Chapter 2

Energy Infrastructure Development for Cross-border Energy Trade in Northeast India

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CHAPTER 2

Energy Infrastructure Development for Cross-border Energy Trade in Northeast India

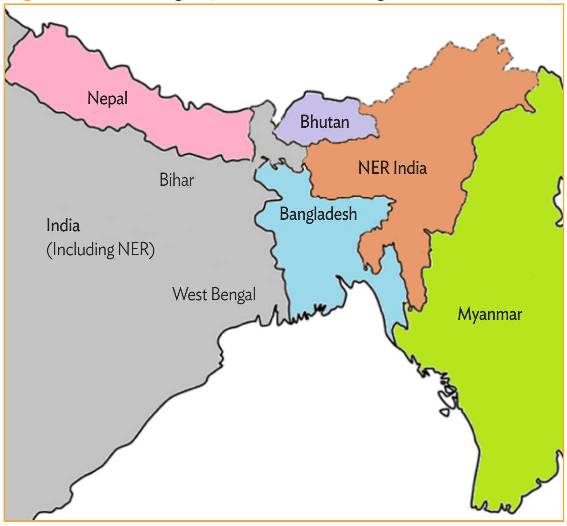
1. Energy Markets in the North Eastern Region of India

To analyse opportunities for cross-border trade in electricity between the North Eastern Region of India (NER) and the neighbouring countries of Bangladesh, Bhutan, Myanmar, and Nepal, this study uses a linear-programming model developed by the Institute of Energy Economics, Japan (IEEJ), known as the electricity supply and trade model. The aim of this study is to find the optimal electricity supply scenario during 2015–2030 in terms of power generation in each region and cross-border grid connections amongst these regions, while minimising costs overall to meet the increasing demand for electricity in the region as a whole.

This study refers to government development plans, such as the Power Sector Master Plan of the Ministry of Power, Energy and Mineral Resources of Bangladesh, to project future electricity demands, and the capacity of each type of power plant in each region. Several different cases are calculated to determine the potential of the NER as a transit provider, generator, and exporter that can promote energy connections and trade in the region.

This study covers Bangladesh, Bhutan, Myanmar, Nepal, and the NER (the NER includes the states of Arunachal Pradesh, Assam, Manipur, Meghalaya, Mizoram, Nagaland, and Tripura). To analyse the electricity trade in this region thoroughly, the study also looks at the rest of India as a whole (‘Other India’).

Figure 2.1 Geographical Coverage of this Study



NER = North Eastern Region of India.

Source: Author.

1.1. Current Situation of the North Eastern Region of India and the Neighbouring Regions Population and Gross Domestic Product in Each Country

Of the countries that neighbour the NER, Bangladesh has the largest population and highest gross domestic product (GDP), surpassing the sum of Bhutan, Myanmar, Nepal, and the NER. The GDP per capita in most of these regions is around $1,000, much lower than the global average ($10,000), as well as the average of countries not in the Organisation of Economic Cooperation and Development (OECD) ($4,400). As such, these regions have significant potential to expand their economic activities and increase their consumption of energy.

Electricity Demand and Supply

In Bhutan, which has abundant hydropower resources and the highest income level of all the regions under study, electricity consumption per capita in 2015 was 3,415 kilowatt-hours (kWh) per person. This was more than triple the consumption of Other India, which came second at 1,066 kWh/person. In contrast, electricity consumption per capita in Bangladesh, Myanmar, Nepal, and the NER was less than 400 kWh/person (Figure 2.2).

Table 2.1 Population and Gross Domestic Product of Each Region (2015)

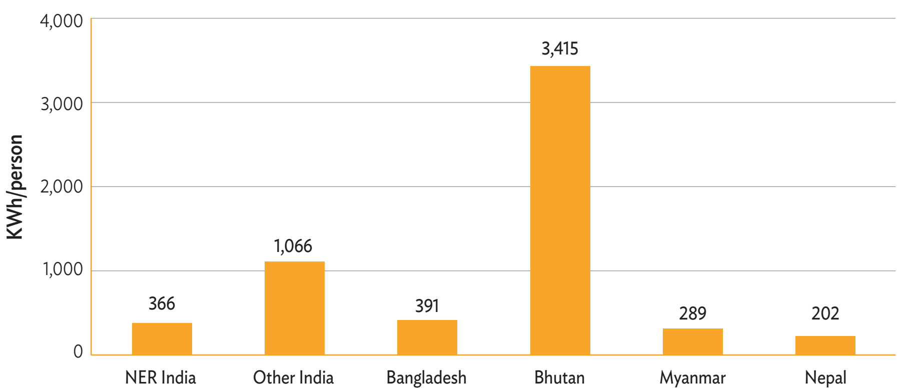
	Population (million people)	GDP ($ billion)	GDP per capita ($/person)
India	1,311	2,089	1,593
NER	49	53	1,077
Other India	1,262	2,036	1,613
Bangladesh	161	195	1,212
Bhutan	1	2	2,656
Myanmar	54	63	1,161
Nepal	29	21	743

GDP = gross domestic product, NER = North Eastern Region of India.

Note: 'Other India' refers to all Indian states and territories other than the eight states in the NER (Arunachal Pradesh, Assam, Manipur, Meghalaya, Mizoram, Nagaland, Sikkim, and Tripura).

Sources: World Bank (2017), World Development Indicators; Government of India, Ministry of Home Affairs.

Figure 2.2 Electricity Consumption per Capita in Each Region (2015)



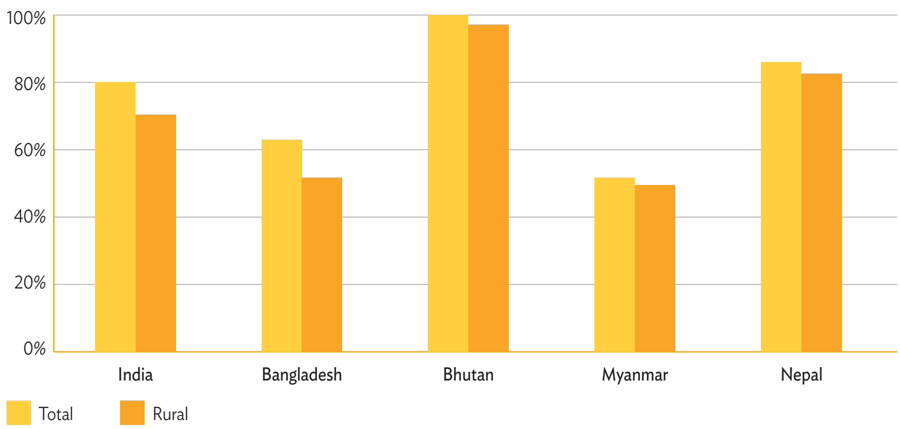
kWh = kilowatt-hour, NER = North Eastern Region of India.

Note: 'Other India' refers to all Indian states and territories other than the eight states in the NER (Arunachal Pradesh, Assam, Manipur, Meghalaya, Mizoram, Nagaland, Sikkim, and Tripura).

Source: Estimated from data from the World Bank, International Energy Agency, and Central Statistics Office of India, amongst others.

Amongst these regions, the rate of electrification in Bhutan is the highest at nearly 100% (95% in rural areas), followed by Nepal (82%) and India (78%). On the lower end, the electrification rate is 60% in Bangladesh and 50% in Myanmar, and many residents in these regions currently have no access to the power grid.

Figure 2.3 Rate of Electrification (2015)



Source: World Bank.

The NER is currently a net importer of electricity, with about 30% of its electricity supply imported from Bhutan and Other India. The largest sources of power generation in the NER are gas and hydropower.

Bangladesh's power supply depends on fossil fuels, with more than half of its supply generated from natural gas-fired power, one-third from oil-fired power plants, and 2% from coal-fired power plants. The country imports the remaining 10% of its electricity supply from India.

Nepal generates nearly 100% of its electricity from hydropower plants. However, due to a lack of investment, its domestic power generation capacity is lower than demand, and Nepal imports electricity from India to meet both peak demand and annual consumption.

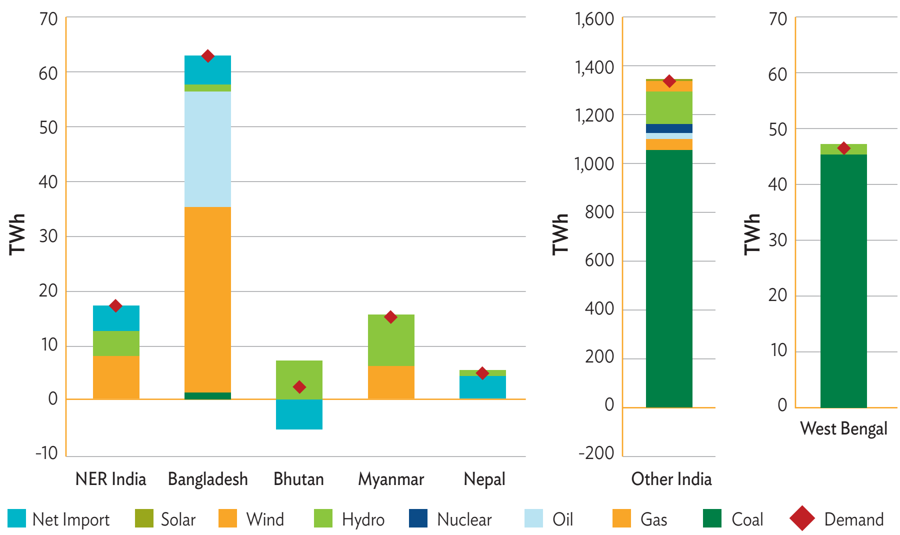
Bhutan is a major exporter of electricity to these regions. Due to its abundant resources, 100% of its power supply comes from hydropower, and its capacity is around five times the domestic peak demand. In 2015, more than 60% of all generated power was exported to India.

