CLIMATE RISK VULNERABILITY ASSESSMENT

I. INTRODUCTION

A. About this Report

1. Overview

1. The Asian Development Bank (ADB) has contracted the South Asia Management and Engineering Services (Pvt.) Ltd to undertake a climate change risk vulnerability assessment (CRVA) Study for the Rupsha 800-Megawatt Combined Cycle Power Plant Project in Bangladesh.

2. Scope of the Assessment

2. At the request of the ADB, a CRVA study has been undertaken to assess and adopt climate change adaptation measures to mitigate anticipated climate change hazards, risks, and impacts facing the Rupsha 800-Megawatt Combined Cycle Power Plant Project, and to incorporate 'future climate change risk' considerations into the design, operations, and maintenance of the Rupsha combined cycle power plant (CCPP).

3. The scope of work is to make qualitative assessments of key climate hazards, risks, and impacts relevant to the proposed 'future' infrastructure, including the physical assets associate with:

(i) Power plant infrastructure: the installation and operation of an 800 MW gas-fired CCPP located in Khulna City, in the south-western part of Bangladesh;
(ii) Gas distribution pipeline infrastructure: the construction of a gas distribution pipeline and related network infrastructure between the Rupsha CCPP plant and the existing Khulna city gas station (CGS); and
(iii) Power transmission system infrastructure: the construction of power transmission interconnection facilities to evacuate power from the new power plant to the existing Khulna south substation.

4. The study identifies a range of climate change adaptation options for the management and reduction of climate vulnerabilities and risks, including project design, construction, and operational activities. The integration of such measures into the Rupsha 800 MW CCPP planning, design, and operation will be crucial aspects for sustainable and tangible results of the project.

B. Project Description

5. The Government of Bangladesh has applied for financing from the ADB toward the cost of Rupsha 800 megawatt (MW) CCPP. The project's executing agency — North-West Power Generation Company Limited (NWPGCL) is planning to develop and operate the 800 MW CCPP. The power plant will be constructed in Khulna City, situated in Khalishpur Upazila, Khulna District in the administrative division of south-western Bangladesh.

6. The project targets strengthening energy security in Bangladesh. The country faces serious electricity shortages in the short- to medium-term and needs to secure cost-effective, new, and diversified energy sources. Key interrelated project components include: (i) the development and operation of the Rupsha 800 MW gas-fired CCPP; (ii) the construction of a gas distribution pipeline and related network infrastructure ensuring reliable supply of fuel to the CCPP; (iii) the construction of a power transmission interconnection facility to transfer the

generated power to the national grid at the existing substation in Khulna; and (iv) capacity strengthening of NWPGCL.

7. Liquefied natural gas (LNG) is a cleaner fuel with less pollutant and carbon dioxide (CO_2) emissions compared to diesel and fuel oil. The project will produce environmental benefits through reduction of CO_2 emissions given that the proposed CCPP power plant would displace diesel or fuel-oil-fired plants. The CO_2 emissions during construction is estimated to be 30,821 tons in accordance with ADB guidelines[1] and the CO_2 emission from the CCPP power plant operating on LNG is estimated to be 1,943,664 tons per year. The annual net emission reduction upon full implementation is estimated to be 1,278,206 tons of CO_2. In addition, as the project will provide LNG to the existing Khulna power plant currently operating on high speed diesel (HSD), the annual net reduction of CO_2 of the Khulna plant by replacing fuel from HSD to LNG is estimated to be 179,425 tons per year. However, this direct emission and emission reduction from the project is out of the climate change adaptation and discussed in the relevant report.

1. Component 1: Rupsha 800 MW CCPP

8. The Rupsha power plant will be built in the (now abandoned) Khulna newsprint factory premises. It will be of a nominal capacity of 800 MW. The power plant will use combined cycle gas turbine technology, comprising two identical generating units, each nominally rated at 400 MW. Each combined cycle unit will consist of one gas turbine and one heat recovery steam generator, forming a one-on-one configuration. At full capacity of 800 MW, the Rupsha power plant is capable of meeting 5% of the forecast peak demand of Bangladesh in year 2022. Condensate leaving the steam turbine will be cooled using a closed-circuit cooling system. The cooling system will consist of cooling towers with upward forced draft with a circulating water rate of 60,000 cubic meter/hour, for which water to make up for blowdown losses and evaporation will be drawn from the nearby Bhairab River.

2. Component 2: Gas Supply to the Power Plant

9. Petrobangla, the national gas utility and the single-buyer for the gas industry, will procure LNG from international sources and deliver regasified LNG to Khulna CGS. The regional gas distribution company, the Sundarban Gas Company Limited will deliver gas from the existing Khulna CGS to the Rupsha power plant. A new 24-inch [0.6 meter (m)] underground gas pipeline 10 kilometer (km) long will be installed from Khulna CGS to the Rupsha 800 MW power plant. The gas receiving and metering station (RMS) will be located at the Rupsha power plant. In addition, a new 20-inch (0.5 m) underground gas pipeline 2 km long will branch off from the line from Khulna CGS to Rupsha power plant, to serve NWPGCL's existing Khulna 225 MW power plant. Owing to non-availability of gas, this 225 MW power plant is presently operating on diesel.

3. Component 3: Power Transmission Interconnection

10. Electricity generated in the Rupsha power plant will be stepped-up to the transmission voltage of 230 kilovolt (kV). A new 29.3 km transmission line will be built from the proposed power plant to the existing Khulna south substation. The conductor to be used is twin-ACCC

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

Hamburg,[2] and the line will have two circuits, each capable of transferring 1,400 MW. The new transmission line will require three main river crossings and several minor river crossings, and would traverse for 29 km, mostly through rice fields. Upon reaching the existing Khulna south substation, the line will be terminated at two new line bays and termination equipment to be installed under the project. Thereafter, electricity produced at Rupsha power plant will flow into the 230 kV transmission network to serve the electricity demand in Khulna and elsewhere in the country.

4. Component 4: Capacity Strengthening of NWPGCL

11. Strengthening institutional capacity has the following three major subcomponents: (i) improving project implementation, management, and construction supervision capabilities; (ii) establishing enterprise resource planning (ERP) system in NWPGCL; and (iii) enhancing operation and maintenance practices through procurement and installation of modern and high technology universal power plant operations training simulator. Project management and construction supervision support will be provided for the development of Rupsha power plant. ERP system support includes both hardware and software for introducing computerized management system for NWPGCL. The ERP system will substantially improve business process and NWPGCL's efficiency and transparency by computerizing the financial accounting, budgeting and costing, human resource management, procurement inventory, planning and monitoring, operations and maintenance, and project management and accounting. This component is not being impacted by the climate change, thus, not included in the scope of this CRVA.

C. Structure of this Report

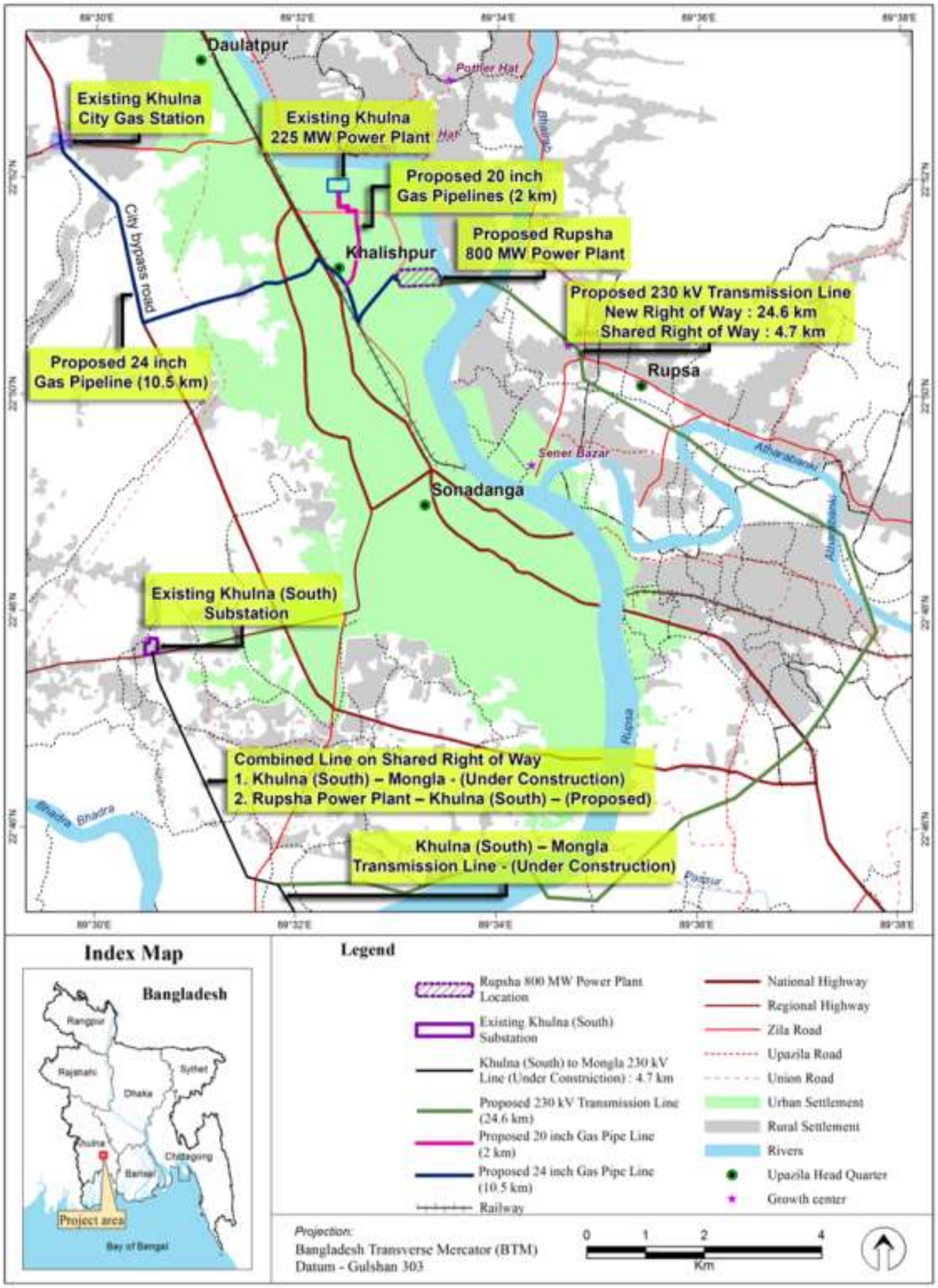
12. The following chapters of this CRVA Study examine the anticipated climate change hazards, risks, and impacts facing the Rupsha CCPP project, and outline options and measures for the mitigation of future climate change risk, and include:

(i) Chapter II: Risk Assessment Methodology;
(ii) Chapter III: Climate Change Observations and Projections (including increasing temperatures, decreasing water availability and increasing storms, flooding, and sea level rise);
(iii) Chapter IV: Climate Change Hazards, Risks, and Vulnerabilities; and
(iv) Chapter V: Climate Hazard Risk Mitigation and Adaptation Measures.

13. In the annexures we present the glossary of terms, CRVA workshop presentations, list of key stakeholders consulted, and the bibliography of references.

[2] Aluminum Conductor Composite Core (ACCC) Hamburg has a current carrying capability of 1,440 amperes at 120ºC.

Figure 1. Location of the Proposed Rupsha CCPP



Source: North-West Power Generation Company Limited.

II. RISK ASSESSMENT METHODOLOGY

A. Overall Approach

14. For the purpose of this study, we have chosen to adopt a qualitative risk-based methodology for the assessment of both the vulnerability and risk to infrastructure of the Rupsha CCPP Project and the associated gas and electricity transmission components. The risk assessment process adopted involves five key steps, these being:

(i) Establish the climate change context: Establish the context of vulnerability of the proposed CCPP infrastructure and assets, which forms the baseline upon which the risk assessment is built.

(ii) Assess current and future climate vulnerability: Assess the likely exposure of critical infrastructure, assets and facilities to climate change variables; and the sensitivity and/or resilience of current and planned infrastructure to the climate hazards including an evaluation of relevant adaptation responses for current and future risks.

(iii) Identify direct threats from climate hazards and impacts to infrastructure and Assets: Characterize regional and localized climate change threats, hazards, and impacts; and evaluate the potential loss and damage as a result of the direct threat from climate change hazards (including impacts on water, transport, and energy infrastructure, and assets).

(iv) Qualitative evaluation of climate hazard risks: Qualitatively asses the likelihood and scale of hazard consequences for the Rupsha energy infrastructure and assets (including an analysis of control and or mitigation measures) and level of risk.

(v) Identify hazard risk mitigation and adaptation options and measures: Identify adaptation options that address direct hazards, risks and impacts; and determine priorities for climate proofing infrastructure and responding to long term climate change (including capacity building and institutional DRM measures).

15. The approach which has been adapted from the International Standard for Risk Management, ISO 3100 and focuses on identifying the specific systematic risks to critical infrastructure both existing and planned for the water, energy, and transport sectors. It uses expert opinion to estimate likelihood (or frequency) and consequences (or impacts) to define climate risk levels (e.g. high, medium, low).

16. Fundamental to this study is the need to go beyond the usual vulnerability assessment in order to be able to assess the effect of climate change on the CCPP infrastructure; and the consequent flow-on effects on to the economic viability and sustainability of the project.

