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 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
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 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
	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 Binag uri-Malb ase	220 kV Birpara -Chuka D/C	220 kV Birpara-Malbase	400 kV Punat-sanchu Alipurd-war D/C*	400 kV Jigme-ling Alipurdw ar 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 Tanakp urMah endran agar	400 kV Muzaffa rpurDhal kebar	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

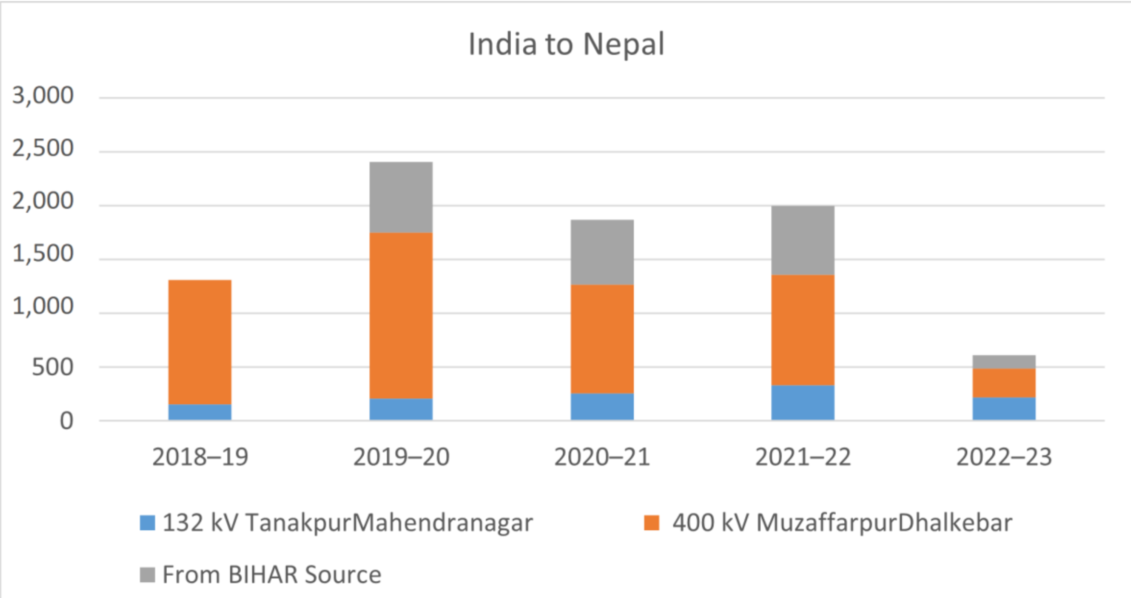
		Bhutan									Bangladesh			Nepal			
		400 kV Tala Binaguri I,II & IV	400 kV Binag uri-Malb ase	220 kV Birpara -Chuka D/C	220 kV Birpara-Malbase	400 kV Punat-sanchu Alipurd-war D/C*	400 kV Jigme-ling Alipurdw ar D/C	132 kV Rangia Motan-ga	132 kV Salakati Gelephu	Bhutan	400 kV Behram-pur Bhera-mara D/C	132 kV Surjyam ani-nagar Comilla D/C	Bangla-desh	132 kV Tanakp urMah endran agar	400 kV Muzaffa rpurDhal kebar	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