Myanmar is currently self-sufficient for electricity. Its primary sources of generated power are hydropower, which accounts for 58% of the total supply; and natural gas, which accounts for 40%. The remaining 2% of its supply comes from coal-fired power plants.

In Other India the power generation structure is much different, with coal accounting for around 80% of the total power supply in 2015. Hydropower provides about 10%, and wind, natural gas, and nuclear each provide about 3% of the total supply.

Currently, the main electricity trade flows in these regions are as follows: Bhutan to India, India to Bangladesh, and India to Nepal.

Figure 2.4 Electricity Demand and Supply (2015)

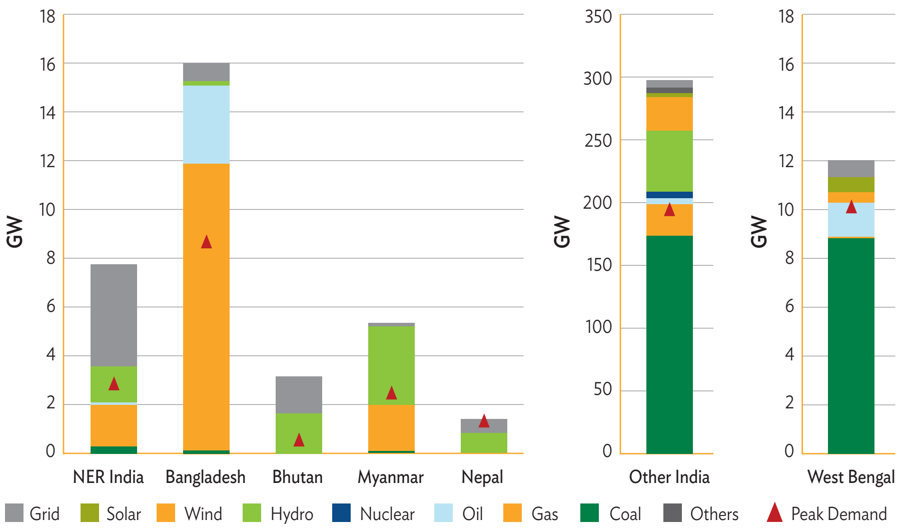


NER = North Eastern Region of India, TWh = terawatt-hour.

Note: 'Other India' refers to all Indian states and territories other than the eight states in the NER (Arunachal Pradesh, Assam, Manipur, Meghalaya, Mizoram, Nagaland, Sikkim, and Tripura).

Sources: International Energy Agency, national master plans and statistics.

Figure 2.5 Power Supply Capacity and Peak Demand (2015)

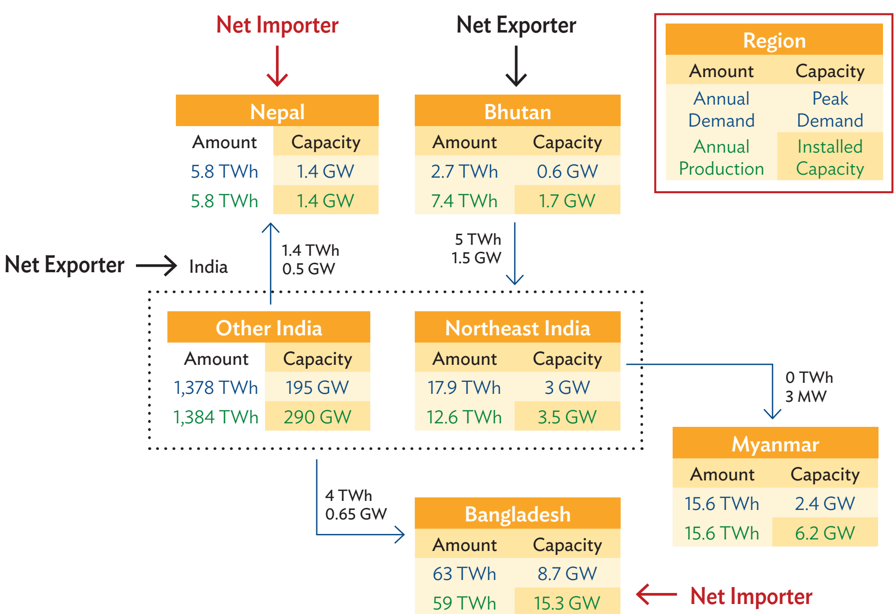


GW = gigawatt, NER = North Eastern Region of India.

Note: 'Other India' refers to all Indian states and territories other than the eight states in the NER (Arunachal Pradesh, Assam, Manipur, Meghalaya, Mizoram, Nagaland, Sikkim, and Tripura).

Sources: International Energy Agency, national master plans and statistics.

Figure 2.6 Electricity Balance (2015)



GW = gigawatt, TWh = terawatt-hour.

Note: 'Other India' refers to all Indian states and territories other than the eight states in the North Eastern Region of India (Arunachal Pradesh, Assam, Manipur, Meghalaya, Mizoram, Nagaland, Sikkim, and Tripura).

Sources: International Energy Agency, national master plans and statistics.

2. Methodology and Major Assumptions

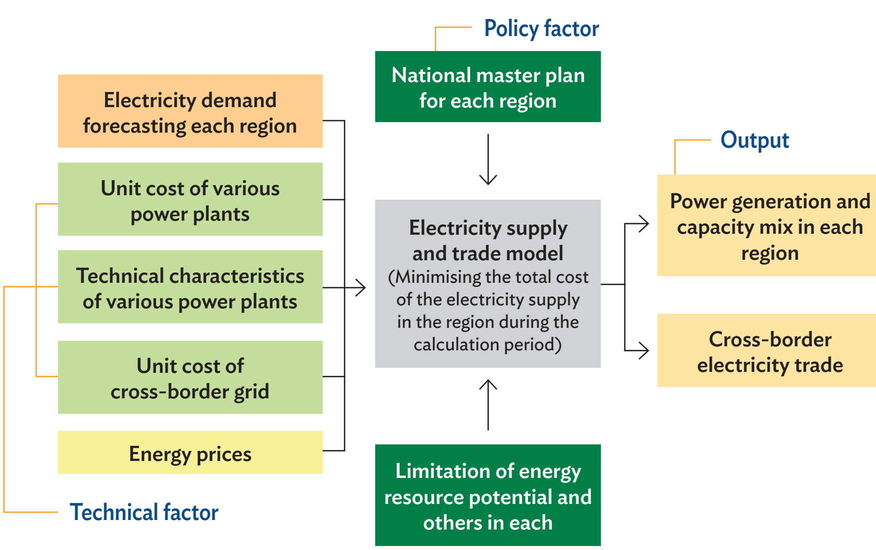
2.1. Overview of the Model

The electricity supply and trade model used in this study was designed to determine a cost-optimal solution for the electricity mix and trade to satisfy given electricity demand levels in multiple countries or regions. The electricity demand forecast in each region is drawn from the government plan or official outlook. The unit cost of various power plants and cross-border grids are given values estimated from various sources such as related reports and papers. Finally, the price of fossil fuels during the calculation period (2015–2030) was determined by referring to the IEEJ's Energy Outlook 2018.

To determine whether power supply will meet demand at any time in the future, this study refers to the planned capacity (set out in the official power and/or energy master plans) of nuclear, renewable, and some fossil fuel-fired power plants, as well as cross-border grids, to determine the specific capacity range.

As the solution to a linear programming problem, the capacity of the power mix and cross-border grid in each time period, power generation, and electricity trade can be determined in each hour of each time period.

Figure 2.7 Framework of the Model Analysis



Source: Authors.

As described in equation 1, the objective function of the calculations is to minimise the total net present value of the power supply cost during the whole period, including investment costs of power plants and cross-border grids, fixed costs such as maintenance and labour, and variable costs for fossil fuels. In this study, the discount rate is set at 5% referring to the average level of public investment in OECD countries.

The major relations in the model are (i) the balance between demand and supply (production and import or export) at each time point (equation 2), and (ii) the limitation of power generation by the current capacity of power plants (equation 3). In the model, one time period is 5 years, each containing three seasons (wet, dry, and inter-season), and there are 24 hours (time points) in a typical day in each season.

$$Min \quad Total\_C = \sum_{t=0}^{T}\left(\frac{1}{(1+r)^t}\left(\sum_{reg=1}^{REG}\sum_{p=1}^{P}\left(I\_P_{t,reg,p} + F\_P_{t,reg,p} + V\_P_{t,reg,p}\right) + \sum_{r1=1}^{REG}\sum_{r2=1}^{REG}\left(\frac{1}{2}\left(I\_G_{t,r1,r2} + F\_G_{t,r1,r2}\right) + V\_G_{t,r1,r2}\right)\right)\right) \quad (1)$$

Min Total_C: total cost during the simulation period in present value; r: discount rate; t: time period; reg: region; p: type of power plant;
I_P, F_P, V_P: investment, fixed cost, variable cost of power plant;
I_G, F_G, V-G: investment, fixed cost, variable cost of cross-border grid.

$$Demand_{t,s,h,reg} \leq \sum_{p=1}^{P} Gen_{t,s,h,reg,p} + \sum_{r2=1}^{REG}\left(Tran_{t,s,h,r2,reg} - Tran_{t,s,h,reg,r2}\right) \quad (2)$$

