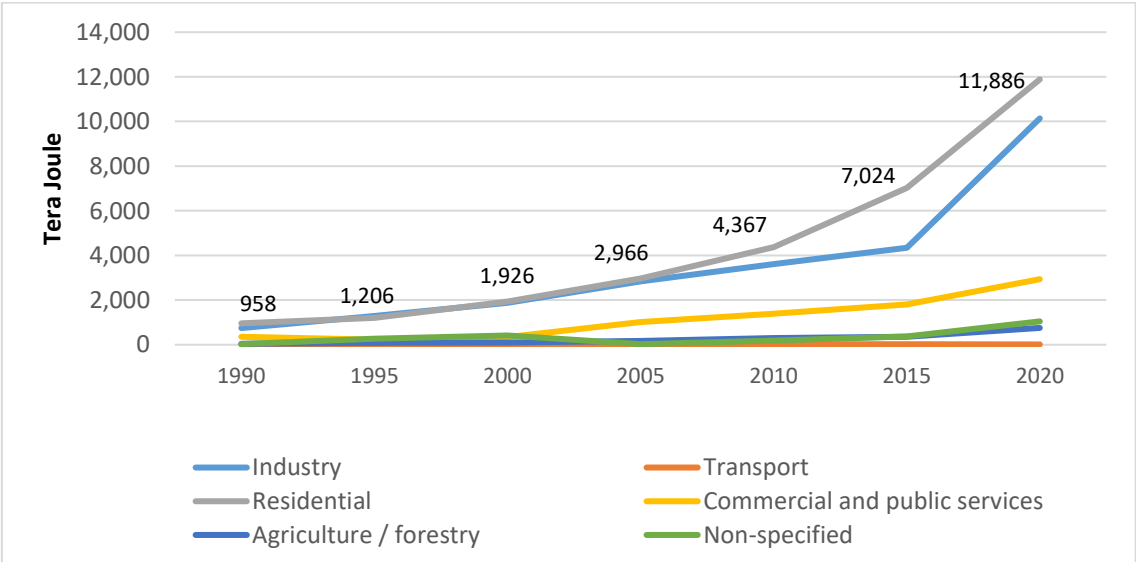
Figure 3.13. Electricity Generation Mix of Nepal from Different Sources, 2010–2020



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

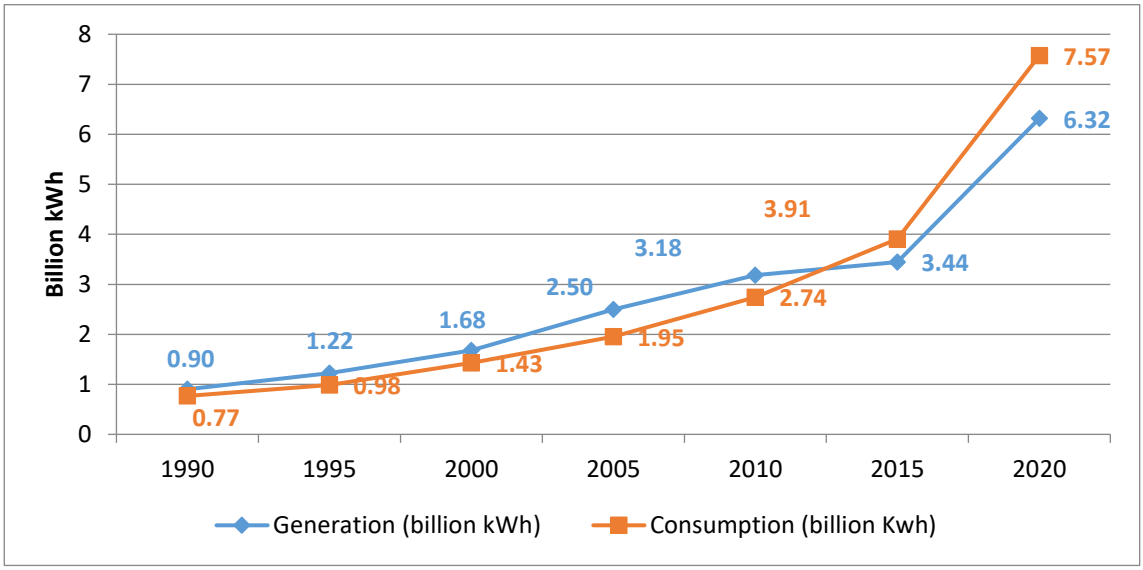


Source: International Energy Agency, 2022.

