SEI

SUSTAINABLE
ENERGY
INITIATIVE

CASE STUDY

QAIROKKUM HYDROPOWER: Planning ahead for a changing climate

European Bank
for Reconstruction and Development

CLIMATE
INVESTMENT
FUNDS

UKaid
from the British people

BMF
BUNDESMINISTERIUM
FÜR FINANZEN

Executive summary

In 2014, the EBRD agreed a US$ 50 million loan with Barki Tojik, Tajikistan's state-owned power utility. It financed the first phase of the modernisation and rehabilitation of the 126 MW Qairokkum hydropower plant, located in northern Tajikistan, which supplies electricity to 500,000 people. The project is jointly financed with the Pilot Program for Climate Resilience (PPCR). This supports Tajikistan, and in particular the country's hydropower sector, in strengthening its resilience to climate change.

Like many other countries Tajikistan is already experiencing changing climate conditions; average temperatures are rising, precipitation patterns are changing and glaciers are retreating. These shifts could have a significant impact on Tajikistan's hydropower sector. Depending on how the climate develops, water inflows into the reservoirs may alter. This in turn will affect the hydropower sector's ability to generate electricity in the future. Given that 98 per cent of Tajikistan's electricity originates from hydropower, these trends could have a serious effect on the population's living standards and the economy as a whole.

The Qairokkum project used a highly innovative approach by incorporating climate change considerations into the investment design. Experts recruited for the project modelled future hydrology – in other words, the water inflow into Qairokkum's reservoir – under different climate change scenarios. This served as a basis for selecting the most suitable rehabilitation design across the range of possible projected climate change scenarios. In addition a dedicated technical assistance package will assist Barki Tojik as it mainstreams climate change into the operational management of hydropower assets.

The impacts of this project extend far beyond the rehabilitation of a hydropower plant. Incorporating climate change considerations into investment design will significantly improve Qairokkum's resilience to Tajikistan's changing climate. It will also secure a reliable electricity supply for the people of the Sugd region. Barki Tojik's management and staff will learn to identify climate change risks associated with hydropower and how to deal with them. Integrating this know-how into the company's business operations will optimise electricity generation and dam safety, thereby helping Barki Tojik move towards international best practice. This is a pilot project. It provides important lessons for hydropower in Tajikistan and across the region and could be replicated in future hydropower investments.

Power cuts: a rising social and economic burden

Hydropower sources are responsible for 98 per cent of Tajikistan's electricity but the sector faces a number of challenges. During the winter months approximately 70 per cent of the population suffers from repeated electricity blackouts. Estimates show these amount to 2,700 GWh, which is equivalent to a quarter of winter's electricity demand. With demand expected to rise, and without major investments in the near future, shortages are forecast to reach 4,500 GWH in 2016. This would be close to a third of electricity demand in winter.[1]

Electricity shortages in winter impose annual financial losses of approximately US$ 200 million, or 3 per cent of the country's Gross Domestic Product. According to the World Bank's Business Economic Environment Survey, frequent power cuts are considered the main obstacle to doing business in Tajikistan. The social impacts associated with chronic electricity shortages in winter are severe. People burning coal and wood in their homes inhale indoor air pollution, while their health is also affected by the extreme winters.

Demand for electricity varies considerably throughout the year – a phenomenon shared by most countries with extreme temperatures in summer and winter. However, Tajikistan's winter electricity demand is unusually high. Unlike most countries experiencing temperature extremes throughout the year, the Tajik population relies mainly on electricity for heating rather than on natural gas and coal. According to the World Bank, this explains why the residential sector accounts for such a large share of total electricity demand (44 per cent) (2012).[2] This is due to limited heating options and relatively low electricity prices.

Unfortunately, high demand for electricity in winter coincides with the period when hydropower plants produce the least amount of power due to hydrological conditions. River flows are lower in winter, reaching their minimum in March. This reduces the output of the whole sector, especially the plants lacking storage capacity.

These chronic electricity shortages have become more acutely evident since 2009, when electricity imports though the Central Asian Power System (CAPS) came to a halt. The CAPS originated in the 1970s under the former Soviet Union. Covering five Central Asian countries it was designed to meet the needs of the region and reduce the overall cost of supply without taking national borders into account. Following the collapse of the former Soviet Union the CAPS member states pursued energy independence in terms of generation capacity and fuel supply. At the same time, differences in each country's resource base meant the systems became unbalanced, and this created tension between the states.

