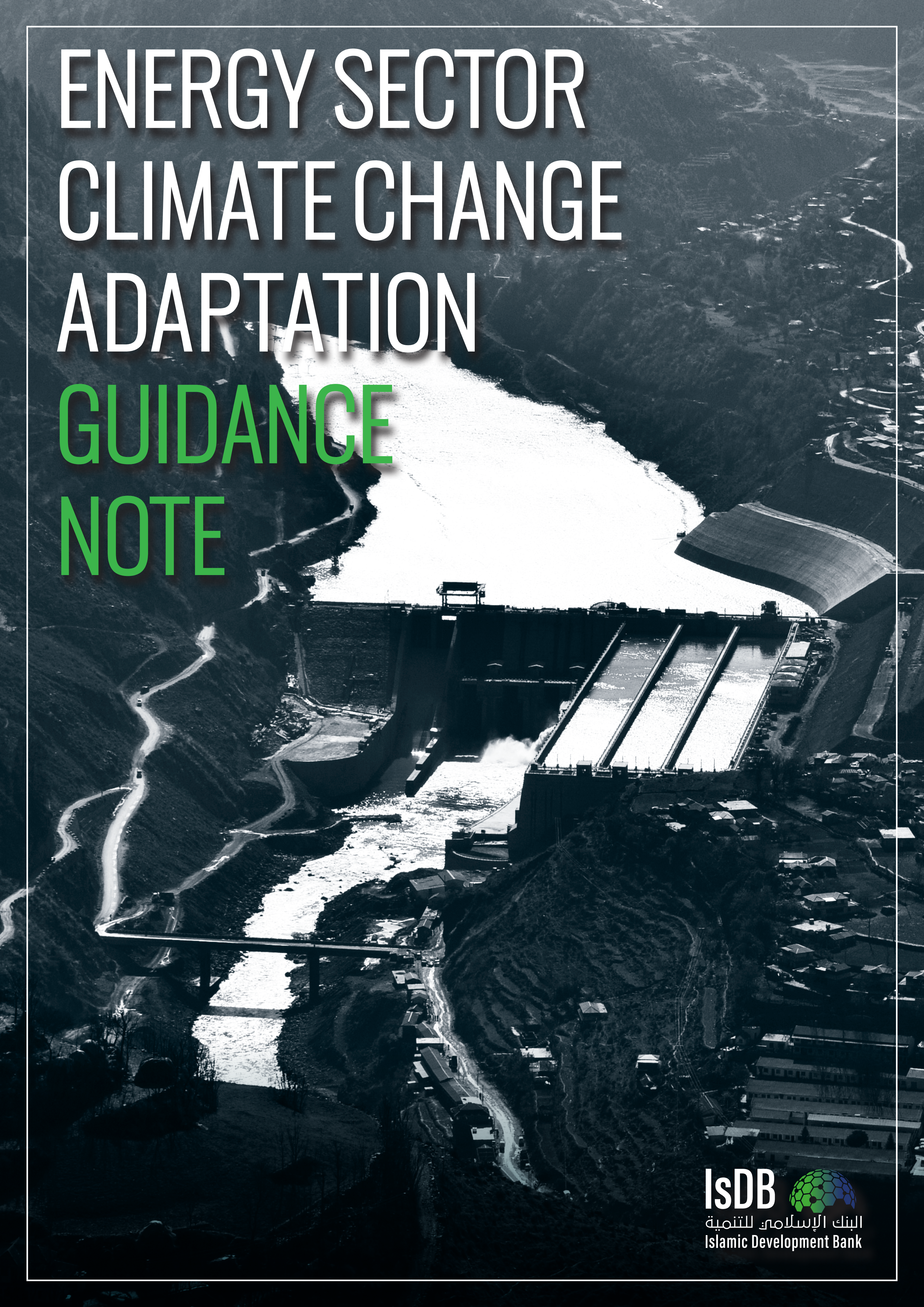
ENERGY SECTOR CLIMATE CHANGE ADAPTATION GUIDANCE NOTE



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1. About this Guidance Note

This energy sector guidance note was prepared by the World Resources Institute (WRI) for the Islamic Development Bank (IsDB) to enable IsDB project teams to integrate information on climate risks into project design. It applies to energy sector projects involving physical assets, largely focusing on the electricity sector. The subsectors covered include the following:

- Thermal power projects
- Hydroelectric power projects
- Solar and wind power projects
- Transmission and distribution projects

After a brief background on projected climate changes in the regions where IsDB operates and their projected impacts on the energy sector (Section 2), Section 3 explains the purpose of this note within a broader climate risk management process. It describes the steps involved in managing a project's climate change risks—beginning with climate risk screening, followed by project impact and adaptation assessments, and ending with project implementation. Section 4 then describes the process of determining potential climate impacts on energy sector projects and identifying adaptation options to address those impacts. Section 5 presents an approach to evaluate adaptation options, and Section 6 concludes with case studies that demonstrate a practical example of this approach.

2. Background: Climate Change and the Energy Sector

In 2017, a total of $3.9 billion was approved from IsDB's Ordinary Capital Resources. (IsDB 2017). IsDB approved 14 energy sector projects for a total of US$1.2 billion in 2017 (IsDB 2017). These included projects to extend energy access, construct thermal power generation, finance renewable energy, and support energy efficiency. IsDB operates in four core regions: the Middle East and North Africa, sub-Saharan Africa, Europe and Central Asia, and Asia and Latin America.[1]

Observed and projected climate changes vary across these regions. Throughout much of Africa, temperatures have increased by at least 0.5°C over the last 50 to 100 years, with minimum temperatures rising faster than maximum temperatures. In terms of model projections, it is likely that land temperatures over Africa will rise faster than the global average, particularly in the more arid regions. Data are lacking in much of the region, making it difficult to draw conclusions about trends in annual precipitation. However, annual precipitation has likely decreased in the Sahel region and increased in parts of eastern and southern Africa. There is considerable uncertainty regarding projected precipitation patterns in sub-Saharan Africa, but there is greater model agreement that precipitation will increase in east Africa and decrease in north and southwest Africa. Across the continent, climate change is expected to exacerbate existing water stress (Niang et al. 2014).

In the past century, much of Asia has experienced warming trends and increasing temperature extremes. There is little agreement on projected precipitation patterns at a subregional scale, but under a higher warming scenario (Representative Concentration Pathway [RCP] 8.5), precipitation is likely to increase at higher latitudes by the middle of the 21st century and in parts of eastern and southern Asia by the late 21st century. Water scarcity is expected to be a major challenge for most of Asia due to increased demand and poor water management (Hijioka et al. 2014). In Europe, future climate projections vary regionally, with projected temperature increases throughout the region, precipitation increases in northern Europe, and precipitation decreases in southern Europe. Across the continent, climate projections indicate a marked increase in heat waves, droughts, and heavy precipitation events (Kovats et al. 2014).

