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THE COST OF IGNORING CLIMATE-DRIVEN UNCERTAINTY: WATER PLANNING IN CENTRAL ASIA'S AMU DARYA RIVER[1]

[1] The analysis described here was undertaken via the USAID Central Asia's Regional Water and Vulnerable Environment Activity (hereafter, the Activity) – a five-year project that aims to strengthen water cooperation among Central Asian countries to increase stability, economic prosperity, and healthy ecosystems. The Activity is implemented by a Tetra Tech ARD Inc. branch in the Republic of Kazakhstan. The technical work was conducted with a team at the Stockholm Environment Institute – US Center, and local experts from each of the countries of the Amu Darya basin.

HIGHLIGHTS

- Water supply projections in the Amu Darya vary by 50% across climate scenarios
- This leads to 50% uncertainty in future hydropower generation due to uncertain water availability under climate change
- Ignoring the implications of climate change uncertainty and other water demands could have significant impacts on investments in the energy sector
- Factoring in climate change and other water demands is crucial in the countries of the Amu Darya, particularly in the energy sector

INTRODUCTION

The Amu Darya is the largest river of Central Asia, supporting the livelihoods of 43 million Kyrgyz, Tajik, Turkmen and Uzbek people across its multinational watershed. Rapid development of agriculture and the construction of numerous multi-purpose reservoirs and irrigation canals has led to overuse and scarcity of the region's key water resources as illustrated by the nine-fold decrease in the total area of the Aral Sea since the 1960s. Before the 1960's the Amu Darya contributed 70% of water inflow to the Aral Sea, today, the Amu Darya ends in Uzbekistan 200 miles before reaching the Aral Sea.

Since 1950, temperatures and precipitation in the headwaters of the Amu Darya have increased, suggesting that while water demands have increased, water supply may remain constant or even increase under climate change with glacial melt adding to available surface water.[2] Yet, climate projections indicate substantial uncertainty in precipitation trends going forward, with precipitation in the near term and in the mid-term ranging from a fifteen percent decrease to an eighteen percent increase over the average historical level[3] (Figure 1). However, progressing glacier melt and more extreme precipitation events under climate change will likely make water supply less reliable, especially in key agricultural seasons where spring melts historically provided timely irrigation.

Over the coming decade, 4 GW of new hydropower developments in the watershed are intended to increase water security and support regional development via consistent and clean energy supply, and reservoirs offering the potential to control collection and release of run-off for irrigation.

Traditionally, water and energy systems have been modeled in isolation, simplifying nexus issues outside the study scope and ignoring tradeoffs between, for example, water used for agriculture versus hydropower. Yet, the substantial uncertainties surrounding climate change and high water demands in the Amu Darya basin require carefully crafted, integrated water-energy assessment tools to determine hydropower's effectiveness in providing reliable energy and supporting economic development in the region. This study used an integrated system of water, energy and economic planning tools: 1) the Low Emission Analysis Platform (LEAP); 2) the Water and Evaluation Planning software (WEAP); and the macroeconomic module, MACRO[4] to examine future resource availability and identify and inform robust, climate resilient policies and infrastructure.

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[2] Murodov, A., L. Cuo, N. Li, D. Murodov, M. Hou, and G. Hussain, 2023: Extreme Hydrometeorological Conditions and Changes in the Amu Darya River Basin in Central Asia. J. Hydrometeor, 24, 315–334, https://doi.org/10.1175/JHM-D-22-0025.1.