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.

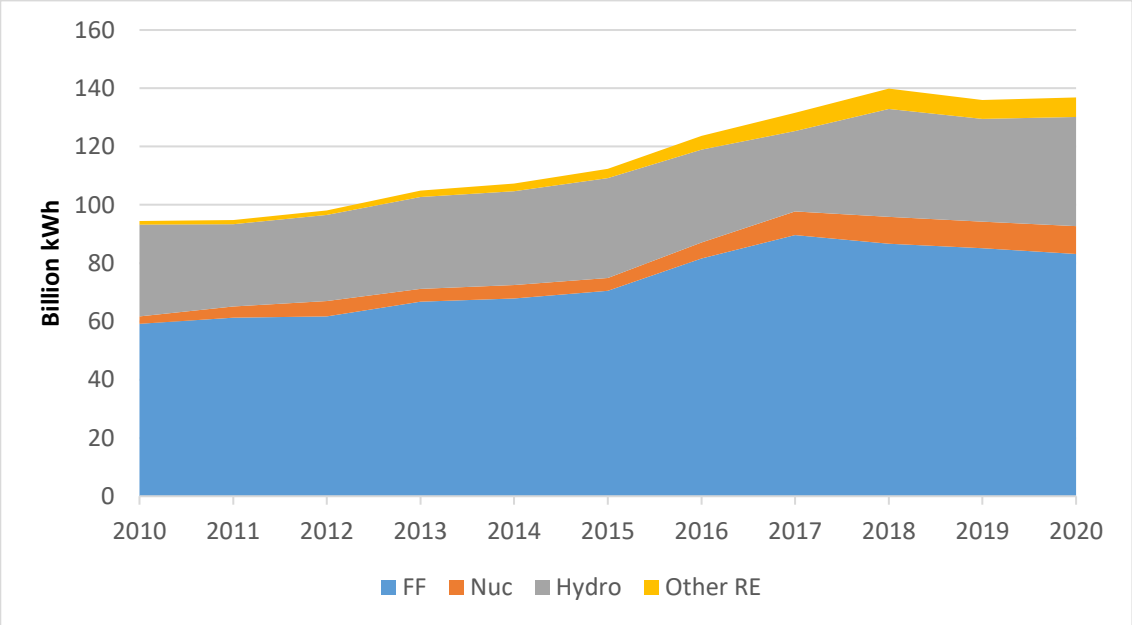
This analysis highlights the evolution of Nepal's electricity consumption and generation, from being self-sufficient to facing a deficit in electricity requirements. Given the limited domestic

