ECONOMIC ANALYSIS OF CLIMATE-PROOFING INVESTMENT

I. INTRODUCTION

1. The economic analysis of climate-proofing investment for Rupsha 800-Megawatt Combined Cycle Power Plant Project was conducted in accordance with Asian Development Bank (ADB) guidelines.[1] The climate change impacts on the proposed power plant and climate change projections during the project life was based on the climate risk vulnerability assessment for the project.[2]

2. The project comprises (i) the construction and operation of the Rupsha 800 MW gas-fired combined cycle power plant at Khulna, in the south-western 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 new power plant to an existing substation at Khulna South, and (iv) strengthening institutional capacity of North-West Power Generation Company Limited.

3. Rupsha power plant is a combined cycle gas turbine thermal power station with a design capacity of 800 megawatt (MW). Under design conditions the plant has a net efficiency of 55.6% and is expected to generate 4,906 gigawatt-hour of electricity per year. The proposed power plant will use imported liquid natural gas as a fuel, which will be regasified at Moheshkhali floating terminal liquefied natural gas in the Bay of Bengal. Construction is scheduled to begin in 2018 to 2022 and the partial capacity of 540 MW would be installed at the end of 2021 and the full level of capacity of 800 MW would be installed at the end of 2022.

4. The aims of this analysis are to (i) show how projected climate change will impact the estimated costs and benefits of the project, (ii) to prove whether the project is still economically viable if there were to be no technically feasible measure to mitigate these impacts, (iii) to answer whether the climate proofing investment is desirable from an economic efficiency point of view, and (iv) if the climate proofing investment is desirable, what the best timing for the investment is.

II. CLIMATE CHANGE VULNERABILITY ASSESSMENT[2]

5. Bangladesh is the most vulnerable country in the world to climate change. The majority of climate change projections for Bangladesh suggest that the average temperature in the country is likely to increase by 1 degree Celsius (°C) by 2030, 1.4°C by 2050, and 2.4°C by 2,100 against the baseline period from 1960 to 1990. The sea levels are expected to rise by between 0.8 meter (m) and 1.5 m by 2100 and up to 2 m higher under extreme warming scenarios. The proposed power plant, located in riverside, is vulnerable to sea level rise, flooding, and storm surge.

6. Based on the assessment report, climate change is expected to have the following impacts on the proposed power plant:

(i) Higher average temperatures and more frequent and severe extreme temperatures are expected to reduce the plant efficiency and the generating capacity;

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[1] ADB. 2017. *Guidelines for the Economic Analysis of Projects*. Manila. ADB; and ADB. 2015. *Economic Analysis of Climate-Proofing Investment Projects.* Manila.

[2] Climate Risk Vulnerability Assessment (accessible from the list of linked documents in Appendix 2 of the report and recommendation of the President).

(ii) Reduced availability of surface water resources and changing seasonal flow patterns of the river as the primary source of cooling water may increase the risk of thermoelectric power plant de-ratings; and

(iii) Accelerating sea level rise, increasing frequency and intensity of storms and cyclonic events increases the vulnerability of flooding, storm surge and saline intrusion.

III. COST–BENEFIT ANALYSIS OF A CLIMATE-PROOFING OPTION

7. The cost-benefit analysis of a climate-proofing option only considered the most significant potential climate change threats among above three threats; rising air and river water temperatures. The analysis quantified the loss of benefit due to increased air and water temperatures. Typically for combined cycle gas turbine plants, power output and energy efficiency decrease as air temperature increases. This is because an increase in air temperature reduces air density and the mass flow of air intake to the compressor and creates a similar reduction in heat transfer efficiency of the air cooling system. As the air temperature increases, more heat will be transferred to the water column, increasing the temperature of the river water. Increased river water without passing through cooling system will decrease the efficiency of heat transfer.

Table 1: Climate Threat and its Impact on the Proposed Power Plant

Climate Threat		Impact on the power plant		Result of impact
Increasing in air temperatures	→	Gas turbine cycle performance	→	Reduce the efficiency
Increasing in river water temperature	→	Steam turbine cycle and coolant water cycle performance	→	rate and reduce the generation capacity

Source: Asian Development Bank projections.

8. **With and without climate change**. Without climate change, the annual capacity factor of 70% and the net efficiency factor of 55.6% would be maintained throughout the project life from 2020 to 2046. Thus, the proposed power plant will generate 4,906 gigawatt-hour of electricity every year with full capacity of 800 MW in the without climate change. With climate change, it is projected that average daily air temperature and river temperature will increase by 0.02°C per year over the operation period. And it was assumed that a 1°C increase in air temperature above the design point of 15 °C will lead to a reduction in generation capacity by approximately 0.45% per year and lead to a reduction in net efficiency by approximately 0.01% per year.

9. In addition, a 1°C increase in water temperature will decrease the generation capacity by 0.16% per year and decrease the net efficiency of the power plant by 0.1% per year.[3] By quantifying the change in air and water temperature based on these projected rates, predictions were made on the reduction of power output and loss in net efficiency, leading to an increase in fuel consumption over the project life.

[3] Assumptions are made based on the climate change vulnerability assessment report (footnote 2).