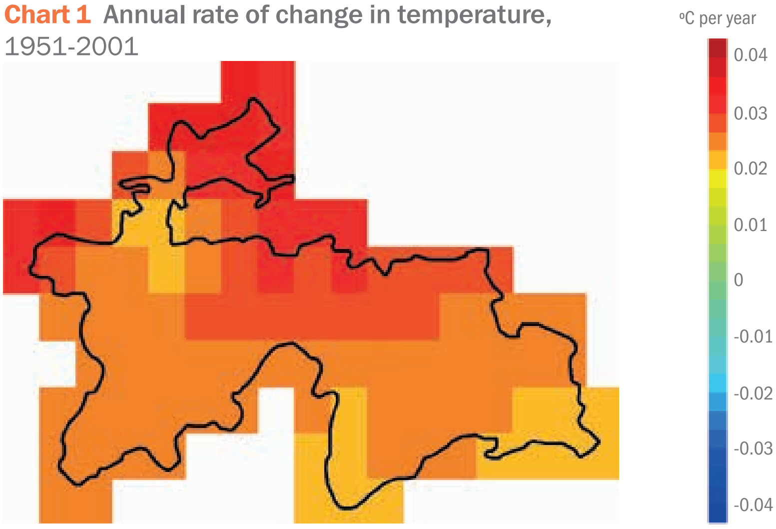
[1] Tajikistan's Winter Energy Crisis: World Bank, 2012.
[2] Ibid.

New risks from climate change

Dominated by hydropower, Tajikistan's electricity sector already faces operational problems, and climate change only adds to these risks. Tajikistan's hydropower plants depend on river basins fed by glacial meltwater and snowmelt. However, as the climate warms, most climate models predict significant changes in the dynamics of Tajik precipitation, as well as alterations to the country's glaciers.

Studies by the Intergovernmental Panel on Climate Change (IPCC) indicate an increase of about 1.2°C in average temperatures in Tajikistan since the 1950s. Most rapid warming occurs in winter. Higher winter temperatures mean that a smaller proportion of precipitation falls as snow. Rainfall has declined by approximately 20 per cent since the 1950s. Changes across the country's glacier volumes are also significant. The state administration for hydrometeorology, Tajik Hydromet, suggests that since the mid-1960s, the Fedchenko glacier (northwest Pamir) retreated by 14 km², or 6 per cent. It is now diminishing by approximately 16 m each year.

Chart 1 Annual rate of change in temperature, 1951-2001

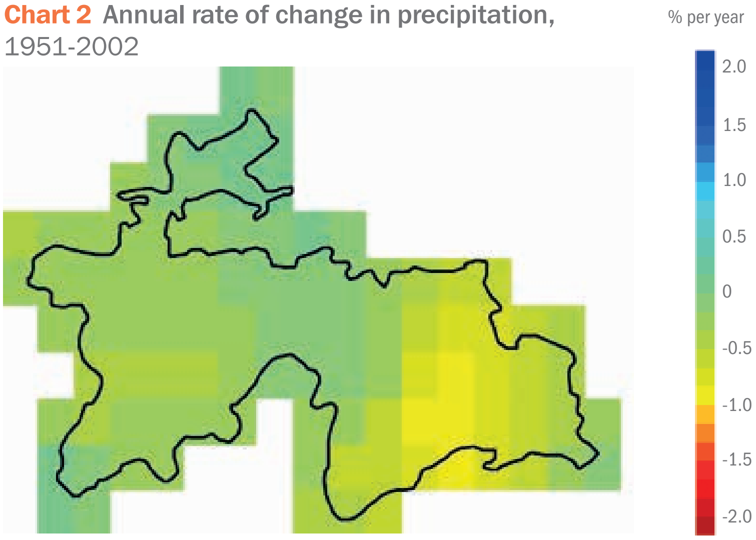


Over the same period, glacier area reduced by more than 25-30 per cent in the Vandj basin (western Pamir) and by 30-40 per cent in the Murghab basin (eastern Pamir). Glaciers are also retreating and thinning in the Garmo and Skogach (Obihingou basin), the GGP (Iskanderkul basin) and Diahandara (Karatag basin).[3]

These trends could raise the water supply from increasing runoff and snowmelt in the near to medium future. However, this could be followed by a severe reduction in water supply as the mass of glacial ice and accumulated snow recedes. These climate impacts create serious implications for power generation capacity, as well as peak supply and demand management.

