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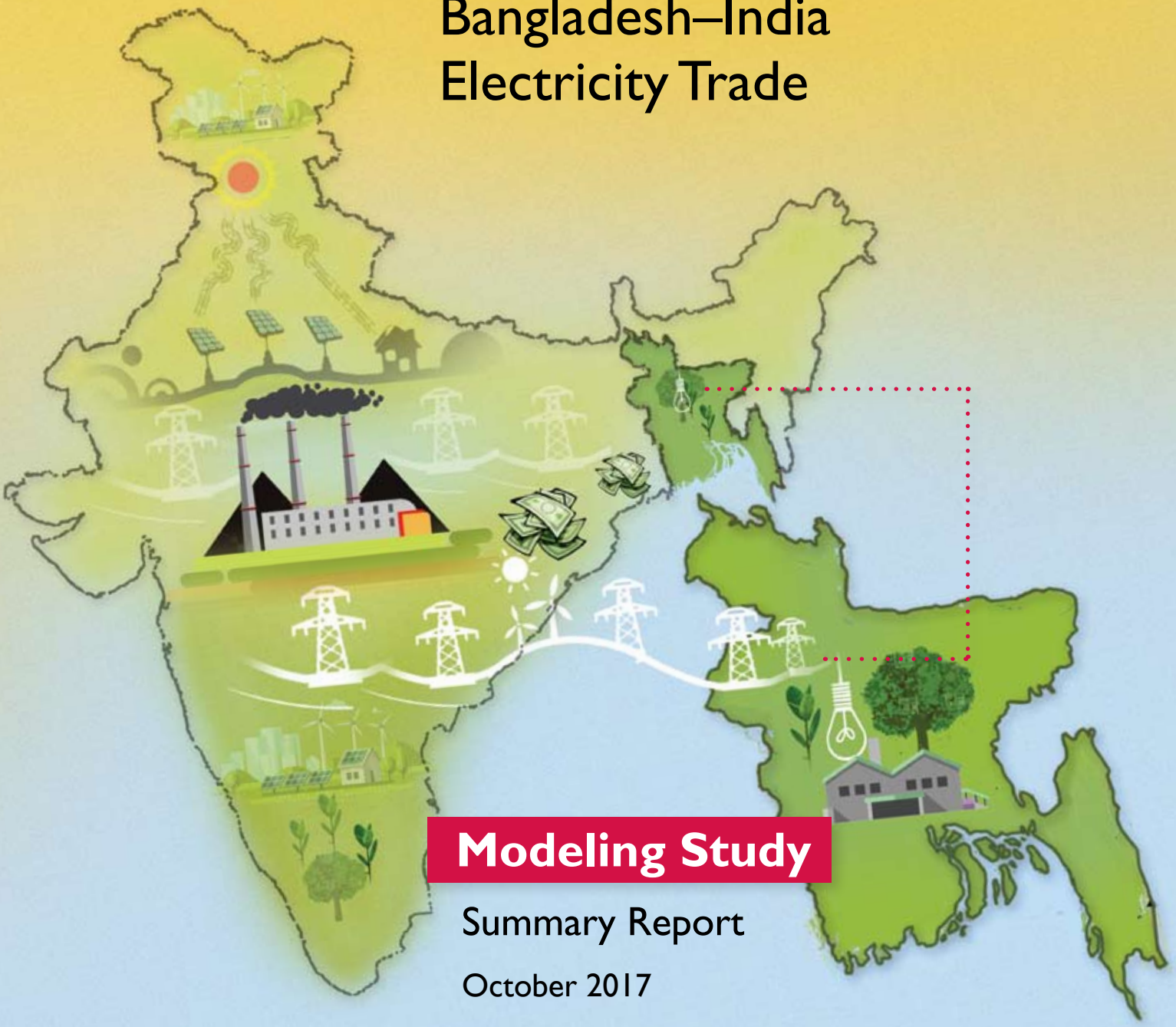
Economic Benefits of Bangladesh–India Electricity Trade



Modeling Study

Summary Report

October 2017

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Preface

We are pleased to present the report, 'Economic Benefits of Bangladesh–India Electricity Trade', carried out under the South Asia Regional Initiative for Energy Integration (SARI/EI) project supported by USAID. It was felt that the macroeconomic benefits of the power trade from a long-term perspective could help to bring wider consensus among power sector experts, economists, financiers, and policymakers.

Bangladesh wishes to be a developing country from its status of 'the least developed country'. Such economic progress requires energy as the country had a per capita consumption of 310 kWh in 2014, compared to India's 806 kWh and the world average of 3,128 kWh. Unfortunately, Bangladesh does not have energy resources beyond 2030 for its vast population of 163 million (2016). Thus, it needs to work out import arrangements from neighboring countries.

We held many discussions with stakeholders, focused groups, and electricity planners from India and Bangladesh. This was a painstaking and novel exercise where the power system models of the two countries were linked at an hourly level (reflecting the average demand and generation for that hour for the month) and for every month of the year to capture the impact of peak and off-peak hours of the different seasons to explore compatible trade. This exercise helped to assess the scope for trade and the resultant gain to both the countries; it gives very different insights than doing it just once, based on the annual overall demand and supply. We also linked this to the macro models of each country to capture the macroeconomic benefits, especially to Bangladesh. The results find substantial gains to the economy of Bangladesh.

We had earlier conducted a similar exercise for the India and Nepal electricity trade. The results showed substantial gains for Nepal's economy and its people.

I am grateful to USAID for supporting this path-breaking modeling exercise and extend my gratitude to our Bangladeshi, Indian, and USAID colleagues who supported our work. I take this opportunity to thank the IRADe team that worked diligently, enthusiastically, and relentlessly for many months.

Dr. Jyoti Parikh
Executive Director, IRADe

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Foreword

Over a decade, the U.S. Agency for International Development (USAID) has been working towards regional energy cooperation in South Asia under USAID's South Asia Regional Initiative for Energy (SARI/E) program. Launched in 2000, the program covers eight countries of Afghanistan, Bangladesh, Bhutan, India, Nepal, Pakistan, Sri Lanka and the Maldives. The fourth phase of the program, called South Asia Regional Initiative for Energy Integration (SARI/EI) was launched in 2012 to promote regional energy integration by increasing cross border power trade.

The program aims to create an enabling environment to support establishment of a South Asian electricity market, create consensus on issues related to cross border power trade and support key decision makers with relevant information and analysis. Towards this, Integrated Research and Action for Development (IRADe), the implementing agency of USAID's SARI/EI program undertook the study "Assessing Macro-economic benefits of Bangladesh-India electricity trade". This study attempts to provide concrete evidence of benefits of power trade to policy and decision makers in both the countries for building consensus to support creation and implementation of regional power trade.

The study used a state-of-the art analytical tool to quantify the power trade potential and macro-economic benefits for both the countries for three different trade scenarios – reference scenario (imports limited by the inter-connection built by 2018 called REF), Power Sector Master Plan 2016 scenario (Bangladesh achieving 15% electricity import in its electricity supply by 2040) and TRADE-30 scenario (enhanced electricity import scenario of 30% in the total supply). Extensive consultations were conducted with key stakeholders in both the countries to review the methodology, scenarios and assumptions.

The study throws some interesting figures underlining the fact that power trade is a win-win for both the countries. While Bangladesh benefits from the cheap electricity imports from India to sustain its desired economic growth, India also gains from the export earnings. For Bangladesh, the aggregate expenditure for household consumption

increased by USD 523 billon in the TRADE-30 scenario from 2011 to 2045 compared to the reference scenario. India's cumulated GDP gain is USD 636 billion at 2011-12 market exchange rate between TRADE-30 and reference scenario.

I would like to take this opportunity to acknowledge the excellent work done by IRADe in carrying out such an in-depth analysis. I am confident that the recommendations of this report will be very useful for building trust and creating consensus around power trade in both the countries.

Thank you

Michael Satin
Regional Energy Director,
Clean Energy & Environment Office
USAID/India

Ravindra Kumar Verma
Chairperson

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NEW DELHI-110066, Dated : 3 January 2018

Foreword

As the power sector is capital intensive and over the years the complexity in power sector has increased manifold, many regions of the world are taking initiatives for power pooling in order to create robust regional power grids, increase reliability of supply, lower investment requirements, optimize the use of resources, and reduce overall electricity supply cost. However, such strong power pool is missing in South Asia region, except some bilateral trade of electricity.

For energy resource constrained Bangladesh, expansion of future power system is a serious challenge. However, the South Asian region has significant unevenly distributed energy resources (fossil fuel, hydro and renewables) across the countries. A combined hydro potential of about 350 GW in the region offers a huge scope for tapping/harnessing clean energy and addressing the problems of shortage of electricity. South Asian Electricity trade would not only increase exploitation of the available energy resources and improve energy security but also would help in providing electricity at affordable cost, increasing revenue earnings and promoting environment friendly socio-economic development by sharing energy resources, energy infrastructure and capacity reserves.

IRADE has carried out the study on "Macro-economic benefits of Bangladesh-India electricity trade" that quantifies the trade potential and macro-economic benefits likely to be accrued to two neighbouring countries due to electricity trade. Central Electricity Authority (CEA) has been actively engaged in exploitation of available power generation potential and planning of Cross border transmission system for South Asia Energy co-operation, not only for Bangladesh but also for the other South Asian countries such as Nepal, Bhutan, Sri Lanka and Pakistan.

Therefore, deliberation on this study was held in CEA. The report clearly indicates that export of electricity from India is an economic/cheaper option for Bangladesh and is a win-win option for both the countries. India, being surplus in generation, the export revenue earnings in the trading of electricity with Bangladesh may contribute to higher investment in the power sector and would add to the economy of the country.

I congratulate IRADe Team for carrying out such an intensive analytical work applying state-of-the-art modelling tools under SARI/EI/IRADe Project. I hope the findings of this report would be considered by Power Utilities & Electricity Regulators of both countries for promotion of regional electricity trade leading to socio-economic benefits.

(Ravindra Kumar Verma)

Message

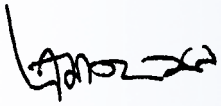
The power sector turns into a global concern rather than a domestic issue. More and more countries of the world are taking power pooling pursuits to make more robust regional power grids to increase the reliability of supply and lower investment demands to minimize the present supply cost. On the other hand, this sort of electricity trade initiative is insignificant in South Asia, although some bilateral trade of around 2,300 MW is happening at present.

Bangladesh is a country with limited options for primary fuel. Therefore, the growth associated with a long-term energy program is really a problem, while the region it belongs to offers substantial fuel sources such as fossil fuel, hydro and renewables, though unevenly dispersed over the countries. The combined hydro potential of 350 GW in the region offers a huge scope for tapping clean energy as well as dealing with the actual persistent difficulties associated with power supply. The electrical power industry might take advantage of the actual assets, supply electricity at reduced rate to all, enhance energy security and promote environment-friendly socio-economic development by sharing energy resources, energy infrastructure, and capacity reserves. Recognizing the complexities of promoting such regional energy trade which has technical, regulatory, political and social challenges, the USAID has launched SARI/EI in 2012, which is the final phase of the SARI/E program launched in 2000. SARI/EI, with its objective of advancing regional energy integration by increasing CBET, is implemented by IRADe, a reputed think-tank/research institute located in Delhi, through a cooperative agreement with USAID.

