Role of Cross Border Electricity Trade in Enabling the Renewable Energy Deployment & Integration in India/ South Asia Region

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I. Executive Summary

The South Asia (SA) region is endowed with abundant natural resources and vast renewable energy (RE) resource potential. Cross-border electricity trade (CBET) presents an opportunity to integrate with neighbouring countries and to tap into the region's renewable energy (RE) potential, in particular to enable large-scale deployment and integration of RE to meet the region's demand and supply. The diversity of the region's resources enables CBET to effectively utilise the developed capacity mix in the region, thereby fostering the region's economic development. Existing power trading has demonstrated that enormous opportunities exist for India, Bangladesh, Bhutan, and Nepal to increase their cooperation in electricity trading through CBET.

The study explores the possibility of utilising CBET as a source to meet the flexibility needs, taking into account the anticipated changes in the generation mix of the nation. The countries of the BBIN region have successfully cooperated to maintain grid balance, utilising the rapid ramping capability of hydropower plants to balance the grid during critical periods. In light of the foregoing, the study's overarching objective is to evaluate the potential of CBET to support RE deployment and integration in the India/South Asia region, thereby reducing the carbon footprint of a RE-based power system in the region.

The approach and methodology of the study include the following: the literature review considering the current scenario, analysis of the existing frameworks, and identification of obstacles / challenges for our study. The study's objective was met, and data was collected from official SAARC government sites such as CEA, NITI AYOG (India), BPDB (Bangladesh), DGPC (Bhutan), NEA (Nepal), CEB (Sri Lanka), MOEE (Myanmar), PTC, NVVN, etc. CBET's transaction data from 2012 to 2022 was collected, analysed, and concluded. On the basis of the study's analysis, the CBET's challenges and benefits were determined and recommendations were made. The future of CBET was also shown.

The findings from price-volume analysis are summarised as follows: India exports electricity to Bangladesh but imports none. Bangladesh imported 8,103 MU from India in FY 2020-21. (an increase of 21.4 percent Year-on-Year). India exports electricity to Bangladesh for Rs 5.4-6.1/kWh on average. Nepal imported 2,805 MU of electricity from India in FY 2020-21 (up 63.1% year-over-year) and exported 32 MU to India. India exports electricity to Nepal for Rs 4.16-8/kWh. Bhutan supplies 70% of India's CBET imports. India imports power from Bhutan for about Rs. 2-3/kWh.

Clean development mechanism (CDM) based formula derived from the methodological tool by UNFCCC revealed India's projected carbon emission reductions in the last five years from CBET is 3.65 million t CO_2 / yr. Also, it was found that CBET (focusing on hydropower) with neighbouring countries reduces carbon emissions annually.

Power Bundling has many advantages. It makes bundled power competitively priced. It helps make RE power available to buyers 24/7/365, otherwise it's difficult. Due to the nature and availability of hydro power, inter-country transmission links are underutilised when supplying hydro power across borders. If hydro power is combined with solar or wind power, transmission line utilisation increases at a competitive cost. Various scenarios have been created to show how bundling helps increase India-Bangladesh inter-country link usage and reduces Bangladesh's power costs. The same benefit will accrue to a country that combines hydro power with solar and wind to get round-the-clock power at a competitive price.

Cost benefit assessment of transmission link was done and the model mapped the base scenario for electricity volume, and the transaction volume was increased through the proposed/assumed transmission line between the countries. As network volume increases, the cost per million units of electricity transmitted falls. It was discovered that, increasing CBET volumes justifies the proposed transmission lines between the countries and enhances CBET as well as RE integration at the same time.

Lastly, the study concludes with following five points as recommendations to increase cross-border power trade, boosting and integrating RE in South Asia:

1. Bundling Hydro Power with other RE power will increase CBET and inter-country transmission link usage. This power consolidation will benefit sellers, buyers, and the country that facilitates multi-country transactions. CBET bundling requires advocacy.
2. Present regulations prohibit Indian companies from fulfilling foreign RPOs. Lack of renewable energy to meet RPO targets could hurt India's electricity sector (GOI). We recommend that obligated entities (CPP, OA consumers, and DISCOMs) use renewable energy from neighbouring countries as part of CBET to fulfil RPOs.
3. With CBET's recent experience, private participation in India's cross-border transmission link would be useful. Policy advocacy and CBET guidelines/regulation changes are needed for participation of private players.
4. Nepal Electricity Authority (NEA) recently cancelled the tender to get a better IEX DAM rate. This NEA experience will help neighbours sell power to India bilaterally or

on an exchange. NEA also buys power from India for the upcoming dry season (December to April). CBET allows these purchase/sale methods by neighbouring countries.

5. CBET transactions are simple. Multinational supply complicates things. In multi-country arrangements, such as Nepal-India-Bangladesh or Bhutan-India-Bangladesh, PPA/PSA/TPA structure, commercial terms and conditions, and dispute resolution make transactions complex and time-consuming. If a few things can be identified, discussed, and settled beforehand, the multi-country arrangement can be completed faster.

1. Introduction

The South Asia (SA) region is blessed with abundant natural resources and enormous potential for renewable energy (RE) resources. Cross border electricity trade (CBET) provides an opportunity to integrate with the neighbouring countries and to tap-in the region's RE potential in particular to enable large scale deployment and integration of renewable energy meeting the demand and supply of the region. The diversity of the resources in the region enables CBET to efficiently utilise the developed capacity mix in the region, further enhancing the economic development in the region [1].

Enhancing CBET can benefit customers throughout South Asia. Existing power trading has shown that opportunities are enormous to undertake more supply of power among India, Bangladesh, Bhutan and Nepal. The buy and sale of power by Nepal in the platform of power exchange in India have signalled interest in increasing the commercial flow of electricity among the cross-border countries. Harmonizing policies on both sides of the border is crucial, however, poor or uncoordinated regulations can suppress CBET and jeopardize the potential public benefits. It can also be mentioned that each participating Cross-border countries are also required to enable the internal system (transmission, distribution system, procedure, regulation, etc) so that maximum benefit can be reaped.

Strengthening cross-border electricity cooperation in South Asia can be part of the solution for providing adequate and reliable electricity availability. One reason is that there are complementarities in electricity demand and supply among these countries due to the diversity of primary energy resources and differences in seasonal patterns of supply and demand [2]. In addition, increased electricity cooperation and trade among countries can bring economies of scale in investments, strengthen electricity sector financing capability, enhance competition and improve sector efficiency, and enable more cost-effective renewable electricity penetration [1, 3].

Majority of the hydropower plants in Bhutan have been developed with Indian assistance. Hydropower generated in Bhutan is sold to India under bilateral arrangement at price agreed between the countries as part of the agreement signed between the two identified entities of India & Bhutan. Several hydroelectric power stations' (such as Tala, Chuka, Kurichu etc.) agreements will expire in the next few years, at which point full ownership will be with the government of Bhutan. As a result, Bhutan will be able to sell more power on the exchange platform at the market clearing price discovered based on demand and supply. This will give opportunity to Bhutan to taste the power market of neighbouring country at a bigger scale and gear up to reap benefit from CBET. In 2016, Nepal was facing huge power crisis and Govt of India extended the support by way of enabling power supply arrangement through two identified entities of Nepal & India. Government of India identified NVVN as the Nodal Agency and Govt. of Nepal identified Nepal Electricity Authority (NEA) as Nodal agency to undertake power supply arrangement through Muzaffarpur (India)–Dhalkhebar (Nepal) (DM line) 400 kV transmission line initially charged at 132 kV and subsequently charged at 400 kV. This supply arrangement between NVVN & NEA was through bilateral mode. When this DM line was charged at 400 kV then power transfer capacity enhanced to 600 MW (this line can carry 1000 MW) and after completion of strengthening work at Nepal end this line will be able to transfer 1000 MW. Nepal stared importing power from PX platform from April 2021, through DM line. On 3rd November, 2021 Nepal started selling power from Trishuli and Devighat (39 MW total) HEP from PX platform after obtaining approval of Designated Authority (DA). Subsequently NEA got the approval of DA for 363.83 MW (to sell power under Day Ahead Market (DAM) of IEX. Also, there are many opportunities for multi-country power supply such as Nepal-India-Bangladesh, Nepal-India-Myanmar, Bhutan – India – Bangladesh which may be started in near future and positively impacts on increase of the CBET. With the start of multi-country transaction, the CBET volume is expected to increase significantly but it would increase operational complexities, commercial and legal challenges which can be addressed through mutual arrangement among the various cross-border entities.

The generation mix in the countries: Bangladesh, Bhutan, India, Nepal, and Sri Lanka is shown in Figure 1. It can be inferred that India and Sri Lanka are the maximum producers of thermal energy generation. Whereas, Bhutan and Nepal produce 70% of the electricity from hydroelectricity power. In addition to this, the seasonal power demand of the neighbouring countries is shown in Table 1. It can be seen from the table that during winters Bangladesh has low electricity demand. Whereas, during monsoon season, Bhutan and Nepal have low demand. In India, the demand varies according to the season (months) as shown in Table 1 [4].

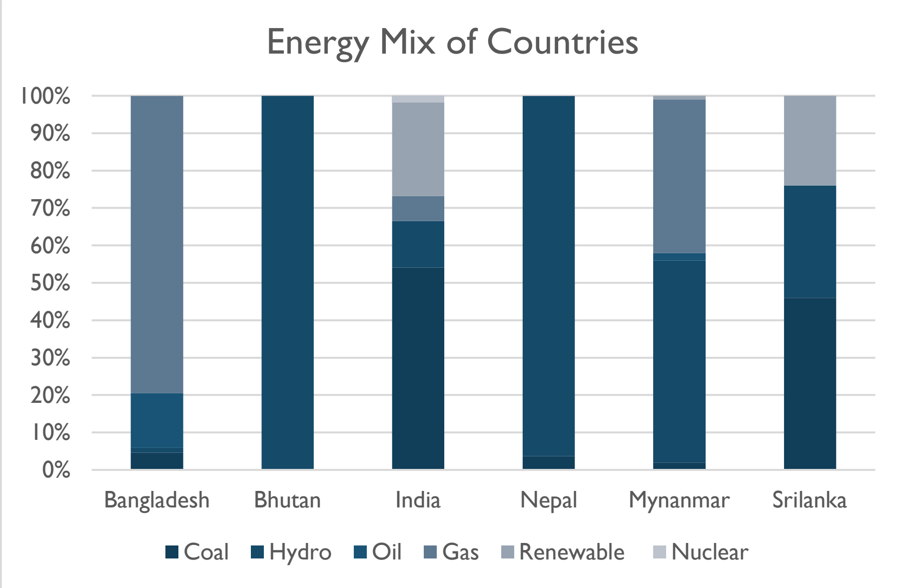


Figure 1 : Generation mix of BBINMS Countries

Table 1: Seasonal power demand of neighbouring countries

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Bangladesh	LD	LD	MD	HD	HD	HD	MD	MD	MD	MD	LD	LD
Bhutan	HD	HD	MD	MD	MD	LD	LD	LD	LD	MD	MD	HD
Nepal	HD	HD	MD	MD	MD	LD	LD	LD	LD	MD	HD	HD
India-East	LD	LD	HD	HD	MD	HD	HD	HD	HD	MD	LD	LD
India-West	HD	HD	HD	MD	MD	MD	LD	LD	LD	LD	LD	LD
India-North	MD	MD	LD	LD	MD	HD	HD	HD	HD	MD	LD	MD
India-South	HD	HD	HD	HD	MD	LD	LD	MD	MD	MD	LD	MD

LD = Low Demand **MD = Medium Demand** **HD = High Demand**

Out of the total installed capacity of the SA region, India contributes approximately up to 80% of the same. In order to minimize the gap between demand and supply in SA (BBIN countries), the required installed capacity by 2040 is estimated as 1068 GW. There is a huge untapped hydro power in the SA region of which only 20% has been exploited to date. Currently, due to less population in the hydro resource-rich countries such as Bhutan, Nepal, and Myanmar, their domestic demand is less. In order to harness these hydro resources, a global approach and robust regional energy/power market need to be established. Sharing of such resources across individual borders needs a boost through a power trading mechanism, which includes planning and development of cross-border transmission lines and harmonization of grid codes [5,6].

SAARC countries anticipate the need for CBET and signed the "SAARC Framework agreement on cooperation in the energy sector (electricity)" on November 27, 2014. The Framework accords the member states to carry out CBET subject to laws, rules, and regulations of the respective member states. It was anticipated that electricity demand would rise by over 50% by 2016 as estimated in 2011. Despite more than half of India's electricity coming from coal-powered thermal plants, there was a coal shortage. It was also estimated that by 2017, the coal deficit could exceed 42,000 megawatts. Insufficient generation capacity could cause devastating power outages. Boosting global economic growth and regional power grid integration gained steam. Seasonal differences between India and its neighbours allowed for utilisation of supply-and-demand variations. With expanding renewable energy capacity in the region, CBET transactions required to be enhanced to maximise energy surplus and increase generator use. Govt. of India took initiative to promote CBET and issued guidelines on CBET in December 2016 which was later revised in December 2018. Central Electricity Regulatory Commission (CERC) issued CBET Regulation based on the guidelines issued by MOP, GOI. GOI identified Member (Power System), CEA as the Designated Authority (DA) and CBET procedure was issued by DA in March 2021. This CBET procedure enabled cross-border entities to participate in the DAM platform of Power Exchange in India.

The objectives of MoP, Guidelines are to:

- Facilitate import / export of electricity between India and neighbouring countries;
- Evolve a dynamic and robust electricity infrastructure for import / export of electricity;
- Promote transparency, consistency and predictability in regulatory mechanism pertaining to import / export of electricity in the country;
- Reliable grid operation and transmission of electricity for import / export.

The major key milestones of India's CBET with the neighbouring countries is shown in Figure 2. The agreement for CBET trade was signed with Bangladesh in 2012 and with Nepal in 2016.

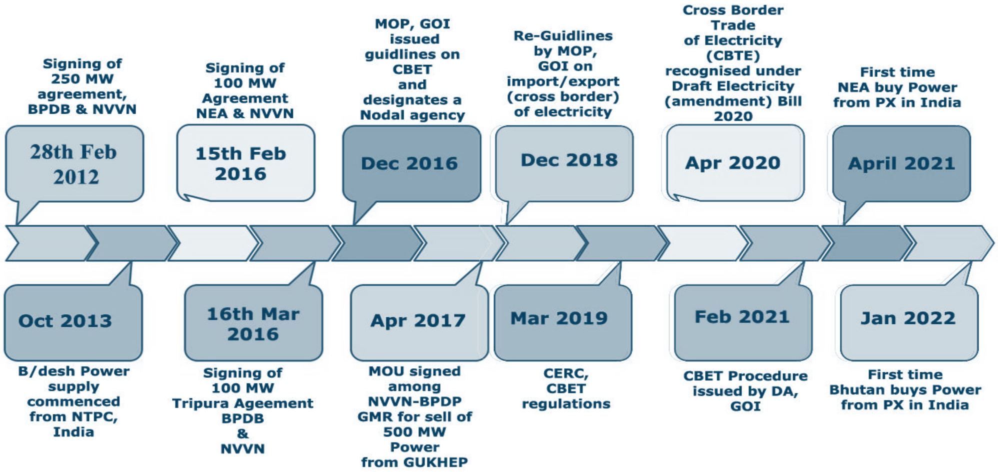


Figure 2: Key milestones of India in CBET

With the above initiative of GoI significantly accelerated SA's CBET transaction via enhancement of trading of electricity through participation of cross-border entities in the PX platform either for sale or purchase of power. Although there are challenges in laying transmission networks, CBET will maximise utilisation of existing transmission network which will make it attractive for investors to support upcoming and proposed interconnections in the SAARC region. Strengthening cross-border power cooperation in SA can be a solution that provides a sufficient and reliable power source and improvement of grid security which is also vital to national security. The diversity in the region also plays a major role in order to enhance the CBET. In Bangladesh, there is a weekly holiday on Friday, in Nepal on Saturday and in India on Sunday. These variations in weekly demand patterns complement the electricity demand and resource supply between these countries. This pattern of weekly holiday throws opportunities for more cross-border electricity trade (CBET) in this region. Bangladesh can sell power, in spite of being a deficit nation, on Fridays due to low demand.

This report mainly focuses on creating awareness of the CBET in SA countries and enhancing the same. The below sections discuss the current status of CBET in terms of volume and price, the impact of carbon emissions on CBET, the share of RE power in CBET trade, the key benefits of SA countries in participating in CBET, the gender aspects of CBET and finally discusses the future aspects in order to enhance the CBET in SA region.

2. Problem statement

Considering the changes in the country's generation mix in the years ahead, the study explores the option of utilising CBET as a source to meet the flexibility requirements. The importance of regional cooperation to maintain grid flexibility was witnessed during the 9 pm 9-minute event on April 5, 2020. The countries in the BBIN region have successfully cooperated in maintaining the grid balance, wherein the fast-ramping feature of hydropower plants was utilised for balancing the grid during the critical period.

With the above context, the broader theme of the study is to assess the potential of CBET to support RE deployment and integration in India / SA region, thereby, minimising carbon footprints by a RE-based power system in the region.

3. Objectives of the study

The study specifically aims to analyse the following research questions:

- How much quantum is traded in CBET market? CBET volume traded in the exchanges.
- Analyse prices of CBET power in bilateral / power exchange platforms.
- Impact of CBET on thermal power plants and resulting emissions.
- Has it enabled effective utilization of the generation mix in the India/SA region?
- Share of RE power in CBET trade.
- Has CBET aided in RE offtake / reducing RE curtailment / capacity addition of RE?
- How countries are benefited from participating in CBET (both buy / sell)? Expected benefits through CBET

4. Methodology

The study is based on primary and secondary research, followed by qualitative and quantitative analysis. The following steps were undertaken in order to perform the study:

1) Literature Review was conducted by considering the current scenario, analysing the existing frameworks, and identifying obstacles / challenges with regard to the targeted questions in our study.
2) The objective of the study was realised and data collection was done from different official government sites of SAARC nations such as CEA, NITI AYOG (India); BPDB

(Bangladesh); DGPC (Bhutan); NEA (Nepal); CEB (Sri Lanka); MOEE (Myanmar), PTC, NVVN etc.

3) The complete 5 years of transaction data of CBET until 2022 were collected, studied, analysed and finally concluded.
4) The challenges and benefits of the CBET based on the analysis of the study have been arrived at and the basis of the recommendations the same were made.
5) Finally, the future perspective in order to enhance CBET was portrayed.

5. Literature Review

Various reports and research papers have been published till date on CBET. The summary of the key papers that we have studied in order to conduct our study is detailed as follows.

Some of the reports of IRADe has been studied on CBET between India and neighbouring countries along with CBET in various SA countries mainly Bangladesh, Bhutan, India & Nepal were analysed and studied.

In one of the reports, the study has been carried out focussing on the economic benefits from Nepal-India electricity trade [8]. The paper mainly focuses on the advantages of how export from Nepal can boost its economy and human development. For understanding these advantages, one of the papers has made the model that addresses the key findings in order to increase trade between Nepal and India, particularly between India's Eastern and Northern LDC areas [9]. Wind and solar energy contribute zero marginal cost generation to India's mix, affecting the times when hydro exports from Nepal to India are profitable under Business-As-Usual (BAU) conditions. Under Coordinated Operations, this effect is insignificant, allowing Nepal's hydro to compete economically even during periods of lower marginal cost generation. In order to study this, one of the papers on the trends in supply and demand is studied [10]. The main objective of this paper focuses on the economic issues affecting the CBET between the two countries. The research examines hourly load data, price data, generation capacity, tariffs, and historical CBET flows to estimate supply and demand characteristics. And finally, the SWOT-AHP analysis of CBET in Nepal is studied [11], which summarizes the study by focussing on the strengths, weaknesses, opportunities and threats in electricity trade in Nepal. The barriers are mainly due to lack of modern technology, inadequate company location, limited resources, untrained human resources, and many more flaws. Political support for hydro project development is inconsistent, and political capacity to facilitate regional electricity cooperation is limited.

Then CBET in Bangladesh is studied. The paper focusses on the main economic benefits of CBET between Bangladesh – India [12]. It summarises, how export from India is economical for Bangladesh rather than other option available and also brings the substantial socio-macroeconomic and environmental gains. In addition to this, it also focusses on the key advantages in terms of India, how generation & PLF is increased, which in terms increase the profitability. Another paper focuses on the SWOT-AHP analysis of CBET in Bangladesh [13]. In this study, it identifies barriers and opportunities for electricity trading for Bangladesh, focusing on the stakeholders' perceptions. The main key findings of the study is Grid interconnection and its commercial operation with India is considered as the key starting point to push forward Bangladesh's long-term strategy of CBET.

