Lighting the Way

Achievements, Opportunities, and Challenges in Bangladesh's Power Sector

Lighting the Way: Achievements, Opportunities, and Challenges in Bangladesh's Power Sector

Sheoli Pargal[1]

Energy and Extractives
South Asia
The World Bank

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[1] Lead Economist, Energy and Extractives Global Practice, the World Bank.

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Abbreviations and Acronyms

AC	Alternating Current
BAPEX	Bangladesh Petroleum Exploration and Production Company
BAU	Business-as-Usual
BBIN	Bangladesh, Bhutan, India, and Nepal Initiative
BERC	Bangladesh Energy Regulatory Commission
BOOT	Build-Own-Operate-Transfer
BPDB	Bangladesh Power Development Board
BPX	Bangladesh Power Exchange
BREB	Bangladesh Rural Electrification Board
CAPEX	Capital Expenditure
CCGT	Combined Cycle Gas Turbine
CGE	Computable General Equilibrium
COP21	2015 United Nations Climate Change Conference
DC	Direct Current
DESCO	Dhaka Electric Supply Company
DPDC	Dhaka Power Distribution Company
EE	Energy Efficiency
EE&C	Energy Efficiency and Conservation
EGCB	Electricity Generation Company of Bangladesh
ESMAP	Energy Sector Management Assistance Program
FDI	Foreign Direct Investment
G2G	Government-to-Government
GDP	Gross Domestic Product
GHG	Greenhouse Gas
GoB	Government of Bangladesh
GSMP	Gas Sector Master Plan
HELP	Hydrocarbon Exploration and Licensing Policy
HFO	Heavy Fuel Oil
HIES	Household Income and Expenditure Survey
HVDC	High-Voltage Direct Current
IEA	International Energy Agency
IEX	Indian Energy Exchange
INDC	Intended Nationally Determined Contributions
IOC	International Oil Company
IPP	Independent Power Producer
KGGTF	Korean Green Growth Trust Fund
LCOE	Levelized Cost of Electricity
LNG	Liquefied Natural Gas
MoU	Memorandum of Understanding
MPEMR	Ministry of Power Energy and Mineral Resources

NDC	Nationally Determined Contribution
NREP	National Renewable Energy Policy
NVVN	Vidyut Vyapar Nigam Ltd
OECD	Organisation for Economic Co-operation and Development
OPEX	Operating Expenditure
PGCB	Power Grid Company of Bangladesh
PLF	Plant Load Factor
PPA	Power Purchase Agreement
PSC	Production Sharing Contract
PSMP	Power Sector Master Plan
PXIL	Power Exchange India Limited
RMG	Ready-Made Garments
SEA4ALL	Sustainable Energy for All
SHS	Solar Home System
SREDA	Sustainable and Renewable Energy Authority
SREP	Scaling Up Renewable Energy Program
WACC	Weighted Average Cost of Capital
WZPDCL	West Zone Power Distribution Company

Executive Summary

1. This report surveys the challenges facing Bangladesh's power sector today and makes recommendations for consideration by national policy makers. Its starting point is the Government's goal of universal access to electricity by 2021, when Bangladesh completes 50 years of independence.

2. Bangladesh can justly be proud of its progress in providing power to its people over the past decade. Generation capacity has steadily grown from 5.5 GW in 2009 to more than 13 GW in 2017—an increase of 140 percent.[2] Starting from levels of access to electricity below 50 percent, today access is around 80 percent, with a globally recognized off-grid rural Solar Home System (SHS) program contributing almost 14 percent of that total. Sector performance is better than that of larger countries in the South Asia Region on key dimensions—distribution and transmission losses (together around 14 percent) and collection efficiency (above 90 percent). Bangladesh was an early mover in initiating private power generation in the late 1990s. The independent power producer (IPP) contracts awarded at that time through a transparent competitive process brought it what remains even today some of the lowest cost power in South Asia. Power imports from India commenced in 2013 and are set to grow—they are a critical element of the Government's strategy to supplement domestic generation with other sources of supply. The country has also demonstrated impressive mobilization and institutional capacity in selected agencies, which it can leverage in its quest to rapidly achieve middle-income status.

3. The Government of Bangladesh (GoB) has targeted gross domestic product (GDP) growth of 7.4 percent per year between 2016 and 2020 in its 7th Five-Year Plan. Solid performance by the power sector is considered crucial to achieving this target. The 2016 Power System Master Plan notes that if Bangladesh were to follow Thailand's growth trajectory it would have to sustain a per capita GDP growth rate of 5.2 percent per year between 2016 and 2041. This would require the development of new export-oriented industries and a significant increase in power generation capacity, potentially to 52 GW by 2041, along with a quadrupling of total energy used.[3]

4. Despite Bangladesh's impressive achievements, demand exceeds the supply of power. Generation capacity is about 60 percent of that in Pakistan, which has a similar population size, and per capita annual generation is less than 400 kWh, one of the lowest levels in the world. As in other countries of South Asia, a majority of manufacturing and service firms in Bangladesh identify a shortage of reliable electricity as the most important constraint they face to smooth operation and expansion (World Bank 2015). Outages result in about 2–3 percent loss of GDP per year, with significant sums needing to be spent on diesel backup.

5. Redoubled efforts to extend the grid to unserved areas mean that universal access to power is now within reach. At the same time, however, the demand of those newly connected to the grid is adding to the gap with supply. If each new connection is to mean more than the ability to switch on a light for a limited number of hours each day, more power will be needed. Consumers will enjoy the full benefits of electrification only when both the quality and the availability of power in the system increase—through savings from enhanced energy efficiency (EE), through investment in new generation and new sources of power, through improvements in the system's ability to transmit and supply power at the consumer end, and so on. A major challenge is the shortage of domestic fuel and the limited

[2] This excludes 2.2 GW of captive power in industry.
[3] Japanese International Cooperation Agency (JICA)/Tokyo Electric Power Company. "PSMP 2015 High-Level Discussion SUMMARY PART," April 2016.

success in recent years in bringing new baseload generation capacity online quickly. In addition, Bangladesh needs to invest in rehabilitation and maintenance and, if possible, in upgrading existing power plants, as well as in extending and upgrading the electricity transmission grid and distribution network.

6. Today, the energy sector has the opportunity to take advantage of a rapidly changing technological environment that has brought down the cost of solar panels, wind power, and energy storage, increasing the potential for renewables to contribute to the country's supply mix. A revolution in EE has reduced the energy required to run many appliances and lowered the required scale of SHS or mini-grids, which are likely to remain important for supply in remote areas. In addition, a steep dip in the gas commodity price cycle just as Bangladesh is looking at importing fuel for power generation is an opportunity to be seized. Finally, while it is recognized that Bangladesh will be negatively affected by climate change (Chattopadhyay and Mukhi 2016), the fact that much of the country's infrastructure will be rebuilt or newly built in the coming years provides an opportunity to build resilience into its systems if consideration of climate impacts is integrated into decision making.

Objective of this report

7. The World Bank carried out a program of energy sector analytic work in Bangladesh from 2014 to 17 to inform its operational engagements in the country. This report presents the findings of that program of analysis, which identified the main challenge facing Bangladesh's power sector as the large, and potentially increasing, gap between the demand and supply of electricity. In view of the low level of average power consumption in the country and the large scope for improvement in quality, the main recommendation is to increase power generation capacity following a least-cost generation expansion path in which climate change considerations and the social cost of carbon have been incorporated.

8. The program of analysis takes as its starting point the Power Sector Master Plan (PSMP) of the GoB. It assesses the realism of the Master Plan's targets in view of evolving prices and technologies in the power sector and increasing global concern over climate change and reviews the menu of options available for achieving these targets. The program identifies policy and/or administrative actions required to successfully implement these options on the path toward universal access to affordable and reliable power. The PSMP was prepared in 2010 and revised in 2016. While the PSMP of 2010 identified a capacity requirement of 40 GW by 2030 (of which 24 GW was anticipated to be met with domestic coal), the pace of capacity addition to date will not permit the achievement of those targets. The least-cost analysis underlying the 2010 PSMP was updated for the 2016 PSMP[4] and, in recognition of the then existing constraints, the import of liquefied natural gas (LNG) was introduced to complement other elements of the fuel mix (including coal). Thus, going forward, baseload electricity generation is expected to rely on either expanding (onshore/offshore) domestic gas production or some form of imported energy—coal, LNG, or imported electricity.

9. The program of analysis explores the potential of EE and improved operational efficiencies in reducing the need to add generation capacity to the system; the magnitude of likely renewable (mainly solar) capacity addition in the medium term; ideas for accelerating the expansion of power trade with Bangladesh's neighbors in view of the multifaceted benefits of such trade; the projected near-term

[4] Power System Master Plan 2016. Power Division, Ministry of Power, Energy, and Mineral Resources, Government of Bangladesh, Dhaka. Accessible at http://powerdivision.portal.gov.bd/site/page/f68eb32d-cc0b-483e-b047-13eb81da6820/Power-System-Master-Plan-2016.

availability of natural gas, likely fiscal impact of continued underpricing of gas, and actions to incentivize efficient use as well as enable the fiscally responsible absorption of forthcoming LNG imports; and finally, given the negative impact on climate change of the coal-heavy path for sector expansion laid out in Bangladesh's Nationally Determined Contributions (NDCs), options for minimizing the use of fossil fuels.

Main findings

10. This report shows that the PSMP 2016 proposal to develop significant coal capacity is likely to need review. Commercial financing for power generated by fossil fuels is likely to become more scarce/expensive as the world seeks to address climate change. Including a carbon price in the least-cost generation plan to reflect this results in coal losing its overwhelming dominance in the recommended generation mix for Bangladesh, with LNG and imported electricity becoming competitive alternatives (even without taking account of the decline in LNG prices since 2015). Once the low number of flood-safe sites suitable for power plants, the limited availability of fallow land, and the shadow price of carbon are taken into account, investment in coal-fired power is even less desirable. The significant recent drop in the price of renewables has also dented the projected market share of all fossil fuel technologies. Because the option of power imports increases climate change resilience and would also allow excess generation from solar/wind in India to be imported, cross-border power trade as an option comes out as an even higher priority than hitherto. Overall, the report underlines the need for a rethink of the policy on pricing for both natural gas and power so that the correct incentives are provided for investment in power and gas production, investment in renewables is not handicapped, the potential savings from improvements in EE are realized, and efficient use of all forms of energy is encouraged. The analysis points to the significant fiscal savings from reducing subsidies to the energy sector and the opportunity cost this represents in terms of social and other welfare expenditure foregone.

11. Specific findings are highlighted in the following paragraphs.

12. **Energy efficiency.** The analysis has underlined the significant potential of improvements in efficiency to reduce the need for investment in additional generation based on a review of demand-side options, the gains from achieving industry standard efficiency in power generation, and the benefits from better management and operation of the power system in the country.

13. Sixteen options on the demand-side were analyzed to assess EE potential over time. The analysis shows that in 2030, 14.3 percent of the total primary energy requirement could be saved through these interventions and the addition of 3,298 MW of new electricity generation capacity (approximately 12 percent of the 2030 peak demand projected by the PSMP 2016) avoided. In terms of generation, the fleet of gas-based power plants includes so many old and inefficient plants that the overall efficiency of this stock in 2014 was only 33.5 percent. As of 2014/15, there was potential for increasing it to about 52 percent by retirement and repowering of old plants in the short term and renovation/modernization of inefficient plants in the medium term. This could result in 55 percent more power generated with the same quantity of gas (~900 mmcfd) that was being consumed. Another way of seeing this is that the amount of power generated could be with significant savings in the amount of gas used if efficiency were enhanced to 45 percent. Conservatively valuing the gas saved at US$2 per thousand cubic feet (mcf), the analysis shows that rehabilitating and modernizing existing plants could save US$30.2 million per year. Together with repowering, approximately US$39.1 million could be saved annually. This opportunity has been recognized by the Government and repowering efforts have been initiated.

14. A third source of savings derives from technical and nontechnical improvements in the management and operation of the power system in Bangladesh. The analysis shows that Bangladesh could obtain more electricity at lower average cost by allocating more of its existing domestic gas to power generation, by modernizing dispatch protocols, and by removing transmission bottlenecks that prevent lower-cost power from reaching load centers. System stability and security would also be boosted by making provision for a spinning reserve, including appropriate payment to generators for this service. An adequate spinning reserve would arguably have averted the major grid failure that occurred on November 1, 2014. Even at its opportunity cost, domestic onshore gas is significantly cheaper than diesel/fuel oil—this represents a substantial part of the gain from optimizing dispatch and from removing constraints on transmission that prevent evacuation of available gas fired power.

15. **Regional electricity trade.** The benefits for Bangladesh of cross-border power trade with India (to date mainly importing surplus off-peak power from eastern India) include a reduction in reliance on oil-based generation during the summer peak period; preservation of limited domestic gas during the off-peak period; displacement of gas-/oil-based domestic generation by Indian surplus renewable generation during off-peak and shoulder periods; phase-out of dilapidated and highly inefficient (gas-based) steam turbines in Bangladesh; and, possibly, the induced development of additional hydro projects in Nepal and Bhutan to sell power in Bangladesh.

16. Starting with individual projects has helped build confidence and mutual trust between the two countries but there could be further benefits to Bangladesh from moving beyond government-to-government (G2G) trade and power purchase agreement (PPA) arrangements and either participating directly in the Indian power market or establishing its own power exchange—not only in terms of the flexibility brought to trading/transactions but also because of the impetus that market-based power trade will give to the development of Bangladesh's power sector more generally by attracting supply and inducing competition even domestically. Tighter integration of the two markets with buyers and sellers from both sides being able to directly participate in both exchanges, effectively treating the Bangladesh power exchange as an additional exchange in the wider Indian market, will help Bangladesh manage its limited spinning reserves and reactive power and thus address the significant fluctuations experienced in system frequency and voltage. These deficiencies—especially inadequate spinning reserves—have led to significant instability in the system and contribute to grid outages even when there is sufficient capacity to meet demand. Development of an ancillary services market would improve system security because these services can also be traded through the market along with energy. Ultimately, policies and regulatory frameworks would need to be harmonized if trade is to be scaled up and a regional power pool established.

17. **Renewables.** As of 2016, renewable energy generation capacity installed in Bangladesh amounted to 430 MW. The 230 MW Kaptai Hydropower Project is the sole grid-connected renewable energy resource; it is supplemented by off-grid SHSs in rural areas (175 MW), urban rooftop solar (15 MW), and a small amount from biogas- and biomass-based captive plants. Resource assessments[5] indicate that Bangladesh has potential for the installation of an additional 3,666 MW of renewable energy capacity (both grid-tied and off-grid) in the short to medium term. Over the longer term, this

[5] See the Scaling Up Renewable Energy Program (SREP) Investment Plan 2015. Note that this estimate takes account of the prevailing land scarcity in Bangladesh, so does not include potential from installing solar on arable land needed for agriculture.

could increase as renewables generation technology matures further and is complemented by development of low cost electricity storage options.

18. **Natural gas.** Over the past decade, demand for natural gas has grown at 7.5 percent per year, outpacing the rate of growth of GDP (6.2 percent per year) (World Bank 2016b). Most of the growth in demand for gas has come from the power sector, which consumes 54 percent of gas supplied in gas-fired power plants, which generate over 80 percent of the electricity consumed in Bangladesh. However, natural gas output is projected to decline from 2,700 mmcfd in 2017 to 700 mmcfd in 2030 (Dorsch Consulting/KPMG 2012). As of July 2015, Bangladesh's onshore reserves amounted to less than 12 years of production at the prevailing rate of consumption (Petrobangla 2015a). In view of the large installed base of gas-fired generation in the country and limited scope for switching to other fuels, the Government has decided to add imported LNG to the fuel mix.

19. Stepped up efforts to enhance domestic gas production are also necessary. Unfortunately, Bangladesh Petroleum Exploration and Production Company (BAPEX), a subsidiary of the national oil company, Petrobangla, has limited capacity and a monopoly in on-shore domestic exploration, which, together, have meant that Bangladesh has shut itself off from international expertise and the latest, most efficient exploration and production technologies. The absence of high-quality geological data to reduce exploration risk and production sharing contracts (PSCs) that are not competitive with those in other countries have made it difficult to attract international companies to invest in exploration and production of off-shore gas.

20. Fiscal considerations militate against maintaining a very low retail price of gas in the face of LNG imports. It is estimated that the delivered cost of LNG in Bangladesh could be US$5 per mmBTU to US$6 per mmBTU; the price of domestic gas has averaged US$2 per mmBTU in recent years. Below opportunity cost administered pricing has resulted in inefficient allocation and use (for both domestic and commercial purposes) of gas and an imbalance in demand and supply, leading to severe shortages. About 1,000–1,500 MW of gas-fired power capacity is idle simply because gas is not available and in the absence of incentives to save gas, the average efficiency of the power generation fleet is approximately 34 percent, well below the 50 percent to 60 percent efficiency that new combined-cycle gas turbines are able to reach (BPDB 2015). As a result, Bangladesh uses almost twice as much gas for generating a unit of electricity than would otherwise be possible.

21. Though LNG imports will result in a price shock, Bangladesh could also benefit from competition among suppliers and the steep reduction in LNG prices internationally following the oil price decline of 2014/15, along with the buyers' market that has emerged in recent years with the development of nontraditional sources of supply.

22. **Pricing.** LNG imports will also have an impact on the price of power generated. The shortage of gas has led to the use of more expensive liquid fuels (heavy fuel oil [HFO], furnace oil, diesel) to generate power, in many cases by short-term rental plants, over the last decade. Although the use of liquid fuels, all of which are imported, pushed up the average cost of power generated, this was considered to be a temporary expedient until lower-priced domestic gas or coal-fired base-load capacity came online. As a result, retail power tariffs were not adjusted to cover the cost of power and the gap was filled by an explicit budgetary transfer to the Bangladesh Power Development Board (BPDB) (which is the single buyer in the Bangladesh power market). In 2013/14 and 2014/15, the annual fiscal transfer

to the BPDB averaged around US$820 million.[6] It is expected that LNG imports would replace imported liquid fuels in power generation. While using liquid fuels is less expensive than oil-fired generation, as long as LNG prices remain linked to the price of crude oil, the cost savings are not likely to be significant. Thus, an adjustment in power tariffs will be necessary if fiscal transfers to the BPDB are to be avoided.[7]

23. The adjustments will need to continue in the near term to match the increased costs of generation. In addition to LNG, the Government plans to add imported coal-fired baseload power plants to the existing generation fleet to bring the share of coal in the generation mix to 40 percent by 2025 from less than 2 percent in 2017, with the share of natural gas (including LNG) dropping from 65 percent to 45 percent. Taking account of the greenhouse gas (GHG) emissions and pollution implications of coal-fired generation and the fact that gas as a transition fuel has carbon emissions half that of coal, significant environmental benefits could accrue if Bangladesh is able to avoid coal to some extent or delay its move to coal. Analysis also shows that coal-fired generation will be more expensive than electricity imported from India.

24. A computable general equilibrium (CGE) analysis of the impact of increasing gas prices and/or removing the electricity subsidy shows that both would increase the cost of goods and services which are gas and/or electricity intensive, with a negative impact on producers and consumers as electricity and gas become more expensive than before. However, removing electricity subsidies frees up budgetary resources and pricing domestically produced gas at the international price of gas generates additional revenues for the exchequer, both of which, when returned to the economy, boost demand. In both cases, the positive impact of the stimulus from revenues generated by correcting pricing is likely to outweigh the short-run negative effects of the price rise apart from the value of signaling scarcity, inducing appropriate levels of consumption in the economy, and limiting the possibility of lock-in to an environmentally costly fuel mix.

25. **Overall, the analysis points to significant potential for reducing the need to add to system capacity by improving EE in the economy.** While natural gas will necessarily remain the transition fuel, the analysis suggests that efforts to minimize coal-fired generation should be prioritized so that Bangladesh can avoid lock-in to a high carbon energy sector growth path and the significant environmental (air and water pollution) costs associated with it. A clear conclusion is that gradually liberalizing domestic gas and electricity prices will help enhance system efficiency across the board and incentivize investment in new capacity as well as directly in energy saving. Prospects for avoiding lock-in would increase if domestic gas production increases consequent on new finds, if incentives improve for efficiency in gas use (including investing in new combined cycle gas turbine (CCGT) or in repowering of existing gas-fired generation), and, if a tax on coal or CO_2 emissions is implemented. This will help to the extent that the uncertainty and price volatility associated with imports of LNG can be ameliorated through modern hedging and other financial/market tools. While the potential for renewables remains to be fully realized,[8] power imports have been recognized as a low-cost, clean supplement to domestic

[6] Subsidies were US$811 million in FY2013–14 and US$830 million in FY2014–15 according to the BPDB's Annual Report.
[7] An increase in the price of domestic gas will incentivize efficiency in the use of gas (for power generation as well as other uses) which may result in a lower demand for LNG and less need for fiscal support both on account of less LNG being used and because the cost of domestic gas-fired power would increase.
[8] Poor resource endowments (hydropower, wind) and other constraints (availability of land/rooftops for solar power) make it unlikely that renewables will contribute more than 5–7 GW to the mix, given today's technology. Given the pace of technological change in the sector, this may not be the last word, however.

generation that will likely take off when the goal of a regional power pool is realized—more work is needed at a government-to-government level to take this option forward.

Conclusions and recommendations

26. The power sector is an important engine of growth in Bangladesh and ensuring that it performs well is a priority for the Government. As shown in this report, the push to provide universal access to adequate power requires that more generation capacity be added to the system. The analysis of options available to Bangladesh suggests that investment in efficiency improvement on the demand and supply sides as well as in system operation (including transmission and dispatch) should be a first priority, followed by efforts to expand power trade, to encourage exploration for domestic gas, and to import LNG. The potential for renewables has been considered limited, but further examination of options such as solar rooftops may show scope for expansion and should be on the agenda.

27. Three overarching issues need attention as the power sector positions itself for the future: (a) weaning it off financial support from the Government, (b) allowing prices to signal scarcity and value, and (c) minimizing the negative impacts on climate change from the power sector's growth trajectory. Sector regulation and planning are important channels for moving forward on these fronts and for reducing the average cost of power supplied.

28. Specific recommendations are as follows:

- **Move toward a wholesale power market for generation and cross-border imports**. A basic challenge emanates from Bangladesh's dependence on its rapidly depleting natural gas reserves to fuel power generation. Alternatives being considered by the Government to domestic gas include imported LNG and coal, but both will result in significantly more expensive power. Power import, initially from India, is a proven option and sustainable in the long term. Proactive initiation of market-based trading of power can attract competitively priced, technologically agnostic private investment in generation to Bangladesh. Going beyond G2G arrangements for power trade and developing a power exchange in Bangladesh that would solicit bids (from domestic players as well as players in neighboring countries such as India) would be a key element of this. It is important that the design of the exchange aligns with the market rules in the Indian electricity market so that product definitions (energy as well as ancillary services), market clearing mechanisms, definition of prices and congestion management rules are compatible across the two markets.

- **Let prices gradually reflect (opportunity) costs.** Limited additions to baseload capacity during the last decade, transmission bottlenecks, and inefficient processes that have prevented dispatch of available capacity have together resulted in significant reliance on oil-fired generation.[9] Oil's share of peak generation has increased from 24 percent to 30 percent since 2011, and this has been an important factor in pushing up the average cost of power generated. Consumers have been shielded from the associated increase in the cost of power procured, but the fiscal burden is significant and comes at a high opportunity cost. Electricity prices need to be increased to maintain sector financial viability, which is critical to ensure that future growth in power demand can be met through the requisite private and public investment—pricing is a key

[9] About 2.4 GW of fuel oil/diesel generation capacity was added from 2010 to 2014; small rental plants accounted for 2 GW of this. These plants tend to be less efficient than the gas-fired plants, particularly larger IPPs.

element of the enabling framework for good sector performance. Appropriate price signals will smooth adaptation to structural changes in the energy sector, the so-called ‘energy transition’ away from fossil-fueled power: pricing energy at opportunity cost creates incentives for conservation/EE; removing fossil fuel subsidies levels the playing field for renewables, and carbon pricing further creates incentives to move away from fossil fuels; and finally, subsidy reform or removal also frees up fiscal resources that can be directed toward priority sector spending such as access expansion or to fund the infrastructure required to absorb renewable energy, among other aspects (in addition to other priorities such as spending on social sectors).

- **Take account of sector and household distributional impacts when adjusting prices.** Depending on the speed of adjustment to price increases, the impact of a price shock on the economy could be disruptive in different sectors. This immediately warrants consideration of both, a gradual price adjustment and provision of transition support through social safety net extension, retraining, and so on, for the industrial workforce. It is recommended that a distributional analysis of the impacts of overall and sectoral price adjustments be undertaken to provide a more complete understanding of the poverty and welfare implications of the price changes, which could then inform the design of schemes to mitigate the impact, even if transitory, on vulnerable sections of the population. A clear takeaway from the analysis, however, is that there is a tremendous opportunity cost to the subsidies to electricity and gas being provided by the Government and welfare could be enhanced by redirecting the spending to more productive channels.

