ECONOMIC ANALYSIS

I. INTRODUCTION

1. The economic analysis of the Rupsha 800-Megawatt (MW) Combined Cycle Power Plant Project was conducted in accordance with Asian Development Bank (ADB) guidelines,[1] and measured the costs and benefits in 2017 constant prices from 2018 to 2046. The economic internal rate of return (EIRR) was calculated by comparing the with- and without-project scenarios. All financial prices were converted into economic prices by applying the corresponding conversion factors. A sensitivity analysis was conducted to ascertain the robustness of the investment.

2. The project includes (i) the construction and operation of the Rupsha 800 MW gas-fired combined cycle power plant in Khulna, in the southwestern part of Bangladesh; (ii) the construction of a gas supply pipeline and related network infrastructure; (iii) the construction of a power transmission interconnection facility to transfer power from the Rupsha power plant to the national grid; and (iv) strengthening of the institutional capacity and overall business process of the project's executing agency, North-West Power Generation Company Limited. The economic analysis included all components.

II. ECONOMIC RATIONALE

A. Country and Sector Analysis

3. Over the last decade, the power sector in Bangladesh has witnessed significant progress in power generation. However, the increase in generation has not been sufficient to meet the rapidly rising demand for electricity, resulting in persistent load shedding. Moreover, the country faces shortages of both electricity and natural gas at a time when the power sector is heavily dependent on natural gas-fired generation.

4. The severe power crisis has compelled the government to enter into contractual agreements for quick rental and small independent power plants, mostly using diesel or liquid fuel. Even though the government prepared an aggressive power generation plan to cope with critical power shortages, delays in implementing planned power plants and failure to commission in a timely manner has forced the government to extend most of the existing rental contracts for another term.

5. The generation cost of rental power plants using diesel or liquid fuel is several times more expensive than the average tariff, which imposes tremendous fiscal pressure on the government's budget and aggravates the financial position of the power sector. The financial deficit will further increase unless short-term rental contracts are terminated and replaced by power plants with the lower electricity generation cost. In addition, power plants operated by public utilities are relatively old and inefficient. Around one-fourth of Bangladesh Power Development Board's power plants are more than 20 years old, and the average efficiency of these plants is around 30%. In line with shortages in natural gas production, improving the efficiency of the gas-based power plants has become critical to improve the effectiveness of gas utilization.

6. **Demand analysis.** Since 2008, peak electricity demand rose annually by 6.8% while electricity generation grew by 6.5% per year. Power demand was forecast in the Power System

[1] ADB. 2017. *Guidelines for the Economic Analysis of Projects*. Manila.

Master Plan[2] to grow at around 9.6% per year from 2017 to 2022 and 6.9% per year from 2022 to 2040.[3] From 2017 to 2046, the industry sector is forecast to account for 50% of total demand, the residential sector 39%, the commercial sector 8%, and the agriculture sector 3%. These demand forecasts by sector were used in the analysis.

B. Associated Infrastructure

7. **Transmission infrastructure.** Electricity generated in the power plant will be stepped up to a transmission voltage of 230 kilovolts. A new 29-kilometer (km) transmission line from the proposed power plant to the existing Khulna south substation will be built under the project, and a new transmission line from the Khulna south substation to the Mongla transmission line is presently under construction. The 400-kilovolt double circuit transmission line from Mongla to Aminbazar, which connects the western region of Bangladesh to the Dhaka region, has been committed by ADB.[4] Therefore, the electricity generated from the power plant can be transferred through an enhanced transmission network by the time of completion. The generated electricity will serve the western region first, and the remaining electricity can be transferred to the Dhaka region later.

8. **Gas infrastructure.** The proposed power plant will use imported liquefied natural gas (LNG) as fuel, which will be regasified at the Moheshkhali floating storage and regasification facilities in the Bay of Bengal. The first LNG terminal in Bangladesh is currently under construction and will be completed within 2018. The regasified LNG will be distributed from the terminal to the Chittagong gas distribution system through a 91 km pipeline (completed in August 2017),[5] and from Chittagong to Khulna city gate station through an existing gas grid facility, and from Khulna city gate station to the power plant through a 10 km gas pipeline, which is included in the project scope. Therefore, it was assessed that the gas transmission network is capable of delivering a continuous supply of gas to the power plant without any interruption.