Among a number of other activities under SARI/EI that encourages CBET in the region, IRADe has carried out this particular analytical study on the macro-economic advantages of Bangladesh-India electrical power trade, which quantifies the actual trade potential as well as the benefits accrued between Bangladesh and India as a result of electricity trade. The research utilizes advanced as well as state-of-the-art modeling resources, depending on the optimization framework, in order to discover numerous queries upon CBET that may be appropriate with regard to policy/decision-makers/planners and acquire their quantifiable solutions. Stakeholders from both countries have been consulted and their feedback is included in the analyses. It found electricity import from India as an economic option for Bangladesh, which has two choices concerning its future electricity supply: build domestic power plants based on imported fuels (fossil fuel, gas or even nuclear energy) or/and import final product electricity from an adjoining country such as India. Electricity import brings several benefits such as reduced power supply cost, import bill, and investment for the power sector. The foreign exchange and investment saved could be diverted into other sectors where it would bring higher socio-economic

improvements. By reducing dependence on imported gas, which has a more volatile market, electricity import would also help to address the energy security issue, which is a key concern for Bangladesh. CBET helps India to better use of its power plants, therefore, enhancing profitability. Export revenue earning makes Indian households gain through increased consumption, which is higher when trade is higher. Export demand and earning contribute to higher investment in the power sector as well as to the entire economy and the GDP increases.

I would like to congratulate the IRADe team for carrying out such an extensive analytical work, applying cutting edge modeling tools, under the SARI/EI/IRADe project. I hope the findings of this report will be considered by the energy utilities/electricity regulatory institutions of both countries for the promotion of electricity trading to produce the highest socio-economic returns from it.



Mohammad Hossain
Executive Director General, Power Cell
Power Division, Ministry of Power, Energy & Mineral Resources
Government of the People's Republic of Bangladesh

The Process

This study was undertaken through a consultative process that involved stakeholder consultations and workshops in Bangladesh and India. The various stakeholder consultations undertaken for this study:

October 18-20, 2016

A mission to Bangladesh to collect data, present the study to stakeholders, and discuss scenarios

- Meeting with representatives of government ministries and the channelization of contacts for data gathering for the macro model and technology model of Bangladesh.
- Presenting the study to the stakeholders and discussions on the various scenarios.

February 2, 2017

Stakeholder meeting, Hotel Sonar Gaon, Dhaka

- Meeting to present and discuss the study, its approach and scenarios, and draft outcomes to the stakeholders; validation of parameters and results by the stakeholders in Bangladesh and their suggestions to improve on the model results.

May 17, 2017

Second stakeholder meeting, Hotel Sonar Gaon, Dhaka

- Meeting to present and discuss the final results on the India-Bangladesh electricity trade and its economic impacts to important stakeholders in Bangladesh and receive their feedback.

August 31, 2017

Expert group consultation meeting, CEA, New Delhi

- Presentations on the results of the India–Bangladesh hourly electricity trade model after integration with the India technology model, and the results of the Bangladesh macro model; showing the economic impact of electricity trade on the economy of both countries to Indian stakeholders; and discussions.

Summary Report

The Issues

The socio-economic development of Bangladesh is constrained by energy supply. Its per capita electricity consumption at 310 kWh (2014) is one of the lowest in the South Asian region. Owing to frequent power outages, many industrial and commercial businesses depend on inefficient and expensive alternatives of generating electricity, such as burning imported diesel or oil. The small quantity of electricity import (600 MW) from India that began in 2013 has given some temporary relief to deal with the acute power shortage that causes economic losses and difficulties in daily life.

The expansion of the future power system is a serious challenge to energy resource constrained Bangladesh, while the South Asia region it belongs to has significant energy resources such as coal, hydro, and renewable. These are, however, unevenly distributed across the countries. A combined hydro potential of 350 GW in the region offers a huge scope for tapping clean energy and addressing the chronic problems of electricity supply shortage. Electricity trade could exploit the resources, provide electricity at lower costs to all, export revenue to some, improve energy security, and promote environment-friendly socio-economic development by sharing energy resources, energy infrastructure, and capacity reserves. SARI/EI aims to facilitate the advanced regional integration by increasing CBET. IRADe, the implementing partner of the program, has undertaken an analytical study focusing on the macroeconomic benefits of electricity trade in South Asian countries. A study on India-Nepal electricity trade has been completed and the focus of this report is on India-Bangladesh electricity trade.

With declining gas reserves, the socio-economic difficulties in expanding the domestic mining of coal, an almost negligible resource of crude, and limited renewable potential, Bangladesh faces serious challenges to secure its future energy supplies, needed for its aspiration to be a developed country. The choice is to expand its electricity supply by building domestic power plants that are based on imported fuels (coal, natural gas or nuclear fuel) and/or import electricity from neighboring countries such as India. Building domestic power plants involves massive investment in power plant construction and fuel supply infrastructure, depriving investment in other sectors and a regular foreign exchange outflow to pay for fuel import. The second option requires building interconnections that may need less time and capital, but then involves regular foreign exchange outflow for payment of electricity import.

Both options have different kinds of economic consequences. In addition, almost complete dependence on imports, implicitly or explicitly, for the supply of such a key product raises concern for energy supply security. Diversification of the power system by fuel type and supply sources improves supply security. Bangladesh needs to strategize its power supply, which would reduce the energy security threat, and, at the same time, keep power supply cost low and balance the investment and foreign exchange availability between the power sector and the rest of the economy. This raises the question that how much electricity trade is possible and desirable to ensure energy security, low power supply cost, and acceptable economic consequences.

With energy security a key concern and diversification of sources a remedy, the Power Sector Master Plan (PSMP) 2016 of Bangladesh, sponsored by the Japan International Cooperation Agency (JICA),[1] developed five scenarios of energy mix with the share of coal and gas in the energy mix varying from 15 percent to 70 percent by 2041. The share of nuclear, Power Import (PI) and Renewable Energy (RE),

[1]Japan International Cooperation Agency. People's Republic of Bangladesh Survey on Power System Master Plan Draft Final Report 2016.

and oil/hydro/others is always kept fixed at 10 percent, 15 percent, and 5 percent, respectively, in the energy mix in all these scenarios. The scenario with a share of both gas and coal in power generation in 2041 each at 35 percent is considered to be the optimum power generation mix and can be used for the basic future power development plan. However, none of these studies carried a socio-economic impact assessment of CBET for the nation as a whole.

Questions Addressed

The present study explores the following questions that would help the policymakers/planners/decision-makers of Bangladesh and India:

- What would be the power supply strategies (capacity, generation, technology, import/export, investment, fuel, power supply cost, and so on) in Bangladesh as well as in India with different levels of power trade?
- What are the macroeconomic implications to Bangladesh and India in terms of the growth of the GDP and investment (in the power sector and the rest of the economy) fuelled by the impact from electricity trade?

The answers to the following questions, which would be of interest to the stakeholders, are also explored here:

- What would be the optimal level of trading and price agreeable to both the buyer and the seller?
- What would be the impact on the living standard measured through per capita consumption levels?
- How would the per capita electricity use change?
- What are the consequential environmental costs and benefits?

To answer these complex techno-economic questions, the study deployed a modeling system with two types of models and a 30-year perspective (2015-2045) for each country. These were a power system model that balances demand and supply on *an hourly basis for 30 years simultaneously* and a macroeconomic model that also solves for 30 years with endogenous demand, investment, and the GDP. It computes the impact on various sectors of the economy and its future development. Iterative linkage between these models produces solutions consistent across various sectors and aspects of the economy. Thus, the demand for power is consistent with the growth and structure of the economy; adequate investment and foreign exchange are available to develop capacities and import goods, including fuels and electricity. In addition, a power system model that links both the countries together is developed to determine the level and time of trade. The modeling system is used to analyze three scenarios.

- The REF scenario assumes interconnections across countries to stay at the level of 2018 (1,100 MW). Each country independently makes its own capacity investments to satisfy its projected demand profile.
- The PSMP scenario, based on the Power Sector Master Plan 2016,[2] prepared by JICA and the Bangladesh Government, recommends that the Bangladesh Power Development Board (BPDB), under the guidance of the Ministry of Energy, adopts an energy security framework for the expansion of the power sector, based on the diversification of sources of power supply. Accordingly, the shares of supply based on coal, natural gas, nuclear, electricity import, hydro and renewables are fixed at 35 percent, 35 percent, 12 percent, 16 percent, and 1 percent, respectively, of the total electricity supply in the country by 2041. To accommodate the 2015-2021 renewables target of the Sustainable and Renewable Energy Development Authority (SREDA), the share of liquid has been reduced to less than 1 percent.

[2]http://powerdivision.portal.gov.bd/sites/default/files/files/powerdivision.portal.gov.bd/page/4f81bf4d_1180_4c53_b27c_8fa0eb11e2c1/%28E%29_FR_PSMP2016_Summary_revised.pdf

- The TRADE-30 scenario is developed to allow electricity import of up to 30 percent of the total electricity supply by 2040. While the import of electricity in this scenario is capped, sources of domestic generation are free so that the import option will substitute the sources for power generation on a least cost basis.

Key Findings

The key findings of the study are highlighted here separately for Bangladesh and India.

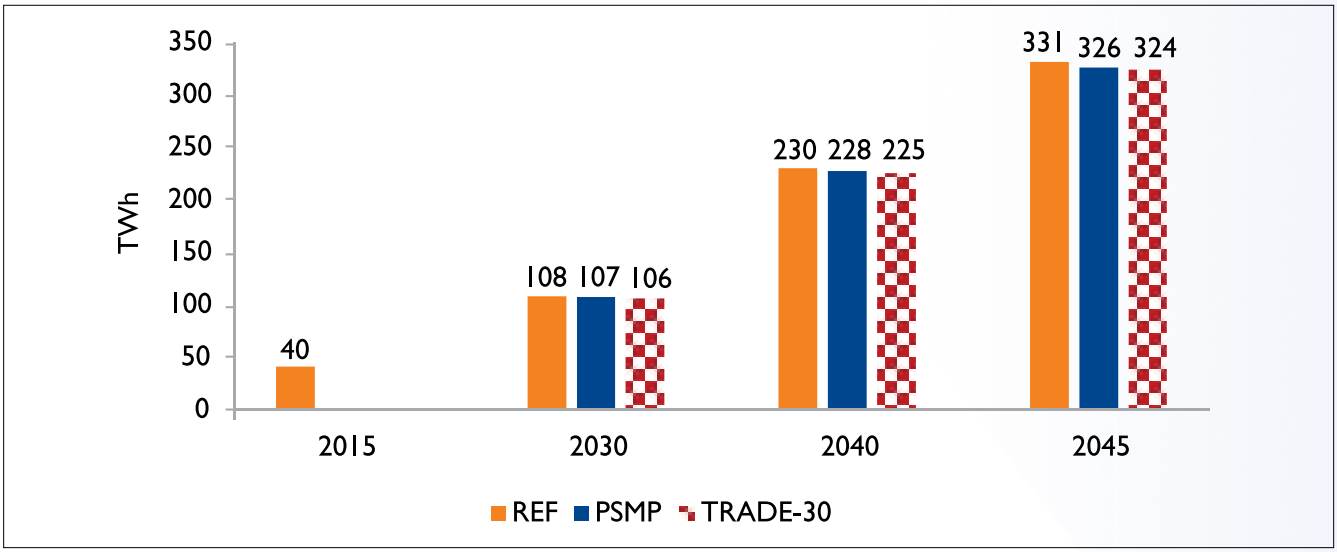
Bangladesh

The study shows that electricity import from neighboring India is more economical than any of the other options available (except coal) and brings substantial socio-macroeconomic and environmental gains.

Electricity Demand in the Economy

The macroeconomic model estimates the total electricity demand in the economy over the study horizon (Figure 1) in three scenarios. This changes only marginally mainly due to the reduced auxiliary consumption on account of the imported electricity.