- **Capture all possible efficiencies.** System-wide inefficiencies contribute to avoidable costs and need to be priorities for Government action. There is significant scope for action on the demand side and, again, simply allowing the price of power to reflect the cost of generation can go a long way toward creating incentives for conservation and efficiency in generation and the use of power, obviating the need to add some capacity. Probably the single most important factor in promoting EE is energy pricing—when electricity and/or fuels are cheap or subsidized, the gain from an EE investment is not enough to justify a disruption of ongoing operations. In addition, stringent policy guidelines are required to encourage adoption of EE practices in both public and private sector power generation. Procurement of new gas-based power plants, for example, should incorporate EE requirements in tender documents and specifications to encourage acquisition of energy-efficient power plants and equipment in the country.

- **Encourage adoption of cleaner energy solutions.** Climate change is an important challenge that suggests a rethink of Bangladesh’s move to build a significant share of coal-fired capacity from a starting point of scarcely any use of coal. Apart from the considerable capital and logistics costs of this move, it is worth noting that once coal imports are a reality a whole ecosystem of coal use —in transport, industry, and so on, is likely to come into being. A later decision to walk back from these would result in massive stranded assets. As noted, LNG will be needed to supplement domestic production, at least as a transitional fuel, if not for the longer term. This will need to be procured on both a term and spot basis—Bangladesh can benefit from lower prices and greater flexibility of commitments if it were to use a mix of G2G, shorter-term, and spot contracts. A well-designed LNG acquisition strategy can ensure stability in supply at relatively better terms than a single long-term contract. As a new and relatively small buyer competing with financially stronger buyers for cargos, credit enhancement will likely help Bangladesh obtain LNG on better terms than otherwise.

- **Maximize potential use of renewable energy sources.** Given low levels of generation from renewables, it is recommended that the authorities continue to invest in collecting and making available good data on the size and quality of the solar and wind resource, to support the development of the market by sponsoring or undertaking pilots and demonstration projects, and to develop risk mitigation offerings to attract private investors into what is still considered a nascent and unproven sector in Bangladesh. While potential for renewables remains to be fully assessed, the potential could increase as renewables generation technology matures further and is complemented by development of low-cost electricity storage options.

- **Build capacity for planning.** A final issue that goes to the heart of these recommendations is the fact that the unbundling of the BPDB has had the unintended consequence of disturbing the planning function for the sector, resulting in a situation of multiple decision making locii and limited coordination among them. Recreating an institutional home for coordinated sector planning should be a priority so that, for example, fuels are not divorced from electricity sector discussions and so on. Moreover, planning must take account of physical and financial constraints, including factors such as the availability of usable land; incorporate the impacts of climate change, especially extreme variability in weather, in modeling; consider the potential for renewables to add to generation; and apply a social cost of carbon. Bottom-up integrated energy planning will help ensure consistency in upstream and downstream decisions as well as ensuring that all links are taken into account in devising a resilient sector expansion strategy. Dedicated capacity to develop long-term integrated energy sector plans and undertake the studies that would provide inputs to the plans is essential. This will allow the PSMP and sector expansion path to be revised at regular intervals in line with the changing policy environment and technological developments.

I. Introduction

1. This report is a synthesis of the findings of a 2014–2017 program of energy sector analytic and advisory work on Bangladesh undertaken at the World Bank. The objective of this program was to understand better selected critical drivers of sector performance and identify opportunities for improvement.

2. The report highlights several key challenges and decisions facing Bangladesh's power sector, including the risk to fuel supply for power generation arising from dwindling reserves of domestic gas, the pressure on tariffs from the sharp increase in the cost of domestic power generation in recent years, and the existence of significant inefficiencies that could be wrung out of the power system (in terms of its functioning and on the demand and supply sides) to improve power availability using existing capacity. The report also points to the potential gains from moving cross-border power trade beyond bilateral government-to-government arrangements and establishing the country's own power exchange to initiate the development of a regional power market and, finally, to the urgency of immunizing the sector against the impact of climate change.

3. Major changes in the sector operating and investment environment have yet to be fully reflected in the Government decisions for the sector, starting with the significant drop in oil prices and the glut in global natural gas supply that have together improved the competitiveness of imported LNG; plummeting costs of renewables due to a combination of maturing technologies, scale economies, and competition; and a growing global consensus on taking into account the social cost of carbon in investment decision making. The report draws on the analytic work carried out by the World Bank to analyze the implications of these changes for the choices facing Bangladesh.

4. The paper is organized as follows. Section II presents the background on the sector and the evolution of its financial and technical performance over the past two decades. Despite a significant increase in generation capacity, supply has not been able to keep up with the rapid increase in demand associated with the Government's vigorous efforts to broaden and accelerate access to power in recent years. Liquid fuel-run plants were introduced in 2009 as an immediate solution to the acute shortage of power, but this was a relatively expensive alternative to domestic gas-fired plants or even imported coal-fired plants and intended to be an interim measure. However, delays in commissioning large planned gas- and coal-fired baseload plants have resulted in continued dependence on liquid fuels and the need for subsidies to keep prices affordable—an ongoing fiscal burden.

5. Section III describes the evolution of access in Bangladesh and highlights the considerable progress made, as well as how shortfalls in the quality and adequacy of power supplied to consumers limit their ability to benefit from electrification. This underlines the need to invest in ensuring better availability of power for all and is the point of takeoff for the paper.

6. Section IV presents the results of a least-cost planning study for 2014–2030 that assesses the capital expenditure (CAPEX)/operating expenditure (OPEX), carbon emissions and timing implications of following the main power generation development paths to 2030 that sector policy makers in Bangladesh have considered in recent years (that is, LNG, cross-border power imports, imported coal, and expansion of domestic gas production). The base-case analysis adjusts for implementation shortfalls observed in practice by setting limits on the maximum capacity that can be added over the period as well as using updated costing for fuels; it was extended to include a shadow price on carbon and, in recognition of the likely impact of climate change, to take account of the limited number of flood-safe

sites available in the country, and the ability of the grid to absorb renewables (mainly solar) which are increasingly cost competitive. The section discusses the potential gains from power trade as well as pragmatic approaches to enhance trade between India and Bangladesh in view of the fact that power imports can be an important, cost-effective, and 'green' supplement to domestic generation. The section also presents data on renewable potential in Bangladesh and the main barriers that will need to be addressed to maximize the contribution of solar and wind energy to the energy mix.

7. Section V takes up the thread of additional power, recognizing that possibly the least-cost way of adding power to the system is by maximizing demand- and supply-side efficiencies and by addressing system-wide waste, for example, in transmission and dispatch. In all cases, there is significant potential that remains to be exploited and the section points to the opportunities that exist.

8. Section VI discusses the state of play in the gas sector in Bangladesh, identifying both the challenges it faces and the opportunities presented by recent market developments for LNG in the context of the existing installed base of gas-fired capacity and associated infrastructure. Although it is carbon based, natural gas is recognized today as a transition fuel for economies that require it. Bangladesh will need to consider how best to minimize reliance on natural gas as it moves toward cleaner alternatives (such as imports of clean power) in the medium term and to maximize efficiency of use, as long as gas remains an option.

9. Finally, Section VII flags two issues that increasingly warrant attention as the power sector positions itself for the future: ensuring sector financial sustainability and minimizing negative climate impacts from the sector's business-as-usual (BAU) growth trajectory (which includes a significant move to coal). It underlines that BAU would result in a fivefold increase in emissions and lock-in to a climate-unfriendly fossil-fueled growth trajectory for the sector. The section also presents the findings of a financial modelling exercise carried out to forecast power sector subsidy requirements in the coming years, based on the power generation expansion plan of the Government. A supplementary macro analysis shows that there is a tremendous opportunity cost to the subsidies to electricity and gas being provided by the Government and that welfare could be enhanced by redirecting the spending to more productive channels.

10. The report (Section VIII) concludes with recommendations for Bangladesh's energy sector as it seeks to power the country to middle-income status.

II. Sector background and performance[10]

11. Bangladesh has historically relied on domestic natural gas for power generation because the country was endowed with significant reserves. In fact, domestic gas accounted for almost 90 percent of power generation until a decade ago.[11] The country started to face a shortage of gas around 2006–2007, in part due to prices that were far from opportunity cost and that encouraged inefficiency and 'over-use' and in part, due to years of under-investment in gas exploration.[12] At that point, policy makers began exploring the use of alternative fuels: coal and LNG in the medium to long term and liquid fuel-run rental power plants as an immediate stopgap measure. In 2010, Bangladesh also embarked on an ambitious generation expansion plan (the 'road map'), which called for a threefold increase in power generation capacity over the following five years (from about 4,300 MW to 11,500 MW by 2015), with the aim of reaching 20,000 MW by 2021.[13] The plan envisaged the introduction of coal into the fuel mix (25 percent share by 2015), followed by liquid fuel (20 percent). In reality, by 2015, capacity had been added in the amount anticipated (installed capacity reached 11,000 MW in 2015 as shown in Figure 2.1), although it came mostly from liquid fuels (30 percent of the capacity mix)[14] and not coal.

12. Despite the increase in generation capacity, supply has not been able to keep up with the rapid increase in demand associated with the Government's vigorous efforts to broaden and accelerate access to power in recent years. The grid has been extended to unserved areas, with 3.8 million new rural connections added last year alone—taking overall access to electricity up to about 80 percent.[15] However, the shortage in power generation and bottlenecks in the network for transmitting electricity mean that even those with grid connections do not receive adequate power and experience routine disruptions in supply. This has limited electricity consumption and affected economic growth. Annual per capita electricity consumption in Bangladesh is relatively low at 370 kWh, compared to 1,010 kWh for India, and 2,600 kWh for China. Bangladesh is ranked 106 out of 128 countries on the Global Competitiveness Index and 110 on the quality of electricity supply.[16] In the World Bank's Doing Business

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[10] Taken from Sadeque and Bankuti (2017).

[11] Coal represented 4 percent of power generation, hydro 1.6 percent, and liquid fuel about 5 percent.

[12] Onshore areas are already relatively well explored; the country is now starting to look for gas resources in deep sea blocks, which are more expensive to explore and require technological know-how that the national exploration company does not have. After the maritime boundary issue was settled with neighboring Myanmar and India, the GoB has recently started to focus on inviting International Oil Companies (IOCs) to explore in deep sea blocks. To align the terms of the PSCs with the market, the GoB is reviewing the PSC terms and conditions. Production of any gas from the deep-sea blocks will take time and is unlikely to materialize within the planning horizon of 2021.

[13] Towards Revamping Power and Energy Sector: A Road Map, June 2010 by Finance Division, Ministry of Finance, Government of Bangladesh. The generation expansion plan has since been updated regularly with the latest plan calling for generation to be increased to 24,000 MW by 2021 (June 2016).

[14] The estimated coal reserve in Bangladesh is 3.3 billion tons (www.bcmcl.bd), most of which remains unutilized. The Barapukuria coal mine started production in 2006 and now produces about 1 million tons per year, 65 percent of which is used as fuel for a 250 MW power plant. There is considerable public debate over the method of coal mining/extraction; open pit technology will have large-scale resettlement issues in this densely populated country while coal mining has associated health and safety risks along with low productivity due to the geology of coal deposits in Bangladesh. The Government policy is to add coal-fired generation capacity based on imported coal until the domestic coal development issue is settled.

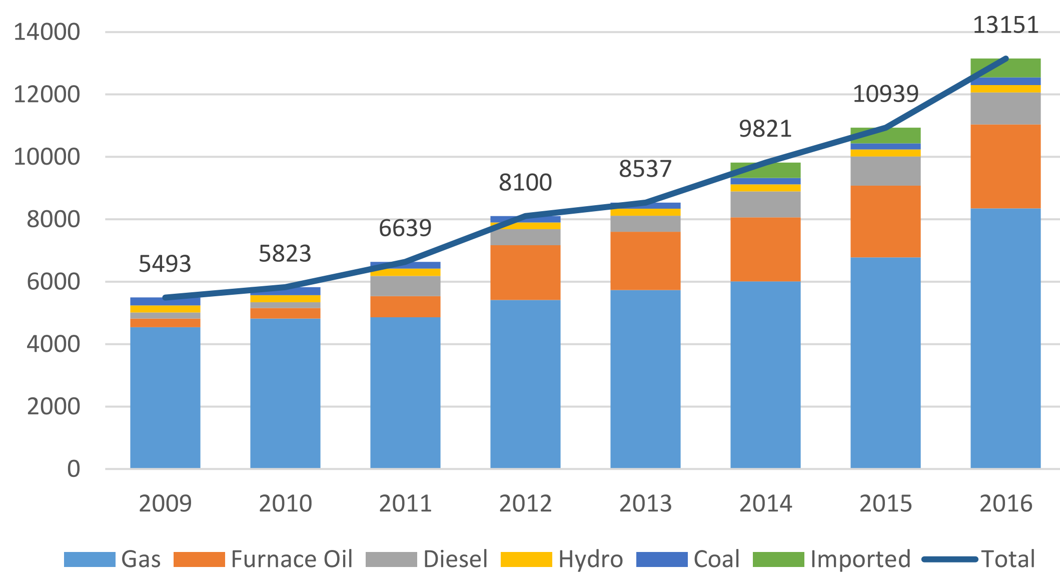
[15] This includes both grid and off-grid (SHSs) connections. About 4.5 million SHSs have been installed in the country, with some of them recently being connected to the grid.

[16] World Economic Forum: The Global Competitiveness Report 2016–2017.

report, Bangladesh was ranked 176 out of 190 economies of the world in 2016 and on the indicator of 'Getting Electricity', it was ranked the fourth lowest out of 190 economies (World Bank 2017b).

13. While liquid fuel-run plants were introduced in 2009 as an immediate solution to the acute shortage of power, this was a relatively expensive alternative to domestic gas-fired plants or even imported coal-fired plants and intended to be an interim measure. However, delays in commissioning large planned gas- and coal-fired baseload plants have resulted in continued dependence on liquid fuels (Figure 2.1). Gas-fired capacity has been added from 2009 to 2016, notwithstanding the impending serious shortage of gas; however, liquid-fuel plants have also continued to be added since low gas pressure is already being experienced in some parts of the gas network. Today, a quarter of total generation comes from liquid fuel-run power plants while natural gas accounts for about 65 percent of power generation and the rest comes from hydro (2 percent), coal (2 percent), and, more recently, imported power from India (5 percent). The liquid fuel-run plants are the most expensive: compared to about Tk 3 per kWh of fuel cost on average for gas-based plants (depending on plant efficiency and based on a price of gas for power generation of US$1 per mcf), the fuel cost from furnace oil and diesel are Tk 20 per kWh and Tk 28 per kWh, respectively. The Government has revised its road map in light of the developments and indicated that LNG will be introduced by 2018 to improve energy security. This implies that the average cost of power generation will rise from Tk 7.51 per kWh in 2016 to Tk 9.25 per kWh by 2020 and over Tk 12.51 per kWh by 2025.[17]

Figure 2.1. Installed capacity by fuel type (MW)



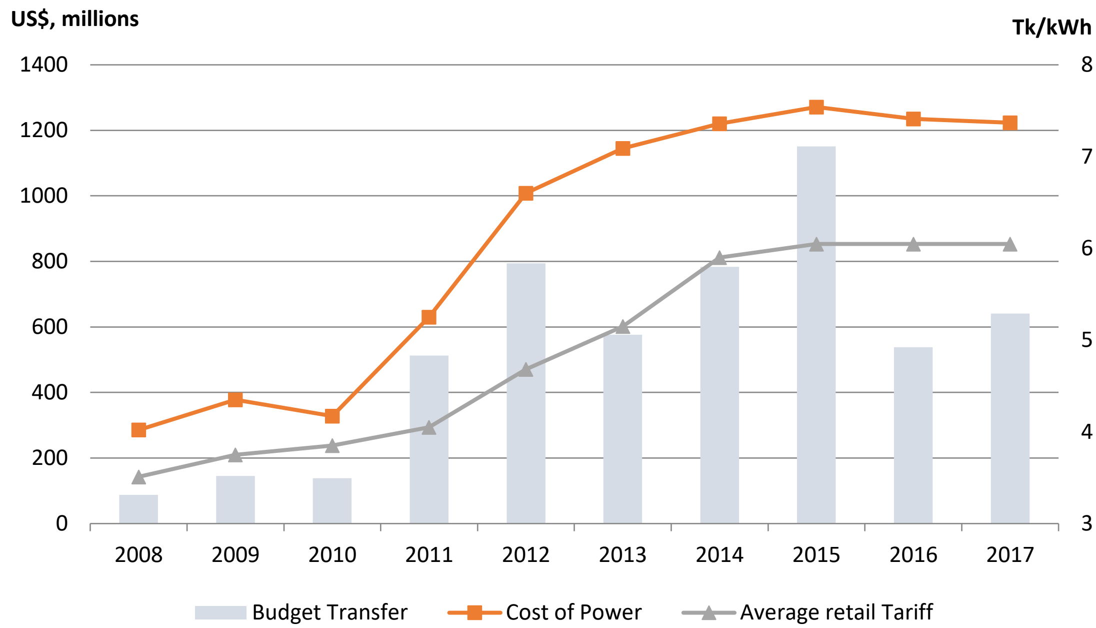
Source: BPDB Annual Reports.

14. Tariff increases have not kept pace with electricity generation costs over the years, resulting in a large financial deficit (that is, difference between costs and revenues) in the sector (Figure 2.2). When the Government introduced liquid fuel-run plants in 2009 for mitigating the shortage in power generation, it decided that the higher costs of these plants should not be fully transferred to consumers as it was a temporary expedient. It was decided to make an annual budgetary transfer, capped at Tk 50 billion (US$640 million at approximately Tk 78 per US$), to the off-taker—BPDB—to meet the short-

[17] US$1 = Tk 80 (Bangladesh Taka).

term ‘additional’ cost due to liquid fuel-based power. A tariff trajectory was planned that would raise the average tariff gradually to be at par with the long-run costs of large baseload plants while the annual budgetary transfer covered the cost of short-term liquid-fuel run plants.[18] The annual budgetary transfer increased from Tk 6 billion (then US$87 million) in 2009 to a peak of almost Tk 90 billion (US$1.15 billion) in 2015 before coming down to Tk 42 billion (US$538 million) in 2016.

Figure 2.2. Sector deficit (US$, millions)



Source: Sadeque and Bankuti 2017.
Note: *2017 deficit figure is the budgeted amount of Tk 50 billion.

15. The prices of fuels (such as HFO and other petroleum derivatives) are administered by the Government. Domestic prices of liquid fuels are not automatically adjusted to the level in the international market although most of the liquid fuel is imported. The deficit in Figure 2.2 is calculated taking into consideration the subsidized cost of fuel used for power generation; the actual deficit would be much higher if the market prices of fuels were taken into account. The budgetary transfer to the BPDB therefore does not reflect the full financial deficit resulting from the reliance on liquid-fuel run plants. It should be noted that the price of natural gas used for power generation is also subsidized, being provided at US$1.05 per mcf[19] to producers, while the Government purchases gas from the international oil companies active in Bangladesh at around US$1.3 per mcf under their PSCs

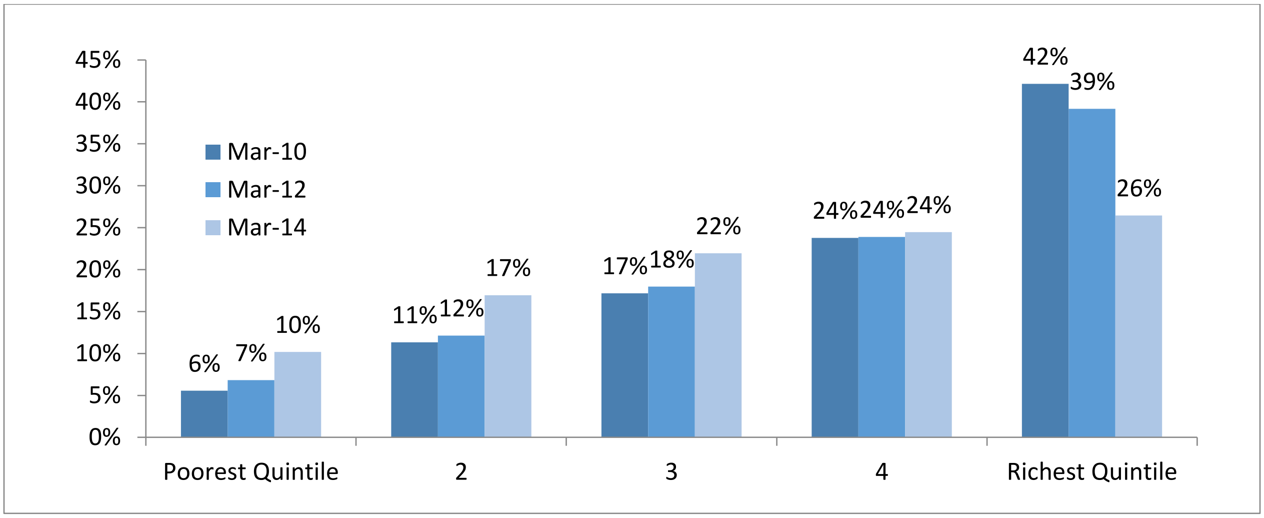
[18] To raise tariffs, utilities are required to submit tariff applications to the independent regulator Bangladesh Energy Regulatory Commission (BERC). The BERC decides on the tariff order following a cost-plus regulation through proper scrutiny of the tariff applications and a public hearing process. Such scrutiny involves reviewing the costs and efficiency of the utilities and only reasonable costs (within the efficiency targets) are included in tariff calculations. To avoid transferring the full cost of liquid fuel-run plants to consumers, the bulk supply tariff (the tariff at which distribution utilities buy power from the off-taker BPDB) is kept below cost and the annual budgetary transfer makes up for the shortfall.

[19] The BERC has issued a tariff order to raise the gas price for power generation to increase by 6 percent effective from March 1, 2017, and another 6 percent effective from June 1, 2017.

(Petrobangla 2015c). The price of natural gas used for power generation in neighboring India and Pakistan in comparison was about US$5 per mcf (as of 2011).[20] LNG sells for around U$8 per mcf[21] in the international market. The projections used in this analysis are based on 2016 subsidized fuel prices; if the cost of electricity were to reflect the true cost of all inputs, the projected cost of electricity and the resulting sector deficit would be significantly higher.

16. The retail tariff has increased by about 60 percent since 2009. The decline in fuel oil prices in 2014/15 has helped reduce the budgetary transfer requirement in the last couple of years. One bright spot is the fact that electricity tariffs are becoming less regressive over time, with the share of subsidies captured by the richest quintile declining, as seen in Figure 2.3.

Figure 2.3. Benefit incidence of electricity subsidies in Bangladesh (through the tariff)



Source: World Bank staff calculations.
Note: Since the 2015 household survey had not been publicly released at the time, this analysis used 2010 household data.

17. It is now recognized that LNG imports will be required to sustain power supply. This will necessitate an increase in overall domestic gas prices, which will have a significant knock-on impact on power prices, prices of goods that use gas, and overall growth, at least in the short term. The need for a significant program of upgrades to investment is another likely cost-push factor. As of end 2017, transmission capacity addition lags generation—there are supply bottlenecks in key commercial corridors (for example, Chittagong - Comilla) and grid security/stability remains a major concern (countrywide blackout November 2014).

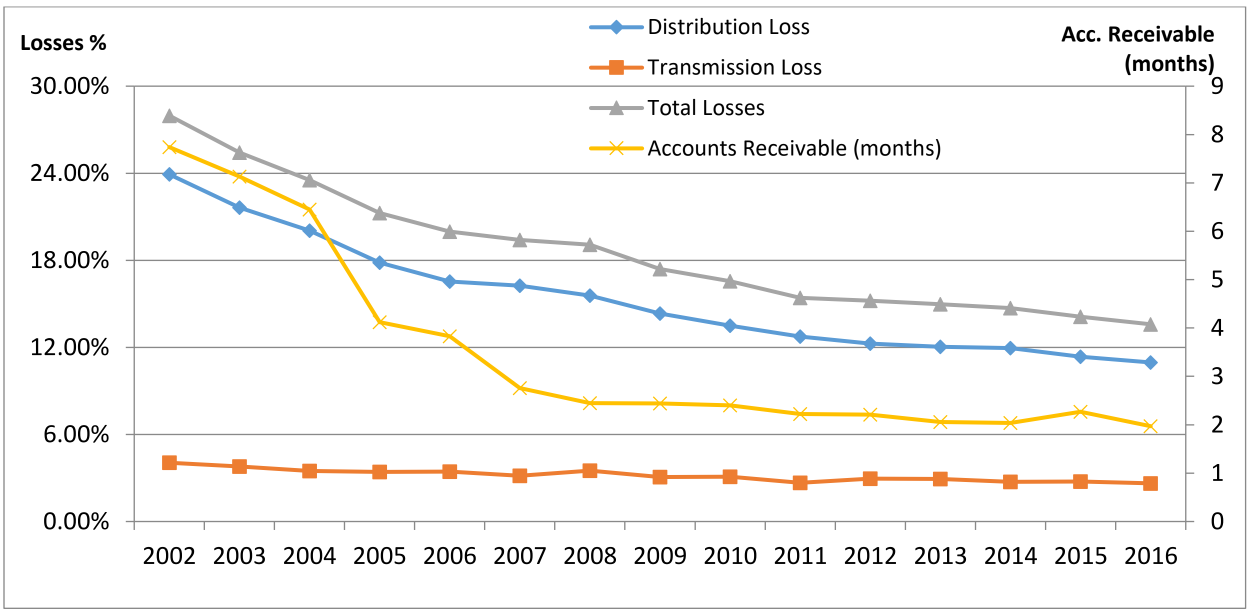
18. Sector structure has evolved from a single vertically integrated utility to a partially unbundled sector with private entry and competition in generation and to a lesser extent in distribution. Till 1996, when the Power Grid Company of Bangladesh (PGCB) and Dhaka Electric Supply Company (DESCO) were carved out of it, the BPDB was the single vertically integrated utility. Over the years, it has been unbundled both horizontally and vertically so that now the sector comprises the BPDB plus several generation companies, one transmission company, and several distribution companies (all of the latter are corporate entities under the 1994 Companies Act). The BPDB operates about half the power

[20] Bangladesh: Tariff Reform and Inter-Sectoral Allocation of Natural Gas: Asian Development Bank, 2013.
[21] The landed price of LNG in India dropped to US$8.64 per mcf in 2015 and has further dropped below US$6 in 2016.

generation capacity in the country while it purchases power from the three generation companies and from the private sector as the single off-taker. The PGCB is the single transmission company, carrying power and receiving a wheeling charge for the power transmitted. It also includes the National Load Dispatch Center. On the distribution side, 72 rural cooperatives (Palli Bidyut Samitis) under the Bangladesh Rural Electrification Board (BREB) distribute about 40 percent of total power supplied in the country; Dhaka Power Distribution Company (DPDC) (19 percent), DESCO (11 percent), and West Zone Power Distribution Company (WZPDCL) (6 percent) distribute about 35 percent, while the rest (about 25 percent) is distributed by the BPDB's distribution zones.