III. COST–BENEFIT ANALYSIS

9. **Assumption.** The economic analysis of the project has been conducted using the following assumptions:

(i) The 5-year project construction period will last from 2018 to 2022, the partial capacity of 540 MW will be installed by the end of 2021, and the full capacity of 800 MW will be installed by the end of 2022.
(ii) There will be an annual capacity factor of 70% and a net efficiency factor of 55.6% throughout the project's life.
(iii) The power station's own-use rate is 3%, the transmission rate is 2.8%, and the distribution loss rate is 10%.
(iv) All costs and benefits were valued using the domestic price numeraire. Tradable inputs were adjusted by the shadow exchange rate factor of 1.03, while unskilled labor was adjusted by a shadow wage rate factor of 0.75, reflecting the level of unemployment and underemployment in the project area.

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[2] Government of Bangladesh; Ministry of Power, Energy and Mineral Resources; Power Division. 2016. *Power System Master Plan 2016.* Dhaka.
[3] Government of Bangladesh; Ministry of Power, Energy and Mineral Resources; Power Division; Bangladesh Power Development Board. 2016. *Survey on Power System Master Plan Draft Final Report.* Dhaka.
[4] ADB. 2017. *Report and Recommendation of the President to the Board of Directors: Proposed Loans and Administration of Grant to the People's Republic of Bangladesh for the Bangladesh Power System Enhancement and Efficiency Improvement Project.* Manila.
[5] A parallel 79 km, 42-inch pipeline is currently under construction to carry additional volumes of imported regasified LNG from Moheshkhali to Anowara, which is expected to be completed by the end of 2018.

(v) The carbon dioxide (CO_2) value was calculated based on $37.03 per ton in 2017 prices, increasing by 2% annually in real terms. The default emission factors by fuel type are taken from the Intergovernmental Panel on Climate Change Guidelines 2006[6] and the grid emission factor of Bangladesh (0.67 tons of CO_2 per megawatt-hour) was taken from the government's Department of Environment.[7]

A. Economic Benefits

10. **Without-project scenario.** The proposed power plant will generate 4,906 gigawatt-hours of electricity every year with a full capacity of 800 MW. Without the project, power would be supplied from expensive quick rental power plants to meet growing demand. If the existing power plants cannot cover the demand, then consumers would have to generate electricity by other available means. In this analysis, under the without-project scenario, it was assumed that residential consumers would use kerosene as an alternate energy source and nonresidential consumers would resort to higher cost diesel-based self-generation. Thus, electricity generated from the proposed power plant will be used firstly to displace small rental power plants in Khulna zone, and secondly to meet unserved demand of customers supplied by the national grid.

11. **Displacing quick rental power plants in Khulna zone.** In Khulna zone, there are currently four power plants with total capacity of 320 MW using furnace oil and diesel under short-term rental contracts.[8] With the project, the partial capacity of 320 MW from the proposed power plant will gradually phase out small quick rental power plants by 2024. The non-incremental benefit of avoided fuel costs and environmental benefits from avoided CO_2 emissions were calculated based on fuel types used by displaced power plants.

12. **Meeting unserved demand of the national grid.** The power plant's remaining capacity of 480 MW will produce energy that will flow to the national grid to meet unserved demand. Incremental outputs were valued using the willingness-to-pay (WTP) methodology, while non-incremental outputs were valued at resource cost savings. Economic benefits include (i) benefits due to electricity consumption by new customers, divided into (a) non-incremental benefits (i.e., replacement of substitutes such as kerosene and diesel) valued at resource cost savings and (b) incremental benefits due to increased consumption valued at WTP; and (ii) incremental benefits from existing customers, comprising incremental revenue valued at tariff and consumer surplus.

13. The average consumption for new residential customers with the project was obtained from the consumption level of domestic customers in the Dhaka area and the prices in the with- and without-project scenarios were obtained from the alternative energy resource cost (kerosene) and current domestic electricity tariffs.[9] The non-incremental benefit for new customers, i.e., the amount of energy displaced by grid electricity, was valued at resource cost savings. Existing customers would also benefit from increased electricity consumption,

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[6] 2006 IPCC Guidelines for National Greenhouse Gas Inventories. https://www.ipcc-nggip.iges.or.jp/public/2006gl/ (accessed 1 March 2018)

[7] Government of Bangladesh, Department of Environment. 2013. *Grid Emission Factor of Bangladesh.* Dhaka.