Figure 1 **Total Electricity Demand in the Economy of Bangladesh**



In the REF scenario, until 2030, the annual growth rate of electricity demand is 7 percent, supporting a GDP growth rate of 6.4 percent. The electricity demand in 2030 is 108 TWh. The demand growth in the next decade is even higher at 7.8 percent per annum, as the annual GDP growth rate is 8.2 percent. The electricity demand reaches 230 TWh and 331 TWh in 2040 and 2045, respectively.

As import reduces domestic electricity generation, this leads to lower output and income with less investment in the power sector. This has a multiplier effect in the overall economy, leading to lower GDP and hence production activities. That brings down the electricity demand in two trade scenarios, although only by 1-2 percent in 2045 when compared with the REF scenario.

The per capita electricity demand, an important indicator for socio-economic development, will double by 2030, reaching 588 kWh, from the level of 246 kWh in 2010. In 2045, it will increase by a factor of 7 to 1,665 kWh. In trade scenarios, as the aggregate demand declines, so does the per capita demand, though only by a negligible amount.

Power Generation Capacity

Figure 2 presents the build-up of power generation capacity needed in Bangladesh in three scenarios. The REF scenario needs the building of many more plants in the country as electricity import is restricted to the level of 2018. It needs 26 GW of capacity by 2030, which reaches 64 GW by 2045, in addition to 1.1 GW of interconnection capacity for import.

Higher import in the PSMP scenario reduces domestic power generation capacity needs. The domestic capacity need in 2030 is 22 GW as against 26 GW in the same year in the REF scenario. In 2045, 53 GW would be sufficient, 11 GW less than the REF scenario. However, there would be a respective interconnection capacity of 3 GW, 5 GW, 7 GW, and 9 GW in 2025, 2030, 2035, and 2040. Beyond 2040, 9 GW will continue (Table 1).

Capacity projection in the PSMP scenario is lower, compared to what is projected in the Power Sector Master Plan 2016 because of the different approach and assumptions. PSMP 2016 assumes constant electricity-GDP elasticity of 1.27 throughout the study period of 2015-2041. This study, uses a constant electricity elasticity of household consumption expenditure of 1.23. The electricity elasticity of GDP would depend on the level and composition of household consumption, which in turn would influence the structure of production in the economy. The electricity elasticity of household consumption expenditure from the GTAP SAM is 0.96. However, for the model we assume a higher elasticity of 1.23 given that after 2011–12 (base year of the SAM) Bangladesh's economy has seen an increase in the rate of growth of domestic electricity demand. Also, while PSMP 2016 assumes that Transmission and Distribution (T&D) losses would be reduced up to 11.5 percent in the future, the study assumes further reduction to 8 percent and 7 percent, respectively, in 2030 and 2040, which also lowers the capacity requirement.

As import is the cheaper option, in the TRADE-30 scenario with its higher import possibility, the domestic capacity build-up declines further than in the PSMP scenario. In 2030, the total capacity is 2 GW less than in the REF scenario, but is half a GW higher than in the PSMP scenario due to a different mix of power plants with different plant factors. The impact increases over time and, by 2045, Bangladesh needs 37 GW domestic capacity, which is 30 percent lower compared to the PSMP scenario and 42 percent lower than the REF scenario. Substantial savings in domestic capacity development is possible, leading to a significant reduction in investment in the power infrastructure, which could be used for investment in other sectors or for consumption. Interconnection capacity is projected as 6 GW, 11 GW, 18 GW, and 25 GW, respectively, in 2025, 2035, 2040, and 2045 (Table 1).

Figure 2 **Power Generation Capacity Requirement**

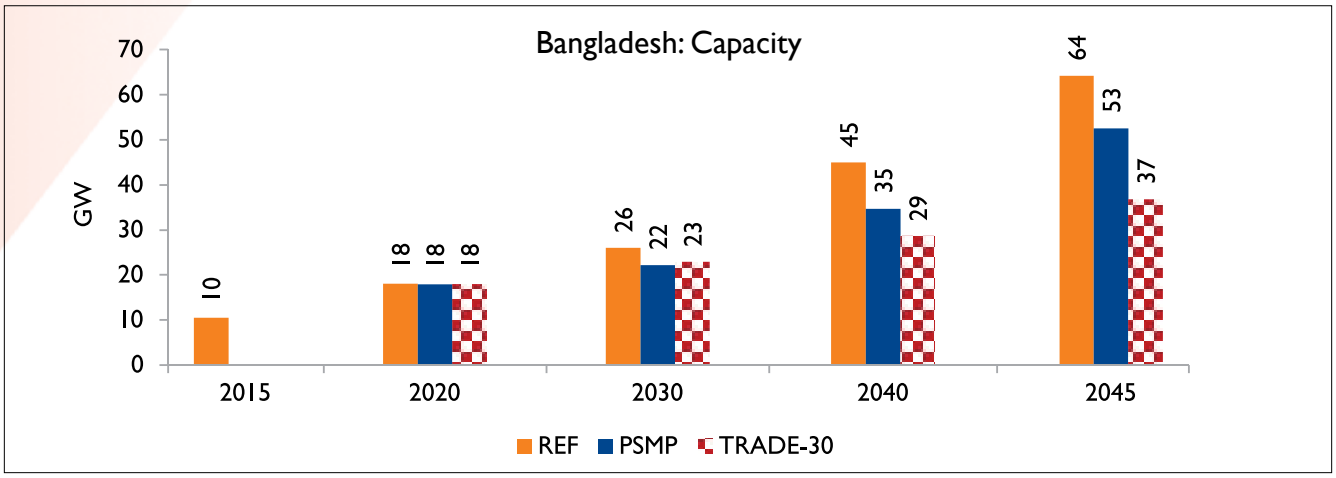
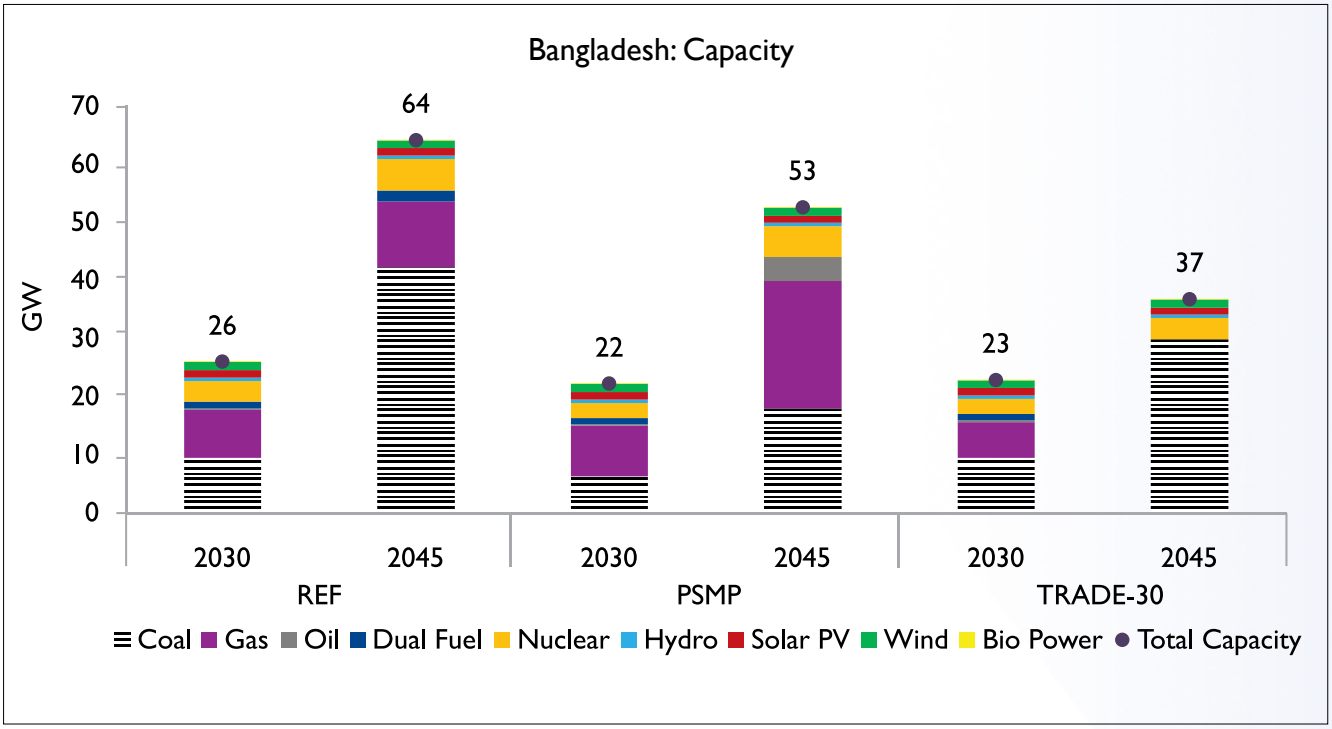


Table 1 **Potential Interconnection Capacity (GW) by Scenario**

Scenario	2025	2030	2035	2040	2045
REF	1.1	1.1	1.1	1.1	1.1
PSMP	3	5	7	9	9
TRADE-30	6	7	11	18	25

Power Capacity Technology Mix

Figure 3 **Capacities of Generating Technology**



Coal, being the cheapest option, dominates future capacity development in Bangladesh in the REF scenario. The country is also introducing nuclear power to counter energy security threat. Two nuclear reactor units at Ruppur, totalling 2.4 GW, are to be installed before 2025. By 2030, the power system will become more diversified as a coal-based capacity of about 9 GW and a nuclear capacity of 3.6 GW is reached. The nuclear capacity is expected to be 5.5 GW by 2045, as reflected in the least cost solution, which also gives about 42 GW of coal capacity. As domestic gas is likely to be depleted by 2027, all gas-based power plants thereafter need to be operated with imported gas, which is the most expensive option. The gas-based capacity, therefore, declines from 10.6 GW in 2020 to 8.2 GW in 2030; however, fluctuations between 8.4-11.3 GW as operational flexibility of the gas-based power plants work in their favor.

Hydro, solar, and wind capacities in all scenarios remain at around 1 GW each, at their estimated total potential.