Most of the country's hydropower plants were constructed during the Soviet era and have seen few upgrades ever since. Not surprisingly many are not in a condition to cope adequately with the projected climate change impacts, especially extreme weather events. The International Commission on Large Dams has therefore emphasised the urgent need to adapt older dams, especially their spillway capacities. The dams need to cope with the new climate conditions, such as an increase in severe floods. For many years Barki Tojik managed to keep its hydropower stations running under difficult conditions. However, rising demand, ageing equipment and the predicted climate change impacts, which may alter the rules governing Tajikistan's hydropower sector, make the sector vulnerable to a major breakdown.

Chart 2 Annual rate of change in precipitation, 1951-2002



[3] Source: Pilot Programme for Climate Resilience Phase I: Improving the Climate Resilience of Tajikistan's Hydropower Sector; Report 1: Climate Variability and Change in Tajikistan

Global hydropower response to climate change

Tajikistan's hydropower sector is not the only one challenged by climate change. Hydropower operators worldwide face the same concerns. They are all experiencing climate change impacts in the form of rising temperatures, changing precipitation patterns and more frequent extreme weather events. In some OECD countries such as Canada where the hydropower share in electricity generation is about 60 per cent, some hydropower operators are now responding by identifying risks specifically related to the climate and finding ways to deal with them. Some of the leading hydropower operators have devised a variety of responses, such as structural design measures. These include, for example, building more robust dams for heavier floods and extreme events, and constructing or augmenting water storage reservoirs. They are also modifying spillway capacities, adjusting the number and types of turbines better suited to expected water flow rates, and modifying channels to better handle water flow changes.

However, hydropower operators at the forefront of international best practice are equally focusing on non-engineering measures. For instance, they are developing hydrological forecasting techniques and adaptive management operating rules, as well as improving upstream land management. This includes afforestation to reduce floods, erosion, silting and mudslides.

HYDRO TASMANIA
A company shaping international best practice in Australia

Climate change has strategic implications for Hydro Tasmania, Tasmania's leading hydropower operator. The company aims to incorporate climate change considerations into every relevant area of its operations.

Hydro Tasmania concentrates on continuous plant upgrades and refurbishments to ensure efficient and economic resource use within a changing climate. The company has established partnerships with leading climate research institutions to better understand how water inflows into its reservoirs are likely to evolve in the future. This informs its hydrological modelling, and helps it manage water inflow volatility into reservoirs, balancing the risk of shortfall against the risk of spill. By integrating climate data and hydrological modelling into its business processes and planning, Hydro Tasmania has mainstreamed climate change into its operations, minimising its business vulnerability to climate change.

To raise awareness, Hydro Tasmania regularly engages with its staff on issues related to climate. Climate change projects are promoted within the company, and project outcomes and impacts are shared among staff. This ensures that employees understand climate change risks, options, solutions and actions.

Tajikistan's partnership with the PPCR

Recognising that "development as usual" would not suffice as a response to climate change risks, the Tajik government expressed an interest in participating in the PPCR in 2009.

Supported by the EBRD, the Asian Development Bank, the World Bank and various Tajik stakeholders, the Tajik government devised a five-year PPCR Strategic Program for Climate Resilience. This aimed to improve the climate resilience of sectors in the economy considered particularly vulnerable to climate change impacts, including the hydropower sector.

In coordination with the Tajik authorities and other multilateral development banks (MDBs), the EBRD spearheaded the integration of climate resilience in Tajikistan's energy sector. The Qairokkum hydropower plant was selected as a pilot project to demonstrate how to rehabilitate an existing hydropower plant and make it climate resilient. At the same time, the EBRD recognised the importance of gathering and sharing knowledge of climate change risk management associated with hydropower operations. The aim is to ensure a reliable and resilient energy supply for the local population.

THE PILOT PROGRAM FOR CLIMATE RESILIENCE

The PPCR is a special programme of the Strategic Climate Fund, one of the two Climate Investment Funds (CIFs). The CIF is the largest climate fund to date. It provides 48 developing and middle-income countries with resources to mitigate and manage climate change and reduce their greenhouse gas emissions.

The PPCR aims to pilot and demonstrate ways in which climate risks and resilience can be integrated into core development planning and implementation. This is achieved through incentives to initiate transformational change and scale up action.

The PPCR provides funds for technical assistance to help developing countries integrate climate resilience into national and sectoral development plans. In addition, it funds public and private sector adaptation projects that demonstrate how climate resilience can be integrated into investment planning.