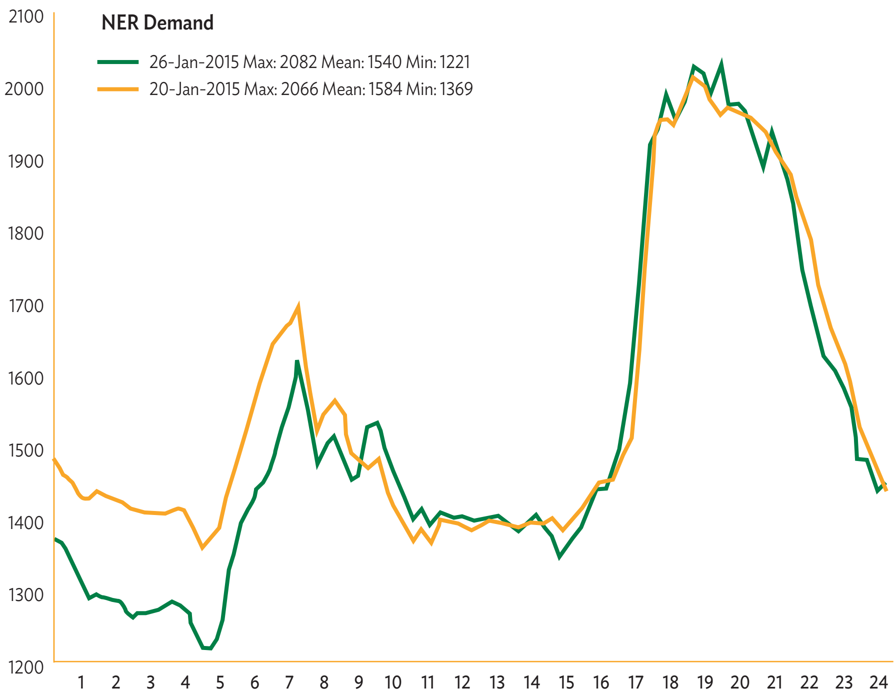
Demand: electricity demand; Gen: electricity generation; Tran: electricity transmission; s: season; h: hour.

$$Gen_{t,s,h,reg,p} \leq \sum_{p=1}^{P}\left(Cap\_E_{reg,p,t} + \sum_{t'=0}^{t} Cap\_N_{reg,p,t'}\right) \quad (3)$$

Cap_E: existing power plant; Cap_N: new power plant.

In the model, the load curves of electricity demand in each region are set in each season.

Figure 2.8 Load Curve of Electricity Demand (in the North Eastern Region of India)



max = maximum, min = minimum, NER = North Eastern Region of India.

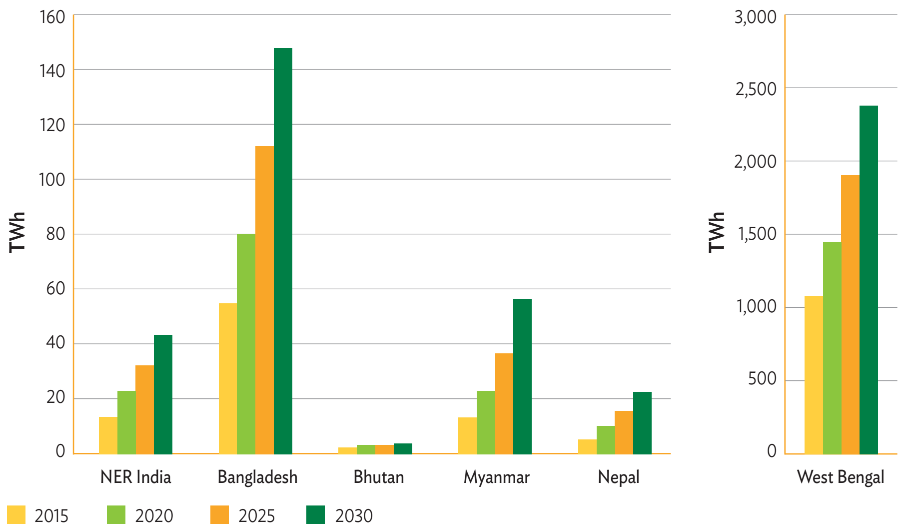
Source: Government of India, Ministry of Power (2016), Report of the Technical Committee on Large Scale Integration of Renewable Energy, Need for Balancing, Deviation Settlement Mechanism (DSM) and Associated Issues. Delhi.

2.2. Major Assumptions

Electricity Demand Forecast

To estimate the future electricity demand in each region, this study refers to forecasts in government plans. According to these forecasts, from 2015 to 2030 the demand for electricity will increase 3 times in the NER, 2.7 times in Bangladesh, and 1.7 times in Bhutan. In Myanmar and Nepal, which have the lowest electricity consumption per capita of the regions under study, the power demand will more than quadruple from current levels. The sum of the electricity demand in all these regions will reach 273 terawatt-hours in 2030, triple the demand in 2015. During the same period, the electricity demand of Other India will increase to about 2,400 terawatt-hours, 2.2 times the current level.

Figure 2.9 Power Supply Capacity and Peak Demand (2015)



NER = North Eastern Region of India, TWh = terawatt-hour.

Note: 'Other India' refers to all Indian states and territories other than the eight states in the North Eastern Region of India (Arunachal Pradesh, Assam, Manipur, Meghalaya, Mizoram, Nagaland, Sikkim, and Tripura).

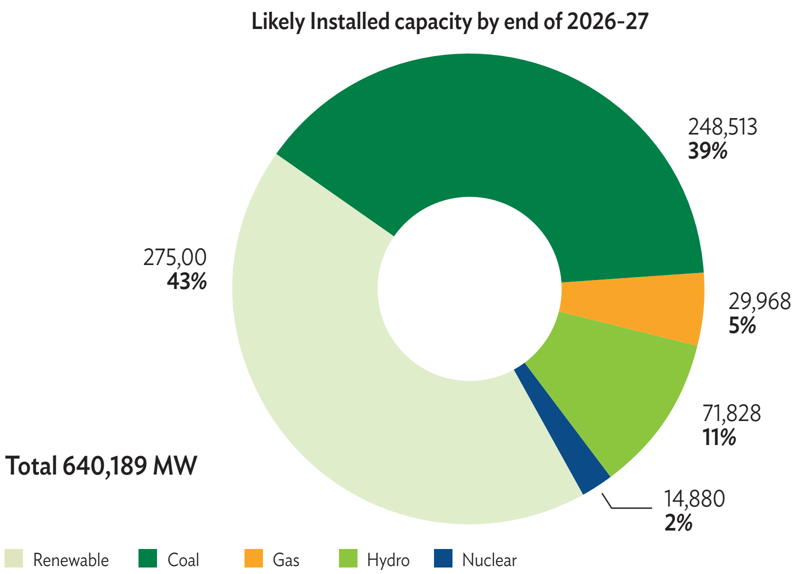
Sources: International Energy Agency, national master plans and statistics.

Plans for Power Supply and Cross-Border Grid Expansion

As announced in its National Electricity Plan, India is planning to accelerate the introduction of renewable energy such as wind power and solar photovoltaics. It is also aiming to increase the share of renewable power including hydropower to more than 50% by the mid-2020s. Currently, the installed capacity of coal-fired power plants is about 180 gigawatts (GW), 60% of total installed capacity. In the coming decades, while growth in this area will be lower than in renewables, coal-fired power plants are projected to continue increasing, remaining the largest source of power generated in this region.

Given the low-cost of coal, Bangladesh is planning to expand the share of coal-fired power in the domestic supply capacity to meet the increasing demand for electricity. The country is also planning to introduce nuclear power plants as a baseload electricity source in the mid-2020s. Currently, more than 70% of installed capacity comes from gas-fired power, which will remain a major source of power in the future. However, due to a lack of domestic resources, Bangladesh will also increasingly depend on imported electricity.

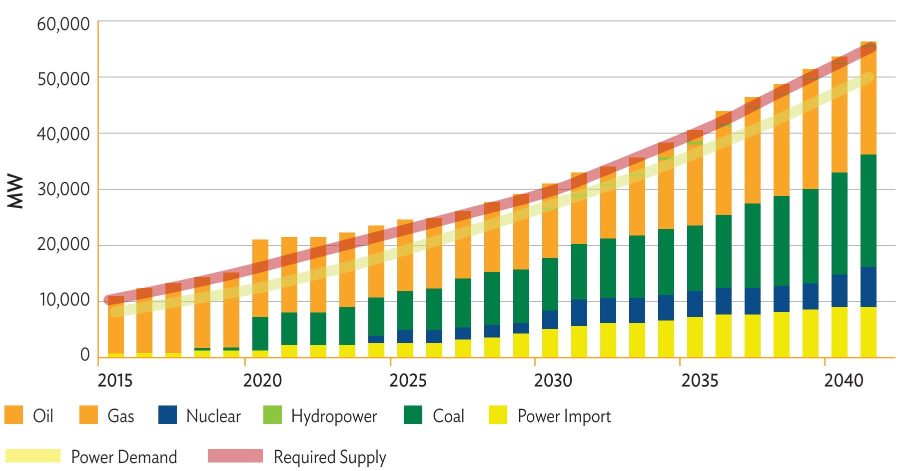
Figure 2.10 Generation Expansion Plan of India



hydro = hydropower, MW = megawatt.

Source: Central Electricity Authority of India (2016), Draft National Electricity Plan. Delhi.

Figure 2.11 Power Development Plan of Bangladesh



MW = megawatt.

Source: Government of Bangladesh, Ministry of Power, Energy and Mineral Resources (2016), *Power System Master Plan 2016*. Dhaka.