Lastly, significant trends in precipitation and temperature have been observed in Central America and South America, but the patterns vary regionally, with annual rainfall increasing in southeastern South America and decreasing in Central America and central-southern Chile. Increased warming has been observed throughout the region, with the exception of the Chilean coast. Increases in temperature extremes have been measured in Central America and most of tropical and subtropical South America, while more frequent extreme rainfall in southeastern South America has produced more landslides and flash floods. Under the RCP 8.5, climate models project a mean reduction of 10 percent in annual precipitation for Central America (with a reduction in summer precipitation) by 2100, a decrease of 10 percent for tropical South America east of the Andes, and an increase of 15 to 20 percent for southeastern South America. One major concern is the melting of the Andean cryosphere, which is altering the seasonal distribution of streamflow. Combined with possible precipitation reductions and higher evapotranspiration, this could lead to water shortages, particularly for cities highly dependent on glacial outflows (Magrin et al. 2014).

The potential impacts in the energy sector are varied across energy supply, transmission, and distribution infrastructure. For thermal fossil fuel–fired power plants and hydropower electricity projects, the effect of climate change on water resources is the critical issue. Changes in total precipitation or precipitation variability could lead to changes in runoff that consequently alter hydropower generation.[2] Increased intra-annual precipitation variability could lead to seasonal shifts in power generation, creating potential for temporal mismatches between electricity generation and demand. Reductions in surface water availability due to decreased precipitation or increased temperature could reduce the water available for cooling in thermal plants, leading to curtailment. Increases in temperature can reduce the efficiency of thermal conversion as well (Arent et al. 2014).

Climate change may also affect renewable energy, such as solar and wind. Increased temperatures can reduce the efficiency of solar photovoltaics and concentrated solar power requiring water cooling. Increased cloudiness in some areas with more frequent rainfall would reduce solar generation capacity. Extreme weather events, such as hail and heat waves, can damage and more quickly deteriorate solar materials. For wind power, changing weather patterns could change wind speeds and alter power outputs. Floods and coastal storm surge can physically damage all types of power generation assets.

For electricity transmission and distribution infrastructure, increases in temperature can lead to greater electricity losses and reduce the capacity of lines. Extreme weather events, such as storms, high winds, and hurricanes, can physically damage overhead lines, towers, poles, and substations, while extreme high temperatures can cause lines and transformers to overheat (Arent et al. 2014).

There are also a number of indirect effects of climate change. Studies indicate that overall climate change will lead to increased energy demand in most regions of the world; increased cooling demand will generally outweigh reductions in heating demand. In macroeconomic terms, energy-related economic impacts are projected to be negative for developing countries and positive in developed countries (Arent et al. 2014).

3. Project Climate Risk Management

This guidance aims to help project teams incorporate climate change considerations into project planning and design. It will support the broader climate risk management process, which begins with climate risk screening and concludes with project implementation. Figure 1 below briefly summarizes the climate risk management process.[3] Though the terminology and precise sequencing of steps vary, many comparable institutions, including multilateral development banks and bilateral development agencies, apply processes similar to the one described in Figure 1.

The first phase of the process is climate risk screening. IsDB plans to begin using Acclimatise Aware, a climate risk screening tool, for this phase.[4] It will use Aware at the early concept stage for all projects involving physical assets. In addition to generating an overall climate risk ranking, Aware identifies key climate risk areas for the project, based on project category and location. If the initial climate risk screening using Aware indicates that a project has some level of climate risk, project impact and adaptation assessments follow. This guidance note is meant to support those phases of the climate risk management process.

Climate risk screening and project impact assessment together establish the climate change vulnerability context of a project. That context informs the adaptation assessment that follows, which aims to identify those measures best suited to reduce climate vulnerability, thereby establishing a direct link between specific project activities and the overall objective of reducing climate vulnerability. The sections that follow discuss project impact and adaptation assessments in greater detail.

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FIGURE 1: CLIMATE RISK MANAGEMENT PROCESS

CLIMATE RISK SCREENING

Preliminary, rapid assessment of the risks posed to a planned project as a result of climate change. Tools and methodologies used include Acclimatise, Aware; World Bank, Climate and Disaster Risk Screening Tool; International Institute for Sustainable Development, Community-Based Risk Screening Tool—Adaptation & Livelihoods (CRiSTAL).

PROJECT IMPACT ASSESSMENT

- Identify the climatic variables of interest for the project. These may include meteorological (e.g., temperature, precipitation); hydrologic (e.g., runoff volume, groundwater recharge, soil moisture); and other environmental (e.g., sea-level rise) variables. When their impacts are harmful, these variables are referred to as climate hazards.

ADAPTATION ASSESSMENT

- Establish adaptation objective.
- Identify adaptation options.
- Use a multi-criteria approach to appraise adaptation options (e.g., functional effectiveness, technical feasibility, affordability, stakeholder acceptability, etc.).

IMPLEMENTATION

- Establish implementation arrangements for selected adaptation measures (determine roles and responsibilities; identify needs for technical support and capacity building, etc.).

Sources: ADB 2014b; ADB 2013; USAID 2015; GIZ 2014

	• Identify the changes in environmental conditions (or *system impacts*) likely to follow from changes in the above variables (e.g., reduced raw water quality, increased evapotranspiration, increased frequency of floods).	• Determine the vulnerability of different project components to changes in environmental conditions. Vulnerability is a function of th project's exposure, sensitivity, and adaptive capacity to a specific climate hazard.

	• Conduct economic assessment of shortlisted adaptation options.	• Select adaptation strategy.	• Stakeholder engagement is critical to all of these steps.

This guidance note can help to inform these steps.

	• Provide for ongoing monitoring and evaluation.

4. Identifying Potential Impacts and Adaptation Options

As explained above, the Aware climate risk screening tool identifies the key climate risk areas based on the project's type and location. Project teams can use this information, along with other available climate data and expert judgment, to determine which climate hazards are most likely to be relevant for a project. The World Bank's Climate Change Knowledge Portal[5] and The Nature Conservancy's Climate Wizard[6] are two examples of publicly available tools for identifying location-specific climate information (USAID 2017a).[7] From there, project teams can begin to evaluate the likely impacts and potential adaptation responses. This section provides tools to support this evaluation.

Identifying Potential Impacts

The decision trees below can guide project teams in identifying potential climate vulnerabilities of projects involving thermal power (Figure 2), hydroelectric power (Figure 3), solar and wind power (Figure 4), and transmission and distribution (Figure 5). For example, if the Aware tool flags drought as a key risk area for a proposed thermal power plant project, the project team would see that water scarcity could restrict the plant's access to cooling water, which could jeopardize the continued operation of any plant using a wet cooling system (see Figure 2).