Then papers on CBET in Bhutan is focussed. The paper focuses on the key benefits of India-Bhutan Power Corporation [14]. This article argues that as India and Bhutan have moved into the second phase of power cooperation, it is important that the two countries revisit their policies and identify approaches that will be sustainable in the long term. The main key findings are policies of the two countries are studied and approaches are identified for increase in CBET. Bhutan and India are in its hydropower collaboration. To study the key aspects of this, the paper has been studied [15], which illustrates the India and Bhutan have moved into the second phase of power cooperation.

After studying and analysing the key benefits and limitations of each country, some papers of CBET ~~is~~ studies in India's perspective in order to enhance the electricity trade. One of the research papers summarizes the CBET in India [2]. The paper mainly focusses how India is transacting power to neighbouring countries in spite of having severe challenges. Another report focuses on the multilateral electricity trade between BBIN countries [16]. It mainly covers how BBIN countries are benefitted in CBET covering the social-economic factors, policy and regulations. Another paper on CBET in SA [6] is studied. In this paper, a deeper electricity market reforms are not a necessity for further development of cross-border electricity trade, but limited progress in overcoming regional and domestic barriers will limit the scope of the regional market and the benefits it can provide. This paper has analysed the existing state of electricity cooperation in SA Region, and considered barriers to increase cross-border cooperation and trade.

In order to increase RE trade in CBET, the paper on review of challenges from increasing renewable generation in the Indian Power Sector is studied [17]. The objective of the study is that about 70% of India's current energy mix comprises of coal, and the increase in generation from renewable (RE) sources is affecting the health of the power system. In this paper, this effect through the lens of asset utilisation, cost and the social disruption caused by accelerating RE into the Indian Power System is investigated. This study presented a systemic review of the challenges that the Indian Power Sector faces due to the accelerated renewable generation post-2015 reforms given its Intended Nationally Determined Contributions (INDCs).

To minimize the drawbacks, study was carried out on international scenario of CBET in various other countries. The paper on Grid integration of renewables in China [18] is studied. The main objective of the study is that how countries / states like California, Germany & Denmark has managed to integrate & balance RE and how relevant is to China in RE. The methodology in this paper which is followed is the study on current market and policy frameworks for renewables integration in three jurisdictions: California, Germany & Denmark. The main key findings of this paper is that in all three cases, interconnections and transmission / distribution planning with neighbouring electricity systems were considered for effective integration and balancing of RE sources. Another paper on the Danish Experience with Integrating Variable Renewable Energy [19] is studied. The report studies how Denmark has enabled deployment of greater shares of wind power & the flexibility measures taken to achieve the same. The main findings from the study are that apart from flexibilisation of conventional power plants and integration with heat systems, Denmark has market based power exchange with neighbouring countries- Norway, Sweden and Germany. This enabled Denmark to sell electricity during times of high wind production, and to import electricity in times of low wind production. The export with Germany is sometimes limited depending on the wind conditions in Northern Germany. The paper on the direct interconnection of the UK and Nordic power market [20] is studied. The objective of study is implications of the direct interconnection of the UK and Nordic power market. The key findings of the paper is that after the operation of the new interconnection between Norway and the UK (North Sea Link), the overall socio-economic benefits (social welfare) in the region will likely improve by 220-230 million euro per year, without considering the cost of the interconnector itself. UK-Nordic market coupling enhances the flexibility of the UK power system in wind integration, irrespective of the share of wind in the Nordic countries. However, increasing wind capacity in the UK will diminish the economic benefits of the link.

6. Analysis

Currently, bilateral arrangements for cross-border supply of power in this region ~~are~~ predominant. Mainly, the bilateral power supply between Nepal-India, India-Bhutan, and India-Bangladesh dominates regional electricity corporation in the SA region. These bilateral supplies of power are mostly based on government-to-government arrangements, with a minimum role played by the private sector. The following section provides and overview of the power market and its arrangement across SA countries, namely Bangladesh, Bhutan, India, Nepal, Myanmar and Sri Lanka (BBINMS).

6.1. Overview of Power Market in SA Countries

6.1.1. Bangladesh

Bangladesh is situated in the delta of the Ganges and Brahmaputra rivers of the north-eastern part of India [21]. As per Bangladesh Power Development Board (BPDB) annual report for FY 2020-21, Bangladesh's total installed capacity and energy generation is 22031 MW and 80423 GWh. Bangladesh has domestic natural gas reserves, but production has failed to meet rising demand in the electricity sector. The generation mix in Bangladesh can be seen in Figure 1. There is an existing organisation structure for the power department of Bangladesh which can be seen in detail in Appendix A.1.

Currently, Bangladesh only imports power from India. The total imported power is 1160 MW which is only ~5% of the total installed capacity [6]. As per Power System Master Plan (PSMP) 2016, a total of 9000 MW of power will be imported from neighbouring countries by 2041. In the short future, Bangladesh is expected to enter in Regional Electricity Market i.e., Day-Ahead Market, and take the initiative of electricity trading via synchronous mode operation [22]. The detailed CBET information can be referred to Appendix A.2.

There is an under planning transmission project to enhance CBET: about 1000 MW additional capacity in future (after connection with Bangladesh grid) - *Synchronous*

- A new 765 kV D/c transmission line of 415 km between Katihar (India) – Parbotipur (Bangladesh) – Bornagar (India) will be implemented.

6.1.2. Bhutan

Bhutan is a landlocked country. It shares borders with the Indian State of Arunachal Pradesh to the east, and the Indian States of Assam and West Bengal to the south. Bhutan, a significant hydro-rich nation, exports power to the utilities in India and imports power from India during the lean hydro season [23]. This year 2022, first time, Bhutan purchased power from the power exchange platform of India in DAM category after obtaining approval from DA of India. In 2008, the Bhutanese cabinet endorsed the Sustainable Hydro Development Policy, which delineated measures to invite private sector participation and foreign investment to develop hydropower resources in Bhutan. Given the clear shift in Bhutan's policy towards 'opening up', in December 2009 India and Bhutan agreed to issue a joint press statement reiterating their commitment to achieving the target of 10,000 MW of power generation by 2020, thus blocking any participation of foreign players in the hydel sector [14]. The generation mix of Bhutan can be seen in Figure 1. Also, an existing organisation structure of power department in Bhutan can be seen in detail in Appendix B.1

Currently, 70% of the total generation power is exported to India by Bhutan. There is a total of 8 generating power plants in Bhutan, out of which CHP, THP, KHP, and MHEP. are under a long-term PPA with PTC India for the sale of surplus power from Bhutan. Dagachhu HEP is a JV between TATA & Druk Green Power Corporation (DGPC). Bhutan sells its power to India through Tata Power Trading Company Ltd (TPTCL) India. Bhutan obtained DA, India, approval to import power from Jan 2022 to 16th March 2022 up to 400 MW from the Day-Ahead Market in the Power Exchange. PTC, India is the trading partner of Bhutan. DGPC was appointed as a trading entity from Bhutan to import / export power from Indian Energy Exchange (IEX). The detailed information about CBET in Bhutan can be referred to in Appendix B.2.

Few under-construction power plants in Bhutan are shown in Table 2:

Table 2: Details of under construction power plants [7]

GENERATION POWER PLANTS	CAPACITY (MW)	STATUS
Punatsangchu-II	1020	Expected by 2023-24
Punatsangchu-I	1200	Expected by 2024-25

Kholongchhu	600	-
Nikachhu	118	-

6.1.3. India

India is the third-largest consumer of power in the world. Increasing electricity demand is the effect of a growing population. Increasing demand for energy is one argument for supporting market competition so that consumers can obtain power at a reasonable price [2,23].

The Indian electricity sector is undergoing a tremendous transformation that has altered the outlook of the business. India's electricity demand continues to be driven by sustained economic expansion. The Government of India's emphasis on achieving "Power for everyone" has hastened the country's capacity expansion. At the same time, both the market and supply sides are experiencing a rise in competitive intensity (fuel, logistics, finances, and manpower). As per data from MoP, India has a total installed power capacity of 402.82 GW on 31st May 2022 [24], India's installed capacity for renewable energy is 159.95 GW or 39.7% of the country's total installed power capacity. Solar energy contributes 56.95 GW, followed by 40.71 GW from wind energy, 10.21 GW from biomass, and 46.72 GW from hydropower [16, 25]. The energy mix of India can be seen in Figure 1.

The complete details of organisation framework, CBET guidelines and framework can be referred to Appendix C.

6.1.4. Nepal

Nepal is a mountainous nation surrounded by the Himalayan range. With an expanse of 147,181 km^2, the country is blessed with many rivers fed by the Himalayan glaciers, which gives Nepal a valuable resource for hydroelectric power generation [26]. The country has a subtropical monsoon climate and there are six seasons in the country Basanta Ritu (Spring), Grishma Ritu (Early Summer), Barkha Ritu (Summer Monsoon), Sharad Ritu (Early Autumn), Hemanta Ritu (Late Autumn) and Shishir Ritu (Winter). The geography of Nepal also brings some implementation challenges regarding the distribution of electricity, transportation, and public services [27,28].

Nepal has an agrarian economy. Agriculture provides livelihood to about 60% of its people and accounts for about 25% of its GDP [29]. Nepal has a GDP of 3,365.72 crores USD (2020) [30]. A major earthquake (measuring 7.8 on the Richter scale) on the 25th of April 2015 triggered a huge setback in Nepal's infrastructure and livelihood. Apart from the loss of life and property, Nepal's 14 hydroelectric power plants got damaged and caused a 30% loss in generating capacity for the national grid [31,32]. The event also led to a domino effect of adverse impact on the manufacturing sector due to power shortage [33].

Nepal is moving towards achieving its goal of being a middle-income country by FY2030, focusing on achieving an installed capacity of power generation of 5,280 MW, with 12% of it being renewable energy [34,35]. As of 2022, Nepal has a total installed generation capacity of 1,451.34 MW (of which about 96% is hydroelectric power). The generation mix of Nepal can be seen in Figure 1. The complete organisation structure of Nepal can be seen from Appendix D.1.

Nepal's largest hydroelectric power project, the Upper Tamakoshi project, is in the implementation phase. It will take Nepal's total installed generation capacity to over 1,800 MW. This would be more than enough to meet the peak demand of 1,550 MW and will also open up an opportunity for Nepal to export its surplus energy in the future [36].

The direct transaction with State Distribution Companies of Bihar, UP, and Uttarakhand under Indo-Nepal PEC mechanism is taking place since long under radial mode. Nepal started importing electricity from India in a big way with the commissioning of DM line since 2016. Nepal started exporting (selling) power to India from Nov 2021 through DM line under a Power Trading Agreement signed between NVVN & NEA. NEA has two bilateral agreement and one Power Trading Agreement with NVVN & PTC for trading of power through DM line and Tanakpur - Mahendragarh line. These arrangements are short agreements finalised year to year basis depending upon the requirement / surplus power of NEA. More details of CBET in Nepal can be referred to in Appendix D.2.

Following are upcoming transmission projects in Nepal to enhance CBET:

Under-Construction: Additional about 1800 MW - *Synchronous*

- Arun-3 HEP (900 MW) – Dhalkebar – Sitamarhi 400 kV D/c (Quad) line (250 km) – Apr 2023
- New Butwal (Nepal) – Gorakhpur (India) 400kV D/c (Quad) line (140km)– JV of NEA and PG being formed)

Under Planning: Additional about 4670 MW

High capacity 400 kV interconnections: *Synchronous*

- New Lumki – Bareilly 400kV D/c (Quad Moose) line (218km)
- New Duhabi – New Purnea 400kV D/c (Quad Moose) line (135km)
- Kohalpur – Lucknow 400kV D/c (Quad Moose) line (140km)

New 132 kV interconnection from Indian states of Bihar & Uttar Pradesh to Nepal: *Radial*

- 2nd ckt stringing of Kataiya (Bihar) – Kusaha (Nepal) 132kV S/c on D/c line
- 2nd ckt stringing of Raxaul (Bihar) – Parwanipur (Nepal) 132kV S/c on D/c line
- New Nautanwa (UP) – Mainhiya (Nepal) 132kV D/c line
- Nanpara (UP) – Kohalpur (Nepal) 132kV D/c line

6.1.5. Myanmar

India and Myanmar share a 1,643-kilometer international border. The land border runs through the north-eastern Indian states of Arunachal Pradesh, Manipur, Mizoram, and Nagaland. Myanmar is strategically important to India because it connects South Asia to Southeast Asia. It is the only member of the Association of Southeast Asian Nations (ASEAN) that shares a border with India [37]. As of May 2020, Myanmar had a total installed capacity of 6034 MW [38]. Hydroelectricity accounts for over half of the installed capacity. Natural gas is one of Myanmar's primary sources of electricity. The country intends to be completely electrified by 2030 [39]. By 2025, Myanmar hopes to generate 12% of its electricity from renewable sources [40, 41]. Under the auspices of the Ministry of Electricity and Energy (MOEE) in Myanmar, a number of energy-related divisions operate. Figure 1 shows the classification of energy generation from different sources [42, 43,44].

Below Table 3 shows the present and future Installed Capacity and demand of the Myanmar country:

Table 3: Details of installed capacity and demand of Myanmar.

Present (2022)		Future (3-4yrs)	
Installed Capacity (GW)	**Demand (GW)**	**Installed Capacity (GW)**	**Demand (GW)**
5.8 (Coal-2%, Gas-39%, Diesel-2%, RE-57%)	3.7	11.5 (Coal-1%, Gas-47%, Import-3%, RE-49%)	6.6

6.1.6. Sri Lanka

Located off the coast of India, Sri Lanka is an island republic. In total, it covers an area of 65,610 Km^2 and is 435 Km long by 240 Km broad. A thin strait known as the Palk Strait separates India and Sri Lanka. It stretches from the Bay of Bengal to Palk Bay, and ranges from 53 to 82 kilometres. Power system designers in India and Sri Lanka have been considering a high-voltage direct current (HVDC) transmission link to connect the two nations for many years [45]. CBET could lessen the requirement for investments in new thermal generation capacity while providing Sri Lanka with access to India's vast and diverse power system. Also, CBET can enable the integration of renewable energy (RE) by enabling the two countries to utilise balancing resources and wind and solar variations on a broader geographic scale with greater efficiency. It has been found that the benefits of CBET in terms of avoided capital and operating costs and greater reliability outweigh the project's cost [46].

Figure 1 shows the classification of energy generation from different sources.

Below Table 4 shows the present and future Installed Capacity and demand of the Sri Lanka country.

Table 4: Details of installed capacity and demand of Sri Lanka.

Present (2022)		Future (3-4yrs)	
Installed Capacity (GW)	**Demand (GW)**	**Installed Capacity (GW)**	**Demand (GW)**

4.3 (Hydro-32%, Thermal-51%, RE-17%)	2.7	6.9 (Hydro-33%, Thermal-36%, RE-31%)	4

The study of technological viability has already been finished. According to the memorandum of understanding, dated 9th June 2010, the feasibility study will be conducted jointly by the executing agencies with the support of an external consultant if needed. The total cost of the feasibility study is estimated to be USD 3 million which will be shared equally between Govt. of India (GoI) and Govt. of Sri Lanka (GoSL) [47, 48].

The projected cost of having external agencies/consultants perform maritime survey work/environmental impact assessment in the marine part, etc. is USD 1.5 million. The remaining tasks to be performed individually by POWERGRID (India) and CEB (Sri Lanka) will cost USD 0.875 million and USD 0.625 million, respectively.

India-Sri Lanka Proposed Interconnection:

The proposed 400kV HVDC grid interconnection between India and Sri Lanka requires the building of an HVDC link between Madurai (India) and Anuradhapura (Sri Lanka) over the Palk Strait. The projected length of the link is 387 kilometres, including 127 kilometres of submarine cables, with an initial capacity of 500 megawatts and a future capacity of one gigawatt [5].

Under Planning Project: ***Asynchronous***

Phase-1: ±320kV Madurai-New (India) to New Habarana (Sri Lanka) HVDC line (overhead) along with 500MW VSC based HVDC terminals at both ends. (Line length: about 400km)

Phase-2: 2nd 500MW VSC based HVDC terminal at Madurai-New and New Habarana.

6.2. Analysis of CBET Volume Traded & Analysis of Price

The current scenario of CBET in different BBIN countries is detailed below. A summary of the CBET between the neighbouring countries is shown in Figure 3:

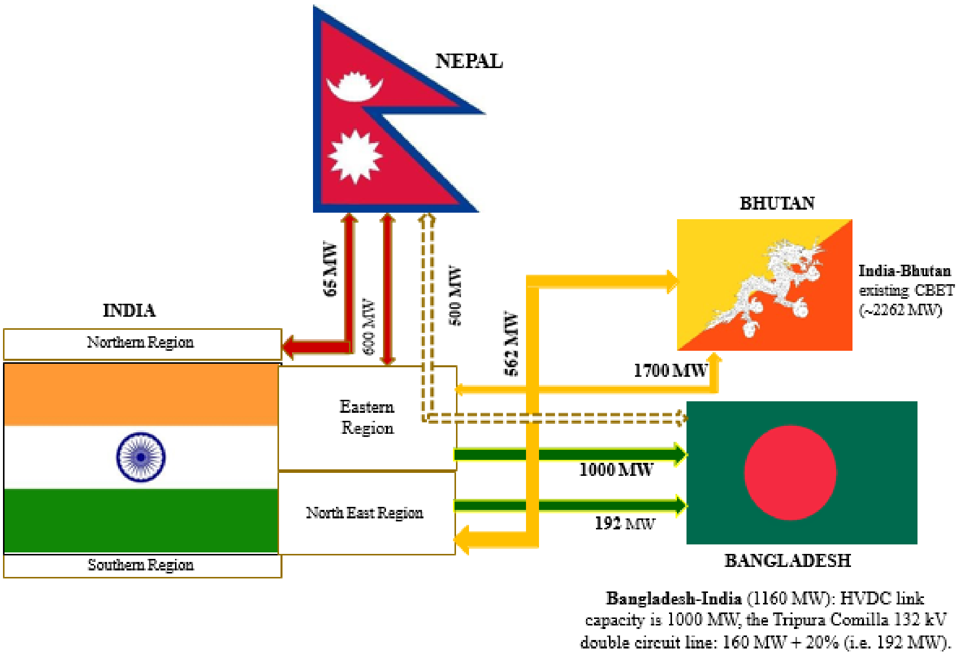


Figure 3: Summary of CBET between BBIN countries

In order to address the objective of the study, the first initial two questions i.e., how much quantum is traded in the CBET market? CBET volume traded in the exchanges? And, second, prices of CBET power in bilateral/power exchange platforms are analysed. To address these questions, the data was collected from annual reports of various trading companies such as PTC, India, NVVN, and power/energy ministries of different countries (BPDB, DGPC, CEA). An overview of overall CBET across BBIN countries is presented in Table 5.

Table 5: Overview of CBET across BBIN countries

S.No.	Particulars	Quantum (MW)	Transmission link
1	India -Bangladesh	1160	i. Bharampur-Bheramara HVDC interconnection (1000 MW) ii. Surajmaninagar-North Comilla 400kV interconnection charged at 132 kV(160 + 20%)

2	India - Nepal	600 - 865	i. 400 kV Muzaffarpur (Bihar, India)—Dhalkabar (Nepal) transmission line (1000 MW) ii. Bihar / UP / UK – 200 MW Radial link iii. Tanakpur Mahendragarh Radial Link - 65 MW
3	India - Bhutan	2325	400 kV Transmission link : 1. Tala (1020 MW) 2. Chukha (336 MW) 3. Kurrichu (60MW) 4. Dagachhu (126 MW) - DGPC & TPTCL JV 5. Mangdechhu (720 MW) 6. Basochhu (63MW - Merchant)
4	India - Myanmar	3 - 5	1. Radial link (5 MW)

A detailed analysis with reference to each country are discussed as follows.

6.2.1. India-Bangladesh

In the present scenario, Bangladesh imports 1160 MW of power from India. First supply of power from India to Bangladesh started under G-t-G mode through NVVN supplying 250 MW power from 9 stations (13 stages) of NTPC stations all over India. Subsequently, Bangladesh Power Development Board (BPDB) issued tender for purchase of power from Indian market through competitive bidding. WBSEDCL, DVC, Sembcorb, Meenakshi were selected bidder to supply power from India through various traders of India. Presently, Bangladesh and India have two interconnections one HVDC system from Bohorampur, West Bengal and another from Surajmaninagar, Tripura, under radial mode totalling 1160 MW (1000 MW & 160 MW respectively) as shown in Table 6.