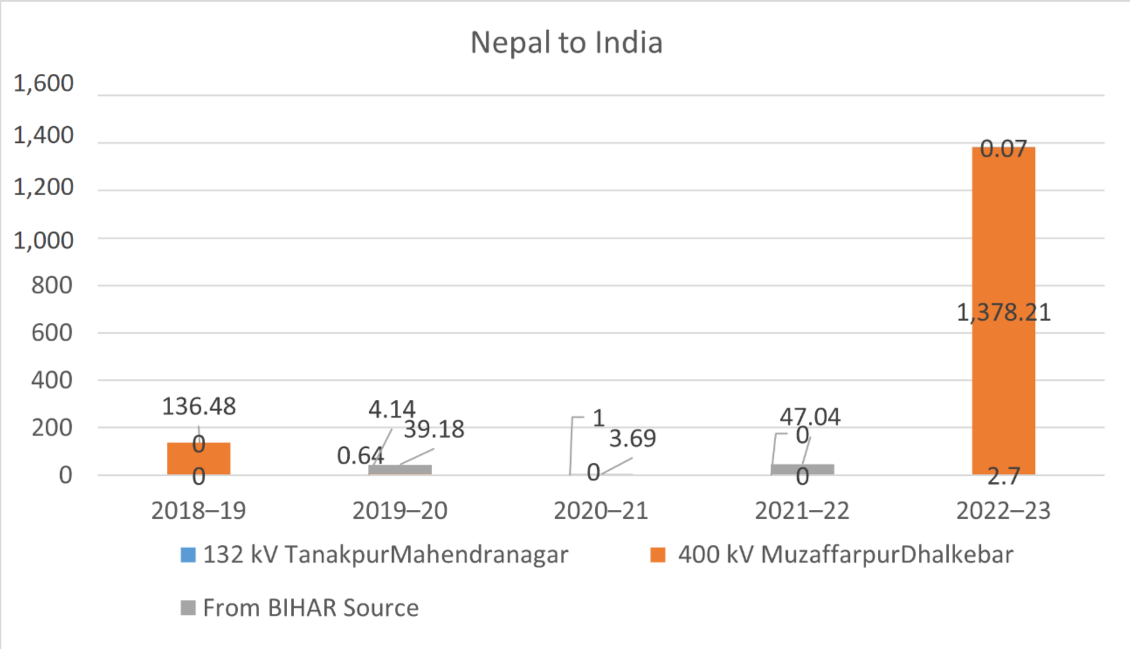
Nepal is already involved in cross-border exchange of electricity, which includes both export and import with other South Asian countries, especially India. The annual electricity exports and imports between India and Nepal through various sources are shown in Figures A2.1 and A2.2, which indicate that, 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).

Present Power Transfer

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).

Under-construction Interconnections

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.

Future interconnections

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:

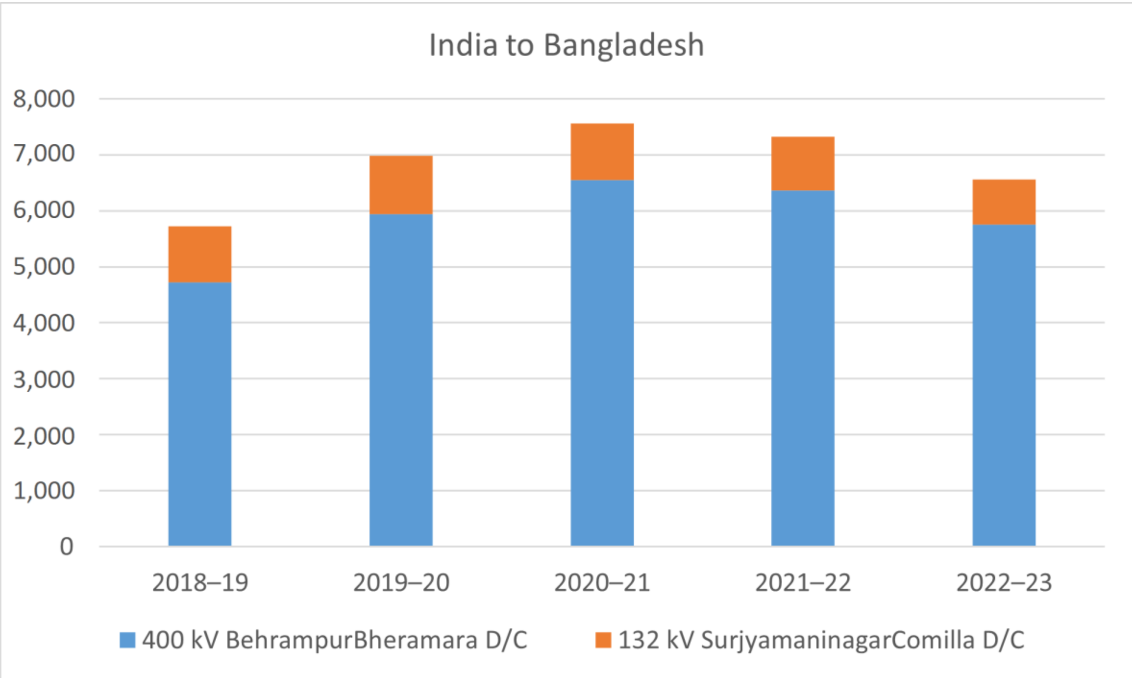
- Gorakhpur (India)–New Butwal (Nepal) 400 kV D/c (Quad) line
- Second circuit of Kataiya–Kusaha and Raxaul–Parwanipur 132 kV lines
- New 132 kV radial lines from Uttar Pradesh to Nepal
- Transmission system of Arun-III HEP

- 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.