However, project teams must be aware of several important caveats in using the decision trees. First, the trees provide a generalized overview of potential impacts, but climate change is likely to affect different types of projects across different regions in diverse and highly context-specific ways. Second, the different climate drivers cannot be viewed in isolation. Instead, project teams must consider how the various drivers interact with each other. Some climate drivers may amplify one another, while others counteract one another. At the same time, a variety of nonclimate factors, such as population growth, land-use change, economic development, and urbanization, could pose significant challenges to the energy sector (USAID 2014). In many instances, these nonclimate stressors interact with climate stressors in similarly complex ways (USAID 2014).

Third, the decision trees focus primarily on the potential physical impacts of climate change, but climate change could affect the energy sector in diverse ways, including direct and indirect physical impacts and a variety of nonphysical impacts. Potential nonphysical impacts include market, legal, and reputational impacts. Climate change could cause shifts in demand. For instance, rising temperatures and extreme heat could prompt increased electricity demand for cooling (Ebinger and Vergara 2011). Changing conditions could also lead to revised regulatory requirements. Because nonphysical impacts tend to be context- and project-specific, they are not the focus below. The precise legal impacts, for example, will depend entirely on the legal and regulatory framework in the project country or the specific contractual arrangements underlying a project. That said, upon identifying potential physical project vulnerabilities, project teams should consider whether such vulnerabilities could have follow-on, nonphysical consequences for a particular project.

Identifying Adaptation Options

Once a project team determines potential project vulnerabilities, it can proceed to identifying possible adaptation solutions. An important preliminary step is defining the objective of adaptation. In setting objectives, project teams should consider what vulnerabilities they seek to address and what their desired outcomes are. Seeking input from relevant stakeholders for this stage and throughout the process will improve the likelihood that the ultimate adaptation decisions are deemed successful (UK Climate Impacts Programme 2007).

Ideally, the objective would include specific timelines and measurable thresholds for what would and would not be considered successful adaptation. For example, the objective could be to achieve a certain level of flood protection (e.g., protect facility from physical damage

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FIGURE 2: DECISION TREE FOR THERMAL POWER PROJEC

CLIMATE HAZARD

Increasing precipitation or frequency of extreme precipitation events

Sea-level rise and storm surge

SYSTEM IMPACTS

High winds, associated with storms

Increased flood risk and water turbidity

Saltwater intrusion of coastal aquifers/ surface water

Increased electricity demand for cooling

Higher temperatures; more frequent & intense heat waves

PROJECT VULNERABILITIES

Potential damage to infrastructure; disruption of operations; inability to access plant; increased maintenance cost

Plants that provide peak power may struggle to produce adequate power to meet peak summer demand

Decreased efficiency of thermal conversion; reduced output

ADAPTATION OPTIONS

- ✓Incorporate climate change into site assessment; avoid siting new plants in high-risk areas
- ✓Adopt design standards that account for projected increased flood risk or wind loading
- ✓Incorporate flood protection measures, including built and/or green infrastructure, into plant design to protect key infrastructure
- ✓Install waterproofing features (e.g., concrete moat walls, floodgates and watertight doors, sluice gates, reinforced walls, submersible pumps, etc.)
- ✓Relocate or elevate critical equipment
- ✓Reinforce elevated structures (e.g., cooling towers, water towers, smokestacks, etc.) to withstand greater wind loading
- ✓Develop alternative fuel delivery options and improve protection for fuel storage
- ✓Improve emergency management plans and performance monitoring systems (including real-time monitoring and early warning systems)
- ✓Install filtering system to reduce turbidity and remove suspended solids

- ✓Install additional generation capacity
- ✓Diversify energy sources
- ✓Promote demand-management and end-use energy efficiency measures

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Temperature increase	Decreasing precipitation and drought	Increasing variability in precipitation patterns

Higher water temperature	Increased surface evaporation	Increased demand for competing water uses	Reduced snowpack/ earlier snow melt alter runoff patterns	Reduced runoff and surface water resources	Increasing variability in runoff and flow rates

Plants with wet cooling systems: Reduced efficiency of cooling system; potential curtailment or shutdown if water temperature exceeds technical specifications	*Plants with wet cooling systems:* Decreased cooling water availability could disrupt operations, particularly for plants with once-through cooling systems	*Plants with wet cooling systems:* Decreased reliability of cooling water supply complicates operational management, particularly for plants with once-through cooling systems

✓Site new plants in cooler areas, if possible
✓Add or improve cooling and ventilation equipment to improve system performance
✓Maximize efficiency in transmission and distribution *(see transmission and distribution decision tree)*

✓Incorporate climate change into site assessment; avoid siting new plants in water-stressed areas
✓Install water-saving cooling technology (closed-loop, hybrid wet-dry, or dry cooling), if possible
✓Install water treatment system so that plant can use saline water for cooling purposes
✓Install equipment capable of using alternate water sources (e.g., brackish groundwater, municipal wastewater) for cooling
✓Secure back-up water supply
✓Install monitoring systems on source water supplies and develop operating procedures for low water conditions
✓Account for changes in water levels and temperatures in design and placement of cooling water intake and outflow system channels and pipes
✓Ensure proper design of water intake and discharge systems
✓Promote demand-management and end-use energy efficiency measures
✓Diversify energy sources (supplement with technologies that are less dependent on water)
✓Support water-use efficiency and demand-side management in other water uses, such as agriculture

FIGURE 3: DECISION TREE FOR HYDROELECTRIC POWER I

CLIMATE HAZARD

- **Increasing variability in precipitation patterns**
- **Temperature increase**

SYSTEM IMPACTS

- Increasing variability in runoff and flow rates
- Increased electricity demand for cooling
- Higher rates of glacial melt may increase near-term runoff and decrease long-term runoff
- Reduced snowpack and earlier snow melt alter runoff patterns

PROJECT VULNERABILITIES

- Increased variability and reduced reliability of output (particularly for run-of-river hydropower plant)
- Plants that provide peak power may struggle to produce adequate power to meet peak summer demand
- Potential increase in near-term generation, decrease in long-term generation (in glacial-fed rivers)

ADAPTATION OPTIONS

✓Install additional generation capacity
✓Diversify energy sources
✓Promote demand-management and end-use energy efficiency measures

✓Select turbines and other equipment that perform well over a range of flows (e.g., install multiple turbines in varying sizes to allow operation over a wide range of flows)
✓Increase dam height to accommodate near-term or seasonal increases in runoff