B. Establishing the Vulnerability Context

17. The first step in the CRVA process is to establish the context of vulnerability of the proposed CCPP upon which the risk assessment is built. It allows us to examine the potential impacts and risks for each infrastructure component to better understand the cumulative and systematic risk associated with the operation and functioning of the CCPP components.

C. Assessing Current and Future Vulnerability

18. The analysis of vulnerability for this study is based on the presence (or absence) of climate hazards, and the emphasis is fundamentally oriented to, and focused on the exposure and sensitivity of the CCPP, associated gas pipeline infrastructure and power transmission and

their interdependencies. The aim of the vulnerability assessment is to describe the climate induced vulnerability context for the infrastructure under consideration. It focuses on two key aspects, these being: (i) the exposure of the asset or infrastructure to climate to threats and hazards; and (ii) the relative sensitivity of the asset or infrastructure to the impact of the hazard.

19. Typically, a vulnerability analysis commences with a screening of the scenarios in accordance to their level of vulnerability. ADB has already completed a Climate Risk Screening Report for the proposed project. The key findings from this study are summarized in Section IV.

D. Identifying Direct Threats to Infrastructure from Climate Hazards and Impacts

20. The third step involved broadening the picture by addressing the probability of the climate threats or hazards exploiting the identified vulnerabilities, i.e. going from vulnerability analysis towards risk analysis. Theoretically, it should be a relatively straight forward process to incorporate the probability of threats and hazards using generic failure rated for power infrastructure and assets. However, there are very few studies in the literature that qualitatively asses the impacts of climate change impacts on power plants of this nature. Given the low level of knowledge in the literature of both the consequences and the probability of the threat or hazard exploiting the vulnerability, we will focus on quantifying exposure of CCPP infrastructure, assets and facilities to climate change variables, and sensitivity of the infrastructure to specific or multiple hazards or threats.

21. In order for the vulnerability of infrastructure to be meaningful in this process, it must be directly related to the specific hazard or impact exposures. Based on the key findings from the CCPP site visits, it is clear that the CCPP site and associated infrastructures are clearly exposed to a range of key climate hazard vulnerabilities including, but not limited to:

- (i) Average temperature effects (ambient air and water temperatures) and extreme temperature effects;
- (ii) Extreme storm events, cyclones, and flooding;
- (iii) Changes in seasonality and river flows and drought; and
- (iv) Sea level rise, storm surge, and saline intrusion (river and groundwater).

E. Evaluation of Climate Hazard Risk

22. Step four of the CRVA process involves a qualitative evaluation of the likelihood and scale of hazard consequences for the CCPP infrastructure and assets (including an analysis of control and/or mitigation measures). The level of risk and the process for achieving this is outlined in the following sections.

23. The risk analysis methodology adopted for the assessment of infrastructure risk associated with this study is based on the International Standard for Risk Management, ISO 3100 Risk Assessment Matrix methodology. The terms Likelihood (L), Consequence (C), and Risk (R) are essential to the methodology, and we have adopted the definitions outlined in International Standard for Risk Management, ISO 3100 Risk Assessment Matrix methodology (2009). Figure 2 illustrates a typical risk matrix that links the likelihood (or frequency) of the hazard with the scale of the consequence, and the resulting level of risk.

Figure 2. Risk Assessment Matrix

Likelihood Level	**Consequence Level** 1 Insignificant	2 Minor	3 Moderate	4 Major	5 Catastrophic
5 Almost Certain	L (5)	M (10)	H (15)	E (20)	E (25)
4 Likely	L (4)	M (8)	H (12)	H (16)	E (20)
3 Possible	L (3)	M (6)	M (9)	H (12)	H (15)
2 Unlikely	L (2)	L (4)	M (6)	M (8)	M (10)
1 Rare	L (1)	L (2)	L (3)	L (4)	M (5)

E = > 20	Extreme Risk: potentially threatening the overall viability of the project and requiring priority action
H = > 12	High Risk: the most severe risks that can be accepted as part of the design and routine operation of the CCPP infrastructure and facilities.
M = > 5	Medium Risk: risk that can be expected to influence the design and routine operation of the CCPP infrastructure and facilities and where control measures can be applied and will be sufficient.
L = < 5	Low Risk: where existing control measures will be sufficient to mitigate any potential impacts and /or where no action will be required to treat them unless they become more severe.

Source: International Standard for Risk Management, ISO 3100 Risk Assessment Matrix' methodology.

24. The risk matrix defines the level of risk for a particular combination of consequence and likelihood. The risk ratings are a combination of the probability (or likelihood) of a climate hazard (derived from the climate modelling) and the consequence in terms of impacts on infrastructure (derived in a large part from the sensitivity analysis). Using this approach, we can use a standard risk assessment matrix to determine the level of infrastructure risk for each category of asset and climate hazard, where risk is defined in terms of the probability of a particular climatic outcome multiplied by the consequences of that outcome. Instead of using fixed values, the use of classes allows for more flexibility and incorporation of expert opinion.

25. This approach also permits to visualize the effects and consequences of risk reduction measures and to give a framework to understand risk assessment. The system depends on the quality of the group of experts that are formed to identify the hazard scenarios and carry out the hazard filtering and ranking in several sub-stages characterized by likelihood (probability) and consequences (of impacts) and their corresponding limits.

26. This risk assessment process also requires a uniform approach to determining the likelihood and consequence of each impact. The qualitative measures of 'likelihood' and 'consequence' for this assessment are described in Tables 1 and 2, respectively below.

Table 1. Qualitative Measures of Likelihood

Level	Descriptor	Likelihood	Annual Exceedance Probability
5	**Almost Certain**	There is a high possibility the event will occur as there is a history of frequent occurrence. The event is expected to occur in most circumstances	Will probably occur more than once a year
4	**Likely**	It is likely that the event will occur as there is a history of casual occurrence. The event has occurred several times or more in the past.	Will probably occur once in 1-10 years
3	**Possible**	The event has occurred at least in the past and may occur again	May occur once in 10-100 years
2	**Unlikely**	There is a low possibility that the event will occur, however, there is a history of infrequent and/or isolated occurrence.	May occur once in 100 years
1	**Rare**	It is highly unlikely that the event will occur except in extreme/exceptional circumstances, which have not been recorded historically.	Unlikely during the next 100 years

Source: Adapted from International Standard for Risk Management, ISO 3100 Risk Assessment Matrix Methodology.

27. Likelihood can be described as the level of probability that, or the frequency with which, a specific climate change hazard may impact upon the CCPP infrastructure. The likelihood levels applied in the assessment of risk are quantified using six categories, ranging from 'rare' (1) to 'almost certain' (6) and is based on past experience and climate modeling available for the region.

28. A consequence on the other hand, can be defined as an outcome or impact from an event occurring. Five categories, ranging from 'catastrophic' (5) to 'insignificant' (1) as illustrated in Table 1, have been used to describe the type and severity of a consequence of an impact on the CCPP infrastructure resulting from a specific climate hazard event or combination of impacts. As multiple consequences may apply for a single hazard or aspect, the approach used was to take the worst credible risk (in terms of consequence versus likelihood).

Table 2. Qualitative Measures of Consequence

Level	Descriptor	Infrastructure Services
1	**Insignificant**	No infrastructure damages Numerous risk reduction and control measures exist.
2	**Minor**	Localized infrastructure services disruption. No permanent damage. Some minor restoration work required. Early renewal of infrastructure by 5–10%. Suitable risk reduction and control measures exist.
3	**Moderate**	Widespread infrastructure damage and loss of service Damage recoverable by maintenance and minor repair. Early renewal of infrastructure by 10–20%. Some suitable risk reduction and control measures exist.
4	**Major**	Extensive infrastructure damage requiring extensive repair. Permanent loss of regional infrastructure services e.g. transmission lines washed away by flooding. Early renewal of Infrastructure by 20-50%. Loss or retreat of usable land for power generation, gas supply or transmission of electricity. Few suitable risk reduction and control measures exist.
5	**Catastrophic**	Permanent damage and/or loss of infrastructure services. Loss or retreat of infrastructure support and translocation of power generation and transmission facilities and services. No suitable risk reduction and control measures exist.

Source: Adapted from International Standard for Risk Management, ISO 3100 Risk Assessment Matrix Methodology.

F. Hazard Risk Mitigation and Adaptation Options and Measures

29. Step five involves identification of priority intervention options for risk treatment to reduce asset sensitivity and hazard exposure; and formulate risk management measures to prepare and respond to critical hazard risks and threats. This is the last step in the CRVA process, and necessitates the adoption of a risk management and risk reduction perspective, whereby a number of key questions are addressed, these being:

(i) What can be done and what adaptation and risk management options are available to protect critical CCPP assets and infrastructure;
(ii) What are the priorities for climate proofing infrastructure and responding to long term climate change;
(iii) What are the tradeoffs in terms of all the relevant costs (including the costs of impacts, adaptation or inaction); and
(iv) How can we best finance these climate change investment interventions? and
(v) What are the likely implications of planning, design and operational decisions now on future options – and how can we build flexibility into the adaptation planning and decision-making process.

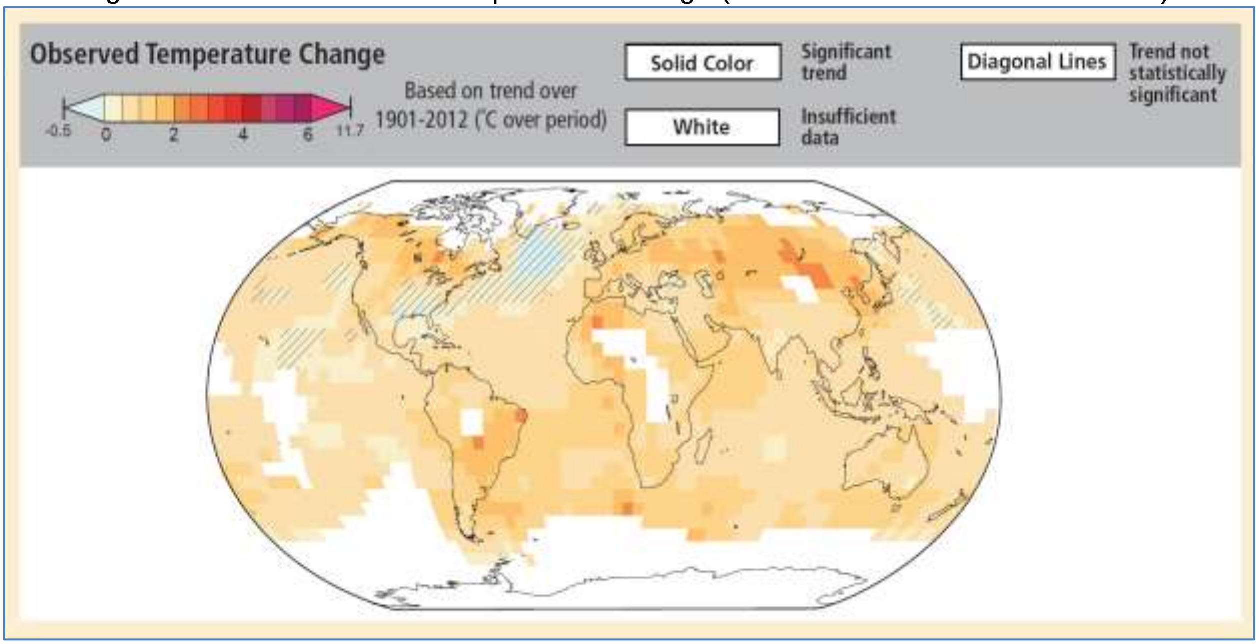
30. Clearly, these are questions that the proponent will need to address during the detailed design stage of the project. Understanding how the infrastructure associated with the proposed Rupsha CCPP is exposed to climate induced hazards, their vulnerability to impacts and damage from these hazards, and how these may change over time, is the foundation for developing effective and appropriate risk management and risk reduction options and measures. That understanding will provide a foundation from which informed decisions may be made about the acceptable level of risk, and how such risk should be managed or reduced through the introduction of adaptation options and risk management measures.

III. CLIMATE CHANGE OBSERVATIONS AND PROJECTIONS

A. Observed Climate Variability and Change

31. Climate change is a major environmental challenge for Bangladesh. The main indicator of climate change is global warming due to greenhouse gas emissions from human activities. Climate change also leads to a strong fluctuation in rainfall and an increase in weather and climate extremes such as floods and droughts.[3]

Figure 3. Observed Global Temperature Change (based on trends over 1901–2012)



Source: IPCC WGII AR5 Summary for Policymakers Climate Change 2014: Impacts, Adaptation, and Vulnerability.