Table 2.2 Hydropower Development Plan of Bhutan

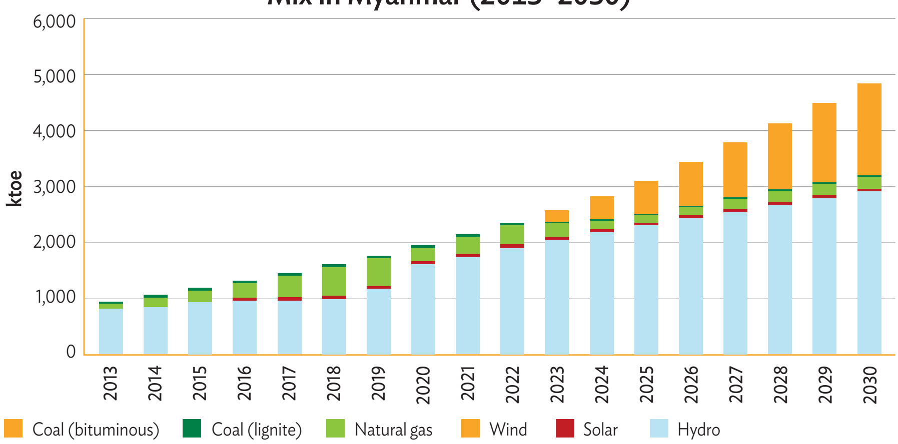
Existing I.C.	Capacity addition by 2020	I.C. at the end of 2020	Capacity addition during 2020-2030	I.C. at the end of 2030
1,480 MW	10,334 MW (fourteen HEPs)	11,814 MW	14,720 MW (sixtyone HEPs)	26,534 MW

HEP = hydroelectric project, IC = installed capacity, MW = megawatt.

Source: Central Electricity Authority of India (2012), National Transmission Grid Master Plan for Bhutan, 2012. Delhi.

As announced in its Energy Master Plan, Myanmar will develop more hydropower and coal-fired power to meet the increased electricity demand. By 2030, it is projected that 60% of all power generated in the country will come from hydropower and 30% from coal, with most of the remainder provided by gas-fired power.

Figure 2.12 Projected Power Generation Fuel Mix in Myanmar (2013–2030)



hydro = hydropower, ktoe = kilotonnes of oil equivalent.

Note: Case 2 (balanced hydropower: less planned hydropower displaced by coal and solar photovoltaics).

Source: Government of Myanmar, National Energy Management Committee (2015), *Myanmar Energy Master Plan, 2015*. Nay Pyi Taw.

Nepal is currently a net importer of electricity. The country's hydropower capacity is projected to increase to nearly 5 GW by 2030, through the utilisation of the huge potential of its domestic hydropower resources (Nepal Electricity Authority, 2014). As power generated mainly from hydropower surpasses annual domestic demand, Nepal will become a net exporter of electricity. However, in the dry season, due to the low supply capacity of run-of-river hydropower plants, Nepal will still need to import electricity from India when the available supply capacity, which relies on hydropower, falls below peak demand.

Table 2.3 Power Development Plan of Nepal

Base Case

FY	Project	Total Installed capacity (MW)	LOLP (%)
(2011/12)	(Existing)	862.1	-
2012/13	-	862.1	50.375
2013/14	-	862.1	53.789
2014/15	-	862.1	57.975
2015/16	Kulekhani No. 3 (14), Chameliya (30), Khani Khola (25)	1,081.1	32.637
2016/17	Upper Sanjen (11), Sanjen (42.9) Upper Trishuli 3A (60), Uppper Tamakoshi (456)	1,651.0	2.733
2017/18	Madhya (Middle) Botekoshi (102), Rasuwagadi (111), Rahughat (32), Upper Marsyangdi (50), Mistri (42)	1,988.0	1.575
2018/19	ROR (100 in total)	2,088.0	1.927
2019/20	Upper Trishuli 3B (37), ROR (100 in total)	2,225.0	2.579
2020/21	Tanahu (140), Upper Modi A (42), ROR (100 in total)	2,507.0	1.919
2021/22	Tamakoshi V (87)	2,594.0	3.087
2022/23	Budhi Gandaki (600)	3,194.0	0.130
2023/24	-	3,194.0	0.516
2024/25	ROR (100 in total)	3,294.0	1.225
2025/26	Upper Arun (335), ROR (100 in total)	3,729.0	0.666
2026/27	Dudh Koshi (300)	4,029.0	0.336
2027/28	-	4,029.0	1.079
2028/29	Nalsyau Gad (410)	4,439.0	0.440
2029/30	Andhi Khola (180), ROR (300 in total)	4,919.0	1.331
2030/31	-	4,919.0	1.330
2031/32	Chera-1 (149), Madi (200)	5,268.0	1.232

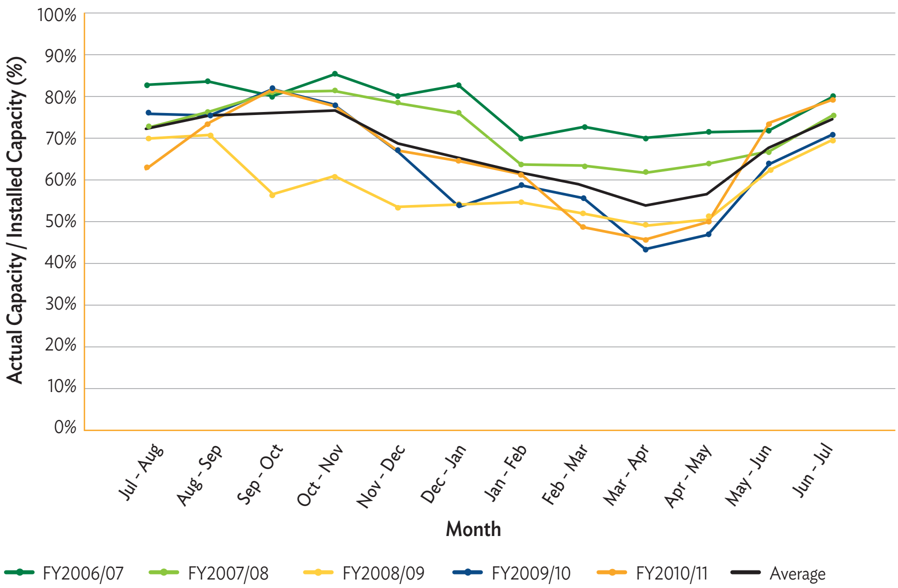
LOLP = loss of load probability, MW = megawatt, ROR = run-of-river.

Notes: 'FY' before a calendar year denotes the year in which the fiscal year ends, e.g., FY2018 ends on

15 July 2018. The number in the case arc is the capacity of identified power plants in MW.

Source: Nepal Electricity Authority (2014), *Nationwide Master Plan Study on Storage-Type Hydroelectric Power Development in Nepal, 2014*. Kathmandu.

Figure 2.13 Rates of Maximum Output to Installed Hydropower Capacity in Nepal by Month



Note: 'FY' before a calendar year denotes the year in which the fiscal year ends, e.g., FY2018 ends on 15 July 2018.

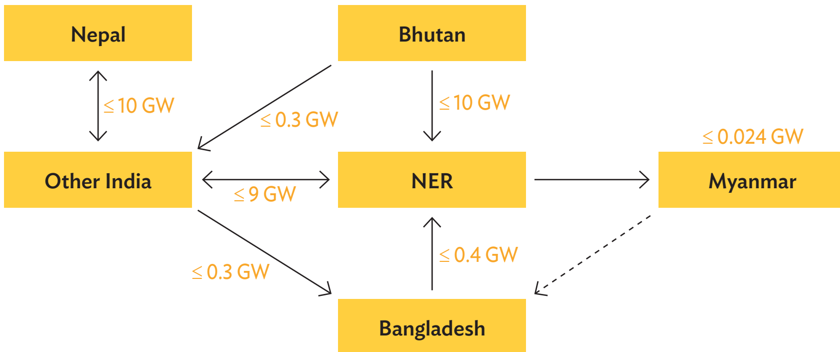
Source: Nepal Electricity Authority (2014), *Nationwide Master Plan Study on Storage-Type Hydroelectric Power Development in Nepal, 2014*. Kathmandu.

Based on national energy and master power plans, this study determined the limitations of cross-border transmission capacity (Figure 2.14). Under the current plans, the interconnections between Bhutan and the NER, and between Nepal and India will be enhanced. In addition, Bangladesh will import more electricity from India via the expanded capacity of the interconnection line between the two countries.

Economic and Technical Parameters of Power Generation and Cross-Border Lines

This study refers to the IEEJ's Energy Outlook 2018 for the estimated price of fossil fuels (the inputs to thermal power plants). This report projects that oil prices will rise gradually in the coming decades, mainly due to increasing oil demand in non-OECD countries and the depletion of existing low-cost oil fields. Natural gas and coal are also projected to increase in price by 2030.

Figure 2.14 Estimated Capacity of Cross-Border Grids

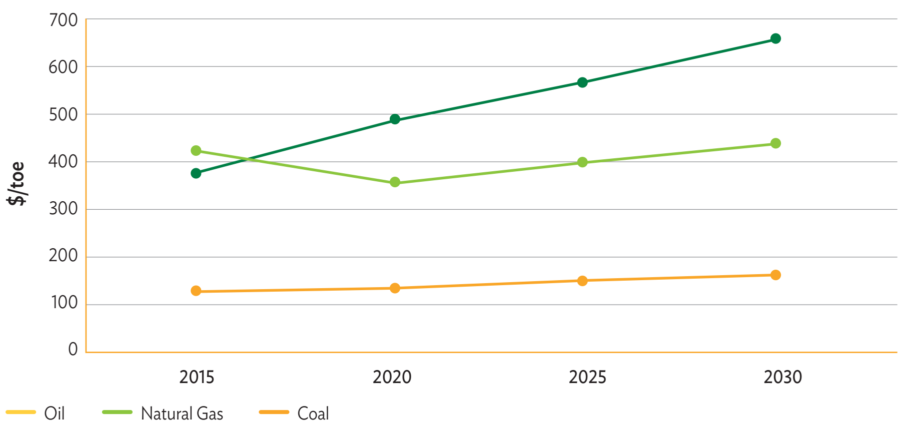


GW = gigawatt, NER = North Eastern Region of India.

