Deliverable 5.4: Hydro4U Replication plan. 3rd release

WP5, Task 5.1

Date of document: 31/05/2024 (M36)

Dissemination Level:	**PU**
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This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 101022905.

Document History

Project Acronym	Hydro4U
Project ID	101022905
Project Title	Hydropower For You – Sustainable small-scale hydropower in Central Asia
Project Coordinator	Technical University Munich (TUM)
Project Duration	01/06/2021 – 31/05/2026
Deliverable	D5.4 – Hydro4U Replication plan. 3rd release
Dissemination level	Public
Deliverable Lead	Fundación CARTIF (CARTIF)
Due date / M	31/05/2024 (M36)
Submission date / M	31/05/2024 (M36)
Version	2.0
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Work Package	WP 5 – Replication of sustainable SHP potential
Work Package Lead	CARTIF

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Abbreviations and Acronyms

Acronym	Description
CA	Central Asia
CAIPS	Central Asia Integrated Power System
D	Deliverable
EDB	Eurasian Development Bank
ESIA	Environmental and Social Impact Assessment
EU	European Union
EIB	European Investment Bank
ERBD	European Bank for Reconstruction and Development
FCPS	Francis Container Power Solution
FIT	Feed-in Tariffs
GDP	Gross Domestic Product
GHG	Greenhouse Gas
GIS	Geographic Information System
H2020	Horizon 2020 (8th Framework Programme for Research of the EU)
HP	Hydropower
HPP	Hydropower Plant
HSPS	Hydroshaft Power Solution
IDA	International Development Association
IEA	International Energy Agency
IHA	International Hydropower Association
KAZ	Republic of Kazakhstan
KEGOC	Kazakhstan Electricity Grid Operating Company
KER	Key Exploitable Result
KGZ	Republic of Kyrgyzstan
NDC	Nationally Determined Contributions
PA	Planning Activities
PPA	Power Purchase Agreements
PV	Photovoltaic
RES	Renewable Energy Sources
SDG	Sustainable Development Goal
SHP	Small Hydropower
TES	Total Energy Supply
TFC	Total Final energy Consumption
TJK	Republic of Tajikistan
TKM	Republic of Turkmenistan
UNIDO	United Nations Industrial Development Organization
UZB	Republic of Uzbekistan
WFEC	Water-Food -Energy - Climate
WP	Work Package

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1. Publishable Summary

Hydro4U Project aims to adapt hydropower European technologies to Central Asia (CA) by demonstrating their viability through design alterations for price-competitiveness and considering a cross-border Water-Food-Energy-Climate (WFEC) Nexus context.

Hydro4U Project is carrying out the demonstration of **two Small Hydropower (SHP) plants**, which will radically reduce planning and construction costs, without compromising efficiency. Those are:

- Francis Container Power Solution (FCPS). Two modules of approx. 1.2 MW, medium-head plant, are being installed in Shakhimardan site at Koksu River in Uzbekistan (UZB),
- Hydroshaft Power Solution (HSPS). One module of approx. 1.6 MW low-head eco-friendly run-of-river plant based on a Kaplan EVO turbine, is being installed in At-Bashy River in Kyrgyzstan (KGZ).

Hydro4U also addresses the development of a standardized methodology for the assessment of the unexploited and sustainable SHP potential in the region. A **replication model** is being developed in order to demonstrate EU quality standards and to create entry points in developing markets for the European SHP industry. These goals are supported by arising technical, organisational, managerial, and financial innovations which need to be exploited for an increased impact of the project.

This report corresponds to the **Deliverable 5.4: "Hydro4U Replication plan. 3rd release"**, which is the third deliverable from WP5: "Replication of sustainable SHP potential". D5.4 is the outcome from the work carried out so far within Task 5.1: "Hydro4U replication plan". This report, submitted by M36, updates the information reported in the D5.2: "Hydro4U Replication plan. 2nd release" submitted by M24. The Hydro4U replication strategy to be developed within Task 5.1 will be reviewed and updated within the final release in D5.7 (by M48).

This Deliverable D5.4 is divided into the following chapters:

Chapter 3 provides an updated overview of the energy sector in the region and describes in detail the generation, consumption, governance and the assessment of renewable energy policies and measures in all the countries.

Chapter 4 addresses the political context regarding water management, environment and hydropower production.

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Chapter 5 addresses the description of the current SHP development in Central Asia, based on the methodology developed within WP1 for the calculation of the technical and sustainable SHP potential. This Chapter is completed the description of the on-going initiatives for SHP development and the effects associated to the different HP plants.

Chapter 6 focuses on the guidelines for promoting green and sustainable SHP projects in CA, which include technical, economic, legal & political and environment & social criteria. Chapter 6 also describes the lessons learnt during the installation of the SHP plants in the two project demonstration sites.

Finally, Chapter 7 describes the current approach for the Hydro4U replication guideline tool. This tool will be based on the WFEC Nexus model which is being developed within Task 5.2: "Assessment of hydropower development scenarios beyond the project timeframe". This Nexus model will be leverage on the form of a tool within Task 5.4: "Hydro4U replication guideline". Through an interactive interface the tool will simulate future scenarios of SHP development, considering transboundary effects and impacts of the WFEC nexus. The tool has been selected as one of the Key Exploitable Result of the Project (KER). This Chapter 7 summarizes the analysis of the target audience (future investors, project promoters, etc.) and market, being done within WP6.

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2. Introduction & Relation to Project Progress

2.1. Purpose of Deliverable

This deliverable aims at elaborating a comprehensive Replication plan in order to ensure that all the research activities are oriented to maximize future replicability and impact among potential project promoters in CA as well as among the EU hydropower industry.

2.2. Objectives of WP & Expected Impact

WP5 aims at facilitating the sustainable implementation of future SHP plants in CA and, potentially, other geographical contexts and to support the international leadership of the European hydropower industry beyond the project timeframe. In the core of WP5 is the specific objective 6: “Support the competitiveness and sustainable market uptake of European SHP technologies in CA and globally”. In this context, WP5 comprises **four main objectives**, which are addressed in four different Tasks:

Objective 1. Development of a **comprehensive replication plan** to strengthen the position of European hydropower partners in the region by providing innovative, cost-efficient and sustainable solutions adapted to the climate changes scenarios.

→ Task 5.1. Hydro4U replication plan

Objective 2. Assessment of different **hydropower development scenarios** beyond the project according to future prospective analyses from demographic, political and economic dimensions as well as including **WFEC Nexus** constraints and requirements.

→ Task 5.2. Assessment of hydropower development scenarios beyond project timeframe.

Objective 3. Development of feasibility studies in at least **three test cases** where the implementation of Hydro4U solutions will be analysed considering the experience, tools and methods developed in other project activities.

→ Task 5.3. Feasibility studies and planning at test cases

Objective 4. Compilation of lessons learnt, general recommendations and decision support material in the form of an **interactive Replication Guideline tool**, which will be validated in three test cases.

→ Task 5.4. Hydro4U replication guideline tool

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2.3. Relation to other activities in the project

The tasks foreseen in WP5 fall on the **levels 1, 2 and 3** of the novel methodological approach proposed in Hydro4U, which moves away from classical planning concepts that are difficult to implement in the region towards innovative, regionally adapted solutions, as is shown in the Figure 1 below.

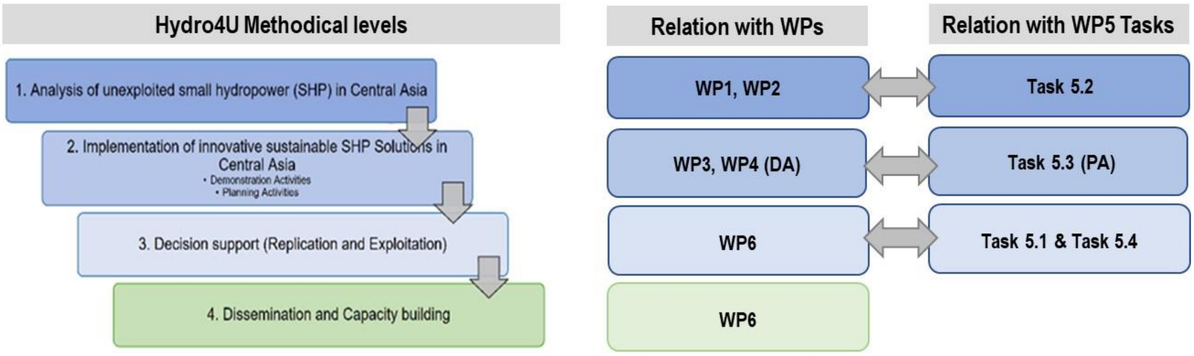

Figure 1: Alignment of WP5 with Hydro4U methodology

Level 1: Analysis of unexploited SHP potential in CA

Within Hydro4U, an interdisciplinary GIS-based approach is being developed to map the sustainable, so far unexploited SHP potential in a transparent, comprehensive and freely accessible way, considering WFEC Nexus constraints (WP1 and WP2). Information from local partners and stakeholders will be prepared for a web-based geo-database, supplemented by modelling tools from the fields of i) natural, ii) engineering and iii) socio-economic sciences.

Level 2: Implementation of innovative sustainable SHP solutions in CA: Demonstration Activities and Planning Activities

Hydro4U is not a theoretical work, as the innovative hydropower solutions are realized on site within the project lifetime (WP3 and WP4) in the two project Demonstration Activities in Shakhimardan site (UZB) and the At-Bashy River (KGZ). In order to demonstrate that the solutions will also work under different conditions on other sites, virtual follow up studies are conducted in the so-called Planning Activities (PA), that are being developed in three planning sites throughout the region and which will end in **technical and bankable feasibility studies** (WP5). This work constitutes the basis and background to create overall guidelines and a comprehensive framework for a replication guideline with respect to existing EU and CA regulations, guidelines and legislatives.

Level 3: Decision support

Hydro4U wants to show that SHP can be standardized and thus significantly increase efficiency in terms of cost and time. Level 3 is primarily about harmonizing the potential of

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Level 1 with the hydropower solutions and guidelines of Level 2. The target group is not just a few experts who are familiar with the specific details, but broadly-based decision makers, investors and politicians (public use). Considering the above mentioned, Hydro4U shapes the forward-looking long-term development of a region and enables growth and prosperity. Hydro4U provides this group with a decision-support tool, i.e. the **interactive Replication Guideline tool** (WP5), based on the available potential and appropriate technical solutions, considering related factors such as WFEC Nexus, climate impact and socio-economic viability.

In addition, the relationship between WP5 and the different activities of the rest of the WP of the Project are shown in the Table 1 below:

Table 1: Relation to other activities in the project

R&D activities within WP1-WP4		Replication approach within WP5
WP1	Definition of the methodology to calculate SHP potential in CA and further quantification (Task 1.2)	Assessment of the impact of the estimated SHP potential in the region (Chapter 5 of this report) and integration of the methodology in the assessment of HP scenarios (Task 5.2)
WP1	Definition of a methodology for site assessment, GIS tool development and validation in 10 sites (Task 1.3-1.7)	Use of this methodology in the selection and assessment of the Planning Activities (Task 5.3)
WP2	Innovative web-based WFEC accounting system (Task 2.2): Count4D. Online nexus toolbox based on an innovative monitoring and accounting methodology	Synergies with this new online Nexus toolbox will be considered during the design of the replication guideline tool (Task 5.4).
WP3	Analysis of the optimization potential of SHP technologies to be demonstrated HSPS and FCPS (Task 3.1)	The optimized SHP technologies will be promoted via the replication products of WP5. Additionally, a screening of other SHP technologies will be performed to include other European SHP technologies matching the conditions in CA.
WP3	Demonstration Activities (Task 3.5)	The demonstrated SHPs of Hydro4U in Central Asia, will serve as best practice examples how to plan, finance, build and operate SHP in a sustainable way. The findings from the demonstration activities will be promoted in the Replication guidelines, having a lighthouse character.
WP4	Assessment strategy integrating environmental, financial and socio-economic sustainability (Task 4.3)	Hydro4Us sustainability assessment strategy elaborated at the demonstration sites will be integrated with international standards, such as IHA protocols and WB guidelines.
WP4	Demo-site design development and optimization (Task 4.4), Demo-site implementation (Task 4.7), Assessment of the operation (Task 4.8)	The detailed planning at the demonstration sites will be included in the replication documents as best practice examples and blueprints for future SHP projects in CA.

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2.4. Contribution of Partners

In total, four partners are involved in Task 5.1. CARTIF as the task leader and the partners BOKU, TUM and KSTU contributed with different shares to this deliverable. See Table 2 below for a detailed work description per partner.

Table 2: Contribution of Partners to D5.4

Partner Short name	Contributions
CARTIF	CARTIF has coordinated the execution of this deliverable. CARTIF has been responsible for the description of the political context regarding water management and hydropower production (Chapter 4) and the overview of ongoing initiatives for the development of SHP in CA (Chapter 5.5). Moreover, CARTIF gives an updated description of the guidelines for promoting SHP projects in Central Asia, including economic, legal, political, environmental and social guidelines (Chapter 6) and the replication guideline tool (Chapter 7).
BOKU	BOKU contributed to this report by giving an overview of the sustainable HP potential of CA, including updated maps (Chapter 5). This has been addressed within Task 1.2 and was discussed in detail in D1.4. Here, these assessments, approaches, and results are placed in the context of developing a replication plan.
KSTU	KSTU has been responsible for the overview of the electricity sector in Central Asia (Chapter 3) and the revision of the political context regarding water management and hydropower production (Chapter 4).
TUM	TUM contributed to the guidelines for technical design (Chapter 6.1), including the lessons learnt in the process.

2.5. Definitions

Small Hydropower (SHP): The definition of SHP varies throughout the Central Asia region. Kazakhstan (KAZ) has the highest upper limit of installed capacity in its definition of SHP, at 35 MW, while Kyrgyzstan (KGZ), Uzbekistan (UZB) and Tajikistan (TAJ) maintain a 30 MW limit. Turkmenistan does not have an official definition. The standard EU definition up to 10 MW is used in the present report.

Gross theoretical SHP potential: It expresses the total amount of electricity that could potentially be generated if all available water resources were devoted to this use. The gross capacity of a HP plant in a river can be calculated as:

$$P = \rho \cdot g \cdot H \cdot Q \qquad (1)$$

where P is the hydropower capacity (in W), ρ is the density of water (kg/m^3), g is the gravitational acceleration (m/s^2), H is the head (m) and Q is the discharge (m^3/s). The maximum annual energy production is reached when 100% of the annual runoff is used for hydropower production (i.e. gross potential).

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Technically exploitable SHP potential: it represents the SHP capacity that is attractive and readily available with existing technology.

Economically feasible SHP potential: it is the amount of SHP generating capacity that could be built at current prices and with a positive outcome after conducting a feasibility study for each site. Technical and economic feasibility is strongly dependent on local conditions and therefore requires in-depth studies at each potential site, which is why we focus on gross theoretical potential.

Remaining sustainable SHP potential: it represents the SHP capacity based on the method developed by Hydro4U (D1.4: "First technical report", De Keyser *et al*., 2023b). The SHP potential was computed using a multistage procedure that progressively breaks down theoretical line potential based on the hydrological conditions to remaining sustainable potential based on environmental parameters, ecological and geomorphological constraints and climate change considerations.

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3. Overview of the energy sector in Central Asia

From the 1970s until 1990, the Central Asia Integrated Power System (CAIPS) was a centralized body which provided electricity to all the CA region regardless of national borders. CAIPS was also in charge of resolving energy and water related problems and generated 30% of electricity from hydropower and 70% from thermal power. After the disintegration of the Soviet Union, the CAIPS collapsed and national electricity systems were separated. As the resources are non-uniformly spread across the countries, supplies of water and power in the region became imbalanced and electricity consumption dropped severely.

The countries of the region can be divided in terms of water resources. Most hydropower resources are concentrated in Kyrgyzstan and Tajikistan, with mountainous territories, e.g., within the Pamir and Tian Shan Mountain ranges and which are considered “upstream” countries (see Figure 2). On the other hand, Kazakhstan, Turkmenistan and Uzbekistan have an abundance of thermal resources such as fossil fuels and can be considered “downstream” countries (Hamidov *et. al*, 2016). This imbalance drove the countries to undertake measures and agree on maintaining parallel operations within the separately functioning power systems (World Bank, 2017a).

Figure 2: Overview of the Central Asian countries and their topography (Data source: https://gadm.org/index.html; Basemap: Esri, 2021)

Economic development and urbanization combined with energy independence have been an impetus for the expansion of the national energy sectors, in particular, electric generation. Electrification rates in the region have been steadily increasing, having reached 100% in all countries, except Tajikistan with 99.3% (World Bank, n.d.).

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Tajikistan and the Kyrgyz Republic are considered the most energy insecure countries in the region. Both nations have the potential to provide major exports of HP in the summer and are therefore important partners in the energy sector. In addition, changes in weather patterns and extreme conditions negatively affect energy supply and power distribution. Severe landslides could permanently affect SHP Plants, as well as other Renewable Energy facilities.

All countries of the region, except Turkmenistan, have adopted primary legislation on renewable energy and energy efficiency. The legislation framework includes introducing incentives such as grid-access, tax exemptions and feed-in tariffs (FITs). FITs have been introduced in Kazakhstan, Kyrgyzstan and Tajikistan. However, starting from 2018, Kazakhstan switched from the FIT system to an auction system (Liu *et al*., 2019).

Compared to the second release of the Hydro4U replication plan (D5.2), this third release includes an updated description of the energy and electricity sectors in CA, including the different renewable energy policies and measures being adopted by each country. This exhaustive revision of the energy and electricity sectors of the CA countries is being very relevant during the development of the WFEC Nexus model within task 5.2, specifically when defining the variables and policies within the Energy sector (see Chapter 7.2 of this document).

3.1. Kazakhstan

3.1.1 Energy sector in Kazakhstan

Energy generation

The country is the largest in the region. About 90% of Kazakhstan has an arid or semi-arid climate. Over 70% of the country consists of desert or steppe. Apart from the mountainous region in the south and southeast of the country, little precipitation falls in Kazakhstan.

Thanks to its natural resource reserves and production capacity of coal, oil and natural gas, Kazakhstan produces more energy than it requires to meet its own needs. In 2020 Kazakhstan exported almost 60% of domestic energy production (see Figure 3).

Fossil fuels historically account for virtually all of **total energy supply** (TES). Coal was the largest energy source in 2020 (50% of TES), followed by natural gas (31%) and oil (18%). The contribution of renewables is currently modest at less than 2%.

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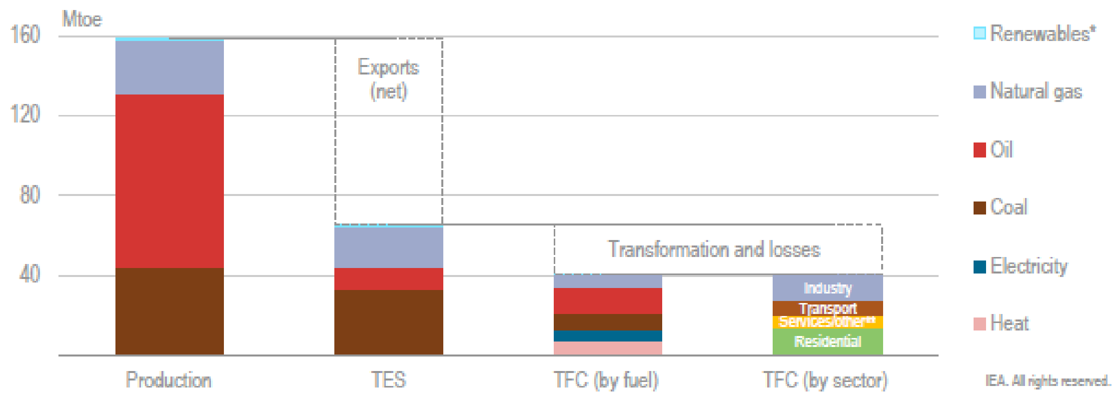

Kazakhstan exports around 60% of its energy production.

* Includes hydro, wind, solar photovoltaic (PV) and solid biofuels.
** Includes commercial and public services, agriculture and forestry.
Notes: Mtoe = million tonnes of oil equivalent. Bunker fuels of around 0.3 Mtoe are not included in TES. Electricity exports accounting for 0.1% of TES (negative) are not shown in the chart.
Source: IEA (2022), *World Energy Statistics and Balances* (database), https://www.iea.org/data-and-statistics.

Figure 3: Overview of Kazakhstan's energy system by fuel and sector, 2022, IEA

Energy consumption

Almost one-third of total final energy consumption (TFC) in 2020 was covered by oil (31%), followed by coal (22%), while heat, natural gas and electricity each account for around 15%. Consumption by the residential sector has grown quickly, accounting for 33% of TFC in 2020. It has surpassed industry (32%) as the largest consuming sector in 2020. Transport accounted for 18% of TFC, while the remainder (16%) was consumed by services and other sectors (see Figure 3).

With the exception of RES, energy prices in KAZ are typically maintained at lower levels not through direct subsidies but through regulatory and administrative measures. For instance, tariffs for conventional power producers fail to adequately incorporate maintenance, replacement costs, as well as environmental and climate externalities. Consequently, RES and other emerging generation capacities face competition from coal plants that operate with amortized costs and do not have to fully consider externalities.

The issue of energy prices is a socially sensitive matter in KAZ. Nevertheless, the Kazakh government could potentially benefit from the successful experiences of other countries that have eliminated price distortions. This could mean that prices are gradually increased over time and subsidies for end consumers or social benefits are specifically targeted at the most vulnerable population groups.

Energy sector governance

The main institutions in Kazakhstan's energy sector are the following:

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- The Ministry of Energy is the main policy-making body, with regulatory authority over oil and gas exploration and production, oil refining, gas processing, the coal sector, and nuclear energy.
- The Ministry of National Economy is responsible for macroeconomic policy. It also oversees the country's long-term carbon-neutral development.
- The Ministry of Ecology, Geology and Natural Resources is responsible for environmental protection and the development of the "green economy". The Department of Climate Policy and Green Technologies is responsible for climate policy and the implementation of the United Nations Framework Convention on Climate Change (UNFCCC) related commitments and other international agreements in the field of climate change.
- The Ministry of Industry and Infrastructure Development is responsible for industrial policy covering the country's most important energy-consuming industries (mining, metallurgy and chemicals).