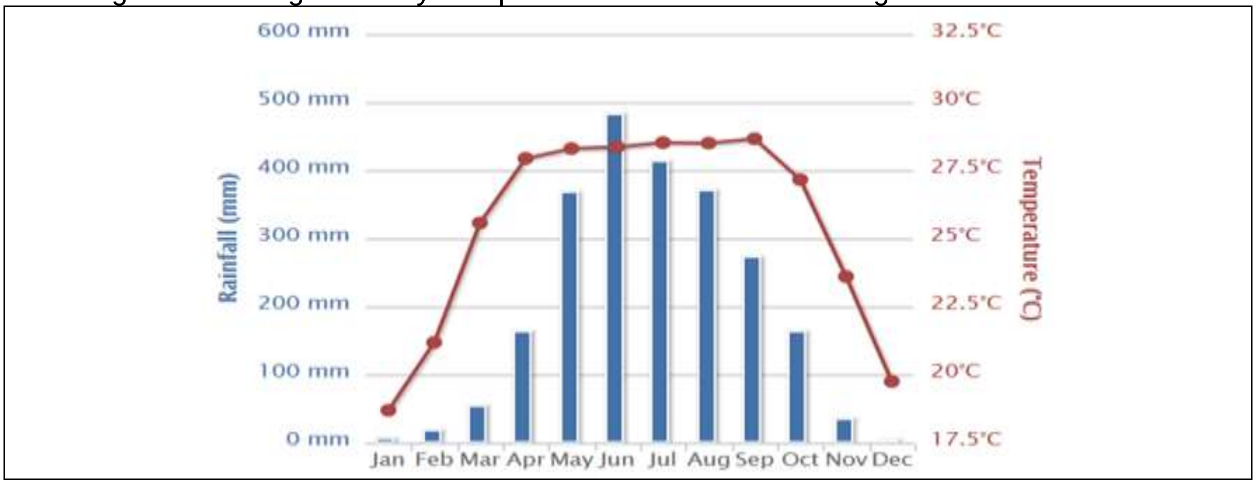
32. Air temperature evolution is important because it can have direct and indirect impacts on the energy sector and associated infrastructure. Over the past 100 years (1906–2005), the global average temperature has increased about 0.74°C, while the increase during last 50 years has nearly doubled the previous 50 years. Increasing air temperature is especially important as a source of numerous indirect impacts (from sea level rise to enhance cyclonic activities). Indeed, rising temperatures are the main driver of climate change impacts.

33. In Bangladesh, the annual average temperature increased about 0.3°C since 1900. Average monsoon-season maximum and minimum temperatures show an increasing trend annually at the rate of 0.05°C and 0.03°C, respectively. An increasing trend of about 1°C in May and 0.5°C in November during the 14–year period from 1985 to 1998 has also been observed.

[3] The climate change information and graphics used in this report were taken from: Intergovernmental Panel on Climate Change Working Group II Assessment Report 5 (IPCC WGII AR5) Summary for Policymakers, Climate Change (2014): Impacts, Adaptation, and Vulnerability; Fahad et al (2014): The Projection of Temperature and Precipitation over Bangladesh under Representative Concentration Pathways (RCP) Scenarios using Climate Model Inter comparison Project 5 (CMIP5) Multi-Model Ensemble; Hasan et al (2015): Changes of rainfall in the future over Bangladesh simulated by a high resolution regional climate model considering the RCP scenarios, Institute of Water and Flood Management, Bangladesh University of Engineering and Technology; and statistics from Climate Future The World Bank's Climate Change Knowledge Portal.

Figure 4 highlights the changes in monthly temperature and rainfall for Bangladesh from 1901–2012.

Figure 4. Average Monthly Temperature and Rainfall for Bangladesh from 1901–2012



Source: World Bank Group Climate Change Knowledge Portal Bangladesh Dashboard Climate Future.

34. Annual rainfall has decreased by 2% to 3% across Bangladesh this century, with most of this reduction occurring during the December–February period, the wettest season of the year. The seasonality of precipitation (wet and dry seasons) has also changed, with wet season rainfall in the southern region increasing whilst the dry season rainfall in the northern region has decreased. The key trends in seasonality include:

(i) The pre-monsoon season (March–May): experiencing high temperatures with average maximum of 36.7°C;
(ii) The monsoon season (June–September): typically experiencing hot and humid weather, with heavy torrential rainfall contributing to most of the year's rainfall;
(iii) The post-monsoon season (October–November): experiencing a shorter season with less rainfall and lower temperatures, particularly in the evenings;
(iv) The winter season (December–February): being relatively cooler and drier; and
(v) Changes in the frequency of cyclonic events: significant increasing trends in cyclone frequency over the Bay of Bengal during November and May.

B. Future Climate Change Projections

1. Global Projections

35. In early 2014, the IPCC has announced representative concentration pathways (RCP) emission scenarios to assess impacts of climate change at a more regional scale. The RCPs are four greenhouse gas concentration (not emissions) trajectories adopted by the IPCC for its Fifth Assessment Report (AR5) in 2014 and supersede the Special Report on Emissions Scenarios projections published in 2000. The RCPs are consistent with a wide range of possible changes in future anthropogenic (i.e., human) greenhouse gas emissions.

36. The RCPs describe four possible climate futures, all of which are considered possible depending on how much greenhouse gases are emitted in the years to come. The four RCPs, RCP2.6, RCP4.5, RCP6, and RCP8.5, are named after a possible range of radiative forcing

values in the year of 2100 relative to pre-industrial values (+2.6, +4.5, +6.0, and +8.5 watts per square meter (W/m^2,[4], respectively).

Table 3. Representative Concentration Pathways Scenarios

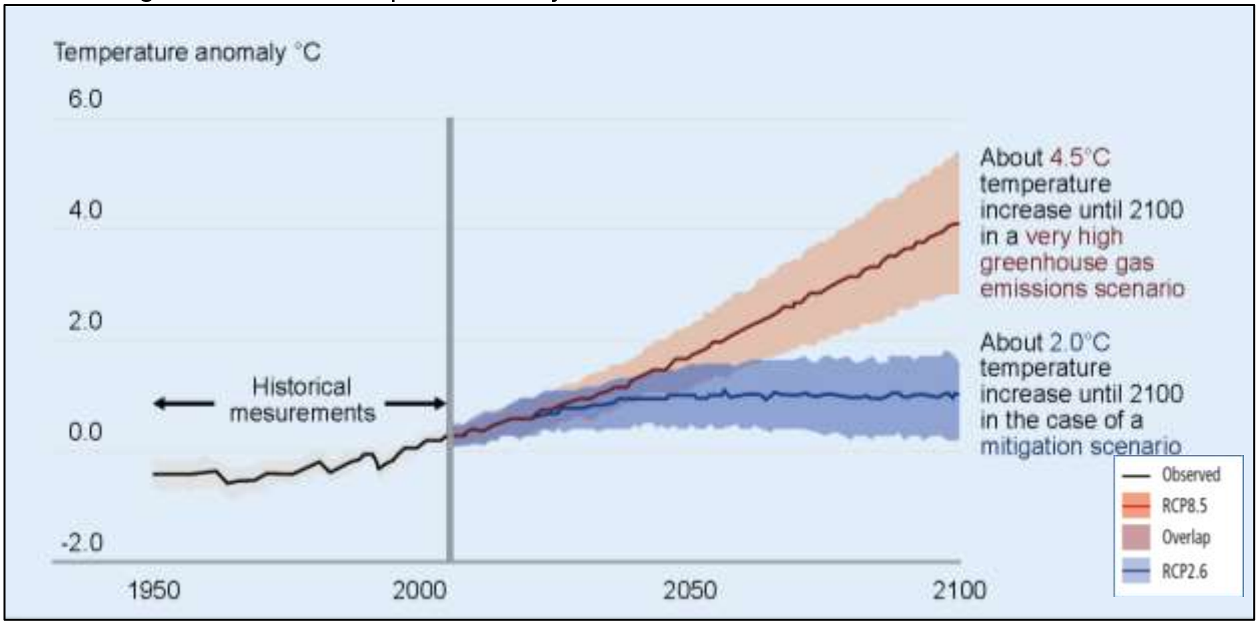
Scenarios	$CO_{2\text{-eq}}$ Concentration in the year of 2100 (ppm)	Description
RCP 2.6	430–480	Low emissions, a stringent mitigation scenario with ambitious greenhouse gas emissions reductions
RCP 4.5	580–720	Intermediate emissions, a future with relatively ambitious emissions reductions
RCP 6	720–1000 ppm	Intermediate emissions, application of a range of technologies and strategies for reducing greenhouse gas emissions.
RCP 8.5	> 1000 ppm	High emissions, no policy changes to reduce emissions.

For comparison, the CO2-eq concentration in 2011 is estimated to be 430 ppm (uncertainty range 340 to 520 ppm)
CO2-eq = carbon dioxide equivalent, ppm = parts per million, RCP = representative concentration pathways.
Source: https://www.ipcc.ch/pdf/assessment-report/ar5/syr/AR5_SYR_FINAL_SPM.pdf; https://www.sei-international.org/mediamanager/documents/A-guide-to-RCPs.pdf.

37. For the purposes of this report we have opted to primarily use two RCP emission scenarios, these being RCP8.5 (a high emission scenario) and RCP2.6 (a low emission scenario) to illustrate the impact of climate change on the basis of radiative forcing (as illustrated in Figure 5).

[4] Watt per square meter.

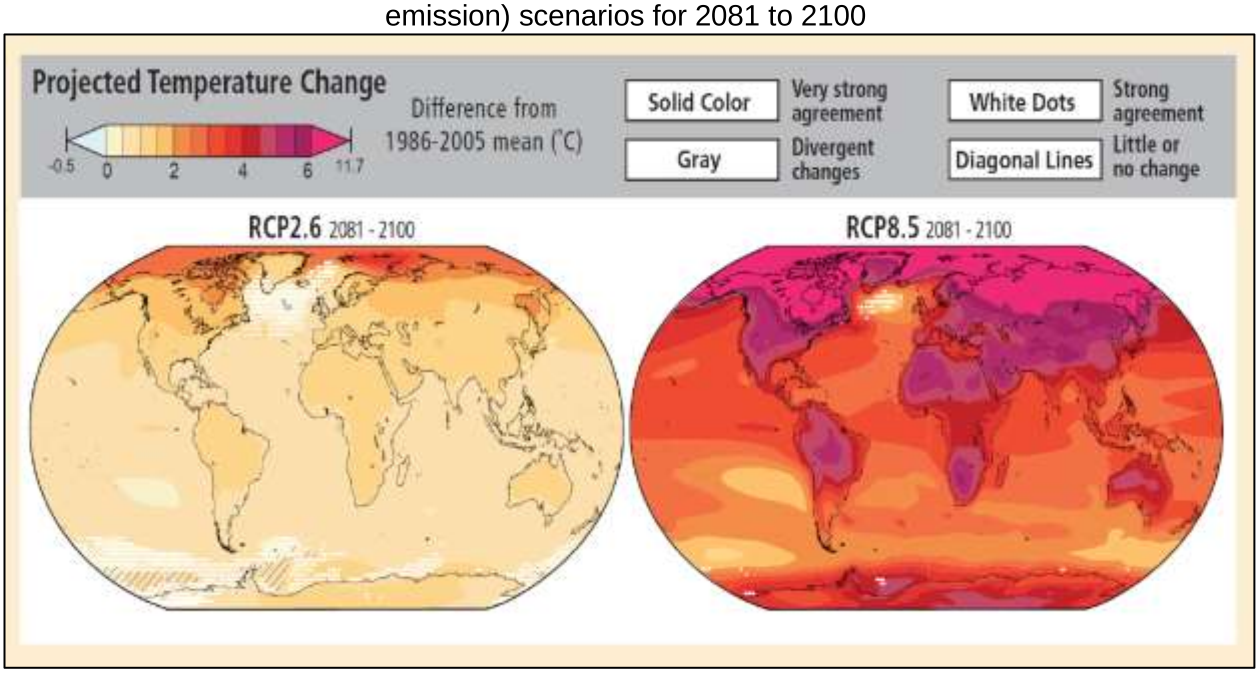
Figure 5. Global Temperature Projections for RCP8.5 and RCP2.6, 1950–2100



Source: IPCC AR5 2015.

38. Across all RCPs, global mean temperature is projected to rise by 0.3 to 4.8°C by the late 21st century. Figure 6 highlights the key difference between the global temperature projections for representative concentration pathways for RCP8.5 (a high emission scenario) and RCP2.6 (a low emission scenario).

Figure 6. Projected Temperature Change for RCP8.5 (high emission) and RCP2.6 (low emission) scenarios for 2081 to 2100



Source: IPCC WGII AR5 Summary for Policymakers WGII AR5 Climate Change 2014: Impacts, Adaptation, and Vulnerability.

39. The RCP scenarios are purely driven by global emissions, and currently we are tracking close to the RCP8.5 emissions scenario highlighted below; and it is highly unlikely that emissions will be constrained to the low or medium emissions target under the current circumstances. Even with the increasing commitments from developed countries arising from the Paris Agreement to significantly increase investment in climate mitigation in order to limit global average temperature increase to 2°C above the pre-industrial level—with currently implemented government policies, greenhouse gas emissions are projected to lead to a warming of 3.7°C by the end of this century.

40. Table 4 provides a summary of climate change predictions under RCP8.5 (a high emission scenario) and RCP2.6 (a low emission scenario) for the mid-21st century (2046–2065) projections of global warming and global mean sea level rise from the IPCC Fifth Assessment Report (IPCC AR5 WGII 2014).

Table 4. Global Climate Change Predictions Under RCP8.5 (a high emission scenario) and RCP2.6 (a low emission scenario) for the Mid-21st Century (2046–2065).

