CLIMATE RESILIENCE AND ADAPTATION

iha
international hydropower association

BRIEFING

MODERNISATION OF HYDROPOWER FACILITIES: CLIMATE RESILIENCE CASE STUDIES

With growing populations and livelihoods, managing freshwater will be one of the major tasks for society in the foreseeable future. Infrastructure including hydropower facilities will play an increasing role in multipurpose freshwater management.

Hydropower operations are designed around climatic conditions, and therefore exposed to climate-change risks. Climate change has the potential to impact the hydro sector through regional changes in rainfall and water availability, protracted drought events, significant variation in historical temperature regimes, and more frequent and severe weather events, potentially leading to natural disasters.

These risks deserve close attention from operators, regulatory bodies including hydrological and meteorological agencies, and financial institutions. Operators and planners need to develop ways of understanding and anticipating increasing climatic and hydrological variability in order to ensure that existing and future facilities are designed or enhanced to be resilient to a much more variable climate. Partnerships are needed between operators and hydrological/meteorological agencies so that climatic change projections can be used to build a more resilient basis for decision-making for planning, design and operational management, instead of relying solely on historic hydro-meteorological records. This may include, for example, the revision of dam safety criteria, greater operational flexibility and adjusted/adjustable turbine capacity to accommodate future uncertainty, better hydro-meteorological data management and monitoring, and updated dam operating rules. Financial institutions seek to address climate risk by encouraging projects to be resilient to climate change, while businesses must consider how to incorporate climate risks into project design and operations. While hydro facilities are inherently able to provide adaptive capacity through flood and drought regulation and rapid response to load variation, building in resilience to climate extremes requires a broader discussion.

This briefing describes examples of projects where climate resilience has been incorporated into the modernisation of existing hydropower facilities. These case studies illustrate how organisations worldwide have considered the risks associated with a more variable and extreme climate in the modernisation of their projects. The briefing also outlines the need for the development of industry guidance on best practice in climate risk management in hydropower operations.

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Case study: Qairokkum, Tajikistan

In 2014 the European Bank for Reconstruction and Development (EBRD) agreed to finance the modernisation of the Qairokkum hydropower plant, a 126 MW facility located in northern Tajikistan, owned and managed by Barki Tojik, Tajikistan's state power utility.

Like many other countries, Tajikistan is already experiencing changing climatic conditions; average temperatures are rising, precipitation patterns are changing and glaciers are retreating. Hydropower generates 98% of Tajikistan's electricity, which means that changing conditions could significantly affect Tajikistan's power supply, the population's living standards and the economy as a whole.

This project adopted a highly innovative approach that incorporated climate change considerations both into the investment design and into the development of improved systems for operational decision-making. The first stage of this work entailed detailed modelling analysis on the impacts of climate change on the facility's operations. Projected future hydrologic conditions were modelled under a range of future hydro-climatic scenarios in order to understand the potential variability in reservoir inflow conditions taking into account the influence of climate change.

This analysis identified a significant range of potential variability in average precipitation, ranging from -10% to +20% for 2050 and an even greater range of -15% to +30% for 2080 as seen in the table above. By applying the full range of variation in temperature and precipitation as boundary conditions to a hydrological model, scenarios of future inflows to the Qairokkom reservoir were developed. The resultant scenarios were used as a basis to model Qairokkum's projected energy production and revealed that electricity generation varies significantly depending on the climate change scenario and hydrological model applied.

