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Energy Security of Hydropower Producing Countries—The Cases of Tajikistan and Kyrgyzstan

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Abstract: Energy security, as one of the most important components of state security, is a permanent element of academic debates and political discussions. Owing to the multidimensional and multifaceted nature of energy security, defining it is a complex process, requiring the consideration of a wide range of factors straddling economics, geology, ecology and geopolitics which decide whether we are dealing with the state of energy security or the lack of it. Energy security is usually equated with the security of supply. Another group of definitions of energy security focuses on the concept of security of services. A different approach to energy security issues is presented by energy exporting countries, whose objective is to ensure sufficiently high and stable income from sales of energy resource exports (security of demand). The subject of this paper is an analysis of the energy security of hydropower-producing countries—Tajikistan and Kyrgyzstan. Energy security has been analyzed in the context of security of supply, services, and demand on the basis of the approach proposed by Llamosas and Sovacool. So far, no work has been carried out to analyse the hydropower sectors of Kyrgyzstan and Tajikistan in the context of the energy security comparison of both countries. It is worth emphasising that their energy security and mutual relations are important from the point of view of the stability of the entire Central Asian region. Kyrgyzstan and Tajikistan have large hydropower potential, which, if properly used, could cover their domestic electricity demand and the surplus can be exported to neighbouring countries. Unfortunately, both countries are not utilising this potential for the time being. The main difficulty in the area of security of supply and services is the seasonality and low reliability of electricity supplies. Among the reasons for this are the poor technical and economic conditions of energy companies as a result of maintaining low tariffs, the irrecoverability of consumers' energy bills, electricity theft, significant transmission loses and a high level of corruption. Although both countries aspire to the role of an energy exporters, they are themselves forced to import electricity from neighboring countries.

Keywords: energy security; hydropower; Kyrgyzstan; Tajikistan; electricity; energy; Central Asia

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1. Introduction

Nowadays, many scientists argue that in the twenty-first century, not hydrocarbons but water will be a key factor for economic development, prosperity and quality of life. Among renewable energy sources, hydropower comes first: more than 9000 dams registered worldwide provide nearly 70% of all renewable energy [1]. Hydropower accounts for the vast majority (more than two-thirds) of electricity production in 34 countries, most of which are considered medium-developed to underdeveloped [2]. Hydropower is projected to remain the most important contributor to low-carbon electricity production until 2040 [3].

Currently, a large part of the untapped hydropower potential is located in cross-border river regions, which indicates the need for a deeper study of this area, so far poorly analyzed by scientists. It is estimated that more than 70% of dams being built or planned have a cross-border character [4].

Countries with high hydropower potential can meet their own electricity needs and benefit from energy exports through cross-border power grids. The benefits range from the sale of hydropower or the construction of hydroelectric power plants that are otherwise unprofitable [5]. Nevertheless, hydroelectric power plants built on cross-border rivers are a source of benefits for some countries and a source of losses for others [1]. Therefore, hydropower, in the case of transboundary rivers, has its own geopolitical dynamics [6]. Conflicts between the countries are breaking out around cross-border rivers around the world, and they concern the use of water resources and cross-border hydropower [7]. In this situation, due to their potential, cross-border dams are critical for the future of hydropower.

The presented article analyses the energy security of two Central Asian countries—Tajikistan and Kyrgyzstan—which base their energy on water resources. Hydroelectric power plants in the case of both countries are built on rivers that are tributaries of the two largest rivers of this region—Syr-Daria and Amu-Daria. The latter two are, in turn, cross-border rivers, covering the entire Central Asian region and economies of all Central Asian countries are highly dependent on the use of transboundary water resources, which complicates relations between them.

In the literature on the subject, one can find works analyzing the impact of dams on a local, regional or national scale [8]. Some of the studies are national or local case studies. Works dealing with the subject of hydropower of central Asian countries mainly concern geopolitical issues:

- The issue of the division and management of water resources by Central Asian countries [9–14];
- The issue of the conflict between Uzbekistan and Tajikistan regarding the construction of the Rogun hydroelectric power plant [15–17];
- The issue of economic benefits for the countries of the region resulting from the trade in hydropower through cross-border energy networks [5].