✓Site new hydropower plants based on projected changes in flow regime
✓Develop integrated water management plans that account for changing climate conditions/ water availability
✓Support water-use efficiency and demand-side management in other water uses, such as agriculture
✓Diversify energy sources (supplement hydropower generation with technologies that are less water dependent)
✓Modify the number and type of turbines that are most suited for expected water flow rates; upgrade turbine runners to increase ability to operate in lower-capacity conditions
✓Increase water storage capacity to capture more water during wetter periods

PROJECTS

Decreasing precipitation and drought

Increasing precipitation or frequency of extreme precipitation events

Increased surface evaporation

Increased demand for competing water uses

Reduced runoff, lower surface water levels, and increased water scarcity

Increased sedimentation from upstream erosion and deposition

Increased runoff; increased surface water flows

Increased flood risk

Potential decline in summer production as earlier snowmelt shifts peak production earlier in the year

Less water available for generation; reduced output and operational flexibility

More rapid siltation of reservoirs and deterioration of turbines, resulting in lower output

More water available for generation; increased output and operational flexibility

Potential damage to infrastructure; service disruption; and increased likelihood of emergency releases causing downstream flooding

✓Implement erosion control measures (e.g., slope stabilization, planting vegetation, or installing drainage pipes in hillsides) to reduce siltation
✓Implement system of regular inspection and maintenance to attend to possible increase in wear and tear on turbines
✓Employ sediment expulsion technology
✓Install controllable spillway gates to flush silted reservoirs
✓Modify the number and type of turbines to better suit expected increase in suspended sediment loads

✓Incorporate climate change into site assessment; avoid siting new plants in high-risk areas
✓Adopt design standards that account for projected increase in peak flows
✓Design more robust dams and infrastructure for heavier flooding and extreme events
✓Incorporate flood protection measures, including built and/or green infrastructure, into plant design to protect key infrastructure (intake structure, power house, etc.)
✓Increase dam height and/or build small dams upstream to capture increased peak flows
✓Modify existing spillways to increase discharge capacity
✓Develop flood-management plans and improve flood risk and plant performance monitoring systems (including real-time monitoring and early warning systems)

FIGURE 4: DECISION TREE FOR SOLAR AND WIND POWER

CLIMATE HAZARD

Decreasing precipitation and drought

Temperature increase

SYSTEM IMPACTS

Reduced runoff; lower water levels in rivers and lakes

Increased evaporation; reduced snowpack or earlier snowmelt

Higher average temperature; increased frequency and intensity of heat waves

PROJECT VULNERABILITIES

Decreased cooling water availability for concentrated solar power systems with water cooling

Reduced efficiency of solar cells and concentrated solar power systems with water cooling

Altered wind power potential; increased variability in wind patterns challenges accurate prediction of output and financial viability

ADAPTATION OPTIONS

- ✓Avoid siting new CSP with water cooling in water-scarce areas
- ✓Install water-saving cooling technology (closed-loop, hybrid wet-dry, or dry cooling)
- ✓Use alternative water sources (e.g., brackish groundwater, municipal wastewater)
- ✓Consider changing water levels/ temperatures in design and placement of cooling water intake and outflow system channels and pipes
- ✓Install monitoring systems on source water supplies; develop operating procedures for low water conditions
- ✓Diversify energy sources (supplement with technologies that are less water dependent)

- ✓Site systems in cooler areas, where possible
- ✓Choose photovoltaic modules with more heat-resistant photovoltaic cells and module materials designed to withstand high temperature peaks
- ✓Add or improve cooling and ventilation; adopt designs that enhance passive airflow beneath mounting structure or use active cooling systems

- ✓Incorporate expected changes in wind speeds into site assessment
- ✓Improve reliability of expected output with better climate modeling
- ✓Use smart grid technologies to ensure system reliability despite potential variability in renewable resources

PROJECTS

Increasing precipitation or frequency of extreme precipitation events

Sea-level rise and storm surge

- Potential changes in distribution, average speed, variability, and timing of winds
- Higher temperatures and relative humidity may increase cloud cover in some areas
- More frequent rain increases cloud cover and reduces solar radiation
- Extreme winds associated with storms
- Increased wave height or force associated with storms and hurricanes
- Increased flood risk/ coastal inundation

- Reduced solar energy output, particularly for concentrated solar power systems, which cannot use diffuse light
- Deposition of dust/sand on or damage to solar systems; reduced efficiency; increased maintenance costs
- Damage to or shutdown of wind turbines; reduced output; increased maintenance costs
- Damage to offshore turbines, foundation instability, or cable exposure; increased maintenance costs
- Damage to turbine foundations; saltwater corrosion in coastal areas; increased maintenance costs

✓Account for projected changes in cloud cover in site assessment
✓Use photovoltaic technologies that best capture diffuse light (e.g., panels with rougher surfaces)
✓Optimize fixed mounting angle or apply tracking system to adjust angle for diffuse light conditions
✓Install or increase storage capacity
✓Use smart grid technologies to ensure system reliability despite potential variability in renewable resources

Wind & Solar
✓Incorporate climate change into site assessment; avoid siting projects in excessively risky areas within pipes
✓Develop emergency response plans
✓Ensure presence of rapid emergency repair teams to repair damaged turbines quickly
✓Insure against impacts of storms on infrastructure and on long-term yield
✓Conduct regular inspection and maintenance to ensure equipment integrity

Wind
✓Design turbines that can operate at and physically withstand higher wind speed and increases in wind-sea force
✓Use lidar-based protective technology
✓Design turbine foundations to withstand increased flooding and erosion
✓Use corrosion-resistant component materials

Solar
✓Design systems to withstand high or fluctuating winds
✓Ensure tracking units and raised mounting structures are sufficiently robust

FIGURE 5: DECISION TREE FOR TRANSMISSION AND DIST

CLIMATE HAZARD

Temperature increas

Decreasing precipitation and drought

SYSTEM IMPACTS

Higher average temperature; increased frequency and intensity of heat waves

Increased electricity demand for cooling

Increased fire risk

PROJECT VULNERABILITIES

Increased resistance lowers line carrying capacity and increases system transmission

Lines expand and sag posing potential safety hazard and increasing chance of outages

Increased electricity demand for cooling could strain capacity, decreasing system reliability

ADAPTATION OPTIONS

- ✓Site substations and transformers in cooler locations, where possible
- ✓Consider underground distribution systems
- ✓Employ shading and more effective cooling systems for substations and transformers
- ✓Replace old equipment with equipment that has a higher thermal rating
- ✓Reduce distance between transmission towers and increase tower heights
- ✓Increase tension in the line to reduce sag
- ✓Install smart grid devices to speed identification of faults and service restoration