Climate change scenarios for the Sudg region, based on the IPCC's Fourth Assessment Report

2050s	Temperature	Precipitation
Hot-dry	+4°C	-10%
Central	+3°C	+5%
Warm-wet	+1.5°C	+20%
2080s	**Temperature**	**Precipitation**
Hot-dry	+6°C	-15%
Central	+4°C	+5%
Warm-wet	+2°C	+30%

Technical options for the Qairokum hydropower plant rehabilitation

Scenario 1	Scenario 2	Scenario 3
Scenario 1 envisaged a replacement of all turbines. The new turbines would have the same flow rate (177 m^3 per second), but their efficiency would be much higher. The plant's generation capacity after the rehabilitation would be 174 MW.	Scenario 2 envisaged a replacement of all turbines and the installation of an additional turbine with a generation capacity of 40 MW. This would increase the generation capacity of the rehabilitated power plant to 214 MW.	Scenario 3 envisaged a replacement of four turbines in the same way as proposed in scenario 1. The other two turbines would run until tey could no longer be in service. Thereafter, electricity generation would continue with four turbines – a scenario thought suitable for climate scenarios under which the water flow into Qairokkum's reservoir would decrease over time.

A full spectrum of projected inflow conditions was modelled, allowing an assessment of the plant's ability to generate electricity under a broad range of climate scenarios. This scenario-based approach served as a basis for selecting a robust rehabilitation design across the range of possible projected climate change scenarios. The subsequent task was to design the refit of the facility in order to ensure optimal productivity and dam safety across all the projected climate change scenarios.

The findings of the modelling work were then used to inform the investment design of the modernisation of the Qairokkum project. Unlike greenfield investment, a rehabilitation project of this kind inevitably faces certain physical boundaries, which may limit options on the number or type of turbines to be installed, and on turbine design.

For economic reasons it was decided that the general layout of the hydropower plant should be maintained, as well as the set-up of its powerhouse. Within these given boundaries, the project team identified three possible technical options for the turbine upgrade. Each of these envisaged an increase in generation capacity by improving the design and manufacture of new water turbines.

The economic performances of the upgrade options were analysed across the entire range of hydro-climatic scenarios. This enabled the rehabilitation design to optimise the facility's resilience to the projected range of climatic conditions under which it may have to operate. Based on the findings of this analysis, the first option, replacing each turbine with highly efficient 29 MW turbines was the most suitable technical solution, which will result in an increase of its generation capacity to 174 MW.

Importantly, the physical works on the modernisation of the dam were also accompanied by longer-term support for building technical capacities for improved climate risk management in the operations of Qairokkum and other hydropower facilities in Tajikistan. This entailed dedicated technical support to Barki Tojik, as well as Tajik Hydromet and the Ministry of Energy and Water Resources, on climate risk management in hydropower operations in Tajikistan. This support includes the introduction of best international practices in using hydro-meteorological data and climate change projections for updating operational rules and reservoir planning as well as an evidence-based understanding of the regional demand loads in the country. It also involves twinning the Tajik agencies with hydropower experts from Canada, a country that has made significant advances in hydropower sector climate risk management.

This case study also illustrates the importance of sharing lessons and expertise on hydropower sector climate resilience between different countries. For example, when designing this approach, EBRD drew the experience of OECD countries that have made good progress in hydropower climate risk management, such as Canada (Hydro-Québec, BC Hydro) and Australia (Hydro Tasmania). EBRD has subsequently begun to apply similar approaches on hydropower investment activities in other countries such as Morocco and Albania. Other international financing institutions that have also addressed climate resilience in their hydropower financing operations include the World Bank Group, International Finance Corporation (Nepal, Zambia) and the Inter-American Development Bank (Costa Rica).

Case study: Landsvirkun, Iceland

The hydroelectric sector stands to benefit from some aspects of climate change, such as increased flows due to melting glaciers. To take advantage of these potential opportunities, however, requires considerable knowledge of climate change projections and hydroelectric generation. Landsvirkjun, the national power company of Iceland, has become a leader in this field during the last 15 years. In collaboration with other power companies, universities and meteorological services across Scandinavia, Landsvirkjun has produced data on river flows that incorporate climate trends. Every five years, the company uses the data to adjust its reservoir-management plans. Landsvirkjun also uses the long-term perspective provided by climate projections to design and adjust existing and proposed new assets to take advantage of anticipated increases in flow rates.