3.1.2 Electricity sector in Kazakhstan

Electricity generation

In 2020, the volume of electricity generation amounted to 110.9 TWh (coal 67.3%, natural gas 21.7%, hydro 8.7%, solar 1.3%, wind 0.9%, oil 0.1%, bioenergy <0.1%), +34.2% since 2010.

As of the beginning of 2021, Kazakhstan had **179 power plants** with a total installed capacity of 23.6 GW and an available capacity of 20.1 GW (KEGOC, 2021). Power plants are divided among various forms of ownership, including national power plants, industrial power plants and regional power plants. KAZ's power sector is dominated by coal. Overall, about 57% of total installed capacity is coal-fired. In second place is gas-fired capacity with around 25%, which is largely based on steam turbines that can also be operated with fuel oil. RES, including hydropower, wind power, solar power and biogas, account for nearly 18% of installed capacity, or 6% if hydropower is not included.

Electricity consumption

Electricity consumption amounted to 105.1 TWh, which indicates the full coverage of the country's economy's need for electricity. By Decree of the Minister of Energy of the Republic of Kazakhstan dated January 15, 2020, No. 15, the forecast balance of electric energy and capacity for 2020-2026 was approved. According to this, the volume of generation and consumption of electrical energy should be as shown in Table 3.

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Table 3: Forecast balance of electric energy and capacity for 2020-2026

Year	Production (TWh)	Consumption(TWh)
2020	110.9	105.1
2021	113.5	110.7
2022	116.1	112.7
2023	120.9	114.5
2024	123.5	118.0
2025	128.1	120.8
2026	128.5	124.1

Electricity transmission sector

The electric networks in KAZ are a set of substations, switchgears and power transmission lines connecting them with a voltage of 0.4–1150 kV, intended for the transmission and (or) distribution of electrical energy. The role of the backbone network in the United energy System is performed by the national electric grid, which provides electrical connections between the regions of KAZ and the energy systems of neighbouring states (the Russian Federation, KGZ and UZB), as well as the issuance of electrical energy by power plants and its transmission to wholesale consumers. Substations, switchgears, interregional and (or) interstate power lines and power lines that supply electric power to power plants with a voltage of 220 kV and above, which are part of the National Power Grid, are on the balance sheet of KEGOC JSC.

Electric networks of the regional level provide electrical connections within the regions, as well as the transmission of electrical energy to retail consumers. Electric networks of the regional level are on the balance and operation of 19 regional electric grid companies, including the transmission of electric energy, which is carried out by 130 smaller electricity transmission organizations.

Power transmission organizations carry out the transmission of electrical energy to consumers in the wholesale and retail markets or to power supply organizations on the basis of contracts via owned or used (rental, leasing, trust management and other types of use) power grids.

3.1.3 Renewable energy in Kazakhstan

In 2021, **134 RES facilities** supply power to the grid in KAZ with a total installed capacity of more than 2 GW. Most of the electricity generated from RES came from large HPPs (1.6 GW), though only around 1% of this came from SHP (IEA Kazakhstan 2022, Energy Sector Review). The share of RES in Kazakhstan's TES is currently low, varying between 1% and 2%.

Initially relying on FITs, KAZ shifted **to auction-based tariff** determination for renewable energy projects from 2018 onwards. During the period 2018-2021, over 1,700 MW of

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renewable energy capacity were auctioned, resulting in the realization of 75 projects. Auction-based power purchase agreements (PPAs) allow electricity producers to sell their entire output to a designated centralized buyer of renewable energy and therefore benefit from priority dispatch.

As renewable energy capacity in KAZ continues to grow, integration poses an increasing challenge. The power system, dominated by coal-fired baseload capacity, lacks the necessary flexible capacity to swiftly accommodate the intermittent nature of RES. In December 2021, KAZ expanded its auction approach, similar to that used for RES, to attract investments in flexible generating capacity, including large gas-fired and hydropower projects.

Currently, there's no incentive for RES projects in KAZ to incorporate storage, as auction rules don't mandate it, and resulting PPAs relieve developers of financial responsibility for balancing. However, inclusion of storage would significantly increase costs and possibly lead to higher tariffs than the current ones.

A crucial consideration is that if tariffs comprehensively accounted for the long-term upgrade and replacement costs and environmental impacts of conventional power producers, RES would likely be in a much stronger position to compete in the power market, especially in developing flexibility through energy storage.

3.1.4 Renewable energy policies and measures

In 2012, the government launched the "Kazakhstan 2050 strategy" which identified policies and reforms aimed at placing Kazakhstan among the top 30 economies in the world by 2050.

Then, in 2013, the Kazak government defined the **Green Economy concept** (IEA Kazakhstan 2022, Energy Sector Review). According to this national Action plan for transitioning to a green economy, the share of alternative and RES including nuclear, should be 3% by 2020, 15% by 2030, and 50% by 2050 (Liu *et al.*, 2019). The plan pledges to reduce the country's GHG emissions by phasing out ageing infrastructure, promoting energy efficiency and introducing a pilot emissions trading system. In 2020, the government adopted an Action Plan for implementing the Green Economy Concept.

There is considerable interest from investors to develop SHP in KAZ, with many new prospective projects. In the course of the **Action Plan for 2050**, 106 facilities with a total capacity of 3,055 MW are planned (IEA Kazakhstan 2022, Energy Sector Review): (i) 41 SHP plants (totalling 539 MW), (ii) 34 wind farms (totalling 1,787 MW), (iii) 28 solar parks (totalling 714 MW) and (iv) 3 biofuel plants (totalling 15 MW).

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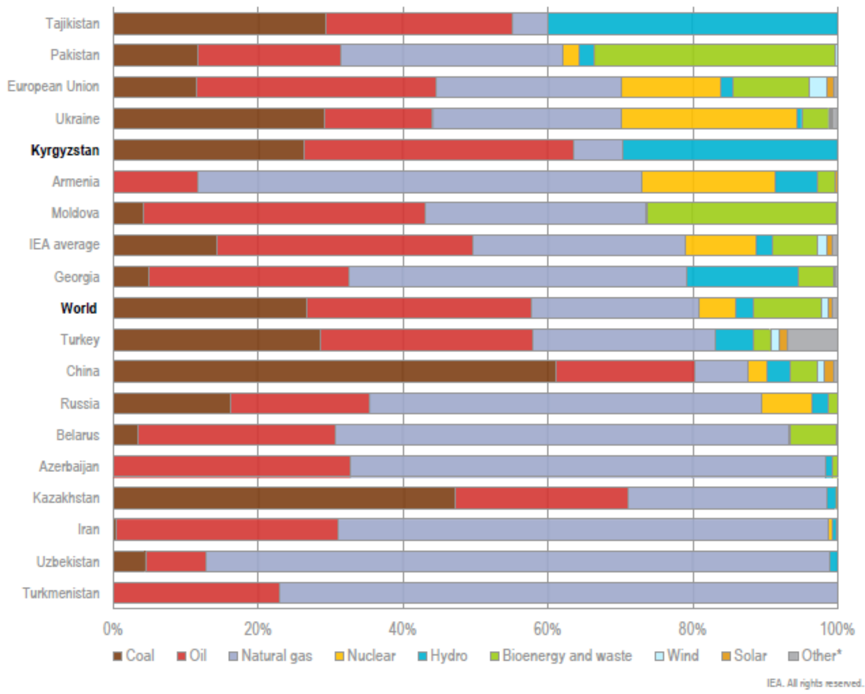
3.2. Kyrgyzstan

3.2.1 Energy sector in Kyrgyzstan

Energy generation

The energy sector represents 4% of GDP and 16% of industrial production, and hydropower accounts for two-thirds of energy production. KGZ exploits coal and some oil and gas, but most hydrocarbons are imported. In fact, it relies on oil and gas imports for more than half of its energy needs, particularly during the winter months when hydropower production is low. For this reason, regional integration with neighbouring countries is important.

Total energy supply (TES). As it can be seen in Figure 4 below, oil was the largest energy source in 2020 (33.4% of TES), followed by hydro (31.8%), coal (27.1%) and natural gas (7.5%). There is no official data available on the contribution of renewables or other consumption of renewable energy (IEA Kyrgyzstan 2022, Energy Sector Review).



Source: IEA (2022), World Energy Statistics and Balances (database), https://www.iea.org/data-and-statistics

Figure 4: Breakdown of total energy supply in Kyrgyzstan, 2019

The high availability of energy resources created favourable conditions for the rapid development of the energy complex of KGZ, which since the beginning of the 80's has become a major producer of hydropower in CA, and supplied up to 50% of the generated cheap and environmentally friendly electricity to the IPS of Central Asia. The energy system operates **18 power plants** with an installed capacity of 3,666 MW, **including 16 HP plants** and **two thermal power plants**. The maximum possibility of annual electricity generation reaches 15

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billion kWh. The energy system of KGZ fully provides the sectors of the economy and the population with electric energy and ensures export to other countries. It has a connection with the states of CA via 220-500 kV main networks and operates in a single energy mode. Through the backbone networks of KAZ, there is access to the energy system of the Russian Federation. Kyrgyzstan is a stable exporter of electricity to KAZ, UZB and China. The volume of exports is 2-2.5 billion kWh per year, which can be increased to 3.0 billion kWh.

The energy sector faces challenges that have accumulated and worsened over the years. The country has an energy deficit driven by insufficient generation, especially in the winter when demand is 2.5-3 times higher than in summer. The total losses in the sector are about 20% of net generation, more than twice as high as commercial and technical losses in high- and some middle-income countries. About half of generation capacity and up to 70% of distribution assets are beyond their useful lives, leading to frequent supply disruptions due to equipment failures and overloading across the country. Moreover, KGZ has one of the lowest electricity tariff rates in the world. The sector is heavily indebted, with cumulative debt of above KGS 130 billion (equivalent to about $1.5 billion) or around 20% of the GDP, placing a heavy fiscal burden on the country.

Energy consumption

As it can be seen in Figure 5, the Total final consumption (TFC) in 2020 was 3.2 million tonnes of oil equivalent (Mtoe), of which 37% was oil, 33% electricity, 15% coal, 9% district heat and 5% natural gas. Also, the residential sector accounted for 47% of the TFC, followed by the transport sector (34%). The remaining amount was reportedly consumed by industry (9%), and services and other sectors (11%). From August 1, 2023, an emergency situation regime began to operate in the Kyrgyz energy industry. Because the growth rate of electricity consumption in KGZ is noticeably ahead of its generation capabilities; in addition, the country annually faces the negative consequences of climate change, and the water inflow in the Naryn River basin is decreasing. The government calls on the citizens of the republic not to worry, since the introduction of an emergency regime in the energy sector only gives the relevant ministry more opportunities to develop the fuel and energy complex.

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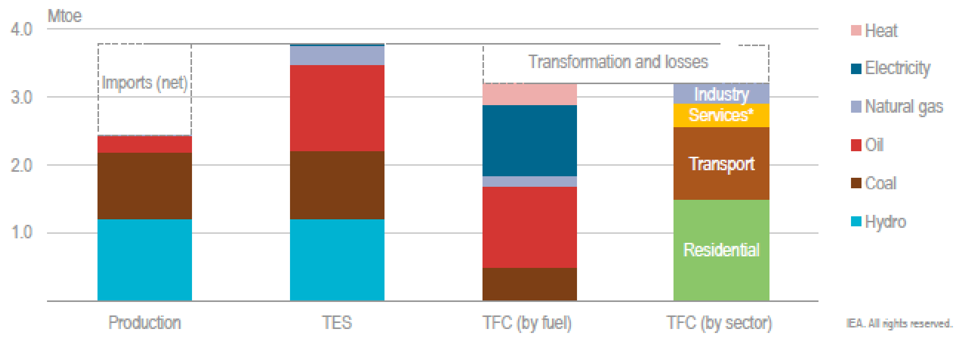

Bunker fuels of around 0.01 Mtoe are not included in TES. Consumption of solid biofuels not quantified and therefore not present in the figure.

* includes commercial and public services, agriculture and forestry and unspecified energy consumption.
Note: Mtoe = million tonnes of oil equivalent.
Source: IEA (2022), World Energy Statistics and Balances (database), https://www.iea.org/data-and-statistics

Figure 5: Overview of Kyrgyzstan's energy system by fuel and sector, 2022, IEA

Energy sector governance

State management in the energy power industry is carried out through the State Fund for State Property Management and the Ministry of Energy of the Kyrgyz Republic. Regulation of the energy sector is implemented by four public bodies (Figure 6):

- Ministry of Energy, develops forecasts, analyses and evaluates the energy development of KGZ. It provides and implements state policy in the fuel and energy complex.
- State Agency for Regulation of the Fuel and Energy Complex, licensing of subjects of the energy sector, tariff policy.
- State Inspectorate for Environmental and Technical Safety, implementation of control and supervision over ensuring the reliability, security and uninterrupted power supply in the production, transmission, distribution and consumption of energy and natural gas.
- National Energy Holding Company, management of energy joint-stock companies - subjects of natural monopolies.

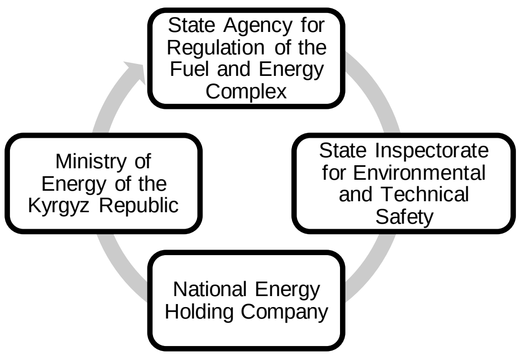

Figure 6: Management structure of the energy sector of the Kyrgyz Republic

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In order to ensure effective management of the energy industry, reliable energy supply to consumers, and improve the quality of energy services, on February 8, 2022, the Concept for Restructuring the Energy Management System of the Kyrgyz Republic No. 51-r was approved. According to which, the reorganization was carried out in three key areas (see Figure 7 below):

1) association of distribution energy companies (OJSC "Severelectro", OJSC "Vostokelektro", OJSC "Oshelectro" and OJSC "Jalalabatelectro").
2) association of energy companies (OJSC "Electric Stations" and OJSC "Bishkekteploset").
3) consolidation of the assets of JSC "National Electric Grids of Kyrgyzstan" and the united RECs with the allocation of the function of selling electric energy.

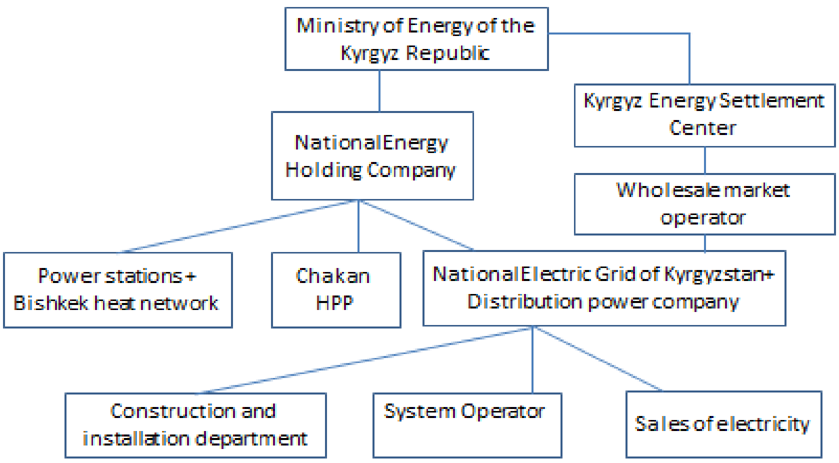

Figure 7: Management structure of the energy sector of the Kyrgyz Republic after the restructuring.

3.2.2 Electricity sector in Kyrgyzstan

Electricity generation

The electrification rate in the Kyrgyz Republic is 100% (World Bank, 2017b). Kyrgyzstan's power sector is relatively small with total generating capacity of around 3.9 gigawatts (GW), producing around 15.4 terawatt-hours (TWh) in 2020.

Electric energy in KGZ is supplied by a hydroelectric system and by a thermal generation system. The hydroelectric system consists of several power plants which, in their majority, operate with water released from the Toktogul reservoir and are known as the Naryn Cascade. The storage capacity of Toktogul allows regulation of the flow of the Naryn River between the wet spring and summer months and the dry winter months as well as allowing some mitigation of longer-term dry and wet hydrology cycles. The thermal system consists of co-generation

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plants which supply electricity to the power grid and hot water and steam to the municipal heating network (IEA Kyrgyzstan 2022, Energy Sector Review).

Electricity consumption

Electricity consumption in 2020 amounted to 12.3 GWh. Residential customers account for the largest share of consumption – 76%, and almost three times more than in 2010. Industry, dominated by manufacturing and some mineral extraction, accounted for 12% (down by 20%). Services covered 9% of demand in 2020. Agriculture accounted for 1.5% with reported consumption having declined by half since 2010. The transport sector consumed only about 0.1%, although its share is likely to grow in the coming years.

Growth in residential consumption was driven largely by the increased use of electricity for heating. This was triggered by a combination of low electricity tariffs (under USD 0.01) and rising fossil fuel prices.

Monthly electricity consumption peaks around January, with the peak having increased notably in the last decade. A local peak is observed also in July, mostly due to irrigation and cooling needs. Domestic consumption has reached the available generation capacity (IEA Kyrgyzstan 2022, Energy Sector Review).

Electricity transmission sector

The history of the development of electrical networks in KGZ is closely connected with the overall development of the energy sector of the republic. With the growth of the capacities of power plants, their combination for parallel operation, the centralization of power supply, the voltage classes of power transmission lines and their length grew. In 1934, the Bureau of the Kyrobkom of the All-Union Communist Party of Bolsheviks adopted a resolution on the transfer of the Frunze city networks to a voltage of 6 kV, the creation of a dispatch service and the approval of the organizational and structural body for managing the Frunze energy system - the FOGES trust. Since the adoption of this document, the history of the development of the energy system of Kyrgyzstan has begun.

Figure 8 shows the structure of the electric power industry of the Kyrgyz Republic, with several generating, transmission and distribution companies:

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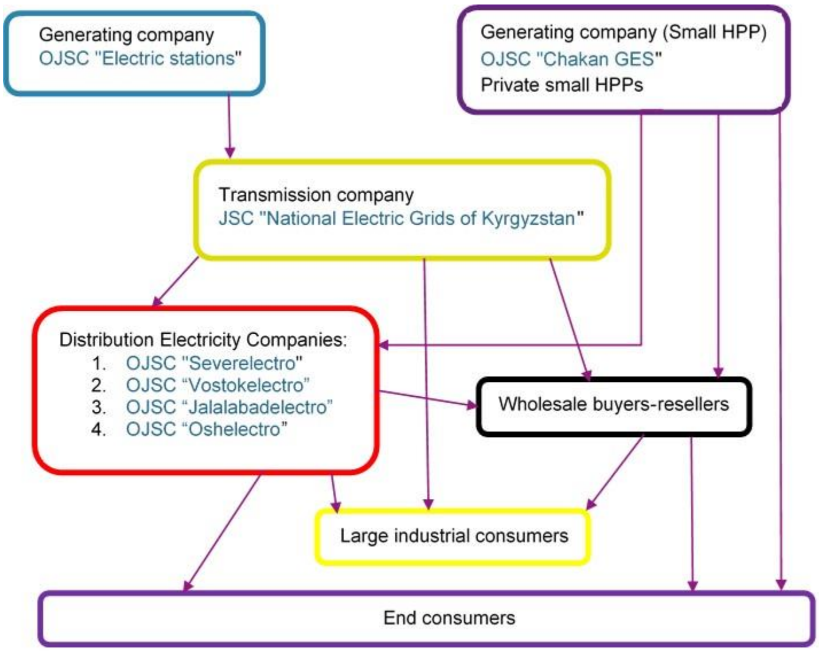

Figure 8: Structure of the electric power industry of the Kyrgyz Republic

Generating companies:

OJSC "Electric stations"**,** is the basis of the Kyrgyz electric power industry. The generating company generates 98% of all electricity in Kyrgyzstan, provides domestic and foreign consumers with it, regulates the frequency in the Central Asian Unified Energy System. The company includes 7 HPPs and 2 CHPs. These are HPPs: Toktogulskaya, Kurpsaiskaya, Shamaldysayskaya, Tash- Kumyrskaya, Uch-Kurganskaya, Kambarata-2 and At-Bashinskaya. Of these, Toktogul HPP produces 30% of all electricity in the country.

JSC "Chakan GES", the main activities are the generation, transmission and sale of electricity. The company includes 9 small HPPs with a total capacity of 38.5 MW.

Transmission company:

JSC "National Electric Grids of Kyrgyzstan", is an energy company that transports electricity generated by power plants through high-voltage networks throughout the Kyrgyz Republic to distribution companies and large industrial consumers. Also, JSC "National Electric Grid of Kyrgyzstan" is a system operator that carries out centralized operational and dispatch control of the national energy system of Kyrgyzstan. The company has high-voltage electrical networks, including:

- Overhead transmission lines of 110 kV, 220 kV and 500 kV with a total length of 7641 km;
- 119 substations with a voltage of 110 - 500 kV, divided in: 181 substations of 110 kV, 14 substations of 220 kV and 4 substations of 500 kV.

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Distribution Electricity Companies (OJSC "Severelectro", OJSC "Vostokelectro", OJSC "Jalalabadelectro", OJSC "Oshelectro"), carry out the purchase, transportation, distribution and sale of electricity generated in the republic for the domestic market, as well as repair, maintenance and operational maintenance of distribution electrical networks with a voltage of 35-10-6-0.4 kV throughout the country.

Finally, private companies ("NK GROUP" LLC, "Ak-Terek HPP" LLC, "Kochkor HPP" LLC, "Koisuu HPP" LLC, "Tegirmentinsky HPP" LLC), carry out electrical installation work, construction and electricity generation by hydroelectric power plants.

There are also 16 wholesale buyers and resellers of electricity, 21 private companies which operate portions of the distribution network in certain areas of Bishkek and one district heating company (JSC Bishkekteploset). The Kyrgyz Government owns nearly 95% of the shares of the energy sector companies (World Bank, 2017c).

3.2.3 Renewable energy in Kyrgyzstan

The Kyrgyz Republic has fairly good Renewable energy resources. This is especially true for hydropower resources, the potential of which is estimated at 142 TWh, of which about **10% have been developed to date**. More than 10,000 km of high-voltage transmission lines with a voltage of 35-500 kV, more than 70,000 km of distribution networks of 10-0.4 kV, 518 units of substations of 35 kV and above are in operation. The maximum potential for annual electricity generation exceeds **15 TWh**.