[8] Bangladesh Power Development Board. *Annual Report, 2015–2016.* Dhaka. The four power plants are (i) Khulna (Khulna Power Company Limited) power plant 1 (110 MW, furnace oil); (ii) Khulna (Khulna Power Company Limited) power plant 2 (115 MW, furnace oil); (iii) Khulna Aggreko power plant (55 MW, high-speed diesel); and (iv) Noapara rental power plant (40 MW, furnace oil).

[9] Bangladesh Rural Electrification Board. 2017. *Management Information System for December 2016.* Dhaka.

consisting of incremental revenue and consumer surplus.[10] The weighted average retail tariff in 2017 was Tk7.8 per kilowatt-hour (kWh), the WTP for new customers was estimated at Tk11.9/kWh, and the WTP for existing customers was estimated at Tk8.7/kWh.

B. Economic Cost

14. **Investment cost.** The project cost includes all investment costs (including the climate proofing investment[11] and capacity development), operation and maintenance costs, fuel costs, and transmission and distribution costs. Investment costs were estimated at Tk68,442 million in economic prices, excluding taxes and duties, price contingency, and financing charges during construction. Costs and benefits were categorized into traded goods, nontraded goods, foreign skilled labor, local skilled labor, and local unskilled labor, and were adjusted with appropriate conversion factors. The transmission and distribution costs were derived from the levelized cost (including capital and operation and maintenance costs) of the transmission line from Aminbarzar to Mongla and the distribution line covering the Dhaka, Chittagong, and Sylhet areas (footnote 4).

15. **Land value.** The proposed power plant will be located in the abandoned Khulna Newsprint Mill complex, which is owned by the Ministry of Industries. The economic price of the land for the power plant was valued at its opportunity cost. Without the project, it was assumed that the land would produce agricultural output every year and the opportunity cost of the land was calculated at the net agricultural output (crop income minus crop input) foregone, measured at economic prices.

16. **Fuel price.** The economic price of natural gas used in the power plant was based on the import price and was assumed to be $8.1 per million British thermal units during the project's life, measured in 2017 prices.[12] To make a border parity price in the project site, regasification, storage, and transmission costs of LNG from the Moheshkhali floating storage and regasification facilities to the Khulna city gas station were added; the import parity price in the project site amounts to $10.3 per million British thermal units in 2017 prices. The economic prices of different energy sources delivered to the plant and/or to consumers for self-generation were based on the crude oil price in energy terms based on the average spot price during 2011–2016 and include 5% transportation cost; these prices were assumed to be 128% of the crude oil price for kerosene, 130% for diesel, and 100% for fuel oil.[13]

C. Environmental Impact and Economic Rate of Return

17. **Environmental costs and benefits.** LNG is a relatively clean fuel with fewer local pollutants and CO_2 emissions compared to diesel- or fuel oil-fired power plants. The project will produce environmental benefits through the reduction of CO_2 emissions, since the proposed power plant will displace electricity generated in the diesel- or fuel oil-fired power plants and electricity in the grid system. CO_2 emissions during construction were estimated to be 30,821 tons, in accordance with ADB guidelines,[14] and the CO_2 emissions from the power plant

[10] Consumer surplus was estimated using the following equation: consumer surplus = $0.5[P_E (\Delta Q)^2] / [e_d Q_1]$, using the Asian average for price elasticity of demand (–0.430) as a proxy value for Bangladesh.

[11] Economic Analysis of Climate-Proofing Investment (accessible from the list of linked documents in Appendix 2 of the report and recommendation of the President).

[12] Japan Liquefied Natural Gas Import Price. https://ycharts.com/indicators/japan_liquefied_natural_gas_import_price (accessed 1 March 2018).

[13] United States Energy Information Administration. Petroleum & Other Liquids. Spot Prices. https://www.eia.gov/dnav/pet/pet_pri_spt_s1_a.htm (accessed 1 March 2018).