Feature	Low Global Warming Scenario		High Global Warming Scenario	
	Estimate of Change	Uncertainty	Estimate of Change	Uncertainty
Annual average temperature	+0.6^{0}C	+/-0.2^{0}C	+1.3^{0}C	+/-0.6^{0}C
Annual average rainfall	-1.5%	+/-5%	-3.5%	+/-11%
Average summer rainfall	-1.5%	+/-5%	-3.5%	+/-11%
Average autumn rainfall	0%	+/-6.5%	0%	+/-15%
Annual average potential evaporation	+1.6%	+/-1.1%	+3.7%	+/-2.5%
Annual average number of hot days (>35^{0}C)	+10 days		+90 days	
Tropical cyclone wind-speeds	+5%		+10%	
Carbon dioxide concentration	+73ppm		+102ppm	
Average sea level rise	+3cm	+17cm		

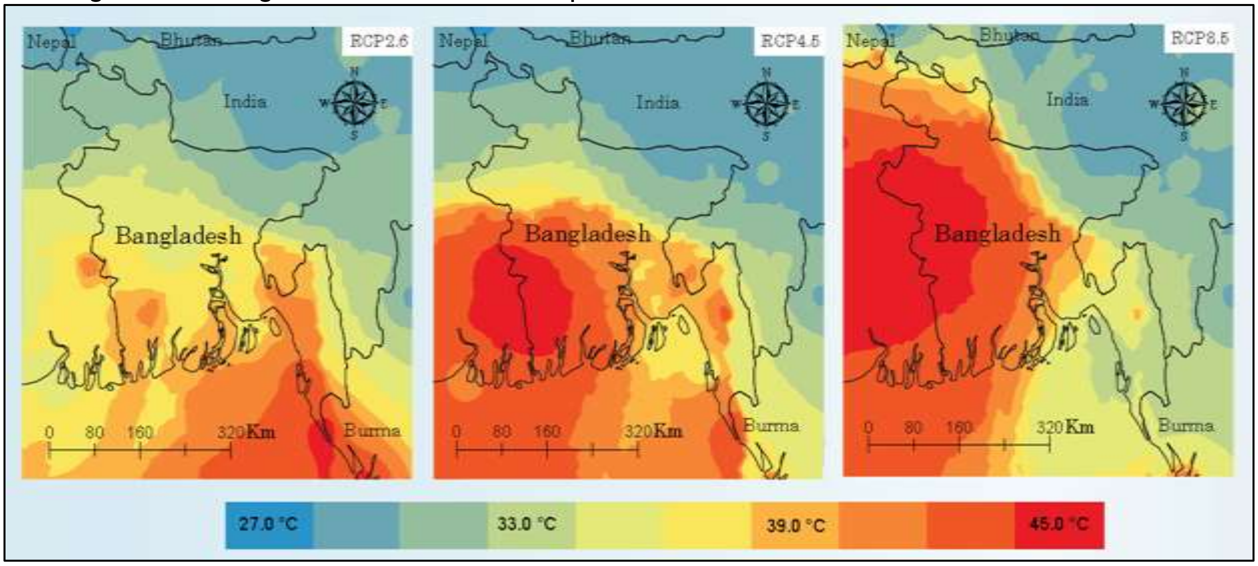
Source: IPCC WGII AR5 Summary for Policymakers, Climate Change 2014: Impacts, Adaptation, and Vulnerability.

2. Projected Changes in Temperature in Bangladesh under RCP Scenarios

41. The majority of climate change projections for Bangladesh suggest that the average temperature in the country is likely to increase by 1°C by 2030, 1.4°C by 2050, and 2.4°C by 2100 (Ramamasy & Baas, 2007) against the baseline period (1960–1990). The highest temperature rise is projected to occur in the month of February (>2.72^{0}C), and the lowest rise is projected for the month of August (<2.06^{0}C).

42. Figure 7 highlights the spatio-temporal difference in mean annual temperature change for 2050 for the three RCP scenarios RCP8.5, RCP4.5, and RCP2.6 for Bangladesh. Clearly, temperature rise will increase from coastal regions to inland regions (i.e. from the south to the north) across all RCPs by 2050, and clearly the Khulna area will be severely affected by 2050 under the high emissions scenario RCP8.5 (as opposed to the impacts under RCP2.6).

Figure 7. Change in Mean Annual Temperature for 2050 for the Three RCP Scenarios.



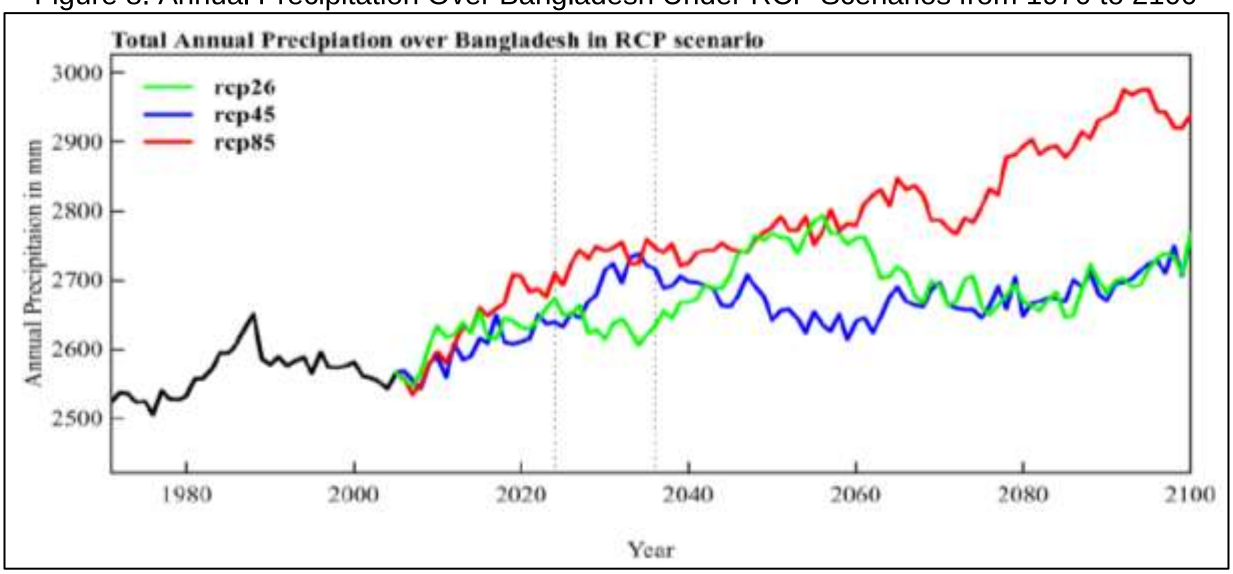
Source: Ramamasy & Baas (2007).

3. Projected Changes in Rainfall under RCP Scenarios

(a) Annual Precipitation

43. The modeling suggests that Bangladesh will experience an increase in rainfall during the monsoon season and a decline in rainfall during the winter months—with annual precipitation projected to increase by 70 mm, which represents a 3.9% increase over the baseline period.

Figure 8. Annual Precipitation Over Bangladesh Under RCP Scenarios from 1970 to 2100



Source: Hasan et al (2015), Changes of Rainfall in the future over Bangladesh (BUET).

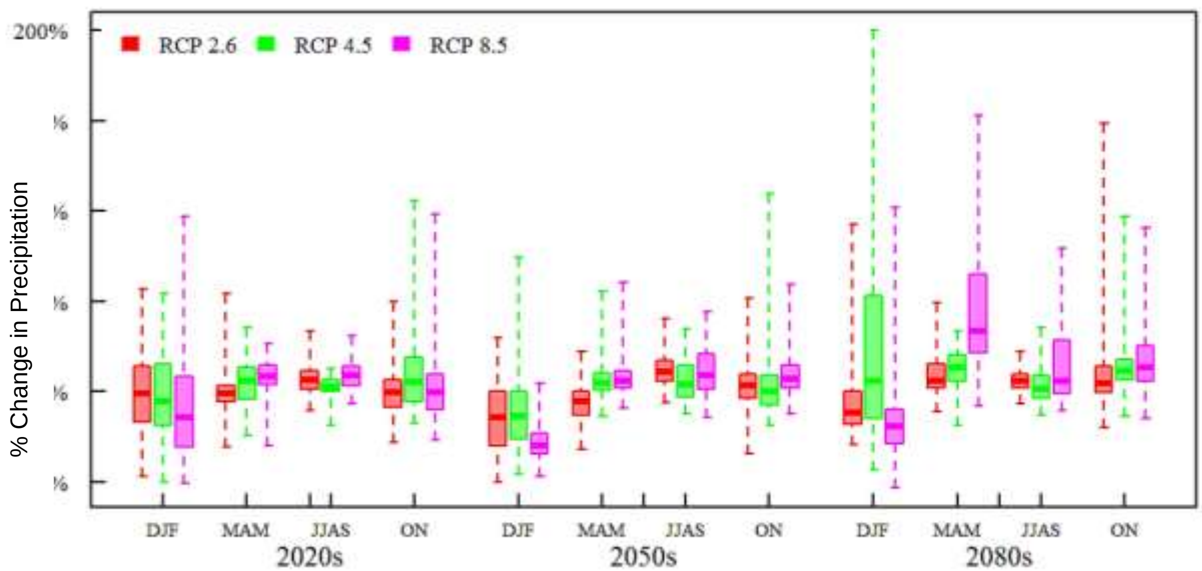
44. Figure 8 shows the projected annual precipitation by the end of the 21st century under the RCP2.6, RCP4.5, and RCP8.5 scenarios with respect to the present day simulation (RCP Historical simulation). It is clear that the annual precipitation is projected to increase across the

whole of Bangladesh, with a larger increase in RCP8.5 at the end of the century. Under RCP 2.6 and RCP 4.5, the annual precipitation over Bangladesh also shows increasing trends.

(b) Seasonal Changes in Rainfall

45. In terms of changes in seasonal precipitation, it is projected that the increase in annual precipitation is almost overwhelmingly likely to occur during the monsoon season from May to October. At the same time, precipitation during the dry seasons (November–December, and January–April) is expected to decrease slightly by around 3.2 mm, or 1.6%.

Figure 9. Changes in Seasonal Precipitation under RCP Scenarios for Bangladesh



Source: Hasan et al (2015): Changes of Rainfall in the future over Bangladesh (BUET).

46. Figure 9 shows the projected seasonal changes in precipitation for three future time periods (i.e. 2020, 2050 and 2080) for each the RCP 2.6, RCP 4.5, and RCP 8.5 scenarios. Under the RCP8.5 high emissions scenario, the amount of precipitation is likely to be increased during pre-monsoon seasons towards the end of century. The likely range of increase in the annual precipitation is projected to be 5%–50% during pre-monsoon and 10% for both monsoon and post-monsoon seasons under the RCP8.5 for 2080. However, up to 45% reduction of precipitation will be observed during winter in 2050s under the RCP 8.5 scenario. In the future, precipitation is expected to decrease across almost all parts of the country during winter season.

47. Under the RCP2.6 and RCP4.5 scenarios, it is predicted that the amount of precipitation will increase during the early parts of the 21st century but became steady in the latter part the century. However, these two RCP scenarios show higher degree of spatial variability of precipitation in comparison to that of the RCP 8.5 scenarios.

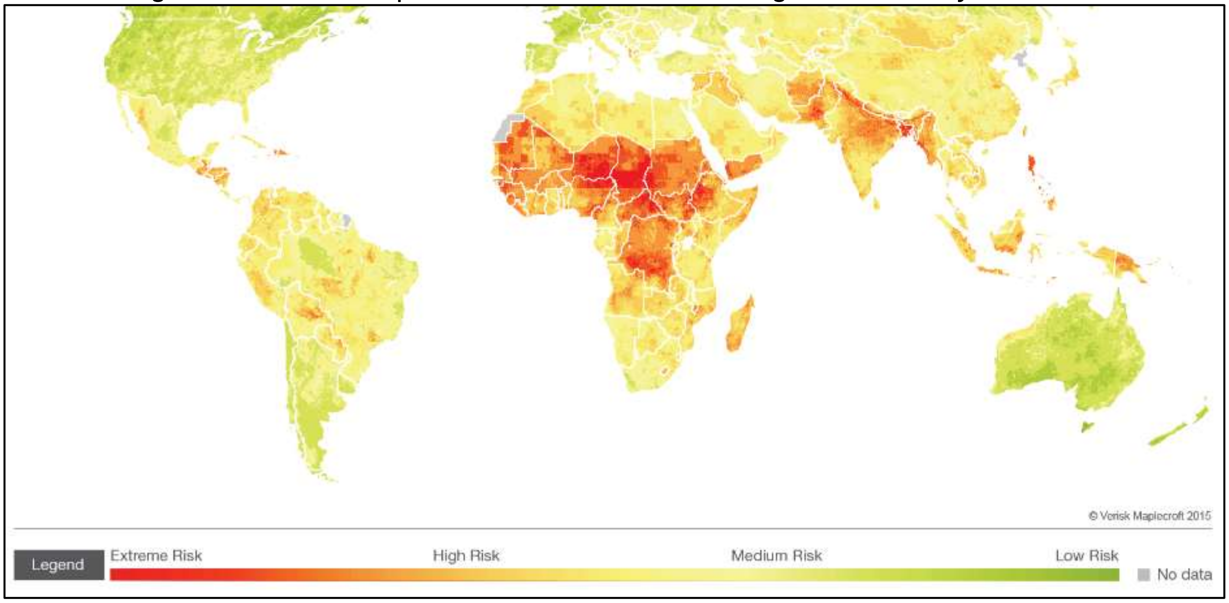
IV. CLIMATE CHANGE HAZARDS, RISKS & VULNERABILITIES

A. Regional Context

48. Bangladesh is extremely vulnerable to the effects of climate change (Karim et al., 1998; World Bank, 2010, and Agrawala et al. 2003). As outlined above the median predictions from the general circulation models are for Bangladesh to be 1.5°C warmer and 4 percent wetter by the 2050s (World Bank, 2010). These trends, which are expected to continue (NOAA 2013b, IPCC 2012, and USGCRP 2009), could restrict the supply of secure, sustainable, and affordable energy critical to the economic growth and development in Bangladesh.