Qairokkum: investing in the future of a hydropower plant

Owned and operated by Barki Tojik, Qairokkum is the only major energy generation facility in northern Tajikistan. It supplies 500,000 households with electricity. Constructed in the early 1950s, Qairokkum had always been well maintained. Nevertheless, most of the plant's mechanical, electrical and electronic components have reached the end of their lifetime, and equipment breakdowns are reported more often.

The 126 MW Qairokkum scheme was constructed to generate hydropower and to provide storage for irrigation. The scheme consists of an earthfill dam 32 m in height, a combined powerhouse and spillway structure. The powerhouse comprises six double-regulated 21 MW Kaplan turbines and was designed to generate on average 700 GWh each year.

QAIROKKUM RESERVOIR

The Qairokkum reservoir is fed by the Syr Darya River. This is formed out of the confluence of two other rivers – the Kara Darya and the Naryn – whose source is in the Tian Shan Mountains of the Kyrgyz Republic. Flows in the Naryn downstream from Kara-Koel in the Kyrgyz Republic are regulated by the Toktogul reservoir and several large irrigation channels. The Syr Darya reaches Tajikistan at Aqjar from where it continues southwest to the Qairokkum reservoir. The reservoir has a volume of 3 km³ and a surface area of approximately 450 km². From the reservoir, the Syr Darya flows west through the Fergana Valley into Uzbekistan.

Integrating climate resilience into an infrastructure investment

Incorporating climate change considerations into critical infrastructure investments like rehabilitating the Qairokkum scheme is not easy, as forecasting the specific impacts of climate change involves a high degree of uncertainty. The precise timing, distribution and severity of climate change impacts can be difficult to predict, and this poses additional risks associated with the investment. For instance, future water inflow into the Qairokkum reservoir depends very much on the runoff formation in the upstream catchment area. That in turn is linked to the dynamics of Tajikistan's glaciers as well as the country's future snowmelt and precipitation patterns, which are likely to change with increasing temperatures.

The water inflow into the reservoir determines the plant's ability to generate electricity. It also depends on the volume of water extracted to irrigate the Fergana basin, and on the Toktogul reservoir operations upstream in the Kyrgyz Republic. Both are difficult to predict at the best of times, but climate change adds another major element of uncertainty.

Under these circumstances, arriving at an optimal investment decision is about recognising the risks associated with climate change and taking decisions that reduce or take care of the likely impacts and exploit the opportunities.

Embedding climate change risk into investment design

To make a sound investment decision, the EBRD and Barki Tojik had to identify the risks associated with climate change. This meant obtaining a complete picture of future climate change scenarios, along with their implications for water inflow into the reservoir and with it Qairokkum's ability to generate electricity. This information put the Bank and Barki Tojik in a position to select an appropriate investment design for all climate change scenarios.

Building a picture from future climate change scenarios

Using funding from the PPCR, the Bank worked with international and local climate change and hydrology experts to obtain a complete picture of all future climate change scenarios for the Sugd region. The scenarios identified were based on work incorporated in IPCC's Fourth Assessment report. The different scenarios comprised a range of temperature shifts for the period leading up to 2050. They varied from +1.5 °C (warm-wet scenario) to +4 °C (hot-dry scenario). For the period leading up to 2080, they ranged from +2°C to +6°C. Variations in precipitation ranged from -10 per cent (hot-dry scenario) to +20 per cent (warm-wet scenario) from now to 2050 and from -15 per cent to +30 per cent for the period up to 2080.

Modelling Qairokkum's water inflow under different climate scenarios

To model the water inflow into Qairokkum reservoir, the experts applied four climate scenarios (comprising the hot-dry scenario, the central scenario, the warm-wet scenario and one scenario without climate change) to three different hydrological models: (i) a snowmelt runoff model, which has been widely applied to the context of Central Asia; (ii) a regression model; and (iii) a water balance model. These both rely on past and present temperature and precipitation data to predict future water inflow into the reservoir. This resulted in 10 scenarios of future water inflows into the Qairokkum reservoir: three climate change scenarios developed from each of the three hydrological models and a baseline scenario that assumes no climate change.

The forecast water inflows varied considerably depending on the climate change scenario and hydrological model used. This range of possible inflow scenarios was taken as the "envelope of uncertainty" within which the plant is expected to have to operate during its expected lifespan.