19. Along with sector unbundling efforts and increased focus on addressing technical and commercial losses, overall sector performance has shown improvement with aggregate system losses coming down to half the level of 2002 (Figure 2.4). Distribution losses came down from 24 percent in 2002 to less than 11 percent in 2016 while the transmission losses came down from 4 percent in 2002 to 2.63 percent. Collection efficiency also improved significantly as is evident from the accounts receivable coming down from about eight months of sales equivalent to a little over two months. Among the utilities, the BREB has the highest system losses (11.2 percent) while DESCO has the lowest (8.03 percent).

Figure 2.4. Sector performance



Source: Power Cell.

III. Success in lighting needs to be followed by access to the other benefits of power[22]

20. This section describes the evolution of access to electricity in Bangladesh, the quality of service received by those who have access, and the implications of both for policy. Universal access to power by 2021 is a key goal of the Government, which has accelerated its efforts to extend the grid to all parts of the country and connect consumers to the network, relying on the well-regarded BREB and its system of associated rural electrification cooperatives, the PBSs. Electricity demand in Bangladesh is primarily domestic (53 percent) with industry (28 percent), commercial use (10 percent), and irrigation (7 percent)

[22] This discussion is taken from Durix (2017).

making up the rest,[23] so the focus on electrification, particularly in rural areas, is well placed. The availability of adequate power so that consumers receive high-quality service will be critical to the success of this endeavor.

21. The latest available official data,[24] indicate across-the-board progress in electrification between 2001 and 2011 through a mix of ‘densifying’ existing electrified pockets and extension of network service to new areas. While this has resulted in higher overall access rates, the poor (bottom two quintiles and/or below poverty line consumers) may still not have been reached. Should newer data (from HIES 2015) show continued densification and parallel improvement of availability and reliability, it will be possible to conclude that the poor have benefited from electrification. Preliminary reports from HIES 2015 indicate that by 2015 overall access to electricity had risen to 76 percent, with rural access at 69 percent and urban areas at 94 percent.

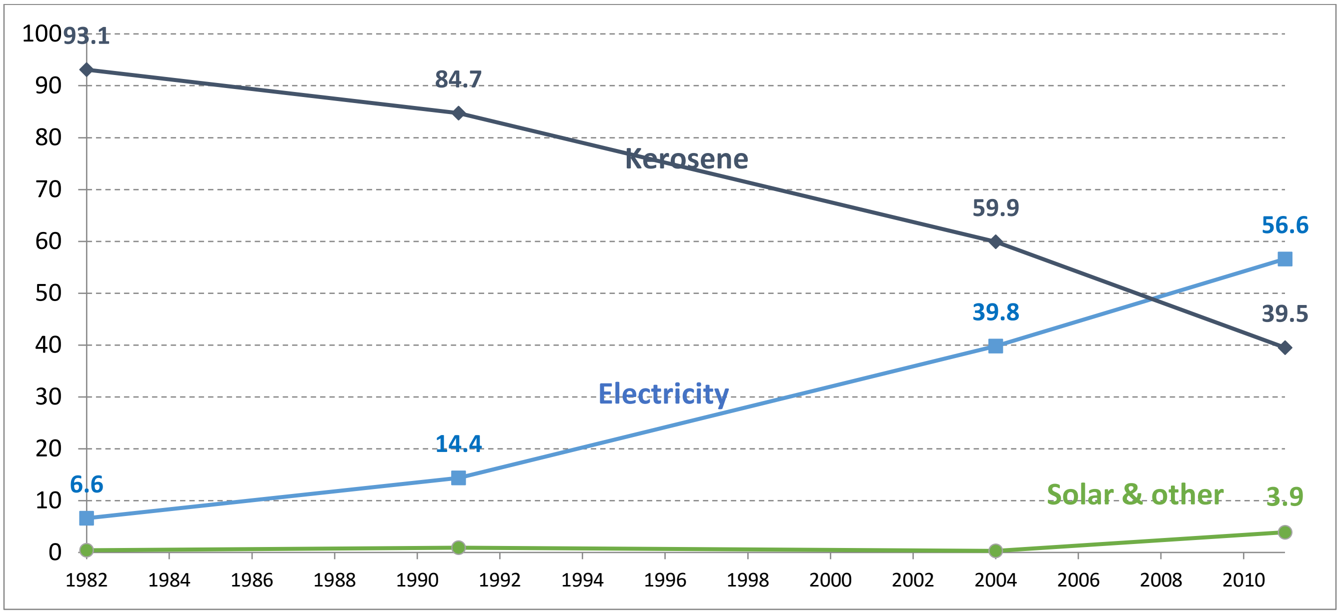
Who receives power?

22. The first application people use electricity for is lighting—in Bangladesh, kerosene is clearly being replaced by electricity as the primary source of lighting over time. However, as shown in Figure 3.1, the switch is relatively recent—it was only in 2008 that the share of electricity users in the population exceeded the share of users of kerosene. The contribution of solar energy starting from around 2004 becomes apparent by 2010 when solar energy shows up in the data as a primary source of lighting (serving 3.3 percent of the population), almost entirely in rural areas (Figure 3.2). The dichotomy between urban and rural access rates is striking—by 2010, rural access was only at the same level as urban access was in 1982.

[23] See Ahmed, Trimble, and Yoshida (2013). Note that industry relies heavily on self-supplied captive power, which is not reflected in these numbers.

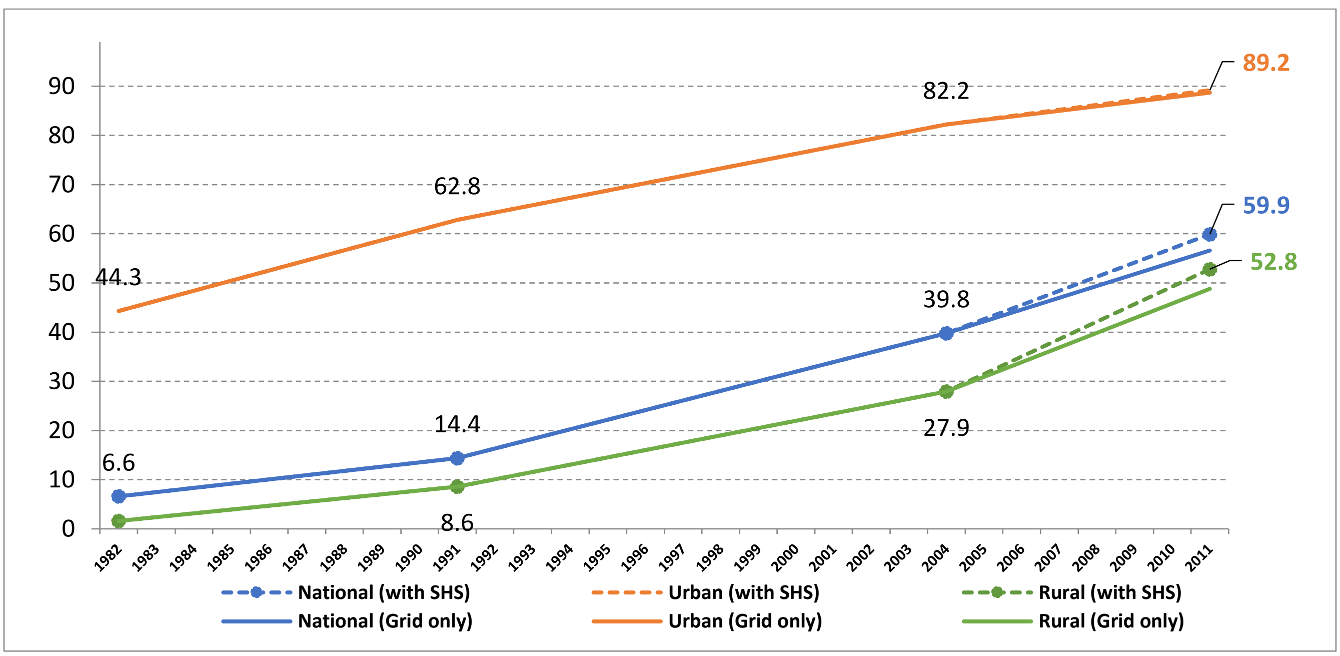
[24] The core data for this note come from (a) The Bangladesh Household Income and Expenditure Surveys (HIES) collected in 2000, 2005, and 2010 and (b) The Bangladesh Population and Housing Census collected in 1991, 2001, and 2011; detailed data from the latest household survey (HIES 2015) have not yet been made available, so these achievements are a bit dated.

Figure 3.1. The evolution of electricity access rates, 1982–2011



Source: World Bank staff calculations.

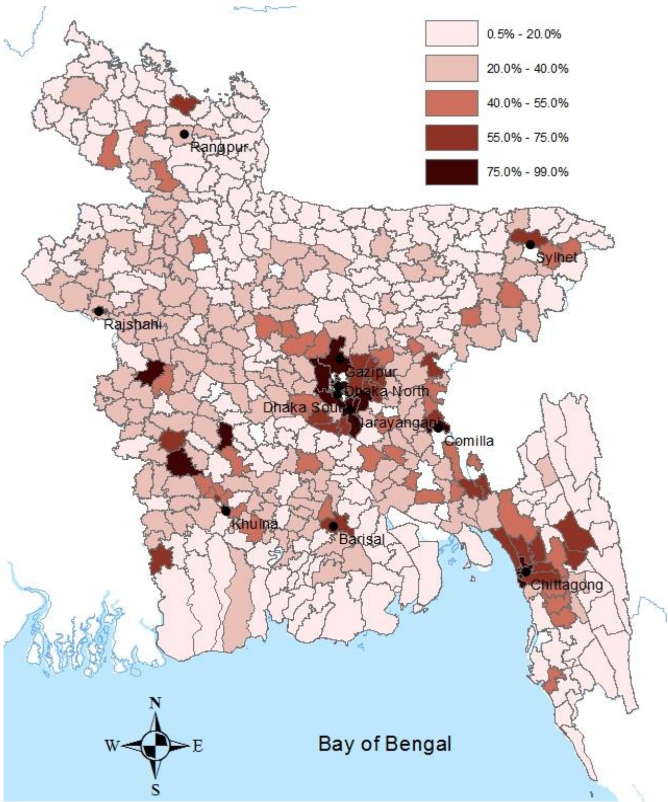
Figure 3.2. Electricity access rate 1982–2011 urban-rural



Source: World Bank staff calculations.

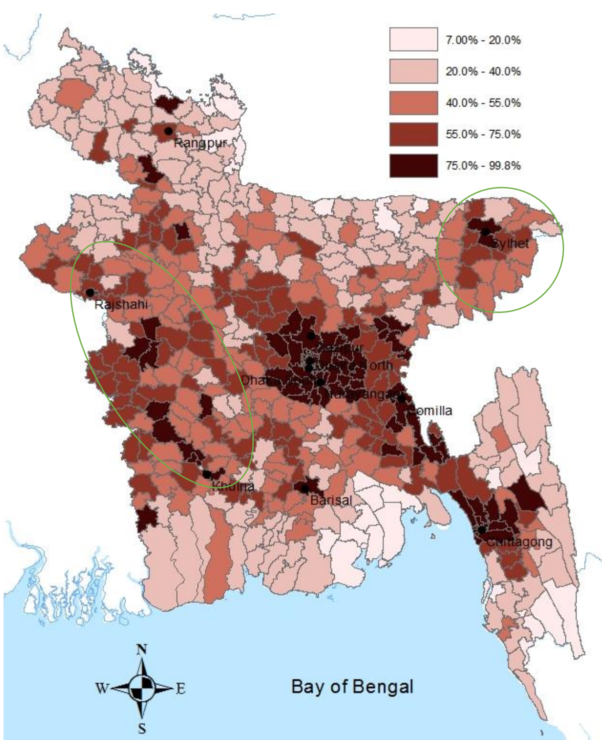
23. The geographic evolution of access at the Upazila (subdistrict) level from 2001 to 2011 is seen in the maps (Figures 3.3 and 3.4) as a steady filling in along existing population centers. Rates of access above 75 percent are seen by 2011 in Dhaka, Chittagong, and the area radiating out from them. While new areas in the northeast and west shows network reinforcement and extension to new areas beyond the urban core, but the far periphery of the country still is underserved.

Figure 3.3. Grid access rates in 2001



Source: World Bank staff calculations.

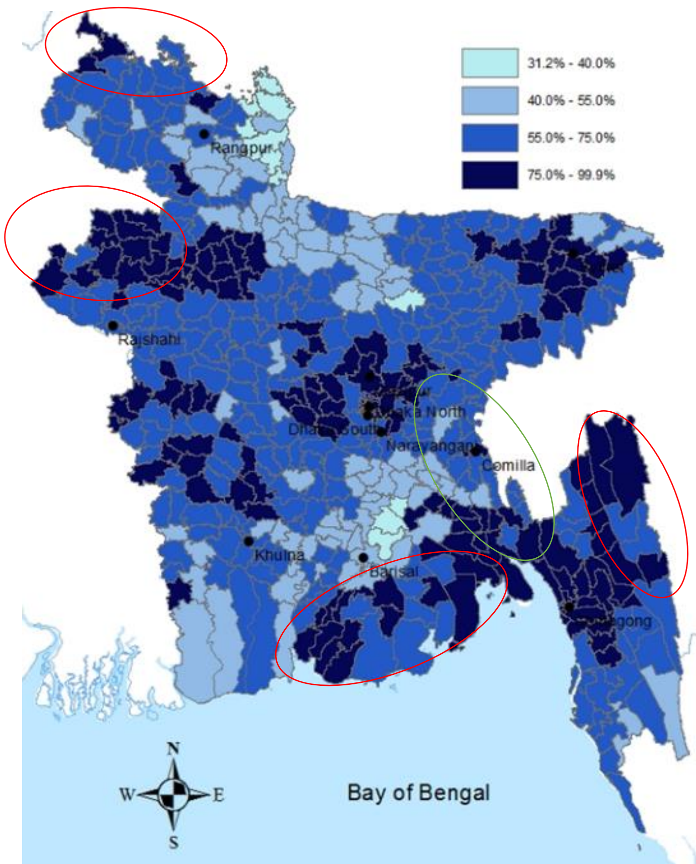
Figure 3.4. Grid access rates in 2011



Source: World Bank staff calculations.

24. Superimposing access on poverty at the Upazila level (Figure 3.5), rates of access are seen to correspond fairly closely with the share of population in the Upazila that is non-poor, except in a few areas. The Dhaka-Chittagong axis (green) shows higher rates of access than the share of non-poor in the population. This is quite reasonable since higher service provision is more likely along an existing network. Lower access than nonpoor rates show several notable 'underserved' areas (red), which could be due to geographic limitations (for example, mountainous terrain). Reviewing the evolution of access between 2001 and 2011, it appears that access rates progressed faster than poverty reduction, meaning that the poor are more likely to have been reached in the area around Dhaka as an outcome of densification in the highly urbanized outskirts of the city. However, the impact of extension is less clear—while access growth overall kept pace with poverty reduction, it fell behind significantly in many peripheral areas.

Figure 3.5. Nonpoor share of the population by Upazila

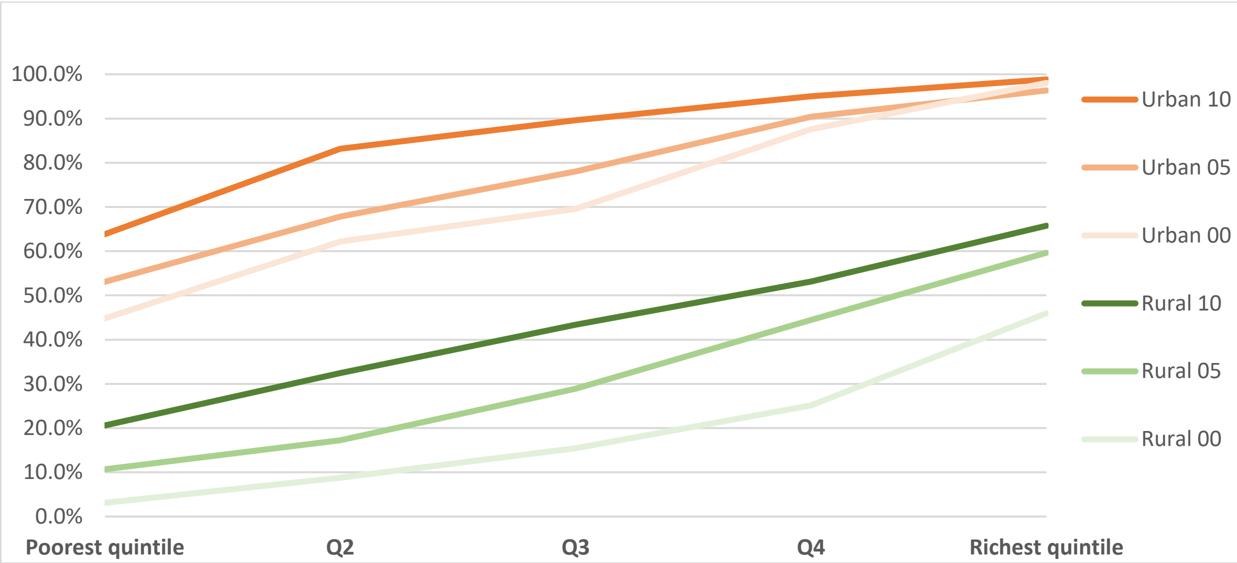


Source: World Bank staff calculations.

25. Figure 3.6 shows the evolution of access by income quintile from 2000 to 2010. Access rates are consistently higher in urban areas than rural but even Q5 (richest) access in rural areas in 2010 was lower than Q1 levels in urban areas. Access in rural areas is also found to be 20 percentage points higher for households which receive remittances, pointing to it being an issue of affordability. Overall, it is clear that reaching the urban non-electrified population is not a technical challenge but that specific funding

mechanisms may be needed to reach the bottom two quintiles. Addressing the access problem in the bottom two quintiles in rural areas is likely to be more challenging on both technical and financial grounds.

Figure 3.6. Access by quintiles, urban-rural in 2000, 2005, and 2010



Source: World Bank staff calculations.

Quality of supply

26. Approximating the quality of supply by using proxies such as ownership of appliances and self-reported hours of availability from the Bangladesh Population and Housing Census of 2011, it appears that in 2010,

- Only 4 million households (12 percent) *used electricity* in a manner consistent with supply at a level of reliability and adequacy such that a refrigerator could be used, let alone other appliances usually associated with grid electricity). Most of those electrified used at most a light, television, and fans; and

- Those with connections had *power in the wires* on average less than 14 hours a day; urban areas had 16 h while rural areas had 12 hours.

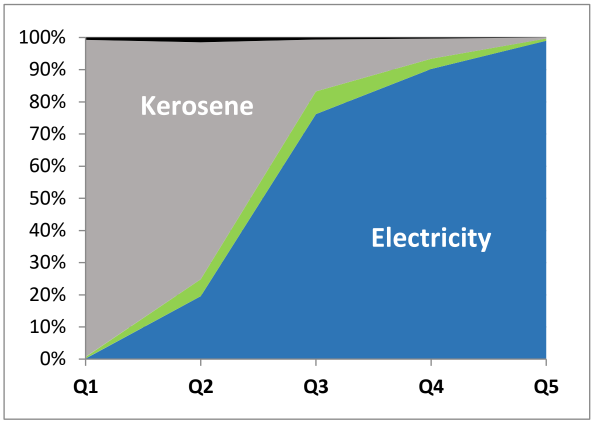
27. The poorest not only disproportionately lacked access to connections but also, when connected, enjoyed lower levels of services delivered (mostly equivalent of basic lighting).

28. Kerosene remains the primary lighting solution for the two poorest quintiles in 2010, in exact reverse proportion to the two highest quintiles (Figure 3.7), indicating that the 39.5 percent of households still using kerosene in 2010 (Figure 3.1) are also for the most part in the bottom 40 percent of the income distribution. *The fact that average access is 30 percent for the bottom quintile of the population (rural and urban combined) but kerosene still remains the primary lighting source for 95*

percent of these households point to the intermittent availability and quality of power, particularly in rural areas.

29. While on a binary basis Bangladesh had an access rate of 56 percent in 2010, that is, 19 million out of the country's 33 million households benefited from electricity, a more nuanced picture emerges using proxies for the quality of service received. A decomposition of access, such as the one developed by the Multi-Tier Framework of the Sustainable Energy for All (SE4All) initiative, shows the following:

Figure 3.7. Lighting by quintile, 2010



Source: World Bank staff calculations.

- About 4 million households receive only basic levels of electricity service, limited to lighting and some very low wattage appliances (cellphone charger and so on) - Tier 1 equivalent.

- About 12 million households receive services one level above basic lighting and cellphone charging services, that is, they can cool off with a fan (the most demanded feature after lighting) and be entertained with a TV - Tier 2 equivalent.

- Only about 4 million households experience a level of electricity supply/service that enables refrigeration (equivalent to Tier 3) and at highest tiers/and income levels, cooling and other appliances.

- Rural households on average have a basic (lighting and cell phone charging, that is, Tier 1 equivalent) level of service. Half of the rural households have no service, 20 percent get by with basic lighting, and additional services are only enjoyed by 30 percent (Tiers 3+).

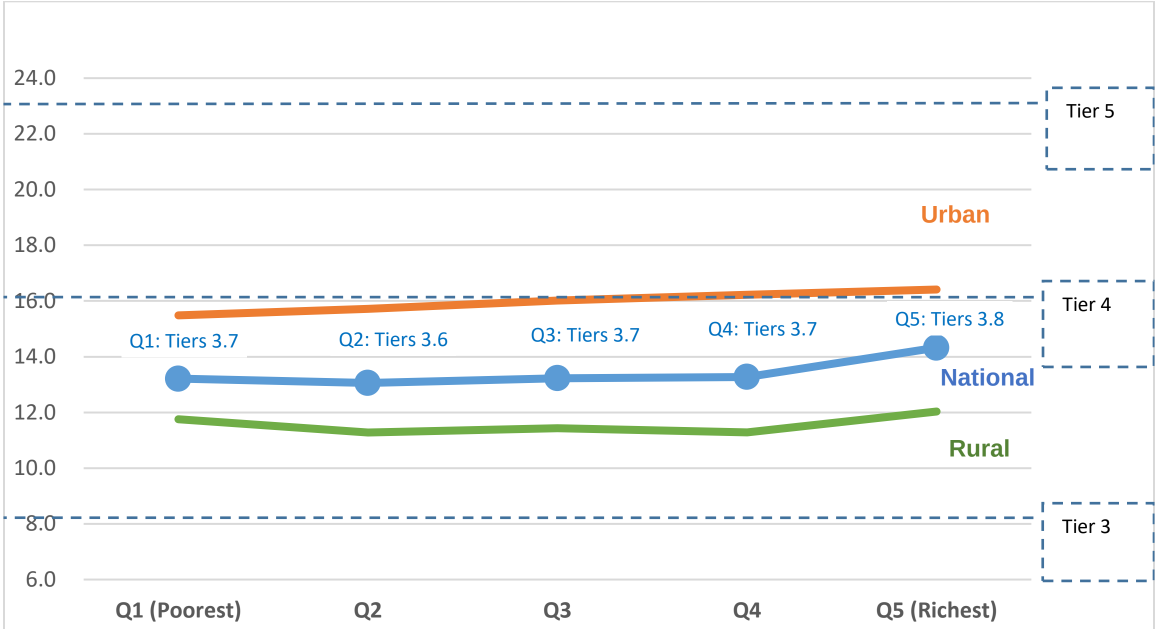
- Conversely, 84 percent of urban households have service that goes beyond lighting (Tier 1) and includes fans, TV, and other appliances to exceed Tier 2 equivalent of service.

- Unreliability of power supply is widespread, with less than 1 percent of households declaring that they receive 23+ hours a day (Tier 5 availability).