This paper deals with the cross-border development of hydropower, a relatively little-studied topic that is critical to a better understanding of the impact and benefits of global hydropower. Secondly, the article brings new insights to research on the energy security of hydropower producer countries by going beyond a single-case analysis and proposing the use of comparative analysis. In this situation, the results and conclusions may become the basis for research in the case of other hydropower producers. So far, no work has been carried out to analyse the hydropower sectors of Kyrgyzstan and Tajikistan in the context of the energy security of both countries. This article aims to fill this gap. The issue of energy security of the hydropower-producing countries of the Central Asian region are considered on the basis of the approach proposed by Llamosas and Sovacool, i.e., the study of the energy security of hydropower producers through the prism of security of supply, services and demand [2]. The authors analyse the energy security of the two poorest countries in the region—Tajikistan and Kyrgyzstan. These countries are also the largest producers of hydropower in Central Asia. In both cases, the energy security has been examined from the point of view of:

- Security of supply:
  - Seasonality;
  - Installed capacity;
- Security of services:
  - Energy tariffs;
  - Reliability;
- Security of demand.

A limitation of the method used to study energy security from the angle of security of supply, security of services and security of demand in the case of Kyrgyzstan and Tajikistan is the superficial treatment of some important contexts in the case of post-Soviet countries. One of them is the geopolitical situation that determines relations in Central Asia and has a significant impact on decisions in the political and economic sphere of Kyrgyzstan and Tajikistan. Another important issue is the fact that, in most post-Soviet states, such as Kyrgyzstan or Tajikistan, we are dealing with a specific hybrid model of the economy with the dominant role of central control. In such countries, the economy remains at the service of politics, being subordinate to the president and his immediate environment or regional clans.

All the maps and charts in this article were created by the authors using R programming language, RStudio IDE and ggplot2 package [18–20].

2. Energy Security

Energy is a key factor that determines many areas of socio-economic life [21]. This is because energy plays a crucial role in the functioning of the economy and economic development [22], social welfare and consumption processes [23]. Sufficient energy resources determines the economic and political strength of a state [24]. Thus, energy becomes an important element in national and international security [25]. The world we live in is dominated by energy [26].

In the development of the concept of energy security, several periods can be distinguished:

1. The non-politicized stage;
2. The politicized stage;
3. The securitized stage [24].

The "oil shocks" and energy crises of the 1970s marked the beginning of the politicization of energy problems [27]. It was then that the awareness of the strategic importance of energy resources became widespread, significantly exceeding the economic context.

The term "energy security" itself has also evolved in recent decades. In the 1970s, it had a narrow definition, usually meaning the aspiration to achieve a high level of energy self-sufficiency (a nationalist approach to the question of energy security) [28], with a focus on better practices of managing energy projects [29] and more efficient utilization of energy technologies [30]. Around the turn of the century, changes in the definition of energy security were also affected by the development of international cooperation between importers and exporters of energy resources, concentration on guaranteeing equal access to energy to all social groups and the increasing importance of environmental issues in energy production [31].

Owing to the multidimensional and multifaceted nature of energy security, defining it is a complex process, requiring consideration of a wide range of factors straddling economics, geology, ecology and geopolitics. The nature and significance of energy security depend on the context [32]. According to Robert Skinner, defining and understanding energy security depends on where and when we are [32]. In many cases, it is the spatiotemporal context that determines the concept of energy security, with the most important component being the condition of the energy market specified at the given moment [33].

Energy security is most often defined as the availability of sufficient supplies at affordable prices [34]. T. Klare defines energy security as a guaranteed supply of energy resources that ensure the basic needs of the state, even in a situation of crisis or international conflict [35]. The Asia Pacific Energy Research Centre defines energy security as "the ability of an economy to guarantee the availability of the supply of energy resources in a sustainable and timely manner with the energy price being at a level that will not adversely affect the economic performance of the economy" [36].