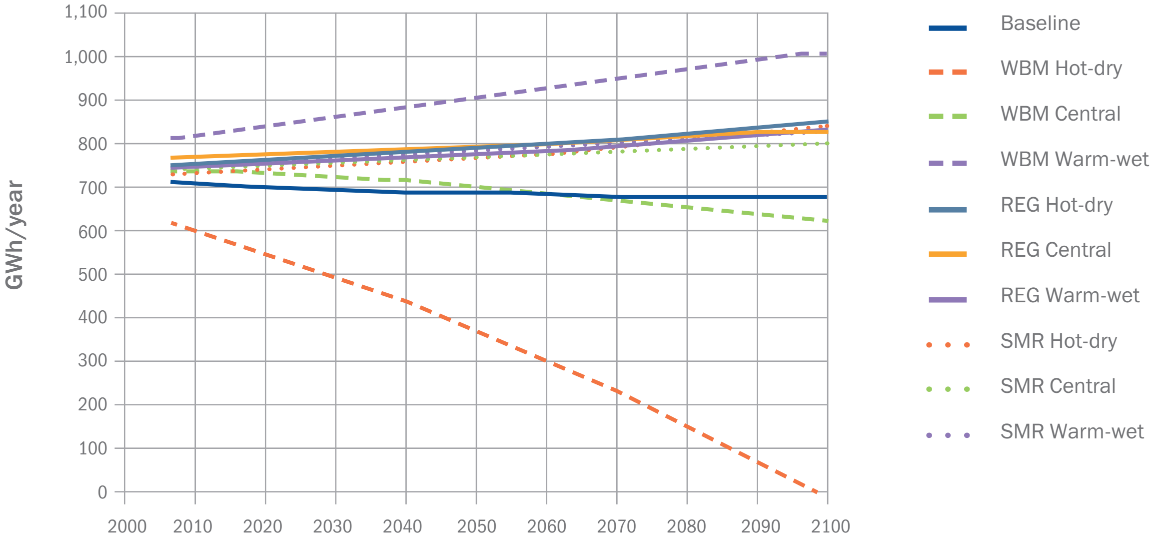
Modelling Qairokkum's capacity to generate electricity under different climate change scenarios

The water inflow scenarios developed in the previous step served as a basis for the experts to model Qairokkum's likely energy production under the different climate scenarios. Results revealed that electricity generation varies significantly depending on the climate change scenario and hydrological model applied. A range of different outcomes emerged. For

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%

Chart 3 Modelling future annual energy production at Qairokkum



example, one shows a 40 per cent increase in electricity generation capacity by the end of the century. Another finds energy production ceases dramatically.

A complete picture of climate change scenarios and related water inflow patterns was obtained, allowing an assessment of the plant's ability to generate electricity under different climate scenarios. The subsequent task was to design Qairokkum's rehabilitation to ensure productivity and safety across all possible climate scenarios.

Selecting a climate resilient investment design

A rehabilitation project such as the Qairokkum scheme faces certain physical boundaries, unlike greenfield projects, which benefit from freedom of choice on the number of turbines 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 the given boundaries, Barki Tojik engineers and experts engaged by the Bank identified three possible technical options. Each of these envisaged an increase in generation capacity by improving the design and manufacture of new water turbines.

A min-max analysis technique was used to identify the upgrade option with the best economic performance across the entire range of climate scenarios. This enabled rehabilitation design to optimise resilience to the projected range of climatic conditions under which the hydropower plant 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. Using this solution, the plant will eventually increase its generation capacity to 174 MW.

The investment was structured into different phases. Phase 1 of the investment plan will finance hydro-mechanical and electro-mechanical equipment for two of the six hydropower plant units. Other upgrade measures, including the remaining four units, will be taken in Phase 2, due to start in 2016.

Technical options for the Qairokkum 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 they 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.

DATA GAPS

The data required to model future water inflows and electricity generation capacity under different climate change scenarios was not easily obtainable. The experts working on the project soon realised that meteorological and hydrological data in Tajikistan was scarce and not always digitally recorded. The civil war between 1992 and 1994 had left particularly large data holes. This was only put right after many months digitalising and modelling data relating to those years.

Mainstreaming climate change in Barki Tojik's business operations

The EBRD's engagement in Qairokkum's modernisation does not cease with the provision of finance. The Bank is also organising a dedicated technical assistance package funded by the Austrian and United Kingdom governments and the EBRD's Shareholder Special Fund. This technical assistance package has two aims. It integrates and mainstreams climate resilience into Qairokkum's operations and it facilitates knowledge-sharing with relevant national and international organisations. This helps Barki Tojik move towards international best practice.