Table 6: Details of interconnecting lines between Bangladesh and India [2]

International Lines	Voltage Level	Length (in CKms)	Capacity
Behrampur(ER,IN)–Bheramara(BD)	400 kV	200	1000 MW

Surajmaninagar (NER, IN) – Comilla South (BD)	132 kV (400 kV charged at 132 kV)	94	160 MW + 20%

The details of various generators in India supplying electricity to Bangladesh in the last five years are as follows (as shown in Table 7):

Table 7: Details of India-Bangladesh electricity transactions

S.No.	Transaction detail	Quantum (MW)	Mode	Nodal agency (Indian entity)	Tariff range (INR)
1	NTPC TO BPDB	250	Government to government	NVVN	2-3
2	DVC TO BPDB	300	Tender (competitive bidding)	NVVN	3-5
3	SEMBCORB/Meenakshi Energy Pvt. Ltd. TO BPDB	200	Tender (competitive bidding)	PTC	4-7
4	SEMBCORB TO BPDB	250	Tender (competitive bidding)	SEMBCORB	4-7
5	TRIPURA TO BPDB	160(+20%)	Bi-lateral	NVVN	5-8
6	WBSEDCL TO BPDB	-	-	PTC	3-6

Apart from the above power supplies, BPDB has tied up 1496 MW [18] power from Godda Thermal Power Project of M/s Adani Power (Jharkhand) Limited, Jharkhand, India to Bangladesh through a dedicated 400 kV DC transmission line to Bangladesh under a long term PPA for 25 years. This supply of power is under a special arrangement through a dedicated transmission line between India and Bangladesh. The PPA is signed between M/s Adani Power, India and BPDB, Bangladesh allows for fixed and variable tariffs denominated in US dollars. The supply of power under this arrangement is yet to be commenced.

Figure 4 shows the volume transacted by different generators in India to Bangladesh in MUs through power traders NVVN and PTC India Limited (PTC). In addition to this, it can be seen that each plant's average price (Rs/kWh) is calculated.

Whereas, the total power imported by Bangladesh from in the last five years is shown in Figure 5.

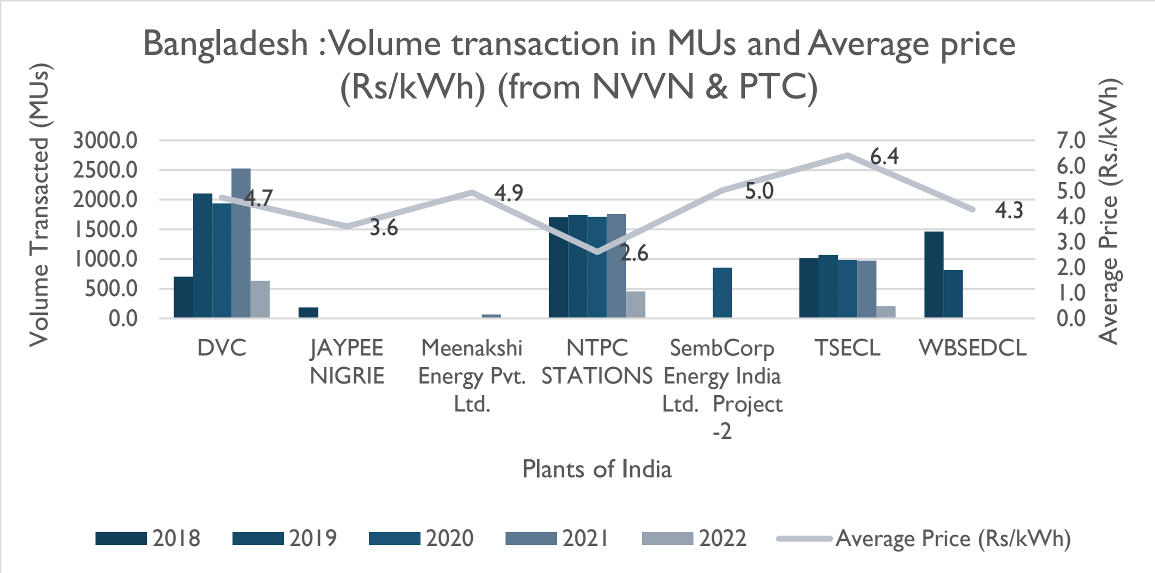


Figure 4: Graph shows the transacted five year volume to Bangladesh from NVVN and PTC

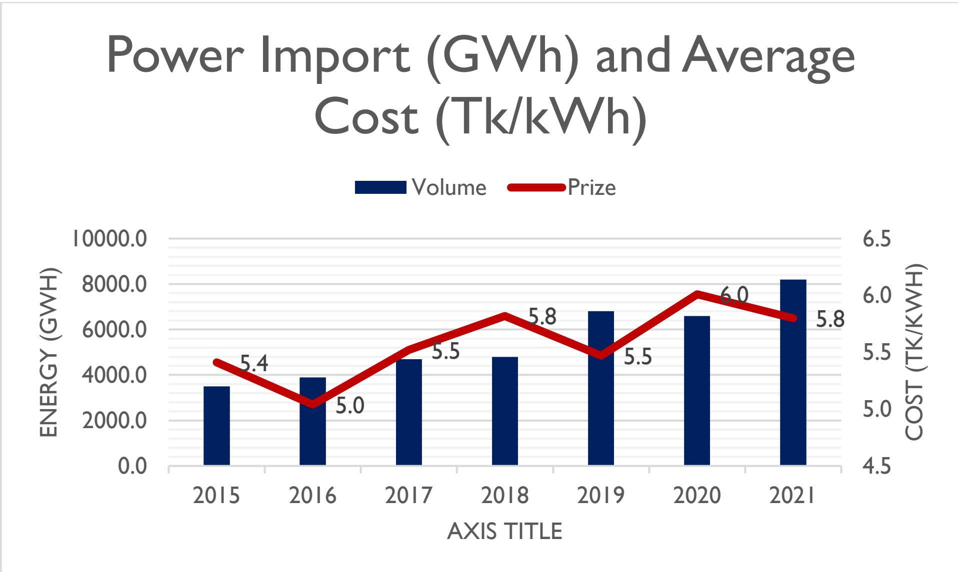


Figure 5 : Power Import and Cost between India and Bangladesh

In order to enhance the import of electricity from India, the Bangladesh government is in the process of participation in the Indian power exchange. This participation will help Bangladesh (Bangladesh Power Development Board - BPDB) either to buy power or sell power in the platform of Power Exchange as per the prevailing market conditions. As Figure 6 shows, there is sufficient variability across seasons in Bangladesh. Participation in the Indian power exchange may support Bangladesh in efficiently managing the demand with optimal resource utilization.

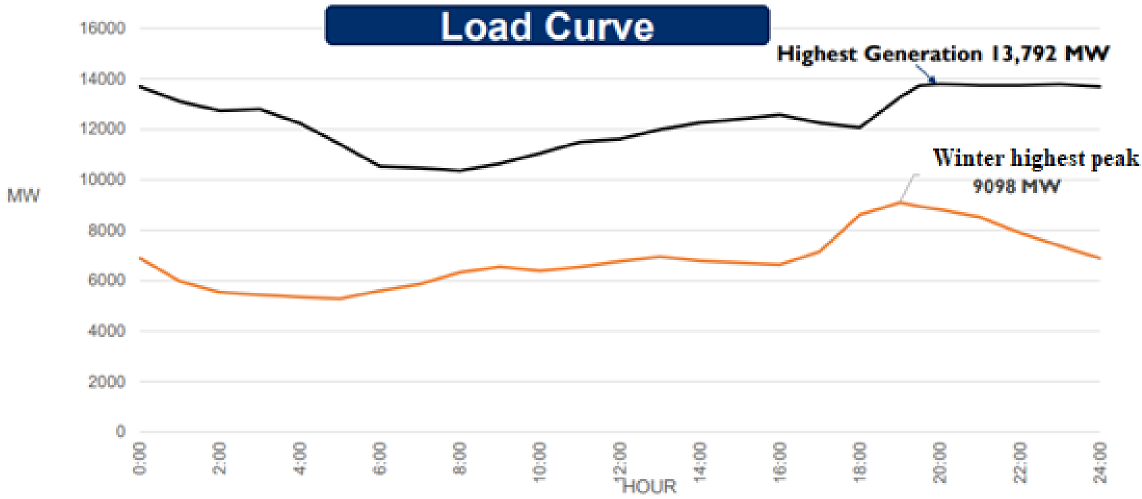


Figure 6: Load curve (summer vs winter) in Bangladesh for FY 2020-21.

6.2.2. India-Bhutan

Bhutan is both a buyer as well as a seller to India. Out of total generated electricity in Bhutan, 70% is exported to India.

Following Table 8 shows the details of generating hydropower plants in Bhutan:

Table 8: Details of generating power plants in Bhutan [2]

GENERATING POWER PLANTS	CAPACITY (MW)
Chukha Hydropower Plant	336
Kurichu Hydropower Plant	60
Basochhu HPP (Upper Stage)	24
Basochhu HPP (Lower Stage)	40
Tala Hydropower Plant	1020
Dagachu Hydropower Plant	126
Mangdechhu Hydropower Plant	720
Micro/Mini	8
TOTAL	**2334**

In the Table 7, all generators are having 100% of their capacities allocated to Indian beneficiaries except Dagachu. Dagachu power plant is selling power through STOA (Short Term Open Access) involving Tata Power Trading Company Ltd (TPTCL) as a trader. PTC Limited is working as a trading agency between Bhutan and Indian constituents for the settlement of actual energy receipt in India. India imports power from Bhutan to meet its load demand. Transactions through all connectivity with India are in Eastern Region and North Eastern Region.

The power links between India and Bhutan are shown in Table 9:

Table 9: The international line links between India and Bhutan

International Lines	Voltage Levels
Binaguri(ER,IN) – Tala I & II(BH)	400 kV
Binaguri(ER,IN)– Tala IV (BH)	400 kV
Binaguri(ER,IN) –Malbase(BH)	400 kV
Alipurduar (ER,IN)–Jigmeling (through Punatsangchhu)(BH)	400 kV
Birpara(ER,IN) –Chukha(BH)	220 kV
Birpara(ER,IN) –Malbase(BH)	220 kV
Salakati(NER,IN) –Gelephu(BH)	132 kV
Rangia(NER,IN) –Motonga(BH)	132 kV

India has the following feeders which are connected with Bhutan radially shown in Table 10. Energy charges for import by Bhutan through these feeders are settled directly between Bhutan and the concerned DISCOM of India [23].

Table 10: The international line links between India and Bhutan

Feeder Name	Connectivity point(India)	Voltage Level
Tamalpur - Sandrupkhonar	Assam(NER grid)	33 kV
Rauta - Diafem	Assam(NER grid)	11 kV

The Figure 7 shows the volume transacted by Bhutan to different plants in India in MUs through power traders TATA Power Trading Company Limited (TPTCL) and PTC. In addition to this, it can be seen that each buyer plant's average price (Rs/kWh) is calculated.

Bhutan earlier imported power during dry season from India through Bilateral means. Bhutan has started to import power from Indian Energy Exchange (IEX) from 1st January-16th March 2022 through PTC India. The total volume transacted to date through IEX is 135.4 MUs.

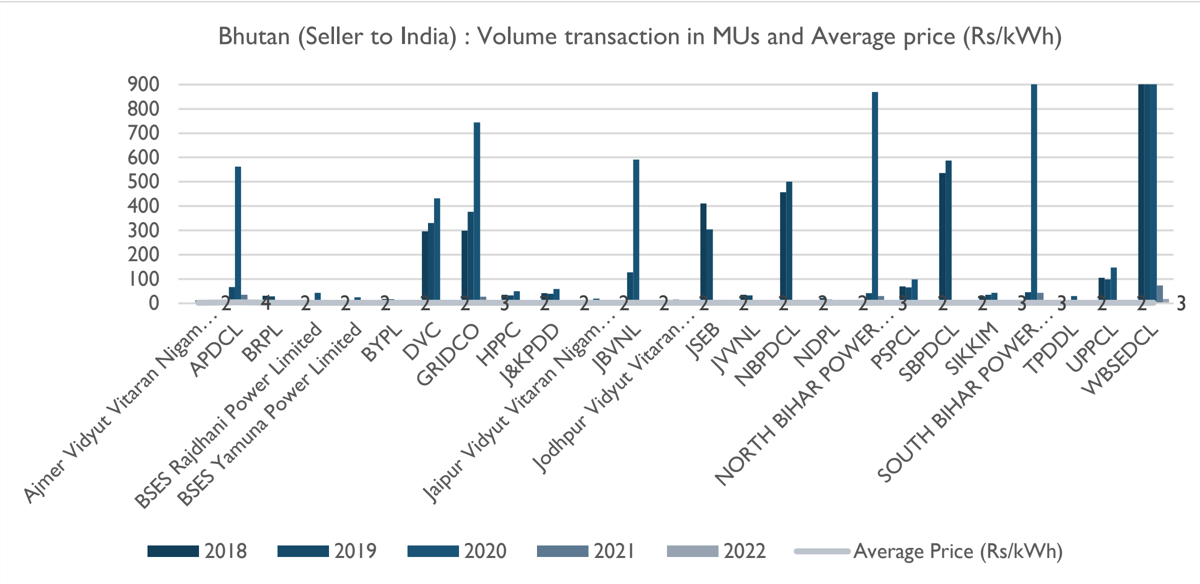


Figure 7: Graph shows the transacted five year volume to India by Bhutan

Tala, Chukha, Kurichu, and Mangdechu HEP are not covered under the CERC (Deviation settlement mechanism) regulations. Energy billing of Tala, Chukha, Kurichu & Mangdechhu to their beneficiaries is done based on actual interchange. Deviations from scheduled interchange are settled at the energy charge rate and the liability is passed on to their beneficiaries as per their share allocation from the plants. PTC is the nodal agency for such energy transactions [2, 22].

Dagachhu HEP sells power through STOA and is covered under the Deviation Settlement mechanism. The deviation is settled by Tata Power Trading Company Limited (TPTCL) with the Eastern Regional Deviation Settlement pool as per CERC DSM regulation. Power of Tala, Chukha, and Dagachu is evacuated to India at Birpara and Binaguri stations of India due to interconnection of Tala-Binaguri & Birpara- Chukha lines at Malbase s/s of Bhutan. There is a mixing of Tala, Chukha, and Dagachu power in these two stations.

6.2.3. India-Nepal

Nepal transacts power from India through both bilateral and power exchange routes. The power exchange route is gaining momentum, considering the seasonal and demand variations across India and Nepal.

Presently, India offers cross border electricity trade to Nepal via the following transmission networks: Muzaffarpur (400 kV), Kataiya (132 kV), Tanakpur (132 kV), Raxaul (132 kV), Ramnagar (132 kV), and Other 33 & 11 kV Inter-country Points [29]. Some of the international lines are not operational at all times, but the details of the existing lines are mentioned below in Table 11:

Table 11: Details of interconnecting lines between Nepal and India

Through Bihar System	Voltage Level
Balmiknagar (Bihar) - Surajpura (Nepal)	132 kV
Surajmaninagar (NER, IN)– Comilla South (BD)	132 kV
Balmiknagar (Bihar) - Surajpura (Nepal)	132 kV
Kataiya (Bihar) - Duhabi (Nepal)	132 kV
D/C Kataiya–Kusaha	132 kV
Raxual-Parwanipur line	132 kV
Thakurganj (Bihar) - Bhadarpur (Nepal)	33 kV
Raxaul (Bihar) - Birganj (Nepal)	33 kV
Kataiya (Bihar) - Biratnagar (Nepal)	33 kV
Jaynagr (Bihar) - Siraha (Nepal)	33 kV
Kataiya (Bihar) - Rajbiraj (Nepal)	33 kV
Sitamari (Bihar) - Jaleswar (Nepal)	33 kV

Jogbani (Bihar) - Biratnagari (Nepal)	11 kV
Bargania (Bihar) - Gaur (Nepal)	11 kV
Through CTU	**Voltage Level**
Mazaffarpur-Dhalkheber (Nepal)	400 kV

The major generators of Nepal that sell power to India are Trishuli Hydropower Station (24 MW), and Devighat Hydropower Station (15 MW). Nepal had submitted application for DA approval to export electricity to India, which includes: Upper Tamakoshi (456 MW), Upper Bhotekoshi (45 MW), Kaligandaki (144 MW), Marshyangdi 69 (MW), Middle Marshyagndi (70 MW) and Chameliya (30MW). NEA has been accorded approval of export of 363 MW power by the Designated Authority of India under DAM category of Power Exchange. The application of Upper Tamakoshi (456 MW) is under consideration of DA in India.

The major generators in India which take part in export to Nepal under bilateral mode are Adani Power Limited (12,450 MW), North Eastern Electric Power Corporation Limited (NEEPCO) (2,057 MW), Sembcorp Energy India Limited (SEIL) (4,370 MW), GMR Power (4,400 MW) [29,30]. These generators supply power to Nepal through NVVN & PTC against the bilateral PPA signed between NEA & NVVN / PTC.

Some of the future hydropower projects are as follows:

The three year prices in the power exchange during the months Nepal has surplus power (wet season) are detailed in Tables 12 and 13. The high prices during this period indicate that Nepal can gain significantly by participating in the Indian power exchange [30]. Further, the trend in the exchange market shows that the prices will climb higher in near future.

Table 12: Average yearly prices in Indian power exchange during the period Nepal is surplus

Year Month	2019	2020	2021	PX Yearly Average (Rs/kWh)
May	3.33	2.57	2.30	2.73
June	3.32	2.35	3.06	2.91
July	3.38	2.47	2.94	2.93
August	3.30	2.43	5.06	3.60
September	2.91	2.69	4.37	3.32
Monthly Average	3.25	2.50	3.55	3.10

Table 13: Details of prices in Indian Power exchange during the period Nepal is surplus

Year	Month	RTC Rs/kWh	Morning Peak (6 to 10) Rs/kWh	Evening Peak (17 to 21) Rs/kWh
2018	May	4.67	3.85	4.68
2018	Jun	3.73	2.85	3.95
2018	Jul	3.46	3.03	4.52
2018	Aug	3.34	3.09	4.46
2018	Sep	4.69	4.21	6.79
2019	May	3.34	2.59	3.58
2019	Jun	3.32	2.43	3.50
2019	Jul	3.38	2.65	4.00
2019	Aug	3.33	2.99	4.23
2019	Sep	2.78	2.58	3.50
2020	May	2.57	2.46	2.39
2020	Jun	2.35	2.22	2.31
2020	Jul	2.47	2.46	2.55
2020	Aug	2.43	2.32	2.72
2020	Sep	2.69	2.49	3.18
2021	May	2.83	2.49	2.90
2021	Jun	3.06	2.47	3.02
2021	Jul	2.95	2.51	3.19
2021	Aug	5.06	4.46	6.96
2021	Sep	4.40	3.49	7.37

During FY 22, the Nepal Electricity Authority (NEA) bought 786 MU and sold 32 MU from the Indian Energy Exchange. Figures 8 and 9 show the trends in volumes transacted and prices.