49. According to the Verisk Maplecroft Global Climate Change Vulnerability Index (CCVI) 2016, which includes an assessment of the climate change vulnerability from the physical impacts of more frequent and extreme climate-related events (such as severe storms, flooding or drought), Bangladesh is the most vulnerable and at-risk country in the world to climate change.

Figure 10. Verisk Maplecroft Global Climate Change Vulnerability Index 2016



Source: Verisk Maplecroft Global Climate Change Vulnerability Index 2016.

50. Maplecroft's CCVI 2016 assesses 193 countries and highlights subnational hotspots of risk. The index is composed of the exposure of countries to climate related natural hazards; the sensitivity of populations in terms of concentration, development, agricultural dependency and conflict. This is then considered in the context of the ability of a countries government and institutions to adapt or take advantage of the potential effects of climate change.

51. Maplecroft's CCVI has been developed to identify climate-related risks to populations, business and governments over the next 30 years, down to a level of 22 km² worldwide. It does so by evaluating three factors:

(i) Exposure to extreme climate-related events, including sea level rise and future changes in temperature, precipitation, and specific humidity;

(ii) The sensitivity of populations, in terms of health, education, agricultural dependence and available infrastructure; and

(iii) The adaptive capacity of countries to combat the impacts of climate change, which encompasses R&D, economic factors, resource security, and the effectiveness of government.

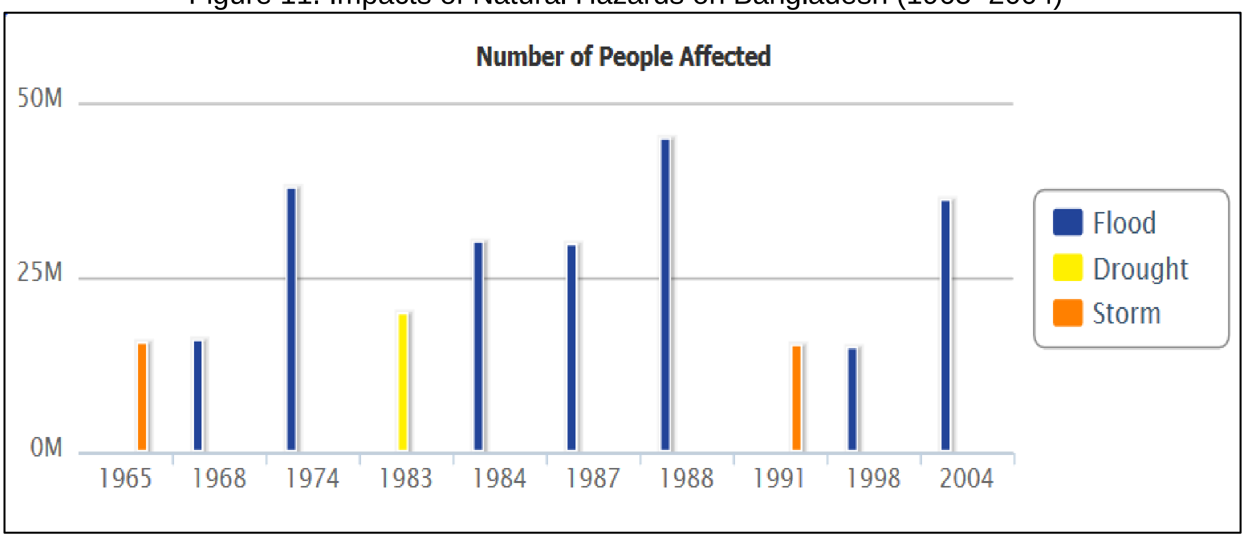
52. Taking these considerations into account, Maplecroft found the economic impacts of climate change will be most keenly felt by Bangladesh (1st and most at risk), Guinea-Bissau (2nd), Sierra Leone (3rd), Haiti (4th), South Sudan (5th), Nigeria (6th), DR Congo (7th), Cambodia (8th), Philippines (9th) and Ethiopia (10th), which make up the 10 most at risk countries out of the 193 rated by the CCVI. According to Maplecroft, Bangladesh is set to suffer more from climate change by 2025 than any other country, primarily due to rising sea levels, severe storms and other extreme climate-related hazards.

B. Key Climate Hazards, Impacts, and Vulnerabilities

53. Bangladesh is already highly vulnerable to the adverse impacts of floods, cyclones, and droughts, and will be even more so due to climate change (in particular from sea level rise and higher cyclone intensity and frequency (IPCC, 2014)). It experiences extreme events (tropical cyclones, storm surges, floods), rainfall variability, riverbank and coastal erosion, salt water intrusion, droughts and many other natural disasters every year. Changes in intensity and frequency of extreme weather events as well as unseasonal deviations from average weather will affect both current and future energy infrastructure and the energy sector's profitability.

54. Recent studies have shown that extreme weather events such as floods, cyclones, severe drought, and sea level rise are already intensifying in South Asia due to the impact of rise of temperature. The rise of temperature will eventually increase the frequency of cyclones and storm surges and increase the probability of drought and saline intrusion. Figure 11 illustrates the extent of exposure in Bangladesh to the three most common climate hazards can affect energy infrastructure, these being floods, storms (cyclones) and drought.

Figure 11. Impacts of Natural Hazards on Bangladesh (1965–2004)



Source: World Bank Knowledge Portal (2015).

55. Bangladesh's high vulnerability to natural hazards induced by climate change may be attributed to its geographic location on the world's largest delta, flat topography, the influence of

monsoons, and very high population density (World Bank, 2010; IPCC, 2014). Bangladesh's high vulnerability to climate change is due to a number of hydro-geological and socio-economic factors that include:

(i) Geographical location in South Asia;
(ii) Flat deltaic topography with very low elevation;
(iii) Extreme climate variability that is governed by monsoon and which results in acute water distribution over space and time;
(iv) High population density and poverty incidence; and
(v) Population being dependent on natural systems for agriculture production which is highly influenced by climate variability and change.

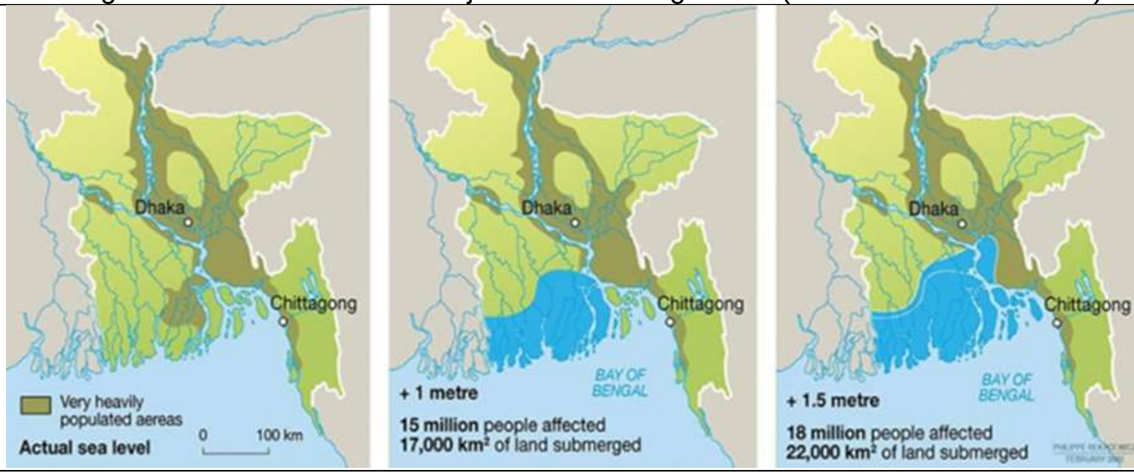
56. Bangladesh is located in a low-lying delta, formed by the dense network of the tributaries of the Ganges, the Brahmaputra, and Meghna, comprising a network of more than 700 major rivers or tributaries and over 24,000 km of waterways between the Himalayas and the Bay of Bengal. About 10% of the country is only 1 meter above the mean sea level, and nearly a third of the country is susceptible to tidal inundation and nearly 70% of the country is subject to frequent inundated, seasonal floods and flash floods and are periodically affected by cyclones and droughts. Seven of the top 10 deadliest cyclones of all time (in terms of loss of life) have occurred Bangladesh and Myanmar.

57. Floods and riverbank erosions affect around 80% of land in Bangladesh and adversely impact over one million people annually in Bangladesh. Once every 3 to 5 years, up to two-thirds of Bangladesh is inundated by floods. Sixty percent of the worldwide deaths caused by cyclones in the last 20 years occurred in Bangladesh. The cyclone that struck the coastal areas of Bangladesh in November 1970 caused over 300,000 deaths and $2.5 billion worth of damage to property. Seasonal droughts in Bangladesh most commonly affect the northwestern region, as it receives lower rainfall than the rest of the country.

58. Flooding occurs on an annual basis. During the last 50 years, at least seven mega floods have occurred, affecting about 35%–75% of the land area. Major flooding recorded in recent years occurred in 1987, 1988, and 1998, 2004, and 2007 (excluding events caused by tropical cyclones). The project area is prone to a high risk of flooding. Whilst flooding occurs mainly in the form of river flooding, the southern part of the city of Khulna is prone to sea level rise and storm surge.

59. IPCC (2007) projects a rise in sea level ranging between 18 and 59 centimeters (cm) by 2100. Sea levels could rise by between 0.8 m and 1.5 m in Bangladesh by the end of this century and up to 2 meters higher under extreme warming scenarios (Pfeffer et al. 2008, Vermeer and Rahmstorf 2009, and Grinsted et al. 2010). This is substantially more than the IPCC forecast in last year's landmark assessment of climate science. Sea level rise of this magnitude would have major impacts on low-lying countries such as Bangladesh, where eighty to ninety per cent of Bangladesh is within a meter or so of sea level as illustrated in Figure 12.

Figure 12. Sea Level Rise Projections for Bangladesh (1 meter and 1.5 meters)



Sources: Dacca University; Intergovernmental Panel on Climate Change.

60. Sea level rise will cause shoreline retreat, resulting in increase in basin area, which in turn will contribute to increasing the cyclone path length and allow the cyclone to remain more time in the water, acquire and release more latent heat, resulting in more energy, intensity and wind speed. The coastal region of Bangladesh already faces high risk of cyclones and storm surges due to its complex geomorphologic position and low elevation from the sea level. Recently, the country has experienced numerous devastating cyclones and storm surges which are widely believed to be due to climate effects [Karim et al. (2005), SMRC (2003)]. From 1981 to 1985, 174 severe cyclones (with wind speeds of more than 54 km/hour) formed in the Bay of Bengal. Increased frequency of cyclones: Super cyclone Sidr November 15th, 2007; Cyclone Nargis 2nd May 2008; Cyclone Rashmi 27th October 2008; Cyclone Aila 26th May 2009; and Cyclone Mahashen on the 16th of May 2013.

61. Karim and Mimura (2008) analyzed nine climate change scenarios based on the three sea surface temperatures (current SST, 2ºC and 4ºC rise) and three sea level scenarios (0 m, 0.3 m, and 1 m sea level rise, respectively) and concluded that:

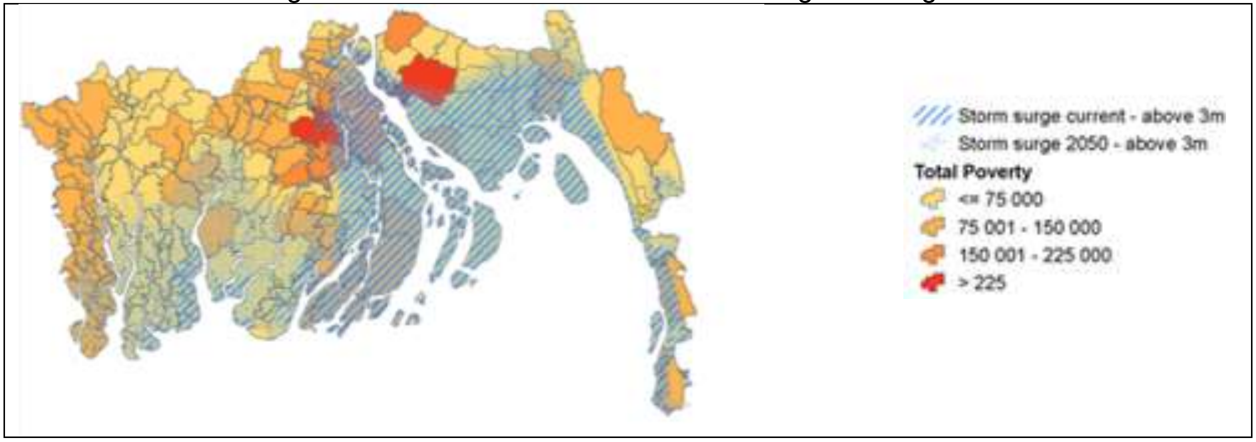
(i) Storm surge height might increase as much as 21% if sea surface temperature (SST) rises by 2ºC (RCP 2.6) and 49% if SST rises by 4ºC (RCP 8.5).