3.2.4 Renewable energy policies and measures

The development of SHP and other RES has been of high importance for many years in Kyrgyzstan, but so far hardly any national plans have been consistently fulfilled. The main laws of primary energy sector legislation affecting the electricity sub-sector and RES are:

Law of the Kyrgyz Republic "On Energy". adopted on 30 October 1996, No. 56, since then amended three times, the most recent being on May 16, 2008. It contains a delegation of norms which allows the Government and the Authorized Government Body in the Energy Sector to exercise significant powers.

Law of the Kyrgyz Republic "On Renewable Energy Sources", as of 31 December 2008, No. 283, supports RE development and includes main RE definitions. Amendments were made in terms of tariff surcharges for each type of RE source.

Additional laws are:

- Law of the Kyrgyz Republic "On Electric Power Industry".

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- Law of the Kyrgyz Republic “On Energy Saving”.
- Law of the Kyrgyz Republic “On energy efficiency of buildings”.

Finally, there are several State programs, plans, strategies and other government documents on sustainable development in the energy sector. Their potential influence on the exploitation on SHP will be elaborated in further version of the replication plan.

Issues and problems of energy security are becoming more acute and relevant every year. To date, the entire produced electrical energy in the amount of about 15 billion kWh has been consumed by KGZ exclusively for its own needs and has moved from the category of export-oriented countries to the category of import-oriented ones. In addition, it is necessary to note the annual growth of domestic consumption of electrical energy. Dependence on external supplies of electricity reduces the energy security of the country and supports the economy of exporting countries instead of the economy of the Kyrgyz Republic. Therefore, the problem of commissioning new capacities is acute today. In the context of a shortage of large generating capacities, the use of renewable energy opportunities should be an important direction for ensuring energy security, solving problems of local energy supply and ensuring sustainable development of the country’s remote areas.

The Kyrgyz Republic has set a target to reduce greenhouse gas emissions by 44% by 2030 and achieve carbon neutrality by 2050. Kyrgyzstan recognizes that renewable energy sources, primarily hydropower, will be the driving force behind zero-carbon policies given their huge potential in the country. The issue of increasing the share of renewable energy sources is a strategic direction today. Is clear the importance of national policies and strategies to increase the use of new and renewable energy sources and carbon reduction technologies, including cleaner fossil fuel technologies.

On October 30, 2020, The Government of the Kyrgyz Republic approved the “Regulation on the conditions and procedure for the implementation of activities for the generation and supply of electrical energy using renewable energy sources” No. 525.

On June 16, 2022 was adopted the New Law of the Kyrgyz Republic Parliament “On Renewable Energy Sources”.

This is a big step towards the real introduction of renewable energy in the Kyrgyz Republic.

A lot of work is being done to financially rehabilitate the energy sector, create a competitive environment and attract investment. The Kyrgyz Republic announced an ambitious “**Electricity Sector Modernization and Sustainability Project**” during the Bishkek International Energy Forum in April 2022. The World Bank’s Board of Executive Directors has

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approved a $50 million project to support the Government of the Kyrgyz Republic in improving the financial performance and operational reliability of the electricity sector in the country. The financing for this Project is provided on highly concessional terms through the International Development Association (IDA). Half of the funding is allocated in the form of a grant, which requires no repayment, while the other half is a credit with a 0.75% administrative fee, the repayments of which are spread out over 38 years, with a six-year grace period. The project is also co-financed by the Swiss State Secretariat for Economic Affairs that will provide additional $8 million in grant funding. The "Electricity Sector Modernization and Sustainability Project" aims to put the electricity sector on a sustainable path and to transform it into a driver for economic growth, job creation, and improvement of the welfare of all citizens. The Project will help improve the financial performance, ensure a reliable electricity supply for the people and businesses, and create a supportive social protection mechanism to the vulnerable groups. Finally, the project will finance soft and hard investments that are urgently needed to improve performance of the energy sector in four main areas: (i) Rehabilitation and Upgrade of Distribution Networks, (ii) Digitalization of Distribution Network, (iii) Strengthening Social Protection Systems and (iv) Institutional Development.

In 2022 the Kyrgyz authorities announced that in the upcoming years, hundreds of new SHP Plants should be put into operation (Big Asia, 2022). The State Committee for Industry, Energy, and Subsoil Use plans to **build and rehabilitate 136 SHP plants** (<30 MW) by 2025 with a total capacity of 278 MW. Among them, 22 promising sites have been identified for SHP Plants in the Naryn region which have also been approved by the government. The design work of these 22 potential SHP Plants are finished and construction has started. Currently, the construction of the Kulanak HPP cascade on the Naryn River is underway.

3.3. Tajikistan

3.3.1 Energy sector in Tajikistan

Energy generation

Tajikistan's energy system depends primarily on hydroelectricity, coal and oil. Hydropower and coal are produced domestically whereas virtually all oil and gas must be imported to meet the demand. This also explains the high share of electricity in final consumption, as well as the increasing use of coal in both transformation and industries. In 2020, TES was 3.7 Mtoe, of which over two-thirds were covered by domestic energy sources. Fossil fuels (natural gas, coal and oil) accounted for around 60% of TES.

Energy consumption

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Tajikistan's TFC amounted to 3.1 Mtoe in 2020, an increase of 58% since 2010. Demand in the residential, industry and transport sectors has seemingly grown, but uncertainty in the historical data hinders the trend analysis. In 2020, the residential sector consumed 33% of TFC, followed by transport (30%) and the industrial sector (20%). Services consumed 9% of TFC and agriculture 7%. Consumption in agriculture has decreased by 27% since 2010. Fossil fuels (mainly oil and coal) accounted for 53% of the TFC in 2020. However, the share of electricity – 43% of TFC – is among the highest in the world. The domestic hydro resource has resulted in high rate of electrification in industry and residential sectors. Natural gas and district heat play only minor roles in the TFC (around 3-4% each). An energy consumption survey conducted by TajStat in 2016 indicates the consumption of bioenergy, particularly by households, may be grossly underestimated (IEA Tajikistan 2022, Energy Sector Review).

Energy sector governance

Regulation of the energy sector is implemented by means of three public bodies:

- The Ministry of Energy and Water Resources is responsible for licensing, approval of investment plans and technical and safety standards.
- The Antimonopoly Service is responsible for the regulation of the energy sector, tariff methodology and tariff level proposals. Final approval and amendment of tariffs for the end-users is within the competency of the President.
- Barki Tojik is a vertically integrated state-owned national power utility. Electricity prices are raised on an annual basis and the tariffs vary by customer type. Due to a high poverty rate in the country, current electricity tariffs are still below the supply costs and are among the lowest in the world. Because of this, the company is continuously running at a loss. There is no sufficient funding to fully cover the operation and maintenance costs of the power plants, so Barki Tojik is using external funding from the international landers for this purpose.

3.3.2 Electricity sector in Tajikistan

Electricity generation

Gross electricity generation in 2020 was 20.1 TWh. As it can be seen in Figure 9, a large majority – 90% – of this was generated from hydro, the rest being mainly from coal (8%) and natural gas (2%). While still relatively low, the share of thermal generation has grown rapidly. A new 400 MW coalfired co-generation plant was commissioned in 2013, and natural gas was reintroduced in the electricity mix only in 2019 after the supplies had been cut off since 2013. Total annual power generation has increased 3.7 TWh, or over 20% since 2010, with similar

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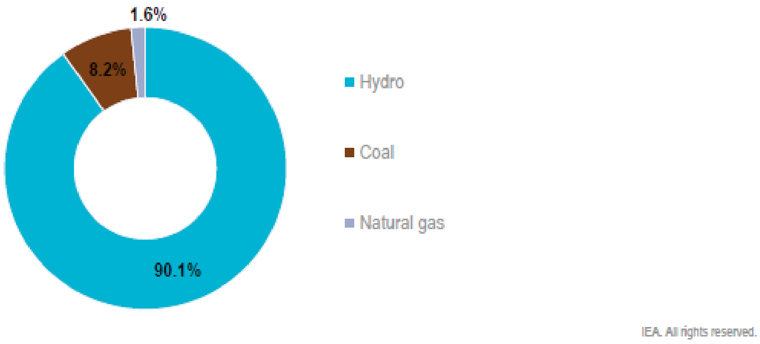
increases in electricity generated from coal and hydro (1.7 TWh each). The rest is attributed to natural gas (IEA Tajikistan 2022, Energy Sector Review).



Hydro is the key energy resource in Tajikistan.

Source: IEA (2022), *World Energy Statistics and Balances* (database), https://www.iea.org/data-and-statistics.

Figure 9: Electricity generation by source, 2020

Electricity consumption

Electricity consumption in 2020 was 15.4 TWh, an increase of almost 10% since 2010. The residential sector accounted for the largest share of consumption at 44%, up 40% since 2015. While in 2020 consumption shares in industry (18%) and services (20%) were roughly equal, their demand patterns are opposite: industry consumption has shrunk by 29% since 2015 whereas consumption in services has almost tripled (+174%) in the same time period. Agriculture – mainly irrigation – consumed 17% of the total and has also contracted notably since 2015 (-32%).

Given that the majority of the electricity is generated via hydro, energy sector own use is very low (0.4%). While transport has always presented only a fraction of electricity consumption (<1%), it is worth noting that only since 2015 consumption has decreased by 79% (IEA Tajikistan 2022, Energy Sector Review).

3.3.3 Renewable energy in Tajikistan

The share of RES in Tajikistan's TES is among the highest in the world due to large hydropower resources and a high rate of electrification. Between 2000 and 2015 around 99% of electricity was generated with hydro, the share being above 90% still in 2020. With the upcoming capacity additions like the Rogun dam under construction, which is planned to have a power output of 3,600 MW (IHA, 2018), the share is likely to increase again. The dominance of hydropower in RES leads to similarities in the patterns of RES in TES and in TFC.

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According to the available data, hydropower accounts for all of the total renewable energy supply in the country. However, the household energy consumption survey conducted in 2016 revealed the magnitude of bioenergy (mainly fuelwood) use that is almost on par with the hydro contribution to the TES (1.2 Mtoe versus 1.6 Mtoe). Wind power and solar PV are yet to be introduced to the Tajikistan's energy system (IEA Tajikistan 2022, Energy Sector Review).

3.3.4 Renewable energy policies and measures

The **Strategy 2030** sets the task to improve the "state of housing and communal services (housing and communal services) of settlements (water supply, sewerage, gas, heat, electricity, collection and utilization of domestic waste)", which in particular will help solve a number of environmental problems. In order to optimize the environmental situation in the transport sector, it is proposed to develop and enforce environmental requirements for transport. The Strategy 2030 also looks at the implementation of energy-efficient technologies in production: the provision of rational production models will be achieved through the introduction of new energy- and resource-saving technologies, reducing waste and CO_2 emissions, thus creating opportunities for green employment.

The incorporated common mechanisms in the Strategy 2030 are described in greater detail in sectoral programmes (Action Plans), in particular in the Programme for the Development of RES and Construction of SHP Plants for 2016-2020, which specifies the RES facilities that need to be built and proposes a mechanism for obtaining more accurate figures on the potential for RES and the elimination of unnecessary administrative barriers (IEA Tajikistan 2022, Energy Sector Review).

Currently, Tajikistan aims to complete the Rogun dam which is under construction and planned to have a power output of 3,600 MW (IHA, 2018). While other new hydropower plants have already been commissioned, this plant is scheduled to achieve full operational capacity by 2028 (NS Energy, n.d., Rogun HP project). Further hydropower investments include the modernization and rehabilitation of other HP Plants:

- The Nurek HPP is currently with 3 GW the biggest plant of its kind in Central Asia. The rehabilitation of the plant is supposed to lead to an increase of 300 MW and is expected to be completed by 2028 (NS Energy, n.d., Nurek Hydropower Plant Rehabilitation Project).
- The modernization of the Qairokkum HPP started in 2019 and is planning to upgrade the plant from 126 MW to 174 MW (NS Energy, n.d., Qairokkum Hydropower Rehabilitation Project).

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Regarding SHP, a capacity of 47 MW is being planned (Available at https://www.undp.org/sites/g/files/zskgke326/files/migration/eurasia/Tajikistan.pdf).

In addition to national efforts, it is also recognized that energy security at the national level requires transnational solutions. The Central Asia-South Asia power project (CASA-1000) is an energy infrastructure project, connecting KGZ and TAJ as electricity exporters with Afghanistan and Pakistan as electricity importers via a 1,200 km long 500 kV line. The project was approved in 2012 and the construction began in 2019. Tajikistan completed the construction in 2022 (IEA, Tajikistan 2022 Energy sector review, 2022) and Kyrgyzstan was expected to complete the activities in 2023 (IEA, Kyrgyz Republic - Energy Profile, 2021).

3.4. Turkmenistan

3.4.1 Energy sector in Turkmenistan

Energy generation

Turkmenistan has a continental and very dry climate. The Kara Kum Desert covers more than 80% of Turkmenistan's territory. Turkmenistan has one of the largest proved natural gas reserves in the world, thus the country generates 99.8% of its electricity from natural gas and only 0.02% from HP (Liu *et al*., 2019). According to International Energy Statistic, in 2021 in Turkmenistan, the total production of primary energy was 3.696 Btu (British thermal unit), while consumption was at the level of 1.895 Btu. Thus, the share of domestic consumption in primary energy production was 51,27%. This makes Turkmenistan a country independent of energy imports (https://aenert.com/countries/asia/energy-industry-in-turkmenistan/).

Energy consumption

In recent years the energy sector of Turkmenistan received a powerful impetus in its development, thus fully meeting the growing demand of domestic consumers and to organize the export of energy supplies in neighbouring countries. Power is the largest consumer of fossil fuels and natural gas in industry (80-85%). The share of industry in gross domestic consumption of gas fuel over 20%. Per capita consumption is 4.4 toe, with electricity accounting for around 2 600 kWh in 2021.Total energy consumption has been increasing by 3.4%/year since 2018, reaching 27 Mtoe in 2021. It had increased rapidly from 2000 to 2015 (4%/year, on average) and then remained stable until 2018. Natural gas represents 71% of that consumption and oil 28% (https://www.enerdata.net/estore/country-profiles/turkmenistan.html).

Energy sector governance

Cabinet of Ministers and the Ministry of Energy are the electricity sector's two main regulators. The country's priority is to develop gas exports and, to a lesser extent, oil exports. The state remains a dominant player in the electricity market, in which generation, distribution, and transmission services are controlled by Turkmenenergo.

3.4.2 Electricity sector in Turkmenistan

Electricity generation

Over the past ten years, total electricity production in Turkmenistan has increased by more than 35%. In 2021, virtually 100% of electricity was generated by fossil fuel-fired power plants, fuelled almost entirely by natural gas. The country has a number of small-scale photovoltaic power plants, but they do not contribute to the overall balance of electricity production. The amount of hydroelectric power that is generated in Turkmenistan is also insignificant.

The volume of electricity generation in Turkmenistan exceeds the volume of consumption, allowing the country to export the remaining production. However, it should be taken into account that due to the bad shape of power infrastructure, the distribution system suffers from severe power losses that exceed 2.892 billion kWh per year. To date, sector electricity production includes seven thermal power plants and one HP Plant. This report covers electricity generation in all existing thermal power plants and power plants that will be commissioned in 2030. The scope includes not only Gindikushskaya hydropower, because it is only 2-3 months a year in operation and the current museum exhibit age is 97 years.

Of the seven power plants, three are equipped with steam turbines(HPP Mary, Turkmenbashi thermal power plant and Seidi CHP), three withgas turbines (Balkanadsakya HPS, HPS Ashgabat and Dashoguz GES) and one power plant with a gas and a steam turbine (Abadan power plant). All gas turbine power plants operate on a simple cycle.

Electricity consumption

The country's domestic electricity is 83-85%. The main consumer of electrical energy, at 29%, is the population, of which 14,8% is accounted for by the urban and peri-urban population and 14.2% by the rural population.

The program for the development of electricity in Turkmenistan foresees an annual increase in electricity consumption by 3-4%, which means that the demand for electricity in 2030 will increase 2.1 times compared to 2009. This increase takes into account the increase in the population's electricity consumption in connection with population growth and the improvement in prosperity, which will increase people's purchasing power to buy more different household

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appliances (https://aenert.com/countries/asia/energy-industry-in-turkmenistan/ and https://www.enerdata.net/estore/energy-market/turkmenistan/).

Electricity transmission sector

The electricity market is managed by the state-owned company Turkmenenergo, maintaining and operating the main electric grid. The new development strategy for Turkmenistan electricity sector (*Concept of the energy industry development for 2013-2020*) includes the future objectives for increasing the installed capacity and exports. In order to do so, it has been planned to upgrade the high-voltage transmission lines, to renovate old plants and install new gas-powered plants.

3.4.3 Renewable energy in Turkmenistan

Turkmenistan has a high potential for renewable energy sources, facilitated by climatic and geographical conditions, the country has virtually no market for renewable energy and the sector is just beginning to develop. Western Turkmenistan along the coast of the Caspian Sea and the Garabogaz Bay in the Balkan region offers very favourable conditions for the development of Wind energy, where wind speeds of more than 7.5 m/s at a height of 50 m can be reached. With more than 300 sunny days a year and an average global horizontal solar radiation of 4.6 to 5.1, Turkmenistan also has enormous potential for the use of solar energy.

3.4.4 Renewable energy policies and measures

No current plans linked to the exploitation of hydropower are known in Turkmenistan. The Government of the country aims to develop renewable energy projects and diversify the country's energy balance, promoting environmental protection and rational use of natural resources. One of the planned projects involves active construction of solar power plants with a capacity of more than 6 MW in remote and sparsely populated areas of Turkmenistan.

Turkmenistan is making efforts to achieve climate neutrality. The government has adopted a National Strategy on Climate Change and a National Strategy for the Development of Renewable Energy until 2030. In addition to the government's focus on the development of wind and solar energy projects, the high content of silicon, a semiconductor material, in the sand of the Karakum Desert is also important and could enable the country to take an important position in the production of photovoltaic panels and the development of photovoltaic energy (CAREC energy outlook 2030). The State Energy Saving Program for 2018-2024 also calls for increasing the role of renewable energy sources. It is planned to launch biogas plants for solid waste processing, install industrial wind turbines at optimal sites for their operation and modernizing the existing grid infrastructure

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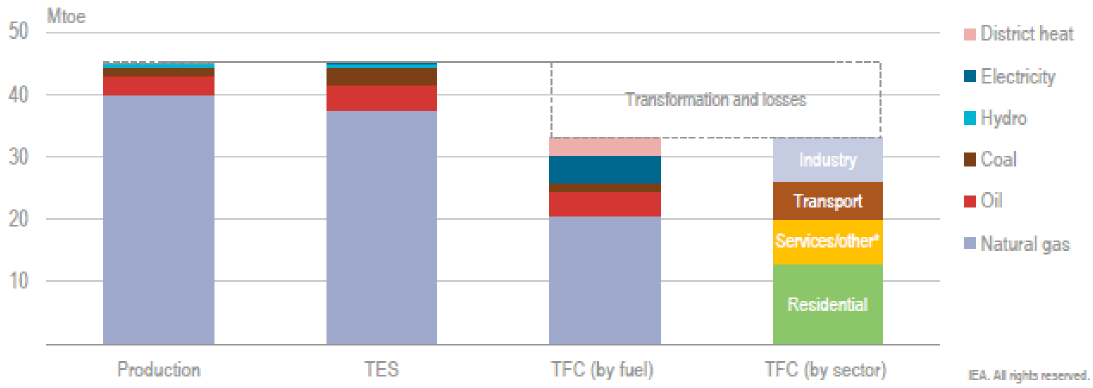
(https://www.adb.org/sites/default/files/publication/850111/carec-energy-outlook-2030.pdf). It is estimated that about 57 MW of hydropower could be developed, mainly by retrofitting existing water infrastructure.

3.5. Uzbekistan

3.5.1 Energy sector in Uzbekistan

Energy generation

Topographically, Uzbekistan can be divided into different areas: 60% of the country is characterized by dry steppe and desert, while the rest is formed by the valleys of the Syr Darya and Amu Darya Rivers, as well as some mountainous areas. As it can be seen in Figure 10 below, energy production focuses on natural gas, but includes also oil and gas. Domestic production of gas is more than enough to satisfy the demand, but oil and coal are increasingly imported to cover their consumption. In 2020, the overall imports and exports were virtually on par for the first time. Fossil fuels historically account for nearly all of total energy supply. Natural gas is the key energy source with 83% share of TES in 2020, followed by oil (9%) and coal (6%). The contribution of renewables is currently modest, below 1%. The share is likely to grow notably in the coming years due to the planned solar and wind capacity additions. Solid biofuels are consumed in the rural areas, but their consumption has not been quantified.



Uzbekistan's energy system is heavily based on natural gas.

* Includes commercial and public services, agriculture and forestry.
Note: Bunker fuels of around 0.1 Mtoe are not included in TES.
Source: IEA (2022), *World Energy Statistics and Balances* (database), https://www.iea.org/data-and-statistics.

Figure 10: Overview of Uzbekistan's energy system by fuel and sector, 2022, IEA

Energy consumption

The share of natural gas in TFC is 63% and is one of the highest in the world (Figure 11). The residential sector is the largest consumer with a share of 39%, although consumption has fallen 25% since 2010 according to the available data. Industry consumed 21% in 2020, 26% less

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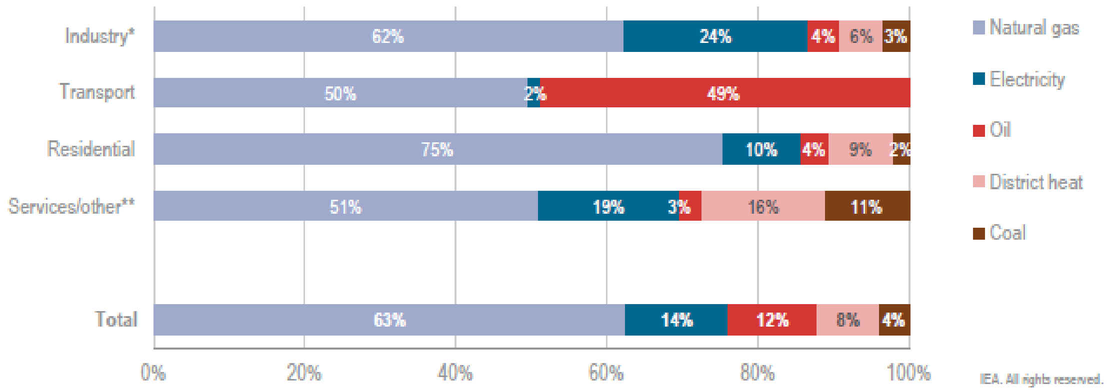
than in 2010. In contrast, consumption in the transport sector (18% of the total in 2020) has grown by 28% (Figure 11). Some of the alleged trends may result from improved statistical reporting in recent years and therefore should be treated with caution. The remainder of TFC, around 22%, was mainly used in service sector and agriculture. With over 60% share of the TFC in 2020, natural gas is the main energy source in all sectors of the economy. This also includes transport, as most of the vehicle fleet in the country is fitted to run on compressed natural gas. Electricity (also mainly generated via natural gas) held the 14% share of the total in 2020. The share of oil was only 12% in 2020, followed by district heat (8%) and coal (4%). Direct use of fossil fuels accounted for almost 80% of the total final consumption in 2020 (Figure 11).