[14] ADB. 2016. *Guidelines for Estimating Greenhouse Gas Emissions of Asian Development Bank Projects: Additional Guidance for Transport Projects*. Manila.

operating using LNG as a fuel were estimated to be 1,764,239 tons per year; the annual net emission reduction upon full implementation was estimated to be 1,098,781 tons of CO_2.[15]

18. **Economic internal rate of return.** The results are summarized in Table 1. The project's EIRR is 17.8% and its economic net present value is Tk53,360 million (at an economic discount rate of 9% per year). Without environmental benefits, the EIRR is 13.4% and the economic net present value is Tk23,671 million.

Table 1: Calculation of Economic Internal Rate of Return of Project (Tk million)

	Benefits			Environmental Impact			Costs				
Year	Fuel Savings	New Customers	Existing Customers	Benefits	Costs	Net	Capital	O&M	Fuel	T&D	Net Benefit
2018	0	0	0	0	10	(10)	9,378	0	0	0	(9,387)
2019	0	0	0	0	20	(20)	13,209	0	0	0	(13,229)
2020	0	0	0	0	30	(30)	22,986	0	0	0	(23,016)
2021	0	0	0	0	31	(31)	19,612	2,176	20,068	819	(19,644)
2022	6,889	9,726	16,246	7,682	4,820	795	3,259	2,725	25,135	958	9,401
2023	10,334	11,377	19,113	9,849	6,144	3,622	0	2,725	25,135	821	15,711
2024	13,779	9,751	16,290	10,120	6,267	3,777	0	2,725	25,135	821	14,992
2025	13,779	9,751	16,290	10,322	6,392	3,853	0	2,725	25,135	821	15,069
2030	13,779	9,751	16,290	10,528	7,057	3,930	0	2,725	25,135	821	15,147
2035	13,779	9,751	16,290	10,739	7,792	4,339	0	2,725	25,135	821	15,478
2040	13,779	9,751	16,290	10,954	8,603	4,790	0	2,725	25,135	821	16,428
2045	13,779	9,751	16,290	11,173	9,498	5,289	0	2,725	25,135	821	16,978
2046	13,779	9,751	16,290	11,396	9,688	5,840	0	2,725	25,135	821	17,095
								EIRR			**17.8%**
								ENPV			**53,360**

( ) = negative, EIRR = economic internal rate of return, ENPV = economic net present value, O&M = operation and maintenance, T&D = transmission and distribution.
Note: Only selected years are shown for brevity.
Source: Asian Development Bank estimates.

E. Risk and Sensitivity Analysis

19. **Sensitivity analysis.** Sensitivity analyses were conducted for adverse changes in six inputs to the EIRR for the project; they indicated that the project is robust against adverse changes. Results are summarized in Table 2. Fuel price is an important consideration, since the project will be the first power plant to use imported LNG as a fuel through the Bangladesh gas transmission network. There is a risk that LNG supply will not be available because of risks related to gas supply arrangements. This will lead to a delay in commissioning, resulting in postponement of the revenue stream. However, the analysis showed that the project would continue to be economically viable with a delay in commissioning lasting up to 7 years.

Table 2: Sensitivity of Economic Internal Rate of Return to Adverse Changes in Key Input Parameters

	Input Parameter	EIRR	Baseline Value	Switching Value
	Base case	17.8%		
1	Capital cost increases 10%	16.0%	1.0	1.8
2	O&M cost increases 10%	17.4%	1.0	3.8
3	Capacity factor decreases 10%	15.8%	70%	40%
4	LNG fuel price increases 10%	15.5%	$8.7	$11.0
5	1-year delay in commissioning	15.4%		7 years
6	Oil price decreases 10%	15.7%	$59	$36
7	Combination of 1, 2, 3, 4, 6	10.0%		

( ) = negative, EIRR = economic internal rate of return, LNG = liquefied natural gas, O&M = operation and maintenance.
Source: Asian Development Bank estimates.

[15] The 2 km gas pipeline under the project, which connects the existing Khulna power plant (225 MW) to the gas grid, will generate additional environmental benefits by replacing high-speed diesel fuel with LNG. The annual net reduction of CO_2 was estimated to be 179,425 tons. The benefits relating to the existing Khulna power plant (fuel savings and avoided CO_2) were not quantified in the cost–benefit analysis.