[3] Excluding outliers

[4] Now called AMES: https://github.com/sei-international/AMES.jl

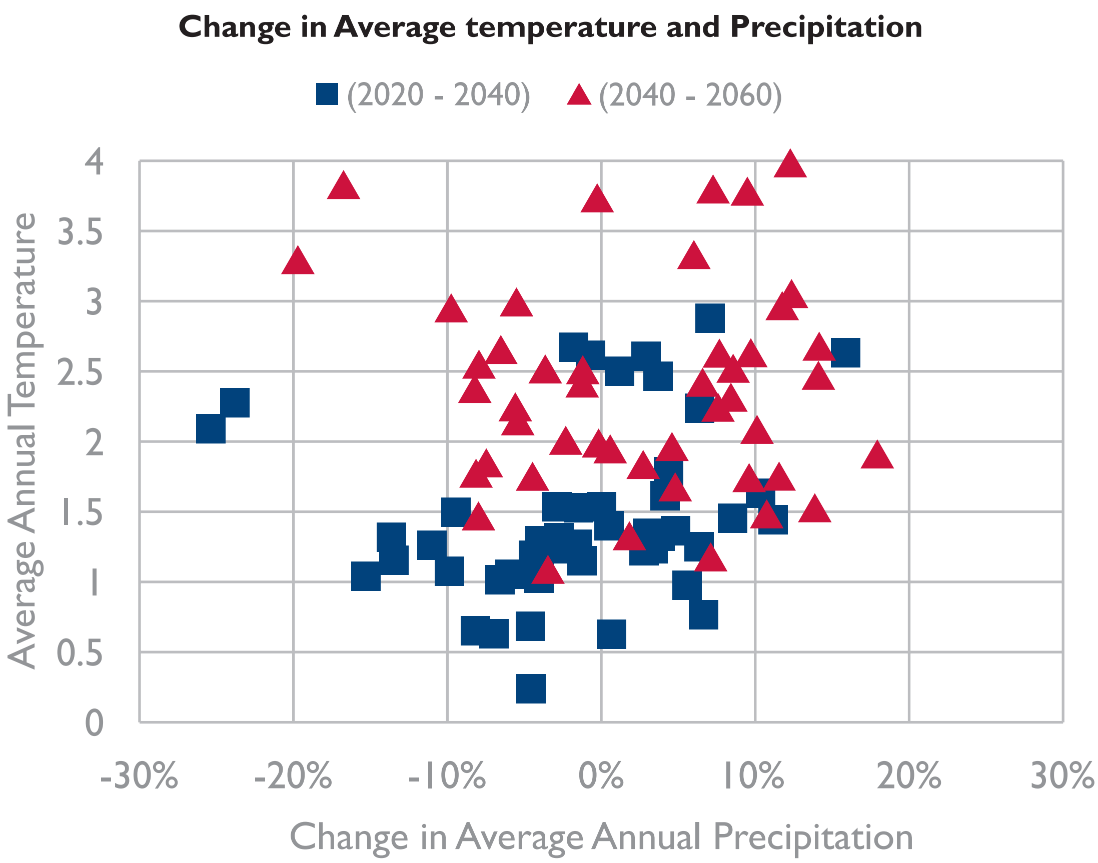

Figure 1. *Projected changes in annual precipitation and temperature for the Amu Darya basin.*

NARRATIVES

Together with representatives from national governments and basin stakeholders in the Amu Darya River Basin, the Activity co-developed four narratives for the future development of the Amu Darya River basin for all four countries of the basin - Kyrgyz Republic, Tajikistan, Turkmenistan and Uzbekistan. Each narrative was evaluated under two different climate projections[5], resulting in 8 scenarios. In this brief, four of those narratives are presented that illustrate the impact of climate change on the water-energy-food nexus in the basin and the risks of siloed approaches to energy and water planning through 2050:

- *(S1)* ***Baseline:*** *based on existing policies and plans by the four countries, as well as a future pursuit of national interest in hydropower and agriculture expansion in the Amu Darya basin, includes new development of 11 GW of hydropower in Amu Darya countries.*
- *(S2)* ***Improved Agriculture:*** *Improved water efficiency and practices in agriculture*
- *(S3)* ***Energy Efficiency and Climate Policies:*** *Increased energy efficiency, expansion of renewable energy, pursuit of climate mitigation and adaptation.*
- *(S4)* ***Cooperation:*** *Prioritizing water for irrigation over hydropower*

These four narratives were modeled with and without integration across the LEAP, WEAP and MACRO models to explore the degree to which climate change will impact regional development in the water-energy-food nexus and to quantify the risks of ignoring nexus interactions.