Natural gas is the main energy source in all sectors of the economy.

* Includes non-energy consumption.
** Includes commercial and public services, agriculture, and forestry as well as unspecified energy consumption.
Source: IEA (2022), *World Energy Statistics and Balances* (database), https://www.iea.org/data-and-statistics.

Figure 11: Total final consumption by source and sector, 2022

Energy sector governance

The presidential administration, Cabinet of Ministers and Ministry of Energy are the main government institutions in the energy sector, while individual subsectors are controlled by several state-owned enterprises. Executive power of the Republic of Uzbekistan is held by the president, and the president assembles a Cabinet of Ministers to organize the work of the executive authorities:

- The Ministry of Energy, established in February 2019, is the central executive authority responsible for implementing state policy and the various regulations, orders and decrees issued by the government for the energy sector. This Ministry is responsible for regulating the production, transmission, distribution and consumption of electric and thermal energy and coal, as well as the production, processing, transportation, distribution, sale and use of oil and gas, and their products.

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- The Ministry of Economic Development and Poverty Reduction. Its main objectives are to analyse and forecast macroeconomic indicators and development, based on proposed economic management market mechanisms and strategies to develop Uzbekistan's main industries including energy. This Ministry, primarily aims to develop and implement innovations in state and public construction, taking into account long-term scenarios of the country's development;
- The Ministry of Finance leads the work of the Interdepartmental Tariff Commission under the Cabinet of Ministers, which determine energy tariffs.
- The Ministry of Investment and Foreign Trade. It is responsible for implementing the unified state investment policy; co-ordinating efforts to attract foreign investments, primarily direct investments; co-operating with international financial institutions and foreign governmental financial organisations;
- The Ministry of Construction, implements a unified state scientific and technical policy in the field of engineering and technical research for urban planning and construction to increase productivity, reduce construction and installation costs, and introduce innovative energy-efficient and energy-saving projects and solutions into construction (IEA Uzbekistan 2022, Energy Sector Review).

All HP Plants of Uzbekistan are owned by JSC Uzbekgidroenergo, co-coordinating body responsible to implement the *Programme for the Hydropower Development in Uzbekistan in 2017–2021*. Most of the power generation, transmission and distribution assets used to be owned and operated by JSC Uzbekgidroenergo. In 2017 after the World Bank recommendations, it was then distributed into different state-owned bodies:

- JSC Thermal Power Plants,
- JSC Uzbekistan National Electric Power Networks,
- JSC Regional Electric Power Networks and
- Uzbekgidroenergo

3.5.2 Electricity sector in Uzbekistan

Electricity generation

UZB is the largest electricity producer in CA and a net exporter of electricity. Around 87% of its electricity demand is generated by gas, and the remaining 13% is produced by hydropower (IEA Uzbekistan 2022, Energy Sector Review).

In 2021, Uzbekistan had 15.9 gigawatts (GW) of electricity generating capacity, of which 12.9 GW were available. The main source of generation is 11 TPPs with a capacity of 13.9 GW and

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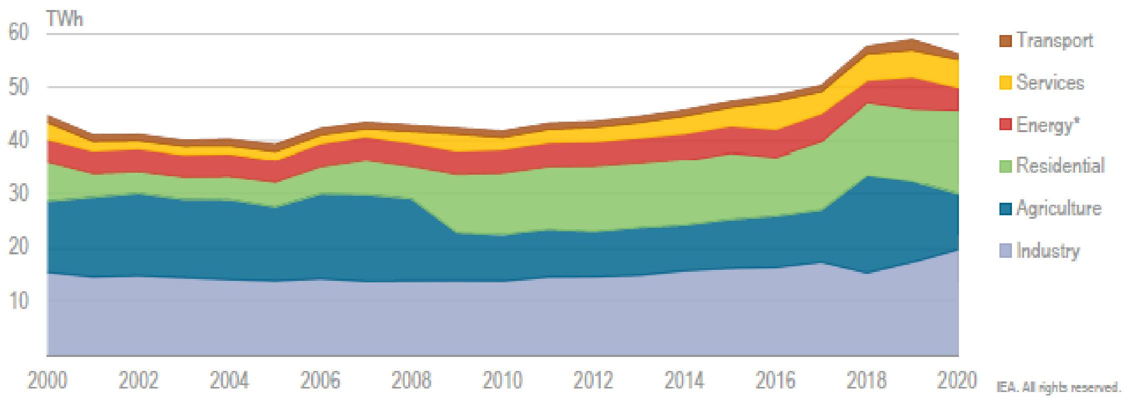
hydropower plants (HPPs) with 1.85 GW. Today, 3.9 GW falls on the energy-efficient power units commissioned in 2012-2021, and 1.9 GW are modernized. The rest of the thermal power capacity – 8.4 GW (60%) – was put into operation in the 1970s and 1990s; Within HPPs, 50% of the capacities are new and/or modernized.

Fifteen new energy projects with a total capacity of 5.8 GW (including 1.7 GW of wind and solar power) are under way, and planned investments amount to USD 5.2 billion. The average age of TPPs was 42 years, co-generation plants 63 years and large HPPs 46 years (IEA Uzbekistan 2022, Energy Sector Review).

Electricity consumption

Electricity consumption in 2020 was 56 TWh, over 30% more than in 2010 (Figure 12). Industry was the largest consumer, at 35% of the total, up 42% since 2010. Iron and steel manufacturing consumes around half of the sectoral total, followed by chemicals and petrochemicals. The residential sector accounted for 28% of consumption (up 36% since 2010), followed by agriculture (18%), where electricity is mostly used by irrigation pumps. The transport sector consumed only around 2%. However, it is likely to grow in response to the government's promotion of electric vehicles. The remainder was consumed by commercial and public services (9%) and the energy sector itself (8%).



Electricity demand declined in 2020 for the first time in more than a decade, but is set to return to continuous growth to 2030.

* Includes own use in electricity and heat generation and unspecified consumption in energy industries.

Source: IEA (2022), *World Energy Statistics and Balances* (database), https://www.iea.org/data-and-statistics.

Figure 12: Electricity consumption by sector, 2000-2020

Electricity transmission sector

Transmission networks are state-owned through the system operator National Electricity Grid of Uzbekistan JSC. They are not subject to privatization and external operation or management. The National Dispatch Centre of the National Electricity Grid of Uzbekistan JSC

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provides centralized operational dispatch of all power plants as well as the transmission and distribution networks.

The National Electricity Grid of Uzbekistan JSC transmits electricity from power plants to the distribution and marketing enterprises of the Regional Electricity Grids JSC via 35 kV to 500 kV main networks, in total 9 800 km of power lines.

Regional Electricity Grids JSC encompasses 16 enterprises, including 14 within territorial (regional) power networks, which operate distribution grids and oversee new construction and reconstruction as well as grid maintenance.

Distribution networks are 0.4 kV to 110 kV and include 29 000 km of power lines at 35 kV to 110 kV and 224 000 km of power lines at 0.4 kV to 10 kV. They also include around 75,000 transformer stations with a total capacity of 13 933 megavolt amperes (MVA).

Most components of the electricity networks have been in service for more than 30 years, including 66% of the transmission and 62% of the distribution networks, 74% of substations, and more than 50% of transformer stations. This is one of the reasons for the relatively high network losses, which amounted to 15.5% in 2020.

3.5.3 Renewable energy policy in Uzbekistan

UZV has only recently started to develop its vast solar and wind energy. The government plan is to install 12 GW of variable renewable energy capacity and 1.5 GW of hydropower capacity by 2030. With high solar irradiation and wind speeds over the vast undeveloped territories, UZB has enormous potential for solar and wind power development that may have regional geopolitical importance and trigger cross border co-operation to make CA a hub for renewable electricity and green hydrogen production. The current intensive gradual development of renewable power might be prioritized and streamlined in view of this strategic opportunity (IEA Uzbekistan 2022, Energy Sector Review).

3.5.4 Renewable energy policies and measures

The government is aiming for higher volumes and shares of renewable energies in the coming years. To ensure energy security and promote the use of renewable energies, it has adopted a wide range of strategies and action plans.

In 2023, the Uzbek government announced the construction of a number of large- and small hydropower projects. This year alone, **17 projects** with a total capacity of 197 MW are to be commissioned (HydroReview, 2023a). Of these 17 projects, ten are SHP with a total capacity

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of 197 MW, which were commissioned last year. In addition, the construction of 50 SHPs with a capacity of 438 MW is to be initiated.

Compared to 2018, the country plans to increase hydropower generation by 1.50 GW by 2030 (IEA Uzbekistan 2022, Energy Sector Review). Uzbekistan also partners with neighbouring countries in bilateral projects, such as the Zarafshan project in Tajikistan, with a planned capacity of 150 MW (HydroReview, 2023b).

In its **Nationally Determined Contributions** (NDCs) ratified in 2018, Uzbekistan committed to decreasing specific emissions of GHGs per unit of GDP by 10% by 2030 (compared with 2010). In its updated NDC in 2021, it raised the commitment to reduce GHG emissions per unit of GDP by 35% from 2010 to 2030. A key part of meeting this pledge is to increase the solar and wind generation capacity to 8 GW by 2026 and 12 GW by 2030 (7 GW solar, 5 GW wind), an increase from the 8 GW target set out in 2019. The Presidential Decree 4422/2019 on Accelerated Measures to Improve Energy Efficiency of Economic and Social Sectors, the Introduction of Energy-Saving Technologies and the Development of RES sets a target for renewable electricity to supply at least 25% of all electricity by 2030. It aims to stimulate widespread further use of energy efficiency measures, solar collectors, biogas facilities and heat pumps, including through subsidies to individuals and companies developing solar PV facilities (IEA Uzbekistan 2022, Energy Sector Review).

The **Green Economy Transition Strategy for 2019-2030** (Presidential Decree No. 4477 of 4 October 2019) encompasses a wide range of objectives for several sectors of the economy. For the energy sector, the objectives include: Raising the renewable energy share in the power mix to more than 25% by 2030 (as compared to 7.5% in 2020). Using solar collectors for water heating; increasing automation for transmission and distribution. Modernizing and reconfiguring the power grid to increase power system stability. Equipping power consumption systems with smart meters.

In response to the previous Strategy for 2019-2030, the government developed the **Concept of Electricity Supply** for 2020-2030. The concept note identified a larger renewable energy capacity as a main objective to improve electricity supply and set a target to increase generating capacity from 12.9 GW in 2019 to 29.3 GW by 2030 and electricity generation from 63.6 TWh in 2019 to 120.8 TWh by 2030. The variable renewables generation capacity was expected to grow by 8 GW to 2030, a sum of 5 GW of solar power and 3 GW of wind power.

The **Law on the Use of Renewable Energy Sources** (RES Law, 2019) adopted in May 2019, creates the basic framework for accelerated development of RES. It defines the responsibilities of public entities in supporting renewable energy and specifies the rules and support schemes

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for renewables power producers. The law defines the Ministry of Energy as the authorized state body in the field of the use of renewable energy

Under the RES Law, legal entities and individuals who install energy facilities are eligible for benefits and incentives, including the following tax incentives and exemptions: Renewable energy producers are exempt from property tax for renewable energy installations (above 100 kW) and land tax in the areas used by these installations for ten years after commissioning. They are also granted the right to create local distribution networks and conclude agreements with legal entities and individuals for the sale of energy (electricity, biogas). Producers of renewable energy equipment are exempt from all taxes for five years from the date of their state registration. Customers are exempt from property tax on off-grid renewable installations in residential buildings for three years. They are also exempt from the land tax.

The **Law of Uzbekistan on Public-Private Partnerships** of 10 May 2019 is directed towards attracting investors in large RES projects. The special public-private partnership agency under the Ministry of Finance is an authorized government body. The public-private partnership project partners can be selected through tenders or direct negotiations. The tenders can be one or two stage; the two-stage tender requires prequalification for projects over USD 1 million. Project awards through direct negotiations are conducted in exceptional cases of: state security importance, exclusive rights of the private partner (intellectual rights and other), mandate by presidential decrees or government resolutions. The law provides the subsidies and concessions to guarantee the minimum income of a private partner. The state support measures include: contributions in the form of assets, land and property needed for public-private partnership project implementation; funds from the budgetary system; budget loans, grants, credit lines and other financing instruments; safeguards and guarantees as compensation for the change of law; and tax incentives. The law has become a basis for construction of all new large-scale solar and wind projects.

In addition, the Cabinet of Ministers has adopted several regulations related to renewable energy, including the regulations: on measures to ensure metering the energy produced from renewable energy sources and installations; on the rules for the placement of large PV plants; on the rules of tendering auctions for lowering the starting price in the field of renewable energy sources; rules for conducting the auctions and the rules on purchasing electricity from small renewable facilities as well as regulation on grid connection of generation entities, including renewable sources; on connecting entities producing electricity, including from renewable energy sources, to the united electric power system (IEA Uzbekistan 2022, Energy Sector Review).

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4. Political context regarding water management and hydropower production

This Chapter is a new contribution to the replication strategy and shows the regulations and institutions in charge of water resources in the five countries in CA. This policy framework will be considered during the selection of HP policies to be implemented in the WFEC nexus model (Task 5.2) and within the feasibility studies to be carried out in three test cases (Task 5.3). The Table 4 shows a short summary of the institutions that regulate water resources by country.

Table 4: Summary of water resources regulation in CA countries

Country	Regulation	Date of last amendment
Kazakhstan	**Ministry of Water Resources and Irrigation**	1st September 2023
	Water Legislation of the Republic of Kazakhstan	2nd January 2021
	Water Fund of the Republic of Kazakhstan (Water Code of the Republic of Kazakhstan)	30th June 2021
Kyrgyzstan	Law of the Kyrgyz Republic on Water	10th December 2021
	Water Code of the Kyrgyz Republic	January 12, 2005 No. 8
	Law on interstate use of water bodies, water resources and water economy constructions	23rd September 2001
	Water Resources Agency of the Government of the Kyrgyz Republic	May 2021
	State program for the development of irrigation of the Kyrgyz Republic for 2017-2026	21 July, 2017, No.440
Tajikistan	Water Code of Tajikistan	2nd April 2020
	Law of Water Security and Supply	30th December 2015
	National Water Council	23rd June 2022
	Basins and Sub-basins Organizations	23rd June 2022
	River Basin Councils	23rd June 2022
Turkmenistan	Code of Turkmenistan “On Water”	1st March 2014
	Law on Water of Turkmenistan	6th March 2023
Uzbekistan	Conceptual Plan for Water Development in 2020-2030	1st July 2020
	Strategy for water resources management and development of the irrigation sector in the Republic of Uzbekistan for 2021-2023	24th February 2021
	Two programs to improve the living conditions of the inhabitants of the country	2nd February 2021
	Decree to ensure the rational use of water resources (create system of water balance)	26th November 2019
	State and Committee on Geology and Water Resources of the Republic of Uzbekistan (Uzhydromet)	23rd June 2022

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4.1. Water regulation in Kazakhstan

The creation of a new and independent **Ministry of Water Resources and Irrigation** was announced on 1st September 2023, due to the strategic importance of water resources in the country, as crucial as oil, gas or metals. The main objectives of the Ministry are to achieve a sustainable, ecological and economical management of water resources, including water supply and sewerage. These objectives are oriented towards the conservation and improvement of living conditions of the population and the preservation of the environment. The objectives of the **Water Legislation of the Republic of KAZ** shall be as follows:

- Implementation of the state policy in the field of use and protection of the state water fund, water supply and sewerage.
- Regulation on water relations in the field of sewerage and water supply.
- Providing a legal basis for the support and development of sustainable water use and the protection of water resources, water supply and sanitation.
- Determine the basics principles and directions of use and protection of water, water supply and sewerage fund.
- Management of relations in the field of study, prospecting, rational and integrated use and protection of water resources, irrigation and drainage systems and hydraulic facilities.
- Determination of directions for the development of land and reclamation.
- Protection of the population and commercial facilities from emergency situations in sanitary works and the consequences thereof.

The **Water Fund of KAZ (Art. 5),** was established on 31st of March 1993 as part of the **Water Code of KAZ**. This Code described the relations related to the ownership, use and management of water, and established the principles for the sustainable management of water resources in the country. According to the Code, all water sources in the territory of the State constitute the Water Fund; this includes rivers, lakes, reservoirs, dams, groundwater resources, glaciers and the waters of the Caspian Sea and the Arak Sea within the state borders of KAZ. Water is the exclusive property of the State, and its use and management are regulated by the competent authorities. The Code also establishes principles for water management, such as priority for drinking water supply and the domestic's needs of the population. In addition, it is based on an economic and territorial administration principles to protect and replicate water resources and ensure optimal water use.

In short, the Water Fund plays a crucial role in the sustainable management of water in this country, ensuring its rational use and the protection of its valuable water resources (Ministry

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of Ecology, Geology and Natural Resources of the Republic of Kazakhstan (2020, October 28). Water and Climate Change in Kazakhstan, https://www.gov.kz/memleket/entities/water?lang=en.

Water or environmental Policies related to hydropower production

The Catchment Authorities of the Ministry of Agriculture of KAZ grants the right for water use, so HPP project developers must submit an application to obtain the **special water use permit** including the HPP installed capacity, the capacity of energy, discharge and other structures, definition of fish protection and fish access structures, and the estimated volume of water resources that are going to be used for electricity generation (https://pdf.usaid.gov/pdf_docs/PA00X2D5.pdf).

4.2. Water regulation in Kyrgyzstan

The **Law of the Kyrgyz Republic on Water** is the basic instrument for regulation of the management and conservation of the country's water resources. Other laws shall be adopted in accordance with this law (Art. 2). Two notable articles to take into account are:

- *"All water bodies occupying land, included those destined for water protection zones, stripes and concentrated in water resources, form of the state found of the Kyrgyz Republic":* (Art. 4, 1st part).
- *"The right of ownership of the water fund within the state territory belong to the Khogorku Kinish of the Republic".* (Art. 5, 2nd part).

Other law concerning water resources in the KGZ is the **Law on interstate use of water bodies, water resources and water economy constructions**, which identifies the main principles and directions of the state policy on interstate water objects, water resources and water economy constructions. The main objectives of the present law shall be the following:

- Conservation, protection and development of the water fund of the Kyrgyz Republic, which is one of the resources of water supply for the CA countries.
- Regulation of the principles of supply of water resources in the Kyrgyz Republic to interested independent states on a reasonable and profitable basis, taking into account the economic relations of the market.

The Constitution, the present law and other legal normative acts of the KGZ regulate relations in the sphere of the use of water objects, resources and water development constructions. If an international agreement in which the KGZ participates establishes rules different from those contained in the legislation of the KGZ, the rules of the international agreement shall apply. The order of mutual agreements and payments within the framework of the implementation of

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joint programmes and projects of water economy is determined by the terms of agreements and contracts concluded by the KGZ. Disputes on water problems between the KGZ and other countries are regulated by consultations and negotiations between authorised representatives and experts of the interested parties.

The **State Water Resources Agency of the Government of the KGZ** is an authorised executive body responsible for state regulations of water management and use. The objectives of the Agency includes:

- Implementation of integrated water resources management.
- Ensuring sustainable management and efficient use of water resources and water management infrastructure, supply and sanitation infrastructures.
- To develop an international cooperation in the field of water in the KGZ.

4.3. Water regulation in Tajikistan

The **Water Code of Tajikistan (Law No. 1688)** regulates social relations related to the ownership, use and management of water resources and water bodies and aims the protection and rational use of water resources, as well as the legal protection of water users. The objectives of the water legislation of Tajikistan are the legal regulation of water resources with the aim of sustainable water management and rational use of water for the needs of the population and sectors of the economy, protection of water bodies against pollution, waste and depletion, prevention and elimination of harmful effects of water, protection of the rights of natural and legal persons and strengthening of the rule of law in the field of water relations. The State Water Fund includes all water bodies and the water resources that they contain within the national territory, as well as land occupied by water bodies with water conservation zones. Water bodies are classified into surface water and groundwater. In TJK, water is the exclusive property of the state, which guarantees its effective use in the interests of the people. Natural and legal persons who violate the right to state ownership of water shall be held liable in accordance with the legislation. The Water Code establishes powers and competences of state bodies in the field of water resources regulation. The planning of the use of water resources must provide for a scientifically based distribution of water among water users, taking into account the priority satisfaction of the population’s drinking and domestic needs and the prevention of its harmful effects. This Code consist of XIII Chapters divided into 94 Articles.

Tajikistan’s Water Sector Reform, the Government decided to reform the country’s water sector to introduce more efficient systems, legal and sustainable mechanisms for water

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resources management, bringing out the **Law of Water Security and Supply (Decree No. 791 of 30th of December 2015).** Its main objectives are:

- Guarantee water supply to all inhabitants of the country.
- To achieve economically and environmentally efficient management of water resources.
- To improve water resources management through Integrated Water Resource Management (IWRM) at the basin level.

For the implementation of IWRM, the Water Sector Reform foresees the creation of new institutional mechanisms, both at national basin level, such as:

- **National Water Council,** will be the main advisory body to the Government in charge of coordinating the activities of various government entities in the planning, management, use and protection of water resources. It will be composed of leaders of ministries and departments related of water resources management and may also include representatives of non-governmental organisations and experts in areas such as water resources, environment and economics.
- **Basins and sub-basins Organisations** will be responsible for water resources management in each basin, including planning, monitoring of resource use and implementation of specific plans for the five designated basins in the country.
- **River Basin Council** in each established basin area to facilitate efficient water resources management and coordinate the activities of the parties involved. These councils will include representatives of state agencies in charge of water regulation and protection, local authorities and water users, as well as associations and other stakeholders.