<u>Present Power Transfer and Future Interconnection</u>

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.

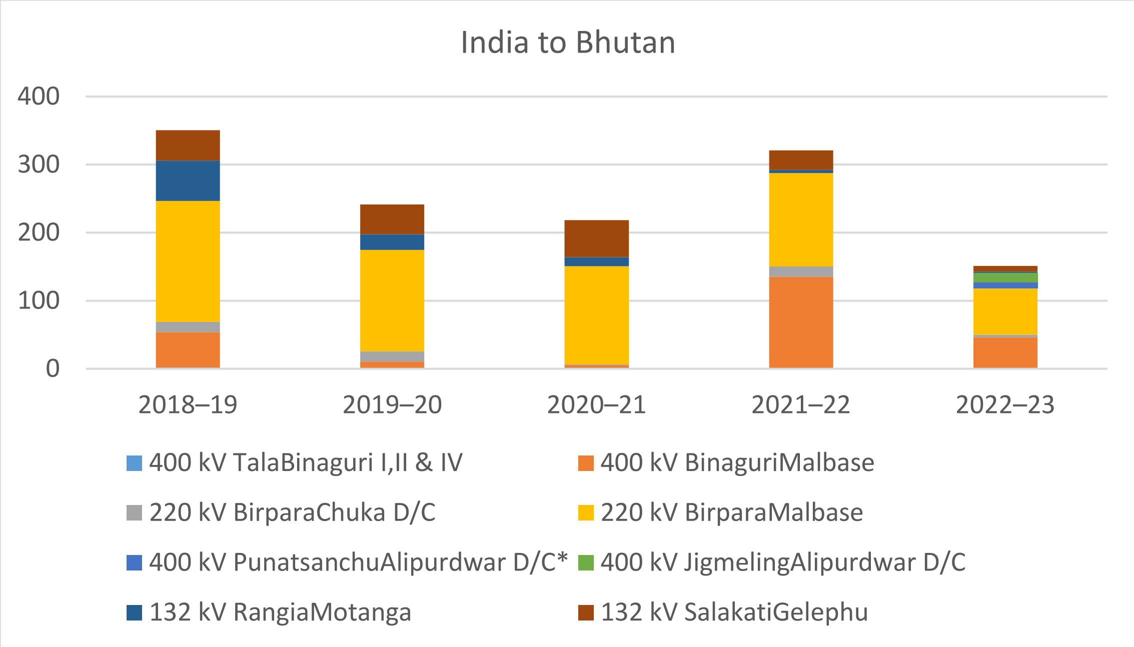
The Government of India has also chosen NTPC Vidyut Vyapar Nigam (NVVN) to serve as the nodal organisation for cross-border power trading with Bangladesh. NVVN and BPDB signed a power purchase agreement in October 2013 for the provision of 250 MW of electricity from NTPC units over a 25-year period. 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.