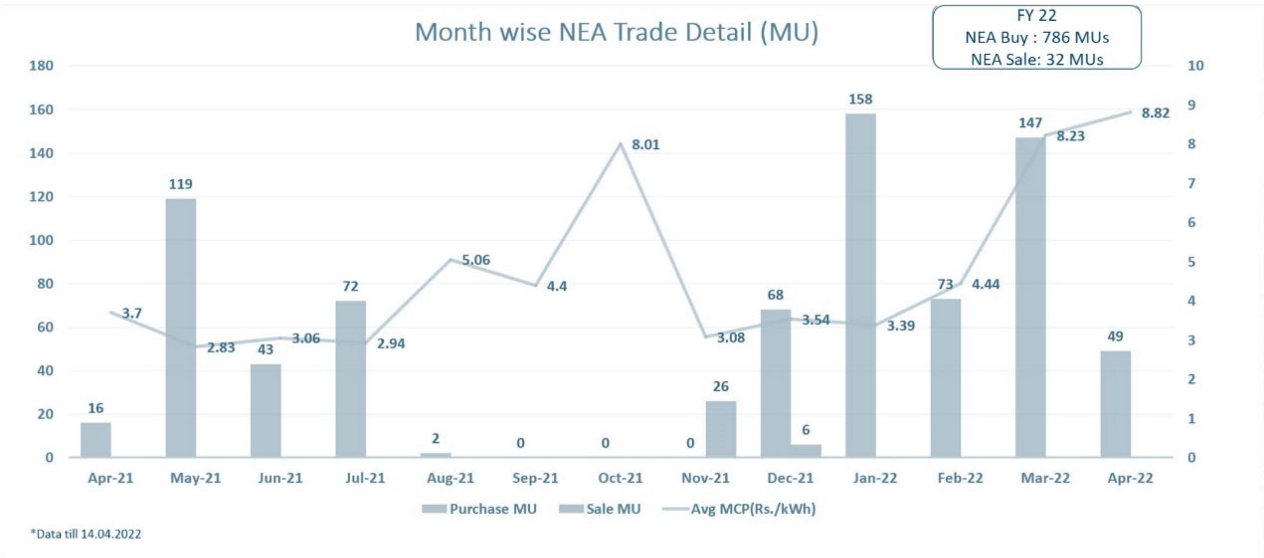


Figure 8: Month wise NEA Trade Detail (MU)

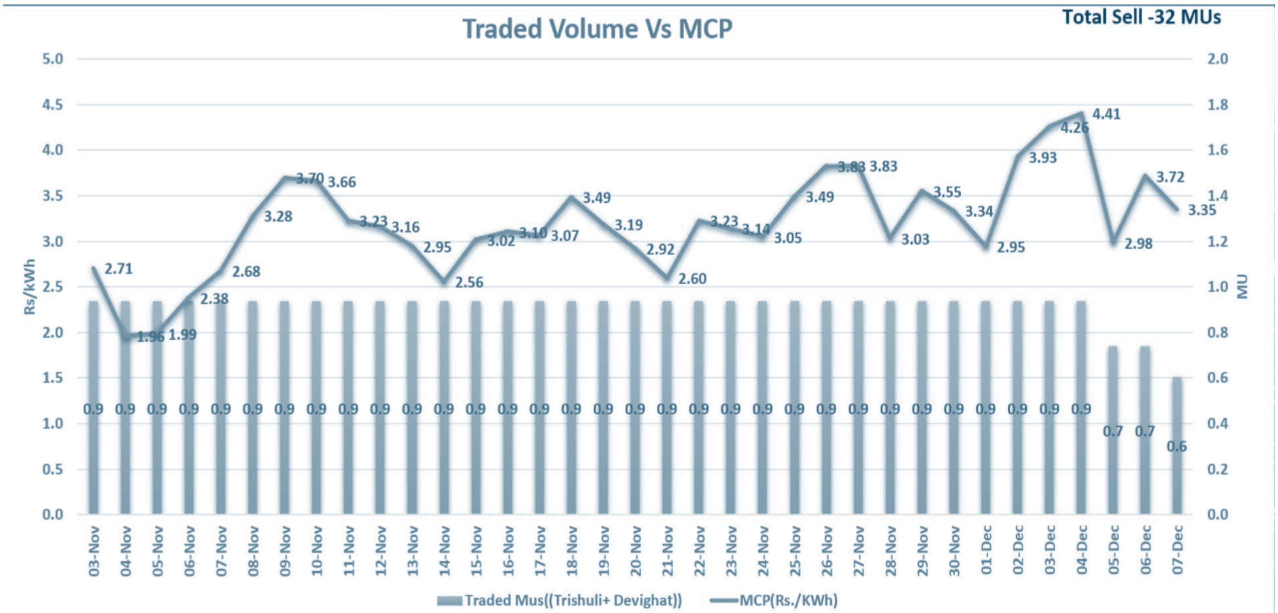


Figure 9: Traded Volume vs Market Clearing Price (MCP)

6.2.4. India – Myanmar

India and Myanmar trade electricity, but at a relatively low volume. Geographic characteristics and proximity between the two nations suggest that cross-border electricity trade has enormous potential. India is transmitting approximately 3 MW of electricity from Moreh in Manipur (India) to Tamu town in Myanmar via an 11 kV transmission line. The strengthening of further low-capacity links at different locations along the border is being coordinated. Also under consideration is a high-capacity transmission link between the nations [43].

Low-Capacity interconnections: Following links have been identified in Radial mode

- Nampong (Arunachal Pradesh, India) – Pansong (Myanmar) 11kV line
- Behiang (Manipur, India) – Cikha (Myanmar) 11kV line
- Zokhawthar (Mizoram, India) – Rikhawdar (Myanmar) 11kV line
- Nagaland (India) to neighbouring villages in Myanmar

High-Capacity interconnections: Asynchronous mode

- Imphal – Tamu 400kV DC line along with 500MW, HVDC B-to-B station at Tamu (Myanmar) (100km)

6.2.5. CBET transactions between BBIN countries

The following Table 14 shows the volume transacted between BBIN (from India's perspective):

Table 14: Details of volume transacted through CBET

Year	Export (in MUs)			Import (in MUs)			Total Export (in MUs)	Total Import (in MUs)	Remarks
	Bangladesh	Nepal	Bhutan	Bangladesh	Nepal	Bhutan			
2020-21	8103	2806	-	0	-44	-3861	10909	-3905	Exporter
2019-20	6674	1721	267.24	0	-107	-4464.97	8662.24	-4571.97	Exporter
2018-19	6786	2813	300.34	0	-35	-4053.59	9899.34	-4088.59	Exporter
2017-18	4782	2582	207.89	0	-2.94	-5068.48	7571.89	-5071.42	Exporter
2016-17	4655	2175	110.64	0	-2.69	-5484	6940.64	-5486.69	Exporter

Bhutan – India: From 2016-17 to 2020-21 i.e. in 5 years, the average exported volume through CBET has been 221.5 MU and the average imported volume through CBET has been 4586 MU. India has been a net importer from Bhutan. In the present scenario, about 2100 MW is exported from Tala, Chukha, Kurichhu, Dagachu and Mangdechhu. Punatsangchhu I and II (2220 MW) HEP transmission and associated infrastructure are now under construction. The Umbrella Agreement agreed between Bhutan and India calls for the development of a 10,000 MW export capacity. Efforts are being made to sell power from several HEPs

Bangladesh – India: From 2016-17 to 2020-21 i.e. in 5 years, the average exported volume through CBET has been 6200 MU and the average imported volume through CBET has been 0 MU. India has been a net exporter of Bangladesh.

An HVDC station has been installed in Boharampur, India, to supply 1000 MW of power from India via the Boharampur-Bheramara 400 kV line. Around 100-160 MW of power is sent to Bangladesh via the Tripura-Comilla transmission line under radial mode. Further, about 1000 MW of additional capacity is in the planning phase via synchronous mode.

Nepal – India: From 2016-17 to 2020-21 i.e., in 5 years, the average exported volume through CBET has been 2419 MU and the average imported volume through CBET has been 38 MU. India has been a net importer of Nepal. India currently exports 400-500 MW of power to Nepal. Multiple 11 kV to 132 kV interconnections exists with a total capacity of 150 MW. Additionally, about 1800 MW of transmission link in synchronous mode is under construction and, about 4670 MW capacity is in the planning phase.

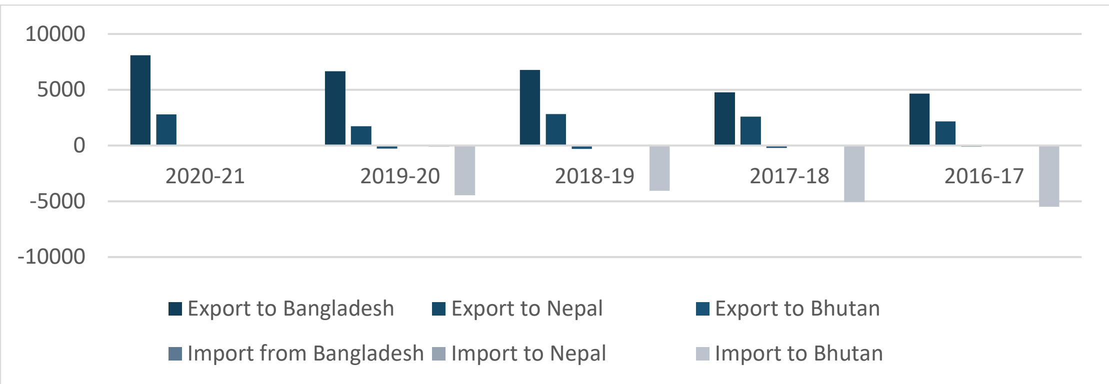


Figure 10: Total Schedule volume transacted in MUs

Key Analysis from above Figure 10:

- Currently, India is only exporting electricity to Bangladesh and not importing from them. In Fiscal Year FY 2020-21 Bangladesh imported 8,103 Million Units (MU) of electricity from India (an increase of 21.4% Year-on-Year).
- The average price of electricity that India is exporting to Bangladesh ranges from Rs 5.4 - 6.1 / kWh.
- In Fiscal Year FY 2020-21 Nepal imported 2,805 Million Units (MU) of electricity from India (an increase of 63.1% Year-on-Year) and exported 32 MU of electricity to India.
- The average price of electricity that India is exporting to Nepal ranges from Rs 4.16-8 / kWh.
- Out of total CBET imports of India 70% of it is from Bhutan. The average price at which India is importing power from Bhutan is around Rs. 2-3 / kWh.

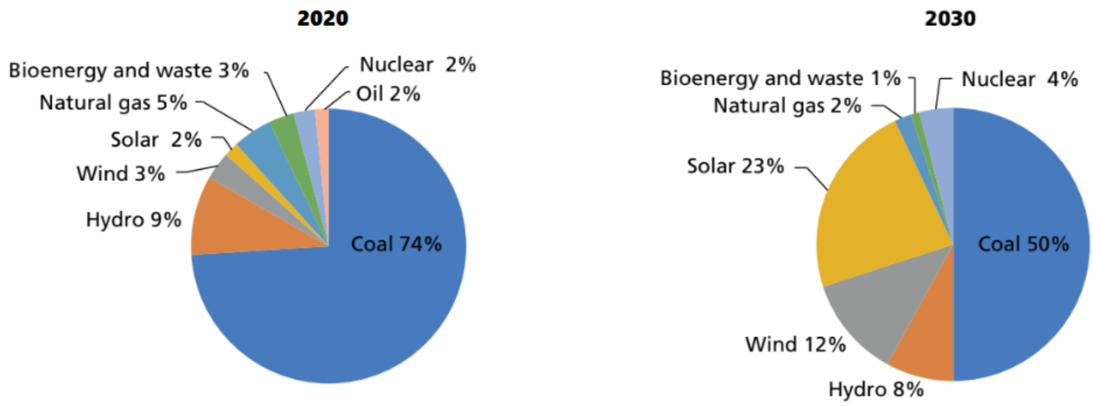
6.3. Impact of CBET on Thermal Power Plant

This section covers the details about the impact of CBET on thermal power plants and how it is affecting the resulting emissions.

6.3.1. Introduction

Human activities have caused the amount of carbon dioxide (CO_2) in the air to rise quickly over the last two hundred years. As CO_2 levels rise, the temperature around the world rises because it is a greenhouse gas (GHG). In 2022, the average amount of CO_2 in the atmosphere around the world is 421 parts per million (ppm). This is about a 50% increase from pre-industrial times when it was around 210 ppm [49]. The world's temperature has already gone up by 0.8°C, and it could go up by another 2°C if strict steps are not taken to cut down on Green House Gas (GHG) emissions [47].

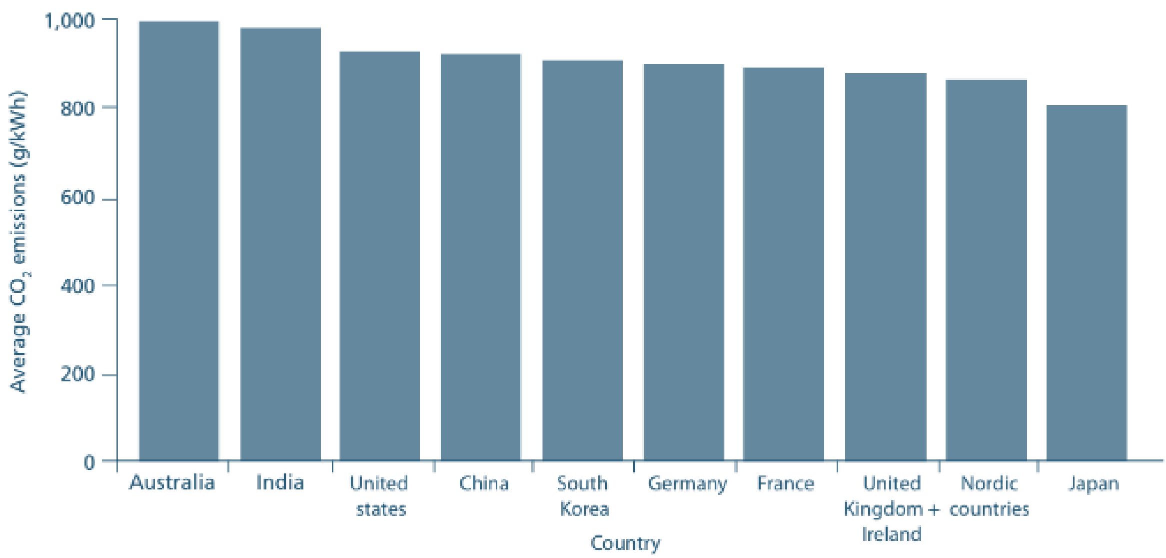
India will continue to depend on coal for its energy security. By 2030, coal will make up 50% of all the power that is made as shown in Figure 11.



Source: IEA, 2020

Figure 11: Present and future generation of coal based power plants.

According to the CEA, India's coal capacity will increase by 38 GW to 266 GW by 2030. This indicates that India has stated it will not invest in new coal after this point [48]. Already, there is a lot of pressure around the world to get rid of coal. Many developed countries have promised to get rid of coal plants and have set deadlines to do so. Nineteen countries want to stop using coal to make electricity by 2030, and some even want to do it by 2040. Even for developing countries, the BAU (Business As Usual) method will not work in this situation. So, if developing countries want to keep using coal to make sure they have enough energy, it is up to them to make sure it is burned efficiently and cleanly. Below Figure 12 shows that in the world, India is the 2nd highest specific CO_2 emissions, standing upto 983g/kWh among various countries. The country with the highest CO_2 emissions is Australia [49,50].



Source: Ecofys, 2018

Figure 12: Global comparison of specific CO2 emissions of coal-based power

6.3.2. Potential Factors to reduce CO_2 emission from India

Understanding the performance of a power plant can be difficult due to the multiple aspects at play, such as availability of fuel/water, installed capacity, unit age, planned outage, etc. Utilized technology largely determines the efficiency of coal consumption and CO_2 emissions of thermal power. The primary distinction between subcritical, supercritical, ultra-supercritical, and advanced ultra-supercritical technologies is their operating temperature and pressure, which affect the heat-carrying capacity of the steam and, consequently, its efficiency (see Figure 13).

The efficiency of a system can be measured in terms of its heat output. The heat rate is the amount of energy required to generate one kilowatt-hour of electricity and is measured in calories per kilowatt-hour. The lower the heat rate, the more efficient the plant and the lower its coal consumption and CO_2 emissions. Estimates of a plant's CO_2 emissions are primarily based on its coal consumption. Nonetheless, if we want to directly correlate CO_2 emissions with a plant's efficiency, a 1% increase in efficiency reduces CO_2 emissions by 2–3% [51, 52].

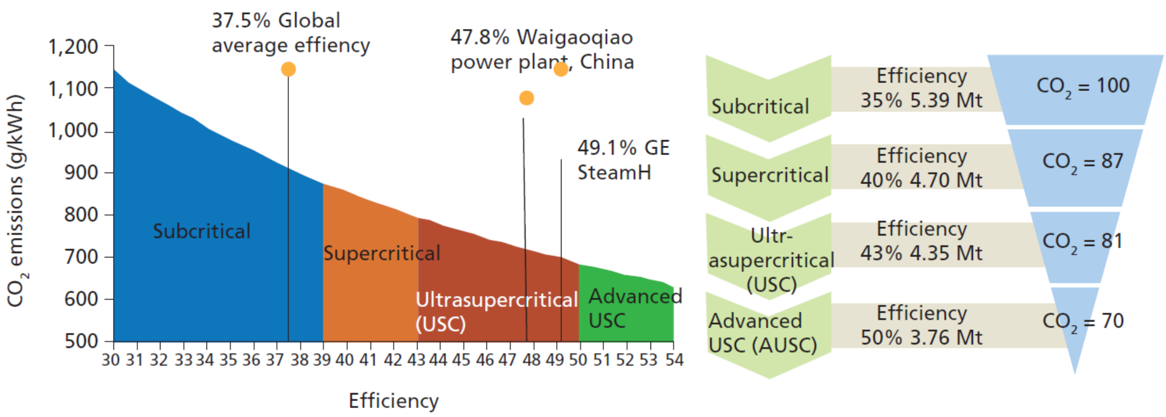


Figure 13: Efficiency & Carbon Emission of TPP technologies, IEA, 2020

By replacing a subcritical unit with an ultra-supercritical unit, CO_2 emissions can be reduced by 30%.

6.3.3. Ways to Increase Efficiency

Coal plays an important role as an affordable, secure, and dispatchable energy source for India's expanding economy although with a gradually diminishing share of the overall energy mix as renewables expand. Therefore, it is imperative to find innovative ways to increase the efficiency and capacity utilization of both conventional and non-conventional sources of energy without negatively impacting either generation. If coal power plants are to remain competitive in a market with a higher proportion of renewable energy sources, they will need to operate in a flexible manner. In India, the average coal unit efficiency is roughly 35% compared to state-of-the-art efficiency of some 47.5% Low Heating Value (LHV). Thus, CO_2 emissions from India's coal fleet might be lowered greatly through a combination of retiring or improving existing units and creating new efficient ones.

There are several incentive schemes to promote the upgrading of subcritical plants and the upgrading of some small units (<200 MW) has resulted in savings of over 100 kt/y coal and 165–190 kt/y of CO2 emissions for each unit with a return on investment in less than two years. By 2023, India is projected to have 250 GW of operational coal-fired utility power generating capacity, of which over a third will be Super Critical (SC) or Ultra Super Critical (USC). The expectation is that this remarkable improvement in efficiency will continue. More emphasis must be placed on planning and readiness for anticipated market and operational environment changes [52].

6.3.4. Role of CBET on decreasing CO_2 emissions

Increasing the volume of CBET will directly result in an increase in the PLF of power plants as a result of demand growth. Moreover, combining electricity generated by Thermal Power Plants (TPP) with renewable energy will help achieve an attractive price for power off takers and alleviate the burden of rising imported coal prices.

Carbon is carried by fossil fuels, with coal being the primary carrier. With the aggressive advancement of contemporary civilization, CO_2 emissions from the combustion of fossil fuels have become the primary source of global greenhouse gas (GHG) emissions caused by humans. In India, thermal power generation is one of the primary uses of fossil fuels (particularly coal). Over 50% of the total installed capacity is derived from coal. Thus, there is potential to reduce CO_2 emissions in the country through fuel substitution by increasing the use of renewable energy sources and enhancing the thermal efficiency of power generation. In this section, we will examine India's carbon emission offsets resulting from CBET.

Carbon footprint is defined as "an event, a product (or service) over its entire life cycle, or a geographic range of direct and indirect CO_2 emissions." This study solely considered CO_2 and no other greenhouse gases (GHG). Since the introduction of the Kyoto Protocol and its Clean Development Mechanism (CDM), energy projects that reduce the carbon intensity of the power grid are able to generate additional revenue from carbon credits. Methodologies approved by the CDM executive board must be used to calculate the resulting emission reductions, using the "baseline" CO_2 emission factor for the relevant geographical area. To facilitate the adoption of authentic baseline emissions data and also to ensure uniformity in the calculations of CO_2 emission reductions by CDM project developers, the CEA has compiled a database containing CO_2 emissions data for all grid-connected power stations in India. The primary emission factors for the unified grid are determined by CEA in compliance with the applicable CDM techniques (see Table 15) [53].

Table 15: Weighted average emission factor, in t CO2/MWh

Operating Margin	Build Margin	Combined Margin
0.94	0.87	0.90

Source: CO_2 Baseline Database for the Indian Power Sector; CEA 2021

The emission factor mentioned in table 14 above has been derived from the methodological tool by UNFCCC [54]. This methodological tool calculates the "combined margin" emission factor (CM) of an electrical system to quantify the CO_2 emission factor for the displacement of electricity generated by power plants in an electricity system.

The "operation margin" (OM) and "build margin" (BM) are the two emission factors that make up the CM, which is a weighted average of these two elements. OM is the emission factor that relates to the group of existing power plants that would be affected by the proposed CDM project activity. BM is an emission factor used to identify which potential power plants would be affected by the planned CDM project activity during their design, building, and operation.

We have assumed that India has opted for purchasing cleaner power from neighbouring countries instead of setting up another thermal plant in accordance with the prevailing transactions happening through CBET. This has led to offset of carbon emissions which would have resulted from the hypothetical new power plant(s). Now, emission factor can be used to determine the savings in terms of carbon dioxide emission for India due to CBET. For our analysis, the electricity imported through CBET from neighbouring countries from hydropower sources has been carried forward below in Table 16 from our previous analysis on volume of CBET transactions.