Note: 'Other India' refers to all Indian states and territories other than the eight states in the NER (Arunachal Pradesh, Assam, Manipur, Meghalaya, Mizoram, Nagaland, Sikkim, and Tripura).

Source: Authors.

Figure 2.15 Estimated Fossil Fuel Prices

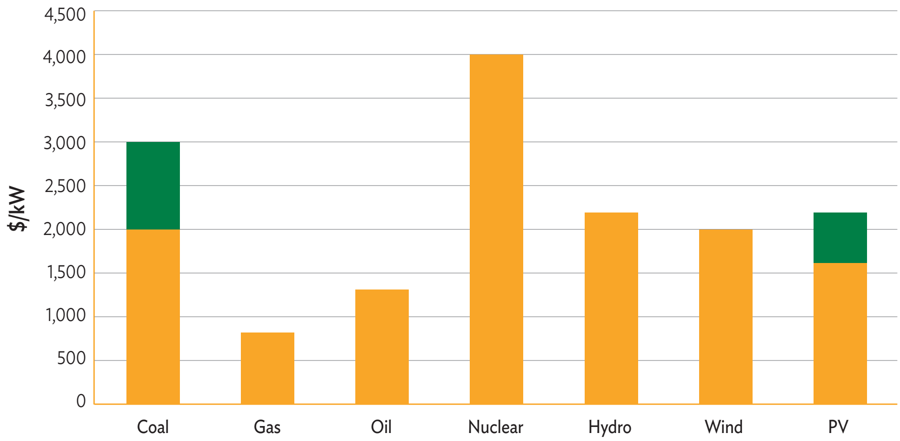


toe = tonnes of oil equivalent.

Source: Institute of Energy Economics, Japan (2017), *Energy Outlook 2018*. Tokyo.

The estimated investment costs for various power plants are shown in Figure 2.16. The initial investment cost of nuclear power is the highest, and that of gas-fired power is the lowest. The investment cost of coal-fired power plants differs by region; for example, it is higher in inland mountain countries. The investment cost of solar photovoltaics will decrease gradually as the technology develops further and production and sales increase.

Figure 2.16 Estimated Investment Cost of Power Plants



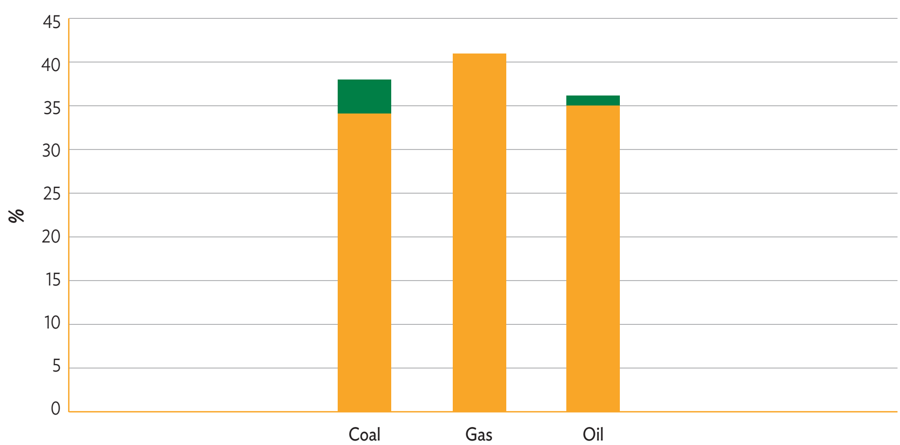
hydro = hydropower, kW = kilowatt, PV = solar photovoltaics.

Note: The cost of investing in coal-fired power plants differs by region. The cost of investing in photovoltaics differs by period.

Source: International Energy Agency, Organisation for Economic Cooperation and Development (2015), *Projected Costs of Generating Electricity*. Paris.

Of all fossil fuel-fired thermal power plants, those fired by gas have the highest thermal efficiency (40%) in the NER and neighbouring regions. The thermal efficiency of coal-fired plants in mountain countries such as Bhutan and Nepal is assumed to be lower than in the other countries.

Figure 2.17 Estimated Thermal Efficiency of New Thermal Power Plants



Source: Institute of Energy Economics, Japan.

Information on the cost of cross-border lines is limited. This study refers to an Asian Development Bank report on cross-border power trading in South Asia to estimate the investment cost (Wijayatunga, Chattopadhyay, and Fernando, 2015). In the model, fixed operation and maintenance costs per year ($/kW) is estimated at 3% of the investment cost, and variable costs per unit of electricity ($/MW-hour) are assumed to be proportional to the investment cost (1% thereof).

Table 2.4 Estimated Cost of Major Cross-Border Grids

Major cross-border line	Investment cost ($/kW)
BHUTAN–NER	71
Nepal–Other India	372
NER–Bangladesh	400
NER–Myanmar	200

kW = kilowatt, NER = North Eastern Region of India.

Note: 'Other India' refers to all Indian states and territories other than the eight states in the NER (Arunachal Pradesh, Assam, Manipur, Meghalaya, Mizoram, Nagaland, Sikkim, and Tripura).

Source: Estimate from Wijayatunga, P., D. Chattopadhyay, and P.N. Fernando (2015), 'Cross-Border Power Trading in South Asia: A Techno Economic Rationale', *Asian Development Bank South Asia Working Paper Series*, No. 38, Manila: Asian Development Bank.

2.3. Case Settings

To estimate the potential of the NER as a transit provider, generator, and exporter, this study calculates three cases. In the reference case, the installed capacity of the major energy sources of power plants to meet the increasing electricity demand in the NER and neighbouring regions aligns with the power development plans mentioned in Section 2.2. The upper capacity limits of cross-border lines are set out in Figure 2.14.

The power plant development scenarios are the same in the enhanced hydropower case (EGC) as in the reference case. The only difference is that in the EGC there is no upper limit on the capacity of cross-border lines connected to the NER, meaning that the capacity of cross-border lines can be expanded as much as necessary to achieve maximum economic efficiency (lower net present value of total cost).

In the reference case, the NER's installed hydropower capacity reaches nearly 5 GW in 2030, triple the 2015 level. However, this only represents 8% of the region's identified potential hydropower capacity (58 GW), far below the current average level in India (around 25%). In the enhanced hydropower and grid case (EHGC), the NER's hydropower capacity is estimated to reach triple the levels in the reference case and EGC. In the EHGC, the impact of the NER as a generator and exporter is also estimated.

Table 2.5 Case Settings

	Reference case	Enhanced grid case	Enhanced hydropower and grid case
Capacity of hydropower plants	Government's plan	Same as reference case	Enhanced in the NER (25% of the potential, threefold increase from the reference case)
Capacity of other power plants	Government's plan	Same as reference case	Same as reference case
Capacity of cross-border grids	As planned*	No high limit	No high limit

*see Fig 2.14.

NER = North Eastern Region of India.

Source: Authors.

3. Results and Discussion

3.1. Results of Reference Case

According to the reference case, by 2030 the NER will need to import electricity to fill the gap between domestic demand and its capacity to generate electricity, with 24% of its annual electricity demand provided by imports from Bhutan. In Bhutan, the expanded production of electricity from hydropower will substantially surpass domestic demand, and the country will increase its presence as an electricity exporter. Due to the geographical location of these regions, these exports will mainly be directed to the NER; however, as these exports will far exceed the NER's import requirements, most of the imported electricity will be sent to Other India and Bangladesh. As such, the NER will play an important role as a transit corridor.

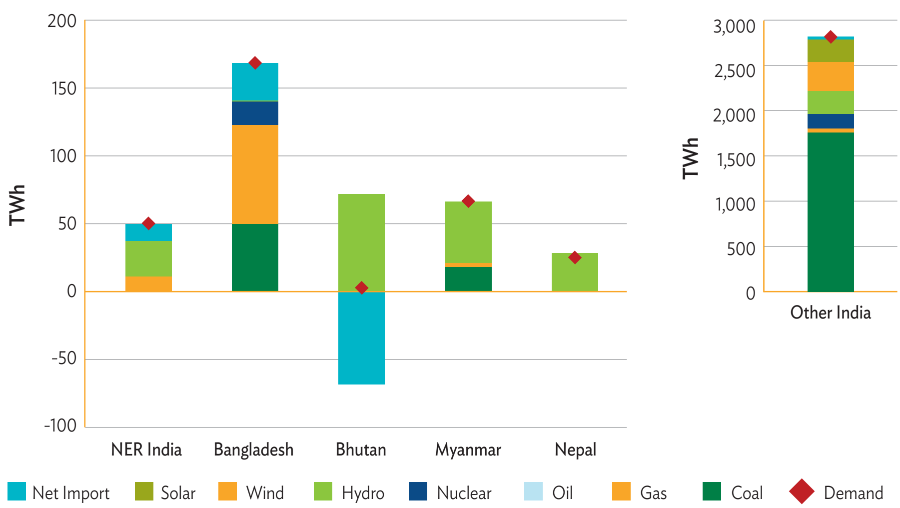
Fossil fuel-fired thermal power will account for a large share of Bangladesh's total installed capacity by 2030. However, given the high cost of oil-fired thermal power, it will be more economical to import electricity from neighbouring countries. Thus, Bangladesh will import more electricity, most of which will be imported indirectly from Bhutan via the NER and Other India.