Four elements can be identified in contemporary definitions of energy security (the 4 A's approach):

- Availability—physical access to energy;
- Accessibility—the possibility of obtaining energy resources, considering geographical, political, demographic and technological limitations;
- Affordability—access to inexpensive energy sources;

- Acceptability—access to sources acceptable to society, especially in terms of environmental factors [31].

Accessibility and affordability are regarded as the most important elements because of their impact on other aspects of energy security [37].

The concept of the 4 A's approach has been adopted in research on energy security. It was the starting point for creating extensive definitions along with a proposal for a quantitative assessment of the phenomenon [38,39]. One of the most comprehensive concepts was proposed by Sovacool and Mukherjee (2011) [40], who defined over 250 different energy security measures.

The terms most often associated with energy security are: "reliable and uninterrupted supply", "reasonable or affordable price", "energy availability", "diversity", etc. On the other hand, the considerations about energy security also focus on other concepts, such as: "threat", "risk", "disruption", "robustness", "vulnerability" or "resilience". Nowadays, environmental issues and the proper mix of renewable energy sources are becoming more and more important [41,42].

The literature on the subject indicates three groups of threats related to energy security:

- The first—technical reasons (infrastructure failure);
- The second—social behavior (e.g., volatility of demand for energy resources, suspension of supplies for political reasons);
- The third—natural threats (e.g., depletion of fossil fuel resources) [43].

Energy security is usually equated with security of supply. In this context, the International Energy Agency (IEA) defines energy security as "uninterrupted availability of energy sources at an affordable price" [44]. Similarly, according to the European Commission, "Energy security or security of supply can be defined as the availability of energy at all times in various forms, in sufficient quantities, and at reasonable and/or affordable prices" [45]. Such definitions of energy security indicate the availability of an adequate amount of energy to satisfy demand through a combination of diversification of energy sources to avoid dependence on one supplier. For many governments around the world, guaranteeing stable energy supplies therefore becomes one of the most important priorities [46,47].

Demand-based definitions of energy security fail to take into account the complex nature of the energy system, disregarding energy consumers, for example [48]. Another group of definitions of energy security therefore focuses on the concept of security of services (or energy services security—ESS), referring to "the extent to which the population in a defined area (country or region) can have access to affordably and competitively priced, environmentally acceptable energy services of adequate quality" [31]. This definition implies a focus on the end user [49–51]. In an approach geared towards energy services, the subject of research becomes the transmission and distribution infrastructure as well as the quality and price of supplies.

A different approach to energy security issues is presented by energy-exporting countries, whose objective is to ensure sufficiently high and stable income from sales of energy resource exports (security of demand) [52]. The economies of most of the largest producers of energy raw materials are therefore dependent on income from their sale, which can mean that they feel the painful effects of both disruptions to supplies of resources and falling prices in global markets. Export income affects the economic development of producer countries, enabling implementation of research and development work, opening of new oil fields and extension of transport and transmission systems. For countries producing energy resources, energy security focuses on security of demand [53], as well as social and political aspects, testing the thesis of the "resource curse" [54] and the "paradox of plenty" [49,50].

An extensive analysis of literature on the "Energy Security" concept is presented in [55]. It deals with the definition, security indicators and indices, and methods of constructing indices. It also elaborates on the wider context of energy policy.

3. Central Asia's Hydropower Potential

The Central Asian Power System (CAPS) was established in the 1970s, encompassing five former Soviet republics: Kazakhstan, Kyrgyzstan, Tajikistan, Turkmenistan and Uzbekistan. The borders between the republics were not taken into account at the time as they were not recognised as independent states. The power plants therefore served the markets on both sides of borders as if they did not exist. In terms of planning and exploitation, everything was optimised to satisfy the needs of the region and reduce the total costs of electric energy supplies [56].