(ii) Over bank flooding would occur as much as 69 km inland for a surge that corresponds to RCP 2.6, while the intrusion reached up to 78 km inland for a surge that corresponds to Scenario RCP 8.5.

(iii) Flooding area will increase by 12.6% for a surge that corresponds to 2ºC temperature rise RCP4.4) and by 24.5% for a surge that corresponds to 4ºC temperature rise (RCP 8.5) if sea level remains unchanged.

62. The coastal regions of Bangladesh are subject to damaging cyclones and storm surge almost every year. Figure 13 highlights all the coastal areas that are projected to be exposed to storm surge and sea level rise due to the climate change, and include the coastal regions of Khulna, Patuakhali, Barisal, Noakhali and Chittagong and the offshore islands of Bhola, Hatiya, Sandwip, Manpura, Kutubdia, Maheshkhali, Nijhum Dwip, and Urir Char.

Figure 13. Sea Level Rise and Storm Surge in Bangladesh



Source: Sarwar (2005).

63. With regard to saline intrusion, the coastal districts such as Satkhira, Khulna, Bagerhat, Barguna, Pataskala, and Barisal are already affected by salinity intrusion. In dry season, 5 ppt isohaline intrude more than 90 km landward than monsoon period at the western part of the coastal area in the Sunbdarbans. Mohal et al. (2007) developed a mathematical model of the Bay of Bengal to predict the invasion of sea water to the country's mainland river networks. If the sea level rises 32 cm (2050), the entire Sundarbans will be affected by saline water and the affected areas will include the power plants located in Bhola, Khulna, Barisal, Feni, and Chittagong. It is quite clear that the combined effect of sea level rise and a reduction in freshwater inflow from the upstream due to climate change will convert the present fresh water zones in the Khulna region into saline zones and lower saline zones into the future.

64. Coastal erosion is a recurring natural hazard in Bangladesh (as illustrated in Figure 14). Every year, millions of people are affected by erosion that destroys standing crops, farmland and homestead land. It is estimated that about 5% of the total floodplain of Bangladesh is directly affected by erosion. Some researchers have reported that bank erosion is taking place in about 94 out of 489 upazilas of the country. At present, bank erosion and flood hazards in nearly 100 upazilas have become almost a regular feature. Of these, 35 are severely affected.

Figure 14. Images of Coastal and River Bank Erosion in Bangladesh

Source: North-West Power Generation Company Limited.

65. The Rupsha CCPP site already shows evidence of river bank erosion. It is also evident that increasing river erosion threatens transmission line river crossings and scour of footing foundations near riverbank will increase in the future due to projected increase in peak flow as well as water surface elevation.

C. Impacts on Vulnerable Infrastructure

1. In General

66. The Fifth Assessment Report of the IPCC from 2014 stresses that climate change-related risks stemming from extreme events such as heat waves, extreme precipitation, cyclones, and coastal flooding can already be observed in Bangladesh. The vulnerability of infrastructure to destruction (risk) by climate induced hazards and impacts on coastal regions in Bangladesh will further increase in this century, and there is historical evidence that the impacts of climate change are already being felt in Khulna City, including the proposed location for the Rupsha CCPP facility.

67. Future projections outlined above indicate that it is highly likely that the Khulna province will become increasingly vulnerable to the effects of climate change. Increasing temperatures, decreasing water availability, more intense storm events, and sea level rise will each cause impacts independently, and in some cases in combination. Not only will these phenomena affect the proposed Rupsha CCPP plant, it is highly likely that the interdependencies between hazards (such as cyclones, storm surge, and sea level rise) will have a compounding on the entire spectrum of energy production and transmission.

2. Thermoelectric Power Generation Infrastructure Vulnerability

68. The Rupsha power plant infrastructure includes the installation and operation of an 800 MW gas-fired CCPP located in Khulna City. Climate change is expected to have the following impacts on the Rupsha CCPP infrastructure:

- (i) Higher average temperatures and more frequent and severe extreme temperatures are expected to lower thermoelectric plant efficiency and available generating capacity of the Rupsha CCPP;
- (ii) Reduced availability of surface water resources and changing seasonal flow patterns of the Bhairab River as the primary source of cooling water for the Rupsha CCPP 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 coastal energy infrastructure to increasing inundation, flooding, storm surge, saline intrusion and a higher rate of riverine erosion which in combination have the potential to significantly impact on the Rupsha CCPP.

69. Higher average temperatures are known to reduce the efficiency of thermoelectric power generation capacity, reducing the total amount of power a plant can produce. Natural gas power plants are designed to operate optimally at 15°C and a 1°C increase in ambient temperature above the design point which could lead to a reduction in generation capacity by about 0.7% (Sathaye et al. 2013), and higher water temperature may decrease the efficiency of thermal power plants by between 5-15% (Petrick S., K. Rehdanz, and R. Tol 2010). Based on these rates, climate change-driven temperature increases could lead to significant reductions of the generating capacity of the Rupsha CCPP by the 2050, depending on emissions scenario.

70. Extreme weather events, and especially tropical cyclones and river flooding, also pose a major threat to the Rupsha CCPP, where they could disrupt the functioning of critical equipment and processes that are indispensable to safe operation including cooling equipment, control instruments and back-up generators etc. Changing regional weather patterns are likely to affect the hydrologic cycle that underpins power generation. In some seasons, a decline in rainfall levels and a rise in temperature, leading to increased water loss, could lead to reduced power operations, operation at reduced capacity or even temporary shutdowns.

71. Table 5 provides a summary of how these changes are projected to affect the design, construction and operation of the Rupsha power plant and ancillary facilities.

Table 5. Rupsha CCPP Infrastructure Vulnerability

Climate Change Hazard	Potential Impact on Power Generation Infrastructure	Infrastructure Vulnerability
POWER PLANT		
1. Increasing temperatures (air and water) and increasing magnitude and frequency of extreme heat events	➢ Exposed and sensitive to increasing temperatures, leading to a reduction in plant efficiencies and available generation capacity	Medium
	➢ Higher ambient temperatures will lead to an increased in the peak demand for electricity, higher loads and increased outages during extreme heat wave events.	Medium
2. Changing rainfall patterns, decreasing seasonal water availability and droughts	➢ Exposed and sensitive to changing rainfall patterns, decreasing seasonal water availability and drought which will lead to a reduction in plant efficiencies and available generation capacity (primarily due to saline intrusion and a reduction in available fresh water for cooling).	Medium
3. Increasing intensity and frequency of extreme events (storm events, flooding, and cyclones) and sea level rise	➢ Exposed and sensitive to increasing intensity and frequency of extreme events (storm events, flooding, and cyclones and sea level rise), leading to an increased risk of physical damage and disruption to generation facilities, substations and other gas and electrical infrastructure.	High
	➢ Exposed to higher flooding & inundation potential due to sea level rise combined with cyclones, storm surge and inundation causing damage to infrastructure, river bank erosion, failure of levees in coastal and estuarine areas.	High

Vulnerability Rating Scale	Negligible	Low	Medium	High	Very High

Source: Asian Development Bank projections.

3. Gas Distribution Pipeline Vulnerability

72. The proposed Rupsha power plant project involves the construction gas distribution pipelines. A new 24-inch, 10 km long underground gas pipeline will be installed from Khulna CGS to the Rupsha 800 MW power plant. In addition, a new 20-inch, 2 km long underground gas pipeline will branch off from the line from Khulna CGS to Rupsha power plant, to serve NWPGCL's existing Khulna 225 MW power plant.

73. Although the gas pipeline will be installed underground and as such have a degree of built-in resilience, the Rupsha gas pipelines may be vulnerable to: the increasing intensity and frequency of extreme events (storm events, flooding, and cyclones), sea level rise and salinity. These hazards have the potential to impact natural gas pipelines and ancillary facilities located adjacent to river floodplain areas are likely to experience a greater frequency, duration, and/or depth of inundation, and the adverse effects of increasing erosion and salinization. Such

conditions have the potential to accelerate structural failures or cause damage to above ground ancillary facilities.

74. In addition to this, inundation has the potential to cause damage to natural gas distribution pipelines and ancillary facilities through increased hydrostatic load, erosion, debris flow, and/or corrosion. Inundation with saline or brackish water in particular represent a significant issue in the Khulna area and may impact pipelines by contributing pipeline corrosion. Table 6 provides a summary of how these changes are projected to affect the design, construction and operation of the Rupsha gas distribution pipeline system and ancillary infrastructure and facilities.

Table 6. Gas Transport System Vulnerability

Climate Change Hazard	Potential Impact on Gas Pipeline Infrastructure		Infrastructure Vulnerability
GAS DISTRIBUTION PIPELINE			
1. Increasing temperatures (air and water) and increasing magnitude and frequency of extreme heat events	➢ Increasing temperatures may adversely affect the reliability of pipelines and ancillary facilities.		Low
2. Changing rainfall patterns, decreasing seasonal water availability and droughts	➢ Inundation with saline or brackish water can impact pipelines by contributing to pipeline corrosion.		Low
3. Increasing intensity and frequency of extreme events (storm events, flooding, and cyclones) and sea level rise.	➢ Pipelines and ancillary facilities in coastal areas will be exposed to rising sea levels, flooding and inundation triggered by cyclones and storm surge. However, the sensitivity of the pipeline infrastructure is low as the pipeline is installed underground		Low

Vulnerability Rating Scale	Negligible	Low	Medium	High	Very High

Source: Asian Development Bank projections.

4. Electricity Transmission Infrastructure Vulnerability

75. The proposed Rupsha CCPP project involves the construction of power transmission lines and interconnection facilities necessary to evacuate power to the Khulna South Substation. The Rupsha electricity transmission lines are vulnerable to a variety of climate impacts, including increasing temperatures, extreme storm and cyclone events, flooding and storm surge —which may in turn lead to losses in carrying capacity and efficiency when ambient air temperatures are higher, or increasing physical damage to transmission facilities and infrastructure.

76. Table 7 provides a summary of how these changes are projected to affect the design, construction, and operation of the Rupsha transmission lines and interconnection facilities.

Table 7. Electricity Transmission System Vulnerability

Climate Change Hazard	Potential Impact on Power Transmission Infrastructure	Infrastructure Vulnerability
ELECTRICITY TRANSMISSION SYSTEM		
1. Increasing temperatures (air and water) and increasing magnitude and frequency of extreme heat events	➢ Exposed and sensitive to increasing temperatures, leading to a reduction in transmission efficiency and available transmission capacity.	Medium
	➢ System transmission losses during a heat wave could be significant and contribute to electric power interruptions and power outages.	Medium
	➢ Higher mean and extreme temperatures increased stress and management of electricity on the transmission system due to higher electrical loads.	Low
2. Changing rainfall patterns, decreasing seasonal water availability and droughts	➢ Inundation with saline or brackish water can impact transmission towers by contributing to corrosion of tower footings.	Low
3. Increasing intensity and frequency of extreme events (storm events, flooding, and cyclones) and sea level rise	➢ Exposed to sensitive to more frequent and intense extreme events, especially strong wind, floods, river bank erosion, storm events, flooding, and cyclones leading to increased physical damage, disruption transmission lines and decreased transmission capacity.	Medium
	➢ More frequent and severe lightning storms leading to infrastructure damage and outages	Low

Vulnerability Rating Scale	Negligible	Low	Medium	High	Very High

Source: Asian Development Bank projections.

77. Higher temperatures in particular can reduce the efficiency and capacity of power lines and other power grid components, such as transformers, and can increase the risk of disruption to transmission lines (DOE 2013). Sathaye et al. (2013) estimate that up to 7% of power generated is lost in transmission and distribution, and these losses increase as temperatures increase. In addition, as temperatures increase, the current carrying capacity of electricity lines decreases. Increasing temperatures can also cause sag of overhead transmission lines due to thermal expansion. A relatively small increase in thermal expansion can produce a significant increase in sag. This initial sag increases with line temperature because the conducting material of which the line is made expands as line temperature increases, effectively lengthening the line (Gupta et al. 2012).

78. Extreme weather events, and especially tropical cyclones and river flooding, also pose a major threat to the Rupsha transmission lines and interconnection facilities. Increasing intensity and frequency of extreme events (storm events, flooding, and cyclones) and sea level rise are likely to contribute to increasing physical damage, disruption transmission lines and decreased transmission capacity.

D. Key Climate Risks to Infrastructure

79. Historically, the energy sector in Bangladesh has always been vulnerable to high temperatures and extreme weather events such as cyclones, floods, and drought. The probability of these risks, which already exist for this sector, becoming higher due to climate change, is strong. Whilst studies of the potential regional impacts of climate change on the energy sector in South Asia are limited, current research from other locations around the world suggest that the effects of increased temperatures and precipitation are likely to have an adverse impact on the proposed Rupsha CCPP project in terms of generation capacity, transmission and operation. Table 8 provides a summary of the key climate change related risks to critical infrastructure for the Rupsha CCPP project assessed for 2030 and 2050.