4.4. Water regulation in Turkmenistan

The **Code of Turkmenistan "On Water"** was last amended on 1st of March 2014, and aims to increase the value of rational use protection water resources. Along with measures of organizational, legal, economic and educational impact, this Code will promote the formation of ecological, water law order and ensure the economic impact in TKM.

In the conditions of development of state and private production, as well as urban planning, growth of material wealth of population and increase of versatile water needs, it is necessary to develop ad observe scientifically substantiated and more effective rules for rational use of water. Resources and their protection against pollution, contamination and depletion.

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- Turkmenistan is moving towards a market economy in all sectors and legislation. The “New Code of Turkmenistan” is on the agenda. It’s important that the fundamental principles of the IWRM, which make into account both natural and regional interest, are reflected in the Code.
- The authority and functions of the Mirab so far have no legal basis and are regulated by “temporally provisions on the Mirab”. Strengthening its position is an important factor of public participation in decision-making management.

The **Law on Water,** last amended on 6th of March 2023, regulated relations in the field of stable and rational use of water in order to meet the water resources needs of legal entities and natural persons and aims to increase the value of water resources, ensuring the protection of water against pollution, contamination and depletion, prevention and elimination of native impacts of water, recovery and improvement of the status of water bodies.

4.5. Water regulation in Uzbekistan

UZB has significantly increased the number of improvements and measures aimed at modernising the country’s water supply system, with the objective of preserving and improving natural and climatic conditions. Among the nationwide programmes adopted by the Government are the following:

- **Conceptual Plan for Water Development in 2020-2030.** The plan will be implemented progressively through strategies aimed at the development of Water Economy in the country. The strategies will be approved every three years, taking into account the priority areas, objectives and indicators set out in the plan.
  This plan represents a collective approach to addressing water and sanitation challenges with due urgency, effectiveness and coherence. Its main objective is to accelerate towards targets of Sustainable Development Goal 6 (SDG6). At the start of the Plan period (2020), progress towards these goals was alarmingly off track. In addition to SDG 6, the Plan also focuses on other relevant global goals.
- On 24th of February 2021, the **Strategy for water resources management and development of the irrigation sector in UZB 2021-2023** come into force.
- By Presidential Decree since 2018, **two programmes are being implemented in the country to improve leaving conditions of the population in urban and rural areas.**
- On 26th of November 2019, the President of the Republic signed the **Decree and resolution to ensure rational use of water and create an effective system of water balance management.**

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- Project to improve the drinking water supply of the Jizzakh region by using water from the Zarafshan River.
- Second stage of the project for construction, reconstruction of drinking water supply and sewerage systems in cities and districts of the Tashkent region.
- **State Committee on Geology and Water Resources of the Republic of Uzbekistan (Uzhydromet),** this committee plays a crucial role in the management of water resources in the country. It oversees the implementation of water-related policies and programmes.

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5. Framing the development of the Small Hydropower sector in Central Asia

5.1. Hydropower classification scheme

Hydropower plants can be classified according to various criteria (Wagner *et al*. 2015). These classifications help to understand the operational capabilities, environmental impacts, and economic feasibilities of different hydropower plants.

In the case of Hydro4U, the classification is restricted to SHP facilities with a maximum capacity of 10 MW according to the project objectives. To this aim, a new classification scheme has been defined within **WP1: Analysis of unexploited SHP potential in CA** and is shown in Figure 13 below (D1.5 – De Keyser *et al*., 2023c, Chapter 2). First, SHP are grouped concerning the location of the powerhouse. In the case of a diversion plant, water is taken from the main river channel to generate electricity off-stream. After passing the turbines, the water is either returned to the same river or directed into a separate waterbody. In the case of a river power plant, both the powerhouse and the weir system are positioned directly within the river (instream), forming a unified unit (Mazzorana *et al*. 2015). Both hydropower types can be operated with or without storage. Run-of-the-river plants are without a larger reservoir, usually having a small impoundment to generate a height difference of the water level upstream and downstream of the weir (Sarasúa *et al*. 2014). A reservoir plant refers to a plant that possesses a reservoir of sufficient size to carry over stored water from a couple of days to several months (Majumder and Ghosh 2013). When characterizing hydropower plants according to head, typically, a differentiation between low, medium, and high-head power plants can be made (Majumder and Ghosh 2013). In the context of our objectives towards GIS-based decision support, we reduced these to two classes: (i) low and (ii) medium- to high-head power plants. The innovative HPP types in Hydro4U, the Francis Container Power Solution (FCPS) and the Hydroshaft Power Plant (HSPS), are essentially subtypes of the presented types.

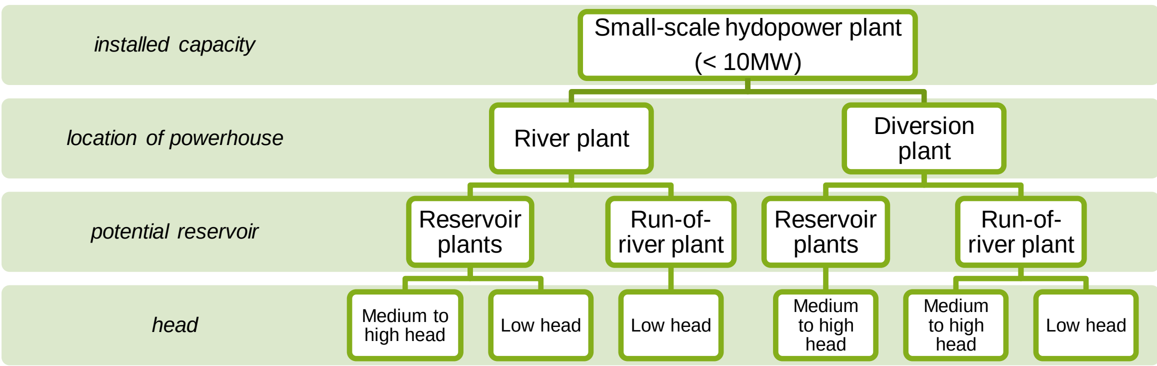

Figure 13: Overview of the SHP classification scheme within the Hydro4U project.

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5.2. The Status Quo of SHP in CA

Hydropower already accounts for almost 25% of the installed energy generation capacity in CA, although the actual share per country differs. For example, according to the UNIDO 2019 World SHP Development Report, Tajikistan generates the majority of its needed electricity from HP; in contrast, the contribution of HP to Turkmenistan's energy sector is negligible (Liu *et al*., 2019). The reason for this non-uniform distribution of the HP potential lies in Central Asia's diverse topography, with mountains and runoff formation situated in the upper reaches of the Aral Sea basin (see Figure 2 in Chapter 3). Therefore, countries like Kyrgyzstan and Tajikistan are predestined for hydropower generation while other areas like Turkmenistan or large parts of Kazakhstan are characterized by an arid climate and a plain topography.

A HP database, which includes data on existing and operational plants, was crucial to estimate the remaining technical potential for hydropower in the region as part of a multi-step approach to assess the sustainable HP potential. To this aim, we consolidated various hydropower and dam data sources (e.g., ICOLD World Register of Dams, GOODD (Mulligan *et al*., 2020), GRanD (Lehner *et al*., 2011), GeoDAR (Wang *et al*., 2022)), excluding possible double entries. Since its second replication plan, the database has undergone several revisions and enhancements. The updated statistics on existing plants across Central Asian countries, relative to those previously published by UNIDO, are detailed in Table 5. The final georeferenced database will be part of the Decision Support System (Task 1.7).

Table 5: Existing hydropower capacities* in Central Asia

Country	Overall installed hydropower (MW)		Installed SHP (MW)	
	UNIDO[1]	Hydro4U[2]	UNIDO[1]	Hydro4U[2]
Kazakhstan	2,699	2,835	116	109 (34 plants)
Kyrgyzstan	3,077	3,167	4	59 (21 plants)
Tajikistan	5,039	5,240	28	37 (19 plants)
Turkmenistan	1	17	1	1 (1 plant)
Uzbekistan	1,879	2,048	76	123 (26 plants)
Total	**12,695**	**13,307**	**226**	**329 (101)**

[1]*Source: UNIDO Report (Liu et al., 2019). Thresholds: KAZ (35 MW), KRG/UBZ/TAY (30 MW).*
[2]*Source: D1.6 (De Keyser et al., 2024). Common threshold of 10 MW for all CA countries.*
**The values presented are rounded for better readability.*

A comparison of small and large HP shows that SHP is under-represented in CA, as shown by the analysis of the above-mentioned database (Figure 14). Their shares highly vary by country (Figure 15).

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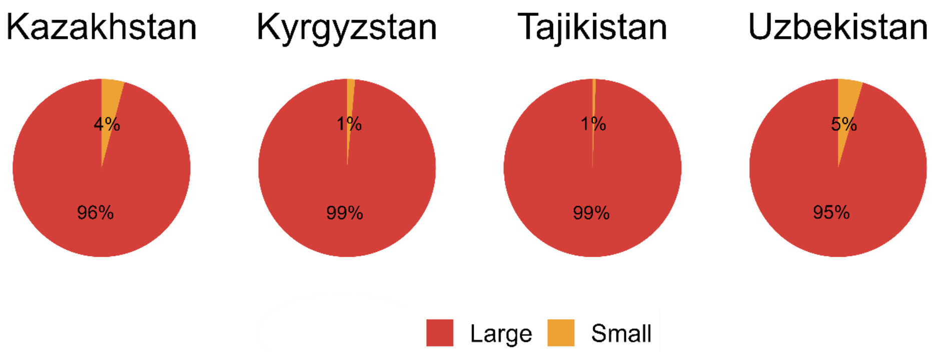

Figure 14: Installed capacity share for small (<10 MW) and large hydropower plants in CA on a country-per-country basis, excluding Turkmenistan

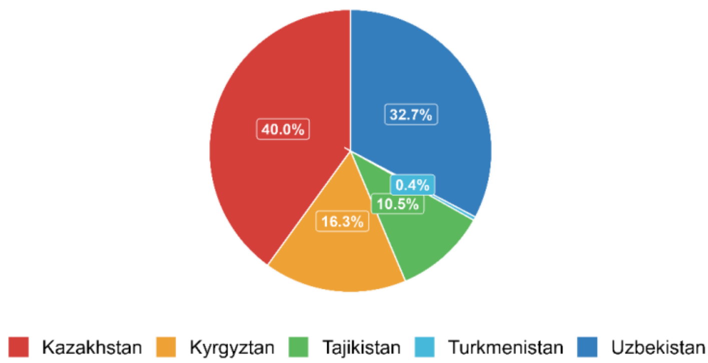

Figure 15: Share of SHP installed capacity in CA.

5.3. Technical and sustainable Small Hydropower potential

Natural resources are non-uniformly spread across CA countries, which are, therefore, strongly interdependent. While upstream countries have abundant water resources, downstream countries are characterized by natural water scarcity but are major producers of crops and fossil fuel energies (Hamidov *et. al*, 2016). Within the Hydro4U project, the hydropower potential was computed using a multistage procedure (Dhaubanjar *et al*., 2021). In this procedure, the theoretical line potential, based on the hydrological conditions, is gradually broken down towards a sustainable potential based on environmental parameters and constraints (see Figure 16). This procedure allowed us to incorporate all kinds of sectors relevant to a sustainable perspective.

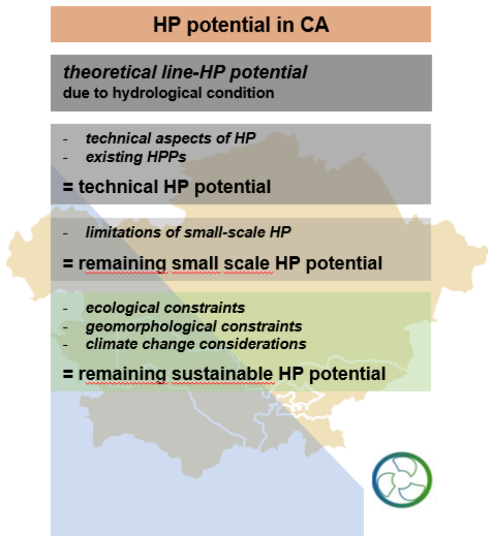

Figure 16: Schematic workflow of the multi-step procedure when computing the sustainable HP potential.

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The following steps were performed to calculate the sustainable hydropower potential: In a first step, (1) the line potential was computed. Following, (2) technical aspects of hydropower plants, such as certain efficiency factors were considered. Furthermore, (3) already existing and operating plants were identified and subtracted from the technical potential. Since Hydro4U addresses only small HP, (4) an additional condition was introduced, limiting the installed capacity of SHP to 10 MW per river segment. Less suitable locations from an environmental point of view were considered by taking (5) ecological as well as (6) geomorphological constraints into account (Figure 16). This transparent methodology of computing the sustainable potential of the different countries is described in more detail in D1.4 (De Keyser *et al*. 2023b), including also forward-looking climate change modelling approaches to examine the availability of the determined potential in the future.

This analysis with such a holistic approach to determine HP potential has not been done before in this region. By highlighting the remaining sustainable hydropower potential and its distribution, this study contributes to the development of SHP in CA. This, together with its integration with a Decision Support System to be developed within WP1, provides a basis for replication of SHP construction in the project area.

Especially in terms of replication (e.g., advocating hydropower development), it is key to include sustainability aspects to avoid overexploitation, particularly in sensitive areas (Moran *et al*. 2018). In summary, these results show that only a small fraction of the existing sustainable HP potential has been used so far in CA. To ensure environmental sustainability additional factors must be considered (Dhaubanjar *et al*., 2021). Therefore, an ecological and geomorphological sustainability assessment for each of the 1 km-long river segments was carried out. (Figure 17). If one of the following presented assessments concluded that generating hydropower at this location is non-sustainable, the specific river segment was not considered in the overall sustainable potential estimation. The sustainability perspective requires defining areas of most ecological sensitivity or value, and therefore delineating where hydropower development should not occur. Furthermore, we used a series of datasets (Wagner *et al*., 2021) to define these critical no-go areas, including information on the following ecological criteria: (i) presence of endangered freshwater species, (ii) key biodiversity areas, (iii) Protected areas, (iv) free-flowing rivers and (v) rare river types.

The map shown in Figure 17 provides an overview of the frequency of criteria per river reach.

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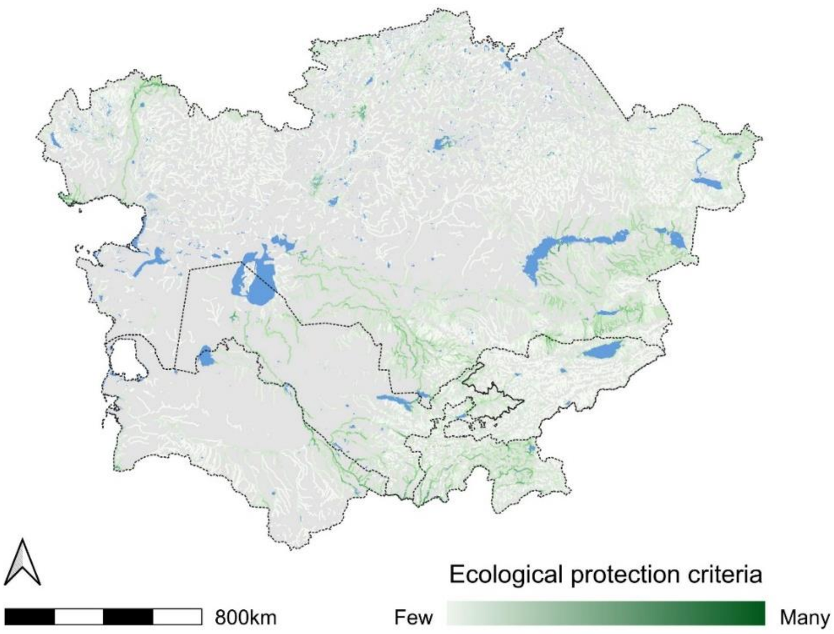

Figure 17: Density of environmental sustainability assessment criteria in Central Asian rivers

The spatial distribution of the technical as well as sustainable hydropower potential is presented in Figure 18.

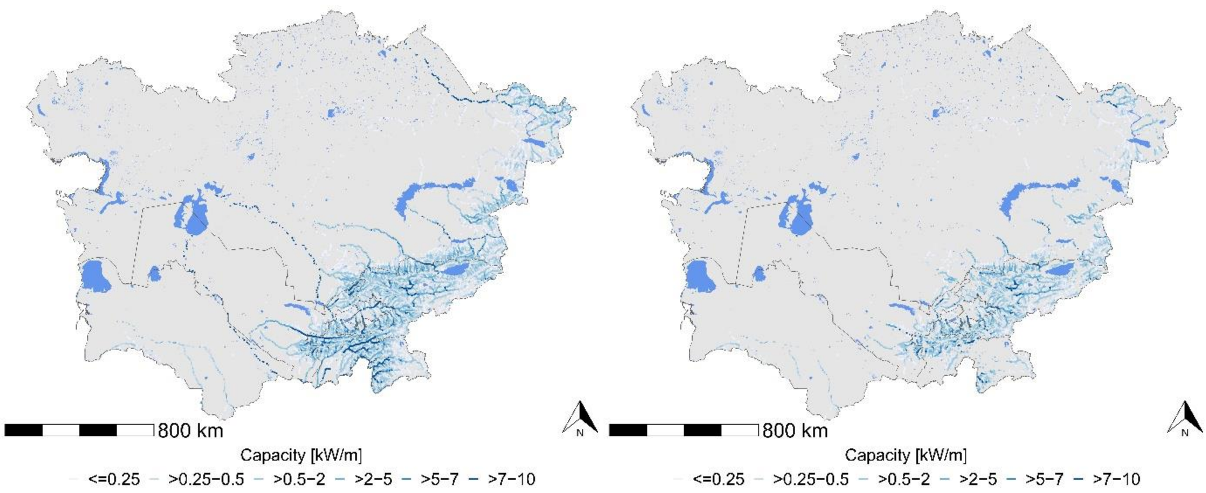

Figure 18: Map of the remaining technical (right) and sustainable (left) small-scale hydropower capacity (D1.3 – De Keyser *et al*., 2023a).

Also, Table 6 shows the remaining sustainable hydropower potential expressed as SHP capacity. A significant discrepancy can be seen between the figures presented by UNIDO (Liu *et al*., 2019) and those calculated in Hydro4U. The fact that the values of some countries are relatively good aligned while others differ by more than an order of magnitude shows that

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UNIDO likely did not apply a standardized methodology. Instead, according to a statement made by UNIDO, the organization gathers data on the HP potential from different local experts. Even though the UNIDO values are widely cited in the literature (e.g., Laldjebaev *et al*., 2021), their significance may, therefore, be limited when comparing the potential of different countries. This underlines the importance of using a standardized method to assess Central Asia's hydropower potential within Hydro4U.

Table 6: Remaining technical and sustainable hydropower potential in Central Asia

Country	Overall SHP potential (MW)[1]	Overall technical HP potential (MW)[2]	Remaining technical SHP potential[2] (MW)	Remaining sustainable SHP potential (MW)[2]
Kazakhstan	2,707	22,499	18,842	6,470
Kyrgyzstan	275	24,905	22,716	13,294
Tajikistan	30,000	24,671	19,160	5,017
Turkmenistan	1,300	2,933	1,117	282
Uzbekistan	76*	11,171	8,446	3,617
Total (MW)	**34,358**	**86,179**	**70,281**	**28,680**

*[1]Source: UNIDO Report (Liu et al. 2019). [2]Source: D1.4 (De Keyser et al., 2023b). * This estimate is based on the installed capacity as no data on potential capacity is available.*

Below it is described the status of **installed capacity** and the comparison with the calculated available **potential** on a more detailed country-per-country basis:

Kazakhstan. The country has significant hydro resources. The Irtysh, Ili and Syr Darya Rivers are the main rivers of the country. The overall installed HP according to Hydro4U (D1.4 – De Keyser *et al*., 2023b) is 2,835 MW (Table 5). Theoretically, the capacity of all hydro resources is 170 billion kWh per year, which provides **10% of the country's needs**. 65% of its current hydropower generation is in the east (mountainous Altai) and in the south of the country. The largest HP plants are Shulbinskaya (720 MW), Bukhtarminskaya (675 MW), Kapchagaiskaya (364 MW) and Ust-Kamenogorskaya (on the Irtysh River, 331 MW). In December 2011, the Moinak HPP (300 MW) was put into operation together with the Bulak HPP (80 MW) and the Kerbulak HPP (50 MW).

Kazakhstan's overall hydropower potential was estimated to be around 22,500 MW, while only 6,400 MW of the remaining small-scale potential is sustainable (Table 6). The potential must be set in relation to its large size compared to much smaller countries like Kyrgyzstan or Tajikistan.

Kyrgyzstan. The Tian Shan Mountain Range makes up 95% of the country, which is characterized by steep mountains and abundant water resources. The Syr Darya River, one of CA's two major waterbodies, originates in these mountains. To date, **90% of the annual**

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electricity is produced by hydropower (IHA, 2018), with an overall installed HP of 3,097 MW (De Keyser *et al., 2023*) as shown in Table 5.

The country has a similar overall technical hydropower potential as Tajikistan with 24,905 MW (Table 6). Of this, 13,294 MW are considered sustainable SHP potential. Keeping in mind that the installed small-scale capacity is 59 MW, it can be concluded that only 0.44% of the sustainable SHP potential is utilized. According to UNIDO (Liu *et al*., 2019), the country's potential is only 275 MW. This low number can only be explained by an assessment error, or this value is based on single case studies, where feasibility studies have already been carried out.

Tajikistan. The country, located in the southeast of CA in the upper reach of the Aral Sea basin, has a comparable mountainous topography as Kyrgyzstan. Ranging between 300 and 7,495 meters above sea level, its topography is predestined for hydropower development. 60% of CA's total runoff is generated in this area (IHA, 2018). Tajikistan already produces almost **90% of its electric energy from hydropower** (Ministry of Energy and Water Resources of the Republic of Tajikistan). We identified an overall generation capacity of around 5,240 MW, whereas only a negligible share of 37 MW is currently generated by SHP (Table 5). According to the methodology developed within Hydro4U (D1.4 – De Keyser *et al*., 2023b), the overall hydropower potential in Tajikistan is 24,671 MW (Table 6). When only considering the remaining sustainable SHP potential, this number reduces to 5,017 MW.