The collapse of the Soviet Union in 1991 resulted in the formation of five sovereign countries in Central Asia. The major rivers flowing through their territory therefore became border lines and the individual states' governments faced the difficult task of finding mutually beneficial solutions for managing and protecting their water resources by working together (Figure 1).

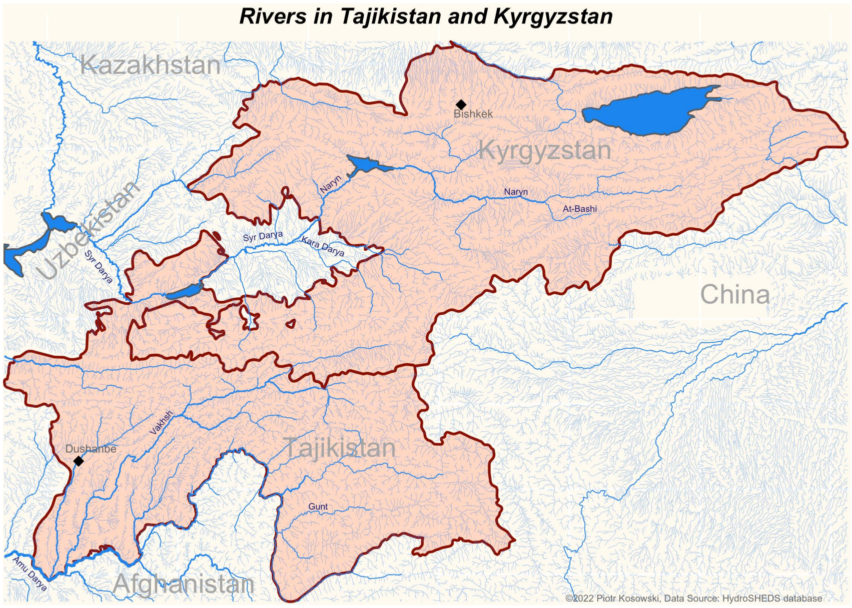

Figure 1. Rivers in Tajikistan and Kyrgyzstan.

The toughest situation was managing transborder hydropower resources developed on the Amu Darya and Syr Darya, the largest rivers in Central Asia, with Tajikistan and Kyrgyzstan lying in their basins [57]. Around 74% of the flow of the Amu Darya River is formed in Tajikistan, while 75% of the water resources of the Syr Darya basin is produced within Kyrgyzstan's borders (Figure 2). In total, approximately 76.3% of the flow of both rivers in the Aral Sea Basin is formed in the territory of the two countries lying in the upper course of the Amu Darya and Syr Darya rivers (Table 1 and Figure 3) [58].

Table 1. Total natural river discharge in the Aral Sea basin (average annual discharge, km^3 annually.)

	River Basin		Aral Sea Basin	
Country	**Syr Darya**	**Amu Darya**	**km^2**	**%**
Kazakhstan	2516	-	2516	2.2
Kyrgyzstan	27,542	1654	29,196	25.2
Tajikistan	1005	58,732	59,737	51.1
Turkmenistan	-	1405	1405	1.2
Uzbekistan	5562	6791	12,353	10.6
Afghanistan and Iran	-	10,814	10,814	9.3
Total	36,625	79,396	116,021	100.0

Source: Investicii v vodno-jenergeticheskij kompleks Central'noj Azii, Evrazijskij Bank Razvitija, Almaty 2021, p. 13.