Nepal still needs to import power from India to meet peak demand; however, due to its expanded hydropower capacity, Nepal will be able to export electricity when domestic demand is low. Based on annual averages, Nepal will become a net exporter of electricity.

Myanmar’s domestic electricity demand and supply will remain almost balanced.

The increasing energy demand in Other India will be satisfied by domestic production, mainly from coal-fired power but also from renewables, which are expanding rapidly.

Figure 2.18 Electricity Demand and Supply in 2030 (Reference Case)

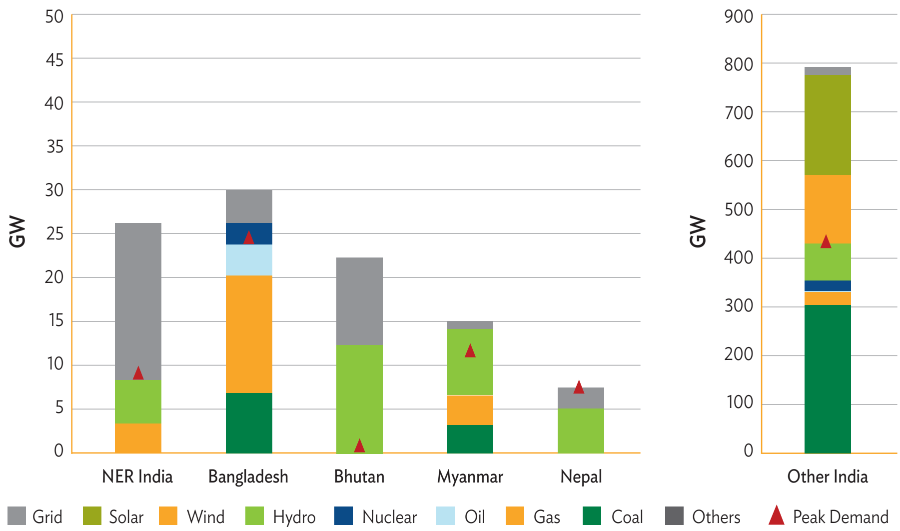


NER = North Eastern Region of India, TWh = terawatt-hour.

Note: ‘Other India’ refers to all Indian states and territories other than the eight states in the NER (Arunachal Pradesh, Assam, Manipur, Meghalaya, Mizoram, Nagaland, Sikkim, and Tripura).

Source: Authors.

Figure 2.19 Power Supply Capacity in 2030 (Reference Case)

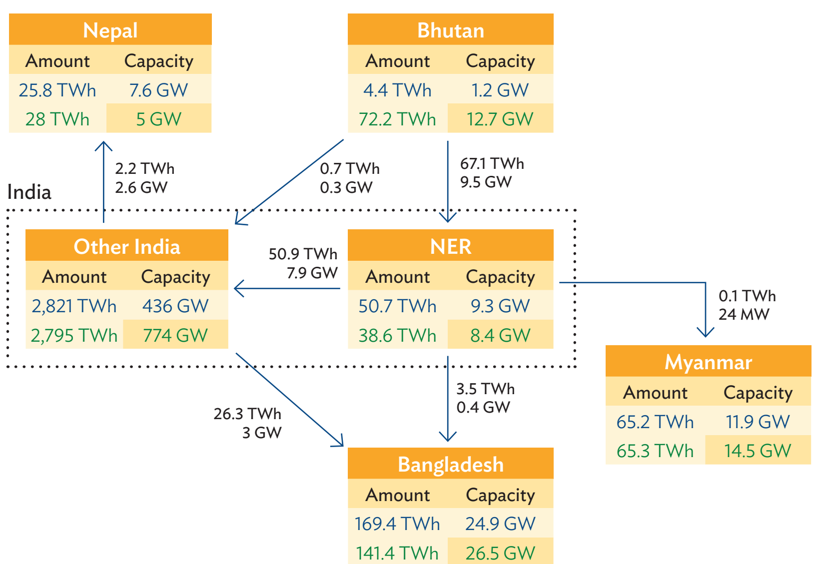


GW = gigawatt-hour, NER = North Eastern Region of India.

Note: 'Other India' refers to all Indian states and territories other than the eight states in the NER (Arunachal Pradesh, Assam, Manipur, Meghalaya, Mizoram, Nagaland, Sikkim, and Tripura).

Source: Authors.

Figure 2.20 Electricity Balance and Trade in 2030 (Reference Case)



GW = gigawatt, NER = North Eastern Region of India, TWh = terawatt-hour.

Note: 'Other India' refers to all Indian states and territories other than the eight states in the NER (Arunachal Pradesh, Assam, Manipur, Meghalaya, Mizoram, Nagaland, Sikkim, and Tripura).

Source: Authors.

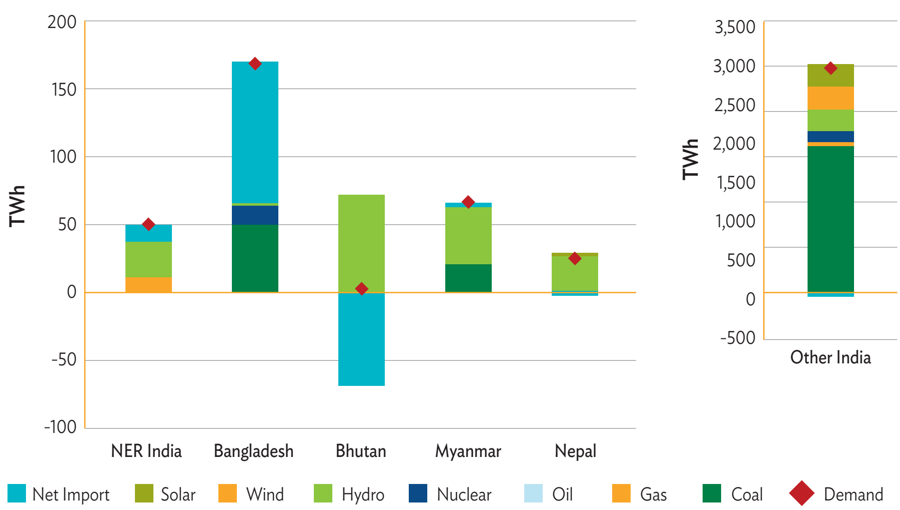
3.2. Results of the Enhanced Grid Case

In the EGC, the electricity generation scenario in the NER, Bhutan, and Nepal is almost the same as in the reference case. Bangladesh imports more electricity from the NER, and generates less gas-fired power; Myanmar replaces electricity produced from domestic gas-fired power with energy imports from the NER; and Other India generates more electricity by boosting the operation rate of coal-fired power, the capacity of which will relatively exceed demand by 2030.

Compared to the reference case, the capacity of the NER–Bangladesh connection line increased from 0.4 GW to 10.4 GW, while that of the NER–Myanmar line increased from 24 MW to 1.5 GW in the EGC. The role of the NER as a transit corridor between neighbouring regions became more important, as Bhutan's hydropower and Other India's coal-fired power are transported to Bangladesh and Myanmar via the NER.

In the EGC as a whole, gas-fired power generated from high-cost fuel is replaced by power generated from low-cost coal.

Figure 2.21 Electricity Demand and Supply in 2030 (Enhanced Grid Case)

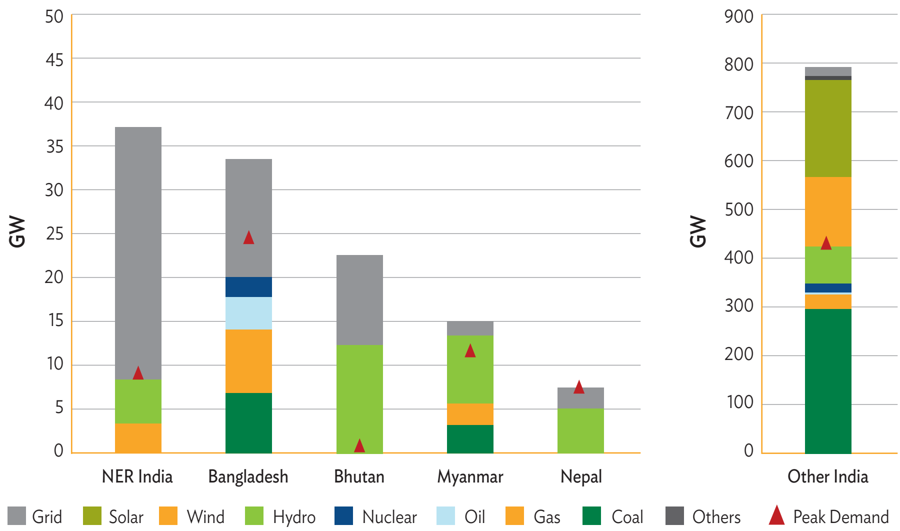


NER = North Eastern Region of India, TWh = terawatt-hour.

Note: 'Other India' refers to all Indian states and territories other than the eight states in the NER (Arunachal Pradesh, Assam, Manipur, Meghalaya, Mizoram, Nagaland, Sikkim, and Tripura).

Source: Authors.