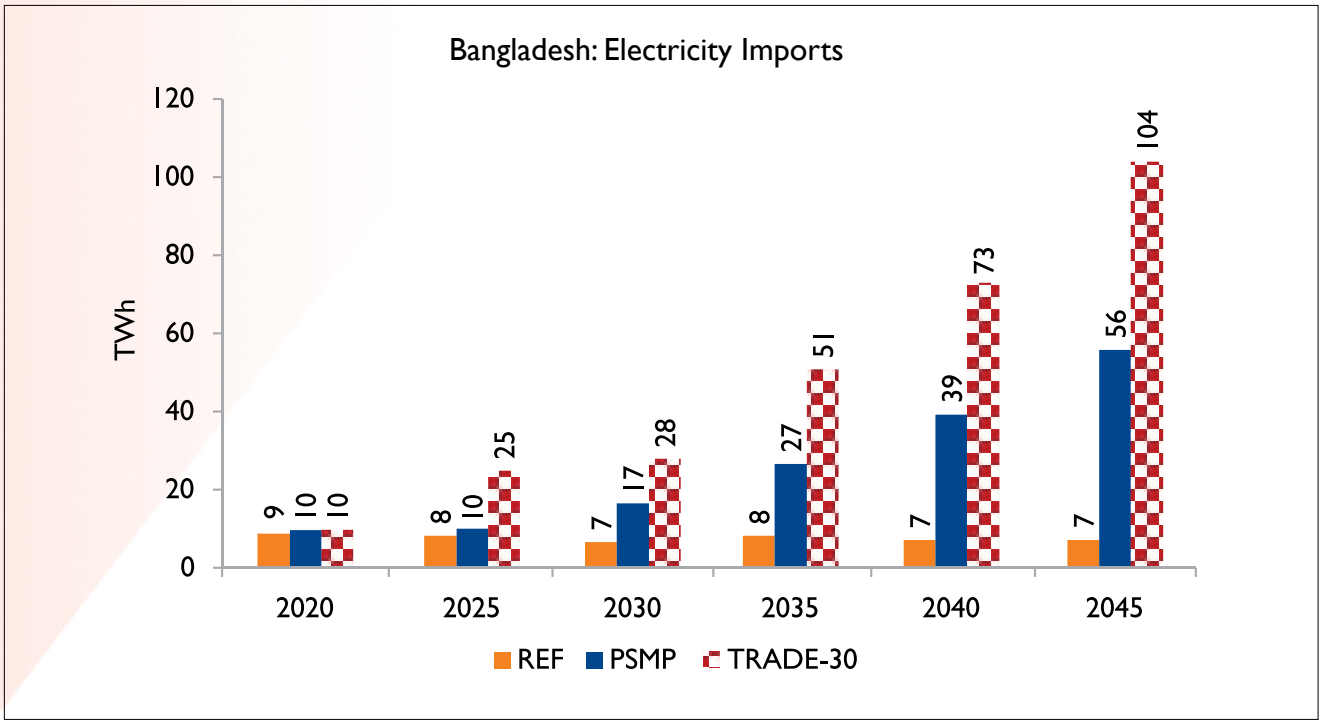
The technology mix in the PSMP scenario is driven by the scenario definition, characterized with an equal share (35 percent) of coal and gas in power supply from 2040 onwards. The capacity, based on coal and gas, is 6.3 GW and 8.7 GW, respectively, in 2030; it will go up to 18 GW and 22 GW, respectively, in 2045. Nuclear capacity development is little slower until 2030, compared to the REF scenario, but reaches the same level as the REF scenario in 2045.

In the TRADE-30 scenario, where no capacities are forced and only upper bounds on total potential are prescribed, coal, being the cheapest option, dominates the generation capacity, reaching 30 GW in 2045. Nuclear capacity declines to some extent. Electricity import from India replaces gas-based capacity, as can be expected, since it is the most expensive power generation option because of higher gas price, despite the investment cost being lower.

Electricity Import

Electricity import from India was 3.8 TWh in 2015, which will increase slightly in the future in the REF scenario, as a new capacity for imports of 500 MW will be available from 2018. Thereafter, it will remain at the same level, in the range of 7-9 TWh, only contributing 2-3 percent of the total supply. In the PSMP scenario, import in 2030 and 2040 is 17 TWh and 39 TWh, respectively, which is much higher than in the REF scenario. In the TRADE-30 scenario, import is expected to be 28 TWh in 2030, going up further to 104 TWh in 2045 (Figure 4).

Figure 4 **Electricity Import**



Variation of Import Across Time

Electricity import varies from hour to hour and month to month. The maximum import takes place during May-July, when the demand is high as the annual peak demand occurs in June-July. Import contributes to meet the daily peak that occurs in the evening. Figure 5 shows imports and the demand over the hours in 2045 in both, the PSMP and TRADE-30 scenarios. Such data are generated for all the years.

Since the constraint on the share of imports in the total supply is imposed for the whole year, imports are optimized over the hours of the year. In the TRADE-30 scenario, which has greater flexibility, imports vary substantially across the hours of the day. The variation in the PSMP scenario is much smaller as it has substantial gas capacity to meet some of the peak demand.

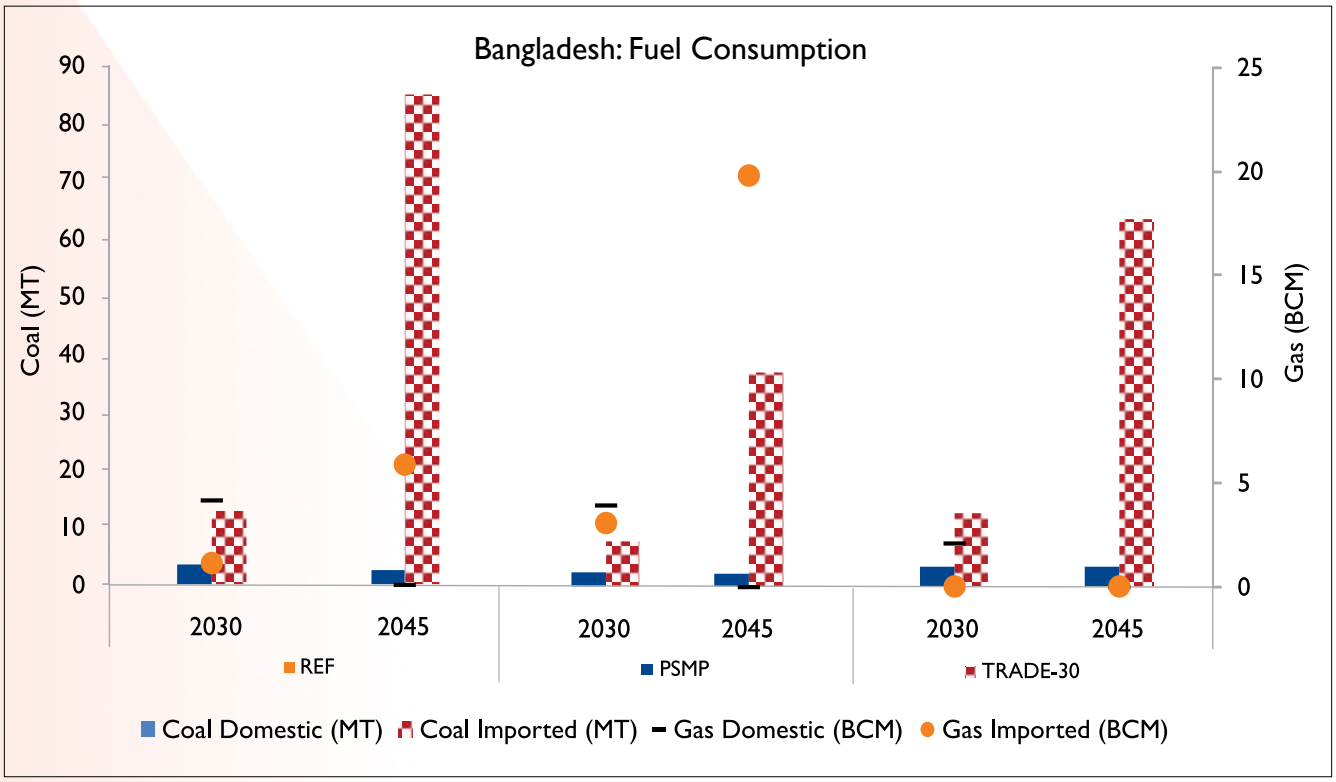
Figure 5 **Imports and Demand (Supply) over the Hours of the Year 2045 in the TRADE-30 (top) and PSMP (below) Scenarios**

Import Dependence of the Power Sector

The scenarios require different levels of fuel imports. To assess the import dependence of the Bangladesh power sector, the cost of imports of electricity and fuels has to be compared. Figure 6 shows the imports of fuels in the scenarios.

Fuel requirement in the REF scenario is high, which mostly needs to be imported. In 2030, Bangladesh needs to import 13 million tonnes (MT) of coal and 1 billion cubic meter (BCM) of gas. By 2045, coal and gas imports go up to 85 MT and 6 BCM.

Figure 6 **Fuel Imports in the REF, PSMP, and TRADE-30 Scenarios**



The PSMP scenario depends on modest electricity import. This is also a fuel diversification scenario, with equal share of coal and gas in power supply. The import demand for coal is 8 MT and 37 MT in 2030 and 2045, respectively. The gas demand is 7 BCM in 2030; however, as domestic gas is available, only 3 BCM of gas needs to be imported. By 2045, the gas demand goes up to 20 BCM, and the entire amount needs to be imported. The fuel import bill would be larger than in the REF scenario as gas is more expensive than coal. In addition, the electricity import bill may be significant in comparison to the REF scenario.

In the TRADE-30 scenario, as electricity import replaces gas-based generation as well as some coal-based generation, the coal demand is reduced. The gas demand is much lower than in the other two scenarios in 2030 and, in 2045, there is no demand for gas. Therefore, the import of fuels (coal and gas) declines, but electricity imports increase. Table 2 shows power sector costs.

As stated earlier, Bangladesh's energy future lies on import, which is reflected in the increase in its energy imports under the three scenarios over time. The share of energy in the total import bill in the REF scenario increases from 34 percent in 2020 to 41 percent in 2030 and further to 45 percent in 2045. The PSMP scenario increases the total import bill significantly, by 8 percent and 16 percent in 2030 and 2045, respectively, over the REF scenario. The higher electricity import in the TRADE-30 scenario, however, brings down the total import bill over the PSMP scenario. The PSMP scenario, therefore, increases the energy import dependence in monetary terms.

The cost of the import of fuels and electricity is lowest at 18.0 Trillion BDT (TBDT) in the TRADE-30 scenario and the highest in the PSMP scenario at 24.2 TBDT over 2012 to 2045. Thus, the energy security provided by the PSMP scenario through diversification involves a larger dependence on imports.

Table 2 **Bangladesh Cumulative Power Sector Cost (Trillion BDT)**

Cumulated Period	Scenario	CAPEX	Fixed O&M	Fuel Cost		Imported Electricity Cost	Total Cost
				Domestic	Imported		
2012-30	REF	1.9	0.9	2.9	5.2	0.9	9.1
	PSMP	1.6	0.8	3.0	2.6	1.0	9.0
	TRADE-30	1.7	0.9	2.2	2.0	1.3	8.0
2012-45	REF	6.8	2.9	4.4	16.4	1.9	32.5
	PSMP	5.0	2.3	4.3	18.5	5.7	35.7
	TRADE-30	4.9	2.2	3.5	10.0	7.0	27.6

Power Sector Costs

Table 2 gives the cost of capital expenditure for setting up power plants in the country as well as domestic fuel and fixed O&M costs. The total cumulated costs are the highest for the PSMP scenario, at US$ 436 billion (2011-12) or 35.7 trillion BDT and the lowest for the TRADE-30 scenario, at US$ 337 billion (2011-12) or 27.6 trillion BDT.

The PSMP scenario, which is devised as an energy security strategy, is more expensive than the REF scenario. The cost of energy security is an additional cost over the REF scenario, in the order of US$ 36.6 billion (2011-12) or 3 trillion BDT over 2012 to 2045. By enhancing electricity import from India, in combination with using coal for domestic power generation and minimizing the use of expensive gas, Bangladesh can get energy security at a significantly lower cost, 8 trillion BDT or US$ 97 billion, from the PSMP scenario. The enhancing of electricity import, therefore, brings significant economic gains as well as energy security benefits through supply source diversification.