- Of those electrified, only 40 percent have electricity for more than 16 hours a day and 20 percent had it for less than 8 hours.

- For electrified households, there appears to be a fairly stable 4-hour availability difference between urban and rural households with negligible variation across quintiles.

Figure 3.8. Hours of electricity in 2010 by quintile and location (only electrified households)



Source: World Bank staff calculations.

30. Unofficial numbers (for example, Sadeque and Bankuti 2017) indicate that in 2017 access has improved to 80 percent (grid and off-grid), in part due to the vigorous extension of the grid in rural areas over the past two years. Still, as shown in this section, a binary definition of access is not consistent with realizing the full benefits of electrification. It is clear that there is an urgent need to increase power in the system to make sure that the newly connected are assured an adequate supply of reliable and affordable electricity. The importance of harnessing all sources of electricity and minimizing the cost of doing so is self-evident. The following section presents the options for Bangladesh as it looks toward achieving universal access by 2021 while being conscious of the importance of managing its environmental footprint and likely contribution to climate change.

IV. What are Bangladesh's choices in terms of sources of power?

31. This section discusses Bangladesh's resource endowments and its options for generating power. As Bangladesh's economy and population continue to grow, the electricity sector has faced difficulties in meeting the rising demand for power and in keeping costs down. The availability of domestic gas is declining and at existing rates of exploitation, known onshore gas reserves are projected to be nearly depleted by 2030. Bangladesh has invested in relatively expensive oil-fired power plants to supplement gas generation in recent years, resulting in upward pressure on the price of power. Economic growth and social development will suffer if adequate and reliable energy supply at an affordable price cannot be ensured in the near future.

32. The difficulties occasioned by a singular focus on domestic gas-fired generation in the past have led the Government to pursue fuel diversification as a conscious part of its strategy for supplying power to all. Power trade is an important part of this equation. Also, it is moving to exploit Bangladesh's potential for both wind and solar power generation; the latter, however, is limited due to the lack of vacant/fallow land while resource assessment for wind is still ongoing. Finally, as discussed in this section, an additional challenge faced by Bangladesh in its effort to build sufficient power generation capacity is the need for plans and targets for capacity expansion to explicitly take into account the likely impact of climate change on infrastructure.

Options and constraints suggested by least-cost planning for sector expansion[25]

33. Generation capacity has grown significantly over the last 10 years, starting from 5 GW in 2005 to around 13 GW in early 2017 (excluding captive power). This includes about 2 GW of 'rental' power stations, mostly run on fuel oil/diesel, and 8 GW of gas-based capacity (although an acute shortage of domestic gas has rendered about 1 GW of this capacity idle). There is also a new bid under process to acquire an additional 1 GW of HFO capacity.[26]

34. To meet the 'Government Policy' target of 33 GW (peak demand) in 2030, the PSMP of 2010/11 identified a capacity requirement of 40 GW by 2030[27] (of which 24 GW is anticipated to be met with domestic coal). This implies a threefold increase in capacity, that is, maintaining the same growth rate achieved in the last 5 years, over the next 15 years. It is estimated that this would require US$40 to US$60 billion in new capital expenditure (CAPEX), a significant part of which would need to be incurred over the next decade.

35. Over the years, since approval of the 2010 PSMP, actual capacity addition has fallen well short of the target. Domestic coal capacity has been slow to come online for environmental, logistical, and financial reasons:[28] none of the coal projects identified under the PSMP have been completed to date

[25] The foundational pieces for this section are Chattopadhyay (2014) and Nikolakakis and Chattopadhyay (2015).
[26] Ten units of 100 MW, per the BPDB bid announcement: http://www.bpdb.gov.bd/bpdb/index.php?option=com_content&view=article&id=383.
[27] Allowing for ~20 percent reserve margin. The installed capacity in 2016 exceeded 10 GW but the maximum demand met was around 7.5 GW, that is, capacity is about 33 percent higher than peak demand.
[28] The envisaged exploitation of domestic coal has been hamstrung by the lack of movement on a national policy on coal and significant social opposition. The construction of a coal-fired power plant in Rampal has raised environmental concerns on account of its proximity to the Sundarbans mangrove forest. Another challenge for the development of new coal power infrastructure in Bangladesh relates to the level of investment required and the need to mobilize financing as well as take into account climate effects on power system infrastructure (World Bank 2017).

and only 250 MW of domestic coal capacity was operational in 2017. The least-cost analysis underlying the 2010 PSMP was updated for the 2016 PSMP[29] and takes cognizance of this performance. It retains the use of coal but also introduces the import of LNG as a key complement to other constituents of the fuel mix. Thus, going forward, baseload electricity generation is expected to rely on either expanding (onshore/offshore) domestic gas production or some form of imported energy—coal, LNG, or imported electricity.

36. In addition to CAPEX (varying between US$40 and US$60 billion), operating expenditure (OPEX) to purchase imported fuel/electricity is significant for all these options. LNG is three to five times more expensive than domestic gas, which costs US$1.35 per mmBTU. It is possible that domestic gas production could be expanded through exploration and new gas field development, including offshore development, though that is quite uncertain at this stage. New offshore gas is also likely to be at least two to four times more expensive than the cost of domestic onshore gas. Moreover, if climatic factors suggest a reconsideration of plant siting decisions, and if politically acceptable sites cannot be found, supply alternatives, such as renewables and power imports, at levels higher than those considered in the 2016 PSMP, will need to be considered.

37. Given that environmental concerns have hindered the implementation of the 2010 PSMP, it is surprising that such effects are not well-integrated into the least-cost methodology applied to the latest PSMP. Bangladesh lies in Asia's largest and the world's most densely populated delta and is highly vulnerable to climate change, with the country's power sector particularly at risk on account of the potential impact on the efficiency of power generation of a higher ambient temperature, a rise in sea level, increased salinity of water resources, drought, and frequent flooding. Capturing the risks of flooding and other phenomena traceable to climate change should be a priority for planners (World Bank 2017a)

38. In view of the logistical challenges of building necessary infrastructure for generation, transmission and fuel imports, a least-cost planning study for 2014–2030 was carried out by the World Bank (Nikolakakis and Chattopadhyay 2015) with the objective of assessing the CAPEX/OPEX, carbon emissions, and timing implications of following the four main power generation development paths to 2030 that sector policy makers in Bangladesh have considered in recent years (that is, LNG, cross-border power imports, imported coal, and expansion of domestic gas production). The study used a linear programming model that minimizes total system costs (including capital, fuel and other operation and

[29] Power System Master Plan 2016. Power Division, Ministry of Power, Energy, and Mineral Resources, Government of Bangladesh, Dhaka. Accessible at: http://powerdivision.portal.gov.bd/site/page/f68eb32d-cc0b-483e-b047-13eb81da6820/Power-System-Master-Plan-2016.

maintenance costs, and the cost of unserved energy) to meet specified demand. Key assumptions for the analysis are laid out in Chattopadhyay (2014).[30]

39. Since the study was completed, the sector's operating and investment environment has evolved, starting with a significant drop in oil and gas prices from 2014 to 2015 that has made LNG more competitive with coal. In addition, plummeting costs of renewables due to a combination of maturing technologies, scale economies, and competition, and a growing global consensus on taking into account the social cost of carbon in investment decision making, have resulted in increased competitiveness of renewables in relation to gas- or coal-based generation. These aspects have been incorporated in recent updates and least-cost analyses carried out by the power sector planning team at the World Bank,[31] and the results are reported here to provide a more complete picture of the options facing Bangladesh today.

(i) Least-cost plan - unconstrained

40. Insights from the unconstrained scenario analysis carried out in 2014/15 are as follows. Lowest average system costs (compared to other scenarios) result from an expansion of domestic gas-based power generation. This would mean greater self-reliance than other options but, given the limited availability of domestic gas, it would need to be supplemented by other fuels. Coal has the next lowest average system cost but has high CAPEX (it would require about US$46 billion in new investments, or an average of US$3.6 billion in spending per year, including the cost of handling infrastructure for imports), requires vacant land for installing greenfield plants, and would result in high CO_2 emissions. The average system cost of imported power (as of end 2017 coming only from India) is marginally higher than the system cost under the coal scenario but the imported power scenario has considerably lower CAPEX requirements while also keeping local CO_2 emissions to the minimum.[32] It is estimated that imports (from Nepal, Bhutan, and India) could maximally reach 12 GW, meaning that supplemental new capacity would be needed in this scenario. Finally, while LNG has low CAPEX requirements and, like domestic gas, results in lower emissions than coal, the total cost is the highest of the four options—reflecting the high

[30] Key assumptions include the following: (a) in the 'High Demand' case, peak demand is projected to be 33 GW in 2030 for consistency with 'Government Policy'; under the 'Base Case', peak demand is projected to be a more realistic 25 GW in 2030 (as opposed to the original 33 GW target) because growth in capacity by 2014 was far short of the target and a 25 GW peak demand target corresponds to a 6 percent per year GDP growth rate, according to the PSMP 2010; (b) acknowledgement of implementation constraints, by directly setting limits on the maximum capacity of coal (7–24 GW)/gas (domestic: 7–10 GW, LNG: 10 GW)/imports (3–8 GW) that can be added over the period or, indirectly, by limiting the total capital available to the sector as a whole; (c) levelized cost of electricity is based on capital cost of a large-scale (1,000–1,300 MW) coal project in Bangladesh (including coal import and handling facilities) being US$2700 per kW (from BPBD); power imports up to 12 GW estimated to cost US$200 per kW on average (based on the cost of the existing interconnector, the estimated cost of transmission and grid strengthening for India-Bhutan trade, and so on); delivered imported coal priced at US$5.50 per mmBTU in 2014, rising to US$7.50 per mmBTU in real terms by 2030; delivered LNG price to power stations in Bangladesh US$15–16.50 per mmBTU over the same period. Domestic gas prices start at US$1.2 per mmBTU in 2014 but reach US$4.30 per mmBTU in 2019. The price of new off-shore domestic gas starts at around US$5.5 per mmBTU in 2014/15 and rises to US$10 per mmBTU by 2030; (d) carbon prices start from US$30 per ton of CO_2 in 2015 and increase to US$80 per ton of CO_2 in real terms (constant US$ of 2014) by 2050; (e) high coal scenario is one in which coal-based capacity can be developed at a rapid rate of up to 5 GW per year.
[31] These papers were prepared by a team led by Debabrata Chattopadhyay outside the purview of the program of energy sector analytic work on Bangladesh.
[32] Imported power is assumed to have zero carbon intensity—any carbon emissions associated with imports are attributed to the exporting country.

level of global oil and gas prices at the time the study was conducted—while also implying reliance on a global commodity with volatile prices.

41. Based on these findings, the study recommended a balanced combination of LNG, coal, and imports (rather than the coal heavy expansion path proposed in PSMP 2010), which is aligned with the revision to the 2010 plan incorporated in PSMP 2016. The study also pointed to the rehabilitation of existing inefficient gas plants and investment in enhancing EE as substantially cheaper (although limited in scope) options in the near term than new investment to improve the demand-supply balance.

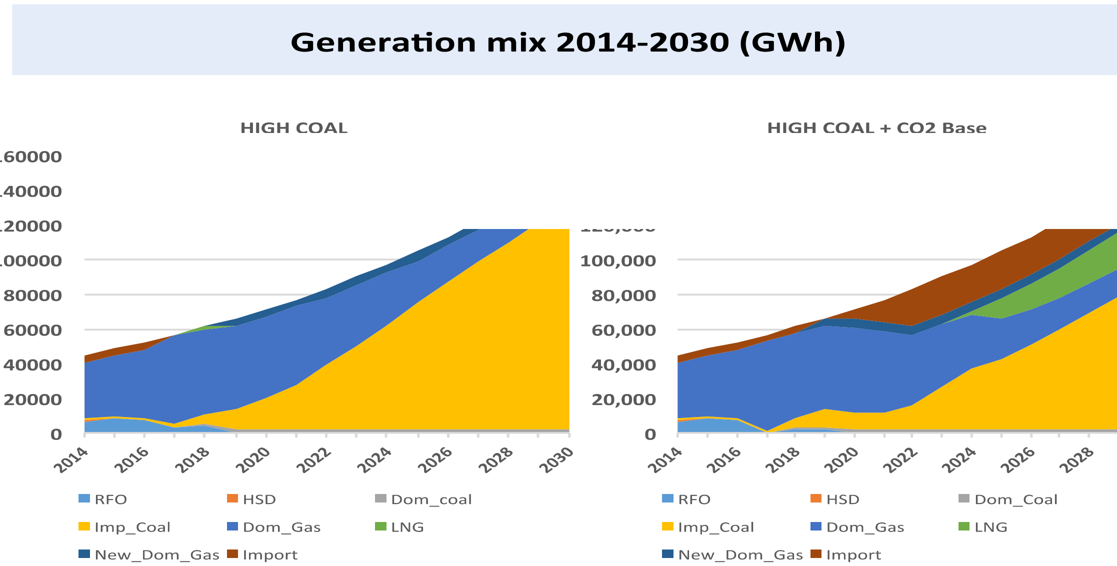
42. A key point to note is that this least-cost analysis does not impose reality checks such as an upper bound on the financial resources available for investment in coal-fired power plants, take into account the limited availability of greenfield sites with a low risk of coastal/riverine floods for locating new thermal power plants, apply a shadow price of carbon to account for increased emissions, or acknowledge increasingly competitive renewable energy (and its integration into the system).

(ii) Least-cost plan - implementing a shadow price of carbon

43. The least-cost planning study was updated to implement guidance on the base case price path for CO_2 suggested by the World Bank (namely, starting from US$30 per ton in 2015 going up to US$80 per ton by 2050). Pricing CO_2 emissions leads to a significant increase in the average system cost of coal-fired generation under the 'high coal'[33] scenario for addition of new capacity. This is despite the fact that CAPEX declines under this scenario because the price on emissions shifts fuel preference away from coal to LNG (savings accrue from the fact that the large installed base of gas capacity means that new investment to utilize LNG is avoided, at least initially). As seen in Figure 4.1, the inclusion of a carbon price results in coal losing its overwhelming dominance in the generation mix for Bangladesh, with LNG and imported electricity becoming competitive alternatives (even without taking account of the decline in LNG prices since 2015). The effects are magnified at higher prices for CO_2, resulting in even earlier entry of LNG into the generation mix and a larger scale of power imports. While the average system cost is higher, CO_2 emissions are significantly lower than in the unconstrained least-cost scenario.

[33] 'High coal' is a scenario in which coal-based capacity is developed at the high rate of 5 GW per year. For more details, see Chattopadhyay and Nikolakakis (2015a).

Figure 4.1. Fuel mix of 'high coal' scenario with and without a price on CO_2



Source: World Bank staff calculations.

44. Further analysis shows that not only would the 2010 PSMP 'Government Policy' scenario of 24 GW coal capacity by 2030 require capital investment of about US$46 billion, this would also require a minimum of 20 greenfield sites in this densely populated country, posing a significant challenge in terms of land acquisition. Chattopadhyay et al. (2016) have calculated that land limitations mean that less than 10 GW of coal-fired capacity can be built in flood-safe zones, with additional capacity coming under increasing risk of flooding (Chattopadhyay et al. 2016). As shown earlier (Chattopadhyay 2014), the discounted system cost of a generation mix with significant power imports (12 GW, which assumes the maximum potential that has been discussed in policy circles, including from Bhutan, Nepal, and northeast India, materializes) is only marginally higher than that of the option heavy in coal. The import option, however, requires substantially lower capital spending and avoids the risk of flooding around new plants in the country. Thus, power imports should be a critical part of the generation mix and, to the extent to which limited capital or lack of flood-safe sites prevent coal plants from being built, imports can supplant imported coal-based generation in the country.

45. Chattopadhyay (2017) addresses the impact on the use of coal of lower LNG prices as well as a shadow price of carbon. Assuming a long-term LNG price of US$7 per mmBTU for Bangladesh, the price of CO_2 at which LNG and coal generation costs are equal,[34] that is, the break-even price of CO_2, is found to lie between US$38 and US$45 per ton, depending on the cost of capital, as shown in the annex. Specifically, the CO_2 breakeven price is around US$42 per ton for the base case of 8 percent Weighted Average Cost of Capital (with prices of US$3 per mmBTU for coal and US$7 per mmBTU for gas, that is, a fuel price differential of US$4 per mmBTU) but will drop to about US$20 per ton if the fuel price differential is US$3 per mmBTU and rises to US$63 per ton for a differential of US$5 per mmBTU.

[34] This is a function of CAPEX, weighted average cost of capital and relative price of gas versus coal. Relative fuel prices are key to this calculation. At US$6 per mmBTU for LNG and US$4 per mmBTU for coal (a relative fuel price gap of only US$2 per mmBTU), LNG-based generation is slightly cheaper than coal, that is, the breakeven cost of CO_2 is negative.

46. It is evident that at a shadow price of carbon within the ranges being considered by the international community today, LNG would be the fuel of choice to supplement imports in the fuel mix for Bangladesh as long as the price differential with coal remains relatively narrow, as is projected to be the case for the next decade.

(iii) Least-cost plan - incorporating renewables

47. Bangladesh's NDC[35] has the following particular objectives relating to renewables: increase penetration of wind power (specifically, install 400 MW of wind generating capacity by 2030) and implement 1,000 MW of utility-scale, that is, grid-connected, solar plants, to diversify the existing electricity generation mix. The 7th Five-Year Plan (2016–2020) called for a 10 percent share of renewables in the generation mix by 2020, which has been calculated to translate into the installation of approximately 4.2 GW of solar generation capacity (Bankuti, Chattopadhyay, and Song 2017).

48. Renewables—especially utility-scale solar—have become more cost competitive in recent years as the cost of solar PV capacity has dropped to US$1.0–US$1.5 per watt and continues to decline. Solar has negligible fuel costs, so investment and financing costs are the critical factors in determining the cost of generation and its ability to match other sources. Besides this, the price of gas in Bangladesh is anticipated to increase as LNG imports supplement domestic production over time, putting upward pressure on the cost of power generation and thus increasing the likelihood of solar being competitive.

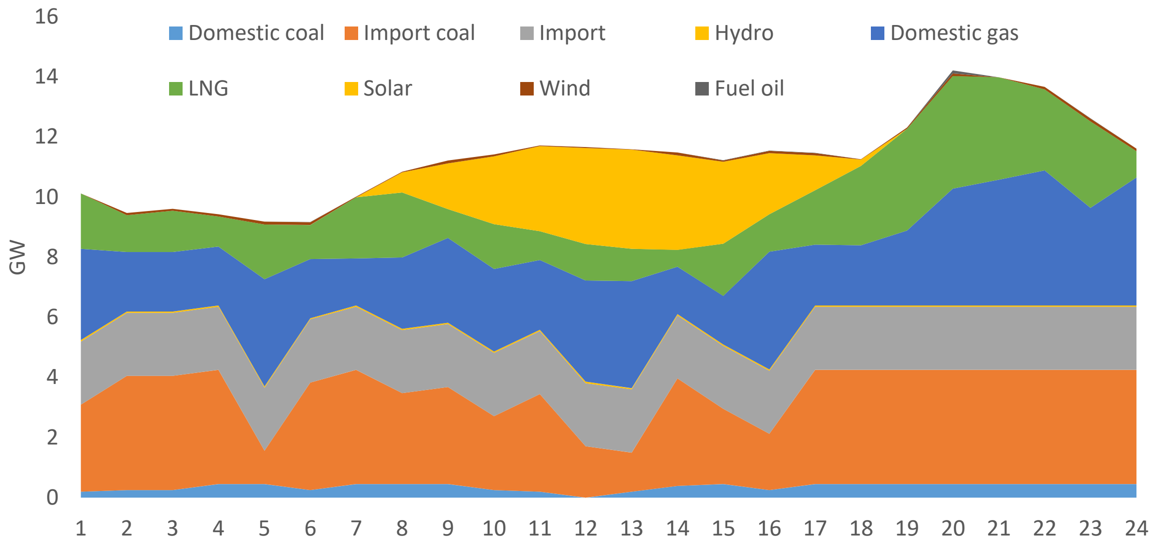
49. The least-cost planning study has been updated to analyze the grid integration of renewables, in line with the above targets (installing 4,200 MW of solar and 400 MW of wind capacity) (Bankuti, Chattopadhyay, and Song 2017). For solar to be economically viable in Bangladesh, its generation cost would have to drop below the projected system cost of US$¢6.59 per kWh in 2025. At a 6 percent cost of financing, the authors calculate that a feed-in tariff of 7c per kWh would enable immediate deployment of solar once solar generation costs drop to that level. Worldwide, competitive procurement through auctions has led to bids significantly below these levels in the Middle East and recently in India, so there is significant potential for solar costs to decline in Bangladesh. An increase in the price of LNG/gas or a reduction in the cost of financing will both make the case for solar more compelling.

50. Apart from the substantial up-front cost of renewable technologies, the main challenge with incorporating intermittent or variable sources such as solar or wind into the generation mix is ensuring that the system is able to instantaneously balance supply and demand when there are fluctuations in supply. Overall, the following aspects need to be addressed: (a) need for fast response or spinning reserves to increase system flexibility and ability to deal with the variability of solar/wind, (b) upgrades to the transmission and distribution system to permit it to absorb variable power, and (c) automated system control to ensure adequate primary response to cover requirements. The study finds that the existing plans for large-scale generation expansion and associated expansion of the transmission network will enable the grid to accommodate 4.2 GW of solar and 550 MW of wind capacity.[36]

[35] http://www4.unfccc.int/ndcregistry/PublishedDocuments/Bangladesh%20First/INDC_2015_of_Bangladesh.pdf.

[36] Even in the absence of renewable generation capacity, spinning reserves are projected to grow to an adequate level by 2025 but making this capacity available to balance renewables will be costly in terms of deviations from merit order dispatch and the need to compensate generators for making the capacity available.

Figure 4.2. Hourly dispatch of power in 2025



Source: World Bank staff calculations.

51. The study demonstrates that the inclusion of solar and wind in the generation mix reduces total carbon emissions by 2 million tons per year by 2025 with the reduction coming mainly from the displacement of fuel oil and some gas generation during peak hours of solar generation as can be seen from the expected hourly dispatch of power in Figure 4.2.[37]

52. To summarize, the PSMP proposal to develop significant coal capacity is likely to need recalibration once the limited number of flood-safe sites suitable for power plants, the limited availability of fallow land, and the shadow price of carbon are taken into account. The drop in the price of renewables has also dented the projected market share of all fossil fuel technologies, including coal. Because the option of power imports increases climate change resilience and would also allow excess generation from solar/wind in India to be imported, cross-border power trade is an option that should be accorded an even higher priority than hitherto.

(iv) Key messages from least-cost planning exercise

53. The exercise emphasizes the utility of an integrated analysis that considers all power supply options but that includes realistic/practicable limits on them. This results in a recommendation for balanced development of the Bangladesh energy system using a diversified fuel mix that includes power imports as well as a mix of other fuels and renewables. Such a mix is not only likely to face fewer implementation delays/hurdles (extrapolating from the checkered track record of project implementation in Bangladesh) and thus be less risky than a more extreme choice but is also more affordable in terms of investment and system costs and associated implications for tariffs. Finally, a diversified mix enhances energy security for Bangladesh. In conclusion, the study suggests the following:

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[37] Not addressed in this analysis is whether there is adequate land available for solar PV installations and thus, what could be the full potential of solar; also, rooftop or floating solar installations have significant potential that is only now being exploited.

- **Energy efficiency measures** can help preserve limited domestic gas and reduce reliance on oil, thus lowering overall system costs if an action plan to target specific end-use sectors is implemented, and concerted action taken by the utilities, regulators, and customers, in line with the Government's Energy Efficiency Master Plan.

- **Climate-associated risks and environmental concerns** need to be integrated into the least-cost methodology of planners. The global community, including financiers, is moving to a shadow price of carbon that will likely make coal-fired generation uneconomic. While natural gas is recognized as a transition fuel for the coming decades, Bangladesh needs to put in place incentives to use gas efficiently, minimize system leakages, and gradually maximize the use of non-fossil sources (including imports) to minimize negative climate impacts. The opportunity to avoid being locked into coal for decades to come needs to be grasped.

    - **Large-scale power imports to complement coal/gas**-based generation have significant potential and must be an integral part of power system and transmission expansion planning.

    - **Over time, the potential of renewable technologies is likely to increase with technological change and competitive procurement.** The amounts projected to be produced in the near term can be absorbed by the system under expansion plans in place in 2017.

    - **Investment in domestic gas exploration** should be prioritized so that electricity generation using domestic gas can be maintained or even increased.

    - **LNG has a role to play** given the extensive gas-based capacity that is already in place and the shortage of domestically produced gas, which has steadily increased reliance on oil-based generation. In fact, LNG is likely to remain in the generation mix over the long term in view of the limited alternatives, especially for peaking generation because it is cheaper than oil-based peaking.

Increasing imports of power

54. The potential role of increased regional electricity trade in helping meet the demand for power and in helping reduce reliance on fossil fuels, particularly coal, in South Asia is well understood (see, for instance, Toman and Timilsina 2017). The large potential gains from increased regional power sector cooperation and trade emanate from the existence of significant seasonal complementarities in power demands across the region, meaning that countries with lower demands relative to capacity could cost-effectively sell power to countries with higher demands. In addition, there are large hydroelectric resources in the region that can only be developed profitably if there is access to a regional market.