- ✓Install additional transmission capacity
- ✓Employ demand-management measures
- ✓Employ smart grid technologies to increase efficiency and reduce peak loads

- ✓Increase vegetation management efforts (tree trimming, forest thinning, prescribed burning)
- ✓Site equipment in areas less prone to wildfires
- ✓Replace wood poles and support structures with fire-resistant materials (steel or concrete)
- ✓Use covered or insulated conductors on overhead lines to reduce risk of ignition if trees contact overhead lines

Sources (Figures 2-5): ADB 2012; ADB 2013; Cox 2016; Cox 2017; Davis and Clemmer 2014; Gundlach and Webb 2018; Nierop 2013; Patt, et al. 2013; Pryc

RIBUTION PROJECTS

Increasing precipitation or frequency of extreme weather events

Sea-level rise and storm surge

High winds, associated with storms/ hurricanes

Increased erosion, land movement, and mudflows

Increased flood risk

Damage to equipment, including wooden poles, conductors, and insulators

Storm- and fire-related grid outages increase repair costs and disrupt economic activity, critical services, and recovery efforts

Damage to overhead lines, utility poles, and transmission towers

Damage to tower structures and equipment mounted at ground level in substations

- ✓Develop island-able microgrids and back-up generators to keep certain loads operational during outages
- ✓Install smart grid devices to speed identification of faults and service restoration
- ✓Increase redundancies in system; increase flexibility and ability to reroute during outages
- ✓Use of distributed generation systems, which can reduce need for large facilities in high-risk areas
- ✓Increase emergency management and response planning
- ✓Utilize mobile transformers and substations

- ✓Avoid locating equipment in high-risk areas
- ✓Relocate and/or elevate critical equipment
- ✓Conduct regular inspection and maintenance to ensure equipment integrity
- ✓Increase flood protections, including built and green infrastructure, near substations
- ✓Increase coastal protections, including sea walls and naturally-occurring protections, like sand dunes and wetlands
- ✓Install water-level monitoring systems and communications equipment inside vulnerable substations
- ✓Install equipment that is submersible and resistant to corrosion by salt water
- ✓Implement erosion control and slope stabilization measures
- ✓Design equipment to withstand maximum expected wind loading
- ✓Reinforce towers and poles
- ✓Trim trees near power lines to prevent damage from high winds
- ✓Consider underground distribution systems

r and Barthelmie 2010; Schaeffer, et al. 2012; Stuart 2018; USAID 2017b; Hellmuth, et al. 2017; Zamuda, et al. 2013; Zamuda, et al. 2015.

The project team would first identify the appropriate criteria for the given project. Possible criteria include the following (USAID 2015; European Commission 2013; Weiland and Troltzsch 2015):

- Functional effectiveness
  - » Does the adaptation measure accomplish the desired outcome?
  - » Does it do so within an acceptable timeframe?
- Technical feasibility
  - » Is the measure technically feasible in the project location?
- Affordability
  - » Are upfront costs of the measure affordable?
  - » Are operations and maintenance costs of the measure affordable?
- Stakeholder acceptability
  - » Does the measure have cultural, economic, or environmental effects that could influence stakeholder or community acceptance?
- Ease of implementation
  - » Are there factors (e.g., those related to human capital, availability of materials, or existing technical skills) that may impede implementation?
- Flexibility/Robustness
  - » How effective will the measure be in the face of uncertain future conditions?
- Sustainability
  - » Does the measure have lasting impact?
  - » Are the operations and maintenance costs of the measure sustainable?
- Cobenefits
  - » Does the measure support other climate-related (e.g., carbon sequestration) or development objectives (e.g., economic security, private sector development, institutional strengthening)?

The project team would then agree on a scale or metric for each criterion. In some cases, quantitative metrics, like cost, may be available. In others, qualitative metrics can be translated into a numerical form (e.g., on a 1 to 5 scale) (USAID 2013; Van Ierland et al. 2013). Project teams could also attach different weights to different criteria to reflect relative importance (USAID 2013).

Next, the project team would score projects, incorporating the different adaptation alternatives against each of the criteria. As described above, the performance of different options will depend on projected climate conditions. For example, evaluating the functional effectiveness of a planned shoreline protection measure would require sea-level-rise projections for the lifetime of the project.

Finally, the project team would compare the weight-adjusted scores of the various alternatives (UNFCCC 2011). The project team could use the outcome to produce a short list of preferred options that perform best against the selected criteria.

Box 1 | Soft Adaptation Options

Soft adaptation encompasses management, operational or policy changes, and capacity-building and knowledge-management activities. Many soft adaptation measures are not specific to a particular subsector or category of project and, instead, are sensible across a wide range of projects. For example, improved data collection and forecasting capabilities, climate information services, and early warning systems may be critical to the success of projects in any of the subsectors this note covers.

Other examples of soft adaptation measures include **policy measures**, such as modifying design standards for transmission and distribution infrastructure to increase resilience; **capacity-building efforts**, like training on or demonstrations of end-use energy efficiency measures; and **institutional changes** to support mainstreaming consideration of climate change into development and sector strategies.

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Detailed Economic Assessment

The remaining options can then be evaluated in greater detail using a quantitative economic assessment. Two possible techniques for economic assessment of adaptation options are cost-benefit analysis and cost-effectiveness analysis (GIZ 2013; UNFCCC 2011).

- *Cost-benefit analysis*

Cost-benefit analysis (CBA) involves quantifying (in present-value terms) and comparing the costs and benefits of an adaptation investment to determine its likely efficiency (UNFCCC 2011). CBA is generally the preferred technique, so long as all costs and benefits of adaptation can be expressed in monetary terms (GIZ 2013). Adaptation costs include direct costs, like initial investment and operating costs, as well as any indirect costs, like transitional costs or social welfare losses (UNFCCC 2011).

Adaptation benefits include benefits accrued and losses avoided as a result of an adaptation measure (IPCC 2007). As such, adaptation benefits are assessed relative to a project baseline (i.e., the project without adaptation).[11] The appropriate project baseline and net benefits of different adaptation options relative to that baseline are ultimately dependent on future climate conditions. Project teams first assess the costs and benefits of the project baseline under projected climate conditions. Where multiple future scenarios are plausible, there would be multiple baselines (European Commission 2013). They then assess the net benefits of various adaptation alternatives relative to the baseline(s).

Adaptation projects often involve impacts on things like public health, environmental quality, or cultural heritage. These sorts of nonmarket costs and benefits are difficult to quantify but should not be excluded from any economic analysis conducted. Instead, techniques like contingent valuation should be used to estimate nonmarket costs and benefits, where possible (UNFCCC 2011). Contingent valuation uses the stated preferences of impacted individuals to estimate the economic value of nonmarket goods, like ecosystem services. For example, contingent valuation could be used to estimate the monetary value of an artificial wetland's benefit to water quality by asking impacted individuals how much they would be willing to pay for an equivalent water quality improvement.