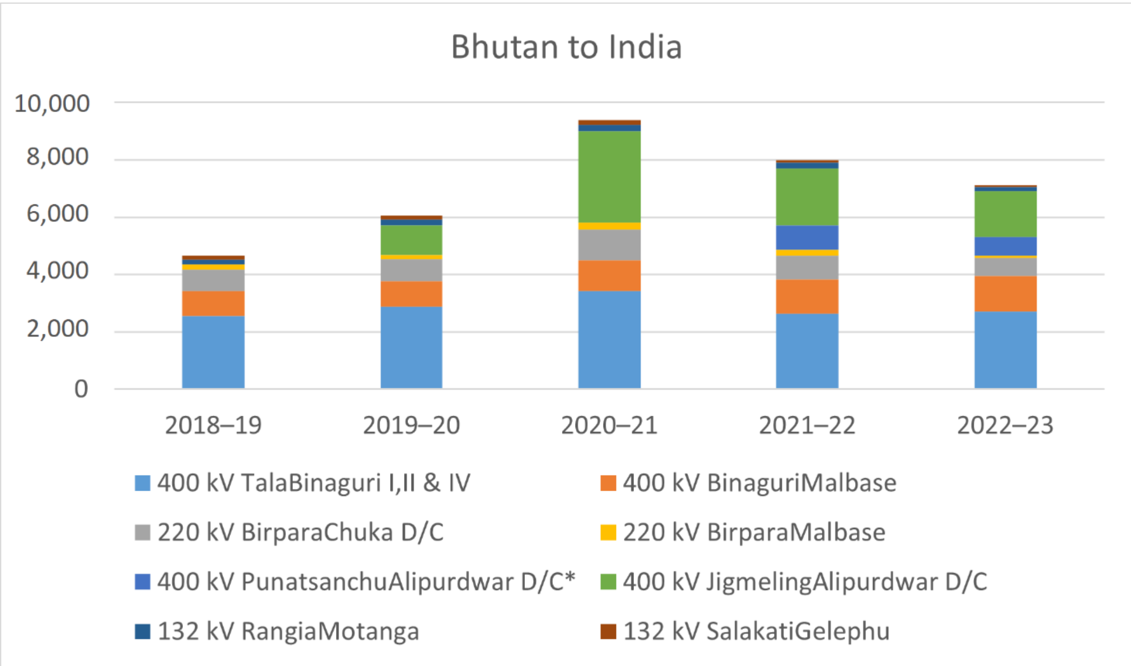
Additionally, Bhutan currently exports about 75.5% of electricity generated in the country to India. According to Bhutan's 'Richness Experiences in Cross Border Electricity Trade, 2022' report, this is about 117,715.31 GWh of the total power generation of 155,925.81 GWh. The report states that electricity 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

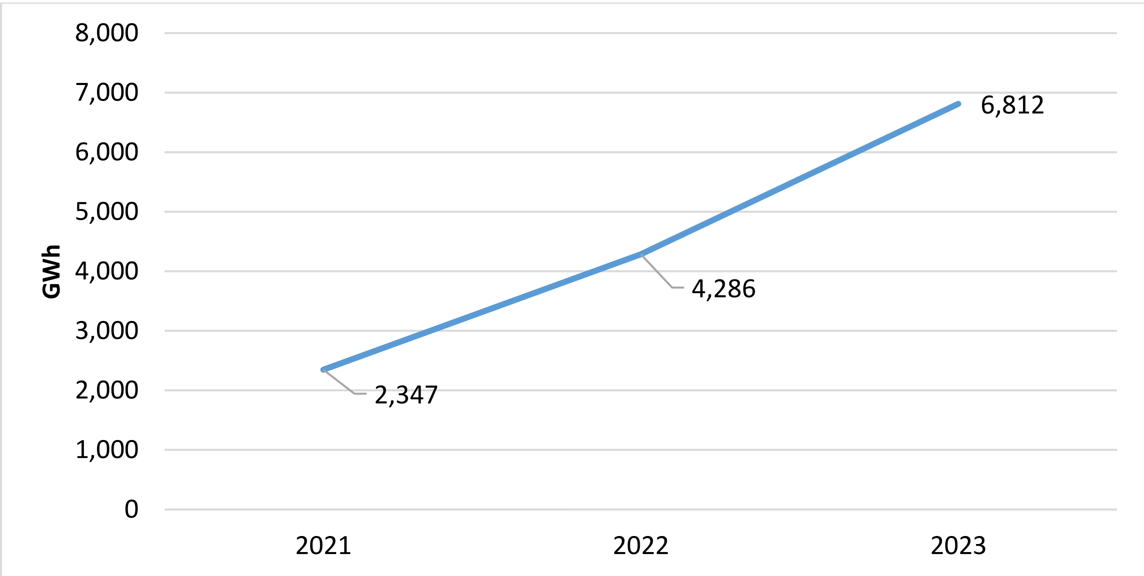


Source: TERI Estimation based on POSOCO Monthly Reports, Various months, 2018–19 to 2022–23.

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).

<u>Bhutan</u>–<u>Bangladesh as power trade potential</u>

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.