55. While it would require significant new investment in expanding cross-border transmission interconnections,[38] the potential benefits over 2015–2040 from regionwide cross-border electricity trade in South Asia are estimated to amount to about US$226 billion (US$9 billion per year) or US$94

[38] Long-term contracts are needed to make investments in generation and transmission infrastructure financially viable and so address the physical infrastructure constraints that can be a critical barrier to trade.

billion in present value terms, with a benefit-cost ratio of 5.3 (Timilsina et al. 2015).[39] In other words, the present value of fuel and other operating cost savings from expanded trade exceeds the present value of the net increase in generation and interconnection investment costs by more than five to one. Hydropower is an important source of the benefits from trade. The region is estimated to have more than 300 GW of hydropower potential (Chatham House 2016), which can complement renewable power to move the region toward a greener energy mix while significantly enhancing supply. Trade would facilitate the creation of a regional market for hydropower, making it more likely that a significant amount of new hydro capacity would be built instead of new coal plants. This would result in a reduction of CO_2 emissions due to changes in the power generation mix alone (by 8 percent during the period analyzed), even without proactive measures to reduce CO_2 or harmful local pollutants.

56. The above quantification of supply-side cost savings does not take into account the positive impacts of lower electricity costs and more stable supplies on overall economic growth in South Asia or the benefits of a larger and more integrated grid for increasing the use of solar and wind power. Also, the potentially substantial economic and health benefits of reduced local air pollution are not included. Additional benefits would accrue to countries from steps taken to enhance the creditworthiness of the sector entities (particularly distribution companies as off-takers of power) and reduce inefficiencies in their respective national power systems as a prerequisite to significantly increasing cross-border interconnections and trade.

57. Commensurate gains have been estimated from sub-regional trade involving India, Bangladesh, Bhutan, and Nepal; these gains would largely accrue from the substitution of coal-based generation in India and Bangladesh with hydro-based generation in Nepal and Bhutan.

58. While a separate calculation of the gains from bilateral power trade between Bangladesh and India has not been undertaken, the import of electricity, initially from India, is part of the strategy of the GoB for addressing the shortage of power and the high cost of emergency generation. Power imports are recognized as an important supplement to domestic generation, necessary for extending access and improving the quality of power supplied to the population while being considerably less capital intensive and polluting than new coal- or gas-fired power.

59. The benefits for Bangladesh of cross-border power trade with India (mainly importing surplus off-peak power from eastern India) include a reduction in reliance on oil-based generation during the summer peak period; preservation of limited domestic gas during the off-peak period; displacement of gas-/oil-based generation in Bangladesh by Indian surplus renewable generation during off-peak and shoulder periods; phase-out of dilapidated and highly inefficient (gas-based) steam turbines in Bangladesh; and, finally, the development of additional hydro projects in Nepal and Bhutan to sell power in Bangladesh. In the longer term, greater integration of the two systems would also permit more efficient management of the sector in Bangladesh because the expansion of regional interconnection and trade generally provides an impetus for regulatory and institutional reforms that improve domestic power sector performance.

60. The benefits of bilateral power trade from the perspective of India are also quite compelling, beyond the obvious value of strong positive links with its neighbor. As of 2017, India has 'excess' power available, because the economics of retail pricing in the country make it nonremunerative for

[39] The analysis compares a projection of the status quo, with very little cross-border trade, to a hypothetical scenario with no technical, institutional, or political barriers to regional electricity interconnection and trade. While this is quite an optimistic assumption, it gives us an idea of what the potential gains might be.

distribution companies to serve the unserved, resulting in no takers for a significant volume of generation. Distribution companies in many states are also financially stressed and therefore not making discretionary power purchases.[40] This has resulted in low capacity utilization in power plants, with merchant plants/IPPs actively competing for buyers. Indian transmission companies would also earn additional revenues from wheeling power to Bangladesh.

61. Broadly speaking, the benefits of trade and integration of power systems include the following:[41]

- *Increased security and reliability of electricity supply*. In an integrated system, reserve capacity can be shared, reducing the total amount that would be required to manage the system below the sum of the amounts required for separate constituent systems. At the same time, this gives each system operator access to more reserve capacity than it would have separately, providing it more flexibility to respond to power plant outages or grid failures. The greater diversity of generation composition and loads across the integrated system also facilitate balancing of supply and demand.

- *Reduced operating costs.* Electricity trade in interconnected systems allows for the optimal use of complementary power generation sources, for example, using cheap hydropower when it is available and sharing thermal generation when necessary. Pooling ancillary/complementary services reduces the need to invest in backup generation, as well as reducing system costs on secondary reserves. Power-importing countries, particularly those heavily reliant on liquid fuels as primary or backup sources of supply, stand to benefit from significantly lower electricity costs.

- *Greater penetration of renewable energy.* The larger size of regionally integrated systems allows the variability of renewable resources within specific geographic areas to be smoothed across space and time, further reducing the need for backup generation and secondary reserves and permitting the absorption of greater volumes of intermittent renewable energy (solar and wind) in the system. As noted already, the scale of regional systems makes investments in larger hydro plants (as in Nepal, for instance) financially viable, even if the individual/local market cannot absorb the full amount of power generated.

- *System resilience to climate change*. Regional integration of power systems improves resilience, mainly because it allows the addition of larger amounts of renewable energy capacity in the power system, thereby mitigating climate change impacts. In addition, because integrated power systems facilitate the transfer of power across geographic locations, this can help countries handle variations in power generation due to drought or other climate-induced downturns, which are expected to be more frequent or exacerbated by climate change.

(i) Status and plans

62. Power trade between Bangladesh and India has developed rapidly since 2010 when an initial Memorandum of Understanding (MoU) was signed between the two countries. Starting with 500 MW of power imports by Bangladesh in 2013, and going up to 600 MW in 2016, imports are now on track to

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[40] A good time for Bangladesh to enter the market as a buyer since "excess supply" means the additional demand will not put pressure on prices.
[41] Adapted from Bazex, Karen. 'Programmatic Approach for Facilitating Power Trade in SSA', Concept Note 2017.

increase to 1,100–1,200 MW by the middle of 2018 and could potentially go up to more than 5,000 MW by 2030 (Zaheer 2017).

63. As of end 2017, Bangladesh imports 660 MW of power annually from India. Of this, 500 MW is on the western side through the 400 kV cross-border interconnection between Baharampur in India and Bheramara in Bangladesh that was commissioned in September 2013; 250 MW through a Government to Government agreement in which Bangladesh is supplied with power from the Indian centrally owned generator, NTPC Ltd., at India's domestic generation tariff; and 250 MW through an agreement between the BPDB and Power Trade Corporation (India) for power sourced from the Indian market. A further 160 MW is being imported under a similar bilateral contract between the BPDB and NTPC Vidyut Vyapar Nigam Ltd. (NVVN), using an alternating current (AC) interconnection between Suryamaninagar in Tripura and the South Comilla District of Bangladesh (Economic Times 2017).

64. The original 400 kV high-voltage direct current (HVDC) interconnection is now being expanded to allow another 500 MW of imports and is expected to be commissioned by mid-2018. Bangladesh is also planning to build the country's third 500 MW back-to-back HVDC substation in Comilla to import an additional 340 MW power from India—NVVN is expected to supply 340 MW power from Bongaigaon in Assam by December 2019 (Rasel 2017). In addition, discussions are ongoing regarding a new 400 kV direct current (DC) line on the west, which would permit another 1,000 MW of power imports from India.

65. Over the medium term, large hydro-capacity is planned to come up in north-eastern India and Bhutan, which will require evacuation. India is proposing to build a 5,000 MW transmission line connecting its north-eastern regional grid to its eastern regional grid through Bangladesh, in part to facilitate evacuation of hydropower. The proposed high-capacity AC line would connect Katihar, Bihar, to Bornagar, Assam, through an HVDC back-to-back interconnection at Parbotipur in Bangladesh (JTT 2016). In return, Bangladesh will get a share of the electricity transmitted (amount subject to negotiations) (Bose 2017). Finally, there have been discussions between Bangladesh, India, and Bhutan about a possible trilateral joint venture in a 700–1,000 MW hydropower project on the Kuri River in Bhutan, which would give Bangladesh additional clean energy.

66. Starting with individual projects has helped build confidence and mutual trust. The next step is efforts to harmonize policies and regulatory frameworks, which would provide the basis for scaling up trade and potentially establishing a regional power pool.

(ii) Accelerating trade

67. This section presents ideas for accelerating and expanding Bangladesh's power trade with India, drawing from Ravinder (2016). There are significant benefits to be gained from Bangladesh moving beyond the government-to-government and firm PPA arrangements described earlier and either participating directly in the Indian power market or establishing the country's own power exchange—not only in terms of the flexibility brought to trading/transactions but also, as indicated in this section, the impetus that development of a market-based model of power trade will give to the development of the Bangladesh power sector more generally in terms of attracting supply and inducing competition even domestically. It will also position Bangladesh well for participating in a regional market if that eventually comes about.

68. Realizing a significant part of the benefits from trade hinges on Bangladesh's ability to integrate into the Indian market in the short to medium term and on the expansion of this market to the

Bangladesh, Bhutan, India, and Nepal Initiative (BBIN) and further to all of South Asia. Within South Asia, however, the absence of reciprocal open access across countries and limitations on the participation of foreign entities in the Indian power exchanges (Indian Energy Exchange [IEX] and Power Exchange India Limited [PXIL])—and vice versa—are stumbling blocks in the growth of electricity trade. Although India allows 100 percent foreign direct investment (FDI) in the power sector and introduced open access to transmission lines for domestic players as early as 2004, no rules were put in place for foreign entities to directly avail access to the Indian power grid. Subsequently (2016/17), guidelines (Government of India 2016) and draft regulations (Central Electricity Regulatory Commission 2017) on cross-border electricity trade were notified, but a policy on electricity trade has not yet been finalized. As of the end of 2017, foreign-owned entities are not allowed, directly or indirectly, to trade on the Indian power exchange. A foreign entity cannot directly avail of open access—it has to go through an Indian-owned trader. In general, short-term open access is provided on available transmission margins only, and there is no regulatory mandate to create adequate transmission to meet the needs of the electricity market.

69. The BPDB could avoid the disadvantages inherent in participating as a foreign entity on the Indian exchange if it were to start inviting supply bids from willing sellers in India on an electronic platform.[42] This could be a first step in the creation of a Bangladesh Power Exchange (BPX), beginning with supply-side cross-border bids to top up the 250 MW G2G long-term PPA. An initiative of this nature would create incentives for public and private generators in India to push to be allowed access to the Bangladesh market and catalyze competition among them to supply the BPDB, creating within India a vocal and powerful constituency for power trade. 'Surplus supply' in India is likely to continue because 50 GW of new capacity is under construction in the country, and there is an ambitious renewable energy capacity addition program of 175 GW by 2022 at the same time as demand growth has moderated.

70. The National Load Dispatch Center of Bangladesh, which is part of the PGCB, is already doing national load forecasting, confirming the availability of power plants, arranging cross-border imports, and scheduling the dispatch of power from Bangladesh power plants on the merit order of energy cost. The market can be progressively developed from this point on without exposing consumers to price risk, recognizing that cross-border bidding would be a stepping stone toward developing an internal market in Bangladesh, including potentially moving away from the existing single-buyer model toward wholesale competition among distribution companies to procure power at the best possible price. Key recommendations to be considered in market development, at least in the first phase, are as follows:

- The task of designing and operating the exchange in a time-bound manner should be entrusted to a private party or a joint venture, with BERC oversight through a transparent and competitive selection process.

- Bangladesh should announce its intent to set up its own power exchange and solicit India's cooperation, retaining existing practices, that is, that the nodal agency for settlement of deviations and the trader for long-term supply are provided by the Indian Government.

- No changes in the operating agreement with India for coordinated grid operation.

[42] Once the concept is agreed and finalized, the electronic bid guarantee, electronic payment, and transfer from the BPDB to the chosen sellers in India, qualifying requirements, electronic undertakings, electronic signatures, banking arrangements, rules, and so on, are a matter of design details.

- All existing contracts could be retained as they are, but they would be mandated to bid in the Bangladesh pool/power exchange at their contracted price or approved tariff, along with cross-border bids.

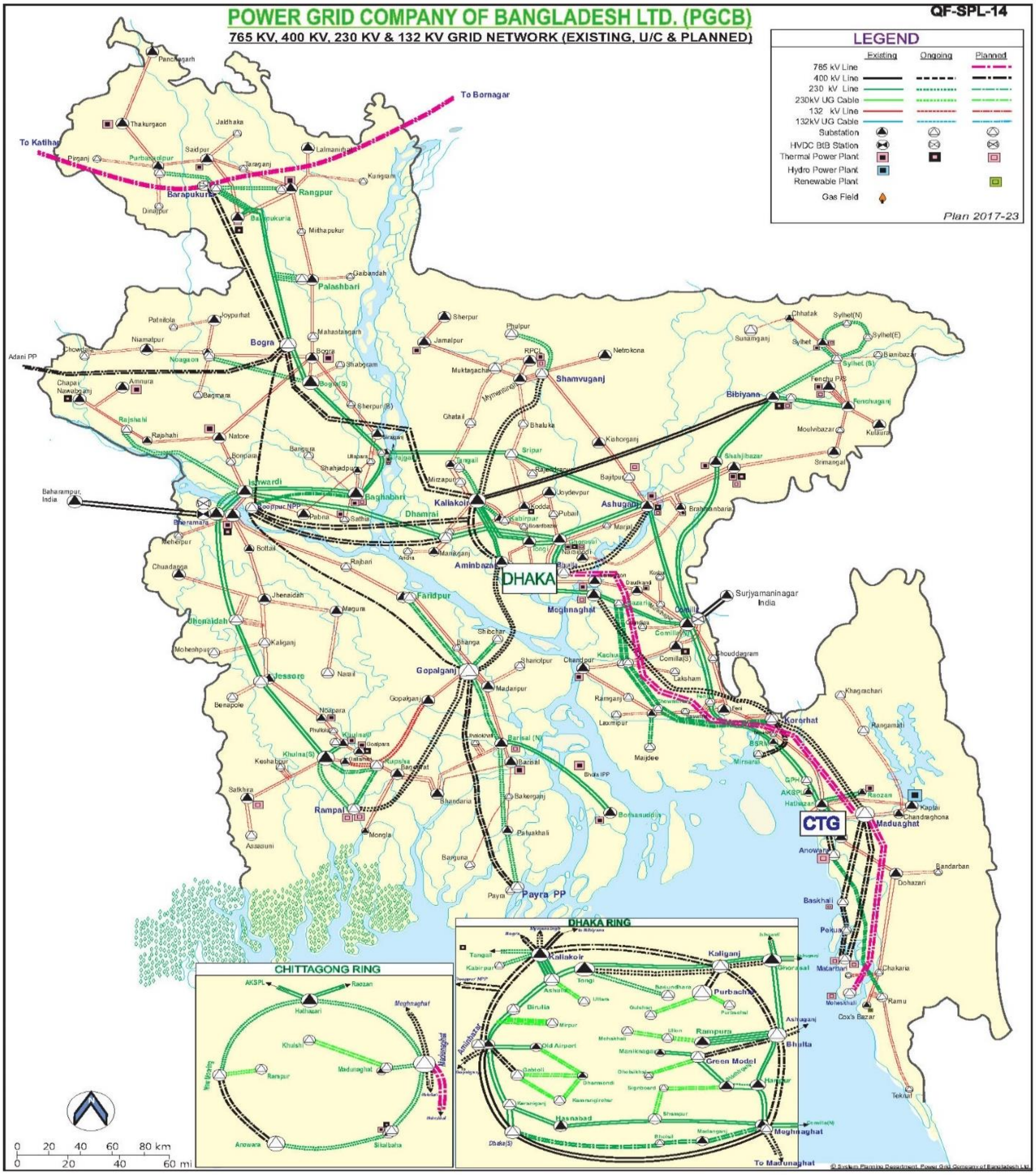
- The method of price discovery and bid selection for dispatch would be on a transparent merit order basis to meet the forecast demand of the next day.

- All pre-contracted or historical contracts would be paid capacity charges, if applicable, whether or not they are selected for dispatch by the BPX.

71. Once the initial phase of bilateral contracting and a Bangladesh pool with cross-border power trading are successfully achieved, spot price-based trades should augment bilateral trades. There is also the possibility of tighter integration of the two markets with buyers and sellers from both sides being able to directly participate in both exchanges, effectively treating BPX as an additional exchange in the wider Indian market. It is important that the initial BPX design allows for this possibility and aligns with the market rules in the Indian electricity market so that product definitions (energy as well as ancillary services), market clearing mechanism, definition of prices, and congestion management rules are compatible across the two markets.

72. As of 2017, Bangladesh lacks adequate spinning reserves and reactive power, and it experiences significant fluctuations in system frequency and voltage. These deficiencies—especially inadequate spinning reserve—render the system unstable and contribute to grid outages even when there is sufficient capacity to meet demand. Development of an ancillary services market would be an important step toward rendering the Bangladesh system secure because these services can also be traded through the market along with energy. In fact, it is recommended that at a suitable stage of market integration an AC interconnection be contemplated to synchronize the two systems—that would indeed be the most cost-effective way to manage frequency in Bangladesh.

Figure 4.3. PGCB map showing planned and existing cross -border connectors



Source: PGCB 2017.

(iii) Broader lessons

73. Experience suggests that cross-border trade generally begins with a few bilateral contracts and deepens over time. Individual projects can be successfully implemented with relatively simple rules for governing and operating the interconnections and mechanisms for account settlement with respect to power transactions. As bilateral trade increases, expanded participation by third parties is possible. Nonetheless, while regional cooperation based on a collection of bilateral agreements can provide significant benefits, the development of a more formal regional power trading system or exchange for wholesale power supplies greatly facilitates expansion of trade and investment. Cross-border, subregional, and regional connectivity and trade can and should be progressively integrated into country power system planning and scenario analysis.

74. Increased dependence on power imports or exports inevitably leads to concern about supply security, although it is worth noting that the relationship will likely be one of interdependence if exports from one country become very significant. It is vital to address this concern because seeking energy independence with the aim of ensuring 'energy security' results in higher costs of power overall. Ultimately, trade depends on assurances that power supply and purchase agreements will be honored and only time and experience interacting with each other will address the initial lack of trust between trading partners and reluctance to rely upon others. Another frequent problem is inadequate institutional capacity for planning and managing regional trade; the early years help build institutional experience in coordination between national authorities and for implementation of cross-border contracts and development of dispute resolution mechanisms.

75. The more a regional trading system can introduce effective competition in wholesale power supplies, the more efficient the system will be. Weak sector finances, especially of the off-taking utilities, needs to be addressed up front, particularly when trade is no longer backed by government to government agreements. In this context, the role of well-functioning domestic power markets also is key.

Renewable energy potential and plans

76. Bangladesh's goals for renewable energy have been articulated over time in different documents. The National Renewable Energy Policy (NREP) 2008 set a goal of renewable energy constituting 5 percent of total generation by 2015 and 10 percent by 2020—generation capacity of 2,000 MW from renewable sources was planned to be added by 2020. The SREP Investment Plan[43] notes that the Government had two sets of directives for renewable energy investment. The first is the 500 MW Solar Program (2012) which aimed to add 500 MW of solar generation capacity by 2016 in both the public and private sectors. The Government also set renewable energy development targets for several technologies for each year from 2015 to 2021 ('RE Development Targets'), which called for an *additional* 3,100 MW of renewable energy capacity to be installed by 2021. Most of the new capacity was expected to come from solar (1,676 MW, or 54 percent) and wind (1,370 MW, or 44 percent). Smaller targets have been set for waste-to-energy (40 MW),[44] biomass (47 MW), biogas (7 MW), and hydro (4 MW). In

[43] Scaling up Renewable Energy in Low Income Countries Program. SREP Investment Plan of Bangladesh: http://www.climateinvestmentfunds.org/sites/default/files/meeting-documents/bangladesh_srep_ip_final.pdf.

[44] About 13,383 tons of solid waste are produced daily in Bangladesh, with more than 4,379 tons coming from Dhaka alone. Despite this, there is no waste-to-energy facility in operation in Dhaka, and the actual technical potential cannot be estimated without procedures being established for delivering the waste to a power plant.

addition, PSMP 2010 included goals for fuel diversification, with an emphasis on increasing the role of renewable energy in the power generation mix.

77. Installed renewable energy generation capacity in Bangladesh amounted to 430 MW in 2017. The 230 MW Kaptai Hydropower Project is still the sole grid-connected renewable energy resource; it is supplemented by off-grid SHSs in rural areas (175 MW), urban rooftop solar (15 MW),[45] and the balance from biogas- and biomass-based captive plants. Resource assessments reported in the SREP Investment Plan indicate that Bangladesh has potential for the installation of an additional 3,666 MW of renewable energy capacity (both grid-tied and off-grid) (Table 4.1). Given the prevailing land scarcity in Bangladesh, this estimate excludes arable land needed for agriculture. The total potential for ground-mounted solar and wind and solar rooftop capacity is assessed at about 2,600 MW.

Table 4.1. Renewable energy technical potential of Bangladesh

Technology	Resource	Capacity (MW)	Annual Generation (GWh)
Solar Parks	Solar	1,400[a]	2,000
Solar Rooftop	Solar	635	860
SHSs	Solar	100	115
Solar Irrigation	Solar	545	735
Wind Farms	Wind	637[b]	1,250
Biomass	Rice husk	275	1,800
Biogas	Animal waste	10	40
Waste to Energy	Municipal waste	1[b]	6
Small Hydropower Plants	Hydropower	60	200
Mini and Microgrids	Hybrid	3	4
Total		**3,666**	**7,010**

Source: SREP Investment Plan for Bangladesh
Note:
a. Excluding arable land.
b. Excluding flood-prone land.
c. Technical potential unknown; 1 MW is the capacity of proposed plant in Dhaka only.

78. Three models are being followed for investment in utility-scale solar parks and wind farms: Government investment on Government-owned land, IPP investment on Government land, and private investment on private land. Auctions will be held for IPP investment on Government land and to negotiate fixed tariff contracts for private investment on private land. Feed-in-tariffs are only considered for small-scale generation and microgrid projects.

79. Despite Government commitment, to date no utility-scale solar PV projects have come onstream in Bangladesh. The primary reasons for this include a lack of data to inform project development, constraints on land availability, and limited financing.

80. The SREP Investment Plan for Bangladesh (2015) notes that utility-scale and rooftop solar are close to parity, on a levelized cost of electricity (LCOE) basis, with the cost of emergency diesel generation in the country. Utility-scale wind projects are ranked similarly. Their viability as potential projects will depend critically on completion of the wind mapping exercise undertaken by the GoB and

[45] These solar rooftop PV systems were installed in the main cities to comply with a Government requirement for a certain percentage of lighting load to come from solar. However, inadequate quality control resulted in installation of poor quality panels so most of this capacity produces little or no energy.

United States Agency for International Development. For utility-scale solar, a more detailed resource assessment than the existing will be needed to characterize the solar resource potential in the areas targeted for solar development. For rooftop-solar, a more detailed mapping exercise is needed to determine all the suitable rooftops in the largest urban areas. Successful renewable energy pilot projects will provide better access to data on renewable energy over time. They will also demonstrate viable business models that can be replicated by local banks and allow local workers the opportunity to learn the necessary technical skills.

81. The difficulty of obtaining suitable sites is the main reason given for privately promoted renewable energy projects not to have progressed to financial closure or implementation. Utility-scale solar requires large tracts of land,[46] which are hard to come by in such a densely populated country. Agricultural land cannot be diverted to other uses, so the only land available for solar PV installations is Government-owned land in river islands and/or low-lying areas subject to seasonal flooding. This makes the land unsuitable for habitation or for other productive uses but also makes it expensive to install solar facilities on it.

82. Even for projects that have managed to secure land from the market, financial closure continues to be a challenge. Commercial banks lack experience/knowledge of utility-scale renewable energy projects; have limited technical capacity to conduct due diligence, implementation, and monitoring; and along with low risk appetite for long-term lending, have limited capacity to handle foreign currency transactions. Project financing tenors are limited to seven years. In addition, traditional infrastructure projects that lenders are familiar with compete for the funding available from domestic financiers. Another barrier to mobilizing financing for grid-tied renewable energy projects is the off-taker risk seen by the (primarily foreign) sponsors and investors in renewables underlining the need for appropriate risk mitigation and credit enhancement to improve bankability and affordability of projects.

83. Overall, recommendations are for the authorities to invest in collecting and making available good data on the size and quality of the solar and wind resource, as indeed they are doing; support the development of the market and make information widely available by sponsoring or undertaking pilots and demonstration projects; and develop risk mitigation offerings to attract private investors into what is still considered a nascent and unproven sector in Bangladesh.

[46] 1 MW of solar is estimated to require 4–5 acres of land given the solar irradiance of Bangladesh.

V. Energy efficiency

84. This section reviews Bangladesh's opportunities for saving energy and quantifies the potential savings from implementing EE investments on the demand-side, supply-side (in generation), and in system-wide operations, particularly by improving dispatch.

Demand-side potential[47]

85. With the establishment of the Sustainable and Renewable Energy Authority (SREDA) in 2014, Bangladesh now has a nodal agency with the mandate to take forward energy conservation and EE. Even though high levels of energy inefficiency exist across all sectors, a framework for pursuing EE programs has only recently been developed as the SREDA gears up for an active role in the sector.