[5] A dry climate scenario from the IMN and a wet climate scenario from the GFDL ESMs

RESULTS

UNCERTAIN AND VARIABLE WATER SUPPLY UNDERMINES HYDROPOWER TARGETS

Regional development will lead both energy and water demand for agriculture to grow substantially by 2050, driven by population growth, economic development, increased crop water requirements and agricultural expansion. However, projected stream flows in Amu Darya headwaters indicate uncertainty of ~50% between wet and dry climate projections (5-year average, 2046-2050, Figure 2). Major uncertainty in the future water supply combined with substantial and increasing interannual variability, has important reliability implications for irrigated agriculture and hydropower generation.

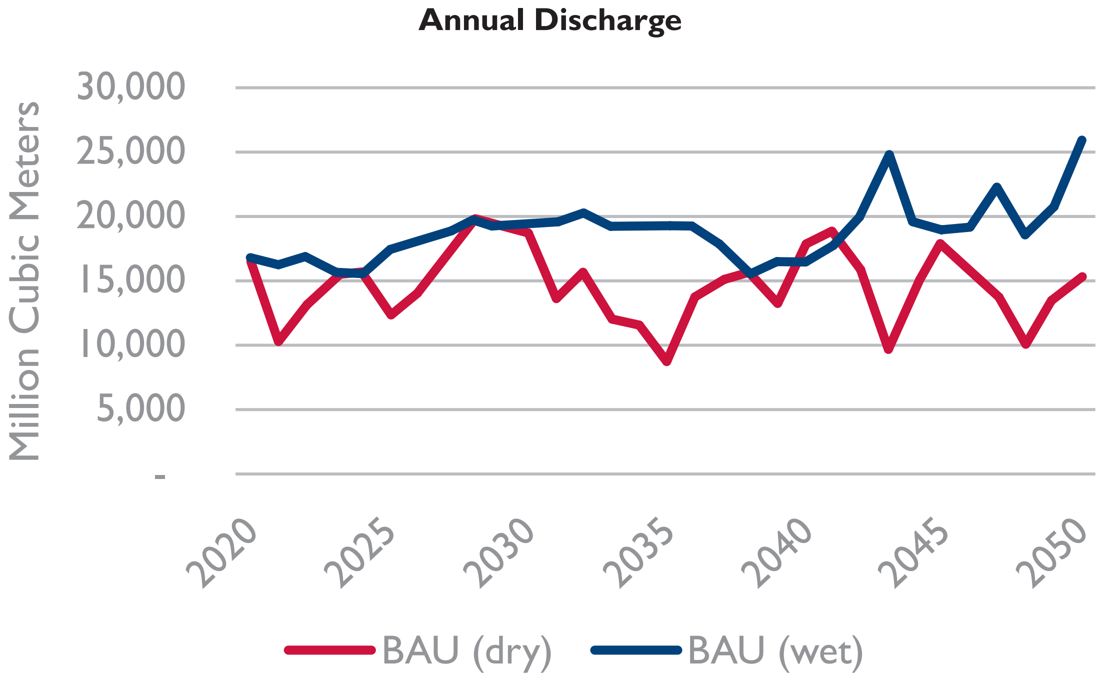

***Figure 2.** Projected river flows in Amu Darya headwaters under different climate scenarios, 2020-2050.*[6]

Development of 4 GW of new hydropower capacity in the Amu Darya basin, primarily in Tajikistan, is intended to manage variability in water supply and satisfy 7-fold growth in energy demand over the period 2020-2050. The integrated modeling under the Baseline policy path (S1) indicates that there is substantial uncertainty in the effective output of this new capacity. Average annual electricity supply across the four riparian countries is 35% lower under the dry compared to the wet climate scenario (26 and 40 TWh yr-1) and varies by up to 20% between years (Figure 3), indicating that hydropower generation may not provide the expected electricity output under climate change, and highlighting that the development of additional clean energy sources is desirable.