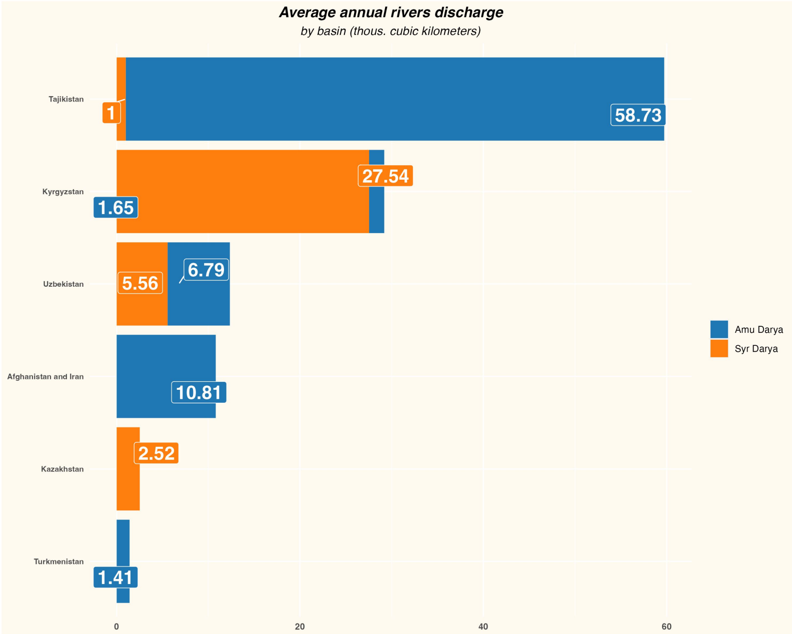

Figure 2. Average total rivers' discharge in Aral Sea basin by country and river. Data source: Investicii v vodno-jenergeticheskij kompleks Central'noj Azii, Evrazijskij Bank Razvitija, Almaty 2021, p. 13.

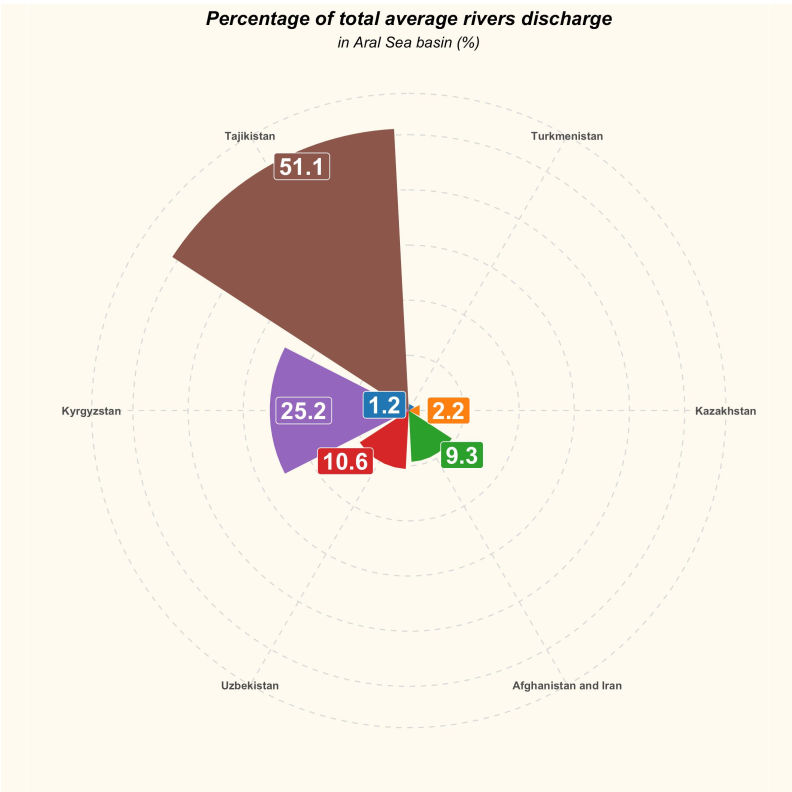

Figure 3. Percentage of average total rivers' discharge in Aral Sea basin per country. Data source: Investicii v vodno-jenergeticheskij kompleks Central'noj Azii, Evrazijskij Bank Razvitija, Almaty 2021, p. 13.