Table 8. Climate Change Risk Assessment for Key Infrastructure (2030 and 2050)

Risk Category	***Risk Rating 2030***	***Risk Rating 2050***	***Risk to Infrastructure***	***Likelihood***		***Consequences***	
Higher Temperatures	*6 MODERATE RISK*	*8 MODERATE RISK*	*REDUCTIONS IN ENERGY GENERATION CAPACITY & HIGHER COSTS* *Increasing temperatures (air and water) and increasing magnitude and frequency of extreme heat events will lead to a reduction in energy generation potential, and this will add to operational and maintenance costs.*	*3 Possible*	▲ *Temperature projected to increase +1°C by 2030*	*2 Minor*	*Higher temperatures and extremes are expected to lead to minor loss in cooling capacity and increases in operational costs. Suitable risk reduction and control measures exist.*
				4 Likely	▲ *Temperature projected to increase 1.4°C by 2050*		
Reduced water availability and drought	*8 MODERATE RISK*	*10 MODERATE RISK*	*REDUCTIONS IN ENERGY GENERATION CAPACITY & HIGHER COSTS* *Changes in seasonal rainfall patterns are expected to lead to decreasing seasonal water availability, lower river flows and water availability in the dry season and a corresponding reduction in cooling efficiencies and an increase energy generation costs.*	*4 Likely*	▲*+ 5% change in annual rainfall* ▲ *Discharge during the monsoon (May to September) by 2030 will increase by about 5%.*	*2 Minor*	*Changes in seasonal water availability and increasing salinity are expected to lead to minor disruptions to cooling and increases in treatment costs. Suitable risk reduction and control measures exist.*
				5 Almost Certain	▲ *+ 6% change in annual rainfall* ▲ *Discharge during the monsoon (May to September) by 2050 will increase by about12%.*		
Increasing intensity and frequency of extreme events (storms and cyclones)	*16 HIGH RISK*	*20 EXTREME RISK*	*DAMAGE TO INFRASTRUCTURE, REDUCED ASSET OPERATION & PERFORMANCE* *More extreme events and tropical cyclones add significant risk to the design, construction and operation of power generation facilities and services. Combined with sea level rise, storm surge and saline intrusion these events lead to increased capital costs (associated with climate rating building and facilities), increased operating costs through loss of generating efficiency and decreased revenue from shutdowns and reduced productivity.*	*4 Likely*	▲ *Climate change modeling predicts an increase in the intensity of cyclones of 60% by 2030*	*4 Major*	*An increase in the frequency and intensity of extreme events and cyclones may incur extensive infrastructure damage and disruptions to power generation and supply. Few suitable risk reduction and control measures exist.*
				5 Almost Certain	▲ *Climate change modeling predicts an increase in the intensity of cyclones of 140 % by 2070*		

Risk Category	Risk Rating 2030	Risk Rating 2050	Risk to Infrastructure	Likelihood		Consequences	
Flooding	16 MEDIUM RISK	20 EXTREME RISK	DAMAGE TO INFRASTRUCTURE & LOSS OF PRODUCTION The Rupsha CCPP plant site already experiences regular flooding to a depth of up to 80cm. Flooding events pose risks to the CCPP such as damage to facilities and loss of production. Potential increase in the number of intense tropical cyclones heavy rainfall events contributing to widespread river based and coastal flooding leading to damage to infrastructure and the loss of production.	4 Likely	▲ Flood heights are expected to increase by +30 cm by 2030.	4 Major	An increase in the frequency and intensity of flooding may incur extensive infrastructure damage and disruptions to power generation and supply in the absence of flood mitigation and control structures. *Few suitable risk reduction and control measures exist.*
				5 Almost Certain	▲ Flood heights are expected to increase by +50 cm by 2050.		
Sea level rise & storm surge	12 HIGH RISK	15 HIGH RISK	DAMAGE TO INFRASTRUCTURE & LOSS OF PRODUCTION Sea Level rise, in combination with an increase in the number of intense tropical cyclones heavy rainfall events will contribute to widespread river based and coastal flooding leading to damage to infrastructure and the loss of production.	4 Likely	▲ Sea level rise is projected to rise for Bangladesh by 9 cm by 2030	3 Moderate	Sea Level rise, in combination with heavy rainfall events, and storm surge are expected to contribute to moderate infrastructure damage and loss of service. Damage recoverable by maintenance and minor repair. *Some suitable risk reduction and control measures exist.*
				5 Almost Certain	▲ Sea level rise is projected to rise for Bangladesh by 40 cm by 2050		

Risk = Likelihood × Consequences

E = > 20	Extreme Risk: potentially threatening the overall viability of the project and requiring priority action	**M = > 5**	Moderate Risk: risk that can be expected to influence the design and routine operation of the CCPP infrastructure and facilities and where control measures can be applied and will be sufficient.
H = > 12	High Risk: are the most severe risks that can be accepted as part of the design and routine operation of the CCPP infrastructure and facilities.	**L = < 5**	Low Risk: where existing control measures will be sufficient to mitigate any potential impacts and /or where no action will be required to treat them unless they become more severe.

Source: Asian Development Bank projections.

V. CLIMATE HAZARD RISK MITIGATION & ADAPTATION MEASURES

A. Adaptation Options, Measures, and Priorities

80. There are various options by which the Rupsha project can improve its resilience to climate change. A number of technological improvements are available for the power plants which may bring efficiency gains that more than compensate for losses due to higher ambient temperatures or losses in cooling efficiencies associated with reductions in water availability. Table 9 provides a range of hazard risk mitigation and adaptation measures that may be adopted or deployed for the Rupsha power plant and its associated infrastructure. These measures include technical and engineering solutions and adjusting operation to extreme conditions. The energy sector already deploys risk management practices for many of the risks outlined above, that are ubiquitous with power generation and transmission in Bangladesh already. However, changes in climate will add another dimension of complexity to these risks, and therefore we have developed a range of indicative risk management options that will assist the Rupsha project management unit to develop adaptation plans that will mitigate and manage the risks identified and evaluated as being a risk to the long-term operation of the facility.

Table 9. Potential Climate Adaptation Measures in Response to Climate Risks

Priority	Risk	Potential Climate Adaptation Measures
Power Generation Infrastructure		
1	**Risks of damage or loss of power generation capacity due to increasing frequency and intensity of extreme weather events (flooding, cyclones, and storm surge).**	**Priority Control Measures:** A moderate range of control measures are available in terms of flood control and mitigation, cyclone rated building construction and emergency response planning and disaster risk reduction (DRR) and management systems (early warning, cyclone shelters, evacuation procedures etc.). Key measures include: ➢ Risk reduction via non-structural adaptation measures, effective planning and design, and building institutional capacity for risk management and reduction. ➢ Update siting, design and operational plans to account for sea level rise, flooding and storm surge. Risk reduction via structural adaptation measures, including elevation of critical infrastructure and equipment, enhance levees and flood control structures. ➢ Incorporate more resilient/robust design specifications and construction standards (cyclone ratings etc.), including waterproofing measures. ➢ Prepare emergency response plans and early warning systems to account for higher frequency of intense storms, flooding and cyclones.
2	**Risks of damage or loss of power generation capacity from due rising temperatures and extreme heat events.**	➢ Priority Control Measures: A reasonable number of control measures are available in terms of future infrastructure building design and construction measures to accommodate higher mean air and water temperatures and reduce exposure to extreme heat. Key measures include: ➢ Include extreme temperature scenarios in future infrastructure building design and construction measures to accommodate higher mean air and water temperatures and reduce exposure to extreme heat.

Priority	Risk	Potential Climate Adaptation Measures
		➢ Design, engineer, and construct structures suited for rising temperatures and heat waves. ➢ Develop best operating practices for equipment at high temperatures.
3	**Risks of reduced or loss of water resources for cooling due to lower river flows, declining water availability, drought and saline intrusion.**	**Priority Control Measures:** A moderate number of control measures are available in terms of improved water use efficiencies, water recapture, storage and re-use technologies to accommodate reduced water availability and increasing exposure to drought. Key measures include: ➢ Include changes in precipitation and river flow scenarios in future infrastructure building design and construction measures to accommodate changes in water supply and security. ➢ Improve water use efficiencies, water recapture, storage and re-use technologies. ➢ Diversification of water supply technologies, including water supply augmentation, alternative water sources and the potential to use saline waters for cooling. Install equipment capable of using alternative water sources (e.g. brackish water etc.) for cooling.
Gas Distribution Infrastructure		
1	**Damage or loss of gas pipeline distribution facilities from extreme weather events.**	Given that the gas supply pipeline proposed for Rupsha is already underground and highly resilient to extreme events (flooding, cyclones, and storm surge), there are only a small range of additional control measures available to protect the gas pipeline system. Key measures include: ➢ Site equipment in areas less prone to river flooding and bank erosion. ➢ Protect above ground ancillary facilities with protective structures or natural barriers including river levees, flood control structures and riverbank protection works and riparian buffer plantings. ➢ Use pipeline materials that are more resilient to salinity and corrosion.
Power Transmission Infrastructure		
1	**Damage or loss of power transmission infrastructure and capacity from extreme weather events.**	A moderate range of control measures are available in terms of flood control and mitigation, cyclone rated construction and emergency response planning and DRR and management systems (early warning, etc.). Key measures include: ➢ Update design, siting and operational planning for extreme events (flooding, storms, cyclones and sea level rise), and including the identification of alternative routes for transmission lines to avoid flooding and river bank erosion. ➢ Improved design standards for specific components of the electricity grid and protective measures for lightning, wind, flooding, and other extreme events.
2	**Damage or loss of power transmission infrastructure and capacity from rising temperatures and extreme heat events.**	A moderate number of control measures are available in terms of operational and infrastructure improvements to enhance safety, reliability measures to accommodate higher mean temperatures, and reduce exposure to extreme heat. Key measures include: ➢ Incorporate future temperature projections into

Priority	Risk	Potential Climate Adaptation Measures
		planning, design and construction. ➢ Deploy equipment and lines with higher design temperatures and upgrade transformers (eg forced air/forced oil cooling).

Source: Asian Development Bank projections.

B. Climate Change Adaptation Measures

81. Climate change adaptation is a process that is aimed at reducing the risks (such as those identified above) that an investment project may face as a result of climate change. It involves ensuring that risks are reduced to acceptable levels at one or more of the following stages in the project cycle: planning, design, construction, operation, and decommissioning (ADB 2005). Based on the climate change risk assessment undertaken for this project, we have identified a range of possible near and long-term climate change adaptation actions that may be suitable for the Rupsha CCCP project, and these include:

(i) Revisiting the built infrastructure and engineering design standards for resilience to extreme events (storms, flooding, and cyclones);
(ii) Revisit planning time frames and implementation schedule for future investments to better reflect anticipated climate trends and timeline;
(iii) Assess the need to retrofit existing infrastructure; and
(iv) Adopt beneficial and cost-effective adaptation measures.

82. Focusing on these activities can help advance opportunities for climate preparedness and resilience in the Rupsha CCPP project and potential safeguards for responding to the threats from climate change. Subject to financial and economic analysis, beneficial and cost-effective measures will be adopted. The decision making should not be delayed excusing the uncertainly in the timing of climate change impacts.

83. Possible future low or 'no regret' adaptation measures for the Rupsha project may include: (i) climate-proofed designs for infrastructure (e.g. raising site and infrastructure levels, increased resilience of energy infrastructure to cyclones, floods, and sea level rise, including 'hardening' of facilities and structures such as power plant, transmission and distribution lines, and gas pipeline); (ii) nonstructural interventions, such as water-efficient technologies for cooling, improved energy efficiency, and reduced water intensity for power generation; and (iii) capacity building support for preparing and responding to climate risks.

C. Investing in Adaptation

84. As already noted, the uncertainty ranges of future climate projections increase significantly beyond the next three to four decades. Therefore, flexible but robust designs, together with adaptive management practices will be critical in managing climate risks and adaptation for the Rupsha CCPP project. As the CCPP component is under the highest risk among four project outputs, the investment for climate change adaptation is also focused on the CCPP rather than transmission interconnection and gas pipeline infrastructures. The climate adaptation finance is calculated based on the incremental cost of the adaptation activities, which is the cost associated with the elements of project design that address climate-related risks and vulnerabilities in comparison with a project design that does not address them.

85. The project adopts a closed-loop cooling tower instead of one through release considering lack of water resources due to drought which is worsen by the climate change. The cost difference between cooling tower and one through release system is counted as adaptation finance. In addition, the project includes demineralized water treatment system as the sea level rise causes saline water interruption to the river which is source of the cooling water. The demineralized treatment facility is required to secure water resources preparing for sea level rise which is also worsen by the climate change, thus the cost for this equipment is incremental and counted as adaptation finance. The total leveling height of the CCPP project site is 5.5m, and the average flood level on and around the site is 2.95m, so 2.55m is additional leveling. Among 2.55m, 0.4m is buffer under the current condition, so the cost for rest of 2.15m (after rounding up 2.2m) is considered as adaptation finance. The unit cost to incorporate emergency and protection system is U$64.58/$m^2$ and the system can cover 21.04 ha which is slightly larger than the CCPP project site. In total, the adaptation finance of the project is estimated as $41.13 million of which $25.08 million is counted as ADB's adaptation finance considering ADB's OCR (regular loan) is covering 61% of the relevant costs. The rest is financed by IDB and the government. Table 10 below outlines a range of climate adaptation measures with their costs to improve the climate resiliency of the project.

Table 10. Indicative Amount of Climate Change Adaptation Measures

Items	Linked Adaptation Measures	Adaptation Finance (US$ million)	ADB's Adaptation Finance (US$ million)	Remarks for Adaptation Finance
Closed-loop Cooling Tower	Water use efficiency and reuse	4.34	2.64	Cost difference between one-through system and cooling tower for CCPP
Demineralized Water Treatment System	Alternative water resources	21.75	13.27	Entire cost for desalination of intake water
River Bank Protection & Leveling	Waterproofing & Elevation of critical infrastructure	1.45	0.88	Cost for additional 2.2 m among total leveling height
Auxiliaries System	Emergency / protection system	13.59	8.29	Based on unit cost for the emergency system U$64.58/$m^2$
Total		**41.13**	**25.08**	

Source: Asian Development Bank estimates.