86. In a situation where demand exceeds available power at prevailing prices, EE improvements across the supply and demand chain can be an important contributor to decreasing the gap. EE can also help Bangladesh meet its global commitments through its NDCs toward climate change mitigation. By contributing to energy savings, EE can contribute to increased access to energy, reduced energy poverty and energy supply security, in addition to avoidance of GHG emissions. The Government's Energy Efficiency Master Plan prepared by the SREDA aims at a reduction of 15 percent by 2021 in primary energy consumption per unit of GDP, with a target of 20 percent reduction in energy intensity of GDP by 2030.

87. Despite the enormous potential for EE across all sectors in Bangladesh, there are considerable barriers to large-scale EE adoption and market transformation, particularly across various demand-side sectors, remains weak. The focus of this section is demand-side EE opportunities for both primary energy (oil, gas, and coal) and electricity.

88. This study determines the energy efficiency and conservation (EE&C) potential of various EE end-use technologies and subsectors compared to a BAU scenario. The BAU scenario, which has been taken from the Second National Communication of the Bangladesh Government, is essentially a projection of energy consumption in the absence of EE&C measures being undertaken. This study has estimated the reduction in energy demand as a result of implementing 16 identified high potential measures.[48] The savings potential is calculated as baseline energy consumption in the BAU scenario minus energy consumption in the 'Efficiency' scenario, which has been constructed assuming specific penetration rates of efficient devices.

89. Industry and domestic users account for nearly 75 percent of national primary energy consumption (if only electricity consumption is considered, then their share is even higher). The analysis shows that air-conditioning and lighting have the greatest potential for EE. This is because of the rapid

[47] This section draws from Hossain, Sarkar, and Pargal (2017).

[48] The options chosen for analysis represent the most promising prospective candidates for demand-side EE improvement. The selection of end-use options (appliances, equipment, processes, and so on) and corresponding EE improvement measures was based on the following broad based criteria: (a) the energy consumption of the baseline end-use must represent at least 1 percent of total energy consumption; (b) potential for EE improvements must exist for this end-use, that is, the existing baseline technology is fairly inefficient for the particular end-use; and (c) reasonable amount of data and information exists to permit analysis of the energy savings potential.

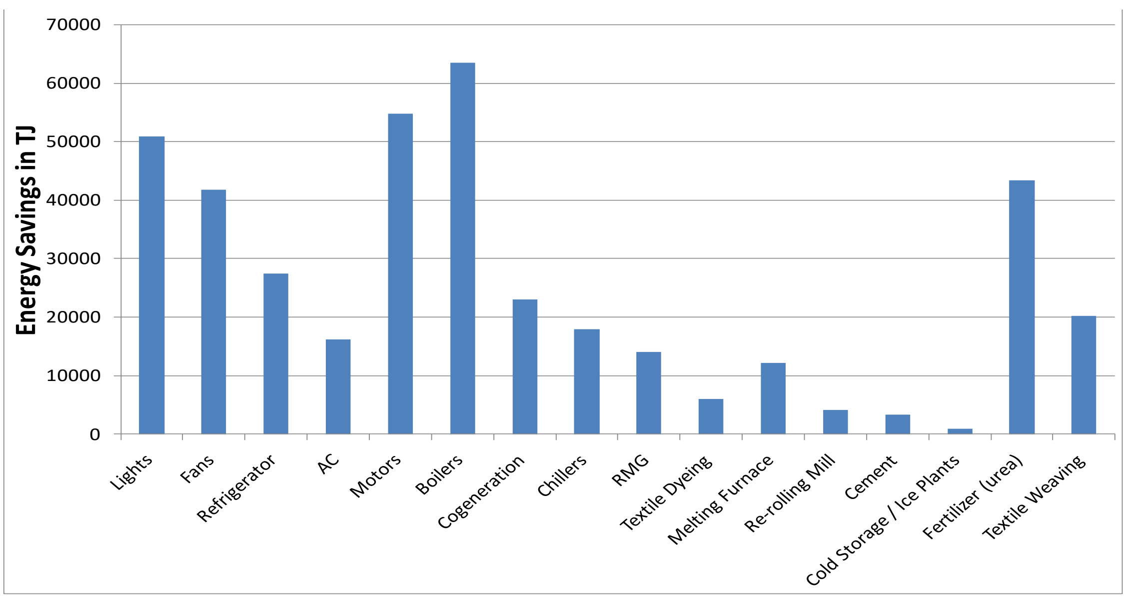
increase in household electrification and in the cooling load due to increasing prosperity of households as well as the large reduction in energy use possible from LED lighting.

90. One of the most important factors promoting EE is energy pricing. In recent years, the price of electricity has increased, but the price of gas is still much lower than its opportunity cost. Large or energy-intensive industries depend on captive generation using low-priced gas that was provided to them in agreement with the Government when power was in extremely short supply in the mid-2000s. However, this has removed incentives for conservation and efficient use: for example, plants with captive generators can produce their own electricity at less than Tk 2.5 per kWh, while industry pays Tk. 7.5 per kWh for electricity from the grid. In fact, gas is so cheap that it is not cost-effective to install waste heat boilers to produce steam, so factories burn natural gas to produce steam despite the fact that the waste heat of the gas engine generators could be used for that purpose.

91. Since 2005, the country has been experiencing electricity and gas shortages. In the last five years, using hurriedly built oil-fired power stations, the Government has alleviated the electricity shortage but at the cost of increased electricity prices. Gas shortage and high electricity prices have forced many industries into conservation and EE improvement, and the energy intensity of the economy has actually improved.

92. The 16 options analyzed to track EE potential on the demand side indicate that a total of 400 PJ can be saved in the year 2030 (Figure 5.1). The projected total primary energy requirement in 2030 is approximately 2,800 PJ,[49] so these savings amount to 14.3 percent of the total primary energy requirement.

Figure 5.1. Energy savings potential in 2030

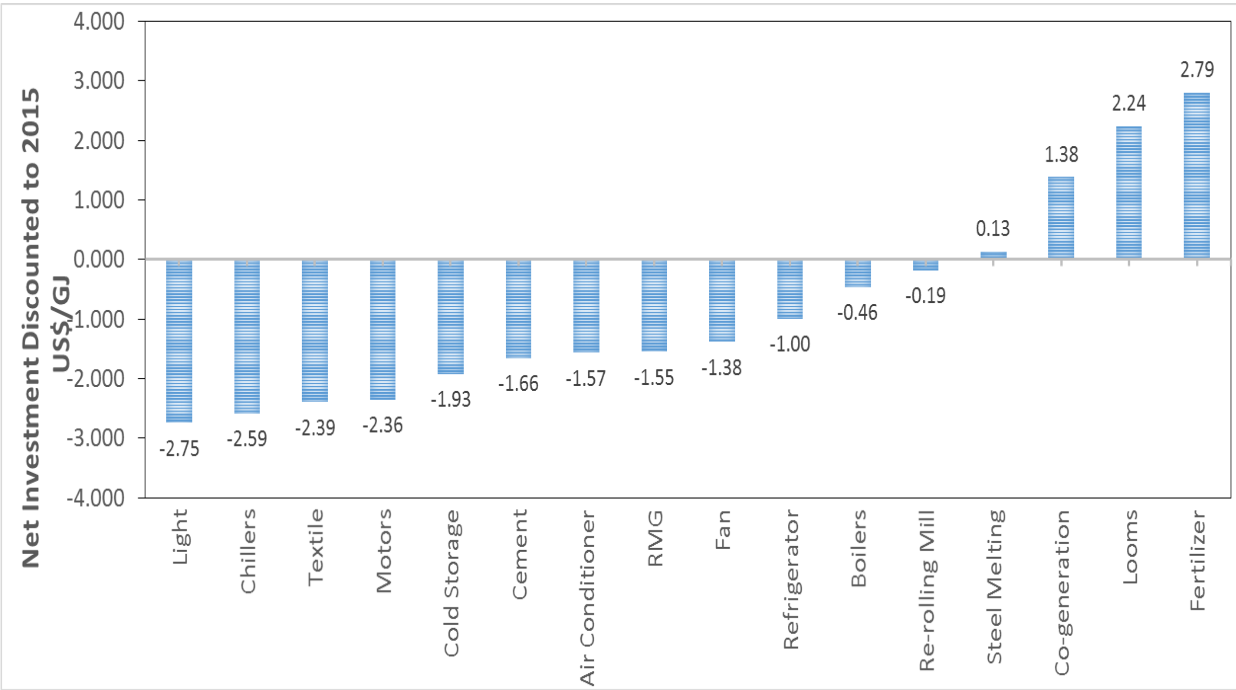


Source: World Bank staff calculations.

[49] This figure is slightly modified from that in the Second National Communication and SREDA Master Plan.

93. The analysis also shows that the avoided electricity generation capacity addition as a result of the electricity saving options amounts to 3,298 MW. This is a significant saving given the fact that only 16 EE measures were considered and the projected average electricity demand in 2030 according to the PSMP 2016 is less than 25,000 MW. Even if the projected peak demand of 27,000 MW, according to the PSMP 2016, is considered, the savings amount to 12 percent.

Figure 5.2. Cost of energy saved by EE investment in different sectors



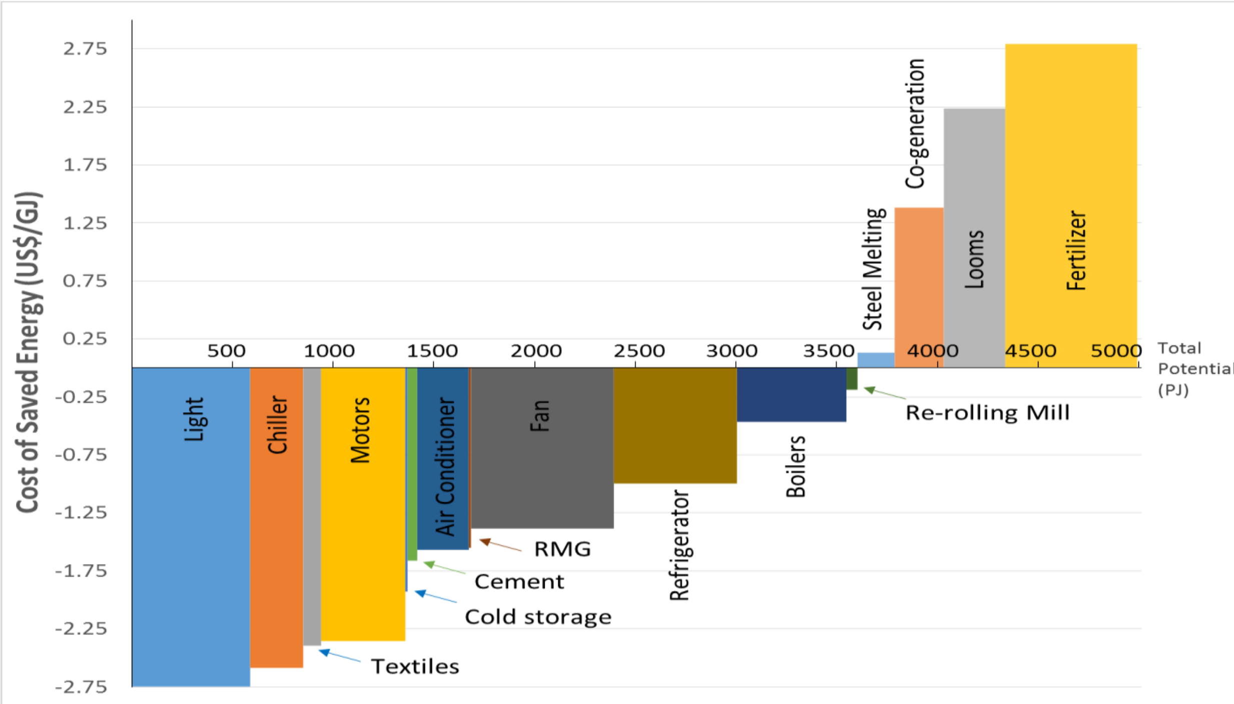
94. A back-of-the-envelope calculation of the relative cost-effectiveness[50] of the different options analyzed provides a measure of the cost versus benefits of these EE options; this is laid out in Figure 5.2, which ranks different options by the net cost per unit of energy saved (in US$ per GJ). Despite the fact that prices of electricity and gas are fairly low when compared to international market prices, the cost of saved energy for most options considered in the analysis are either low or negative. Clearly, in the Bangladesh context, these EE project investments entail a favorable rate of return and should be implemented, as a part of the energy sector development road map in Bangladesh. Note that a higher electricity or gas price would increase the cost-effectiveness of all these options because the monetized value of energy saved would be higher.

95. Figure 5.3 shows cost-effectiveness or cost of saved energy (US$ per GJ) of each EE option plotted against the total energy savings potential (in PJ) of that EE option, for 2015–2030.[51]

[50] The literature on EE and GHG mitigation has traditionally used the concept of cost-effectiveness with units of US$ per GJ saved or US$ per ton of CO_2 reduced, respectively. Cost-effectiveness is represented here by the Cost of Saved Energy.

[51] Most noteworthy among the low potential options are the RMG and textile options. This may appear counterintuitive because the ready-made garments (RMG) and textile subsectors are the two largest industrial subsectors, accounting for more than 80 percent of all industrial production. The reason behind this anomaly is that the study analyzed generic, cross-cutting technologies/devices/equipment in all the sectors. This implies that a significant proportion of the EE

Figure 5.3. Cost of saved energy (US$/GJ) of EE option versus the total energy savings



Source: World Bank staff calculations.

96. Figure 5.3 can be used in prioritizing the actions based on criteria that consolidate both parameters, that is, combines cost-effectiveness (Cost of Saved Energy, in US$ per GJ saved) and the energy savings potential (in PJ). While the former is a good indicator of the attractiveness of investment at the end-user consumer level (that is, industries, utility, or energy service companies, and so on), from the Government or policy maker's perspective, EE measures that score high in terms of total volume of potential energy savings could be better candidates for support.

97. There are both direct and indirect barriers to implementation of EE programs. The latter have to do with the inertia of owners and workers in industries, especially where industries are running smoothly and profitably. In such cases, the EE retrofit or changeover yields very little financial gain. This is also the case when electricity and/or fuels are cheap or subsidized. In both cases, the gain from an EE project is not enough to justify a disruption of operations. Implementation of EE programs and projects depends strongly on the type of intervention and the technology in question. Thus, a 'Fan' dissemination program will be very different from a 'Fertilizer' retrofit project. Implementation strategies generally fall into the following categories: (a) standardization (MEPS) and EE labeling programs, (b) utility-driven programs, (c) energy audit and energy management programs, and (d) incentive-based programs. EE implementation programs must therefore be carefully designed. It is often not sufficient to provide low-cost financing and to demonstrate the benefits of energy-efficient technologies. A well-structured regulatory regime enforced and managed by a competent agency is crucial for the success of an EE program.

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potential in industries such as RMG and textiles is already being accounted for in the form of lights, fans, boilers, motors, and/or chillers, leaving only specialized equipment/devices and process improvement to be considered.

Energy efficiency potential of gas-based electricity generation[52]

98. With limited gas resources and availability in Bangladesh and competing needs for this gas such as in fertilizer production and household cooking, it is in the interest of the country's energy security that available gas should be utilized as efficiently as possible, and the energy content in gas should be converted to electricity to the maximum extent possible.

99. The fleet of gas-based power plants comprises many old and inefficient plants. The overall efficiency level of this stock in 2014 was only 33.5 percent but there is potential for increasing it to about 52 percent by retirement and repowering of old plants in the short term and renovation/modernization of inefficient plants in the medium term. This could result in 55 percent more power generated with the quantity of gas (~900 mmcfd) that is presently consumed.

100. Table 5.1 shows that the amount of power generated by the country's fleet of gas-fired plants could be generated with significant savings in the amount of gas used if efficiency were enhanced to 45 percent. Conservatively valuing the gas saved at US$2 per mcf, it is seen that rehabilitating and modernizing these plants could save US$30.2 million per year. Together with repowering, approximately US$39.1 million could be saved annually.

Table 5.1. Summary of savings from supply-side EE interventions

Activity	**Potential Gas Savings Per Year (mmcf)[a]**	**Potential Cost Savings Per Year (US$, millions)[b]**
Repowering public plants	3,481	6.9
Repowering private plants	993	2.0
Rehabilitation of plants	15,097	30.2
Total	19,571	39.1

Note: a. Based on 2014 capacity with improved efficiency and same utilization. Utilization is likely to increase after repowering/rehabilitation.
b. Fuel cost of US$2 per mcf.

101. Very conservatively, assuming that the prevailing (low) plant load factors (PLF) and utilization continue, the volume of gas actually consumed by the identified inefficient units is sufficient to run more-efficient plants with higher capacities. Repowering and rehabilitating these plants could actually generate 12,567 MkWh more than they are generating, achieving a financial benefit of US$339 million per year, as shown in Table 5.2.

[52] From Rahman et al. (2016).

Table 5.2. Summary of enhancement of generation output from EE interventions

Activity	Capacity After Activity (MW)	2014 Capacity (MW)	Increased Generation Output Per Year (MkWh)[a]	Value of Additional Output Per Year (US$, millions)[b]
Repowering public plants	1,200	560	7,770	495
Repowering private plants	135	70	1,005	53
Rehabilitation of plants	880	808	3,792	241
Total	2,215	1,438	12,567	339

Note: a. Based on 2014 capacity and improved capacity with existing utilization respectively. Utilization is likely to increase after repowering/rehabilitation.
b. Tk 5 per kWh. US$1= Tk 78.50.

102. It is estimated that the repowering of identified old public and private sector-owned plants by CCGT technology will result in a net addition of 705 MW to system capacity at a cost of about US$1.36 billion; the additional annual revenue earned from selling the power at existing tariffs would amount to US$548 million. Similarly, the rehabilitation/modernization of inefficient power plants in the system will add 72 MW to system capacity at a cost of about US$634 million; additional revenues earned annually at prevailing tariffs would be US$241 million. The expected payback periods for these interventions are about three years and two years, respectively.

103. An enabling and supportive policy framework supported by stringent policy guidelines is a prerequisite for implementing EE practices in both public and private sector gas-based power generation. Procurement of new gas-based power plants, for example, should incorporate EE requirements in tender documents and specifications to encourage acquisition of energy-efficient power plants and equipment in the country. The BERC can formulate and enforce the regulations to attain the desired energy and thermal efficiency in power generation. At the same time, national codes and standards need to be developed to set performance standards for equipment and systems. Reputed international codes and standards can provide a convenient first step in this.

Operational efficiency or systemwide dispatch efficiency potential[53]

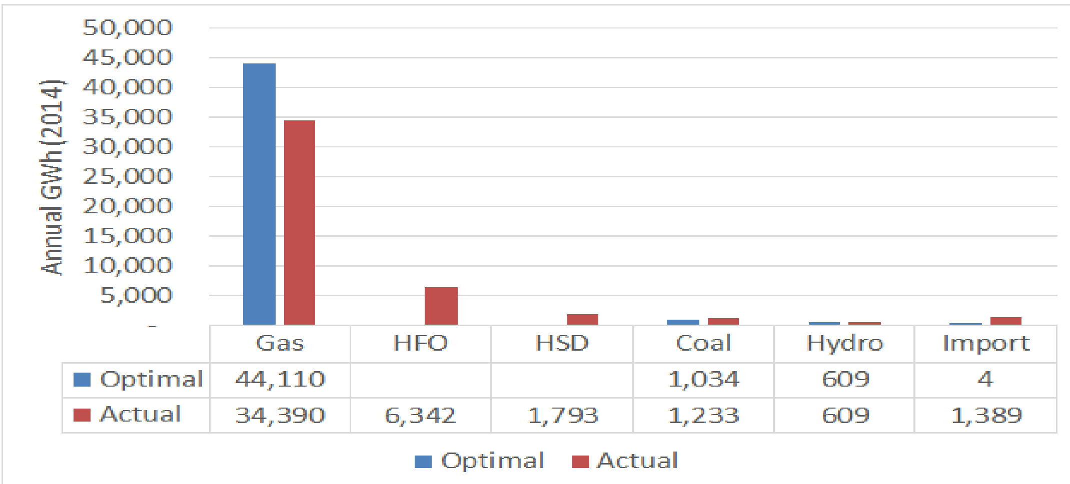
104. Despite the need to deliver the maximum power possible at the lowest cost, there is considerable room for both technical and nontechnical improvements in the management and operation of the power system in Bangladesh. For example, dispatch protocols are still manual, resulting in unnecessary preemptive use of expensive fuel oil- and diesel-based generators. Bangladesh could obtain more electricity at lower average cost by allocating more of its existing domestic gas to power generation, by modernizing dispatch protocols and by removing transmission bottlenecks that prevent lower-cost power from reaching load centers. In addition, system stability and security would be boosted by making provision for a spinning reserve, including appropriate payment to generators for this service. An adequate spinning reserve would arguably have averted the major grid failure that occurred on November 1, 2014.

105. Using an hourly dispatch and ancillary services co-optimization model that also optimizes short- to medium-term investment decisions, Chattopadhyay and Nikolakakis (2015b) compared *theoretical optimal* hourly dispatch for 2014 against what was actually observed. They concluded that significant cost savings (up to 63 percent) would theoretically have been achievable using the same amount of gas if dispatch were not manual and had followed the merit order and that a 23 percent increase in the

[53] From Chattopadhyay and Nikolakakis (2015b).

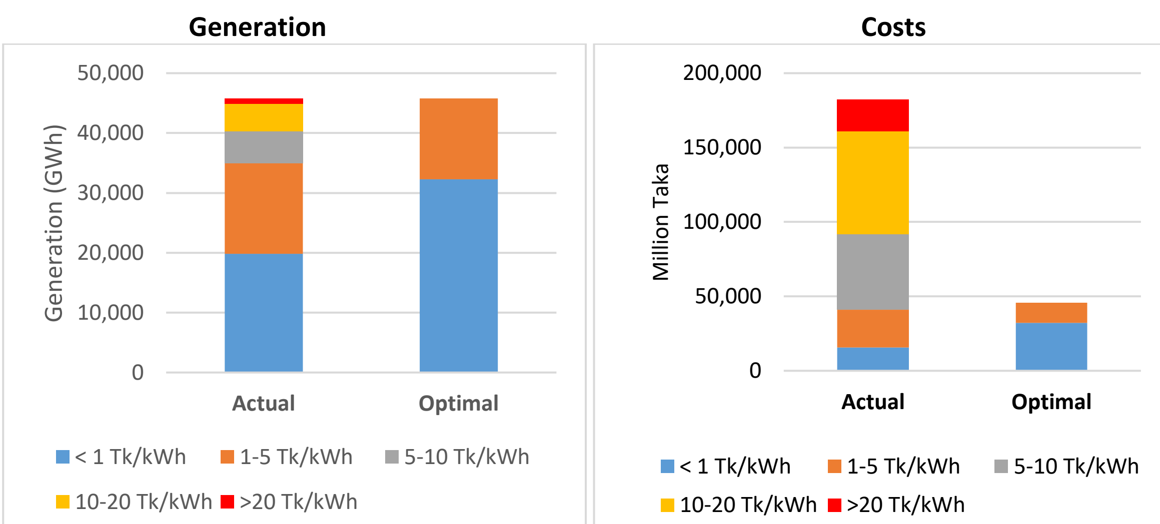
amount of gas (212 mmcfd) allocated to electricity generation could potentially have reduced the average cost of power by 77 percent. Figure 5.4 shows that the bulk of system cost savings comes from improving the fuel mix —from shifting generation away from more expensive generators (>Tk 5 per kWh) to available gas capacity (<Tk 1 per kWh).

Figure 5.4. Actual versus optimal dispatch - fuel mix



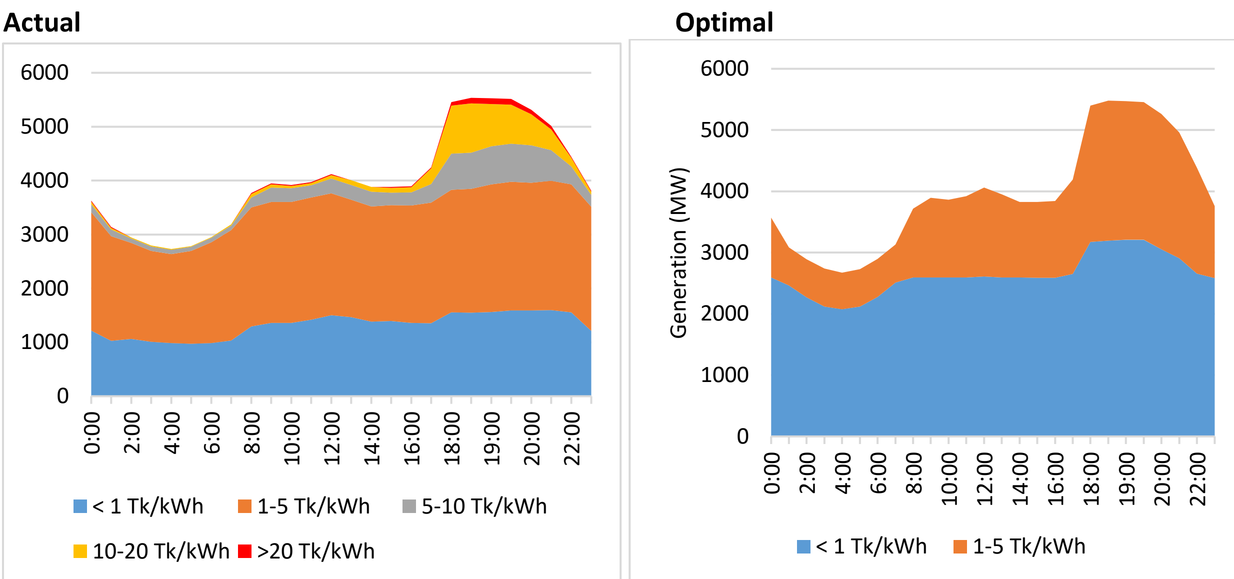
106. Figure 5.5 stacks power from different sources to derive the average cost of a unit of power. The associated merit order in which generation should be brought online makes clear how the lack of such a merit order can affect the average cost of power generated. Generation from units with costs in excess of Tk 5 per kWh in 'Actual' represents less than a quarter of total generation but accounts for 77 percent of total cost. In the simulation, the average generation cost in 'Actual' is Tk 3.98 (~US¢ 5 per kWh) compared with Tk 0.96 per kWh (~US¢ 1.2 per kWh) in 'Optimal.' In Bangladesh, the absence of automated dispatch protocols is in large part responsible for the operators' reliance on preemptively running oil-based generators. This gives them the capability of responding swiftly to demand-supply imbalances and for management of grid frequency mismatches.