Having quantified all costs and benefits, project teams discount them to present value and aggregate them to compute the net present value (NPV) of each alternative. The NPVs of different adaptation options can then be compared to identify the most suitable option or options.

- *Cost-effectiveness analysis*

Cost-effectiveness analysis identifies the least cost option or set of options for achieving adaptation objectives (UNFCCC 2011). It can be applied when adaptation benefits are difficult to quantify and express in monetary terms.[12] Cost-effectiveness analysis may also be appropriate in situations where the issue is not whether to adopt adaptation measures, but rather, how to achieve a certain level of adaptation in the most cost-effective way.

Like cost-benefit analysis, this technique requires planners to quantify (in monetary terms) the various costs of adaptation options. Project teams quantify all costs, discount them to present value, and aggregate them. Rather than quantifying project benefits in monetary terms, project teams quantify them in physical terms (Watkiss et al. 2013). The unit of measurement depends on the adaptation objective. Project teams can then compare different options in terms of their cost effectiveness, measured as cost per unit of benefit delivered.

Incorporating Uncertainty into Adaptation Decision-Making

Traditional economic assessment techniques, like those described above, assume an ability to confidently predict future climate conditions or at least attach probabilities to possible future scenarios. In reality, there is considerable uncertainty about the speed, direction, and magnitude of future climate changes in many regions, particularly on the scale relevant to a specific project (Ranger et al. 2013). Uncertainty has countless sources, including uncertainty about emissions trajectory and uncertainty stemming from climate models and efforts to downscale model projections to regional or local levels, particularly in areas with complex topography (ADB 2015). Questions surrounding future socioeconomic development, population growth, and other nonclimate stressors only add to this uncertainty.

The presence of uncertainty does not invalidate techniques like cost-benefit analysis or cost-effectiveness analysis, but decision-makers must take uncertainty into account, and doing so might require them to alter their decision-making approach. Traditional decision-making processes predict future conditions and design projects that perform optimally under those conditions. Alternatively, if multiple future states are possible, probabilities of occurrence can be attached to the different future states, and projects can then be designed to maximize expected NPV. As uncertainty increases, however, this sort of "predict-then-act" approach becomes less applicable (Hallegatte et al. 2012).

Rather than using economic assessments to identify the optimal solution for a single, best-guess projection, decision-making under uncertainty is focused on increasing the robustness of a project—that is, the project's ability to fulfill its intended objective across a range of plausible futures (Hallegatte et al. 2012). Certain simple strategies exist for adding robustness to traditional decision-making processes (Ray and Brown 2015).

- *Incorporating safety margins into adaptation planning* (Hallegatte et al. 2012). Where the marginal cost is low, incorporating safety margins into adaptation planning is a practical way to deal with uncertainty over future conditions. Increasing the height of a planned sea wall to hedge against the worst-case scenario is an example of a safety margin strategy (Ray and Brown 2015). Factors such as incremental cost, consequences of system failure, and life span of the asset would all inform the size of any safety margin incorporated into a project (Ray and Brown 2015). This sort of conservative approach is especially important when the adaptation measure under consideration is irreversible (Hallegatte et al. 2012).
- *Stress testing the outcomes of economic assessments using sensitivity analysis* (Penning-Rowsell et al. 2013). Sensitivity analysis tests how changes in key parameters impact project performance (Ray and Brown 2015; Penning-Rowsell et al. 2013). In particular, project teams can test the sensitivity of the project's NPV to changes in uncertain variables, such as rainfall projections (ADB 2015). While a practical tool for exploring the possible impacts of uncertainty on project performance, sensitivity analysis is subjective, relying on judgment rather than empirical evidence, and as such, is of limited usefulness in the presence of substantial uncertainty (ADB 2015).
- *Identifying no-regret and low-regret measures to implement in the near term that will yield benefits regardless of the nature and extent of climate change.* No-regret and low-regret options are beneficial even if climate projections end up being incorrect (Hallegatte et al. 2012). An example is use of weather forecasting and climate information to improve operational management. One way to identify no- or low-regret strategies is to recognize present problems that can be cost-effectively addressed using measures that also reduce longer-term climate vulnerabilities; in fact, addressing current adaptation deficits is often an effective near-term, no-regrets strategy (Hallegatte et al. 2012).

Decision-making under uncertainty also emphasizes flexibility. Because uncertainty will decrease over time, flexible approaches that can be modified or reversed as more information becomes available are preferable (UNFCCC 2011). This includes both structural and planning flexibility. Structural flexibility involves engineering features so that infrastructure can be enhanced in the future if climate impacts are high. Planning flexibility refers to decision-making that is intentionally iterative and designed to be adjusted over time (UNFCCC 2011).

In situations of greater uncertainty (situations involving investments in long-lived infrastructure, for instance), project teams may need to turn to new, more complex methodologies specifically designed to support decision-making in the context of uncertainty. These include robust decision-making (Lempert et al. 2006; Lempert et al. 2013; Hallegatte et al. 2012; Swart et al. 2013), real options analysis (Swart et al. 2013; Hallegatte et al. 2012; Linquiti and Vonortas 2012), and portfolio analysis (Swart et al. 2013). The details of these methodologies are beyond the scope of this guidance, but briefly, robust decision-making uses sophisticated analytical tools to identify adaptation strategies that perform well over a wide range of possible future climates (Ray and Brown 2015). Real options analysis extends more traditional cost-benefit analysis to explicitly include valuation of the flexibility or adaptability of design options; it can be useful in deciding whether to invest in adaptation immediately or to delay investment (Hallegatte et al. 2012). Portfolio analysis guides the selection of a set of adaptation options (rather than a single option) that together perform well across a range of plausible future climates (Hunt and Watkiss 2013).

6. Case Studies

The following case studies provide illustrative examples of how the above processes might look in practice. The first introduces a European Bank for Reconstruction and Development (EBRD) and Pilot Program for Climate Resilience (PPCR) project in Tajikistan, where detailed climate and hydrological modeling was used to assess climate impacts on a hydropower plant and to design appropriate risk-reduction measures for that plant. The second describes a thermal power plant project in Bangladesh, and the Asian Development Bank's (ADB) process of assessing project vulnerabilities and adaptation options.