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

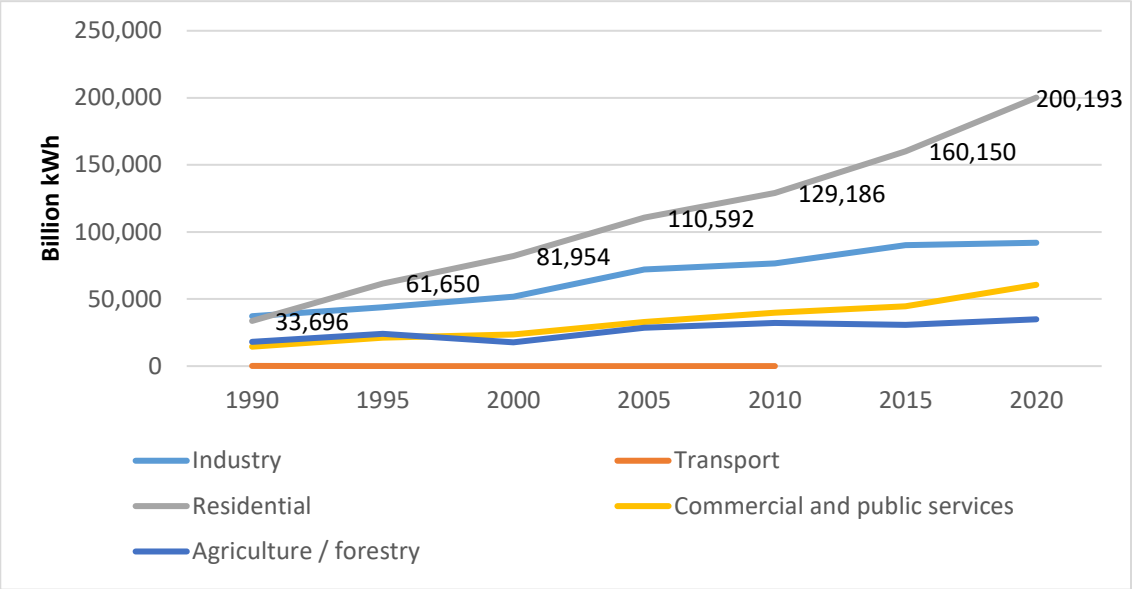


FF = Fossil fuels, Nuc = Nuclear, RE = renewable energy sources
Source: International Energy Agency, 2022.

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)



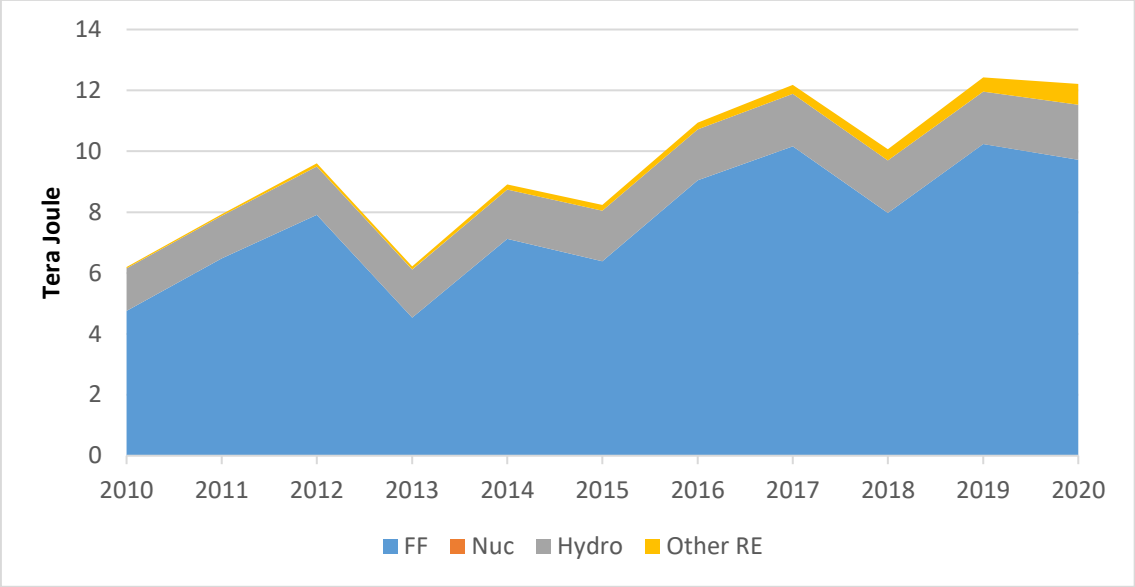
Source: International Energy Agency, 2022.

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.