Turkmenistan. According to our dataset, there are only two plants operating in Turkmenistan with a combined capacity of 17 MW. Of these, one is a SHP with an installed capacity of 1.2 MW (Table 5). The country's overall hydropower potential is estimated to be almost 3,000 MW (Table 6), one-third of which is the remaining SHP potential of 1,100 MW. Of this, 282 MW are classified as sustainable. UNIDO proposes a potential in a similar order of magnitude with 1,300 MW. Due to the country's topography and water scarcity, it is not best suited for strong SHP development when compared to its neighbouring countries.

Uzbekistan. The overall installed HP according to Hydro4U (D1.4 – De Keyser *et al*., 2023b) is 1,849 MW (Table 5), which provides **13% of the country's energy needs**. The country's remaining sustainable small-scale potential was estimated to be 3,617 MW (Table 6). Considering that only around 123 MW have been exploited so far (Table 5), it can be concluded that much SHP development is still feasible in Uzbekistan – even in this largely rather arid country. However, it should be noted that irrigated crops are grown in many parts of the country, resulting in high water demand. In such irrigated areas, there are high uncertainties regarding the discharge in the natural river system, entailing uncertainties in estimating the HP

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potential. Therefore, the present study might overestimate the potential within the natural stream network.

5.4. Effects of hydropower plants

Hydropower as a renewable energy source boasts numerous advantages that make it an attractive option for meeting energy needs. Firstly, hydropower produces less greenhouse gas emissions and air pollutants compared to fossil fuel-based power generation (Newmar *et al*. 2020). This characteristic not only mitigates climate change but also reduces the impact of pollution on human health and ecosystems. In many areas in Central Asia, where energy security is a pressing concern, hydropower offers a reliable and local energy source, reducing dependence on imported fuels and enhancing sovereignty (Metha *et al*. 2021). However different types of hydropower plants (see chapter 5.1) show various (a) technical-economic and (b) social-economic benefits and drawbacks while affecting the (c) ecology and (d) geomorphology in multiple ways. Depending on the local conditions of a site, some plants are better suited than others. To facilitate decision-making processes towards sustainable hydropower generation, a set of parameters has been developed, which will aid in evaluating the effects of the different hydropower types (D1.5 - De Keyser *et al*. 2023c).

Concerning **technical-economic parameters**, we first compare the expenses of different hydropower plants. Besides operating costs, two major cost components when constructing hydropower projects are civil works and cost-intensive electro-mechanical equipment (IRENA 2012). Another technical-economic aspect worth including in a decision matrix is efficiency (Pöyry 2008, 2018). On the one hand, we consider technical efficiency (e.g., losses within the turbine, generator, and transformer, as well as hydraulic losses of the flow) and on the other hand potential losses due to potential residual flow releases. Moreover, hydropower is, in general, highly exposed to climate change, so climate change resilience, especially regarding its effects on hydrology, must be adequately assessed (Hänggi and Plattner, 2009; Stanzel and Nachtnebel, 2010). Lastly, the security of supply is considered, which refers to ensuring a reliable and consistent provision of electricity generated from hydropower sources – an issue particularly important in CA.

When considering **socio-economic aspects**, we first rated the ability of the hydropower plant to provide flood control. Similarly, the capacity for water supply and irrigation storage was assessed. Hydropower contributes to emissions/climate change especially in combination with reservoir construction, when biomass decomposition produces carbon dioxide and methane emissions (Lu *et al.*, 2020). Resettlement might also be considered as the construction of dams

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and reservoirs leads to loss of land and the possible need for the resettlement of the people who previously lived in the hydropower construction area, as well as the possibility of involuntary displacement of people dependent on river water goods and services due to changes in the river's condition (Richter *et al*., 2010; Hay *et al*., 2019). This parameter is of less importance for small-scale hydropower generation compared to large plants but potentially needs to be taken into account. Finally, the overall change that the project may cause to the landscape is considered through the criteria of landscape and visual impact (Ioannidis & Koutsoyiannis, 2020; Beer *et al*., 2023).

Regarding **ecological aspects**, we first evaluate alterations concerning river connectivity. The multi-dimensional movement of matter and organisms can be described through three sub-criteria: longitudinal, lateral, and vertical connectivity (Ward, 1989). Secondly, hydropower alters river hydrology upstream of the weir by impeding water movement, creating an impoundment, and downstream in case of water diversion or hydropeaking (Poff *et al.*, 1997; Hayes *et al.*, 2018). Habitat is the third ecological criterion, being a baseline for aquatic life. The impoundment constitutes a hybrid ecosystem, while downstream habitats are affected by alterations of sediment and water flows, including river-floodplain processes (Schmutz & Moog, 2018). The fourth criterion, water quality, is assessed by changes in dissolved oxygen content and water temperatures through hydropower operations.

The last set of parameters refers to the impact of hydropower on **geomorphological processes**. Morphodynamics and sediment continuity/budget are two strongly interrelated processes that cannot be considered independently. While morphodynamics focuses on the processes and mechanisms that drive morphological changes in rivers in general, sediment continuity refers in the context of this deliverable only to the longitudinal transport of sediments. Both parameters can be strongly influenced by hydropower plants and are therefore worth considering (Habersack *et al*. 2008).

5.5. Description of on-going initiatives for the development of Small Hydropower

In Europe, the majority of the hydropower potential has already been exploited over the last century, having limited unused profitable potential available (Xu *et al*., 2023). Therefore, activities have been more and more shifting from commissioning new sites to technological and operational optimization of existing plants (Wagner *et al*., 2021). Central Asia is a fast-developing region with increasing energy demand. As shown previously in Chapter 5.3, within Hydro4U, a new methodology has been developed to standardize the calculation of the remaining sustainable SHP potential, which considers environmental, ecological, geo-

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morphological and climate change constraints. According to our procedure, the total **remaining sustainable SHP potential in the region is 28,680 MW**, which is distributed heterogeneously between countries with a high potential (KGZ, KAZ or TJK) and others where this capacity is lower (UZB) or residual (TKM). Despite this high potential, small-scale hydropower is not well developed, **with only 329 MW installed** in the region by 2023 as already described in the Chapter 5.2. Various policies and initiatives are investing in HP technologies and the construction new hydropower facilities in order to encore energy security and increase sustainable energy generation to tackle climate change. Table 7 below shows this regional overview of the SHP, including current and foreseen capacity installed:

Table 7: Current and planned SHP Projects in CA.

Country	Installed SHP by 2023[1]	Remaining sustainable SHP potential by 2023[2]	Recently SHP installed in 2023-2024	Foreseen SHP
Kazakhstan	109 MW (34 plants)	6,470 MW		621 MW
Kyrgyzstan	59 MW (21 plants)	13,294 MW	4.38 MW (1 plant)	278 MW (136 plants) by 2025
Tajikistan	37 MW (19 plants)	5,017 MW		47 MW (3 plants rehabilitation)
Turkmenistan	1 MW (1 plant)	282 MW		--
Uzbekistan	123 MW (26 plants)	3,617 MW	197 MW (10 plants)	438 MW (50 plants)
TOTAL	**329 MW (101 plants)**	**28,680 MW**	**201.38 MW (11 plants)**	**1,384 MW (189 plants)**

[1]*Source: D1.6 (De Keyser et al., 2024) and Table 5 of this report.*

[2]*Source: D1.4 (De Keyser et al., 2023b) and Table 6 of this report.*

The following paragraphs describe short-medium term planned initiatives on a country-per-country basis to deliver an overview of the development of hydropower in Central Asia.

Kazakhstan. There is considerable interest from investors to develop SHP in Kazakhstan, with many new prospective projects. In the course of the **Action Plan for 2050**, 41 SHP plants with a total capacity of **539 MW are planned** (IEA Energy Sector review, 2022). In 2018, a further **82 MW** of SHP capacity was already approved for development through tenders for renewable energy projects (Liu *et al*., 2019).

Kyrgyzstan. By today, hydropower is the most important energy source in Kyrgyzstan. Especially the development of small-scale hydropower is a major goal to increase national production, making the country less dependent on energy imports, especially during the cold winter (IEA, Kyrgyz Republic Energy Profile, 2021). At the moment, there are 22 SHP Plants already in operation with a capacity of 63.38 MW.

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Hydropower investments target the modernization of the Naryn cascade (IHA, 2018). In 2022 the Kyrgyz authorities announced that in the upcoming years, hundreds of new SHP Plants should be put into operation (Big Asia, 2022).

The State Committee for Industry, Energy, and Subsoil Use plans to **build and rehabilitate 136 SHP plants** (<30 MW) by 2025 with a total capacity of 278 MW. Among them, 22 promising sites have been identified for SHPPs in the Naryn region which have also been approved by the government. The design work of these 22 potential SHPPs are finished and construction has started. Currently, the construction of the Kulanak HPP cascade on the Naryn River is underway. By 2024, 1 plant have been commissioned with a total capacity of 4.38 MW.

According to the SHP Construction Plan 2023-2027, a further 34 plants are expected to be operational (Admin, 2023).

Tajikistan. Tajikistan plans to increase total generating capacity to 10 GW by 2030, therefore, doubling its hydropower output compared to today (IHA Sustainability Ltd, n.d.). Nevertheless, SHP plays a minor role since Tajikistan's energy production relies on major hydropower plants. Several restoration initiatives in the SHP sector are underway together with an Action Plan for investment in SHP, which focuses on the commercialization of SHP, feed-in tariffs, and grid access systems, SHP tax regime, and accessible investment procedures.
Nowadays, the construction and rehabilitation of SHP Plants with a capacity of 47 MW is being planned (Available at https://www.undp.org/sites/g/files/zskgke326/files/migration/eurasia/Tajikistan.pdf).

Turkmenistan. The country is located on large natural gas and oil sources, contributing to 99.8% of its energy production. According to Liu *et al*. (2019), renewable energy sources will even by 2030 contribute less than 1% of the country's energy mix. **Therefore, no current plans linked to the exploitation of SHP are known in Turkmenistan.**

Uzbekistan. HP potential in Uzbekistan derived from the Amu Darya and Syr Darya Rivers has not been widely developed due to the built canals, which altered the river flows and have affected the Aral Sea, The Uzbek government added a hydropower capacity of 260 MW in recent years. In 2023, it announced plans to continue constructing a series of large- and small-scale hydropower projects, 17 projects scheduled to be commissioned this year alone (HydroReview, 2023a). As it has been already mentioned in the Section 3.5.4 of this document, of these 17, ten of them are SHP with a total capacity of 197 MW have been commissioned during last year. In addition, it is projected to build 50 SHPs with a capacity of 438 MW will be started.

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Outlook. Many Central Asian countries have ambitious goals, including expanding sustainable SHP. Therefore, the technologies developed and demonstrated within the Hydro4U project will likely increase the attention of potential investors and other stakeholders. Previous SHP targets defined by each country will be considered during the definition of HP development scenarios to be implemented in the WFEC nexus model (see Chapter 7.2).

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6. Promoting green and sustainable energy Projects in Central Asia

Hydro4U replication strategy aims to bring European HP solutions to CA by maximizing the impact over potential project promoters. In order to determine the viability of a sustainable SHP project, any project developer has to follow several criteria, as it is shown in Figure 19 below:

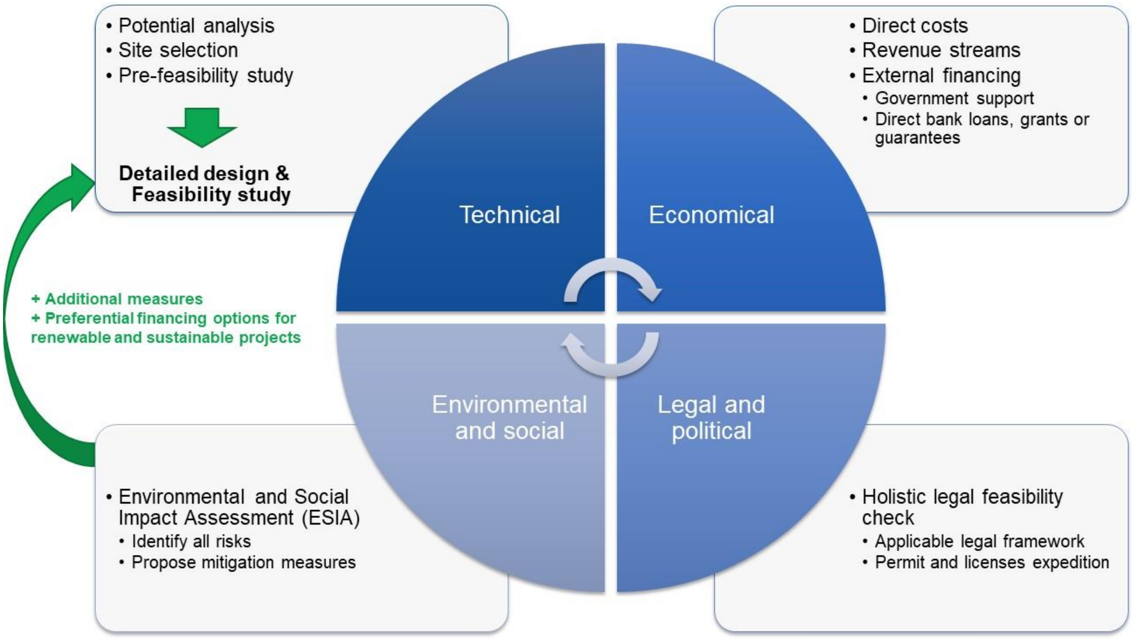

Figure 19: Guidelines for green and sustainable HP projects in CA

Technical assessment: The technical design of a sustainable SHP project should include several planning phases with increasing level of detail which ensure the economic feasibility of a project. Starting from the potential analysis, suitable sites can be identified and one site can then be selected using information from field visits and data collection. The pre-feasibility study then provides basic assessment and rough estimations to define if a site is technically and economically feasible. The feasibility study includes more detailed assessments and the comparison of different technical design options as well as financing possibilities. Then, the project developer can choose one suitable design and bring the project to a detailed design level, where all civils works are designed in detail and all costs are accounted for. The technical design should always be linked to and adapted according to environmental, social and economic aspects to obtain a sustainable SHP project. This might include the design of additional measures to ensure environmental protection and accounting for renewable and sustainable financing options [Chapter 6.1].

Economical assessment: The project developer must analyse all direct costs associated to the project and its financial viability based on expected revenue streams [Chapter 6.2] and

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possible sources of financing: (i) sustainable policies to promote sustainable RE projects, as tax exemptions [Chapter 6.2.1], or (ii) access to better private funding though local bank loans designed to promote renewables, or (iii) external financing from European or international institutions [Chapter 6.2.2].

Legal and political assessment: In order to define the project eligibility to these preferable financing options, an exhaustive assessment of the legal requirements must be made since an early stage of the project [Chapter 6.3]. The legal framework may not be always fully clear and can be complex due to of gaps or conflicts of interest. Because of this, it is highly recommended that the project developer identifies the necessary permits and licenses, together with the requirements, including the identification of all entities which can play a role during the approval process. Finally, the legal framework and the project governance may be altered by the political situation (inflation, interest rates…).

Environmental and social impact assessment: The Environmental and Social Impact Assessment (ESIA) [Chapter 6.4] includes the description of benefits and needs, as well as a list of the main risks and impacts of a SHP project to keep in mind during the design and implementation phase of the project. If the project meets the ESIA or European requirements, it may be eligible for preferable financing options.

These criteria will be considered during the development of the **Bankable feasibility studies**, for the three selected planning sites and will reported in D5.8 by M48 (May 2025), as the final outcome of the **Task 5.3: "Feasibility studies and planning at test cases"**. A detailed description of the criteria is provided in the following sections.

6.1. Guidelines for technical design

Both the optimization of technical hydropower equipment and the elaboration of innovative workflows and planning methods are at the core of the Hydro4U project. Both the technologies and the planning methods are designed with the goal of high replicability in CA – and beyond. In this chapter the approaches how to reach a high replication potential regarding the technical design and construction process are described.

In the D5.2 (López *et a*l. 2022) main barriers and drivers to SHP development were identified, as Political, Economic, Social, Technological, Legal and Environmental. In this third release of the replication plan, the Hydro4U approach to address them have been identified in Table 8 below:

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Table 8: Main technical barriers and drivers to SHP development

Main barriers to SHP development	Hydro4U approach
Lack of suitable sites.	Development and application of the Hydro4U hydropower potential tool (WP1) and replication tool WP5 to identify suitable sites and facilitate their successful implementation. Regular field visits and use of innovative and modern survey methods such as structure from motion or aerial images and satellite data to obtained necessary information. Regular meetings and knowledge exchange with local investors / project developers (clients) and hydropower experts to understand and assess local conditions.
Lack of reliable data due to problems with data collection or where no historical records are available.	
Lack of an effective project plan and delivery (higher upfront costs).	
Availability of electrical Transmission and distribution infrastructure.	
Lack of qualified and trained local experts in the management, operation and maintenance of SHP plants and facilities.	
Main drivers to SHP development	
Innovative SHP technical solutions (like those developed in Hydro4U) can help adapt the technology to local framework conditions.	
Utilization of existing waterways and pipelines helping to support renewable energy targets and reduce greenhouse gas emissions.	

6.1.1 Optimization of innovative Small Hydropower equipment

The two core technologies of the Hydro4U project are the Hydroshaft Power Solution (HSPS) for low heads and small to medium flows, and the Francis Container Power Solution (FCPS) for medium heads and small flows. Both technical concepts have been tested and implemented before Hydro4U, but their implementation has been characterized by complexity, customization and on-site construction, resulting in long construction periods and high costs. Therefore, both technologies were further developed and optimized into modular and standardized systems, with the goal of maintaining their proven advantages while decreasing complexity, construction time and project costs. The aim was to ensure that the final optimized products can be implemented in as many locations as possible without placing high demands on logistical, economic and infrastructure-related framework conditions and thus offer the highest possible replication potential.

To reach this objective, the first step was to collect and summarize the optimization potential for both the FCPS and the HSPS, which was elaborated by reviewing and analysing the state of the art of both technologies, based on projects that were realized with these concepts. This potential is described in detail within D3.1. The result was a list of measures that was then used to improve the technologies in the design phase during Task 3.2. A short overview, on how the identified developments help to increase the replicative ability of the small hydropower equipment is given for each technology in the following two subchapters:

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6.1.1.1 Hydroshaft Power Solution

The main lever to reach higher replicative ability of this system lies in reducing on-site complexity, meaning that construction works have to be reduced to simple and easy-to build structures and the installation of the technical equipment must follow a modular logic with standardized components without the need to adapt them on site. Further, it is necessary to enable access to the technical equipment for service and revision works without great effort.

The first step of implementation will always remain the site-specific design and establishment of a construction pit including dewatering in which the highly simplified structure, per HSPS unit mainly consisting of a foundation, two side walls and a transverse wall with mounting points for the technical equipment is constructed. Once this structure is completed, the technical equipment is mounted to the concrete structure´s pre-defined mounting points. The following main components are mounted to the concrete structure: turbine-generator unit with guide-frame and lifting system, flow gate incl. electrical drive system, tiltable trash rack with cleaning mechanism. Electrical plant controls are placed in a small building or container next to the river. The system is being designed in a way, that the structural work can always be held as simple as described above, therefore enabling replication of such projects also at remote sites with only simple construction methods and low infrastructure and logistic requirements. The technically complex components come pre-assembled to the site and thus can be quickly and efficiently assembled to complete the power plant.

The design of this system has been elaborated within WP3 and presented in detail in D3.2. In brief, the main features of the optimized system are as follows:

- Simplified constructional setup with approach flow channel
- Hydraulically optimized intake dimensions for one-sided approach flow
- Modular Straflo-type Turbine-Generator Unit “KaplanEVO”
- Turbine module frame for easy installation and revision
- Electrically driven sliding gate system
- Modular and tiltable electrically operated trash-rack units
- Standardization of electrical components

During the demonstration site design development within WP4 the above-mentioned modular design framework built the technical basis for the site-specific planning work. It is important to note here, that this modular system still needs a certain amount of adaptation to the site. This

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is mainly because of varying site parameters such as available head, flow and given boundary conditions (such as the geometry of an existing structure).

In case of the At-Bashy demonstration site for example, the project includes the refurbishment of the existing structures, the addition of a new fish pass and the change of the operating water levels. Therefore, the HSPS-modules only make up a part of the project, with the rest being related activities. Overall, it proved very helpful and effort-minimizing, that the technical parameters of the system were all available on very short notice as it was needed for the site-specific design, which is one of the big advantages of the modular and standardized design framework.

6.1.1.2 Francis Container Power Solution

The optimization of the FCPS follows a similar logic, thus reduction of on-site complexity, the simplest possible construction process and pre-assembly of all technically complex components in the factory. The main technical optimizations include the reduction of construction site material, the optimization and minimization or, where possible, the elimination of hydro-mechanical elements (such as pressure relief pipes, shaft sleeve, slotted levers, bypass line etc.). Additionally, the applicable turbine runner types are simplified and the number of possible types is reduced to the necessary minimum, that both ensures a wide operating range of the system, but at the same time enables a modular planning and fabrication procedure without much variation.

The replicable potential of the FCPS system is given by the fact that all technically complex components are placed in a standard container with standardized connection possibilities to the on-site infrastructure. With further measures, such as the development of a real-time suspended sediment monitoring, the constructional requirements can also be reduced, as this may eliminate the need for a costly sand trap at the inlet structure. With this method, the components of the power plant setup that need to be constructed on site are a simple inlet structure, a pressure pipe and the foundation of the powerhouse. The powerhouse itself, with all its components pre-assembled, comes in form of the container mentioned before, that is simply placed on the foundation and connected to the pressure pipe on site.

Same as for the HSPS, also the optimized design of the FCPS has been elaborated within WP3 and was presented in D3.2. The main features of the optimized design include: (i) a newly developed turbine dimensioning tool, (ii) the use of additive manufacturing, (iii) the development of a generic base frame that can be used for various turbine sizes and (iv) standardization of electrical components.

Also, for the FCPS it has to mentioned, that site-specific adaption cannot be completely avoided in hydropower development. But this system - due to the arrangement of all technical equipment within the container – needs even less site-specific adaption compared to the HSPS. Some relevant boundary conditions that generally need to be taken into account regarding adaption are the connection of the containers to the penstock, the operation scheme of the plant (e.g. island or grid-connected operation, or both), connection of the tailwater levels to the river.

6.1.2 Technical planning, sustainability and assessment

The development and implementation of SHP in CA provides the possibility to gain the relevant experience and formulate precise statements about which steps, measures and information are necessary in order to successfully and sustainably develop, build and operate SHP facilities in CA. The gathered information and all lessons learnt regarding the technical planning are summarized here to provide guidance for future planning and implementation of additional hydropower projects in the study area.