Enhancing the Climate Resilience of Tajikistan's Energy Sector

In 2014, the EBRD, together with the PPCR, approved funding for a project entitled Tajikistan: Enhancing the Climate Resilience of the Energy Sector (PPCR 2013). As part of this project, EBRD undertook the first phase of a program to rehabilitate and upgrade the Kairakkum hydropower plant on the Syr Darya River. The 126 megawatt (MW) hydropower plant is the only major energy generation facility in northern Tajikistan, where it serves 500,000 households. Constructed in the 1950s, it consists of an earthfill dam and a combined powerhouse and spillway structure (EBRD 2015).

Over 90 percent of Tajikistan's power comes from hydropower, and climate change could have significant implications for future hydropower generation capacity, as well as peak supply and demand management. Since 1950, Tajikistan has experienced a 1.2°C increase in average temperatures, with the most rapid warming occurring in winter months. Total rainfall has dropped by about 20 percent since 1950 (EBRD 2015). Climate projections for Tajikistan indicate that temperatures will continue to rise, and overall precipitation will continue to fall (ADB 2017b). Climate projections also suggest that extreme weather events, including floods, droughts, and storms will occur with greater frequency (ADB 2017b).

Higher winter temperatures mean that a smaller proportion of total precipitation has fallen as snow in recent years. The country has also seen a significant increase in the rate of glacial retreat and thinning across a number of river basins. These trends, which are likely to continue, have the potential to increase water supply runoff and snowmelt in the near to medium term, while sharply reducing water supply in the longer term (ADB 2017b). Moreover, climate projections suggest that the hydrologic cycle will become increasingly variable. This variability could affect future river flows and long-term water availability for hydropower production. Increasingly frequent extreme weather events, including floods and drought, will complicate peak supply and demand management and could jeopardize dam safety.

To better understand the potential vulnerably, EBRD oversaw an in-depth analysis of the implications for climate change for hydropower production in Tajikistan (Wilby et al. 2011). It used this analysis as the basis for designing upgrades to the Kairakkum hydropower plant.

For the vulnerability assessment, experts sought to quantify water flows into the Kairakkum reservoir for the period from 2007 to 2100. Reservoir inflows depend on runoff patterns in the upstream catchment area, which depend on glacier and snowmelt dynamics and future precipitation, all of which may be affected by climate change. As such, quantifying projected inflows required detailed climate and hydrological modeling. Experts applied four climate scenarios (hot-dry scenario, central scenario, warm-wet scenario, without-climate scenario) to three different hydrological models to develop a set of scenarios of future water inflows into the Kairakkum reservoir (EBRD 2015). The resulting scenarios, which varied widely, represented the range of possible conditions the hydropower plant may confront in the future (EBRD 2015).

Experts then set out to identify robust options for the plant's rehabilitation that would ensure efficiency and safety across all possible scenarios. They identified a number of potential turbine upgrades, as well as operational changes, and modeled energy production with the different upgrades across the various scenarios. They identified the upgrade option that performed best across the entire range of scenarios. The selected option involved replacing all six turbines with highly efficient 29 MW turbines, which would increase capacity by nearly 40 percent (EBRD 2015). The water inflow scenarios were also used to inform modeling of the probable maximum flooding in the reservoir to help identify improved dam safety measures, including rehabilitating the plant's embankment dam and installing new monitoring and safety instrumentation (PPCR 2013).

Tajikistan currently experiences significant energy deficits, and energy demand is likely to grow in the future (ADB 2014a). At the same time, only about 10 percent of Tajikistan's total hydropower potential has been developed (ADB 2014a). Under these circumstances, hydropower represents a substantial opportunity in Tajikistan, so long as it can be developed in a climate-resilient and sustainable manner. Thus, for Tajikistan's energy sector to be climate-resilient, it must build capacity to monitor, analyze, and forecast climate change data; assess and quantify risks; and develop appropriate adaptation strategies.

By conducting a detailed vulnerability assessment and using it as the basis for designing upgrades to the Kairakkum hydropower plant—and by doing so in close consultation with local energy sector institutions—the project demonstrated a process of integrating climate considerations into energy sector investments that can be replicated throughout the country. The project also included an array of activities to build the capacity of energy sector institutions to mainstream climate considerations into energy sector planning and hydropower operations (PPCR 2013). For example, the project provided training to Tajikistan's hydromet staff and to its state-owned power utility on seasonal forecasting and climate risk assessment (EBRD 2015).

Climate Vulnerability and Adaptation for a Gas-Fired Thermal Power Plant in Bangladesh

With cofinancing from the Islamic Development Bank and the Japan Fund for Poverty Reduction, the ADB is currently implementing the Rupsha 800-Megawatt Combined Cycle Power Plant Project (ADB 2018d). The project will construct an 800 MW gas-fired combined cycle power plant in Khulna City, in southwestern Bangladesh, as well as power transmission and interconnection facilities to deliver power from the new plant to the existing Khulna substation (ADB 2018d).

Vulnerability Assessment

After initial climate risk screening determined that the proposed project faced significant climate risk, the project team conducted a comprehensive climate change risk vulnerability assessment (ADB 2018b). The assessment detailed observed and projected climate changes and evaluated how those changes could affect the proposed project.

- Rising temperatures

Annual average temperature in Bangladesh has increased by about 0.3°C since 1900, and average temperatures are projected to increase by an additional 2.4°C by 2100 (ADB 2018b). Higher temperatures, including more frequent and severe heat waves, could lower the thermal efficiency and generating capacity of the proposed plant. The plant is designed to operate optimally at an ambient temperature of 15°C, and in its economic analysis of adaptation options, the project team assumed that each 1°C increase in air temperature over this optimal temperature would reduce generation capacity by 0.45 percent per year (ADB 2018c). Similarly, increases in water temperature could decrease plant efficiency.

Higher temperatures could also affect the proposed transmission infrastructure. Higher temperatures could increase transmission system losses and decrease the current carrying capacity of power lines. Increasing temperatures can also cause power lines to expand and sag, which reduces the amount of power that can be safely transported (ADB 2018b).

- Changing rainfall patterns and drought

The assessment also detailed changes in rainfall amounts and seasonal patterns. It found that annual rainfall across Bangladesh has decreased by 2 to 3 percent since 1900, with most of the reduction occurring during the winter months. In the future, modeling suggests rainfall will increase during the monsoon season and decrease during the winter months. Additionally, Bangladesh already suffers from periods of drought, and the assessment found that drought will likely become more frequent in the future (ADB 2018b).

Changes in seasonal rainfall patterns could contribute to lower river flows and limited water availability during the dry season. Plant operations will rely on cooling water from the Bhairab River (ADB 2018b). Insufficient cooling water during the dry winter months or during periods of drought could disrupt plant operations, forcing curtailment or temporary shutdown.

- Sea-level rise and extreme weather events

Sea levels are projected to rise by 0.8 to 1.5 meters in Bangladesh by 2100 (ADB 2018b). As sea levels continue to rise, salt water could infiltrate coastal aquifers and surface waters, including the Bhairab River, which could also disrupt plant operations if the plant is not equipped to use saline cooling water.