"Sometime around 2005, we saw that the flows into the system were different from what the history was suggesting they should be", said Óli Sveinsson, Landsvirkjun's executive vice-president of research and development. At that time, the company was already engaged with Norden, a coalition of Scandinavian governments and research agencies to identify and analyse the impacts of climate change on renewable energy. In this collaborative research, observed temperature and precipitation data, as well as glacier area-volume-elevation curves, were adjusted according to climate model trends. For example, temperature trends call for increases of 0.75°C per century for the period 1950–75, 1.55°C per century for 1975–2000 and 2.35°C per century after 2000. These trends were applied to historical data on observed temperatures to project future climate. This information was then fed into a hydrological model to produce corrected flow series. Watersheds with large shares of glacial inflow showed the strongest responses to increased temperature. For the Karahnjukar watershed, 75% of which is covered by glacier, the corrected flow series shows an increase of about 10% compared to the last 50 years of records.

As the inflow increases with warming climate, modification of reservoir-management plans will not be enough to take full advantage of increased river flows, and higher proportions of the flows will go over the spillway, because the discharge capacity of the generation assets will be exceeded. The runoff increases between the historical records and the 2050 flow scenario is 3.9 TWh/yr, but at the same time, the system can only cope with a 1.9 TWh/yr increase in production capacity. Therefore, Landsvirkjun has also adjusted the designs of planned new assets to take advantage of increased flows.

The proposed expansion of the Bùrfell power plant is a good example. At first, it didn't seem economically feasible to add 70 MW of capacity. But taking into account the corrected flows for 2025, the project is economically feasible and the capacity of the turbine was increased from 70 MW to 100 MW. At another proposed project, Hvammur, the original plan called for a capacity of 83 MW. To accommodate the expected increased flows, the new plan is to increase the capacity to 95 MW. Landsvirkjun has calculated that once those projects are complete, the company will be able to increase its sales of electricity by 8%.

Path Forward

The case studies described in this briefing are excellent examples of how the hydropower sector is responding to observed climate variability and proactively building climate resilience into existing and future hydro projects. However, these design modifications have generally been made on a case-by-case basis and are specific to the facilities and regional climate conditions. In the absence of guidelines for climate resilience, ad-hoc approaches will continue to be developed to assess and build in climate resilience into projects; leading to inconsistent methods and in some cases less credibility.

To mitigate the risks associated with climate variability, and to support wider action on climate resilience across the hydropower industry, there is a growing need for guidance on hydropower sector climate risk management that sets out practical insights and methodologies that can foster improved climate resilience in the hydropower sector. This need is recognised by hydropower operators and regulators, as well as by major development banks, including the World Bank Group and EBRD, and private investors.

This reflects a current trend towards the development of industry-specific technical guidance on climate resilience in a range of climate-vulnerable sectors such as ports and buildings, in which industry associations have begun to collate experience on climate risk management and develop sector-specific guidance and standards for dealing with climate change risks.

Specific climate risk management guidance for the hydropower sector could help to ensure the viability and resilience of hydropower investments and operational management practices by ensuring that they are resilient in the face of the risks and uncertainties associated with climate change and, where possible, that they are designed to take advantage of any opportunities created by climate change.

There is an opportunity to learn from the experiences of industry associations in other sectors and also to make use of recent progress on the development of generic climate resilience such as that developed by the European Financing Institutions Working Group on Adaptation to Climate Change, which may provide a template/inputs for the development of hydropower-specific guidance. The International Hydropower Association, through its work programme, promotes sustainable hydropower development through knowledge building and sharing expertise. To that end, IHA is working closely with the EBRD and the World Bank Group to develop climate resilience guidance for the hydropower sector.

Climate resilience and adaptation will be among the key topics under discussion at the 2017 World Hydropower Congress, which takes place in Addis Ababa on 9–11 May 2017. Find out more at: **www.hydropower.org/congress**

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