Table 16: Import of renewable energy by India

Year	Import (in MUs)		Total Import (in MUs)
	Nepal	Bhutan	
2020-21	44	3861	3905
2019-20	107	4465	4572
2018-19	35	4054	4089
2017-18	3	5068	5071
2016-17	2.7	5484	5486.7
Total	**191.7**	**22,932**	**23123.7**

It can be enumerated that from 2016 to 2020, India imported a total of about 23,123.7 MU of renewable energy from the neighbouring countries, whose average is 4,624.74 MU per year which translates to 4.62 million MWh per year. Therefore, the projected emission reductions would be monitored by following formula (1) [53, 54].

$$Projected\ Emission\ Reductions = Net\ Generation * Fixed\ combined\ margin \quad (1)$$

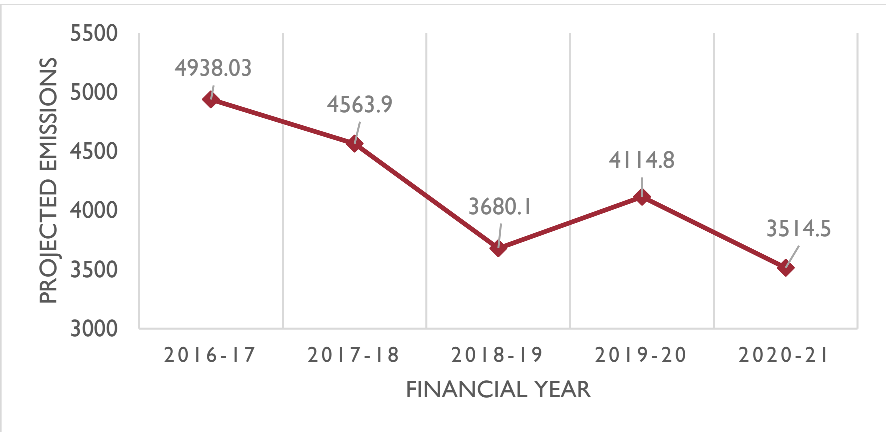


Figure 14: Graph between projected carbon emissions in each financial year

Hence, by using the above formula (1) average of India's projected carbon emission reductions is calculated in the last five years, which is 3.65 million t CO_2 / yr. This is due to an increase in CBET with the neighbouring countries. Also, it can be seen from Figure 14 how carbon emissions are being abated each year because of CBET (focusing on hydropower) with the neighbouring countries.

6.4. Has CBET enabled operational generation mix

The generation mix through CBET can bring operational, economic, as well as environmental benefits to the respective countries. Additionally, the improvement in operational efficiency of thermal generating with a suitable combination of hydro resources is advantageous for the environment globally. Generation mix offers a practical solution to reduce the long-term requirement for capacity to uphold the reliability standard for individual sub-systems and increase the reliability of all sub-systems. The majority of South Asia lacks enough fossil fuel resources and experienced severe electricity shortages. At the same time, the bordering nations have a lot of untapped renewable resources. Given the experience of the growth of the power market in India, we find that even if there are power shortages in all subsystems, there are still opportunities to trade electricity because it sends out the right signals for more economical use of the capacity that already exists and makes use of changes in consumer behaviour to suit the market conditions [55]. The South Asian nations have much potential to maximise the utilisation of regional resources even under the existing conditions because of differences in daily load conditions, seasonal load variance, and generation. An interconnected grid makes it easier to take advantage of opportunities for two-way power trading. For instance, Bhutan, a country with abundant hydropower, imports thermal electricity, particularly in the dry winter months. In a similar vein, Nepal has also taken advantage of the power market in India to get by during times of power shortages [56].

The utilisation of the regional generation mix mainly offers benefits in terms of technical, operational, environmental, financial, economic, and social sector benefits. Some of the key benefits are [57]:

2. Peak time differences - Although the time zones of the region's countries vary by 15 to 30 minutes, the variations in daily load curves offer the potential for improving load-generation balance throughout the region. The differences in daily load curves can be

attributed to a variety of factors, including location, topography, weather conditions, cultural differences, and the generation mix in the individual countries. In addition, there are disparities in designated weekends and annual celebrations which phases out the peak demand across the region due to which, one country's peak demand is shifted to off-peak times for another country and, CBET enables the optimum utilization of generators in the country who is experiencing off-peak time by exporting electricity to the country in need of more electricity.

3. Intra-seasonal differences - In contrast to lean periods (dry winter season), the monsoon season has sufficient excess hydropower generation, where greater thermal power support can be offered. Cross-border opportunities to better utilise existing hydropower plants in Nepal and Bhutan and thermal power plants in India can help meet the daily and seasonal changes in demand and generation. During the rainy season, hydropower output is sufficient to meet demand; but, during the dry winter season, additional thermal power support becomes necessary.
4. Hydrothermal mix - Useful for balancing load throughout the day between peak and off-peak periods. Improved system reliability and the replacement of imported fossil fuels with hydro and renewable resources could reduce the import dependency of the electric system in the region. Through the utilisation of cross-border renewable energy resources, CBET can increase the usage of renewable energy generators.
5. Grid security - CBET's interconnected power grid enables greater penetration of variable renewable energy than any one of the country's individual grids could. Natural disasters that partially or completely disable certain power plants can also be mitigated by interconnected networks.
6. Sharing of reserves - Reserves can also be shared regionally to provide grid operations with cost-effective reliability. CBET can minimise risk exposure to energy imports with long supply lines by diversifying sources and providing energy options to policymakers outside of their borders thus maximising the availability of generators in the participating countries. Also, the countries would be isolated from volatility in global prices of oil, natural gas, and coal.
7. Less impact on the local and global environment - A regional push for clean energy development would enhance the use of more hydro and renewable resources. This would lessen the impact that these resources would have on local and global environments. This would ultimately result in a decrease in carbon emissions on a worldwide scale.

8. Improvement in social indicators - Having access to electricity has a good effect on local security, access to clean water, education, and health care. The case for expanding energy availability in this area is strengthened by these indirect advantages to society.
9. Renewable energy development - The faster development of renewable energy resources in other countries can be facilitated through regional cooperation that enables the exchange of best practices for developing renewable energy. By doing this, non-renewable primary energy resources will be preserved, and the environment will benefit.

6.5. Share of RE Power in CBET Trade

India has been heavily dependent on conventional fossil fuel sources to meet the increasing electricity demand. With the rising concerns on climate change, India has committed to provide 40% non-fossil fuel electricity capacity and to reduce emission intensity by 30-35% by 2030 as part of its Nationally Determined Contribution (NDC) under the Paris Climate Agreement (see Figure 15).

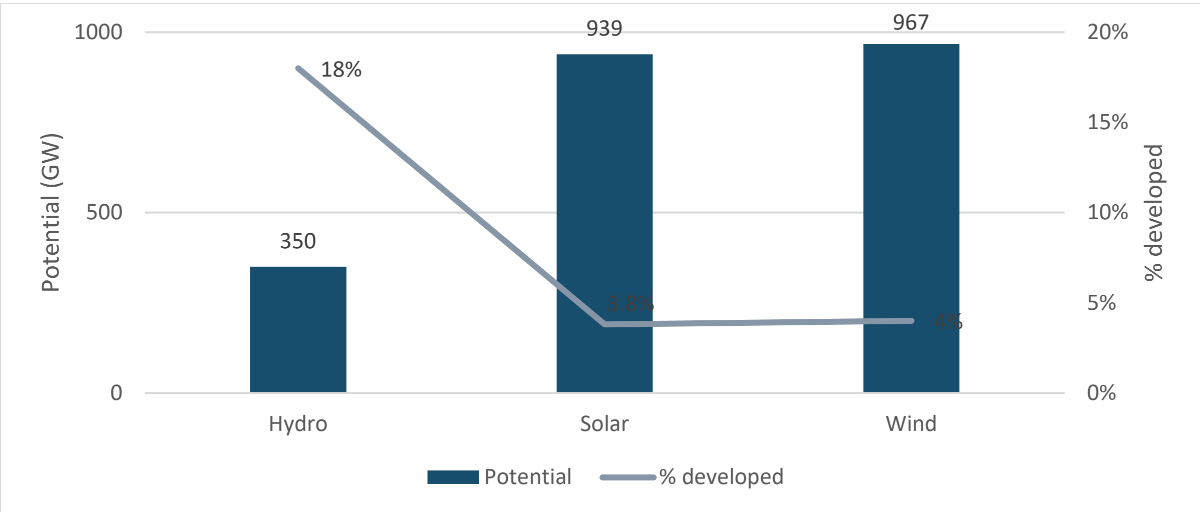


Figure 15: RE potential and percentage developed in the region

In recent years, the share of RE (excluding hydro) capacity in India increased from 12% in 2012 to over 22% in 2021. Furthermore, to realise sustainable development targets, India has set aggressive plans to increase the renewable generating capacity from 104 GW in 2021 to 450 GW in 2030 (Figure 16).

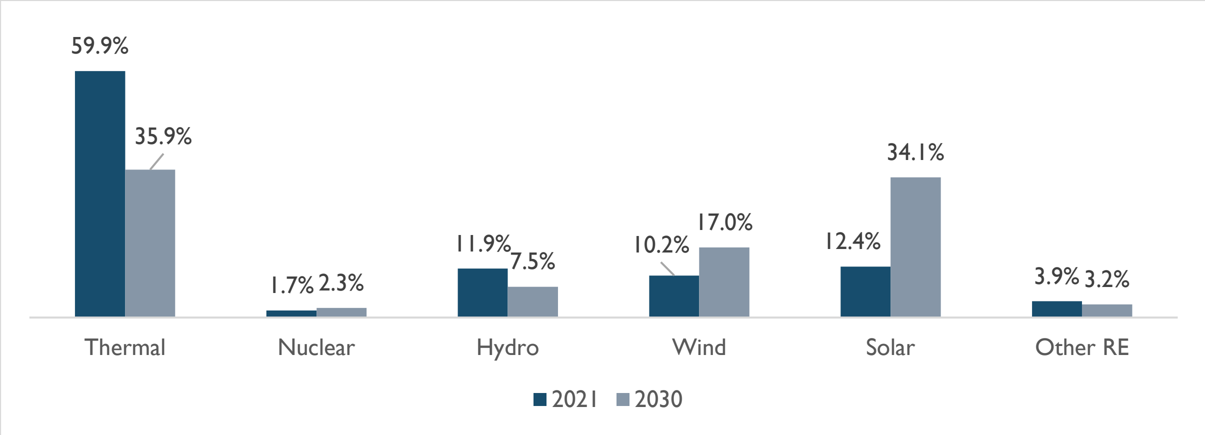


Figure 16: India installed capacity 2021 vs 2030

The RE capacity targets for 2030 mainly constitute solar and wind, which are intermittent in nature. The uncertainty and variability of these sources pose a huge challenge for the power system operations and require the existing system to be more flexible to accommodate the intermittency. The lack of flexibility in the power system restricts full utilisation of available RE generation during its peak generation and could lead to curtailment of RE generation. Significant levels of curtailments impact the attractiveness of the sector as it affects the viability of the project and hamper investors' confidence in the sector [58].

India has expressed aggressive renewable energy (RE) expansion plans to fulfill its sustainable development targets, i.e., reducing dependency on imported fuel, meeting climate change obligations, and ensuring 100% access to electricity for its people. Several policy mechanisms, like state-wise Renewable Portfolio Obligation (RPO), Renewable Energy Certificates (REC), Accelerated Depreciation, and Feed-in Tariff have been promulgated to promote RE generation [59]. In 2015 India announces to achieve 33%–35% less emission intensity per unit of GDP by 2030, compared to the 2005 level as a part of its Nationally Determined Contribution (NDC). It also includes a target to achieve 40% cumulative non-fossil-fuel-based electric power generating capacity by 2030. To fulfil these targets, India has announced to increase its RE capacity to 450 GW by 2030. National Tariff Policy 2016 has proposed to increase the solar RPO target from 3% to 8% in 2022 (excluding hydropower). Thus, with various central and state initiatives, India is currently focusing strongly on renewable energy sources, and steady growth is expected which can overtake the conventional generation capacity addition rate [60].

India's RE expansion plans are mainly constituted of solar and wind which are variable sources of electricity. Additional variability associated with these sources affects power system stability, and reliability, and calls for the existing system to be more flexible [61].

Stable power system operation requires load and generation balance at every point in time. At times of RE over-generation, inflexibility of thermal generators and network security criteria may restrict full utilization of available RE generation. This intentional reduction of generation from variable RE generators is referred to as RE curtailment, which has operational as well as economic consequences. It decreases the capacity factor of RE projects, increases payback time and financing cost, and makes it challenging to meet greenhouse gas emission targets [58].

Generation curtailment is becoming a concern in India as well with increasing solar and wind energy penetration. RE Curtailment has already been witnessed in states like Rajasthan and Tamil Nadu due to inadequate transmission capacity and the unwillingness of distribution companies to buy costlier RE power. In Tamil Nadu, solar PV plants currently face curtailment up to 50%–100%, due to profile mismatch between generation and demand. Other states like Telangana, Karnataka, Andhra Pradesh, and Jharkhand face imminent curtailment challenges due to current PV capacity expansion plans. Though inadequate transmission capacity is often cited as the major cause for curtailment in India, other factors, such as inflexibility of coal-based thermal generators, improper operation strategies, as well as planning protocols, are increasingly becoming prominent. So, the requirement of a robust and adequate electricity network is the backbone of successful RE integration [59]. System operational flexibility can be imported or exported fast upon requirement via transmission lines. Thus, a strongly interconnected system reduces the negative impacts of RE variability and thereby lowers the RE curtailment rate.

Below chart (Figure 17) shows the RE generation data in the FY 2020 and FY 2021 in India. It shows that compared to 2019-20, more electricity is generated in 2020-21 from renewable sources. Further, state wise data will be analysed in the upcoming reports, which will give the complete details on how to decrease RE curtailment and CBET between India and neighbouring BBIN countries.

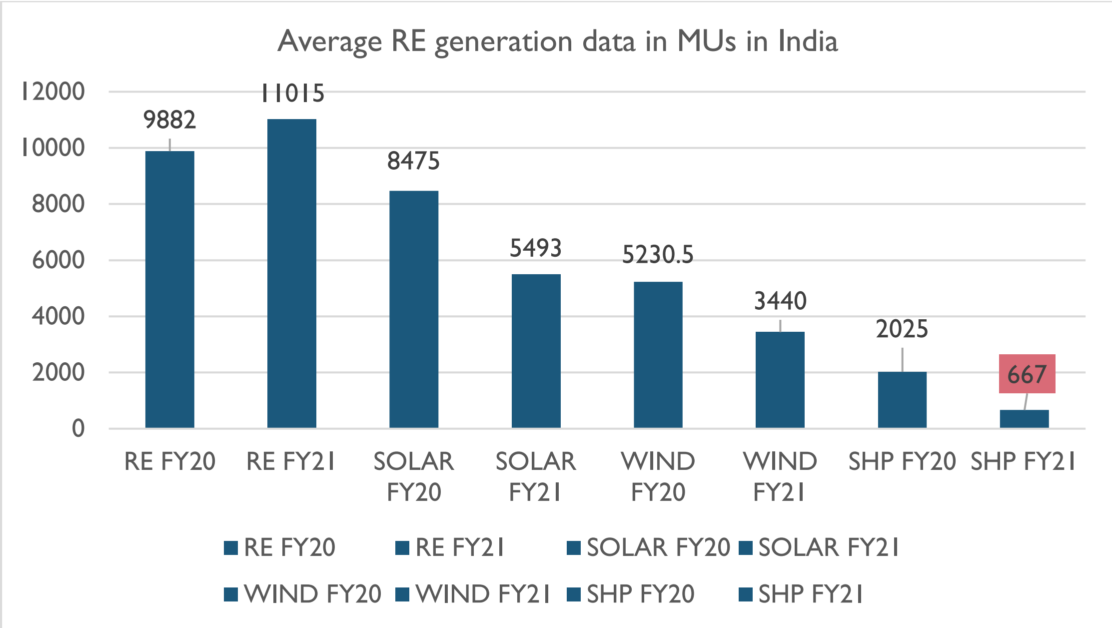


Figure 17: Average RE generation in India in MUs

6.5.1. RE Curtailment

There has been a noticeable correction in RE curtailment since the onset of CBET in India. Presently, the data from the states of Andhra Pradesh and Gujarat has been analysed from the Regional Load Despatch Centres (RLDC) of the respective states, as shown below in Table 17. As per data from the Central Electricity Authority (CEA), Andhra Pradesh and Gujarat have a combined RE generation capacity of 18,951 MW which is about 22% of the total installed capacity in India [62].

Table 17: Details of RE curtailment in India

RE Curtailment				
	Andhra Pradesh		Gujarat	
Year	Total Solar Curtailment (MW)	Total Wind Curtailment (MW)	Total Solar Curtailment (MW)	Total Wind Curtailment (MW)
2019	261880	39549	0	170
2020	158547	71505	-	-
2021	93400	70790	-	-
2022 (to Apr)	3350	540	-	-

Curtailment refers to available wind or PV energy that cannot be utilised to supply load due to constraints such as inflexible generation or insufficient transmission. The southern part of India is more vulnerable to RE curtailment than other regions because of limits linked to thermal plant flexibility, limited linkages with other regions, and high RE penetrations compared to load. Without a DC connection, the Southern area represents 97.7 % (5.1 TWh) of India's total RE curtailment. CBET with Sri Lanka adds another export channel for the Southern region's excess RE generation. An Inter-country tie to Sri Lanka provides an avenue for energy exports during times when solar and wind generation is high and thermal generation cannot be turned down. The Inter-country tie to Sri Lanka reduces annual RE curtailment in the Southern region by 9% (400 gigawatt hours) as per a simulation study [1]. According to this study, CBET, enabled by a 500-MW high voltage direct current transmission link between India and Sri Lanka in 2025, can lower electricity costs, reduce RE curtailment in southern India, and increase system dependability through coordinated use of energy resources.

6.6. How countries are benefited from participating in CBET?

The benefits of CBET include better resource utilisation across interconnected regions, an improved regional hydro-thermal-renewable energy (RE) mix, and the development of a thriving power market throughout the interconnected region. There are several direct and indirect social benefits too especially for people in rural areas who reap the benefit of increased access to electricity. When they don't have to spend time cooking and protecting their crops, they can use that time to do other things like run a business or socialise with others in the community. It has been seen that people of Commilla, Bangladesh have started getting round the clock power with the commencement of power supply from Tripura. The Utility (TSECL) of Tripura has also been benefited by way of increase demand and more revenue. During the media visit under this project in June 2022 and interactions with local people it came to light that people-to-people interaction with two countries have enhanced due to start of the supply of power from Tripura to Bangladesh and also the financial status of TSECL has improved. Even this cross-border transaction has enhanced knowledge base in the area of technical, commercial and managerial level. Various seminar, workshop, round table conference have helped exchange of ideas and views which have directly or indirectly created human touch and trust level.

6.6.1. Bangladesh

1. Commercial Benefits

Following are some commercial benefits:

a. Bangladesh is utilising its gas declining resources for power generation and also has limited hydropower. Because of this, there is a need for supplemented sources in order to meet its growing demand. For this, CBET is the key opportunity that can help to meet the demand of the country. The study found that importing electricity from India is one of Bangladesh's most cost-effective options. Since this prevents Bangladesh from developing fossil fuel-based power plants or exploiting its natural resources, it also lowers the nation's carbon dioxide emissions and has significant environmental advantages.
b. In the future, Bhutan will export to Bangladesh using India as a transit country. This will help both supplier and consumer countries by addressing supply shortages, earning export revenue, and enhancing domestic energy security.
c. CBET can also help in reducing the power sector’s energy capital capacity requirement by providing the access to low-cost electricity generation. This will help in meeting the energy needs of the fast-growing population in the country.
d. CBET can boost the use of RE power by tapping into cross border renewable energy resources.

2. Social Benefits

The increased CBET in the region helps in importing power rather than creating it using primary energy sources and can hasten the process of supplying electricity to the target population, enabling rural villages that were previously without electricity to receive it without having to endure a protracted waiting period. In Bangladesh, the majority of the population of Commilla region got round the clock electricity after the beginning of supply of 160 MW power from Tripura to Commilla under radial mode. Also, people to people interaction with two countries have increased considerably.

In addition to this CBET helped in the field of education, increased work opportunities & incomes, impacted gender, and also helped in providing connectivity and easy accessibility.

CBET also helped in increasing climate benefits through the position of cost-effective pathways for greenhouse gas reduction.

3. Technological benefits

Currently, HVDC interconnection is there between India and Bangladesh. For distances exceeding 600 km, HVDC offers a more economical solution for power transmission compared to alternating current systems. In addition to this, the HVDC line helped two countries enjoy the benefits of seasonal complementarity, this initiative has benefitted Bangladesh by assisting it to reduce its peak demand deficit of 1,000-1,500 MW and its dependence on less efficient and more expensive power plants.

6.6.2. Bhutan

1. Commercial Benefits

Bhutan has enormous hydroelectric potential that is greater than what they now use domestically and is a source of their export revenue. As in the case of Bhutan, trading energy and electricity has the potential to be a key factor in their economic growth.

2. Social Benefits

The hydropower projects in Bhutan have impacted the livelihood mainly people who are living near the power plants. The quality of life in rural households notably that of women and students, has substantially improved, thanks to access to electricity. The quality of other services, such as health, transportation, and communications, has also greatly increased.