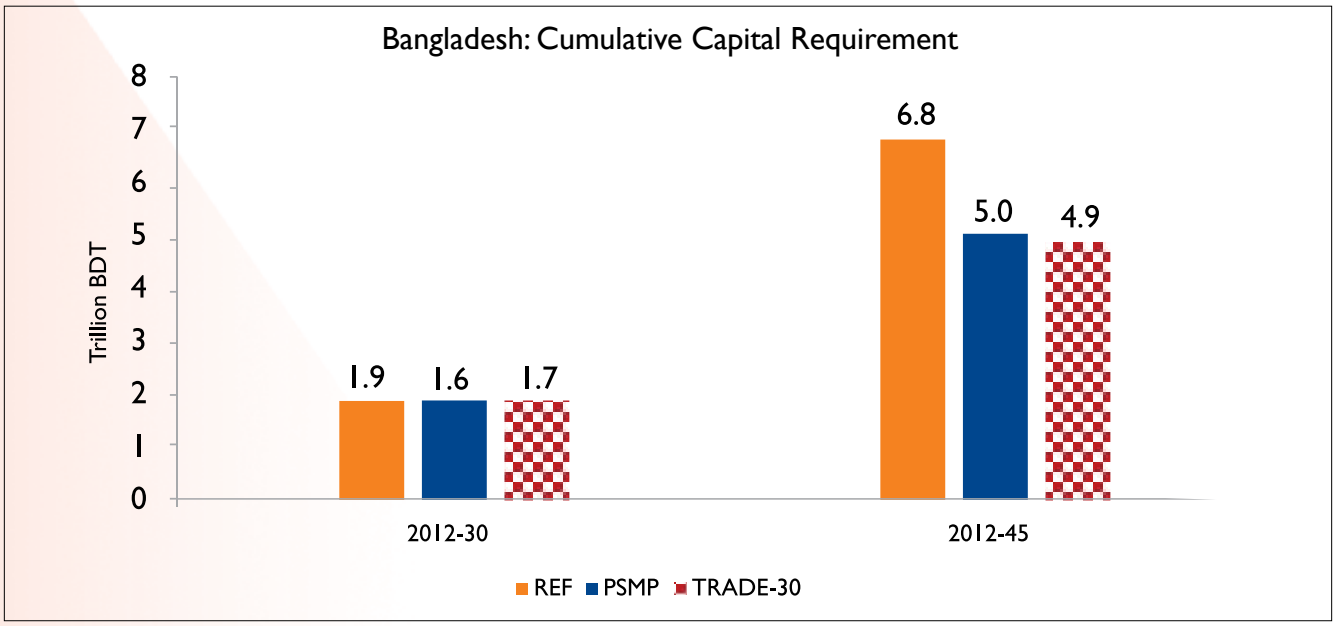
The REF scenario, which depends on the domestic power generation capacity for power supply, needs larger investment in building power generating capacity than the other two scenarios. Fuel cost dominates the power system cost in all scenarios; however, it is largest in the PSMP scenario as it depends on expensive gas import.

Power Sector Capital Investment (CAPEX)

The REF scenario needs the highest amount of investment in power generation capacity, US$ 23 billion (2011-12) or 2 trillion BDT of investment over the period 2012-30, or 105 billion BDT every year (Figure 8). The investment requirement during the same period declines by 17 percent in the PSMP scenario and by 11 percent in the TRADE-30 scenario. The latter needs slightly more capital because it depends on coal plants, which are more expensive, whereas, the PSMP scenario, as defined, relies on more gas plants, which needs less capital to build.

As electricity import reduces fuel needs for power generation, there is less expansion in the fuel sectors used for power generation, both for domestic fuel production as well as for developing import infrastructure, for example, for the import of LNG. However, some amount of investment would be diverted to the sectors dealing with petroleum products, for instance, refining activity or import infrastructure. Thus, electricity trade with India results in a redistribution of investible resources to the non-energy sectors of the Bangladesh economy. The redistribution of investment resources should result in production gain in the non-energy sector, indicating trade-induced production specialization.

Figure 7 **Investment in the Power Sector**



Macroeconomic Impact

Macroeconomic modeling shows the impact of the electricity trade on the total investment, the GDP, household consumption, trade of other goods, and emissions. The macroeconomic variables are shown in Table 3.

Table 3 **Macroeconomic Variables in Bangladesh (US$ Billion, 2011-12)**

	2030			2045		
Variable	REF	PSMP	TRADE-30	REF	PSMP	TRADE-30
		Change over REF			Change over REF	
GDP	1,343	8	-11	4,376	73	4
Household consumption	890	3	16	2,823	10	50
Govt. consumption	84	0	0	267	0	0
Investment	315	2	-3	751	-14	-23
Net exports	99	3	-23	654	75	-21
Exports	471	6	-19	1,777	55	-16
Imports	372	3	4	1,124	-20	4
Tax	45	0	1	119	-1	2
Consumption per capita US$	4,847	17	84	14,202	50	247

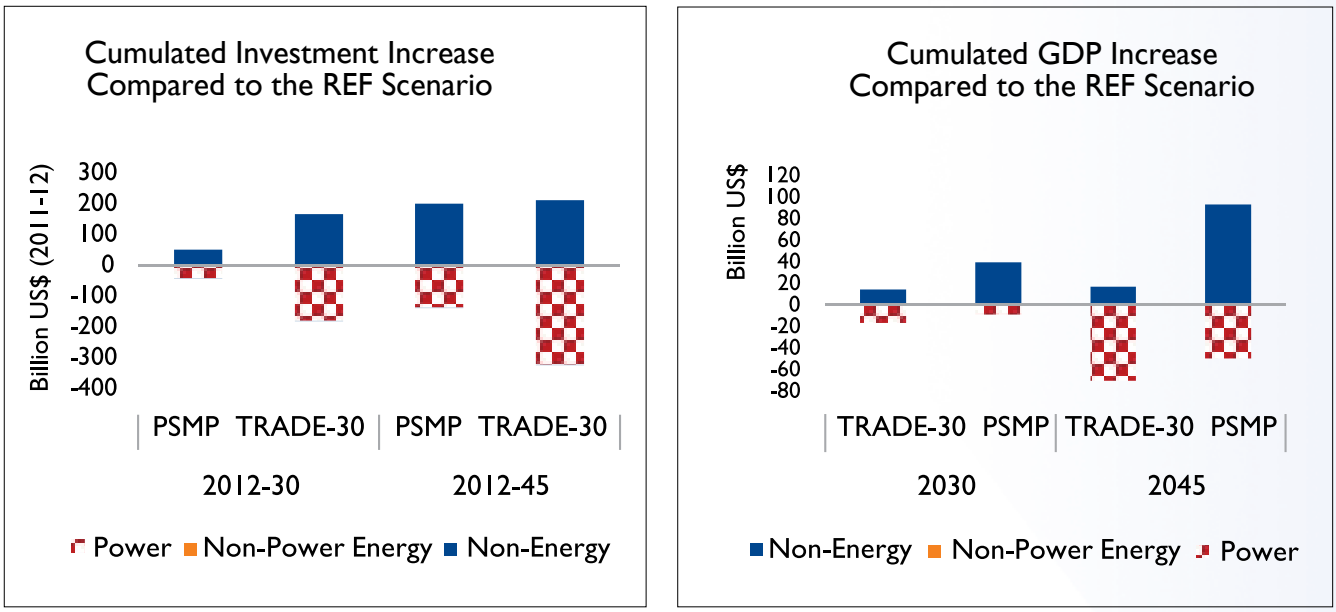
Note: GDP = Investment + HH Cons + Govt. Cons + Net Exports - Tax

The GDP in the TRADE-30 scenario is lower in 2030 and only marginally higher than in the REF scenario in 2045, yet the consumption is higher by a much larger amount. This is because the need for investment in energy infrastructure and power plants, with their high capital output ratios, goes down and more of the resources are available for consumption.

Structural Change

Electricity import reduces the generation requirement or the output of the electricity sector of Bangladesh. This reduces the investment requirement in the power sector. The investible resources, such as capital investment and financial resources, saved from the power sector, are redistributed to the non-power energy and non-energy sectors. The redistribution of investment resources also leads to a redistribution of the GDP across sectors. This impact of increasing the GDP in the non-energy sectors counters the fall in the GDP due to a multiplier impact of output reduction in the power sector. The decrease in the energy sector (power plus fuel sector) GDP outweighs the increase in the non-energy sector GDP, resulting in a slightly lower GDP in the TRADE-30 scenario, as compared to the REF scenario. In the PSMP scenario, however, the increase in the non-energy GDP outweighs the decrease in the power sector GDP, resulting in a higher GDP, as compared to the REF scenario. The GDP is marginally lower in the TRADE-30 scenario and higher in the PSMP scenario. In terms of the GDP, the PSMP scenario seems to be more beneficial for Bangladesh.

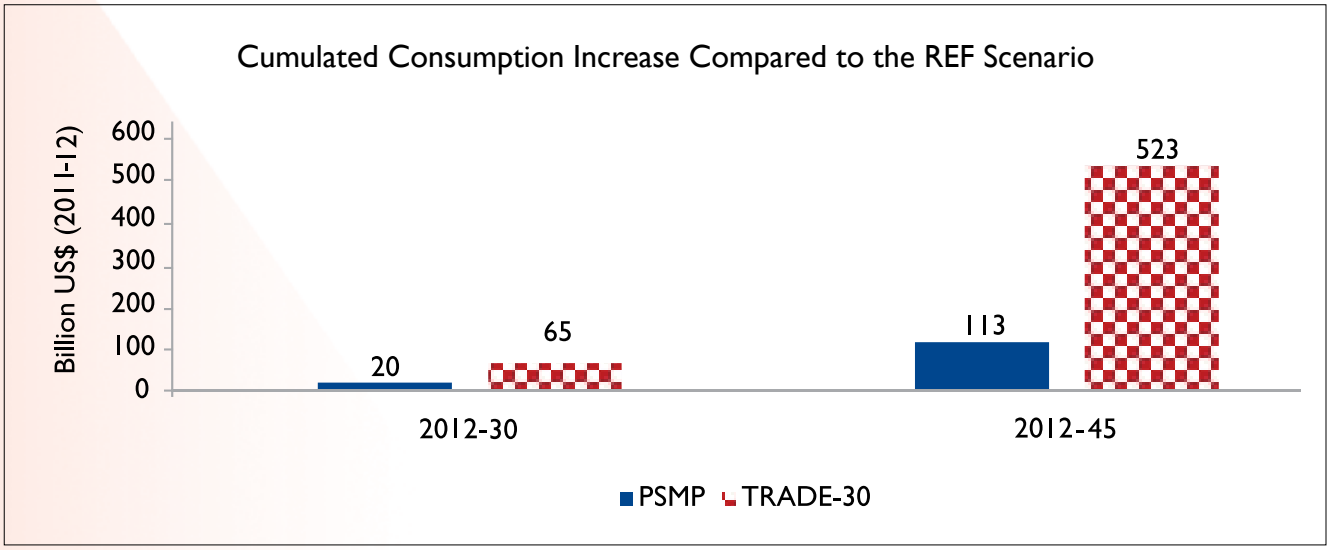
Figure 8 **Impact on Cumulated Investments and the GDP Compared to the REF Scenario**



Impact on Welfare

In terms of higher welfare, which can be measured by aggregate private household consumption for the Bangladesh economy, the TRADE-30 scenario is more beneficial than the PSMP scenario as the gains in terms of household aggregate and per capita electricity consumption, as shown in Figure 10, are much higher. The PSMP scenario, though providing higher GDP, results in a lower consumption increase (Figure 9) than the TRADE-30 scenario. To summarize, the PSMP scenario is costlier and less welfare-maximizing than the TRADE-30 scenario. The gain in cumulated consumption from 2012-2045 is US$ 523 in 2011-12 prices and market exchange rate (Figure 9). This is higher than the corresponding cumulated consumption gain in 2012-2045 for India (Figure 15) of US$ 401 in 2011-12 prices and market exchange rate.