Figure 5.5. A small amount of expensive generation can make a big difference in system costs



107. In addition to manual dispatch protocols, limited gas allocated to power generation and limited transmission capacity have been identified as reasons why significant oil-based generation occurs in the system at 15 percent to 20 percent on average (30 percent in peak hours). The dispatch profile on January 1, 2014, (courtesy National Load Dispatch Center 2015) is evidence of the reliance on oil for peak supply. In fact, if the system were running optimally, there would have been no oil-fired generation dispatched.

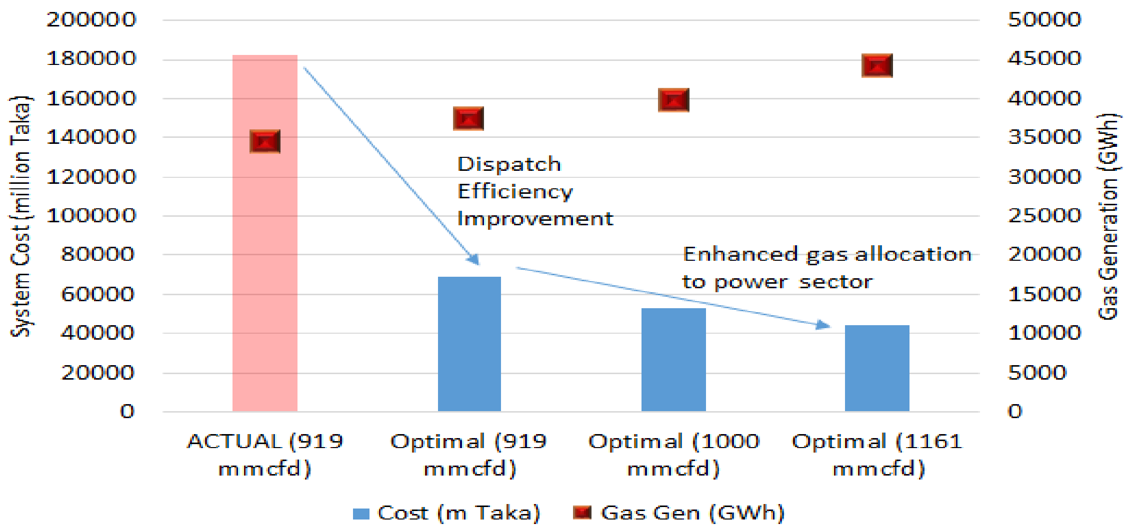
Figure 5.6. Dispatch profile on January 1, 2014



108. The limited availability of domestic gas has led to it being rationed by the Government across different sectors such as fertilizer production, industry (including self/captive power generation), and domestic usage. In 2014, the power sector (excluding captive generation) received only around 900–950 mmcfd of gas on average against a requirement of 1,200 mmcfd. Chattopadhyay and Nikolakakis (2015) show that an additional allocation to power generation of around 300 mmcfd of gas (from 2015 production of around 2,550 mmcfd) would displace expensive oil-fired generation and result in a further lowering of the average cost of power.

109. The relative impact of dispatch efficiency and gas supply constraints are shown in Figure 5.7. Under the scenario of efficient dispatch but in which gas is limited to 919 mmcfd (that is, the same level as in the 'Actual' scenario), costs are 63 percent below 'Actual', indicating that the bulk of the cost difference can be attributed to inefficient dispatch. Adjusting this scenario to marginally increase gas availability to 1,000 mmcfd brings system costs down some more, but it is clear that the suboptimality of dispatch should be addressed as a first priority. Given the significant potential for reducing the cost of power, revisiting the gas allocation policy, especially the allocation of gas for inefficient uses (for example, prioritizing small captive power stations ahead of larger efficient generators), should be next on the agenda.

Figure 5.7. Comparison of Actual versus Optimal dispatch



110. Even at its opportunity cost, domestic onshore gas is significantly cheaper than diesel/fuel oil and therefore, a substantial part of the gain from optimized dispatch reflects a true economic benefit that can be realized from adopting proper protocols. Dispatch protocols should be modernized and automated; constraints on transmission that prevent evacuation of available gas-fired power need to be addressed; and if possible, gas should be allocated to power generation to avoid the need to resort to oil-fired generation and the consequent impact on costs.

111. On a related note, the system is in acute need of ancillary services, especially spinning reserve, during peak hours when demand (load) is very close to the available capacity. An outage of a single large generator can tip the system into crisis as was observed when the 500 MW HVDC link from India came down on November 1, 2014, causing nearly a day of blackout for the entire nation (Rahman 2015). Lack of automation (to enable swift response) and spinning reserve were the key suspects for this grid failure. The dispatch procedure needs to allocate spinning reserve and establish a process to compensate the generators that provide this, recognizing that it is essential for system security.

VI. Gas[54]

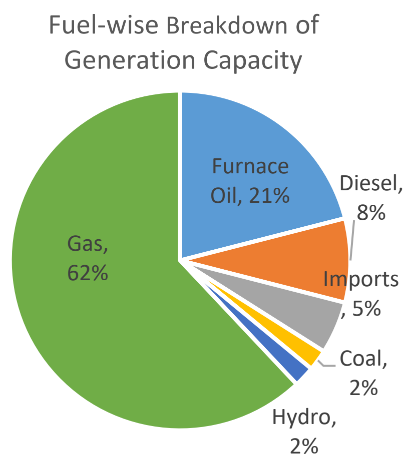
112. This section presents the challenges stemming from declining gas reserves and production of domestic gas and the actions needed to address them. Bangladesh will need to adjust to the price shock resulting from adding imported LNG to the fuel mix, but also should seize the opportunity afforded by greater competition among suppliers and reductions in LNG prices internationally along with the buyers' market that has emerged in recent years with the development of non-traditional sources of supply.

113. Over the past decade, demand for natural gas has grown at 7.5 percent per year, outpacing the rate of growth of GDP (6.2 percent per year) (World Bank 2016b). As of 2015, natural gas accounted for 57 percent of Bangladesh's total primary energy supply (IEA/OECD 2015). Most of the growth in demand for gas has come from the power sector, which consumes 54 percent of gas supplied. Gas-fired power plants generate over 80 percent of the electricity consumed in Bangladesh and account for 65 percent of generation capacity (BPDB 2016). Driven by strong demand, domestic gas production rose to 2,700 mmcfd or nearly 1 Tcf per year in 2015 (Petrobangla 2015b). With many fields nearing peak production, natural gas output is projected to decline from 2,700 mmcfd in 2017 to 700 mmcfd in 2030 (Dorsch Consulting/KPMG 2012). As of July 2015, Bangladesh's onshore reserves amounted to 11.2 Tcf of natural gas, which represents less than 12 years of production at the rate of exploitation (Petrobangla 2015a).

114. The most important issue on the demand side is the approach taken by the authorities with regard to pricing and consequent inefficiency of allocation and use (both domestic and commercial). On the supply side, the key issues are: (a) limited success to date in domestic exploration and production; (b) inadequacy of the gas transmission network and poor performance of downstream distribution companies; and (c) the need to import LNG and to do it in as cost effective a manner as possible. Domestic exploration both on and off shore is stymied by a lack of seismic and other geological data (in most countries, this is made available as a public good by the authorities); the monopoly in onshore domestic exploration accorded to the national oil company the Bangladesh Oil, Gas, and Mineral Corporation (Petrobangla) and its exploration subsidiary, BAPEX, which, in combination with the limited capacity of BAPEX, has meant that Bangladesh has shut itself off from international expertise and the latest, most efficient exploration and production technologies; and PSCs that are not competitive in comparison with those in other countries seeking to attract international companies to invest and produce gas.

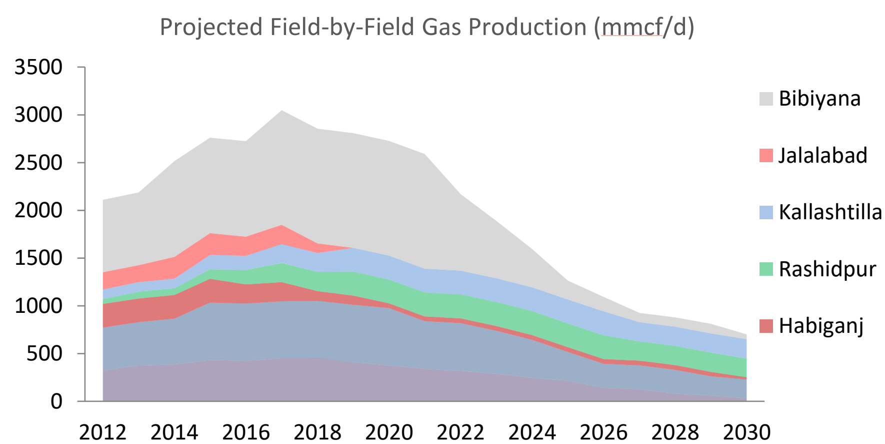
[54] From Bankuti, de Vivies, and Pargal (2016).

Figure 6.1. Gas power generation



Source: BPDB

Figure 6.2. Gas production over time



Source: Gas Sector Update/Dorsch Consult.

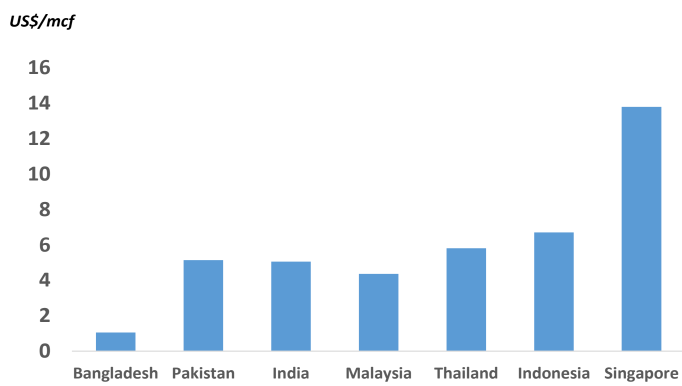
Demand: Pricing and efficiency

115. The price of natural gas in Bangladesh at the retail end is regulated by the BERC. The upstream price is set by the Energy Division of the Ministry of Power Energy and Mineral Resources (MPEMR) as a weighted average of the price of gas *produced* by Petrobangla, the state-owned oil monopoly, and that *purchased* by Petrobangla from IOCs active in Bangladesh. Domestic gas produced by Petrobangla is valued at close to zero at the well-head with a margin to cover the cost of production. Petrobangla is the monopsony buyer of gas produced by the IOCs and the price it pays is contractually determined based on the PSCs awarded to IOCs. The retail price is fixed by BERC on a cost-plus basis. It is derived as the cost of gas provided by Petrobangla plus margins to provide a return and cover the costs incurred at different stages of the supply chain, that is, transmission and distribution.

116. While the retail price covers the cost of production, this cost is extremely low, in part because it reflects fully depreciated assets. The final retail price of gas that results is significantly lower than

domestic gas prices elsewhere in the region and indeed in much of the world excepting the Middle East. It has little relationship with the economic or opportunity cost of gas either in terms of the alternatives to gas or what comparator countries face. Domestic gas prices average just over US$2 per mmBTU across all sectors with prices being around US$1 per mmBTU for power producers and the fertilizer sector (Petrobangla 2015a).

Figure 6.3. Prices paid by power plants for natural gas in selected countries



Source: Energy Policy Options for Sustainable Development in Bangladesh, Asian Development Bank 2013.

117. The administered price of gas is so low that it has resulted in an imbalance in demand and supply, leading to severe shortages. About 1,000–1,500 MW of gas-fired power capacity is idle because gas is not available. Bangladesh produces small amounts of oil and imports almost all of the oil available domestically. Brent crude oil price averaged US$108 per bbl—equivalent of US$18 per mmBTU—in 2013 (World Bank 2016a) and, despite the high oil price, oil imports for power generation grew substantially as a result of a shortage in gas supply. The shortage of gas means that the Government must ration or directly allocate the gas and approve new connections to the gas network. This allocation policy is politically charged and has led to an environment where access to gas is based on special/social interests rather than on economic principles.

118. Gas pricing has resulted in significant economy-wide inefficiencies. For example, the average efficiency of the power generation fleet is approximately 34 percent, which is well below the 50–60 percent efficiency that new combined-cycle gas turbines are able to reach (BPDB 2015). As a result, Bangladesh uses almost twice as much gas for generating a unit of electricity as would otherwise be possible. Residential customers in Dhaka pay a fixed monthly charge for gas regardless of the amount they consume. This fee structure also means that urban customers with access to the gas network pay a substantially lower price for gas than peri-urban customers who have to buy bottled gas; only 9 percent of the population has access to piped natural gas. The situation will change under a planned initiative to introduce LPG in place of natural gas in urban areas.

Supply: Domestic exploration/production, infrastructure needs, and LNG

119. Exploration, both onshore and offshore, will be essential to boost the domestic supply of gas. The potential for discovering new, offshore gas reserves is largely unknown and there is a need for a systematic assessment of likely gas resources, both offshore and deep-onshore. High-quality geological data to underpin exploration; access to expertise and resources to ensure the latest, most-efficient

techniques of exploration and extraction are adopted; and the ability to attract high-quality companies to explore fields in Bangladesh will be critical.

120. Till recently, Petrobangla and its subsidiary, the BAPEX, have had an exclusive right to onshore exploration. Exploration of onshore areas has till now excluded a range of geological thematics that include sealing faults, and deep horizons below high-pressure zones. In the past, BAPEX has struggled with a lack of funding and a shortfall in technical knowledge and manpower resulting in underutilization of the drilling rigs used for identifying and assessing the quality of new reserves. The shortage of funding for exploration is difficult to understand and warrants further analysis because Petrobangla and its distribution subsidiaries appear to have amassed over US$2.3 billion in cash reserves and short-term deposits (Petrobangla 2015a). In addition, the BERC has earmarked a share of the incremental revenues earned due to tariff increases for the Gas Development Fund, created in 2009. Since 2009, US$100 million in gas revenues per year have flown into this Fund, which is dedicated to exploration and development of fields. However, rather than financing the activities of its own exploration company, the Government engaged Gazprom in a G2G deal to drill 10 onshore wells at a total cost of US$200 million. Going forward, BAPEX envisages a significant increase in drilling, and looks to obtain international expertise to explore new geologic formations. To achieve this, Petrobangla aims to enter into joint ventures and joint operating agreements with the private sector.

121. Offshore, a lack of geologic and seismic data has resulted in limited understanding of the potential for new gas finds. However, IOCs have recently discovered significant reserves of gas off the coast in Myanmar, which has a similar offshore geology to that of Bangladesh, pointing to the potential for finding gas offshore. The absence of geological data significantly increases the risk of fruitless exploration and hence the compensation demanded by investors. MPEMR has not been able to attract operators to undertake a multi-client seismic survey, partly, because there seem to be too few firms willing to make an upfront commitment to buy the reserve probability analyses and data that would be collected. One solution would be to for the public sector to fund the seismic survey and make the data publicly available at a nominal cost (as in the United States, for example) to spur interest in exploration.

122. IOCs have also been reluctant to explore for offshore reserves because they consider the PSCs rigid and financially unattractive, and the process of award/licensing is slow and cumbersome. After the 2008 offshore bidding round, the GoB has gradually increased the contractual price for gas purchased from IOCs. However, PSC financial terms are still considered non-remunerative with regard to deep-water production and the gas extracted cannot be sold to parties other than Petrobangla so the private sector has showed little interest in further offshore exploration. Thus far only a fraction of the deep-water areas offered has been explored through seismic surveying. This has been undertaken by companies on their own account and the data discovered is considered proprietary. The PSC terms were a disincentive cited by ConocoPhillips, which explored two deep-water blocks and reportedly found 2Tcf of potential reserves in 2013 but did not proceed to production. The government has since recognized that financial terms for offshore exploration need to be competitive globally and ensure returns that justify exploration in Bangladesh, and a review of PSCs has been initiated.[55]

123. Petrobangla produces 45 percent of domestic gas supplied in the country while Chevron supplies almost all of the remaining 55 percent. Petrobangla inherited its fields from the Pakistan Shell Oil Company, which discovered the majority of the state-owned company's operating fields in the 1960s. Exploration and development by Petrobangla has not significantly expanded reserves or

[55] This is being funded as part of World Bank technical assistance to the sector.

production. In fact, production by Petrobangla has remained flat since 2005 with growth in gas supply coming from IOC production. An independent review of Petrobangla's operations (Schlumberger 2011) has shown that through better maintenance and enhanced recovery, production could be increased from its fields. Limited expertise and lack of access to necessary technology/know-how has hamstrung Petrobangla's production subsidiaries' efforts to enhance the efficiency of production. Opening onshore production to IOCs or entering into joint ventures with international operators can help address these lacunae.[56,57] Incentives for squeezing inefficiencies out of the system are also likely to be enhanced if prices received by producers increase.

(i) Infrastructure needs

124. While Bangladesh's high-pressure gas transmission network is fairly extensive and does not require significant investment, its production and distribution infrastructure need to be upgraded.[58] As its gas fields get depleted, the pressure in them is declining; more compressors are needed to pressurize the gas extracted to ensure that it meets pipeline standards for transport. Production from Petrobangla's fields themselves could be increased through investment in additional wells, well-head compressors and upgrades/workover to existing wells. New compression stations and upgrades together could increase production by up to 100 mmcfd (Schlumberger 2011). The gas pipeline (transmission) network will likely need to be expanded once the planned onshore LNG terminals (see following section) begin operation. The distribution network is undersized and outdated, especially within Dhaka, and a flat-fee domestic rate contributes to wasteful use of gas. Overall, the gas supply infrastructure at the retail end needs to be upgraded with new metering infrastructure, although these are fairly low-cost investments.

(ii) LNG imports

125. The looming decline in domestic gas production in combination with the large installed base of gas-fired power plants that will otherwise be unable to operate has made it urgent to develop alternative supplies of natural gas. With the maturation of LNG markets, the Government has decided to import LNG and is now setting up import, regasification, and storage terminals—one offshore and three planned onshore. Key questions in this regard relate to the larger strategy underpinning the Government's decision on LNG, including (a) the optimality of multiple terminals, (b) clarity on roles of different agencies and responsibilities for investment in associated infrastructure, (c) approach toward procuring LNG, and (d) addressing the implications of the difference in price between domestically produced gas and LNG, at a minimum.

126. Of the proposed onshore terminals, one is being planned by Electricity Generation Company of Bangladesh (EGCB), in its first foray into this business, and two are being considered by Petrobangla. Excelerate, a Houston-based company that supplies ships for floating regasification and storage of LNG, will own and operate the offshore terminal that is due to begin operation in early 2018. The level of LNG demand foreseen, the time horizon over which this demand is expected to materialize, and the rationale for building three onshore terminals (as opposed to building one or two and enlarging capacity in line

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[56] Recognition of this reality in neighboring India has led to the recent notification of a new more market-oriented hydrocarbon exploration and licensing policy (HELP) and an all-out effort to woo IOCs to invest in exploration and production.

[57] Civil society has been vocally against IOC participation, particularly onshore, which has contributed to the difficulty in opening onshore exploration to IOCs.

[58] Based on conversations with officials of Petrobangla.

with growth in demand) have not been presented in the public domain.[59] Nor is there clarity on why BPDB (or its subsidiaries, such as EGCB) should enter the upstream fuel supply business or indeed how the operation of the three terminals will be coordinated and managed across the different entities under the MPEMR. The move to construct three highly capital-intensive onshore terminals may reflect a lack of robust infrastructure planning.[60]

127. The import of LNG is expected to require investment in associated infrastructure, including pipelines to carry gas from the terminals to delivery points, possibly by the private sector on a build-own-operate-transfer (BOOT) basis, and likely by an international operator. Foreign companies, in particular, are likely to require a third-party guarantee or assurance of payment in view of the significant fixed investment[61] involved in these facilities, the risk of them not covering their costs if revenues remain low due to the low domestic retail price of gas, and the absence of a Government track record in making up such revenues through fiscal transfers.

128. the market for LNG has changed significantly. New, non-traditional producers (for example, producers of shale gas in the United States) have entered leading to oversupply and a decline in prices, and a single global spot market appears to be in the making. The lower oil price environment has also affected Asian long-term LNG contract prices. Buyers can procure LNG through term contracts, which can range from a few years to 25 years, or through the spot market. Most suppliers still require long-term, take-or-pay contracts with guarantees to undertake investment in liquefaction facilities and today roughly 80 percent of LNG is traded based on term contracts while the rest is sold on a spot basis (Poten and Partners 2015). However, over the medium and long run, market prices are expected to be maintained at levels significantly lower than those observed as recently as 2014. This has created an opportunity for buyers to obtain gas on far better terms than otherwise.

129. Bangladesh will need to procure LNG on both a term and spot basis. As term contracts lock in payments for up to 25 years, Bangladesh will have to assess the demand for LNG ahead of time to avoid having to pay for cargos it does not need. Hence, an LNG acquisition strategy should be defined, grounded in forecast demand for LNG. Bangladesh signed an MoU to purchase gas from Qatar some years ago. However, it can benefit from both lower prices and greater flexibility if it were to use a mix of G2G, shorter-term, and spot contracts. A well-designed LNG acquisition strategy can ensure stability in supply at relatively better terms than a single long-term contract. As a new and relatively small buyer competing with financially stronger buyers for cargos, credit enhancement will likely help Bangladesh to obtain LNG on better terms than otherwise.

130. The fiscal implications of maintaining a low retail price of gas in the face of LNG imports need to be considered going forward. While considerably cheaper in 2016 than even a couple of years earlier, it is estimated that the delivered cost of LNG in Bangladesh could be US$5 per mmBTU to US$6 per mmBTU. The price of domestic gas in 2016, however, averaged US$2 per mmBTU. If the retail price of gas is not increased and assuming that imports amount to 500 mmcfd initially, the government will need to subsidize gas in the amount of US$730 million per year. Maintaining a uniform price for gas

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[59] It has been suggested that the relatively shallow waters and broad continental shelf around Bangladesh limit the possibility of large ships anchoring at Bangladesh's ports (see Energy and Power at http://ep-bd.com/online/details.php?cid=32&id=17538, July 2016). The few shipping channels with appropriate draft to handle large or mid-sized tankers means several smaller land-based LNG terminals across the coast may, in fact, be cost-effective but the studies presenting these facts are not publicly available.

[60] Only the floating LNG terminal is mentioned in the 7th Five-Year Plan document.

[61] It costs around US$850 million to build an onshore terminal with capacity to handle 500 mmcfd.

consumed *including imports* (that is, 2,700 mmcfd plus 500 mmcfd) such that there is no fiscal burden would require a weighted average retail price of US$ 2.6 per mmBTU or a 30 percent increase on average in the price for natural gas.[62] Two-tiered pricing—one price for domestically produced gas, directed to priority social consumption, and one for LNG, which would be sold at market prices—is an option under consideration.

131. The implications of LNG imports for power generation and prices also need to be considered. The shortage of gas has led to the use of more expensive liquid fuels (HFO, furnace oil, diesel) to generate power, in many cases by short-term rental plants, over the last decade. Although the use of liquid fuels, all of which are imported, pushed up the average cost of power generated, this was considered to be a temporary expedient until more low-priced domestic gas or coal-fired baseload capacity came online. As a result, retail power tariffs were not adjusted to cover the cost of power and the gap was filled by an explicit budgetary transfer to BPDB (which is the single buyer in the Bangladesh power market). In 2013/14 and 2014/15, the annual fiscal transfer to BPDB averaged around US$820 million.[63] It is expected that LNG imports would replace the use of imported liquid fuels for power generation. This would be somewhat less expensive than oil-fired generation, but so long as LNG prices remain linked to the price of crude oil, the cost savings are not likely to be significant. A gradual adjustment in power tariffs will be necessary if fiscal transfers to BPDB are to be avoided.[64]

Key areas for action

132. Institutional weaknesses that have contributed to the picture drawn above should be addressed if the sector is to contribute to the economy in line with its potential. These include an absence of integrated energy planning; the limited independence, role, and capacity of the regulator; and an anachronistic and inefficient industry structure, among others.