3. Technological Benefits

Bhutan's hydropower potential demonstrates how export opportunities would provide ways to both meet and greatly increase domestic demand. According to certain projections, Bhutan's hydropower exportable surplus might increase fourfold between 2020 and 2045.

6.6.3. India

1. Commercial Benefits

For India, CBET has enabled a way to boost return on its investments via trade of its surplus electricity to the rising supply-demand gap in the neighbouring countries. This has increased India's revue from exports, particularly from the trading of power. Existing, current, and proposed CBET opportunities will help India's energy market initiatives. Internal energy markets and renewable energy production will meet domestic and regional energy needs. Thus, collaboration in the energy sector will flow over to other sectors and lead to the development of associated industries, boosting the region's development objectives.

Interconnected grids between India and its neighbours have also enhanced the investment climate and created attractive investment opportunities for private capital to assist the development of new transmission networks. Participation from the private sector can help overcome resource shortages, provide a higher level of operational flexibility than public sector organisations, and provide better opportunities for research and development as well as a broader range of collaborations and managerial dynamism. PPPs in various forms and at various levels of private sector involvement in regionally important generating and transmission projects can be found in international experiences, such as the Southern African Power Pool [63].

2. Social Benefits

As a result of increased CBET in the region, lesser environmental consequences would be achieved by utilising the region's enormous untapped hydropower resources. This will speed up the development of additional renewable energy sources in the region by exchanging industrial practices among the CBET members through increased electricity availability in the region.

3. Technological Benefits

The relatively short distances required for transmission links, complementarities in energy resources – particularly in hydropower and thermal power – diverse demand profiles, and differing seasonal power requirements provide ideal conditions for regional electricity cooperation. More system inertia, less volatility in frequency, and fewer blackouts can be achieved by pooling demand and generation over a larger geographic region. In addition to reducing the complexity associated with land acquisition for establishing power infrastructure and eliminating asset management issues, larger interconnected networks provide more placement options for new power projects. Larger-scale production means greater efficiency improvements and reduced operating costs, as well as lower capacity requirements due to centralised reserve management, smoothing fluctuations in generation and load profiles across borders [64].

6.6.4. Nepal

1. Commercial Benefits

Renewable energy, particularly hydropower in Nepal, is important to supply the region's rapidly rising demand at the lowest possible cost with the least possible environmental impact and ensure energy security, as the region continues to grow. There are multiple significant hydropower sites in Nepal located near major Indian load centres, efforts to develop these resources have increased since the onset of CBET and rise in the trade volumes. During rainy season Nepal is surplus of power and sale of this power brings enormous revenue for Nepal.

2. Social Benefits

A common strategy that supported CBET has been adjacent country's grid rather than the country's national grid because doing so can be less expensive. Although the electrification of these rural border communities is not part of the major CBET projects, it has a favourable influence on poverty and quality of life. Many communities in Nepal's Terai region rely on the Indian power grid for their electricity, and this practise is especially common around the Nepal/India border [64].

3. Technological Benefits

The region's renewable energy costs are exceptionally competitive, with some of the lowest installed costs of renewable energy systems anywhere in the world. There is an opportunity to leapfrog to more modern technologies, both on the generation and demand side because most of the infrastructure that will be in place in 2030 has yet to be constructed [63].

6.6.5. Sri Lanka

1. Commercial Benefits

Energy transfers are bilateral. According to the analysis by Rose et al. (2018), a direct current (DC) link in 2025 will reduce annual production costs by USD 180 million, or by 0.5% of the total cost of generating power in the two countries. Sri Lanka's annual production costs have decreased by 35%, resulting in a cost savings of 14% of the year, particularly in December, when high hydro and coal generation in Sri Lanka generates export prospects to India, it is less expensive to buy power from Sri Lanka. As per the simulation the DC link was found congested for 58 percent of the year, indicating that transfer capacities over 500 MW could bring further economic benefits through bilateral trade [65]. Further studies indicate that the link may provide between 7 to 15% of Sri Lanka's yearly energy demand, primarily during peak hours. It also promotes the transfer of surplus off-peak energy to India, but the net transfer is anticipated to reflect a substantial volume of imports via the link to Sri Lanka. In India, where cross-border commerce accounts for a modest proportion of total output, production costs have remained almost stable [63].

2. Social Benefits

The bilateral relationship of mutual support between India and Sri Lanka has a long standing history that encompasses humanitarian aid, cooking gas, large quantities of fuel, and medicinal supplies both during and after the recent coronavirus pandemic. Sri Lanka is currently facing an acute power shortage and it is becoming difficult to run its thermal power plants due to rising import costs of fuel. CBET between India and Sri Lanka will enhance the availability and accessibility of power from India at competitive rates. Additionally, access to electricity has a positive effect on education, access to clean water, health services, and local security. These secondary societal advantages strengthen the case for expanding electricity availability in this region.

3. Technological Benefits

The southern portion of India is more vulnerable than other parts of India to RE curtailment (wind and solar energy that is available but not consumed). Having a DC connection to Sri Lanka opens the door to energy exports during periods of high solar and wind generation and unabated thermal generation. The DC connection reduces Southern RE curtailment by 9% annually (400 gigawatt hours).

6.7. CBET's Gender Aspects

South Asia's population relies heavily on traditional fuels for cooking, lighting, and heating because the majority of the population lives in rural areas. In rural places without electricity, women must go considerable distances to get firewood. Households in South Asia without access to electricity use kerosene lamps for illumination and firewood or coal for cooking and heating. Using this method exposes the poor, especially women and children, to dangerous gases. Approximately 4 million people die due to pollution that is caused by wood, charcoal, and other traditional sources of energy in households. To alleviate this health burden and empower women, a stable energy supply is needed. This means that women will have more time to dedicate to education and other essential topics [66].

The Healthcare area is another important area where electricity plays a vital role. Without electricity, clinics cannot store vaccines for children. Improved healthcare facilities have a direct impact on pregnant women and small children who need routine immunization. Promoting healthcare facility improves gender equality, and provide great opportunities for females in the healthcare services.

Several major and small projects have been completed or are currently being developed in the BBIN subregion due to the increased desire among developers to access the enormous energy resource potential available for electricity generation. Energy, welfare, and gender are well-known connections. In addition to creating new job opportunities for the local population, energy infrastructure improvements have a positive impact on education, health care, and women's equality in society as a whole. Increasing the number of women in the workforce can be achieved both directly and indirectly through CBET [67, 68]. As a result of CBET's increased supply of low-cost energy, more women in homes will be able to work for pay. This will have a good impact on women's time spent on unpaid home care, as well as on the availability and affordability of renewable energy in South Asia, which will result in lower emissions and greater access to electricity. Also, a reduction in operational costs for womenowned businesses due to the trickling benefits of CBET can contribute to increased employment and social mobility prospects for women [69, 70]. Below Table 18 shows the ratio of males & females on the board of directors in various agencies of CBET in various SA countries. It can be seen that approximately 10% are females on the board of directors in the SA countries.

Table 18: Ratio of Men to Women in CBET agencies in SA countries

S.no.	Countries	Company	Male	Female
1	Bhutan	DGPC	5	2
2	Nepal	NEA	7	1
3	Srilanka	CEB	10	1
4	Bangladesh	BPDB	6	1

In India, the government has allocated 20% of the seats for women candidates. Table 19 shows the data of the Central Electricity Board (CEA), which shows the percentage of the women employees in the organisation.

Table 19: Data of women employees in CEA

Category	No. of Govt. Employees		No. of women employees in position	% age
	Sanctioned	Filled		
Chairperson/ Members	7	7	0	0
CPES GROUP-A	432	312	37	11.8%
CPES GROUP-B	109	37	2	5.4%
Non CPES Group				
Group-A	72	41	21	51.2%
Group-B	290	97	48	49.4%
Group-C	174	95	17	17.9%

Group-C(MTS)	202	93	9	9.6%
TOTAL	**1286**	**681**	**134**	**19.6%**

Today, there has been a rise in women's interest in pursuing careers previously dominated by men, a result of CBET, which has allowed participating countries to hire more individuals and support capacity-building initiatives for upskilling the workforce in the electricity domain.

6.8. Future perspective to enhance CBET

6.8.1. Bundling of Power

Concept of Bundling of solar power with conventional power introduced in 2010 by MNRE under JNNSM scheme. Under this scheme one unit of solar power was bundled with four unit of conventional power from NTPC stations. This scheme was operationalised by NVVN, identified by MNRE, as Nodal Agency, to reduce the cost of solar power. In order to make the scheme competitive reverse auction was introduced among the bidders and solar power cost was reduced drastically. For each MW of solar power installed capacity for which PPA was signed by NVVN, MOP allocated to NVVN an equal MW capacity from the unallocated of NTPC stations. NVVN bundled this power and sold this bundled power at a rate fixed as per CERC Regulations. With the success of the above scheme MNRE has introduced many bundling schemes through Solar Energy Corporation of India (SECI).

Bundling of power can be done in various ways. Conventional power can be bundled with Solar power. Conventional power can be bundled with Wind power. Conventional power can be bundled with Solar & wind power both together. Hydro power can be bundled with Solar power. Hydro power can be bundled with Wind power. Hydro power can be bundled with Solar and wind power.

Bundling of Power has multiple benefits. It helps to bring cost of bundled power very competitive. It helps to bring round the clock RE power available to the buyers otherwise round the clock round the year RE power making available to buyer is very challenging.

In case of cross-border supply of hydro power from one country to a third country transmission link of inter-country line remains under utilised due to nature and availability of hydro power. Hence if this hydro power is bundled with solar or wind power the utilisation factor of transmission line is increased at an economical competitive rate.

Based on the above various scenarios has been created considering hydro power is tied-up by Bangladesh then how bundling helps to increase utilisation of inter-country link between India-Bangladesh and at the same time cost of power also becomes very economical for Bangladesh. The same benefit will accrue to the country who desires to tie-up hydro power and bundled with other RE power like Solar & Wind to get round the clock round the year power at an economical competitive rate.

Bangladesh Power Development Board (BPDB) proposed a bulk power tariff increase of up to 64% to the Bangladesh Energy Regulatory Commission (BERC) in January 2022, citing rising costs associated with importing coal, LNG, and oil (Independent and Plant 2022). As per the annual report of BPDB for the Financial Year (FY) 2020-21 the purchase tariff ranges between 4.43 – 8.02 Tk/kWh (₹3.93 – 7.11 Rs/kWh) out of which over 50% of the electricity is purchased from Independent Power Producers (IPPs) (Board 2020). The tariff details are as follows (Table 20):

Table 20: Purchase tariff in Bangladesh for Power Sector (FY 2020-22)

Particulars	Cost (Tk/kWh)	Cost (INR/kWh)
BPDB's Generation	4.43	3.93
Purchase from IPP	8.02	7.11
Purchase from Rental	7.47	6.61
Purchase from Public Plant	4.29	3.8
Purchase from India	5.8	5.14

Bangladesh is interested to tie-up hydroelectric electricity (HEP) from Nepal and based on that they are in the process of signing of agreement with GUKHEL (GMR Upper Karnali Hydro Electric Limited) for supply of 500 MW power. Considering ~~given~~ the higher cost of procurement of existing domestic power, compared to procurement from outside Bangladesh. In Nepal, for the Dry season the peak tariff ranges between 8.5-10.55 Nepalese Rupee(NPR)/kWh (₹5.31- 6.59 INR/kWh) and non-peak tariff is 8.4 NPR/kWh (₹5.23 INR/kWh). For the Wet season, a fixed tariff of 4.8 NPR/kWh (₹2.99 INR/kWh) is followed

(NEA 2017). Furthermore, power imports from India's Power Trade Corporation (PTC) and the NVVN the trading arm of NTPC provide a cost-effective and practical way to fulfil Bangladesh's expanding power needs at competitive economical rate.

Presently existing inter-country transmission link between India and Bangladesh is exhausted and to import any new tie-up of power by Bangladesh is required establishment of new inter-country transmission link. Understandably, Bangladesh (BPDB) is in the process of tie-ing up of 500 MW power from Nepal and bundling of Nepal's HEP power with India's Renewable Energy (RE) generating plants, on the other hand, would be able to compensate for the seemingly high cost of acquiring power from Nepal and better utilisation of Inter-country India-Bangladesh transmission link.

Furthermore, there are no threats to approval from the Designated Authority (Central Electricity Authority) as outlined in the policy implementation guidelines for CBET because bilateral agreements exist between Nepal and India and Bangladesh and India. The Indian entity will be the intermediary for enabling the import/export of electricity.

A probable solution to bundle the hydroelectric power from Nepal with RE power from India by considering the input parameters as per existing market conditions with regards to cross border energy trading. Hence various scenario has been created to check the possibility of the concept.

Scenario 1: Bundled power calculation for solar and hydro

In the first scenario we have analysed the bundling of Solar Photovoltaic (Solar PV) generation from India with Hydroelectric Power (HEP) from Nepal:

For the proposed scenario (refer to Table 21) the installed capacity for the Solar PV plant is assumed to be 500 MW with a Capacity Utilization Factor (CUF) of 22%. The transmission losses and auxiliary consumption are assumed to be 1% and 0.5% respectively. Transmission charges are assumed at ₹0.5 Rs/kWh and the generation rate of solar power is considered to be ₹2.5 Rs/kWh.

Table 21: Assumption sheet for Solar PV (Scenario: Solar+Hydro)

Solar PV				
Assumption Head	**Sub-Head**	**Sub-Head (2)**	**Unit**	**Assumptions**
Power Generation	Capacity	Installed Power Generation Capacity	MW	500
		Auxiliary Consumption	%	0.50%
		Capacity Utilization Factor	%	22%
		Transmission Losses	%	1%
		Transmission charges	Rs/kWh	₹ 0.50
		Rate/kWh	Rs/kWh	**₹ 2.50**

Hydroelectric Power (HEP) from Nepal is assumed to be 500 MW with a Plant Load Factor (PLF) of 48% (refer to Table 22). The transmission losses and auxiliary consumption are assumed to be 4% and 0.5% respectively. Transmission charges are assumed at ₹0.5 Rs/kWh and the generation rate of hydro power is considered to be ₹4.5 Rs/kWh.

Table 22: Assumption sheet for Hydro (Scenario: Solar+Hydro)

Hydro				
Assumption Head	**Sub-Head**	**Sub-Head (2)**	**Unit**	**Assumptions**
Power Generation	Capacity	Installed Power Generation Capacity	MW	500
		Auxiliary Consumption	%	0.50%
		Plant Load Factor	%	48%
		Transmission Losses	%	4%
		Transmission charges	Rs/kWh	₹ 0.50
		Rate/kWh	Rs/kWh	**₹ 4.50**

For estimating the bundled per unit rate of power we have taken a ratio between the cumulative revenue and cumulative generation from bundled power sources, which in this scenario is Solar PV power from India and Hydroelectric Power from Nepal. The enumeration for the same is as follows:

To find the cumulative revenue, we have analysed the total revenue of Solar PV and HEP respectively; For Solar PV, the Generation after transmission loss was calculated by applying the factor for transmission loss upon generation after auxiliary consumption which arrived at 949.19 MU. Further, we added transmission charges of ₹0.5 Rs/kWh to the Solar PV generation rate and arrived at total charges of ₹3.00 Rs/kWh. This gave us the total revenue from Solar PV at ₹2,847.58 (INR Million) (refer to Table 23).

For HEP, the Generation after transmission loss was calculated by applying the factor for transmission loss upon generation after auxiliary consumption which arrived at 2008.21 MU. Further, we added transmission charges of ₹0.5 Rs/kWh to the HEP generation rate and arrived at total charges of ₹5.00 Rs/kWh. This gave us the total revenue from HEP at ₹10,041.06 (INR Million) (refer to Table 24). The cumulative proposed revenue is ₹12,888.64 (INR Million).

Table 23: Calculation sheet for solar (Scenario: Solar+Hydro)

Solar			Calculation
Units Generation	**Sub- Head**	**Unit**	**Calculation**
Installed Capacity		MW	500
Gross Generation		MU	963.60
Auxiliary Consumption		MU	4.818
Generation (after Aux Consumption)		MU	958.78
Generation (after transmission losses)	Solar	MU	949.19
Rate/kWh		Rs/kWh	₹ 2.50
Transmission charges		Rs/kWh	₹ 0.50
Total Charges		Rs/kWh	₹ 3.00
Total Revenue		Rs (Million)	**₹ 2,847.58**

Table 24: Calculation sheet for hydro (Scenario: Solar+Hydro)

Hydro			
Units Generation	**Sub- Head**	**Unit**	**Calculation**
Installed Capacity		MW	500
Gross Generation		MU	2102.40
Auxiliary Consumption		MU	10.51
Generation (after Aux Consumption)		MU	2091.89
Generation (after transmission losses)	Hydro	MU	2008.21
Rate/kWh		Rs/kWh	₹ 4.50
Transmission charges		Rs/kWh	₹ 0.50
Total Charges		Rs/kWh	₹ 5.00
Total Revenue		Rs (Million)	**₹ 10,041.06**

Total Generation (after auxiliary consumption) from Solar PV is 958.78 million Units (MU) and from HEP is 2091.89 MU which gives the cumulative proposed generation of 3050.67 MU.

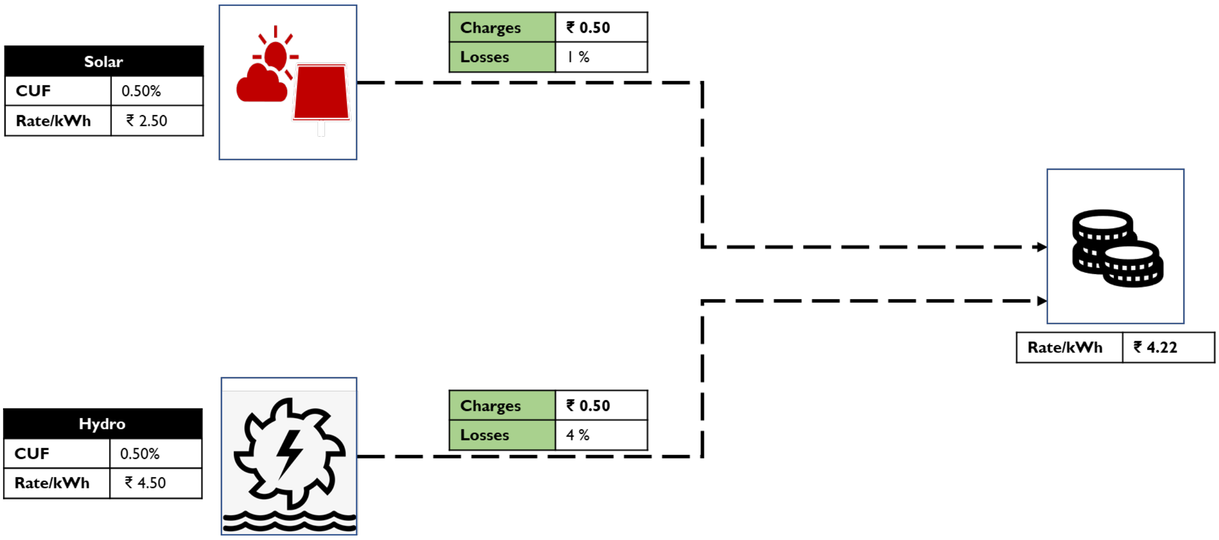


Figure 18: Bundling of solar and hydro power

The cumulative bundled power rate has been calculated as follows (Table 25):

Table 25: Bundled rate for solar and hydro (Scenario: Solar+Hydro)

Units Generation	Sub- Head	Unit	Calculation
Total Revenue (Solar)		Rs (Million)	₹ 2,847.58
Total Revenue (Hydro)		Rs (Million)	₹ 10,041.06
Total Revenue (Cumulative)		Rs (Million)	₹ 12,888.64
Total Generation (Solar)	Cumulative	MU	958.78
Total Generation (Hydro)		MU	2091.89
Total Generation (Cumulative)		MU	3050.67
Rate/kWh		**Rs/kWh**	**₹ 4.22**

$$\frac{Total\ revenue\ (Cumulative)}{Total\ generation\ (Cumulative)} = \frac{₹12{,}888.64\ \text{(INR Million)}}{3050.67\ \text{MU}} = ₹4.22\ \text{Rs/kWh}$$

Scenario 2: Bundled power calculation for solar, hydro and wind

In the second scenario we have analysed bundling of Solar Photovoltaic (Solar PV) generation and Wind Power generation from India with Hydroelectric Power (HEP) from Nepal:

Solar PV generation from India: , where Installed Power Generation Capacity is assumed to be around 500 MW. Auxiliary Consumption is supposed to be about 0.50%, whereas Capacity

Utilization Factor (CUF) is 22%. Transmission Losses are estimated at 1%, and Transmission charges are at ₹0.50 Rs/kWh. The generation rate of solar power is considered to be ₹2.80 Rs/kWh (refer to Table 26).