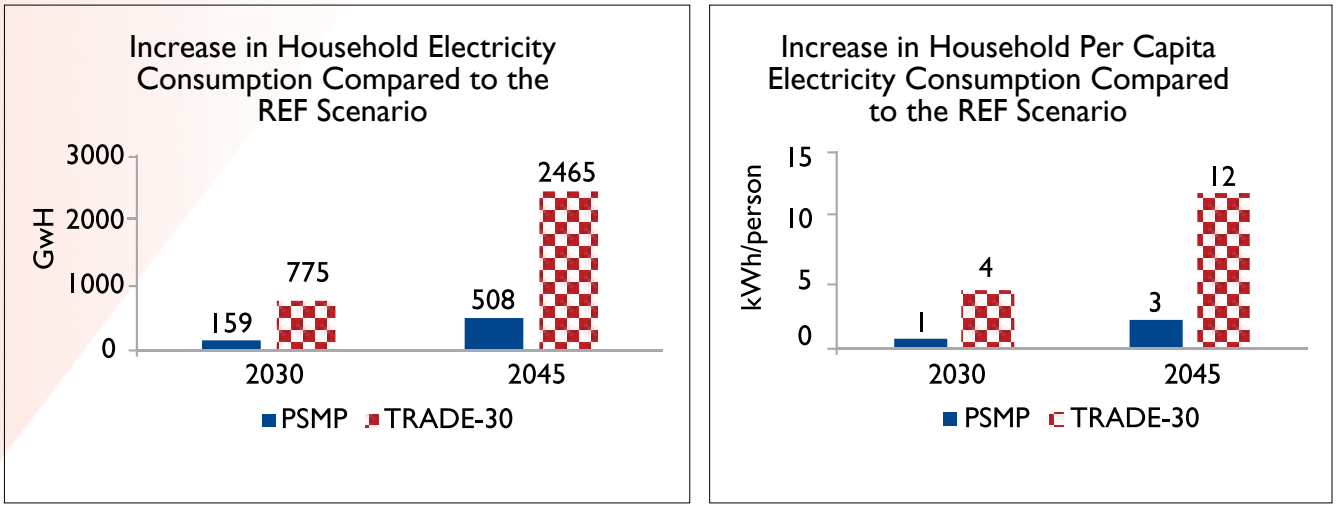
Figure 9 **Impact on Cumulated Investments and the GDP Compared to the REF Scenario**



Household Electricity Consumption

The household consumption of electricity increases in both the TRADE-30 and PSMP scenarios compared to the REF scenario; however, the increase is substantially more in the TRADE-30 scenario (Figure 10). Since electricity imports do not require any auxiliary consumption, the intermediate demand decreases in both the TRADE-30 and PSMP scenarios as compared to the REF scenario.

Figure 10 **Increase in Aggregate and Per Capita Household Electricity Consumption Compared to the REF Scenario**



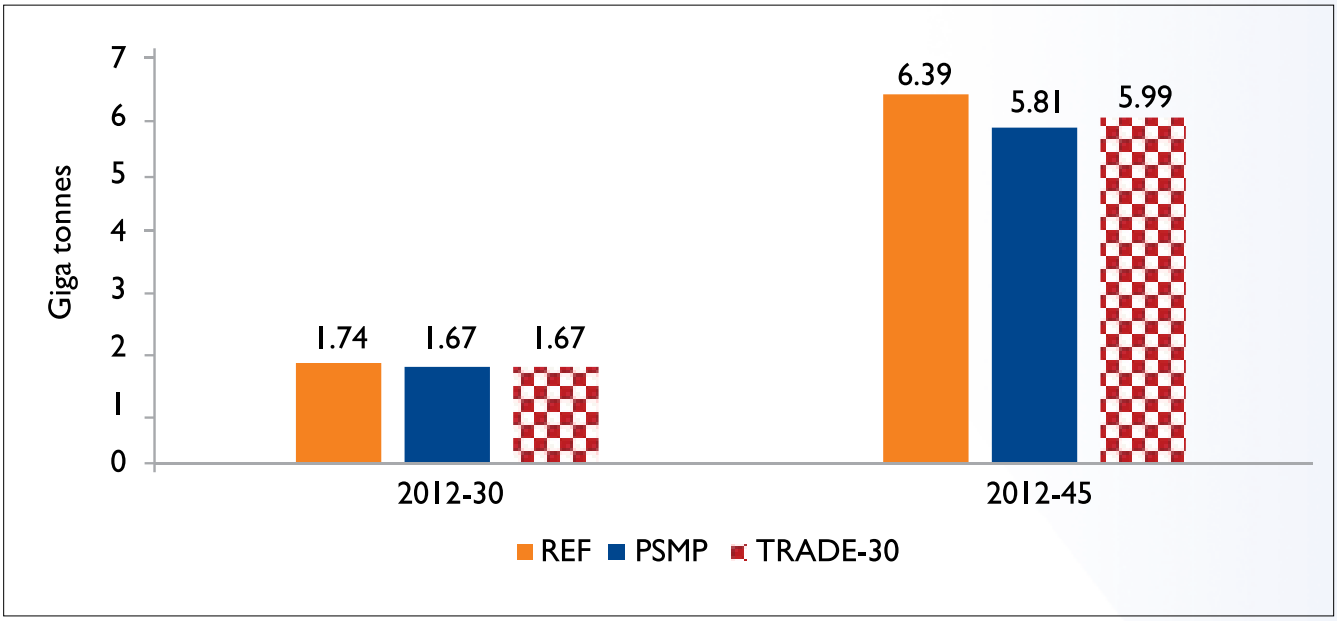
The increase in the total aggregate household consumption for all commodities, however, is much more in the TRADE-30 scenario than in the PSMP scenario (Table 3 and Figure 9). Clearly, if we compare the GDP and the consumption gains for the PSMP and TRADE-30 scenarios, the higher gains from consumption outweigh the lower gains from the GDP for the TRADE-30 scenario.

Thus, to sum up the macroeconomic impacts of the two scenarios, the PSMP scenario provides a higher GDP with a lower welfare (household consumption) at the cost of higher investments while the Trade-30 scenario provides a lower GDP with a higher welfare (consumption) at a lower investment cost to the economy.

CO_2 Emissions

In the REF scenario, CO_2 emissions in 2030 are 41 MT, which go up by more than a factor of 5 in 2045, reaching 222 MT. The presence of nuclear, modest electricity import, combined with a higher share of gas in generation, reduces CO_2 emissions in the PSMP scenario in 2030 and 2045 by 17 percent and 38 percent, respectively, as compared to the REF scenario. In the TRADE-30 scenario, although the emissions are higher than in the PSMP scenario, due to a higher presence of coal, they are substantially lower than the REF scenario. The changes in fossil fuel use, a reduction in generation requirement, and a structural change in the economy reduce the cumulated CO_2 emissions in 2012-45 from 6.4 GT in the REF scenario to 5.8 GT (9 percent reduction) in the TRADE-30 scenario and still furthur to 6 GT (6.3 percent reduction) in the PSMP scenario (Figure 11).

Figure 11 **CO_2 Emissions Cumulated up to the Year from 2012**



India

India's power system in 2015 was more than 30 times (316 GW) than that of Bangladesh (10 GW). The value added in the power sector accounts for a very small share of the Indian economy (2 percent), which will decline still further in the future. Hence, the technical and economic impacts on India are not expected to be substantial and may even be insignificant at times.

Impact on India's Power System

On the technical side, electricity trade with Bangladesh results in increasing generation, higher plant load factors (PLFs) of the power plants in India, and some addition to generating capacities. This increases the profitability of the power sector. The domestic power demand increases in the REF scenario to 2,447 TWh in 2030 and further to 6,709 TWh in 2045. There is a small increase in demand in the two trade scenarios.

Figure 12 presents India's export to Bangladesh in three scenarios. When compared with domestic demand, it is quite miniscule in all the years, just between 1-1.5 percent, even in the TRADE-30 scenario that allows a higher import of electricity in Bangladesh.

In the REF scenario, where electricity export from India to Bangladesh is kept at 1.1 GW, India needs a power generation capacity of 606 GW in 2030 to meet its electricity demand. Capacity requirement further grows to 1,616 GW in 2045 (Figure 13). In the trade scenarios, India does not need extra capacity to meet the electricity import needs of Bangladesh till 2025. The import need could be met by enhancing the capacity utilisation. In 2030, the PSMP scenario needs 3 GW additional capacity, whereas the TRADE-30 scenario requires 6 GW additional capacity, which is less than a 0.5 percent increase. In 2045, the PSMP scenario needs 14 GW additional capacity, whereas the TRADE-30 scenario requires 23 GW additional capacity, which is less than 1-1.5 percent additional capacity, in comparison to the REF scenario in both the scenarios.

Figure 12 **Export Development in the Scenarios**

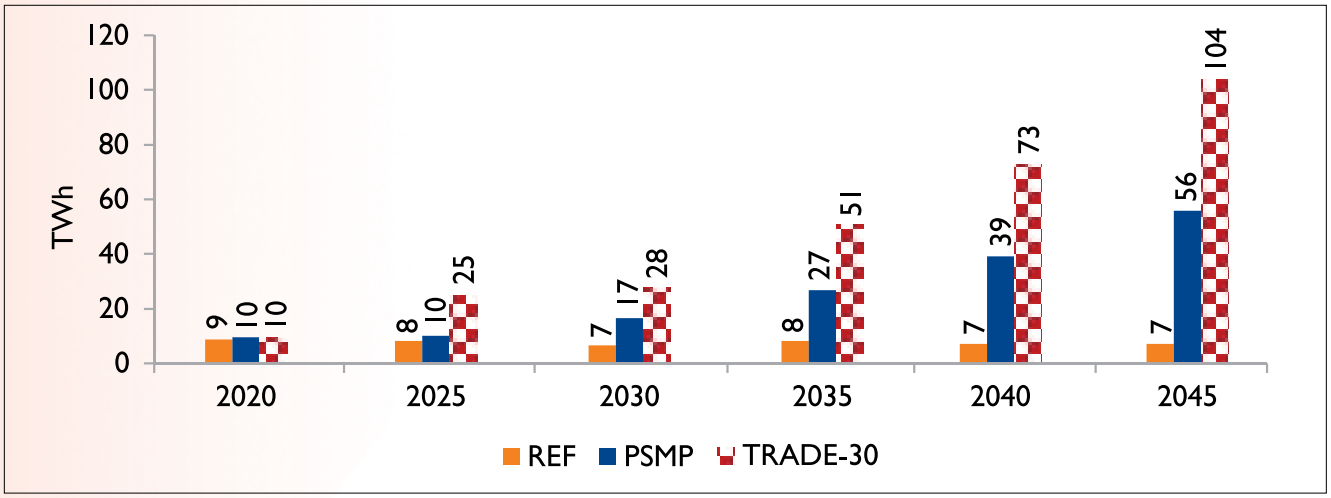
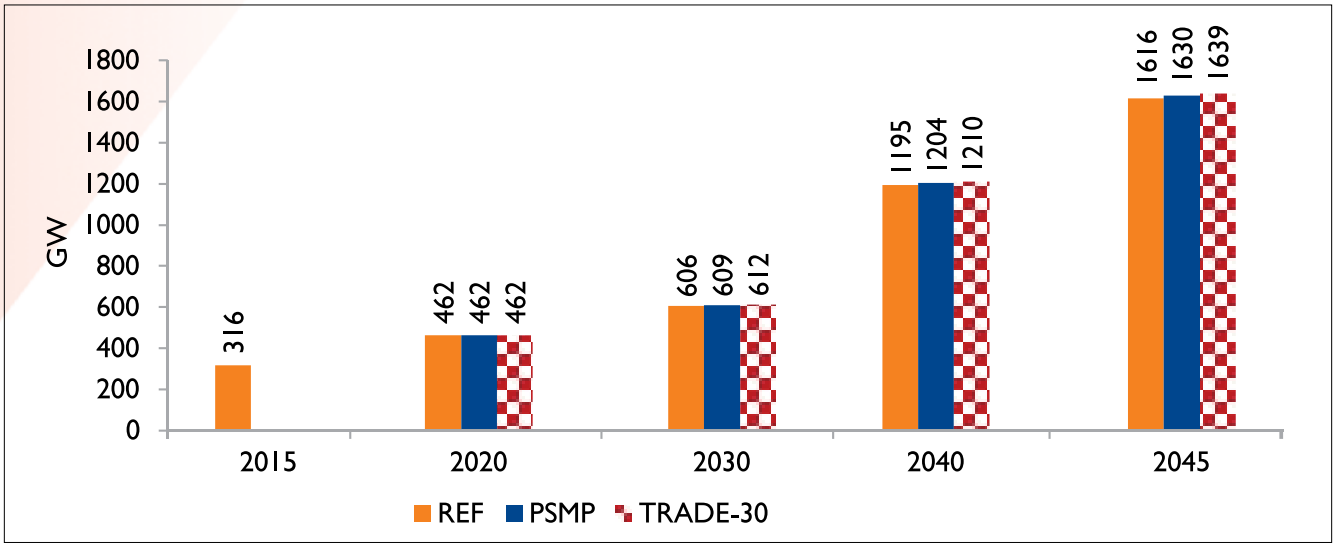