133. It will be important for the Government to take a holistic view when developing its strategy for the sector, starting with a bottom-up integrated energy plan. The 2016 Bangladesh PSMP prepared by JICA focuses on electricity, with minimal analysis of the availability of primary fuel, likely supply and overall energy demand. The Government has recently engaged consultants to prepare a Gas Sector Master Plan (GSMP) to assess infrastructure requirements and investment needs in the sector and to develop a road map to assure gas supply, including plans for LNG imports going forward. The lack of integrated energy planning has led to a belated realization of the limits to domestic gas production, pricing that has encouraged wasteful use of gas and resulted in shortages, absence of a strategy for new field development, and the move to significantly expand coal-fired power generation.

134. It is also important to swiftly implement initiatives to enhance the availability of gas. A strategy for increasing gas availability would necessarily have multiple prongs—enhanced exploration and development as well as gradual revision of gas pricing, in addition to importing LNG. Starting immediately, it would be useful to (a) develop a comprehensive strategy toward exploration and

[62] Over time, as the share of LNG in total gas consumption increases, this weighted average price would need to gradually increase.

[63] Subsidies were US$811 million in FY13–14 and US$830 million in FY14–15 according to the BPDB's Annual Report. While the domestic (administered) price of oil was initially maintained at a higher level than internationally, it has been lowered recently (in May 2016) but oil is still considerably more expensive than LNG.

[64] An upward adjustment in the price of domestic gas will incentivize efficiency in the use of gas (for power generation as well as other uses) which may result in a lower demand for LNG and less need for fiscal support both on account of less LNG being used and because the cost of domestic gas-fired power would increase.

production, which includes an assessment of the geological data available, approaches towards de-risking investment in exploration, and consideration of options to improve the fiscal regime for exploration and production, as well as improvements to the process/speed of concession award; (b) review the national approach toward gas pricing including the role and responsibilities of Petrobangla and the regulator and consider how best to ensure that the appropriate economic signals (for example, relating to scarcity, the value of the next best alternatives, and so on) are not vitiated; (c) prepare and implement a flexible LNG acquisition strategy.

135. It may also be time to revisit the organization of the sector to make sure it is in sync with developments in the rest of the world. The sector is dominated by Petrobangla, the state-owned monopoly responsible for the entire gas supply chain from exploration and production to transport and distribution/marketing, all of which are managed through its subsidiary companies. While IOCs are permitted to explore and produce gas, they must sell the gas at contracted rates to Petrobangla. Petrobangla decides on the PSC terms, manages the concession process and evaluates bids (though awards are approved by the PMO), and supervises the implementation of the agreements, all the while being an active participant in the market itself. An expert review of the implications of this multiplicity of roles, with the aim of minimizing the potential for conflict of interest and hiving off regulatory responsibilities to other sector entities would be useful. It would also be important to assess the extent to which the structure of the sector is holding back its development.

136. Clarify the mandate and strengthen the capacity of the regulator. Regulation of the performance of a statutory monopoly like Petrobangla would appear to be an important priority but Petrobangla is outside BERC's purview. As an instance, regulation of the price of gas is split between the Energy Division of the Ministry, which sets the well-head price of onshore gas produced by Petrobangla, and BERC, which is responsible for deciding the retail price of gas following a cost-plus methodology that ensures that production, transmission, and distribution margins are covered. However, BERC lacks the jurisdiction to assess the efficiency and appropriateness of the production price and margin. At the same time, the capacity and independence of BERC need to be bolstered. It would be useful to start with a review of the mandate of the regulator across the sector, filling in gaps such as those related to gas pricing discussed above; ensuring the regulator is adequately resourced and staffed, in a manner that insulates it from short-term political winds; and giving it tools to enforce its decisions.

VII. Looking ahead

137. Two broad issues warrant attention as the sector positions itself for the future: (a) weaning the sector off financial support from the Government and allowing prices to signal scarcity and value and (b) minimizing the negative impacts on climate change from the power sector's planned growth trajectory. Not only is climate change likely to impact Bangladesh massively, but, over time, carbon pricing is likely to make fossil-fueled power less competitive than it is today at the same time as commercial financing for power generated by fossil fuels will become more scarce/expensive.

Increases in the price of power

138. Any investment in power generation must assure the supply of fuel or risk creating a stranded asset. As gas is still the most important fuel for power generation in Bangladesh, the Government has an interest in assuring economic, efficient production and pricing of gas and its availability for power generation. Fuel risk stems from the sector's overwhelming dependence on gas-fired generation in the face of rapidly depleting domestic natural gas reserves that are estimated to last for 15–20 years at existing rates of exploitation. LNG imports are on the cards and this will provide an impetus to review gas pricing and to move toward prices that are closer to the opportunity cost of gas. But, as indicated below, adjustment to international prices is likely to impose significant short-term costs on the economy. It is, therefore, recommended that the move to full parity with international prices occur gradually and in sync with the share of LNG in the gas mix.

(i) Results from a financial modeling exercise

139. Electricity prices to end-users averaged around Tk 6.39 per kWh, resulting in an annual deficit of Tk 42 billion (US$538 million) in fiscal year 2016. End-user prices of electricity have seen gradual adjustments with the average price increasing by about 60 percent since 2009 in nominal Taka terms (40 percent increase in nominal dollar terms). As noted earlier, Bangladesh plans to import LNG to supplement declining domestic gas production. This means the average cost of gas supplied to the sector will increase as the share of LNG in the total fuel mix rises, causing the cost of power procured to also go up. The expectation is that domestic gas prices will converge in the long run to LNG import prices, altering the economics of generation.

140. A financial modelling exercise, with the planning model of the BPDB as its basis, was carried out to forecast power sector subsidy requirements in coming years (Sadeque and Bankuti 2017), taking the power generation expansion plan of the GoB as its starting point. With 2016 as the base year, the model makes projections for 2017–2025.[65] In the baseline scenario, the cost of power supply to end-users is projected to rise from Tk 7.51 per kWh in 2016 to Tk 9.25 per kWh by 2020, and over Tk 12.51 per kWh by 2025. The increased costs are the result of fuel substitution from low-cost domestic natural gas to more costly options (coal, LNG, liquid fuel) and an assumed higher cost of domestic natural gas (to reach parity with LNG).

141. Going forward, electricity price adjustments will need to continue in the near term to match the increased costs of generation. A tariff increase of 8 percent per year will be required to achieve breakeven by 2020 (that is tariff sufficient to cover costs and therefore no budget transfer required). The baseline scenario in the model reflects a situation of domestic gas priced significantly below

[65] All years are July–June fiscal years.

international levels being used as the primary fuel for power generation, and an ambitious plan of the Government for building low-cost coal-based baseload power plants. The share of coal in the generation mix is assumed to go up from less than 2 percent in 2016 to 40 percent by 2025, with the share of natural gas (including LNG) dropping from 65 percent to 45 percent by 2025.

142. The projections show that coal generation will be more expensive than electricity imported from India, and as such, increasing power imports should be a policy priority to be included in planning for the sector. In this regard, it should be noted that Bangladesh was able to develop the first 500 MW of import capacity in a relatively short period and is looking to add another 500 MW by 2018 while the construction of many coal plants remains in planning stages.

(ii) CGE analysis of the impact of price increases

143. To complement the focused sector-level financial analysis above and better understand the economy-wide impact of electricity tariff increases, a CGE analysis was undertaken using a model developed for Bangladesh (Timilsina et al. 2017). The model was used to trace through the impact of an increase in the price of electricity on GDP, household consumption, economy-wide investment, government income, the trade balance, inflation, and sectoral outputs and prices. Two scenarios were analyzed under which electricity tariffs are increased: (a) on account of the removal of the de facto subsidy that consumers have benefitted from over the past many years and (b) due to an increase in the price of gas consumed domestically to international levels (in anticipation of the import of LNG).

144. The key point illustrated by the CGE analysis is that increasing gas prices and/or removing the electricity subsidy would increase the cost of goods and services which are gas and/or electricity intensive, with a negative impact on producers and consumers as electricity and gas become more expensive than before. On other hand, removing electricity subsidies frees up budgetary resources and pricing domestically produced gas at the international price of gas generates additional revenues for the state, both of which, when returned to the economy, boost demand. The size of the stimulus is so large that it outweighs the short-term negative impact of the increase in price of electricity and gas, respectively, which, as key inputs would put pressure on economy-wide production costs and on consumption in a cascading effect.

145. The value of the model lies in the indicative results, insights and options it provides for decision makers to take into account in their planning and policy formulation. The key to maximizing the impact on GDP and its constituents is the route chosen for recycling the budgetary savings/revenues generated. The study shows that if the savings from electricity subsidy removal are recycled in the form of investment in productive sectors, it would increase GDP and economic welfare and improve the trade surplus. Similar impacts are seen in the analysis of a hike in gas prices, but to understand the full impact of pricing gas at its opportunity cost would require a dynamic model, which is left for a future effort.

146. Depending on the speed of adjustment in different sectors, the impact of the shock on the economy could be more or less disruptive and warrants consideration of a glide path to the new equilibrium. Given the magnitude of GDP and sectoral impacts (considerably higher for the gas policy change than for electricity), and the fact that for gas the deviation from baseline and impact is likely to be lower in outer years, a gradual reduction of subsidies as opposed to a big bang seems reasonable. Of course, the gains to the budget will be lower but the political and other costs of reform will also be more manageable.

147. The impacts (on prices and outputs) are likely to be disruptive in many sectors. Particularly for the sectors that are hardest hit by the increase in gas price, such as manufacturing (output decline of 10 percent), fertilizers and chemicals (declines of ~7 percent), metals and petroleum (~5 percent), transition support is likely to be essential. Even starting from a low base and acknowledging that these may not have been sectors of greatest competitiveness for Bangladesh, the declines would need to be managed with sensitivity through active support for social safety net extension, retraining, and similar initiatives. Several of these same sectors would also be negatively impacted with the removal of electricity price subsidies alone so the same thoughtful approach would apply there as well.

148. Going forward, it would be important to carry out a supplementary distributional analysis of the impacts of overall and sectoral price adjustments to understand the implications for poverty and welfare and thus the full potential impact of the policy changes being analyzed. A clear takeaway from this analysis, however, is that there is a tremendous opportunity cost to the subsidies to electricity and gas being provided by the Government and welfare could be enhanced by redirecting the spending to more productive channels as outlined by the recycling schemes presented here.

Climate change and the move to coal

149. For 2015 United Nations Climate Change Conference (COP21), Bangladesh's Intended Nationally Determined Contributions (INDCs) (see Table 7.1) outlined a modest plan for mitigating carbon emissions from energy—its business-as-usual (BAU) development trajectory is heavy on coal and the Government's proposed climate change mitigation measures include such actions as switching to 100 percent super-critical coal power generation; developing utility-scale solar energy; scaling up wind energy; repowering steam turbines to CCGT; expanding the SHS Program; installing more solar irrigation pumps; expanding solar mini-grids, nano-grids, and pico solar; and scaling up biomass production from sugar.

Table 7.1. Summary of Bangladesh's INDC

Sectors	Base year - 2011 (MtCO2e)	BAU scenario (2030) (MtCO2e)	BAU change from 2011 to 2030	Unconditional contribution scenario (2030) (MtCO2e)	Change vs BAU	Conditional contribution scenario (2030) (MtCO2e)	Change vs BAU
Power	21	91	336%	86	-5%	75	-18%
Transport	17	37	118%	33	-9%	28	-24%
Industry (energy)	26	106	300%	102	-4%	95	-10%
Total	**64**	**234**	**264%**	**222**	**-5%**	**198**	**-15%**

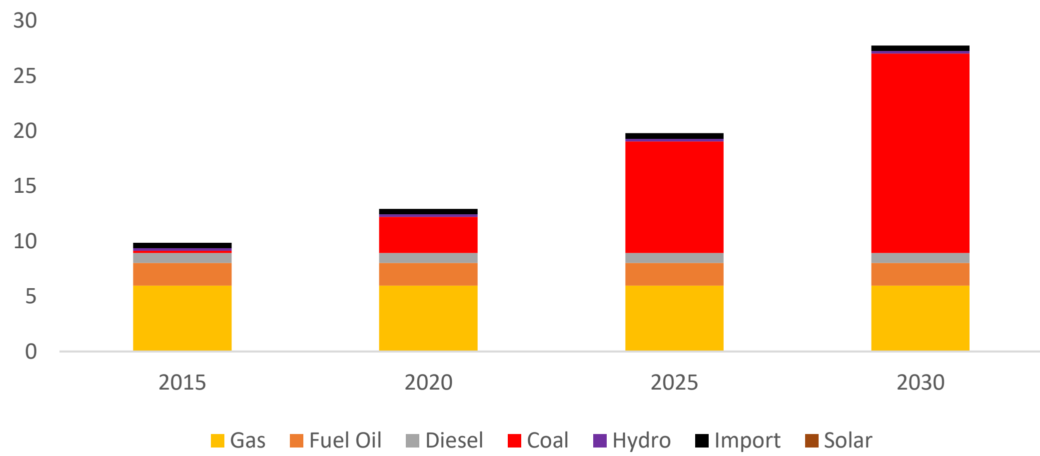
Source: INDCs September 2015.

150. Recognizing the need to diversify its sources of supply, the GoB is moving to imported-coal-fired generation in a big way in the face of declining production of domestic gas. Taking account of the GHG emissions and pollution implications of coal-fired generation and the fact that gas is the cleanest fossil fuel (carbon emissions half that of coal), significant global benefits could accrue if Bangladesh is able to avoid coal to some extent or delay its move to coal.

151. Modeling the climate change implications of the Government's plans, that is, following a least-cost expansion path that does *not* take into account the social cost of carbon and aspects related to the

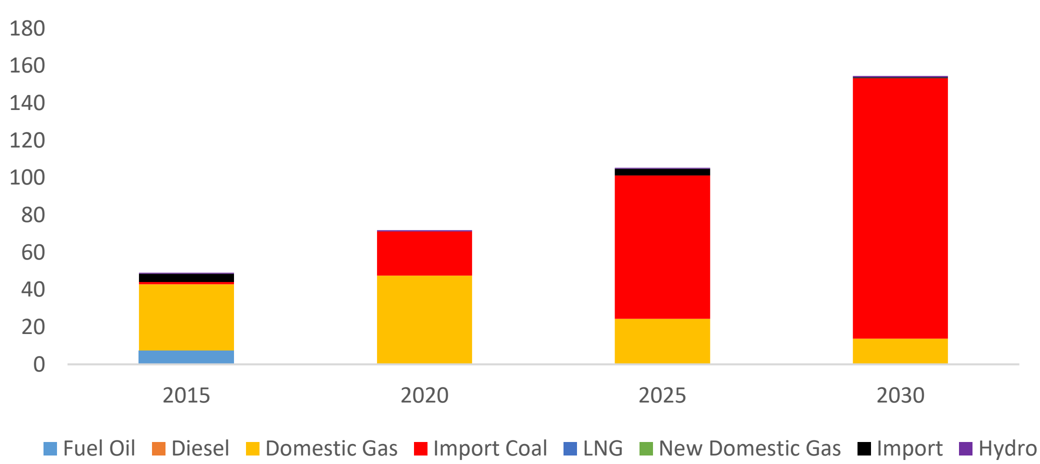
logistics of setting up coal plants described in earlier sections of this report (Bankuti, Chattopadhyay, and Pargal 2016), it is estimated that 20 GW of new capacity would be required to meet demand in 2030. If the social cost of carbon is not accounted for, 18 GW of this would necessarily be coal since it would be the cheapest source of power. Government plans to move to coal will increase emissions fivefold from 21 $mtCO_2$ in 2015 to 110 $mtCO_2$ in 2030 as illustrated in Figures 7.1–7.3.

Figure 7.1. Generation capacity (GW)



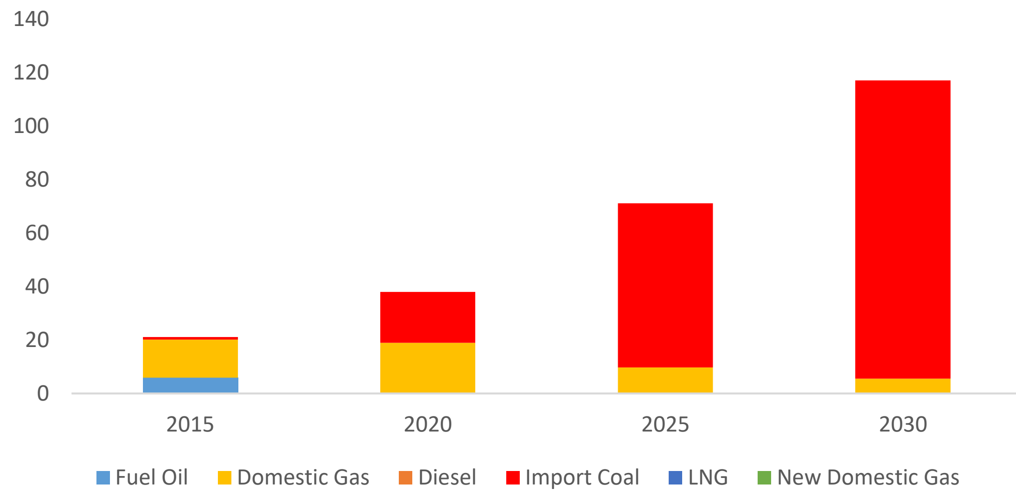
Source: World Bank staff calculations.

Figure 7.2. Electricity generation (TWh)



Source: World Bank staff calculations.

Figure 7.3. CO_2 emissions ($mtCO_2$)



Source: World Bank staff calculations.

152. As seen from the model results, efforts to minimize coal-fired generation should be prioritized so that Bangladesh can avoid lock-in and the significant environmental (air and water pollution) costs associated with it. This could ensue if domestic gas production increases consequent on new finds, pricing improves incentives for efficiency in gas use (including investing in new CCGT or in repowering of existing gas fired generation), pricing of externalities and efficiency of acquisition makes LNG imports competitive with imported coal, and so on. To the extent that domestic exploration and production of gas can be given a fillip and also the uncertainty and price volatility associated with imports of LNG can be ameliorated through modern hedging and other financial/market tools, this will help. The benefits of imposing a carbon tax on oil are already being discussed—it may be opportune to discuss carbon pricing more broadly and its differential impacts on coal, oil and gas.

153. While potential for renewables remains to be fully realized,[66] Bangladesh will need to explore the more conventional choices described above. Power imports are well recognized within the Government as an important low-cost and clean supplement to domestic generation and are set to increase. They will likely take off when the goal of a regional power pool is realized -- more work is needed at a government-to-government level to take this option forward.

154. Overall, consistent with the analysis described in the earlier parts of this report, the Government should try both to minimize the need to add to system capacity as well as encourage investment in non-coal generation if it is to minimize emissions. Potential actions include liberalizing domestic gas and electricity prices to enhance efficiency and incentivize investment (including in exploration and production of domestic gas); investing in EE and in enhancing system efficiencies; implementing a tax on coal or on CO_2 emissions, and so on.

[66] Poor resource endowments (hydropower, wind) and other constraints (availability of land/rooftops for solar power) make it unlikely that renewables will contribute more than 5–7 GW to the mix given today's technology. Given the pace of technological change in the sector, however, this may not be the last word on the topic.

VIII. Conclusions

155. The power sector is an important engine of growth in Bangladesh and ensuring that it performs well is a priority for the Government. This report has highlighted the multiple factors pushing up the cost of power generated at the same time as the push to provide universal access to adequate power requires that more capacity be added to the system.

156. Recommendations emanating from the analyses carried out are as follows

- **Develop a wholesale power market for generation and cross-border imports**. A basic challenge emanates from Bangladesh's dependence on its rapidly depleting natural gas reserves to fuel power generation. Alternatives to domestic gas include imported LNG and coal but both of these will result in significantly more expensive power. Power import, initially from India, is already a proven option and can be attractive and sustainable in the long term. Bangladesh needs to be proactive in developing a power market and market-based trading of power.

- **Let electricity prices gradually rise to reflect costs.** Limited additions to baseload capacity during the last decade and the existence of transmission bottlenecks and inefficient processes that have prevented dispatch of available capacity have together resulted in a significant reliance on oil-fired generation.[67] Oil's share of peak generation has increased from 24 percent to 30 percent since 2011 and this has been an important factor in pushing up the average cost of power generated. Consumers have been shielded from the associated increase in the cost of power procured, but the fiscal burden is significant and comes at a high opportunity cost. Electricity prices should be gradually increased to maintain sector financial viability which is critical to ensure that future growth in power demand can be met through the requisite private and public investment.

- **Harness all possible efficiencies**. System-wide inefficiencies contribute to avoidable costs and need to be priorities for government action. There is significant scope for action on the demand side and, again, simply allowing the price of power to reflect the cost of generation can go a long way toward creating incentives for conservation and efficiency in generation and the use of power, limiting the need for additional capacity.

- **Move toward clean energy solutions.** Another important challenge is climate change and the implications of Bangladesh's move to build a significant share of coal-fired capacity from a starting point of scarcely any use of coal. Apart from the considerable capital and logistics costs of this move, it will also mean greater GHG emissions and negative consequences for climate change, which, for Bangladesh, may be of existential importance even though it is not a large emitter in the global context. It is worth noting that once coal imports are a reality a whole ecosystem of coal use—in transport, industry, and others, is likely to come into being. A decision, later on, to walk back from these would create massive stranded assets.

- **Maximize potential use of renewable energy sources**. Given low levels of generation from renewables, a sound strategy for Government is continuing to invest in collecting and making available good data on the size and quality of the solar and wind resource; supporting the

[67] About 2.4 GW of fuel oil/diesel generation capacity was added from 2010 to 2014; small rental plants accounted for 2 GW of this. These plants tend to be less efficient than the gas-fired plants, particularly larger IPPs.

development of the market by sponsoring or undertaking pilots and demonstration projects; and, developing risk mitigation offerings to attract private investors into what is still considered a nascent and unproven sector in Bangladesh. While the potential for renewables appears limited, this could increase as renewables generation technologies mature and are complemented by development of low-cost electricity storage options.

- **Build capacity for planning.** A final issue that goes to the heart of these recommendations is the fact that the unbundling of BPDB has had the unintended consequence of disturbing the planning function for the sector, resulting in a situation of multiple decision-making loci and limited coordination among them. Recreating an institutional home for coordinated sector planning should be a priority so that, for example, gas sector issues are not divorced from electricity sector discussions, and so on. Bottom-up integrated energy planning would be beneficial for the sector—as a way of ensuring consistency in upstream and downstream decisions as well as ensuring that all linkages are taken into account in devising the sector expansion strategy. It would be good to maintain dedicated capacity to develop long-term integrated energy sector plans and undertake the studies that would provide inputs to the plans. For example, the integrated plans could provide the underpinning for in-house periodic updates to both the recently completed PSMP (developed by JICA) and the GSMP (under preparation by an international consulting firm). In addition, such a unit could develop a coherent strategy for integration of renewable energy into grid supply and consider how best to take advantage of the falling cost of solar PV and storage.

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Annex

Assumptions Underlying Break-even cost analysis

Table: Break-even cost of carbon

		Weighted Average Cost of Capital			Coal/Gas Price US$/mmBTU		
		(Gas US$7/mmBTU, Coal US$3/mmBTU)			Coal 4, Gas 7	Coal 4, Gas 6	Coal 3, Gas 8
WACC		8% (Base)	9%	7%	8% (Base)	8% (Base)	8% (Base)
Coal LCOE	US$/MWh	59.0	61.7	56.4	66.5	66.5	59.0
Gas LCOE	US$/MWh	74.0	74.9	72.3	73.6	66.1	81.1
Breakeven CO_2 Price	US$/ton	42.0	37.9	45.5	20.3	(1.1)	63.2

Notes:

1. Coal price of US$3 per mmBTU is roughly in line with Indonesian or Australian coal price forecasts (http://pubdocs.worldbank.org/en/662641493046964412/CMO-April-2017-Forecasts.pdf)
2. Gas prices in the timeframe coal plants become operational (at least 2022 if not later) would be in the US$7–8 per mmBTU zone rather than the US$5–6 per mmBTU being discussed today according to the World Bank forecast as well as that stated in PLATTS. https://www.platts.com/latest-news/natural-gas/dhaka/bangladesh-plans-first-power-plant-for-imported-27828532
3. We have therefore taken coal at US$3 and gas at US$7 as the base case to go with WACC of 8 percent (which is where most merchant projects are).
4. WACC generally has less of an impact on the difference between gas and coal LCOE but the differential gas-coal price has a **big** impact as one would expect. All things being equal, a differential gas-coal price would virtually render the two LCOES to equate.
5. CO_2 break-even price = (Gas LCOE – Coal LCOE)/(Difference in emission intensity of coal and gas).
6. CO_2 break-even price is around US$42 per ton for the base case of 8 percent WACC (US$3 coal, US$7 gas of a fuel price differential of US$4 per mmBTU) but will drop to ~US$20 per ton if the fuel price differential is US$3 and rises to US$63 per ton for a differential of US$4.

CAPEX of coal projects is assumed to average around US$2,500 per kW and of CCGT around US$1,200 per kW. The ‘high coal’ plant CAPEX includes all coal handling costs according to the BPDB, consistent with JICA PSMP. That is almost double the cost of a coal plant in India.