Table 26: Assumption sheet for Solar PV (Scenario: Solar+Hydro+Wind)

Solar PV				
Assumption Head	**Sub-Head**	**Sub-Head (2)**	**Unit**	**Assumptions**
Power Generation	Capacity	Installed Power Generation Capacity	MW	500
		Auxiliary Consumption	%	0.50%
		Capacity Utilization Factor	%	22%
		Transmission Losses	%	1%
		Transmission charges	Rs/kWh	₹ 0.50
		Rate/kWh	Rs/kWh	**₹ 2.80**

Wind power generation from India: where the installed power generation capacity is 200 MW. Auxiliary Consumption should be about 0.50%, whereas Plant Load Factor should be around 25%. Transmission losses are projected to be 4%, with transmission charges of ₹0.50 per kWh. Generation rate of wind power is considered to be ₹4.00 Rs/kWh (refer Table 27).

Table 27: Assumption sheet for wind (Scenario: Solar+Hydro+Wind)

Wind				
Assumption Head	**Sub-Head**	**Sub-Head(2)**	**Unit**	**Assumptions**
Power Generation	Capacity	Installed Power Generation Capacity	MW	200
		Auxiliary Consumption	%	0.50%
		Plant Load Factor	%	25%
		Transmission Losses	%	4%
		Transmission charges	Rs/kWh	₹ 0.50
		Rate/kWh	Rs/kWh	**₹ 4.00**

The following characteristics have been assumed for Nepal's HEP generator: installed power generation capacity is 500 MW. The Plant Load Factor is 48%, whereas Auxiliary Consumption is intended to be about 0.50%. Transmission losses are anticipated to be 4%, with transmission costs of ₹0.50 per kWh. Generation rate is considered to be ₹4.50 Rs/kWh (refer Table 28).

Table 28: Assumption sheet for Hydro (Scenario: Solar+Hydro+Wind)

Hydro				
Assumption Head	**Sub-Head**	**Sub-Head (2)**	**Unit**	**Assumptions**
Power Generation	Capacity	Installed Power Generation Capacity	MW	500
		Auxiliary Consumption	%	0.50%
		Plant Load Factor	%	48%
		Transmission Losses	%	4%
		Transmission charges	Rs/kWh	₹ 0.50
		Rate/kWh	Rs/kWh	**₹ 4.50**

For estimating the bundled per unit rate of power we have taken a ratio between the cumulative revenue and cumulative generation from bundled power sources, which in this scenario are Solar PV power Wind power from India, and Hydroelectric power from Nepal. The enumeration for the same is as follows:

To find the cumulative revenue, we have analysed the total revenue of Solar PV, Wind power, and HEP respectively:

For Solar PV, the Generation after transmission loss was calculated by applying the factor for transmission loss upon generation after auxiliary consumption which arrived at 949.19 MU. Further, we added transmission charges of ₹0.5 Rs/kWh to Solar PV generation rate and arrived at total charges of ₹3.30 Rs/kWh. This gave us the total revenue from Solar PV at ₹3,132.34 (INR Million) (Table 29).

Table 29: Calculation sheet for solar (Scenario: Solar+Hydro+Wind)

Solar				
Units Generation	**Sub- Head**	**Unit**		**Calculation**
Installed Capacity	Solar	MW		500
Gross Generation		MU		963.60
Auxiliary Consumption		MU		4.82
Generation (after Aux Consumption)		MU		958.78
Generation (after transmission losses)		MU		949.19
Rate/kWh		Rs/kWh		₹ 2.80

Transmission charges		Rs/kWh	₹ 0.50
Total Charges		Rs/kWh	₹ 3.30
Total Revenue		Rs (Million)	₹ 3,132.34

For Wind power, the Generation after transmission loss was calculated by applying the factor for transmission loss upon generation after auxiliary consumption which arrived at 418.38 MU. Further, we added transmission charges of ₹0.5 Rs/kWh to Wind power generation rate and arrived at total charges of ₹4.50 Rs/kWh. This gave us the total revenue from Wind power at ₹1,882.70 (INR Million) (refer Table 30).

Table 30: Calculation sheet for wind (Scenario: Solar+Hydro+Wind)

Wind				
Units Generation	**Sub- Head**	**Unit**		**Calculation**
Installed Capacity		MW		200
Gross Generation		MU		438
Auxiliary Consumption		MU		2.19
Generation (after Aux Consumption)		MU		435.81
Generation (after transmission losses)	Hydro	MU		418.38
Rate/kWh		Rs/kWh		₹ 4.00
Transmission charges		Rs/kWh		₹ 0.50
Total Charges		Rs/kWh		₹ 4.50
Total Revenue		Rs (Million)		₹ 1,882.70

For HEP, the Generation after transmission loss was calculated by applying same process as mentioned above and that gave the output generation at 2008.21 MU. Further, we added transmission charges of ₹0.5 Rs/kWh to HEP generation rate and arrived at total charges of ₹5.00 Rs/kWh. This gave us the total revenue from HEP at ₹10,041.06 (INR Million). The cumulative proposed revenue is ₹15,056.10 (INR Million) (see Table 31).

Table 31: Calculation sheet for hydro (Scenario: Solar+Hydro+Wind)

Hydro				
Units Generation	**Sub- Head**	**Unit**	**Year**	**Calculation**
Installed Capacity	Hydro	MW		500
Gross Generation		MU		2102.40
Auxiliary Consumption		MU		10.51
Generation (after Aux Consumption)		MU		2091.89
Generation (after transmission losses)		MU		2008.21
Rate/kWh		Rs/kWh		₹ 4.50

Transmission charges		Rs/kWh	₹ 0.50
Total Charges		Rs/kWh	₹ 5.00
Total Revenue		Rs (Million)	₹ 10,041.06

Total Generation (after auxiliary consumption) from Solar PV is 958.78 million Units (MU); from Wind Power is 435.81 MU and from HEP is 2091.89 MU which gives the cumulative proposed generation of 3486.48 MU.

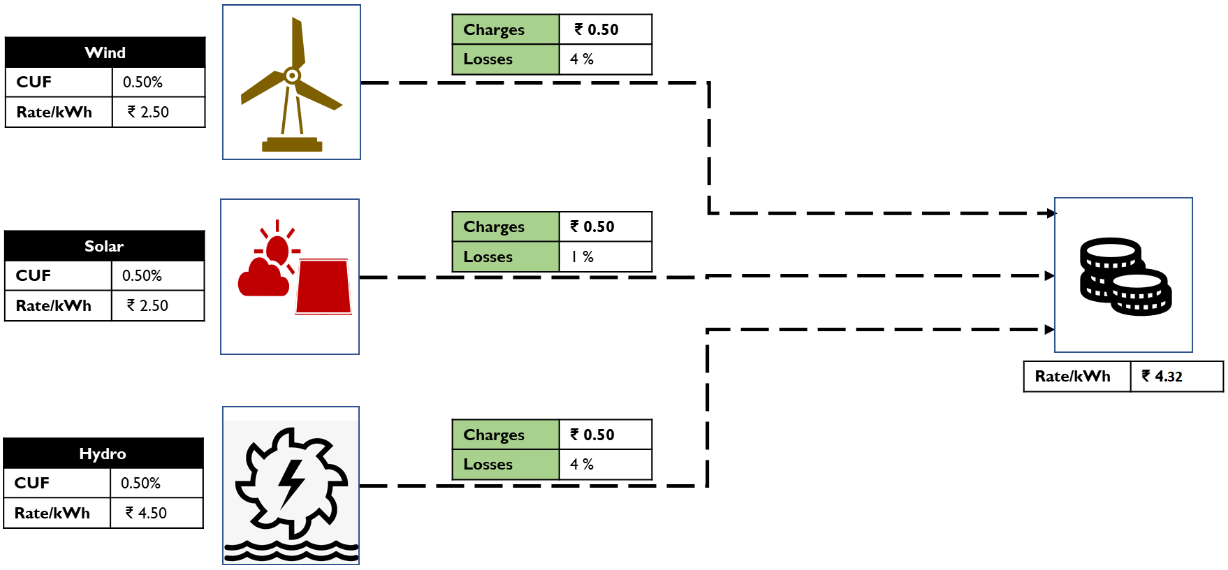


Figure 19: Bundling of Wind, Solar & Hydropower

The cumulative bundled power rate has been calculated as follows (Table 32):

Table 32: Bundled rate for solar, hydro and wind (Scenario: Solar+Hydro+Wind)

Cumulative			
Units Generation	**Sub- Head**	**Unit**	**Year Calculation**
Total Revenue (Solar)	Cumulative	Rs (Million)	₹ 3,132.34
Total Revenue (Hydro)		Rs (Million)	₹ 10,041.06
Total Revenue (Wind)		Rs (Million)	₹ 1,882.70
Total Revenue (Cumulative)		Rs (Million)	₹ 15,056.10
Total Generation (Solar)		MU	958.78
Total Generation (Hydro)		MU	2091.89
Total Generation (Wind)		MU	435.81
Total Generation (Cumulative)		MU	3486.48
Rate/kWh		**Rs/kWh**	**₹ 4.32**

$$\frac{Total\ revenue\ (Cumulative)}{Total\ generation\ (Cumulative)} = \frac{₹15{,}056.10\ \text{(INR Million)}}{3486.48\ \text{MU}} = ₹4.32\ \text{Rs/kWh}$$

6.8.2. Enablement of RPO benefits for use of cross border hydro power by obligated entities in India

For the uptake of renewable energy, obligated entities (discoms, captive users and open access consumers) are mandated to fulfil RPO, as prescribed by the state regulator, under the Act. RPO target is the minimum level of energy from renewable sources (in percentage terms), out of their total consumption, obligated entities need to purchase. The RPO targets at the national and state level are shown in Figure 20.

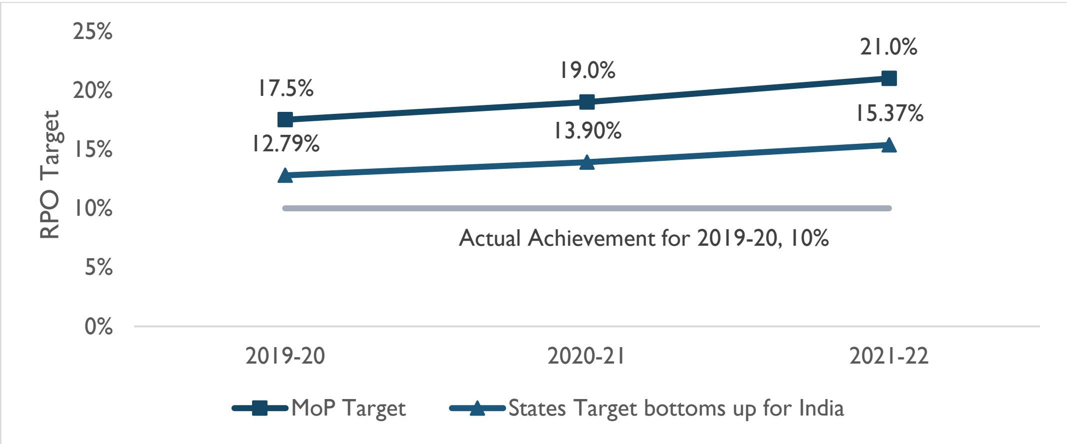


Figure 20: RPO targets[1]

Source: Authors' analysis

The RPO targets are to be fulfilled by purchase of renewable energy from *'eligible renewable sources'* as defined under state Renewable Purchase Obligation Regulation. For most of the states *'eligible renewable sources'* includes[1]: small hydro, wind power project, solar PV and solar thermal power projects, biomass/biogas power projects, located in India. Energy procured from renewable projects located outside India are not considered as '*eligible renewable sources*', thus does not contribute to the fulfilment of RPO.

Given huge potential of renewable energy (especially hydro) in India's neighbouring countries, particularly Bhutan and Nepal, if these projects are also included in the *'eligible renewable source'* it may help obligated entities to fulfil their RPO obligations, thereby promoting RE based CBET in the SA region.

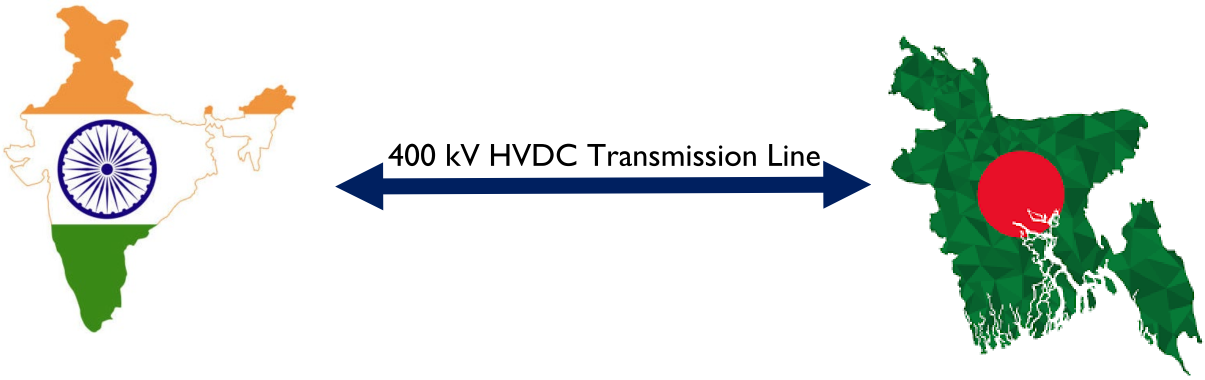
[1] Based on Section 4 of 'Tariff and other terms for supply of electricity from renewable energy sources and non-fossil based co-generating stations Regulation 2010" Uttarakhand Electricity Regulatory Commission.

6.8.3. Introduction of new Transmission Line to enhance CBET

In the following section we have done a cost-benefit analysis of proposed transmission line between India-Bangladesh and India-Nepal to understand how enhancing CBET offsets the cost of laying new transmission network as demand and utilisation of the transmission line increases.

6.8.3.1. Transmission Line between India-Bangladesh

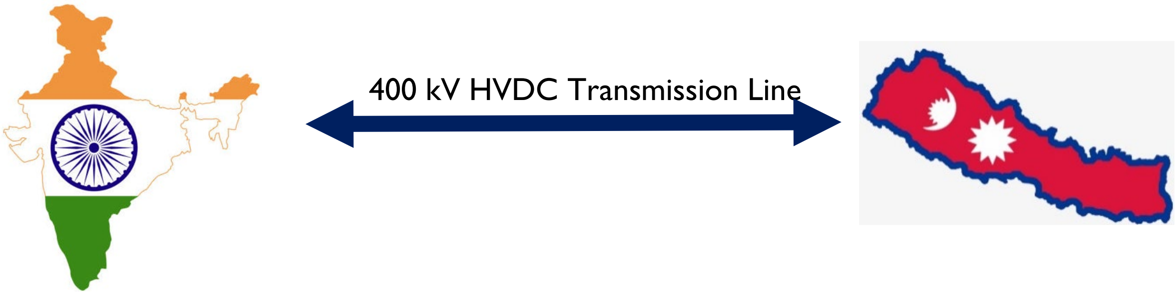
Consider a new 400 kV HVDC bilateral transmission line between India and Bangladesh of 500 km length with the cost of Rs. 9 Crore / km (tentative).



The power generated by renewable energy source is transmitted by India and the power generated from conventional sources is transmitted by Bangladesh. The details are shown in Table 34 at Appendix E.

6.8.3.2. Transmission Line between India-Nepal

Consider a new 400 kV HVDC transmission line between India and Nepal of 140 km length with the cost of Rs. 4 billion/km.



The power generated by renewable energy source (mainly hydro) is transmitted by Nepal and the power generated from conventional sources (thermal) is transmitted by India. The details are shown in Table 35 at Appendix E.

6.8.3.3. Analysis and findings

The base scenario for electricity volume was mapped into our model and the transaction volume was subsequently increased through the aforementioned proposed/ assumed transmission line between the countries. It can be noticed that the cost of transmission line per million unit of electricity being transmitted falls down as we increase the volume of trade through the network. With it can be concluded that enhancing CBET volumes justifies the cost of the proposed transmission lines between the aforementioned countries. The following Figure 21 for transmission line between India – Bangladesh and Figure 22 for transmission line between India – Nepal further elucidates the analysis through graphical view.

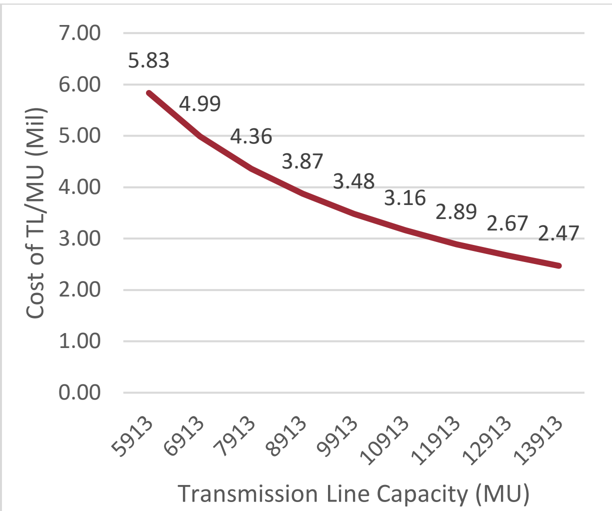


Figure 21: Graph of Transmission line capacity versus cost of TL/MUs between India & Bangladesh.

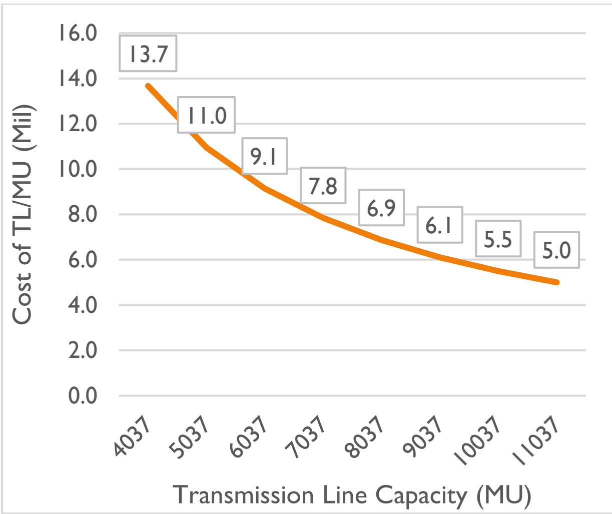


Figure 22: Graph of Transmission line capacity versus the cost of TL/MUs between India and Nepal.

7. Conclusion

From the above discussion, it becomes evident that following five points have potential to enhance cross-border trade of power, thereby enhance and integrate RE in this South Asian Region:

1. Bundling of Hydro Power with other RE power will help enhance CBET at competitive economical rate and increase utilisation of inter-country transmission link. This bundling of power will have advantage both for selling country as well as buying country and also inter-mediatory country who will facilitate the supply for multi-country transactions. However, some policy advocacy is required to implement this bundling concept for CBET.
2. The Ministry of Power (MoP) has announced the target RPO trajectory up to the year 2022, which is set at 21.18% vide order dated 29th January, 2021. As per the new norms, all entities that fall under the RPO should procure 10.5% of their total electricity from solar sources and remaining from non-solar sources (including hydropower). As per the prevailing regulations Indian entities are not allowed to fulfil their RPOs from outside India. There exists a gap in availability of renewable energy in the country to meet the RPO targets because of which The Indian electricity sector might experience considerable economic repercussions in order to meet the RPOs required by the Government of India (GOI). As a solution we recommend that the renewable energy procured from neighbouring countries as part of CBET be considered for fulfilling RPOs by the obligated entities (Captive Power Producer (CPP), Open Access (OA) consumers and DISCOMs) through a policy intervention.
3. As per present CBET Guidelines / regulations Establishment of "the Cross-border transmission link between India and any neighbouring country shall be planned jointly by Transmission planning agencies of the two countries with the approval of the respective Governments keeping in view the future need for electricity trade between India and the neighbouring country" (CBET-CERC regulation, 8th March 2019).

   With the experience of CBET transaction for the last couple of years it is felt that the private participation in the establishment of the cross-border transmission link between India and Neighbouring country would be useful. This has double impact one from investment angle another from execution perspective. However, engagement of private participation requires policy advocacy and change in CBET guidelines / regulation.

4. Recently Nepal Electricity Authority (NEA) issued tender for sale of round the clock 200 MW power in the Indian market from 1st July to 15th November 2022. Many leading traders from India participated in this tender to purchase this power for various DISCOM. The highest rate discovered under this tender for sale of power from Nepal to India by NEA was Rs 4.30/kWh. The prevalent DAM market rate in IEX was much higher than this rate of Rs 4.30/kWh. NEA decided to cancel the tender with the calculated risk of selling power in DAM market of IEX with expectation of getting better rate than discovered through tender. This experience of NEA will be useful for the neighbouring countries who desire to sell power in the power market of India either in bilateral mode or in exchange platform.