Figure 13 **Capacity Requirement in India**



The current dominance of coal in the power system will decline owing to India's green power policies, which include 175 GW of new renewables by 2022 and a share of non-fossil fuel in the total capacity as 40 percent in 2030 and onwards. Yet, coal would have an almost 50 percent share in the total capacity. The green policy will drive a large penetration of solar PV and wind capacity. The need for additional capacity in the PSMP and TRADE-30 scenarios will also be supplied by coal till 2030 and, later, by solar PV and wind as their cost goes down.

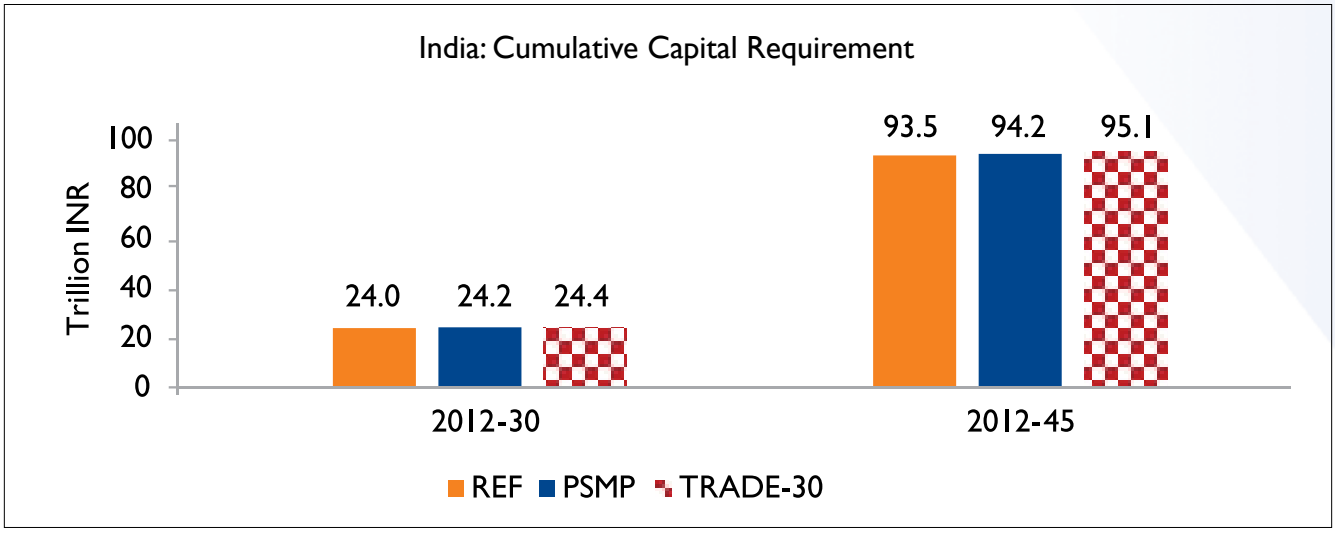
India's current generation is 1,279 TWh (2015). In the REF scenario, which allows only a small quantity of electricity export, generation needs to primarily meet the domestic demand and thus increase by almost two-and-a-half times by 2030, to 2,979 TWh. This further goes up to 7,617 TWh in 2045. As India exports a larger amount of electricity in the PSMP scenario, from 2025, the generation is higher than the REF scenario; however, as import in Bangladesh is constrained, less than 1 percent additional generation is needed over the REF scenario. In the TRADE-30 scenario, which allows higher export than the PSMP scenario, the additional generation need is also higher. This, however, still remains insignificant, in the range of 1-2 percent, as compared to the REF scenario.

Although the green policy reduces the share of coal in the total capacity, generation will still be dominated by coal, with its share in the total generation reaching to about 72 percent by 2045 in all the three scenarios. Till 2035, coal also supplies the entire additional requirement that is needed for export in the PSMP scenario; beyond that, however, solar PV also contributes to the export demand. In the TRADE-30 scenario, the coal power plant also meets the entire export demand till 2035. In 2040, wind accounts for almost 50 percent of the export demand; in 2045, it is again coal power plants that will meet the entire export demand.

India needs a huge amount of coal to fuel its coal power plants. The coal requirement in the power sector is estimated as 811 MT in 2020, which will go up to 3 BT in 2045. The power sector needs 31 BCM of gas in 2030, which declines gradually over the next 15 years and, by 2045, the power sector will require 16 BCM gas. The demand for coal is marginally (less than 1 percent) higher in the trade scenarios.

Investment in the Power Sector

Figure 14 **Cumulated Investment in the Indian Power Sector**

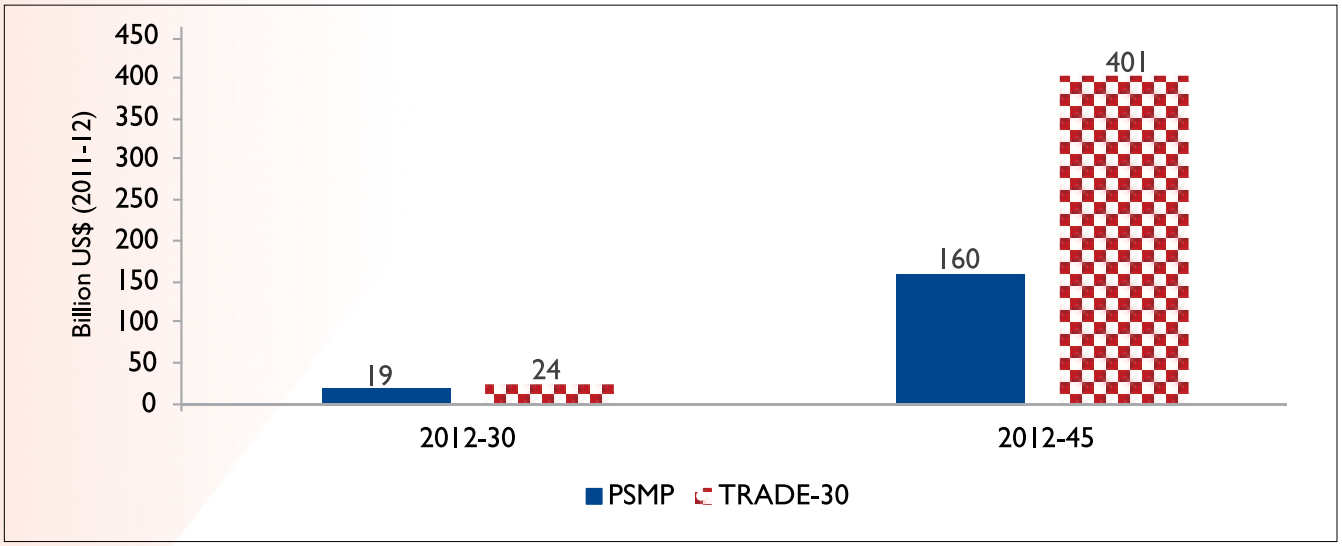


In the REF scenario, the Indian power sector needs US$ 514 billion (2011-12) or Rs 24 trillion of investment (CAPEX) on generation capacity development over the period 2012-30 (Figure 14), almost US$ 28 billion or Rs 1.3 trillion annually. The PSMP scenario needs an additional investment during this period (2012-30) of US$ 4 billion (2011-12) or Rs 170 billion, only 0.7 percent higher than the REF scenario. In the TRADE-30 scenario, this is higher by 1.5 percent (US$ 7 billion or Rs 350 billion) compared to the REF scenario. If we consider the longer period of 2012-45, the total investment requirement on power generation capacity development is US$ 2,004 billion or Rs 93.5 trillion. The additional investment requirement in the two export-oriented scenarios is less than 1 percent higher than the REF scenario.

Consumption and GDP

The export of power to Bangladesh results in export revenue earning, which becomes income earnings for the economy and leads to an increase in consumption and investment. The consumption gain for India is much higher in the TRADE-30 scenario compared to the PSMP scenario because the export quantum and revenue earnings are also higher. The gain in cumulated household aggregate consumption in the TRADE-30 scenario over the period 2012-45, US$ 401 billion (2011-12), is still only 0.4 percent of the total cumulated consumption (Figure 15).

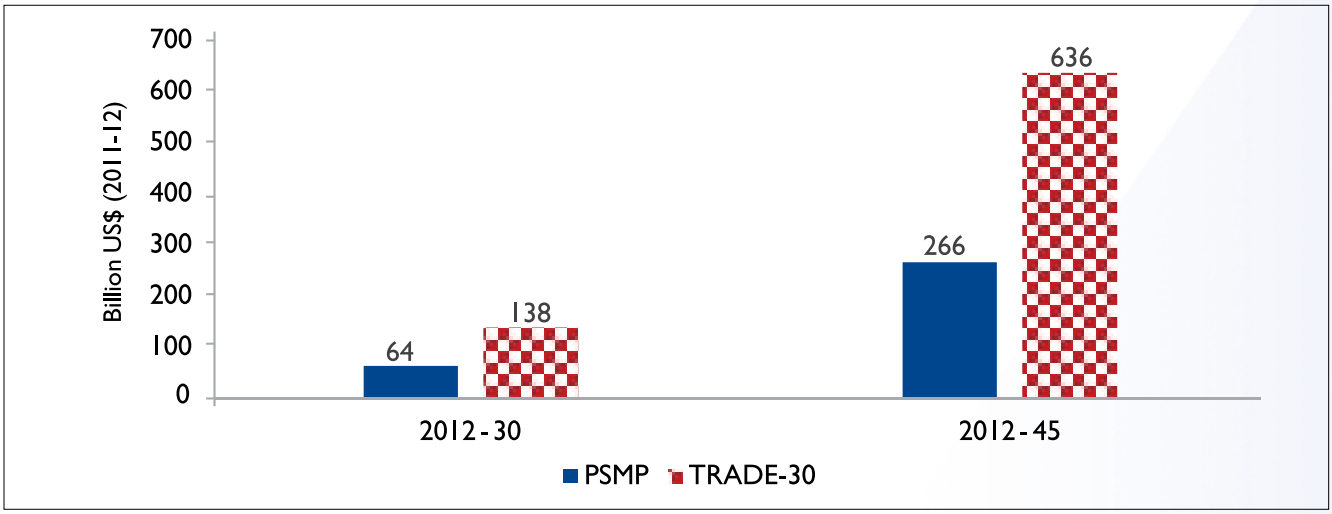
Figure 15 **Gain for India in Cumulated Aggregate Consumption**



The increase in power generation required to meet the additional export demand from Bangladesh results in not only an increase in power sector investment, but also in the entire energy sector as well as the entire economy. As power sector output increases to meet the additional export demand, it also creates an additional intermediate demand for the other sectors of the economy, resulting in higher production for the other sectors as well. Therefore, the total aggregate investment increases much more than the increase in energy sector investment.