Integrating climate resilience into Qairokkum's operations means revisiting the plant's dam operating rules and safety procedures in light of the newly available hydrological and meteorological data. Operating rules and dam safety procedures were adopted during the Soviet era and are based on hydrological and meteorological observations from the early 1980s. Models of extreme flood events and corresponding emergency response measures particularly need to be updated. This means taking into account the new hydrological and meteorological data as well as the projected climate change impact. To address these issues the EBRD has designed a comprehensive skills transfer programme consisting of the following elements:

Integrating climate resilience into Barki Tojik's hydropower operations

- Advanced training: technical workshops with Barki Tojik and Tajik Hydromet that focus on climate diagnostics, climate risk assessment and seasonal forecasting.
- Updating operating rules: assistance given to Barki Tojik in devising dam management practices that maximise energy production, minimise spills and optimise dam safety, including technical support to improve flood emergency responses.
- Facilitating data management and information sharing: assistance to Barki Tojik, Hydromet and other relevant organisations on data management and record-keeping. This also includes the creation of a protocol that sets out the provisions for sharing and using climatological and hydro-meteorological information in hydropower operations.

Assisting Barki Tojik's adoption of international best practice by learning and sharing information

Hydropower operators in several OECD countries have made significant progress in integrating climate change considerations into the management of their operations. Some of the most advanced hydropower operators in this respect can be found in Canada and Australia. To enable Barki Tojik to benefit from this experience, the EBRD incorporated the following elements into the technical assistance package:

- Building long-term partnerships: establish long-term collaborative links

Investment structure

Phase 1 of the investment plan comprised a volume of US$ 75.7 million. The EBRD provided US$ 50 million. The PPCR contribution was US$ 21 million, consisting of a US$ 10 million loan and a US$ 11 million grant. In contrast to the EBRD loan, which had a maturity of 15 years, the PPCR loan was extended on a concessional basis and had a maturity of 40 years.

with international partners in research, engineering and academia around specific PPCR tasks.

- Learning from international best practice: conduct a study tour of hydropower facilities in an OECD country for Barki Tojik staff, Tajik Hydromet and other relevant institutions, providing first-hand experience of best practice in managing climate risks affecting hydropower.
- Capacity-building: assist in strengthening national capabilities in climate risk assessment and adaptation in Barki Tojik, Tajik Hydromet and other relevant institutions by building partnerships and arranging short-term secondments and two-way exchange of technical staff.

Transformational impact

The Qairokkum project shows the remarkable impact achieved by combining the efforts of governments, MDBs and the PPCR. The Tajik government recognised the need to address the country's acute vulnerability to climate change, took the initiative and turned to the PPCR.

The PPCR ensured a comprehensive approach specifically adapted to Tajikistan's offensive against climate change. Its approach allowed for coordinated action among different MDBs and ensured that the most vulnerable sectors of the economy were prioritised.

This laid the ground for the Qairokkum project. Through the dedication and commitment of Barki Tojik this turned out to be a groundbreaking pilot project. It has achieved transformational outcomes that go far beyond power plant rehabilitation. Qairokkum's resistance to future climate change will improve significantly, and this will have tangible consequences for the inhabitants of the Sugd region. Qairokkum will be safer and better able to deal with extreme weather events, particularly floods. It will be more reliable and thus better adjusted to supplying electricity to households and businesses. Following international best practice, Barki Tojik is keen to incorporate the latest hydrological and meteorological data into its business plans to ensure smooth operations even under changing climatic conditions. The path taken by Barki Tojik of improving Qairokkum's resilience to climate change serves as a roadmap benefiting other hydropower plant operators in the country and in the region.

European Bank
for Reconstruction and Development

CONTACTS

Energy Efficiency
and Climate Change team
Craig Davies
Senior Manager,
Climate Change Adaptation
daviesc@ebrd.com

Energy Efficiency
and Climate Change team
Franka Klingel
Knowledge and Policy Manager
klingelf@ebrd.com

Energy, Russia and Central Asia
Veronika Krakovich
Principal Banker
krakoviv@ebrd.com

Donor Co-Financing – Multilaterals
(Climate and Environment)
Marta Simonetti
Senior Manager
simonetm@ebrd.com

European Bank for Reconstruction
and Development

One Exchange Square
London EC2A 2JN
United Kingdom
Tel: +44 20 7338 7478
Fax: +44 20 7338 6942
Website: www.ebrd.com