6.1.2.1 Planning process

This subchapter provides a rather general overview on the overall planning process from site selection to the start of construction. The final aim is to present a process that is as generally applicable as possible, from which potential project developers in the region can calculate the necessary steps, challenges, costs and timelines and thus maximize replication ability. Figure 20 shows the technical planning process over time and with increasing level of detail.

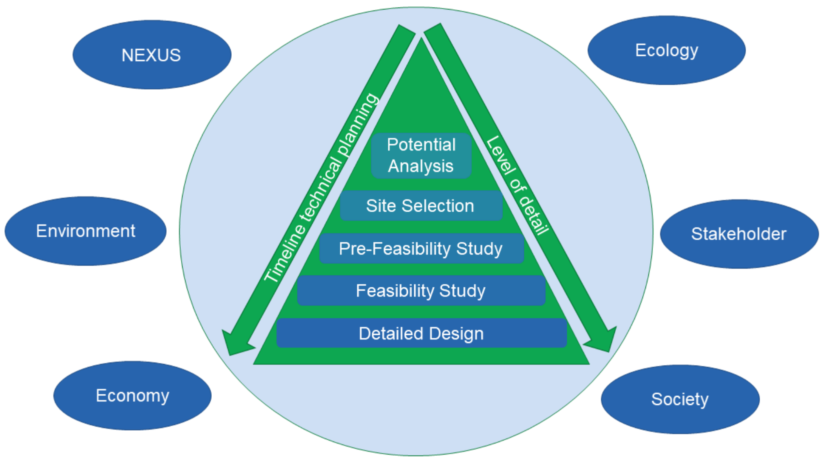

Figure 20: Steps of the technical planning process for small-scale hydropower in CA including all relevant aspects to obtain sustainable HPP solutions

- Potential Analysis: The first step is the **identification of potential sites**. This can be done using contacts to local partners who have good knowledge of the local river systems and also other water uses. As the Hydro4U project progresses, the hydropower potential tool of WP1, which will be incorporated in the guideline tool of WP5 (see also Chapter 5) will also help users to find potentially suitable small hydropower sites.

- Site Selection: **Information exchange** with local partners as well as **field visits** will then provide more detailed information on the potential sites and also the SHP type to be installed (site and technology selection). Hydrological data and first rough hydrological models will additionally produce information on available discharge as basis for the dimensioning of the SHP capacity. As part of this site selection, local stakeholders need to be identified and contacted to obtained as much information as possible regarding additional water uses, to avoid conflicts in the planning process and to maximize the effectiveness and acceptance of the SHP later on. In CA, irrigation is one major water user and is of high importance for food production and the economic situation in general. Local partners or investors help to identify local stakeholders such as authorities, NGOs, local communities and other potential water users and establish ways of communication. Information exchange between stakeholders is necessary to balance different interests and to define suitable and sustainable water uses. At both demonstration sites and also for the potential planning sites (see D4.1) this balancing and optimization of different water uses will be of high importance. Hydro4U's Nexus work, allocated in WP2, supports this process as relevant stakeholders were mapped, and involved in the project progress. In addition, Hydro4U will present in the final replication guideline a country specific analysis of the energy sectors mapping different institutions and explain different laws and national energy programs to consider (see Chapter 3.3).
- **Pre-feasibility study**: This study contains a roughly estimated technical, economic, environmental and social assessment of the future SHP and its effects including a first estimation of construction and equipment costs. Especially, the annual energy output needs to be assessed and considered in relation to capital and operation expenditures in order to design an economically sustainable solution.
- Feasibility Study: Including more and more details in the planning process allows the preparation of a **bankable feasibility study** including a **detailed environmental impact assessment**. Here, additional data obtained during field visits, results of hydrological, hydro-morphological and hydraulic calculations and simulations as well as economic optimizations are elaborated and supplemented by information from stakeholders. This information is used to design and compare different design alternatives for the SHP and finally make a fact-based decision for the best variant overall. This variant needs to be

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presented in the applicable way to the approval authorities according to locally relevant licensing requirements, with presentation, scope and language varying by country.

- Detailed Design: The **detailed construction design** is finally elaborated based on the approved design from the feasibility study. This step includes now the detailed design of all civil works and structural elements as well as the detailed production design of the technical equipment and a precise cost calculation building the basis for the equity and debt financing of a project.
- Construction Supervision: This phase ensures the correct implementation of the detailed design with the necessary accuracy and quality. Documented construction supervision builds the basis for any disputes and for the approval of the implemented measures before commissioning.

Hydro4U advances more sustainable hydropower solutions. This means all steps within the planning process include an assessment of all relevant environmental, social and economic aspects. A close contact with local stakeholders provides the possibility to identify optimized solution addressing all three aspects. In addition, Hydro4U pays particular attention to minimizing the ecological impact of the hydropower production. The entire process of technical planning is supplemented by environmental and ecological assessments (e.g. fish sampling, habitat modelling and fish telemetry studies). Furthermore, the WFEC Nexus approach complements the sustainable approach of Hydro4U.

Based on the experience gained in the Hydro4U project, the individual procedures are revised and expanded with increasing detail and with reference to and examples from the two demonstration projects and the three planning sites within the upcoming revisions of the Hydro4U replication plan. The following sections show the current status of the technical planning for the demonstration and as well as for the planning sites and describe lessons learnt so far.

6.1.2.2 Current state of planning within the Hydro4U project

Within the Hydro4U project, small-scale hydropower technologies are being optimized and installed at two sites (demonstration activities). Parallel to the technology development in WP3 (Task 3.1 and 3.2) the sites are developed step by step in planning terms. For these two sites, first a preliminary layout, then a feasibility study and finally the detailed construction design have been prepared. The authority approval process is also part of these demonstration activities, that is based on the design and assessments of the feasibility study phase. Additionally, at least three further bankable feasibility studies in cooperation with potential investors are elaborated, which are called planning activities in the Hydro4U nomenclature and are being elaborated within Task 5.3. These planning activities aim to develop additional small hydropower projects from Hydro4U in order to increase the replicability and reach of the project, but with financial resources raised elsewhere in an economically sustainable way for their implementation.

At the current state of the project, potential hydropower sites were investigated. In autumn 2021, Hydro4U visited a number of potential sites in Kyrgyzstan, Uzbekistan and Kazakhstan and identified several potentially suitable sites for small-scale hydropower (see D4.1). In the beginning of 2022, it was decided to select the site Shakhimardan at Koksu River in Uzbekistan for a demonstration site for the FCPS and At-Bashy River in Kyrgyzstan for demonstrating the HSPS. The main criterion for the selection of the demonstration sites was the availability of a motivated, committed and creditworthy local investor for the implementation, due to the special situation that the demonstration facilities are to be implemented within a time-limited funding project. Especially within international projects, local experts and qualified partners are important in order to be successful, as they provide detailed knowledge of the specific sites, establish the possibility to exchange information with local authorities and stakeholders and guarantee an efficient and long-term operation of the HPPs.

Within the first assessment phase the head, flow and therefore power potential was estimated. Based on this it is already possible to decide whether it makes sense to carry out more detailed assessments and also which hydropower technologies should be considered.

The next phase comprised the detailed assessment of the condition/usability of existing civil structures, infrastructure and accessibility to the site, connection to the electricity grid and most importantly, the hydrological situation in order to narrow down the size of the power plant and estimate the possible annual energy production, which in turn is necessary to define the financial cost framework. Therefore, discharge data was collected from authorities and hydrological models were developed to obtain hydrographs and flow duration curves. In addition, models were set up to simulate potential effects of different climate-change scenarios in order to estimate their impact on the power plant design. Parallel to this, the ecological situation at both sites was assessed and measures for the preservation and – where possible – improvement of the ecological condition were developed. This includes aspects like upstream and downstream fish migration possibilities, fish protection, habitat-based environmental flow assessment and hydromorphological equilibrium.

All these assessments showed that both sites are well suitable for the further consideration and fit well to each Hydro4U SHP technology options.

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The Hydro4U experts created first the draft design of both demonstration sites presented in D 4.2. Within the following steps, the detailed feasibility / authority approval designs (D4.4) and sustainability reports (D4.3) were developed followed by the detailed construction design (D4.4). In Shakhimardan, the construction works are now finished and the commissioning of the hydropower plant is scheduled for July 2024. In At-Bashy, currently, the authority approvals are pending and expected to be granted to allow a construction start in August 2024.

In addition to the demonstration activities, in June 2022, Badam Reservoir in Kazakhstan was selected to be the location of the first planning activity. The Badam reservoir, which was originally intended as a demonstration site for HSPS, was identified as a suitable planning site that offers the potential to expand the existing infrastructure with a Francis-type power plant due to the available head of the reservoir. First a preliminary variant study describing and comparing different locations for the turbines and different turbine types had been elaborated and discussed with the local investor. Based on the decision of the investor, the planning site was further elaborated with the aim to design a conventional Francis-Turbine-Type Powerhouse, as the Francis Container Solution proved to be not the best variant in economical point of view. Subsequently, the final feasibility study was elaborated and will be handed over to the potential investor in May 2024.

As part of task 5.3 of the project, two further planning sites will be selected.

6.1.2.3 Lessons learnt in the technical design process

Within the realization of the technical planning process at the demonstration sites and the first planning activity as described above, several difficulties emerged which had to be managed by the Hydro4U consortium. These aspects are complementary to the main barriers and drivers to SHP described in D5.1, but are focus on the technical planning process. The following Table 9 summarizes the identified difficulties and the associated lessons learnt which emerged in the specific planning stage so far.

Table 9: Lessons learnt in the technical design process in Hydro4U Project

Planning Phase	Difficulty	Lessons Learnt
Potential Analysis / Site Selection	Low spatial and temporal resolution of hydrological data	- Use of state-of the art climate models and hydrological models
	Missing information and limited knowledge on existing water uses and channel system: Definition of available water resources is difficult	- Close contact to local stakeholders and experts as well as local authorities is needed to enable a good information exchange - Field visits by hydrology and hydropower experts to understand availability and use of local water resources - Use of aerial images as well as topographic tools and hydrological models to detect river and channel systems as well as water quantities - Importance of the in WP1 developed potential analysis tool to facilitate this process in future
Pre-feasibility and Feasibility studies	Limited knowledge of expected material and construction costs / Limited knowledge on expected Feed-in Tariffs (FITs)	- Information exchange with local investors as well as local construction companies to estimate local cost ranges
	Missing or limited information and drawings on existing civil structures	- Close contact to local experts and investors providing contact to authorities in order to find old documents - Use of innovative and modern survey methods such as structure from motion to obtain high resolution terrain data and dimensions of civil structures
	Limited knowledge of local investors on innovative and sustainable hydropower solutions	- Meetings between local investors and hydropower experts at sites to understand the local conditions and to elaborate a sustainable hydropower option together - Invitations of local investors to visit the manufactures as well as existing sustainable hydropower plants - Use of several information platforms in English and Russian to inform the international community about the project goals and sustainable SHP in general (website, social media, conferences, publications, flyers …)
	Low social awareness of the importance of ecosystems integrity and the need of ecological mitigation measures	- Meetings between local investors and hydropower experts to discuss ecological impacts of hydropower and to highlight social importance of ecosystems integrity - Designing mitigation measures which are easily implemented and maintained to increase social acceptance - Motivation of investors / operators to implement ecological measures by making it part of material transfer and funding agreements
	Limited knowledge about geotechnical site conditions	- Exact definition of scope and methods for geotechnical surveys that are adapted to technical possibilities of the locally available equipment and workforce

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Planning Phase	Difficulty	Lessons Learnt
	Limited knowledge of local funding and loans possibilities for potential investors	- Evaluation of different funding and loans options for investing in renewable energies in CA (see Chapter 6.2)
Detailed design phase	Unreliable data basis	- Conduct own assessments whenever possible
	Lack of knowledge on national requirements for the scope of design documents	- Include local but English-speaking experts in the process
	Language barrier – documents to be submitted in local language	
Construction and commissioning phase	Deviations between approved design and actual execution	- Agree on legally binding monitoring and interim approval of construction progress with construction company - Perform regular site visits with pre-defined checklist and prepare protocols
	Unknown / not understandable communication and administration processes on the local investor´s side	- Involve bilingual expert who shall be involved in all communication and regularly document the progress of processes
	Travel restrictions	- Involve high-level authorities as early as possible in travel planning (in case of project sites in restricted areas)
	Infrastructure restrictions	- Prepare for non-availability of internet connection with “offline” equipment
	Unavailability of tools and trained staff	- Perform confirmed tool check by local supporting staff before deployment of international staff - Plan buffer time for basic training of local staff

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6.2. Economic viability analysis

Based on *Hydropower Sustainability Guidelines* (IHA, 2020) a project is financially viable if it generates sufficient cash flow to deliver an appropriate risk-adjusted return on the capital invested. In order to calculate the project's viability, it is important to properly assess the project costs and revenue estimate streams, keeping in mind identified barriers and risks from D5.1 on Table 10 below:

Table 10: Main economic barriers and drivers to SHP development

<table>
<tr><th>Main barriers to SHP development</th><th>Hydro4U approach</th></tr>
<tr><td>High upfront investment required to launch a project, and lack of funding sources (private sector (e.g. equity investment), or financing mechanisms (e.g. loan), or financial support from the Governments (e.g. tax reduction).</td><td rowspan="3">Conduct a proper project's viability assessment including the project costs and revenue estimate streams, including the cost of mitigation measures.

Identify different sources of support and financing, even preferable specific ones for renewable and sustainable projects, and the specific requirements to be eligible for them (legal, environmental and social).</td></tr>
<tr><td>Low electricity prices in comparison to the generation costs, the current Feed-in Tariffs (FITs) are not sufficiently high for making the SHP projects economically viable.</td></tr>
<tr><td>Local banks' ability to support SHP projects is constrained by single- borrower exposure limits imposed by central banks, with their own internal guidelines being predominantly based on collateral borrowing.</td></tr>
<tr><th colspan="2">Main drivers to SHP development</th></tr>
<tr><td colspan="2">Reliable access to electricity through SHP allowed local enterprises.</td></tr>
<tr><td colspan="2">Innovative mechanisms developed by international and local banks (e.g. EBRD risk sharing framework with local banks).</td></tr>
</table>

- **Projects costs** includes Construction and pre-construction costs (e.g. detailed design), operation and maintenance costs, taxes (land acquisition and permits) and derived costs from the additional measures identified in Environmental and Social Impact Assessment (ESIA) or Risk assessment.
- **Revenue estimates** are defined based on the previously defined generation and demand forecasts including ancillary services and market variability. The revenue can come directly from sales to the grid in auction prices with FIT, and/or though PPA (Power Purchase Agreements), self-consumption savings, or ancillary revenues. Positive revenue streams also include state support measures, private financing by local banks or funding by development finance institutions, bilateral agencies, multilateral development banks and sovereign wealth funds.

Main insights regarding the financing of SHP projects are summarized below.

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6.2.1 Government funding support

Local governments may have policies to promote sustainable and green projects, including measures to provide direct support through subsidies, grants, equity investment and loans (i.e. debt). Or indirect support to lower the overall project cost, like waiving fees, costs or tax exemptions. For example, in Kazakhstan SHP projects are considered as *Priority investment project* (see Figure 21), which makes them eligible for state support as, exemption from payment for electricity transmission services and other taxes, as well as having priority to be included in the energy grid when dispatching energy auctions.

Investment preferences	Investment project	Priority investment project
Exemption from imposing customs duties on imports	✓	✓
Import VAT exemption	✓	✓
State in-kind grants	✓	✓
Exemption from CIT		✓
Land tax exemption		✓
Exemption from property tax		✓

Figure 21: KAZ Investment preferences, (USAID, 2022)

Also in 2020, renewable energy projects were included in the *List of priority sectors of the economy,* which gives investment preferences for its implementation, and is managed by Investment Committee under the Ministry of Foreign Affairs of the Republic of Kazakhstan (MFA RK). Applicable for:

- Implementing new facilities ≥ 2 million MCI* (KZT 6.9 bn in 2023)[1]
- Renovation or expansion of existing facilities ≥ 5 million MCI* (KZT 17.25 bn in 2023)

6.2.2 European and International financing in CA

This Chapter includes a brief description of the identified international sources of funding that operates in Central Asia from D5.2 (López *et al*. 2022), which are listed in the Table 11 below.

The most common financing instruments, defined by the EU would be direct funding though grants, indirect funding as subsidies managed by national authorities, and direct loans or guarantees. For example, in Kazakhstan, the most common structure used for financing

[1] Note: Monthly Calculation Index = 3450 KZT in 2023

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renewable energy projects is a mix of 30% of equity financing by local investors, and 70% of debt financing by bank institutions, as listed on the Figure 22 below.

Figure 22: Financing of renewable energy projects in Kazakhstan, (AIFC, 2023)

There are other funding sources aiming to support the sustainability of the electricity sector. One example could be the DAMU FUND, which has already promoted more than a hundred green projects in Kazakhstan. DAMU FUND is administered by Baiterek National Management Holding Joint-Stock Company, a public-private co-funding entity. The instruments used for this purpose are guarantees, subsidies and different types of loan programs. For example, in order to decrease the investments risks for renewable energy projects, this fund will provide working capital up to 25% of the initial investment.

In order to access to this funding instruments, the project must comply with specific requirements from each development bank, some common requirements would be:

- The project must be located on one of their defined eligible countries
- The project must show compliance and alignment with the EU objectives, which would be to demonstrate that is more focused on creating positive impact (environmental and social) rather than just their own economic benefit.

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Table 11: European and international Financing institutions [from D5.2]

Entity[(1)]	Eligible countries	Funding Channel	Instruments
European financing institutions			
EEAS	CA	Builds alliances with different EU delegations and member states.	EU-funded projects, public contracts, grants, budget support.
IFCA	CA	Resources from multilateral and bilateral European Finance Institutions, regional development banks, partner countries and beneficiary institutions in CA.	Investment grants, technical assistance, risk capital and other risk sharing instruments.
EIB	KAZ, KGZ, TJK, UZB	The EU bank, which borrows money on capital markets, lend it on favourable terms to projects aligned with EU objectives.	Loans, guarantees, microfinance, equity investment, blended solutions and even project management.
EBRD	CA	Its main funding channel on CA is the *Investment Facility for Central Asia (IFCA).*	Big projects: Loans, equity investments or guarantees [from M€ 5 to M€ 200], Small projects: direct investments through local intermediaries or programs [less than M€ 5].
EDB	KAZ, KGZ, TJK	Finance sustainable development projects raising funds by issuing green and social bonds, and other in capital markets.	Loans, Equity participation, Structured trade finance or programs, as the *Energy efficiency program*: Non-revolving loan, [from US$50,000 to 25% of facility amount]
KfW	KGZ, TJK, UZB	Indirect support is provided through financial institutions for SMEs.	Grants, Budget funds and loans.
AFD	CA	Bilateral public financial institution	Loans, guarantees and bond issues for company projects. Grants for sustainable development actions.
International financing institutions			
World Bank	CA	The world bank raises funds from the capital markets at low interest rates, allowing to finance developing countries at lower rates.	Indirect for governments: IBRD Loan, IDA credit/grant, and guarantees. For infrastructure and policy development, Direct: Program-for-results, Trust funds and grants in critical situations. Private sector: IFC and MIGA direct investment and guarantees.
ADB	CA	ADB's lending comes mainly from ordinary capital resources at near-market terms and at very low interest rates for lower income countries to help reduce poverty.	Loans, technical assistance, grants, and equity investments. Private sector: Direct and limited financial assistance, Co-financing: Results-Based Lending (RBL) for programs, and Trade finance program (TFP) for banks.

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AIIB	CA	AIIB works with MDBs in co-financing, e.g. World Bank, ADB or even receives funding from the Global Innovation Fund (GIF).	Sovereign and non-sovereign loans mainly, but also grants and funds (Trust-funds and other Special-Funds). For SMEs: vaccine financing and liquidity support, and also the Project Preparation Special Fund (PPSF).
GEF	CA	Funding by GEF is contributed by donor countries, international institutions, civil society organizations and the private sector; for Government projects and programs.	Full-sized Project (FSP): > M€ 2 US dollars. Medium-sized Project (MSP): ≤M€ 2 US dollars. Enabling activities and programs.
GCF	CA	GCF is the financial mechanism under the UNFCCC	Blended finance through grants, concessional loans, subordinated debt, equity, and guarantees.
CIF	CA	Funding channel of the World bank, that disburse the economic resources through MDBs.	Grants, highly concessional loans, and risk mitigation instruments.

(1)**:** Asian Development Bank (ADB), French Development Agency (AFD), Asian Infrastructure Investment Bank (AIIB), Climate Investments Funds (CIF), European External Action Service (EEAS), Eurasian Development Bank (EDB), European Investment Bank (EIB), European Bank for Reconstruction and Development (EBRD), Green Climate Fund (GCF), Global Environment Facility (GEF), Investment Facility for Central Asia (IFCA), KfW Development Bank (KfW)

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6.3. Legal and political guidelines

Legal and political barriers and drivers for SHP development, which were identified in D5.1 (López *et al*. 2022), are included in the Table 12 below.

Table 12: Main legal and political barriers and drivers to SHP development

Main barriers to SHP development	Hydro4U approach
Lack of clear regulation framework to obtain licenses (e.g. grid connection, special water use), or technical specifications.	Realize feasibility studies since the design and planning phase, including a legal assessment, to ensure that all the legal framework has been identified and political risks analysed. With that analysis additional measures or requirements will be identified and included in the initial planned budget, ensuring project approval and avoiding administrative delays.
Lack of well-defined laws and guidelines with regards to foreign/external investment.	
Discontinuity in governance, affects fulfilment of transition and energy plans.	
Promotion to larger projects (energy shortages).	
Main drivers to SHP development	
Green SHP supported by regulations, guidelines, incentive policies and practices, to maintain the ecological safety of the sector.	
Incentive policies for SHP development.	

Legal barriers are mainly related to a lack of clear regulation framework to obtain permits and licenses (e.g. grid connection, land acquisition, special water use), or legal complexity due to the existence of several institutions with responsibilities for different aspects (e.g. different regulators and agencies for electricity generation, pricing, transmission and distribution; dam safety and labour conditions; or environment and water resource management).