   NEA is also in the process of purchase of power through open tender first time from Indian market for the forthcoming dry season (December to April). Earlier they used to purchase it under bilateral mechanism. All these kinds of methods of purchase / sale by neighbouring country have been possible due to existence of sound CBET mechanism.

5. Cross-border transaction between two neighbouring countries is comparatively simple. But complexities rises when multi-country supply takes place. In case of multi-country arrangement say, Nepal-India-Bangladesh or Bhutan-India-Bangladesh, starting from structure of PPA / PSA / TPA (Tri Partite Agreement) to commercial terms and conditions to dispute resolution make transaction complex and time consuming to conclude the arrangement.

   If few things can be identified, discussed and settled before hand through multi-lateral dialogue among different stakeholders then time period can be reduced to conclude the multi-country arrangement. Following items just have been identified just for the sake of way forward and food for thought.

   i. Change in law / change in tax for inter mediatory country
   ii. Governing law -if any non-contractual obligations arising in connection with multi-country supply, then most cases English law is considered.
   iii. Dispute Resolution Mechanism pertaining to inter-mediatory country
   iv. Force Majeure events
   v. LTA booking liability for inter-mediatory country

List is long but if these things can be settled through dialogue among various stake holders beforehand then multi – country CBET will be easy and less time consuming.

APPENDIX A

A.1. Organisation Structure in Bangladesh

The key stakeholder in Bangladesh in the power sector are listed as below:

- Power Division – Under Ministry of Power, Energy & Mineral Resources (MPEMR)
- Regulator – Bangladesh Energy Regulatory Commission (BERC)
- Power cell – Policy, technical support and coordination
- SREDA - Sustainable and Renewable Energy Development Authority Renewable Energy
- BPMI - Bangladesh Power Management Institute
- Office of the Chief Electric Inspector - Electricity safety & Licensing
- EPRC - Bangladesh Energy and Power Research Council
- Generation –
    - Bangladesh Power Development Board (BPDB)
    - Ashuganj Power Station Company Ltd. (APSCL)
    - Electricity Generation Company of Bangladesh (EGCB)
    - North-West Power Generation Company Ltd. (NWPGCL)
    - Coal Power Generation Company Bangladesh Ltd. (CPGCBL)
    - Rural Power Company Ltd. (RPCL)
    - B-R Powergen Ltd (BRPL)
    - Independent Power Producers (IPPs)
    - Joint Venture Power Plant (JV)
- Transmission - Power Grid Company of Bangladesh Ltd (PGCB)
- Distribution – Six utilities responsible for overall performance
    - Bangladesh Power Development Board (BPDB)
    - Dhaka Power Distribution Company (DPDC)
    - Dhaka Electric Supply Company Ltd (DESCO)
    - West Zone Power Distribution Company (WZPDC)
    - Northern Electric Supply Company Ltd (NESCO)
    - Bangladesh Rural Electrification Board (BREB)

The total installed capacity in Bangladesh in FY 2020-21 is 22031 MW. The detailed public-private contribution to generation is shown in detail in Table 33:

Table 33: Public-Private contribution in generation of installed capacity in Bangladesh.

Public Sector	Capacity (MW)
BPDB	6013
APSCL	1444
EGCB	957
NWPGCL	1401
RPCL	182
BR Power gen. (JV of BPDB & RPCL)	149
SUB-TOTAL	**10146 (46%)**
Joint Venture	**Capacity (MW)**
BCPCL (JV of NWPGCL & CMC, China)	1244
SUB-TOTAL	**1244 (6%)**
Private Sector	**Capacity (MW)**
IPPs & SIPPs (BPDB)	8141
SIPPs/ Merchant Plant (BREB)	251
Rental	1089
SUB-TOTAL	**9,481 (43%)**
Power Import	1160 (5%)
TOTAL	**22031**

A.2. CBET in Bangladesh

India and Bangladesh have had an excellent relationship since the independence of Bangladesh in 1971 [16]. India and Bangladesh are geographically connected from various locations in western (West Bengal), and northeastern (Tripura, Meghalaya, Mizoram) states (approximately 27% of the total land border of India). These two countries share bonds of history, language, culture, and a multitude of other commonalities. The excellent bilateral ties reflect an all-encompassing partnership based on sovereignty, equality, trust, and understanding that goes far beyond a strategic partnership.

There was no transmission connectivity between India and Bangladesh before 2010. To strengthen the corporation between the two countries, MoU was signed between the Government of India (GoI) and the Government of Bangladesh (GoB) on the corporation in the power sector in January 2010. A joint technical team was formed consisting of four members from each country to explore the possibility of grid integration between the two countries. The first project between the two countries was "HVDC Grid Interconnection between Bangladesh (Bheramara) and India (Baharampur)", which was financed by Asian Development Bank [17].

On 25th June 2010, the Ministry of Power (MoP), GoI, allocated 250 MW of power from various NTPC stations, for which NTPC Vidyut Vyapar Ltd. (NVVN) was designed as a nodal agency. The GoB authorised Bangladesh Power Development Board (BPDB) to enter into the agreement with NVVN and Power Grid Corporation of India (PGCIL) to accomplish the modalities for purchasing the 250 MW through Behrampur–Bheramara, HVDC interconnection between Bangladesh and India. PGCIL signed an agreement with BPDB for the supply of power through the power grid network in November 2011 and NVVN signed the power purchase agreement with BPDB on 28th February 2012. As per these agreements, NVVN collects the tariff for the supply of power from the NTPC stations and PGCIL collects the tariff from BPDB for carrying the power from NTPC stations. The 25-year government-to-government electricity purchase deal involves providing 250 MW of coal-fired electricity from India to Bangladesh.

APPENDIX B

B.1. Power Sector overview of Bhutan

The overall power sector overview of Bhutan can be seen in Figure 23.

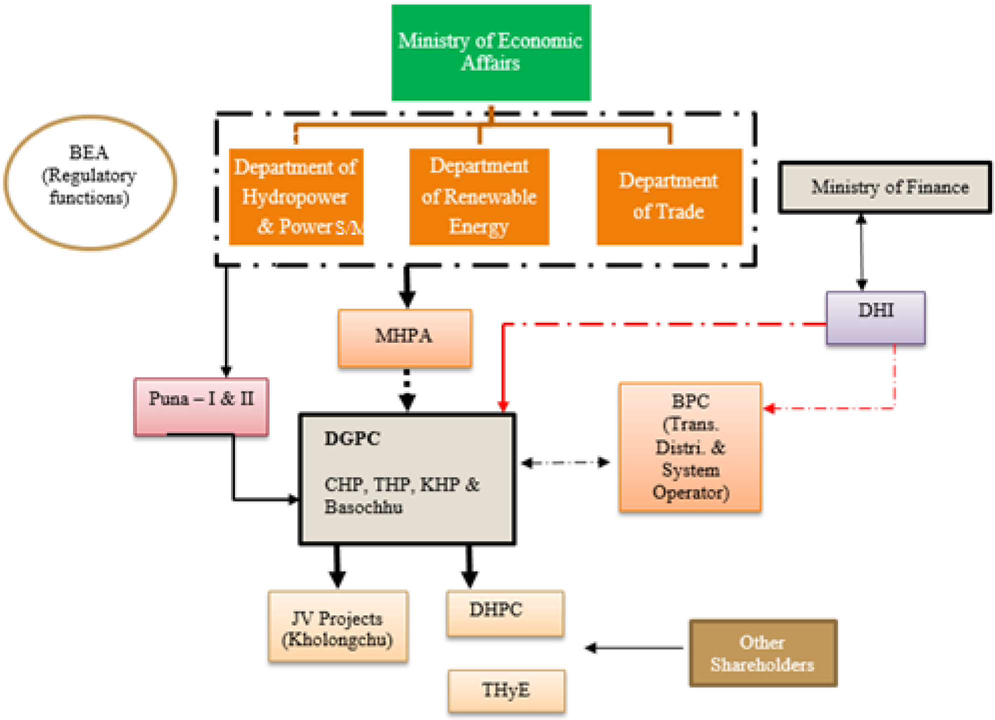


Figure 23: Power sector overview of Bhutan

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B.2. CBET in Bhutan

Electricity was introduced in Bhutan in the 1960s when the first diesel-generating set was installed. In 1967, Bhutan started importing electricity from India, through the Jaldhaka hydropower plant, located on the Indian side of the Indo-Bhutan border in the state of West Bengal. Power export started with the commissioning of the 336 MW Chukha hydel project in 1989, which laid the foundation for India–Bhutan power cooperation. The Chukha hydel project was a significant test case in many ways as it set the tone for future cooperation. With 75 per cent of the total power generated from Chukha being exported to India, Bhutan realised the potential of hydropower projects as a means of earning more revenues. Significantly, after the successful commissioning of the Chukha plant, two other hydro-electric projects came into operation—Kurichhu with a capacity of 60 MW and Tala with a capacity of 1,020 MW. Since 2003, there has been a spike in revenues from Rs. 2.3 billion to Rs. 10 billion in 2009, thereby substantively increasing export revenues from Indian assisted projects (Tala and Kurichhu). Given the incremental returns, India and Bhutan signed a Memorandum of Understanding in December 2009, whereby India committed to buy 10,000 MWof electricity from Bhutan by the year 2020. According to Bhutan's Tenth five year plan, the hydropower sector is expected to contribute 50% of the GDP and over 75% of the fiscal revenues by 2020 [40].

Electricity trade and economic cooperation have been important elements in the bilateral relations. Within the framework of collaboration between India and Bhutan, Bhutan sells approximately 70% of its hydropower to India, with the rest consumed in Bhutan.

APPENDIX C

C.1. Organisation framework of India

The organisation framework of India's power sector can be seen in Figure 24.

Role of System Operators in the Indian Power Sector

Policy Making	Central Government	CEA	State Government
Regulators	Central Electricity Regulatory Commission		State Electricity Regulatory Commission
System Operators	National Load Despatch Centre	Regional Load Despatch Centres	State Load Despatch Centres
Generation	Central Generating Stations	State Generating Stations	Private Sector Players
Transmission	Central Transmission Utility	State Transmission Utilities	Private Sector Players
Distribution	State Sector Distribution Licensee		Private Sector Distribution Licensee
Markets	Trading Licensee	Power Exchanges	Bilateral Markets

Figure 24: Organisation framework of India's power sector

2

C.2. CBET in India

Cross border electricity trade started in the 1980s between India and its bordering countries. The first cross-border interconnection of 400 kV between Baharampur, India, and Bheramara, Bangladesh, was commissioned in September 2013, hence bolstering India's export of electricity to Bangladesh. In addition, the second cross-border connection between Surjyamainagar (Tripura) in India and South Comilla in Bangladesh was activated. During that period India was receiving power from Bhutan and marginally exporting to Nepal in radial mode at 33 kV and 132 kV from Bihar and Uttar Pradesh.

South Asian nations have among of the world's lowest per capita power usage, about 70 percent lower than the global average of 3,265 KWh/Capita [4]. Along with the points mentioned earlier, this gap in per capita electricity consumption is a major opportunity to unlock the barriers to regional electricity trade and increase the volume of CBET. The salient features of CBET regulations effective from 8th March 2019 is mentioned in the following points:

1. Institutional framework
    a. CBET shall be governed by policy/regulation/procedure of MoP/CERC/CEA/SERC
    b. MoP shall appoint Designated Authority (DA) for facilitating the procedure for CBET
    c. Approval of DA is not required for govt. to govt. (G-t-G) transaction
2. Eligibility & other conditions for participation
    a. Import of electricity/ export of electricity
    b. Power exchange participation
    c. Trade through Indian grid
    d. Dedicated transmission line connected with neighbouring country
3. Tariff
    a. Competitive Bidding Process or Through Mutual Agreement
    b. CERC, if Approached by Generator of NC & Agreed by Indian Buyer
    c. Transactions Under G-t-G Mode will be determined by G-t-G Mode
4. Factors to be considered by da for granting approval
    a. DA shall grant export approval after considering availability/ demand
    b. DA shall grant import approval after considering equity pattern of ownership of entities along with other details as prescribed by DA.
5. Transmission system, scheduling & accounting
    a. The transmission link between India and its neighbouring nation will be designed jointly by the respective governments based on the requirement for energy commerce in the foreseeable future and the sharing of information required for analysis and studies.
    b. Cross-border transmission lines may be built between pooling stations of one country and another for secure, safe, and controlled grid operation.

c. CERC regulations define transmission access priority for import/export of electricity in India.
d. Transmission charges, scheduling, metering, accounting, deviation settlement, secure grid operations involving the Indian Grid, and any other associated operational mechanism are governed by Indian government regulations.
e. The Ministry of Power notifies each neighbouring country's Nodal Agency, which is accountable for grid operation-related charges per CERC regulations.

6. Dispute resolution
    a. Disputes within Indian Territory shall be settled as per the provisions of the Electricity Act, 2003.
    b. Disputes involving Entities of separate countries may be mutually agreed by the participating Entities or settled through the International Arbitration Centre as mutually acceptable.

APPENDIX D

D.1. Organisation Structure in Nepal

The organisation structure of the Nepal can be seen in Figure 25.

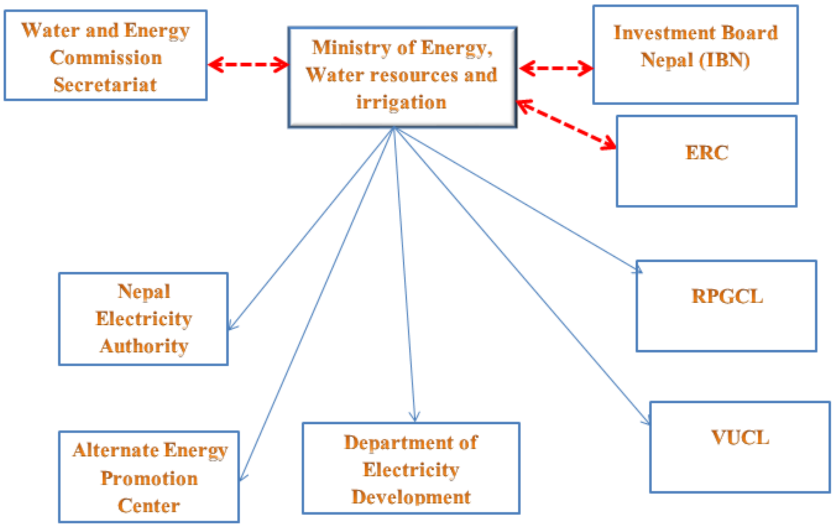

Figure 25: Power Sector Structure of Nepal

D.2. CBET in Nepal

Cross-border power trading with India began a few years ago, on November 11, 2020. The first transmission line between Nepal and India was of 400 kV voltage level, from Dhalkebar to Muzaffarpur. This allowed for power to be imported and exported from/to India through the Indian Energy Exchange (IEX). Nepal was the first among India's neighbouring countries to take part in the IEX [23]. Two additional 132 kV cross-border transmission lines between Kataiya (India) - Kusaha (Nepal) and Raxaul (India) - Parwanipur (Nepal) were completed with India's support in 2017 [24]. The second dedicated cross border transmission line from New Butwal to Gorakhpur was finalized in October 2019, and an agreement was signed in October 2021 for the development of the same with India [25].

Nepal has surplus power in their wet seasons (June to September) and India has a high demand in those seasons, likewise, India has surplus power in dry seasons (January to March) and Nepal has a high demand in those periods. Considering this situation, the Kushaha-Kataiya

132 kV second circuit transmission line project is proposed to strengthen the Nepal-India power trade further. The project cost is estimated to be $5.5 million (USD) and funded by the Government of Nepal (GoN). Nepal Electricity Authority (NEA) is also developing a 400 kV transmission line backbone inside Nepal with support from various donor agencies like the World Bank, Asian Development Bank, KfW Development Bank, Norad, Japan International Cooperation Agency (JICA) and European Investment Bank (EIB) [26].

APPENDIX E

Table 34: Calculation of new transmission line between India and Bangladesh per MUs.

India (Generation)				
Solar PV				
Assumption Head	**Sub-Head**	**Sub-Head(2)**	**Unit**	**Assumptions**
Power Generation	Capacity	Installed Power Generation Capacity	MW	500
		Capacity Utilisation Factor	%	18%
GROSS GENERATION			**MU**	**788.4**
Hydro				
Assumption Head	**Sub-Head**	**Sub-Head (2)**	**Unit**	**Assumptions**
Power Generation	Capacity	Installed Power Generation Capacity	MW	500
		Plant Load Factor	%	35%
GROSS GENERATION			**MU**	**1533**
TOTAL GENERATION OF INDIA			**MU**	**2409**

Bangladesh (Generation)				
Conventional				
Assumption Head	**Sub-Head**	**Sub-Head(2)**	**Unit**	**Assumptions**
Power Generation	Capacity	Installed Power Generation Capacity	MW	500
		Plant Load Factor	%	80%
GROSS GENERATION			**MU**	**3504**
TOTAL GENERATION OF BANGLADESH			**MU**	**3504**
TOTAL GENERATION (Including Bangladesh & India)			**MU**	**5913**

TOTAL COST OF TRANSMISSION LINE	**INR (Mil)**	**3450**
COST OF TRANSMISSION LINE/MU	**INR(Mil)**	**5.8**

Table 35: Calculation of new transmission line between India and Nepal per MUs.

India (Generation)				
Conventional				
Assumption Head	**Sub-Head**	**Sub-Head(2)**	**Unit**	**Assumptions**
Power Generation	Capacity	Installed Power Generation Capacity	MW	500
		Capacity Utilisation Factor	%	80%
GROSS GENERATION			MU	3504
TOTAL GENERATION OF INDIA			**MU**	**3504**
Nepal (Generation)				
Hydro				
Assumption Head	**Sub-Head**	**Sub-Head(2)**	**Unit**	**Assumptions**
Power Generation	Capacity	Installed Power Generation Capacity	MW	500
		Plant Load Factor	%	35%
GROSS GENERATION			MU	1533
TOTAL GENERATION OF NEPAL			MU	1533
TOTAL GENERATION (Including Nepal & India)			**MU**	**5037**
TOTAL COST OF TRANSMISSION LINE			**INR**	**55,20,00,00,000**
COST OF TRANSMISSION LINE/MU			**INR**	**10958904.11**

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About SARI/EI

The US Agency for International Development (USAID) initiated the South Asia Regional Initiative for Energy (SARI/E) program in the year 2000 to promote Energy Security in the South Asia region, working on three focus areas: Cross Border Energy Trade (CBET); Energy Market Formation; and Regional Clean Energy development. The program covers the eight countries in South Asia, viz. Afghanistan, Bangladesh, Bhutan, India, The Maldives, Nepal, Pakistan and Sri Lanka. The fourth and current phase of the program, called South Asia Regional Initiative for Energy Integration (SARI/EI), is aimed at advancing regional grid integration through cross border power trade. This phase is being implemented by Integrated Research and Action for Development (IRADe), leading South Asian Think Tank. SARI/EI program was recently extended to 2022 and is a key program under USAID's Asia EDGE (Enhancing Growth and Development through Energy) Initiative. In its extended phase, SARI/EI will focus on moving the region from bilateral to trilateral and multilateral power trade, and establishing the South Asia Regional Energy Market (SAREM).

For more information, please visit the SARI/EI project website:
Website: https: //sari-energy.org/
Follow us: Twitter: @SARI_EI_2022

About USAID

The United States Agency for International Development (USAID) is an independent government agency that provides economics, development and humanitarian assistance around the world in support of the foreign policy goals of the United States. USAID's mission is to advance broad-based economics growth, democracy, and human progress in developing countries and emerging economies. To do so, it is partnering with governments and other actors, making innovative use of science, technology, and human capital to bring the profound results to a greatest number of people.

About IRADe

IRADe, located in Delhi, is a non-profit and fully autonomous institute for advance research. IRADe's multidisciplinary research and policy analysis aid action programs. It is a hub for a network of diverse stakeholders. Established in 2002, the institute is recognized as an R&D organization by the Department of Scientific and Industrial Research and Ministry of Science and Technology of the Government of India. The Ministry of Urban Development has accorded IRADe the status of Centre of Excellence for Urban Development and Climate Change. Through the SARI/EI program, IRADe is pushing the envelope for sustainable energy access through experts and members from South Asia.

About NTPC Scool of Business

NTPC Limited, a Maharatna company of Government of India, is India's largest energy conglomerate with an installed capacity of 67,657.5 MW (including 13,425 MW through JVs/Subsidiaries). NTPC Limited is instrumental in promoting NTPC Education and Research Society (NEARS). Under the aegis of NEARS, NTPC School of Business (NSB) was set up in the year 2014 with the aim to nurture human capital for the entire energy sector.

NTPC School of Business (NSB) has two AICTE approved programmes, namely, Post Graduate Diploma in Management – Executive (PGDM-E) and Post Graduate Diploma in Energy Management (PGDM-EM). These courses are designed to enrich management learning and practice at all levels of decision making in the area of energy management.