The increased power sector output and the increase in outputs of the other sectors due to the multiplier effect result in additional GDP creation. The cumulated GDP gain is much higher in the TRADE-30 scenario than the PSMP scenario (Figure 16). The increase in cumulated GDP in the TRADE-30 scenario is, however, only 0.3 percent of the cumulated GDP in the REF scenario. In any case, electricity trade with Bangladesh provides a positive gain for the Indian economy.

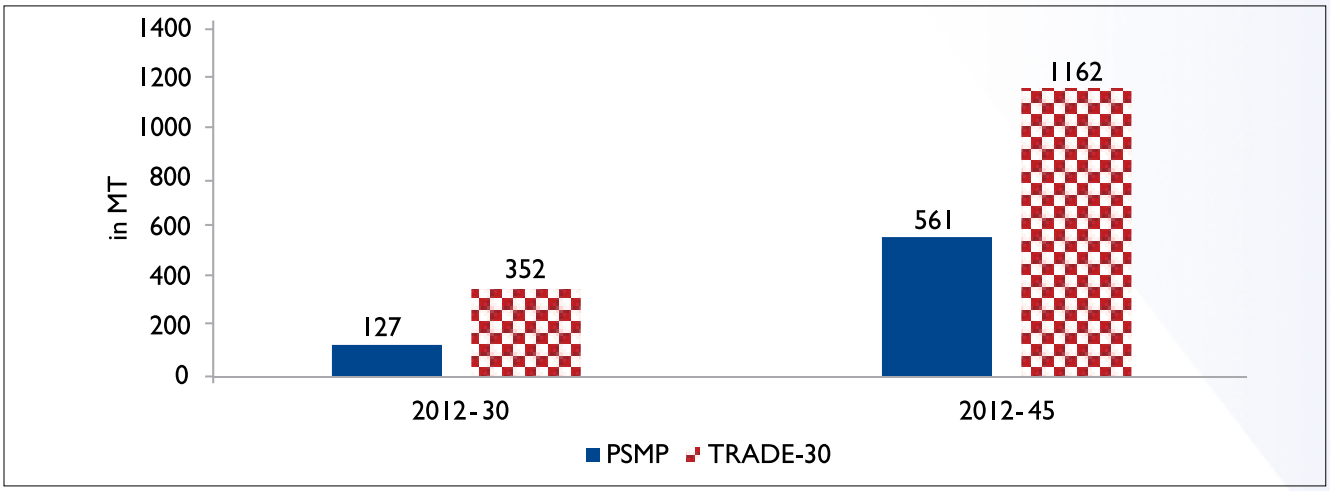
Figure 16 **Impacts on Cumulated GDP**



CO_2 Emissions

The Indian power sector continues to remain a large emitter of CO_2. In 2020, emissions are projected as 1 BT, which will go up to 1.8 BT in 2030, and 4.1 BT in 2045. Clean coal technologies and green polices decarbonize the Indian power system over time, as CO_2 emissions per kWh of electricity decline from 0.65 kg/kWh to 0.54 kg/kWh, which is an about 17 percent fall. As the coal power plant supplies the additional electricity needed for export in the PSMP and TRADE-30 scenarios, coal demand is higher than the REF scenario, as is the CO_2 emission, but it is only at marginal amount, not even 1 percent.

Figure 17 **Increase in Cumulated CO_2 Emissions of India**



Cumulated emissions up until 2045 are shown in Figure 17. There is an increase in cumulated CO_2 emissions of India of 1.2 GT in the TRADE-30 scenario as compared to the REF scenario, with a reduction of 0.4 GT in emissions of Bangladesh up until 2045. Thus, trade marginally increases the combined emissions of India and Bangladesh. *Of course, if Bangladesh, Bhutan, India, and Nepal are linked together, Bangladesh's import of electricity may be mostly supplied by hydropower. The combined emissions of the four countries would then be lower with trade.*

Conclusions

The key findings of the macroeconomic analysis of the Bangladesh-India electricity trade are:

Bangladesh

- Electricity import from India is an economic option for Bangladesh as it is cheaper than all the other options, including generation from coal.
- The trade scenarios need less domestic power generation capacity and hence less investment not only in power generation capacity but also in fuel infrastructure development, which could be diverted to the non-energy sector (agriculture, manufacturing) or for consumption.
- Electricity consumption as well as the aggregate consumption of households increase in the TRADE-30 scenario, leading to welfare gain. The gain can be more if a larger import of electricity is permitted (see box).

Impact of Electricity Import Without Restriction

A scenario (not presented here) has been developed where limits on electricity import were removed. It showed a much larger welfare gain where the cumulated consumption over 2012-2045 is US$ 824 billion (in 2011-12 prices and market exchange rate) compared to US$ 523 billion in the TRADE-30 scenario. The per capita electricity private household or residential consumption in 2045 is 20 kWh/year more, compared to 12 kWh/year in the TRADE-30 scenario.

Electricity imports in 2045 constitute 90 percent of the total electricity supply. Such a dependence on imports may not be considered acceptable, particularly from one source. However, if the grids of Bangladesh, Bhutan, India, and Nepal are linked together, the sources of import would be diversified.

- While the PSMP scenario limits the import (interconnection) capacity to 5 GW in 2030 and 9 GW in 2040 and beyond, the TRADE-30 scenario offers a potential import capacity of 7 GW in 2030, 18 GW in 2040, and 25 GW in 2045.
- The PSMP scenario, which is devised to ensure energy security through diversifying sources of power generation, would cost significantly higher than the other two scenarios.
- The TRADE-30 scenario (enhanced trade) reduces the power supply cost significantly and, at the same time, improves energy security, though the diversification of supply sources is less than in the PSMP scenario.
- The energy import bill in the PSMP scenario is larger than in the other two scenarios, implying that the PSMP scenario enhances the import dependence of the country in monetary terms.
- Both the TRADE-30 and PSMP scenarios reduce investment requirement, as compared to the REF scenario.

- The PSMP scenario has a higher import bill than the TRADE-30 scenario as import of fuels cost more than import of electricity. Thus, the question for Bangladesh is how much reliance on foreign exchange is worth the diversification of energy supply sources.
- Enhanced electricity trade reduces fuel import for power generation, in particular that of gas, which has a more volatile market, thus enhancing energy security. It also reduces the fuel import bill where the released foreign currency could be used for activities with higher socio-economic benefits.
- Bangladesh significantly reduces CO_2 emissions by adopting the enhanced electricity import option.
- The PSMP scenario provides a higher GDP with lower welfare (household consumption) at the cost of a higher economy of total investments.
- The TRADE-30 scenario provides a lower GDP with higher welfare (consumption) at the cost of a lower economy of total investments.

India

- Electricity trade with Bangladesh causes some beneficial impacts although not highly visible because of the size of India's power system and its economy.
- Export to Bangladesh is projected as 17 TWh and 56 TWh in the PSMP scenario in 2030 and 2045. In the TRADE-30 scenario, the figures are 28 TWh and 104 TWh, respectively.
- The power generation capacity need is projected as 606 GW and 1,616 GW for 2030 and 2045. The additional capacity need is not more than 1-1.5 percent to cater to the export in both the scenarios.
- Over the period of 2012-45, the total investment requirement on capacity development for power generation is Rs 93.5 trillion, an average of Rs 2.8 trillion per annum. The additional investment requirement in the two export scenarios is less than 1 percent higher than in the REF scenario.
- Export revenue earning makes Indian households gain in the form of increased consumption, which is higher when trade is higher.
- Export demand and earning contribute to a higher investment in the power sector as well as to the entire economy and subsequently the GDP increases in the higher trade scenario.
- Despite its green policy, the Indian power sector will remain a large emitter of CO_2. However, due to clean coal technologies, together with renewables, the carbon intensity (kg/kWh) of the system will decline.

Importance of Trade and Economic Cooperation

India and Bangladesh have identified infrastructure such as power and transport as potential areas to improve economic cooperation between the two countries, leading to better political relations. This study substantiates the fact that electricity trade is a win-win option for both countries. Import from India is not only a cheaper electricity option for energy resource scarce Bangladesh, which has only limited choices (either import fuels for power generation or import electricity from its neighbor); it also brings larger macroeconomic benefits.

The PSMP scenario, which diversifies supply to multiple sources such as coal, gas, and nuclear, and imports up to 16 percent of the domestic demand, gives more expensive electricity supply, a lower GDP, and low per household consumption compared to the REF scenario. This reflects the cost of energy security through diversification. The TRADE-30 scenario, which permits electricity import up to 30 percent, gives a higher GDP, higher household consumption, and cheaper electricity than the PSMP scenario.

A 30 percent share of electricity import may be within the limit of Bangladesh's way of ensuring energy security by restricting import dependence on a single fuel or source and diversifying the sources of power supply. Since the alternative is a higher dependence on imported gas for power generation (as defined in the PSMP scenario), which has been significantly volatile in the Asian market, Bangladesh, being a small consumer, it would perhaps be easier to manage bilateral relationship with relatively more certainty than depending on an unpredictable gas market.

Trade with Bangladesh also gives India the opportunity to exploit its large hydro potential in the North-East, which could be evacuated through Bangladesh. India has already been assisting its neighbors in the subcontinent to improve their power situation. The India-Bangladesh transmission line is providing safe and reliable interconnection of the power grids to supply 600 MW of power to Bangladesh. Another 500 MW is under construction with support from the Asian Development Bank. The benefit of electricity import is already acknowledged by the Bangladesh authority. The 1,320 MW Maitree Thermal Power Project, a joint venture of NTPC and the Bangladesh Power Development Board, is under development.

On a broader canvas, there is tremendous potential held out by the initiative on sub-regional cooperation among BBIN nations that foresees transit facilitation of power through India as some of these countries have large unexploited hydro potential, which is waiting for a market. The Ministry of Power of the Government of India has come up with the guidelines on CBET.

Trade, indeed, is a win-win option for both India and Bangladesh.

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About SARI/EI

Over the past decade, USAID's South Asia Regional Initiative/Energy (SARI/E) has been advocating energy cooperation in South Asia via regional energy integration and cross-border electricity trade in eight South Asian countries (Afghanistan, Bangladesh, Bhutan, India, the Maldives, Nepal, Pakistan, and Sri Lanka). This fourth and the final phase, titled South Asia Regional Initiative for Energy Integration (SARI/EI), was launched in 2012 and is implemented in partnership with Integrated Research and Action for Development (IRADe) through a cooperative agreement with USAID. SARI/EI addresses policy, legal, and regulatory issues related to cross-border electricity trade in the region, promotes transmission interconnections, and works toward establishing a regional market exchange for electricity.

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About IRADe

IRADe is a fully autonomous advanced research institute, which aims to conduct research and policy analysis and connect various stakeholders including government, non-governmental organizations (NGOs), corporations, and academic and financial institutions. Its research covers many areas such as energy and power systems, urban development, climate change and environment, poverty alleviation and gender, food security and agriculture, as well as the policies that affect these areas.

For more information on the South Asia Regional Initiative for Energy Integration (SARI/EI) program, please visit the project website:

www.sari-energy.org