[6] Estimates from Vakhsh river flows above Nurek dam.

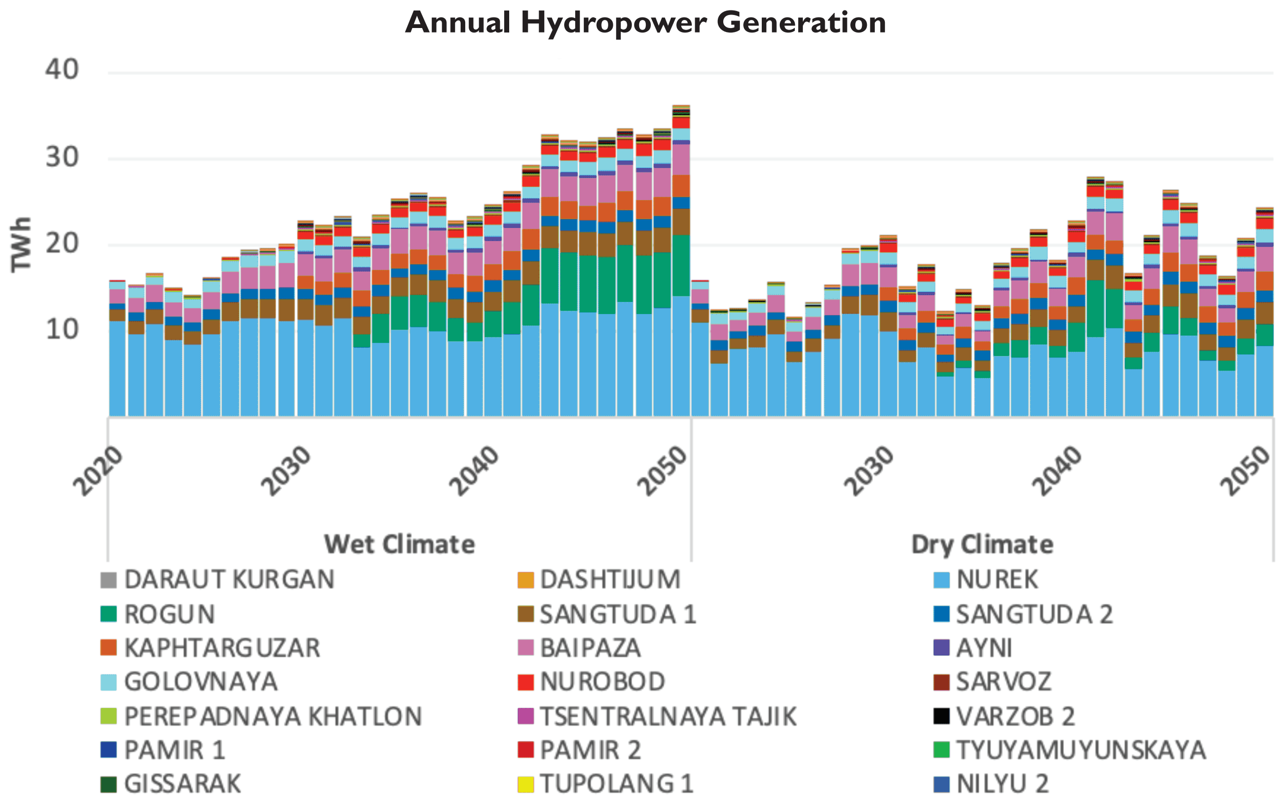

Figure 3. *Annual hydropower generation in Amu Darya Basin with BASELINE policies (S1) under the wet and dry climate scenarios.*

ENSURING ENERGY SECURITY AND AGRICULTURAL DEVELOPMENT

The important shortfalls in hydropower generation due to water scarcity and interannual variability, requires additional energy backstopping to meet future energy demand and ensure climate change preparedness. The study estimates that as much as 3.7 GW of additional energy backstopping capacity might be needed across Amu Darya countries, with coal, wind, and solar capacity being most cost effective (S1 and the dry climate scenario).[7] Such capacity developments would require an additional 6 Billion USD in investments in the four riparian countries, indicating that the financial and energy security risks of ignoring the impacts of climate change and competing water demands in energy planning are substantial.