Figure 2.22 Power Supply Capacity in 2030 (Reference Case)

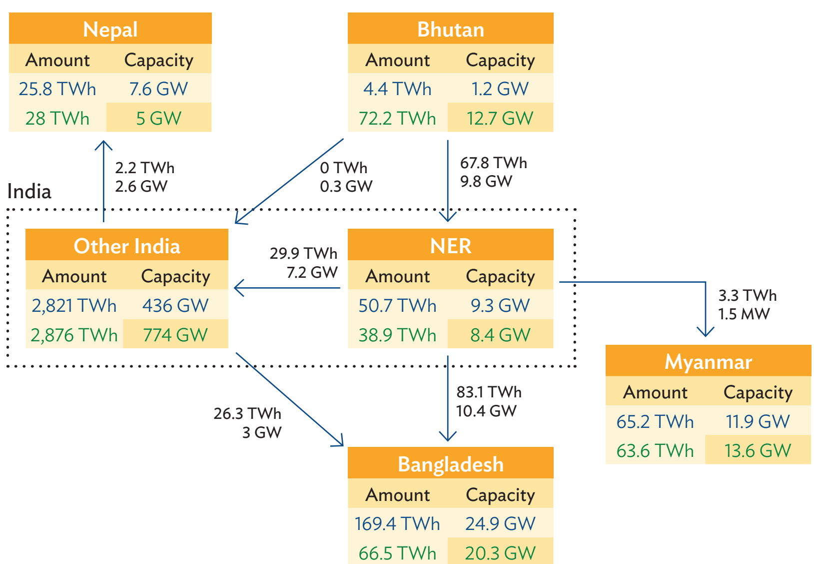


GW = gigawatt, NER = North Eastern Region of India, TWh = terawatt-hour.

Note: 'Other India' refers to all Indian states and territories other than the eight states in the NER (Arunachal Pradesh, Assam, Manipur, Meghalaya, Mizoram, Nagaland, Sikkim, and Tripura).

Source: Authors.

Figure 2.23 Electricity Balance and Trade in 2030 (Enhanced Grid Case)



GW = gigawatt, NER = North Eastern Region of India, TWh = terawatt-hour.

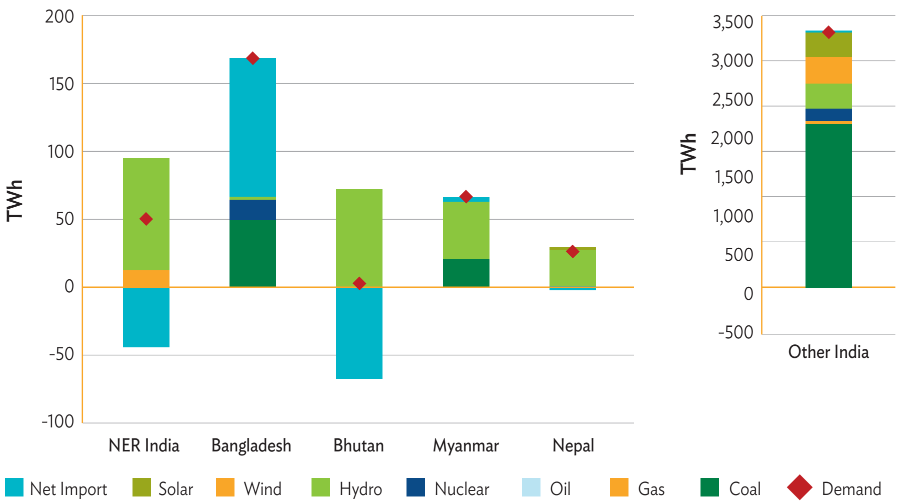
Note: 'Other India' refers to all Indian states and territories other than the eight states in the NER (Arunachal Pradesh, Assam, Manipur, Meghalaya, Mizoram, Nagaland, Sikkim, and Tripura).

Source: Authors.

3.3. Results of the Enhanced Hydropower and Grid Case

In the EHGC, the NER generates more electricity from hydropower, and exports it to neighbouring regions. In the EHGC, in Other India, the increase in coal-fired power generation narrows and exports slow. The capacity of the NER–Bangladesh connection line expands further to 12.4 GW. In the EHGC, the NER acts as generator and exporter as well as a transit corridor. Overall, in the EHGC, fossil fuel-fired power generated from gas and coal is replaced by low-cost, zero-emission hydropower.

Figure 2.24 Electricity Demand and Supply in 2030 (Enhanced Hydropower and Grid Case)

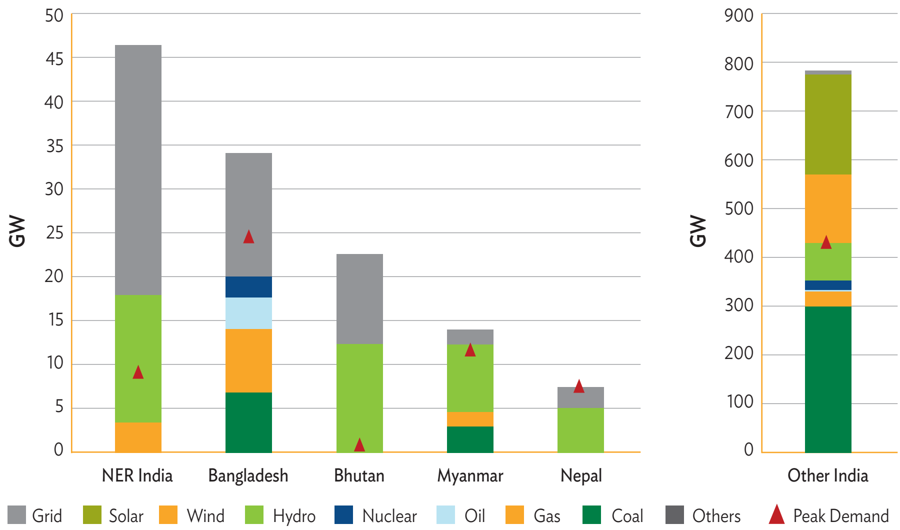


NER = North Eastern Region of India, TWh = terrawatt-hour.

Note: 'Other India' refers to all Indian states and territories other than the eight states in the NER (Arunachal Pradesh, Assam, Manipur, Meghalaya, Mizoram, Nagaland, Sikkim, and Tripura).

Source: Authors.

Figure 2.25 Power Supply Capacity in 2030 (Enhanced Hydropower and Grid Case)

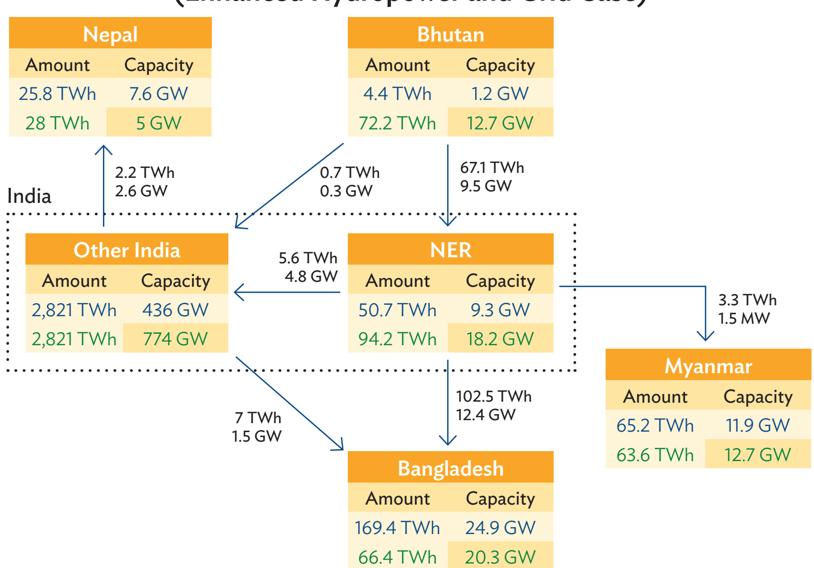


GW = gigawatt, NER = North Eastern Region of India.

Note: 'Other India' refers to all Indian states and territories other than the eight states in the NER (Arunachal Pradesh, Assam, Manipur, Meghalaya, Mizoram, Nagaland, Sikkim, and Tripura).

Source: Authors.

Figure 2.26 Electricity Balance and Trade in 2030 (Enhanced Hydropower and Grid Case)



GW = gigawatt, NER = North Eastern Region of India, TWh = terawatt-hour.

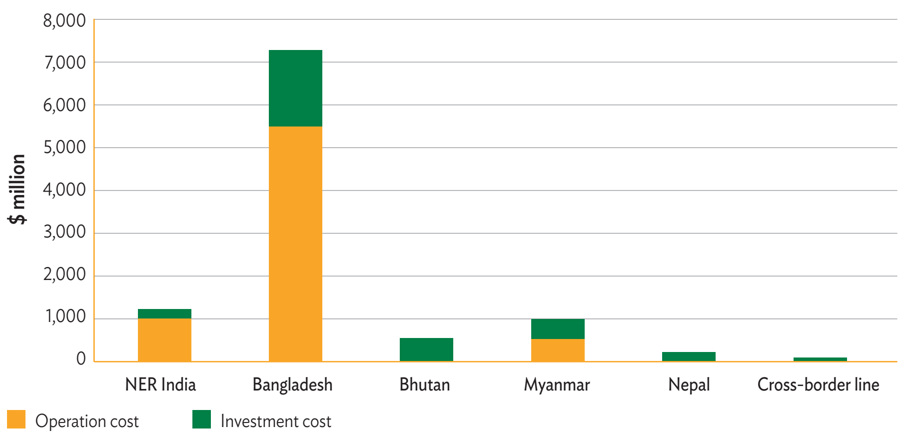
Note: 'Other India' refers to all Indian states and territories other than the eight states in the NER (Arunachal Pradesh, Assam, Manipur, Meghalaya, Mizoram, Nagaland, Sikkim, and Tripura).