86. While all adaptation options outlined above aim to climate proof the project, some adaptation options may also deliver benefits additional to the climate change adaptation benefits (co-benefits), and these positive additional benefits need to be considered in the analysis and selection of future adaptation options. Table 11 highlights the estimated changes in power output and energy efficiency before and after adaptation measures are introduced for the Rupsha project.

87. Also, all adaptation options aim to climate proof the project, some adaptation options may do so at the expense of other sectors of the economy. For example, the groundwater abstraction option may lead to resource use issues with local people and must be considered as part of the planning and design process.

Table 11. Output Changes Before and After Adaptation Measures

	Impact due to climate change WITHOUT adaptation measures (average/annual)	Improvement WITH adaptation measures (average/annual)	Residual impact after adopting adaptation measures by 2050 year (average/annual)
Power Output (GWh)	32.68	22.87	9.8
Net Efficiency (%)	0.12	0.08	0.04
From 2020 to 2050, based on assumption that the air and water temperature changes 0.2ºC/year			

Source: Asian Development Bank estimates

88. Based on the financial and economic analysis developed above:

(i) The costs of climate change adaptation now are estimated to be relatively small while the benefits (the avoided expected costs from not adapting to climate change), even though realized only under future climate change, are estimated to be greater;

(ii) The costs of climate change adaptation at a later point in time are expected to be prohibitive, or climate change adaptation at a later point in time is technically not possible; and/or; and

(iii) The set of climate change adaptation options identified above include options that not only reduce climate risks to the project, but also have other social, environmental or economic benefits. Such options are referred to as 'no regret' climate change adaptation options.

89. As pointed out earlier, it is important to recognize that climate change hazards may change over the lifetime of this project. For example, while current sea level rise and storm surge scenarios may not warrant the construction today of sea dykes suitable to projected higher sea level and stronger storm surges in a distant future, the base of the sea dyke may nonetheless be built large enough today to accommodate a heightening of the sea dyke at a later point in time. It is clear that the project needs to be designed in such a way as to be amenable to being climate proofed in the future if and when circumstances indicate this to be a better option than not adapting to climate change. Inherent to this is adopting an adaptive management approach which allows incremental adaptation options to be put in place over the project's lifetime, which ensures a general and temporal 'readiness' for climate change into the future.

90. The project will utilize advanced technology in the power transmission component, which will be designed to have efficient high temperature and low sag aluminum conductor composite core. The cost of the transmission line is $27.49 million and $23.2 million is allocated to ADB OCR. As per the Guidance Note on Counting Climate Finance in Energy (5 January 2017), a default value of 40% is used for calculation and $9.28 million is considered to be ADB's climate mitigation finance due to efficiency improvement and loss reduction. The project is also constructing gas pipeline to deliver natural gas to the existing 225 MW Khulna power plant which is currently operating on high speed diesel. Natural gas will be used to operate the power plant (Khulna power plant is designed as dual fuel power plant) replacing high speed diesel. This offset component is also counted as climate change mitigation finance. The cost of the gas pipeline is $6.14 million and $5 million is allocated to ADB OCR which is counted as ADB's climate mitigation finance. Table 12 below outlines climate mitigation elements with their costs and ADB's mitigation finance amount.

Table 12. Indicative Amount for Climate Change Mitigation

Items	Mitigation	Mitigation Finance (US$ million)	ADB's Mitigation Finance (US$ million)
230 kV power transmission lines to evacuate generated electricity	Application of efficient HTLS, AAAC conductors.	23.20	9.28
Gas Pipeline to existing Khulna 225 MW Power Plant	Change fuel from high speed diesel (HSD) to LNG	6.14	5.00
Total		**29.34**	**14.28**

LNG = liquefied natural gas, MW = megawatt.
Source:

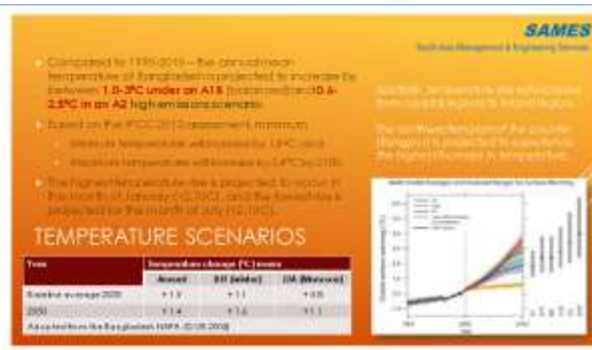
ANNEX 1: GLOSSARY OF TERMS

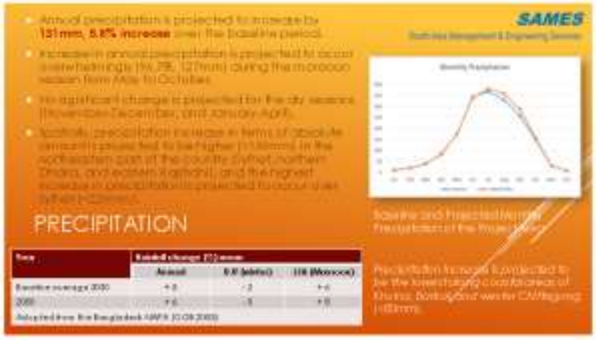
Adaptation	The process of adjustment to actual or expected climate and its effects. In human systems, adaptation seeks to moderate harm or exploit beneficial opportunities. In natural systems, human intervention may facilitate adjustment to expected climate and its effects.
Adaptation assessment	The practice of identifying options to adapt to climate change and evaluating them in terms of criteria such as availability, benefits, costs, effectiveness, efficiency, and feasibility.
Adaptive capacity	The ability of systems, institutions, humans, and other organisms to adjust to potential damage, to take advantage of opportunities, or to respond to consequences
Aggregate impacts	Total impacts integrated across sectors and/or regions. The aggregation of impacts requires knowledge of (or assumptions about) the relative importance of different impacts. Measures of aggregate impacts include, for example, the total number of people affected, or the total economic costs, and are usually bound by time, place, and/or sector.
Adaptation options	The array of strategies and measures that are available and appropriate for addressing adaptation needs. They include a wide range of actions that can be categorized as structural, institutional, or social.
Climate change	Climate change refers to a change in the state of the climate that can be identified (e.g., by using statistical tests) by changes in the mean and/or the variability of its properties, and that persists for an extended period, typically decades or longer. Climate change may be due to natural internal processes or external forcing such as modulations of the solar cycles, volcanic eruptions, and persistent anthropogenic changes in the composition of the atmosphere or in land use. Note that the United Nations Framework Convention on Climate Change (UNFCCC), in its Article 1, defines climate change as: 'a change of climate which is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and which is in addition to natural climate variability observed over comparable time periods.' The UNFCCC thus makes a distinction between climate change attributable to human activities altering the atmospheric composition, and climate variability attributable to natural causes.
Climate change impact assessment	The practice of identifying and evaluating, in monetary and/or non-monetary terms, the effects of climate change on natural and human systems.
Exposure	The presence of people, livelihoods, species or ecosystems, environmental services and resources, infrastructure, or economic, social, or cultural assets in places that could be adversely affected.
Hazard	The potential occurrence of a natural or human-induced physical event or trend or physical impact that may cause loss of life, injury, or other health impacts, as well as damage and loss to property, infrastructure, livelihoods, service provision,

	ecosystems, and environmental resources. In this report, the term hazard usually refers to climate-related physical events or trends or their physical impacts.
Impacts	Effects on natural and human systems. In this report, the term impacts is used primarily to refer to the effects on natural and human systems of extreme weather and climate events and of climate change. Impacts generally refer to effects on lives, livelihoods, health, ecosystems, economies, societies, cultures, services, and infrastructure due to the interaction of climate changes or hazardous climate events occurring within a specific time period and the vulnerability of an exposed society or system. The impacts of climate change on geophysical systems, including floods, droughts, and sea level rise, are a subset of impacts called physical impacts.
Integrated assessment	A method of analysis that combines results and models from the physical, biological, economic, and social sciences, and the interactions among these components, in a consistent framework to evaluate the status and the consequences of environmental change and the policy responses to it.
Resilience	The capacity of a social-ecological system to cope with a hazardous event or disturbance, responding or reorganizing in ways that maintain its essential function, identity, and structure, while also maintaining the capacity for adaptation, learning, and transformation.
Risk	The potential for consequences where something of value is at stake and where the outcome is uncertain, recognizing the diversity of values. Risk is often represented as probability of occurrence of hazardous events or trends multiplied by the impacts if these events or trends occur. Risk results from the interaction of vulnerability, exposure, and hazard. In this report, the term risk is used primarily to refer to the risks of climate-change impacts.
Transformation:	A change in the fundamental attributes of natural and human systems. Within this summary, transformation could reflect strengthened, altered, or aligned paradigms, goals, or values towards promoting adaptation for sustainable development, including poverty reduction.
Transformational adaptation	Adaptation that changes the fundamental attributes of a system in response to climate and its effects.
Vulnerability	The propensity or predisposition to be adversely affected. Vulnerability encompasses a variety of concepts including sensitivity or susceptibility to harm and lack of capacity to cope and adapt.

Source: IPCC, AR5-WGII: The WGII AR5 glossary defines many terms used across chapters of the report. Reflecting progress in science, some definitions differ in breadth and focus from the definitions used in the AR4 and other IPCC reports.

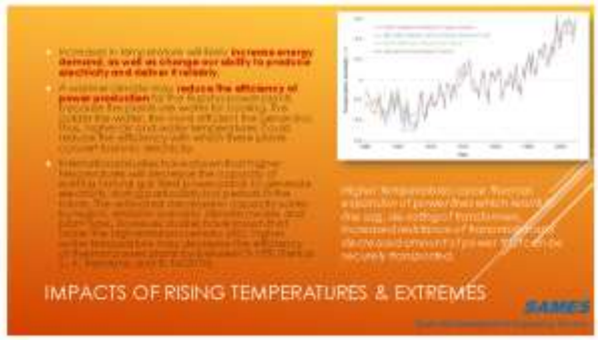
ANNEX II: CCVRA WORKSHOP PRESENTATION




SAMES
PRECIPITATION


CLIMATE RELATED HAZARDS IN KHULNA
SAMES

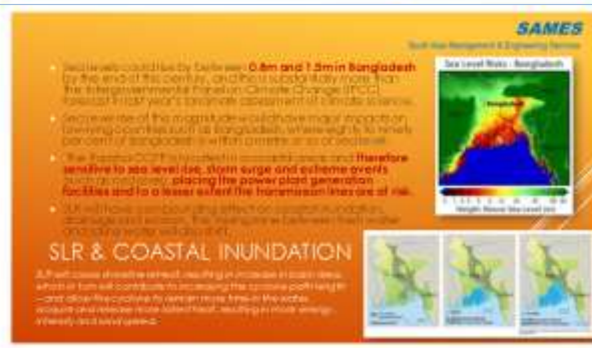

INFRASTRUCTURE AT RISK
SAMES


IMPACTS OF RISING TEMPERATURES & EXTREMES
SAMES


CHANGES IN WATER SECURITY
SAMES


SAMES
DROUGHT RISK


FLOOD RISK
SAMES


SAMES
SLR & COASTAL INUNDATION

Source: Asian Development Bank and South Asia Management and Engineering Services.

ANNEX III: LIST OF STAKEHOLDERS CONSULTED

Name	Position	Organization	Consulted	Workshop
Md. Shahidul Mosalin Jourder	Rupsha Project Director/Chief Engineer	NWPGCL	√	√
Md. Moshior Rahman	General Manager Khulna 225 MW Power Plant	NWPGCL	√	
Md. Imtiaz Ahmed	Assistant Engineer	NWPGCL	√	
Mashuda Parvin	Deputy Manager Environment	NWPGCL	√	√
Md. Golam Mostafa	General Manager	SGCL	√	√
Mohammad Hasmat Ali	Executive Engineer	NWPGCL	√	√
Md Mainuddin Sarker	Executive Engineer Planning & Design	NWPGCL	√	√
Muhammad Saifuddin Ashan	Executive Engineer Planning & Design	NWPGCL	√	√
Rifat Sultana	Assistant Engineer Planning & Design	NWPGCL	√	√
Harendra Nath Mondal	Executive Director	NWPGCL	√	
Dipak Kumar Dhali	Company Secretary	NWPGCL	√	
Dr Kazi Md. Noor Newaz	Environmental Advisor Power & Energy	CEGIS	√	√
Farhana Ahmed	Regional Planning & Climate Change Specialist	CEGIS	√	√
Pronab Kumar Halder	WRD Professional) Water, Energy & Environment	CEGIS	√	√
Md Sharif Hossain Sourav	Junior Specialist Ecology, Forestry and Biodiversity	CEGIS	√	√
Rakshanda Mabin	Senior Professional Human Resources & Business Development	CEGIS	√	
Malik Fida A Khan	Deputy Executive Director Operations	CEGIS	√	
Md Waji Ullah	Executive Director	CEGIS	√	

CEGIS = Center for Environmental and Geographic Information Services, NWPGCL = North-West Power Generation Company Limited, SGCL = Sundarban Gas Company Limited.

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