Table 2. Power Output and Fuel Consumption Projections with Climate Change[a]

Year	Power Output (GWh)			Fuel Consumption (thousand mmbtu)		
	Without Climate Change	With Climate Change	With Climate Proofing	Without Climate Change	With Climate Change	With Climate Proofing
2020	413	411	413	2,539	2,771	2,658
2021	3,916	3,897	3,911	24,032	26,284	25,186
2022	4,906	4,880	4,898	30,099	32,995	31,583
2023	4,906	4,880	4,897	30,099	33,071	31,622
2024	4,906	4,879	4,897	30,099	33,148	31,662
2025	4,906	4,878	4,897	30,099	33,225	31,701
2030	4,906	4,876	4,897	30,099	33,615	31,902
2035	4,906	4,873	4,896	30,099	34,015	32,107
2040	4,906	4,896	4,895	30,099	34,425	32,318
2045	4,906	4,867	4,894	30,099	34,846	32,534
2046	4,906	4,866	4,893	30,099	34,931	32,578

GWh = gigawatt-hour, mmbtu = million British thermal unit.
[a] Only selected years shown for brevity.
Source: ADB's Climate Risk Vulnerability Assessment Report for Rupsha 800 MW Combined Cycle Power Plant.

10. **Cost of Climate Change.** The economic cost of climate change was measured as the reduction in the net present value (NPV) of the project as a result of climate change.[4] The definition of cost of climate change is that how much the NPV of the project would be reduced due to climate change impact. Here, the cost of climate change means the reduced NPV due to increase in air and water temperature. In the event that the NPV is unchanged as a result of climate change, the recommendation would be to proceed without any climate proofing investment. On the other hand, in the event that the NPV with climate change is less than the NPV without climate change impact, it is recommended to consider the climate proofing options.

11. The result of analysis shows that the NPV and the EIRR without climate change are Tk55,884 million and 18.5%, the NPV and the EIRR with climate change are Tk27,885 million and 14.3%, which means the economic cost of climate change (before any consideration of adaptation) amounts to Tk27,999 million. The positive NPV with climate change proves that the project is still economically viable if there were to be no technically feasible measure to mitigate these impacts. However, the positive cost of climate change of Tk27,999 million indicates that the climate change would adversely affect the benefit, and then there arise considerations of technical measure to mitigate the impact.

12. **Climate proofing investment.** To mitigate projected climate change impact, the project considered to include the climate change adaption measure in the project design such as cooling tower, water treatment system, river bank and other auxiliary systems, which summarized as Table 3. The initial cost of climate proofing investment amounts to Tk3,361 million in economic price and the incremental cost of the climate proofing option in present value terms amounts to Tk3,424 million.[5]

[4] Cost of climate change equals to net present value without climate change minus net pesent value with climate change.
[5] In addition to the initial capital cost of climate proofing investment, increased annual operational costs was included.

Table 3. Indicative Cost of Climate Change Adaptation Measures ($ million)

Items	Adaptation Cost		Adaptation Measures
	Financial	Economic	
Closed-loop cooling tower	4.3	4.5	Water use efficiency and reuse
Water treatment system	21.8	22.4	Alternative water resources
River bank protection	1.5	1.6	Waterproofing
Auxiliaries system	13.6	14.0	Emergency and protection system
Physical contingency	1.6	1.7	-
Total	**42.8**	**44.1**	

Source: ADB's Climate Risk Vulnerability Assessment Report for Rupsha 800 MW Combined Cycle Power Plant.

13. **Residual Damage.** The implementation of the climate-proofing measure cannot recover all of the economic cost of climate change, i.e., the NPV lost as a result of climate change. With climate-proofing investment, there are remaining impacts of climate change after adaptation is implemented, which is called a residual damage. The residual damage from climate change is defined as the difference between the NPV without climate change and the NPV with climate proofing under climate change. The residual damage for the project was estimated at Tk16,427 million with assumption that the climate proofing investment will recover 50% of climate change impact in terms of power output and net efficiency rate.

14. **Benefits of Climate Proofing.** The net benefit of climate-proofing investment was measured as the difference between NPV with climate proofing (including the incremental cost of climate proofing investment) and NPV without climate proofing. It means how much the NPV will be recovered by adopting climate proofing adaption in the project. The net benefit of climate proofing was estimated at Tk8,148 million. Given that the net benefit of climate proofing is positive, it is recommended to proceed with project with climate proofing.

Table 4: Climate Change Impact on NPV and EIRR

	Items	NPV (Tk million)	EIRR (%)
A.	NPV and EIRR without climate change	55,884	18.5%
B.	NPV and EIRR with climate change	27,885	14.3%
C.	Cost of climate change (A-B)	27,999	-
D.	NPV and EIRR with climate proofing	39,457	15.8%
E.	NPV and EIRR without climate proofing	27,885	14.3%
F.	Cost of climate proofing in present value	3,424	-
G.	Net benefit of climate proofing (D-E-F)	8,148	-
H.	Residual damage (A-D)	16,427	-

NPV = net present value, EIRR = economic internal rate of return.
Source: ADB's assessments and estimates.

15. **Timing of Implementation of Climate-Proofing Investment.** In terms of best timing to implement the climate-proofing investment, the early adoption in the project design stage for the project was justified in following reasons; (i) the net benefit of project, generated electricity is highly sensitive to current climate variability and climate risk and (ii) there is no flexibility to modify infrastructure design to respond to changes in climate conditions observed in the future. The climate-proofing investment such as cooling tower and water treatment system should be designed and constructed with other structures. Given those circumstances, it is recommended to implement the climate-proofing investment from the project design stage.

IV. CONCLUSIONS

16. As a result of the cost-benefit analysis of climate-proofing investment, climate change impact (increased air and water temperature) on the proposed power plant will adversely impact the benefits by reducing power output and increasing fuel consumption. The reduced NPV with climate change impact amounts to Tk27,999 million. However, the positive NPV with climate change, which is Tk27,885 million proves that the project is still economically viable without any mitigation measurement under climate change. If the project includes the climate proofing investment, which amounts to Tk3,424 million in present value, the NPV will increase by Tk8,148 million. Given that the NPV with climate proofing (which includes the incremental cost of the climate proofing) is larger than NPV without climate proofing, the climate proofing investment is desirable from an economic efficiency point of view and it is recommended to proceed with the project with climate proofing investment.