Source: Authors.

4. Cumulative Electricity Supply Cost and Carbon Dioxide Emissions

In the reference case, to meet the rapidly increasing electricity demand, the NER and neighbouring regions need to more than double their power generation capacity from 2015 to 2030. The average annual costs of the electricity supply[1] in these regions during 2015–2030, including the investment costs of new power plants (except in Other India), cross-border lines, and their operation, reach $10 billion. Of this, investment accounts for 30%, and operations (mainly fuel costs) account for 70%. The annual investment cost of the cross-border grids is $74 million.

Figure 2.27 Average Annual Costs of the Electricity Supply in the Reference Case (2015–2030)



Source: Authors.

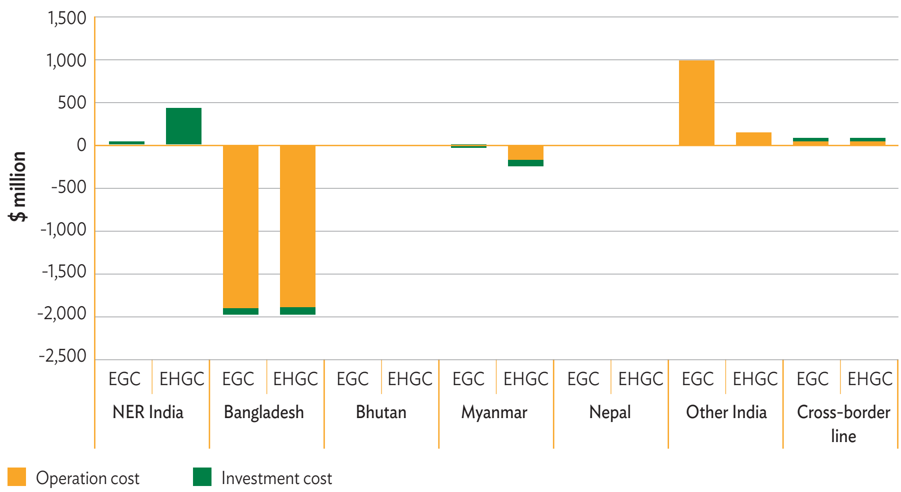
Compared to the reference case, electricity supply costs will be 10% lower in the EGC and 15% lower in the EHGC, due to increased use of lower cost hydropower instead of thermal power. In terms of the region, the cost of power generation is lower in Bangladesh and Myanmar, and higher in Other India in the EGC compared to the reference case. In the EHGC, the cost of power generation in Other India is lower than in the EGC, and hydropower investment grows in the

[1] The scale of the electricity system in Other India is much larger than in the other regions considered here, and it is fundamentally self-sufficient for electricity. Therefore, the total cost here only refers to the cost of Other India trading electricity with other regions.

NER. The annual cost of investing in cross-border lines increases to $146 million in the EGC, and $149 million in the EHGC compared to the reference case.

Importers must pay to import electricity instead of generating it domestically. On the other hand, exporters can use what they earn from their exports to cover the increased cost of generating additional electricity. Thus, it is necessary to determine how best to set the prices of traded electricity (including wheeling charges) between the concerned countries and regions. Stakeholders must also discuss the fair allocation of the benefits (cost reduction).

Figure 2.28 Changes in Average Annual Costs against the Reference Case



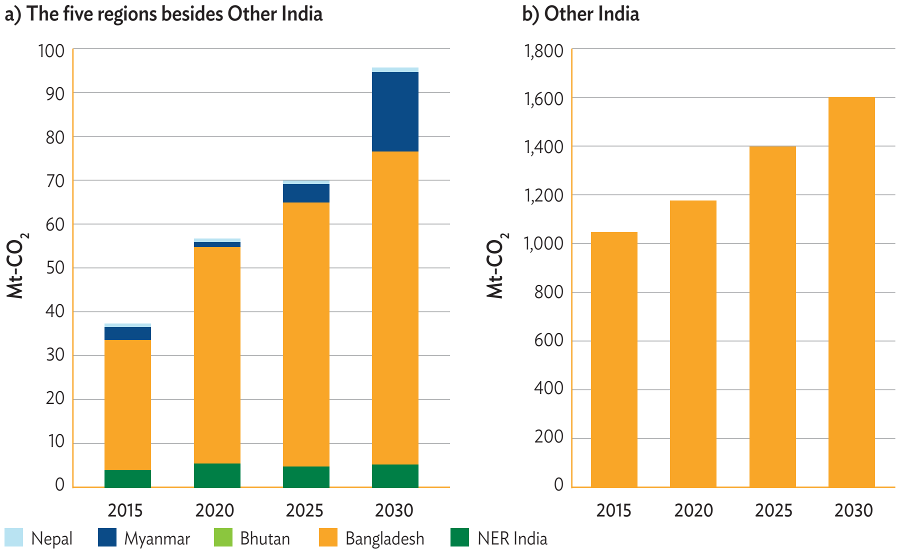
EGC = enhanced grid case, EHGC = enhanced hydropower and grid case, NER = North Eastern Region of India.

Note: 'Other India' refers to all Indian states and territories other than the eight states in the NER (Arunachal Pradesh, Assam, Manipur, Meghalaya, Mizoram, Nagaland, Sikkim, and Tripura).

Source: Authors.

In the reference case, carbon dioxide (CO_2) emissions related to power generation will increase significantly in Bangladesh and Myanmar due to the expansion of fossil fuel-fired power generation in these countries, especially coal-fired power. The sum of CO_2 emissions in the regions excluding Other India will reach 94 million tonnes of CO_2 equivalent in 2030, 2.6 times the 2015 level; and CO_2 emissions from power generation in Other India will almost double, reaching 159 million tonnes of CO_2 equivalent in 2030.

Figure 2.29 Annual Carbon Dioxide Emissions in the Reference Case



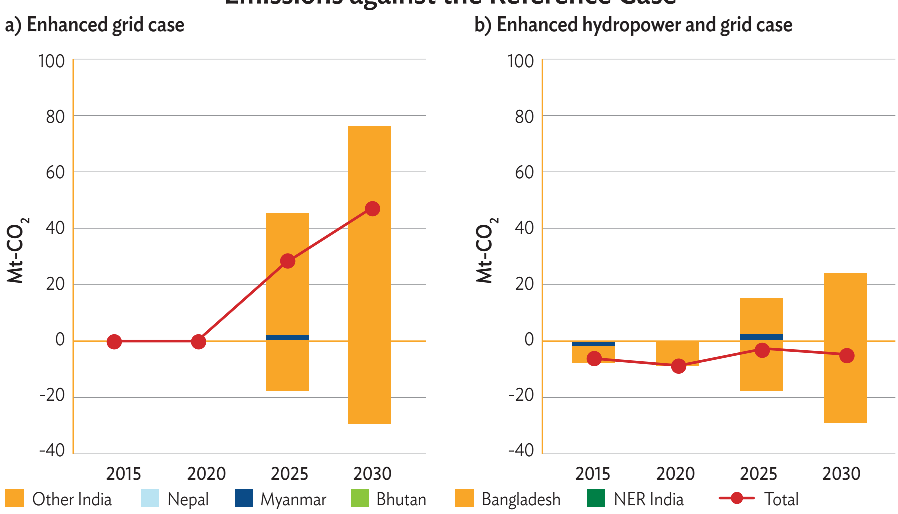
MT-CO_2 = metric tonnes of carbon dioxide equivalent, NER = North Eastern Region of India.

Note: 'Other India' refers to all Indian states and territories other than the eight states in the NER (Arunachal Pradesh, Assam, Manipur, Meghalaya, Mizoram, Nagaland, Sikkim, and Tripura).

Source: Authors.

Compared to the reference case, total CO_2 emissions will increase in the EGC due to the larger amount of coal-fired power generation. In the EHGC, owing to the larger amount of hydropower, total CO_2 emissions during 2015–2030 will be 9% lower than in the reference case.

Figure 2.30 Changes in Annual Carbon Dioxide Emissions against the Reference Case



MT-CO2 = metric tonnes of carbon dioxide equivalent, NER = North Eastern Region of India.

Source: Authors.

5. Conclusions

The NER and neighbouring regions have significant potential for economic development, and the electricity demand in these regions is forecasted to grow rapidly in the coming decades. To meet the increasing electricity demand, these regions need to expand their power generation capacity to triple the current level by 2030.

Bhutan, which has huge hydropower potential, will increase its presence as a net exporter of electricity. Bangladesh needs to increase its thermal power capacity significantly to meet demand when it cannot count on imported electricity.

Thanks to its geographical location, the NER can play an important role as a transit corridor between exporters and importers by enhancing cross-border lines. Furthermore, by utilising its large hydropower potential, the NER can also become an important generator and exporter of renewable power, benefiting both the economy and the environment of these regions.

Additionally, enhancing the cross-border lines in these regions will yield the following benefits, not only for the NER but also for other regions in an economically efficient way:

(i) India can fully utilise the planned capacity of its coal-fired power plants. However, the region needs to create a mechanism to share the cost of emissions amongst the countries;
(ii) Bangladesh can avoid constructing large thermal power plants by importing electricity, making its electricity supply less dependent on fossil fuels.
(iii) Nepal, Bhutan, and Myanmar can reduce the risk of a serious seasonal supply gap for hydropower, and also realise the enormous potentiality for hydropower to contribute significantly to the regions, which will become more prosperous economies.

Thus, it must be asked how best to set the prices (including wheeling charges) of electricity traded between the concerned countries and regions. Stakeholders must also discuss the fair allocation of the benefits (costs and emissions reduction).

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