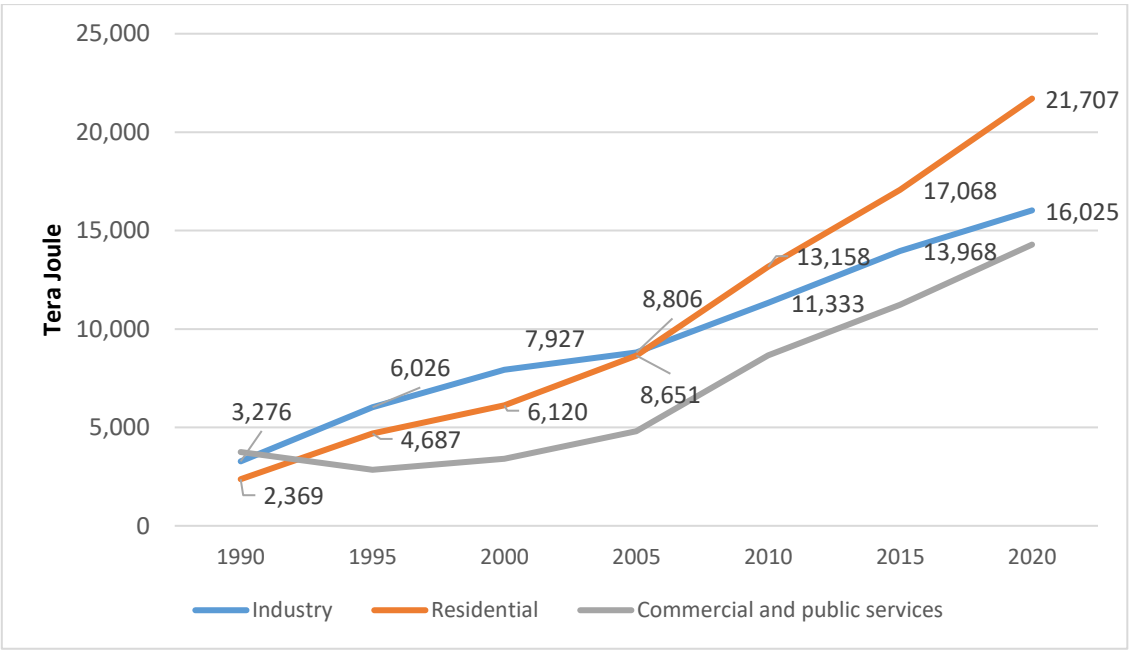
Figure 3.18. Sri Lanka's Electricity Generation by Sector, 2010–2020



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.

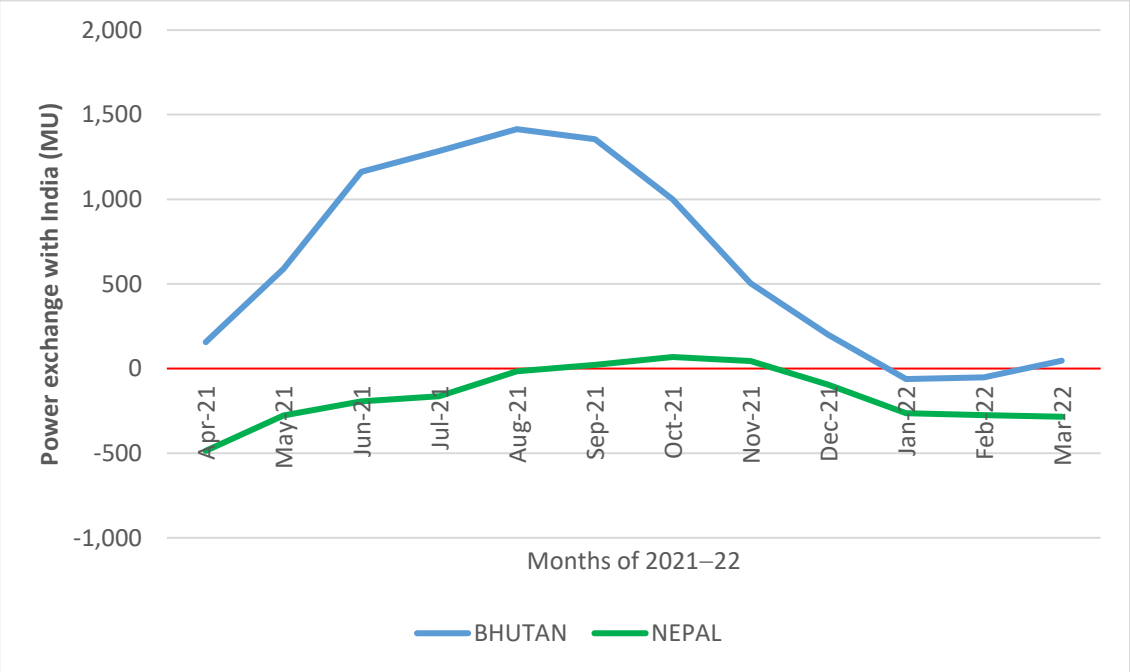
with Nepal for power exchange through India. However, to make the renewable energy trade more effective and efficient, it needs to go beyond a bilateral basis to a multilateral agreement.

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.