Improving agricultural practices, such as lining canals and improved irrigation efficiency, as well as improving energy efficiency and pursuing climate mitigation policies, can reduce water scarcity and boost economic development, compensating in part for the additional investments needed to make the energy sector climate change resilient. In the Kyrgyz Republic alone, such policies may increase cumulative GDP by 0.7-2.5 Billion USD (S2, 2020-2050), largely driven by increased agricultural productivity.[8] Across the region, improved irrigation and agricultural practices that reduce unnecessary water losses also have the potential to increase agricultural productivity by 17-19%, irrespective of climate change trends (Figure 4).

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[7] As indicated by comparing results from the integrated modeling system to the stand-alone energy system model, which is blind to climate driven changes in water supply and competing water demands.

[8] Integrated macroeconomic modeling results are only available for Kyrgyz Republic, due to missing data in other riparian countries.

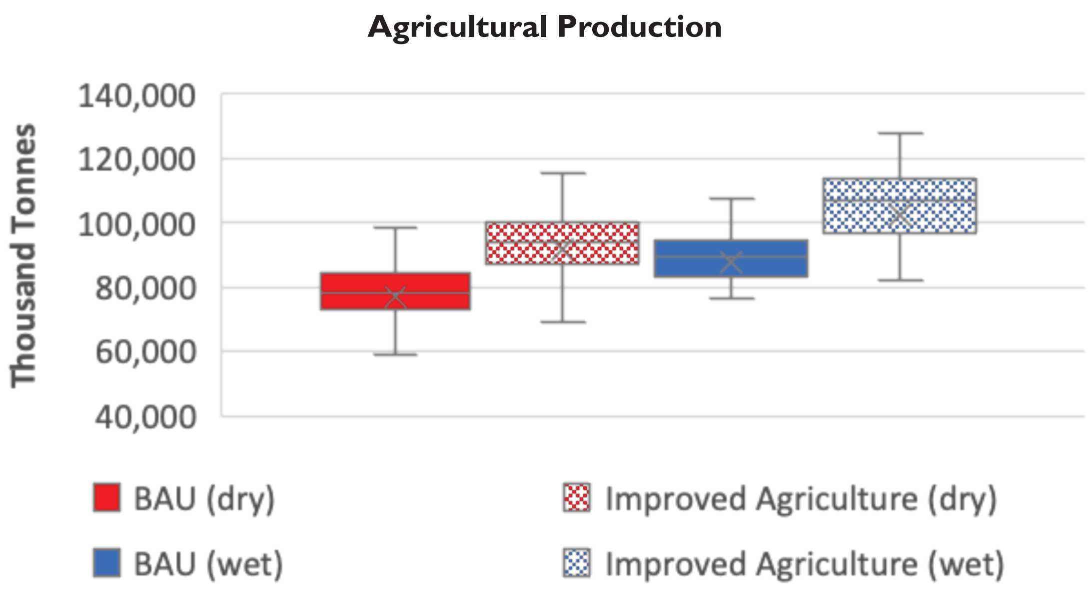

Figure 4. *Annual agricultural production in the Amu Darya Basin under the BASELINE (S1) and the Improved Agriculture policy pathways (ca. 2050).*

IN SUMMARY:

- Major uncertainties in hydropower generation resulting from climate change indicate the need for integrated water-energy planning
- Increased water demand and hydrological variability suggest 6.5 GW of additional backstopping energy capacity might be needed in the Amu Darya River basin to meet hydropower shortfalls by 2050
- Improving agricultural practices and energy efficiency policies can increase economic output, compensating for part of the 6 Billion USD additional investments required in the energy sector

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Key Documents

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