Based on the guide *USAID and Ministry of Energy. Investor's Guide to Renewable Energy Projects in Kazakhstan* (USAID, 2022), a prior legal assessment, as part of feasibility studies; ensures that all the legal framework has been identified and political risks analysed, in order to ensure project approval and avoid delays. For example, in Kazakhstan:

- Special water use permit: provided by the Catchment Authorities of the Ministry of Agriculture of KAZ (MoA RK). In order, to acquire the special water-use permit, the promoter must include the definition of technical and environmental measures, which includes the installation of fish protection and fish access structures, and the amount of water resources to be used.
- Environmental Impact Assessment (EIA): according to the Environmental Code of the Republic of Kazakhstan, EIA is mandatory for HP plants with a total installed capacity of 50 MW or above, or with an installed capacity of an individual generating unit of 10 MW or above. Even though it is not mandatory, it is highly recommended, since projects with a

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proper EIA may be eligible for preferential financing options designed to promote renewable and sustainable projects.

6.4. Environmental and social guidelines

Environmental and social risks for SHP development, which were identified in D5.1 (López *et al*. 2022) are shown in Table 13 below. They include seasonal changes in water availability or unregulated SHP development which can result in significant ecological impacts (e.g. water availability, river ecology, reduced river connectivity) and thus, altered migratory fish and other aquatic species.

Table 13: Main environmental and social barriers and drivers to SHP development

Main barriers to SHP development	Hydro4U approach
Seasonal changes in water availability for SHP generation, versus high availability of non-renewable thermal power sources (e.g. natural gas and coal), and not high off-grid power demand of the communities.	Conduct Environmental and Social Impact Assessment (ESIA) to identify positive and negative impacts of the project over the environment and local communities, to define and implement mitigation measures and promote project's positive impact. Ensuring project approval and compliance with lenders criteria.
Unregulated SHP development can result in significant ecological impacts, including river loss of water, changed river ecology, reduced river connectivity and affected migratory fish and other aquatic species.	
Low social awareness (people, governmental agencies, organizations and institutions) about the benefits of SHP for the Region and its multiple benefits.	
Main drivers to SHP development	
Dissemination activities for policy development and energy planning, as well as to guide investors entering renewable energy markets.	
Mini-grid and off-grid SHP solutions for remote rural areas, more adaptable to the particular community's needs and local conditions, expanding access to RE.	
SHP can trigger an improvement in community's quality life (e.g. Improving employment, public service provision, autonomy and overall health and education).	

In Small Hydropower Projects the environmental assessment and adherence to international standards and guidelines are key to promote sustainable development and minimize negative impacts. Compliance with environmental and social requirements are a key aspect to ensure meeting the expectations of:

- Communities: improving community's quality life; through employment or provision of public services.
- Regulators: Facilitating to meet the legal requirements to obtain the necessary licenses and permits (e.g. grid connection, special water use); which avoids delays or denials in approvals during the project implementation.

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- Lenders: there are preferential funding options for renewable and sustainable projects if they qualify to for development bank loans or for certified green and climate bonds.

The guide *Hydropower Sustainability Guidelines* (IHA, 2020) defines an Environmental and Social Impact Assessment (ESIA) as an assessment that "*identifies, predicts, evaluates and proposes mitigation for the biophysical, social, and other relevant effects and consequences of development proposals prior to major decisions being taken and commitments made.*"

An ESIA must include a technical description and demonstrated need and strategic fit, relevant legal and policy requirements, analysis of potential risks and their impacts (positive and negative) over the environment and affected communities, alongside with proposed mitigation measures and management plans linked to each identified impact; and a monitoring program to ensure their implementation effectiveness.

Common potential risks derived from ESIA study are gathered in the Table 14 below, jointly with their likelihood or probability of occurrence, related project phase, and proposed contingency plans to avoid that risks or minimize their impact. These *Environmental and social potential risks in SHP projects* have been defined based on a literature review:

- World Bank's Environmental and Social Framework (ESF), which gathers **ten different requirements or standards** that apply to general projects aiming to achieve a green, resilient and inclusive development.
- *Hydropower Sustainability Guidelines* (IHA, 2020), which is a compendium of referenced rules related to technical, environmental, social and financial topics.

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Table 14: Environmental and Social Impact Assessment, potential risks analysis for SHP projects

Risk	Likeli-Hood[1]	Phase[2]	Contingency Plan:	Positive Impact:	Adverse Impact:
Alteration of River Flow and Hydrology: The construction of a small-hydropower project can alter the natural flow of the river, leading to changes in the hydrological regime. This can impact downstream ecosystems, aquatic habitats, and water availability for downstream users.	L	Op	Implement environmental flow releases to mimic natural flow patterns and maintain downstream ecosystems' health.	Helps preserve downstream ecosystems, supports aquatic life, and maintains ecosystem services for local communities.	Could potentially affect water availability for other users downstream, leading to conflicts over water resources.
Habitat Loss and Fragmentation: The construction of dams or diversion structures can result in the loss of natural habitats, especially for aquatic species and riparian ecosystems. It can also lead to habitat fragmentation, isolating populations and reducing biodiversity.	L	Cons	Develop and implement habitat restoration and compensation measures, including creating new habitats and re-establishing ecological connectivity and buffer zones to protect sensitive habitats.	Helps restore lost habitats, enhances biodiversity, and improves overall ecosystem health.	Restoration efforts may not fully replicate the original habitats, leading to potential differences in species composition and ecosystem dynamics. Increase of budget.
Fish Migration and Passage: Small-hydropower projects may obstruct fish migration routes, affecting the spawning and feeding patterns of fish species. This can lead to declines in fish populations and negatively impact local fishing communities.	H	Op	Install fish-friendly technologies such as fish ladders, bypass channels, or fish screens to allow for safe fish migration and preserve aquatic ecosystems.	Facilitates fish migration, supports fish populations, and maintains fishery resources for local communities.	Some fish species may not effectively utilize the installed fish passage structures, leading to incomplete migration and potential impacts on fish populations. Increase of budget.
Water Quality Degradation: Sedimentation, changes in water flow, and the release of pollutants from construction activities can lead to water quality degradation,	L	Both	Implement erosion control measures and sediment traps during construction, as well as sedimentation ponds and natural	Reduces water pollution, maintains water quality for both aquatic ecosystems and human consumption.	The installation and maintenance of water treatment systems may have operational costs and energy requirements.

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Risk	Likeli-Hood[1]	Phase[2]	Contingency Plan:	Positive Impact:	Adverse Impact:
affecting both aquatic ecosystems and water resources used for drinking and irrigation.			filtration systems for water quality management.		
Erosion and Sedimentation: The construction phase can cause erosion and sedimentation, leading to the deposition of silt and debris downstream. This can smother aquatic habitats, affect water clarity, and impair the ability of fish to find food.	M	Both	Implement sediment control measures during construction, such as silt fences, vegetative cover, sediment basins, and erosion control blankets.	Minimizes sedimentation downstream, preventing adverse impacts on aquatic habitats.	The installation and maintenance of sediment control measures may require additional resources and expenses.
Noise and Visual Impact: The construction and operation of a small-hydropower project can create noise pollution and alter the visual landscape, impacting the aesthetics and tranquillity of the surrounding area.	L	Both	Implement noise mitigation measures, such as sound barriers and construction scheduling to minimize noise disturbance.	Reduces noise pollution, enhancing the overall environment for local communities.	Implementing noise mitigation measures may add to the project's construction. Increase of budget.
Biodiversity Loss: The alteration of river flow and habitat destruction can lead to the loss of biodiversity, affecting plant and animal species that rely on the riverine ecosystem.	M	Both	Conduct thorough biodiversity assessments before and after project development. Develop and implement biodiversity management plans to protect and enhance the local biodiversity.	Contributes to the preservation and enhancement of biodiversity, supporting ecological balance.	Implementing biodiversity management plans may require additional resources and efforts.
Greenhouse Gas Emissions: While small-hydropower is considered a renewable energy source, the decomposition of organic matter in the reservoirs can lead to the release of greenhouse gases such as methane, which contributes to climate change.	L	Op	Implement measures to reduce organic matter decomposition in reservoirs, such as optimizing reservoir water level management. Consider alternative methane capture and utilization technologies to mitigate greenhouse gas emissions.	Reduces greenhouse gas emissions, contributing to climate change mitigation efforts.	The adoption of alternative technologies may involve initial investment costs and operational adjustments.
Social Impacts: The construction and operation of small-hydropower projects can	L	Both	Develop a comprehensive social management plan, including effective stakeholder	Fosters positive relationships with local communities, enhances	Implementing a social management plan may require additional

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Risk	Likeli-Hood[1]	Phase[2]	Contingency Plan:	Positive Impact:	Adverse Impact:
lead to social impacts, including the displacement of communities, changes in livelihoods, and potential conflicts with local communities over land and water use.			engagement, grievance redressal mechanisms, and livelihood restoration programs for affected communities.	social acceptance, and supports sustainable community development.	administrative efforts and financial resources.
Climate Change Vulnerability: Small-hydropower projects may be vulnerable to climate change impacts, such as changing precipitation patterns and water availability, which can affect energy generation and project sustainability.	H	Both	Conduct climate risk assessments to identify vulnerabilities and develop adaptation strategies for changing hydrological patterns and extreme weather events. Implement climate-resilient infrastructure and operational plans.	Increases project resilience to climate change impacts, ensuring long-term sustainability.	Developing and implementing adaptation measures may involve additional costs and ongoing monitoring and adjustments.

[1] Likelihood: High / Medium / Low

[2] Phase: Construction / Operation / Both

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7. Hydro4U replication guideline tool

In Central Asia allocation **conflicts** between **large-scale hydropower in the upstream and irrigation in the downstream** occur regularly and mostly across complex international borders, especially during water scarce years and low storage conditions. With an increasing attention on climate-neutral hydropower solutions (such SHP), the WFEC Nexus is now under renewed focus in the region. In line with these developments, new Nexus trade-offs are emerging that need to be recognized and quantified, including in a changing climate.

Taking into account this context, replicability in Hydro4U will be addressed by means of a **replication guideline tool**, to support decision-making for new SHP projects considering WFEC Nexus constrains, sustainability of resources, climate change impacts and socio-economic scenarios. The replication guideline tool will make possible the identification of **replication areas** together with feasible policies to build sustainable hydropower scenarios in Central Asia at basin or sub-basin scale.

7.1. The importance of including transboundary WFEC Nexus considerations in the decision making for new SHP projects

Following the global trend, **water demand in Central Asia is increasing** due to the growing agricultural production and changes from rainfed to irrigation systems, the demographic growth or the increased evaporation due to the average temperature rise. However, water resources are non-uniformly spread across Central Asian countries. While upstream countries have abundant water resources, downstream countries are characterized by natural water scarcity. Freshwater shortage already causes 70% of the region's developmental problems, with increasing tensions related to water supply (Severskiy, *et. al*. 2004). Climate change will exacerbate water scarcity and therefore, will increase these local tensions (Sorg, *et. al*. 2014).

Furthermore, CA countries can be divided in terms of **the share of HP Plants in the energy supply**. Currently, 90% of electricity in Tajikistan and Kyrgyzstan comes from hydropower, compared with around 10% in Uzbekistan and Kazakhstan. The two "upstream countries" are interested in generating and exporting more electricity through the construction of hydroelectric dams and reservoirs in the main transboundary tributaries of Amu Darya and Syr Darya. This aspect is creating serious problems for agricultural water supply in other countries in the region and has been the main root of conflict between CA countries for many years.

The stability of the region is also threatened by the increased desire for unilateral and non-coordinated management of water resources of transboundary rivers or the growing tendency

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to commercialize water and treat it as a commodity. Considering the effect of one country's decisions on its neighbours, the WFEC Nexus in Central Asia must not only integrate cross-sectoral considerations but also requires cross-border integration from a geographical as well as political point of view (Liu, *et. al*., 2019).

CA countries need to coordinate and revise their strategies to preserve the common ecosystem and reduce the economic losses associated to loss of resources and ecosystem services. In order to support this process, the Hydro4U replication guideline tool has been conceived as an easy-to-use and user-friendly application and will be based on the following considerations:

Target audience of the tool includes energy Industry and Power Generation Companies, Government and Regulatory Entities, Research Institutions and Academic Centres, Environmental and Energy Consulting Companies, Investors and Financiers, NGOs and Sustainable Development Organizations, Local Communities and Regional Authorities, Manufacturers and Suppliers of Hydroelectric Technology.

In that regard, the **main needs** of the user segment that we are targeting are:

- ease the decision-making process of stakeholders with regards to SHP projects in Central Asia.
- increase the chances of success of future SHP offerings made by technology providers who need to make the case for their products/services.

In order to meet those needs, the Replication tool will showcase the **following features**:

- easy to use application to simulate different scenarios at river basin/sub-basin level.
- simulation of realistic HP development scenarios that take into consideration WFEC Nexus constraints, sustainability of resources, climate change impacts and socio-economic constraints.
- generation of meaningful geo-located values at river basin scale for the scenario simulation, making use of the sustainable hydropower potential methodology as well as of the results from WP1 of the project Hydro4U.

7.2. WFEC Nexus System Dynamics Model

The replication guideline tool will be based on a WFEC Nexus model, which is being developed within Task 5.2. This Nexus model is integrated by **three functional modules for the water, food and energy sectors**, while **climate** is being included as different climate scenarios as it can be seen in the Figure 23:

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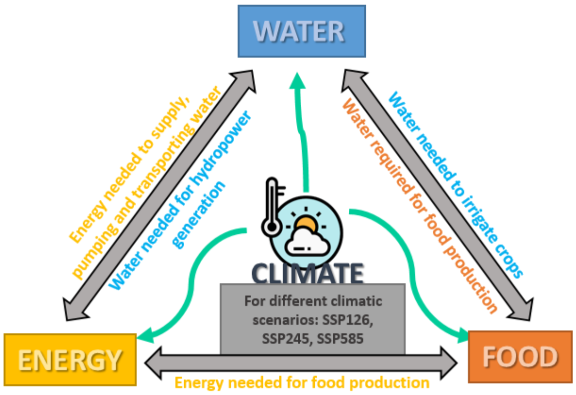

Figure 23: High level conceptual model of the WFEC Nexus in Central Asia.

The computational model is being developed in **System Dynamics** using the **vensim software**. So far, the model comprises around **150 variables**, starting with the main components of the hydrological water cycle and integrating GIS data for the selected country, basin or sub-basin (see Figure 24). The model also includes data from international organizations such as FAO or IEA and other findings of Hydro4U such as the hydropower sustainable potential calculations from WP1 and the Nexus constraints identified in WP2. A **database** is being generated to feed the model, and variables are related to each other by means of mathematical **equations**. Main equations are being defined following reported information (Keyhanpour *et. al* 2021).

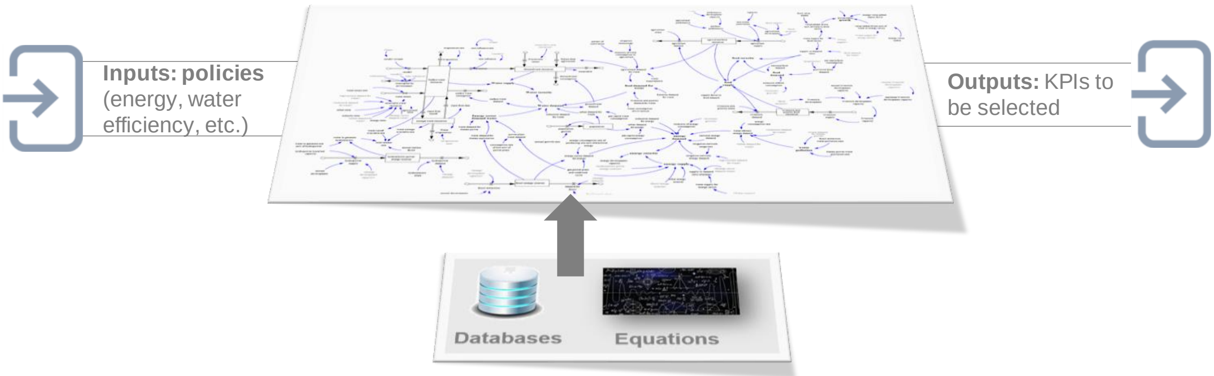

Figure 24: Hydro4U System Dynamic Model.

The model inputs will include local renewable energy policies and measures (described in the Chapter 3) or foreseen targets for SHP development in CA (identified in the Chapter 5.5.). The model will simulate the impact of these policies at different country, basin or sub-basin levels with future projections.

Finally, **the model outputs** will be stated by KPIs previously defined: GHG emissions, SHP installed capacity, etc.

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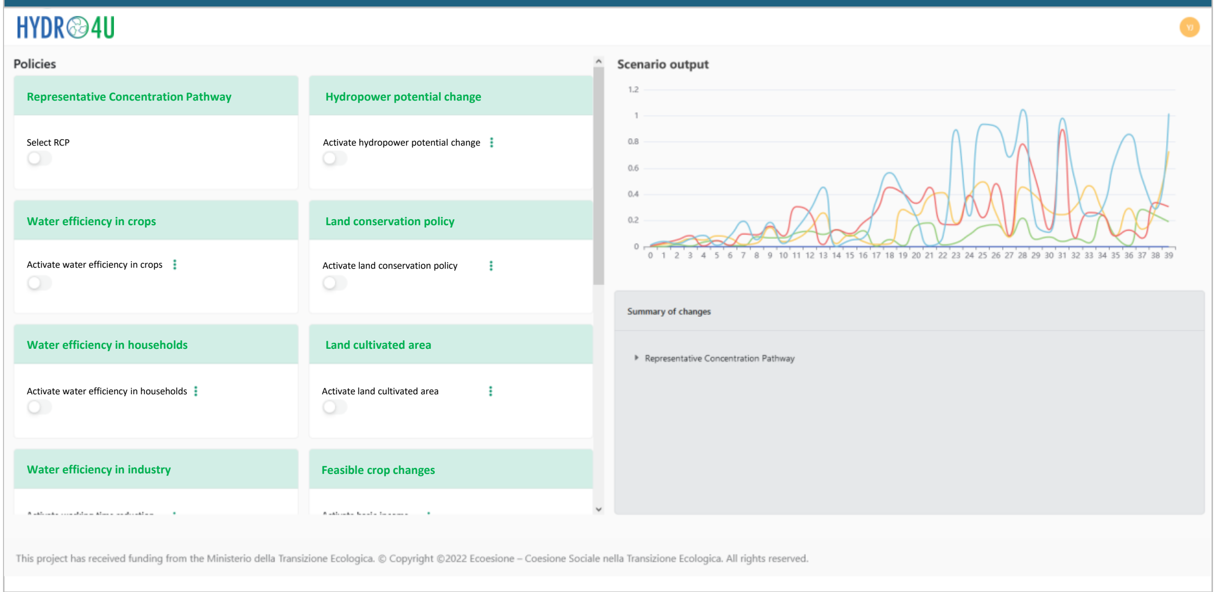
7.3. Replication guideline Tool definition

The Replication guideline tool to be defined within Task 5.4, will be based on a computational model (WFEC Nexus model) and will be able to provide a simulation environment that will help to identify the main areas for the Hydro4U hydropower technologies replication considering also the potential improvements and the associated impacts as a consequence of the implementation of policies and measures related to WFEC Nexus and associated systems. The main idea of the tool is summarized in the Figure 25:

Simulation of hydropower scenarios at river basin level



→ The user will be able to decide Hydropower generation scenarios by (1) selecting the additional HP to be installed or (2) selecting the locations according to the remaining potential.
→ The user will be able to make decisions regarding the efficiency in the water demand.

→ The tool will simulate scenarios of HP generation and water demand decisions and will provide the correspondent outputs in terms of power generation, water efficiency and consumption, GHG emissions, etc.

Figure 25: Concept idea of the replication guideline tool.

Different **tool architectures** will be evaluated for model integration starting from a client-server architecture with a pre-calculated database for the implementation of simulations with the model selecting the initialization data by means of a selection of the basin boundaries in the tool interface. Different alternatives (e.g. emulation, server licensed, real time, etc.) for model integration will be analysed. These alternatives will consider as key, the real time implementation of simulations using the tool. To this end, a Python version of the model or a translation into WebAssembly (WASM) will be analysed to understand the effects of the water demand decisions taken by the user.

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8. Conclusions

Central Asia region has one of the **largest hydropower potential capacity of the world**. Within Hydro4U, a new methodology has been developed to standardize the calculation of the remaining sustainable SHP potential, which considers environmental, ecological, geo-morphological and climate change constraints. According to our procedure, the total **remaining sustainable SHP potential in the region is 28,680 MW**, which is distributed heterogeneously between countries with a high potential (KGZ, KAZ or TJK) and others where this capacity is lower (UZB) or residual (TKM). Despite this high potential, small-scale hydropower is not well developed, **with only 329 MW installed** in the region by 2023.

The growth of the sector is favoured by the political and economic reforms being implemented in CA countries. All countries of the region, except Turkmenistan, have adopted **primary legislation to promote SHP development**, for example, the Kazakhstan 2050 strategy, the Electricity Sector Modernization and Sustainability Project in Kyrgyzstan, or the Program for the Hydropower Development 2017–2021 in Uzbekistan. Countries have set ambitious goals for expanding sustainable SHP and, as far as we are concerned, a capacity of 201.38 MW has been recently installed and **1,384 MW** is foreseen for the next years in the Region.

This 3rd release of the Hydro4U replication plan includes an in-depth assessment of technical, economical, legal &political and environment & social criteria to determine the viability of a sustainable SHP projects. In addition, Hydro4U consortium is gaining an ample experience during the realization of the technical planning process at the two demonstration sites (in UZB and KGZ) and the first planning activity (in KAZ). The **lessons learnt** within the site selection phase or the next bankable feasibility studies (Task 5.3) and future SHP projects.

Central Asia region has a number of geographical characteristics that make it necessary to consider the WFEC Nexus when planning and designing new SHP plants. The two upstream countries (TJK and KGZ) have a large SHP potential and the current installed HP already provides 90% of the country's electricity needs. The two of them are interested in generating and exporting more electricity through the construction of hydroelectric dams and reservoirs in the main transboundary tributaries of Amu Darya and Syr Darya. This aspect is creating serious problems for agricultural water supply in other countries in the region and has been the main root of conflict between CA countries for many years. The **Hydro4U replication guideline tool** is being developed to support decision-making for new SHP projects and will consider WFEC Nexus constrains, sustainability of resources, climate change impacts and socio-economic scenarios. The tool will be based on a computational model integrating GIS information and statistical data.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 101022905.

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This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 101022905.

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This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 101022905.