Bangladesh is already vulnerable to extreme weather events, including tropical cyclones and flooding, and the frequency and magnitude of extreme weather events is likely to increase with climate change. Tropical cyclones and flooding could damage critical power plant equipment, including cooling equipment, control instruments, and back-up generators, and disrupt operations. Increasingly severe storms, together with sea-level rise, will also exacerbate riverbank and coastal erosion, which would further threaten the project site.

Adaptation Measures

Based on this assessment, the project team identified various options to improve the resilience of the Rupsha project. Some key adaptation measures are detailed below:

- Project design will take rising temperatures and heat waves into account in various ways. For example, the transmission line will use a low sag aluminum conductor composite core to improve efficiency in high temperatures. Additionally, the project will develop best operating practices for power plant equipment at high temperatures (ADB 2018b).
- To manage risks related to cooling water availability, the project will install a closed-loop cooling tower[13], which requires significantly less water withdrawal than a once-through system (ADB 2018c).
- Also related to cooling water availability, the project will include a demineralized water treatment system so that it can use saline water for cooling purposes (ADB 2018c).
- The project will incorporate both structural and nonstructural measures to reduce risks associated with extreme weather events, including tropical cyclones and flooding. It will elevate the power plant site by 2.55 meters above the current average flood level to buffer against increasing future flood risk (ADB 2018b). It will also protect against river-based flooding using levees, flood control structures, and riparian buffer planting. Nonstructural measures include preparation of emergency response plans and early warning systems (ADB 2018a).

The project team conducted an economic analysis of adaptation options. Focusing on the most significant climate vulnerabilities, the analysis quantified reductions in power output and losses in net efficiency expected over the project life, based on projected climate conditions. It concluded that without any adaptation measures, climate change would reduce the net present value of the project by over US$300 million (ADB 2018c). The analysis computed any capital and increased operational costs associated with different adaptation measures and calculated their net benefits.

The selected adaptation measures cost approximately US$38 million (in present value terms) and were found to have a net benefit of approximately US$90 million (ADB 2018c). These measures would not, however, eliminate climate risk entirely. In many instances, eliminating the cost of climate change to a project may not be cost effective or technically feasible. Where residual damage is high, it may make sense to consider alternative approaches to achieving the project objective.

Appendix I: Glossary

Adaptation. The process of adjustment to actual or expected climate change and its effects. In human systems, adaptation seeks to moderate or avoid harm or exploit beneficial opportunities. In some natural systems, human intervention may facilitate adjustment to expected climate change and its effects.

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.

Climate change. Climate change refers to a change in the state of the climate that can be identified (for example, via 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.

Exposure. The presence of people, livelihoods, species or ecosystems, environmental functions, services, and resources, infrastructure, or economic, social, or cultural assets in places and settings 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. 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. Impacts are also referred to as consequences and outcomes.

Projection. A projection is a potential future evolution of a quantity or set of quantities, often computed with the aid of a model. Unlike predictions, projections are conditional on assumptions concerning, for example, future socioeconomic and technological developments that may or may not be realized.

Resilience. The capacity of social, economic, and environmental systems to cope with a hazardous event or trend or disturbance, responding or reorganizing in ways that maintain their 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.

Risk management. Plans, actions, or policies to reduce the likelihood and/or consequences of risks or to respond to consequences.

Sensitivity. The degree to which a system or species is affected, either adversely or beneficially, by climate variability or change. The effect may be direct (e.g., a change in crop yield in response to a change in the mean, range, or variability of temperature) or indirect (e.g., damages caused by an increase in the frequency of coastal flooding due to sea-level rise).

Uncertainty. A state of incomplete knowledge that can result from a lack of information or from disagreement about what is known or even knowable. It may have many types of sources, from imprecision in the data to ambiguously defined concepts or terminology, or uncertain projections of human behavior.

Vulnerability. The propensity or predisposition to be adversely affected. Vulnerability encompasses a variety of concepts and elements including sensitivity or susceptibility to harm and lack of capacity to cope and adapt.[14]

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Endnotes

1. For additional information on IsDB's operations, see https://www.isdb.org/where-we-work.
2. The extent of hydropower plant vulnerability depends on plant type and characteristics. Two key types of hydropower plants are run-of-river and storage plants. Run-of-river plants use the available river flow for energy generation without impounding any significant volume of water upstream. Storage hydropower plants include a reservoir upstream of the dam to store water for later use. Run-of-river plants are more vulnerable than storage plants to changes in flow volume and timing. The size of a storage plant's reservoir will dictate the extent to which it can buffer against fluctuations in flow.
3. See Appendix 1 for a glossary of key terms used in Figure 1 and throughout the guidance note.
4. For more information on the Acclimatise Aware tool, see http://www.acclimatise.uk.com/analytics/applications/.
5. For more information on the World Bank Climate Change Knowledge Portal, see http://sdwebx.worldbank.org/climateportal/index.cfm.
6. For more information on The Nature Conservancy's Climate Wizard, see http://www.climatewizard.org/.
7. USAID (2017a) also includes references to a variety of information sources, including various portals and web pages that provide climate data and related information.
8. See e.g., GIZ (2014), European Commission (2013), and USAID(2015).
9. The proposed approach draws on European Commission (2013) and USAID (2015).
10. For more information on the IPCC Data Distribution Centre, see http://www.ipcc-data.org/index.html.
11. ECONADAPT Toolbox: Cost-Benefit Analysis, https://econadapt-toolbox.eu/node/12.
12. ECONADAPT Toolbox: Cost-Effectiveness Analysis, https://econadapt-toolbox.eu/cost-effectiveness-analysis.
13. There are three basic types of cooling systems: once-through, closed-cycle, and dry-cooling. Once-through systems withdraw water from nearby water sources, circulate it through a condenser to absorb heat from the boiler steam, and then discharge the water back into the original source. These systems withdraw large volumes of water. Closed-cycle (or wet-recirculating) systems reuse cooling water. Rather than immediately discharging water back into the original source, closed-cycle systems divert water from the condenser to cooling towers, where the heat it absorbed dissipates through evaporation. The remaining water is then recirculated through the condensers. These systems withdraw significantly less water than once-through systems. Dry-cooling systems use air instead of water to absorb heat from steam. They use almost no water, but they are more expensive and less efficient than the other two. (Union of Concerned Scientists, available at https://www.ucsusa.org/clean-energy/energy-and-water-use/water-energy-electricity-cooling-power-plant#bf-toc-1.)
14. All definitions in Appendix 1 taken from IPCC 2014, 1–32.