Tajikistan and Kyrgyzstan's water resources are used for developing hydroelectric power, a strategic sector of both countries' economies. The capacities of the main hydroelectric power stations in both countries are shown in Figure 4. In Tajikistan, the share of hydropower in the national electrical energy production structure exceeds 90%, while in

Kyrgyzstan, it is around 80% [59]. However, the development of hydropower in Central Asia's two poorest states clashes with the interests of the countries in the lower course of the rivers. Kazakhstan, Turkmenistan and mainly Uzbekistan use the region's water resources for fertilising agricultural land [60], resulting in a conflict that thwarts further resilient development of hydropower in Tajikistan and Kyrgyzstan. Furthermore, the rivers' increased flow variability, lower levels in the Aral Sea basin caused by climate change and growing demand for water have led to greater competition for water between the countries.

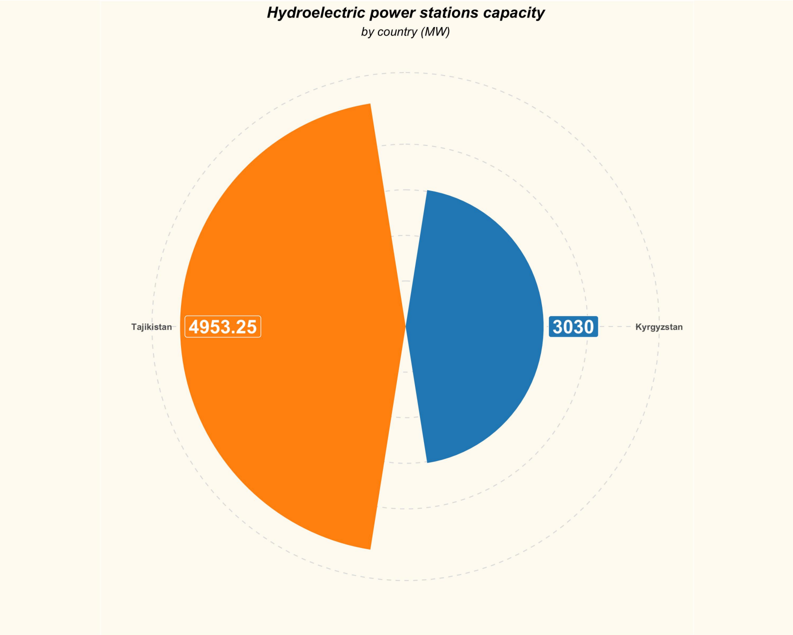

Figure 4. Hydroelectric power station capacities in Tajikistan and Kyrgyzstan. Data source: Investicii v vodno-jenergeticheskij kompleks Central'noj Azii, Evrazijskij Bank Razvitija, Almaty 2021, p. 13.

4. Tajikistan

4.1. General Information

Tajikistan is the southernmost post-Soviet republic, bordering with Afghanistan, China, Uzbekistan and Kyrgyzstan. Some 93% of the country's surface is mountainous, and more than half lies at an altitude over 3000 m above sea level. Tajikistan is one of the poorest countries of the former USSR, with weak industrial development and a GDP of USD 8.2 billion (2020) [61]. Failure to resolve the country's socio-economic problems in the past three decades has meant that 26.3% [62] of the population of 9.5 million [63] today live below the poverty line. According to official data, more than 40% of Tajikistan's GDP comes from money sent by economic migrants, mostly from Russia [64]. Tajikistan is an agricultural country based mainly on cotton production. Its natural resources also include silver, gold, uranium, and tungsten, but these are not extracted on a large scale.

A key role in Tajikistan's economy is played by its hydro resources, generated by glaciers, rivers, lakes and groundwater (Figure 5). These vast water supplies are currently the country's main source of energy—more than 95% of Tajikistan's electrical energy is produced by hydropower plants [65]. National hydropower reserves, at a level of 527 billion kWh, put the Central Asian republic at fifth place in the world in this category. From a technical point of view, however, the country's annual hydropower resources are estimated at 317 billion kWh, of which just 4–5% is so far being used [66]. Tajikistan's hydroelectric potential is three times higher than the current use of electric power in the whole of Central Asia. The main hydropower potential is concentrated in the basins of the Panj, Vakhsh, Kofarnihan and Zeravshan rivers, which are tributaries of the Amu Darya.

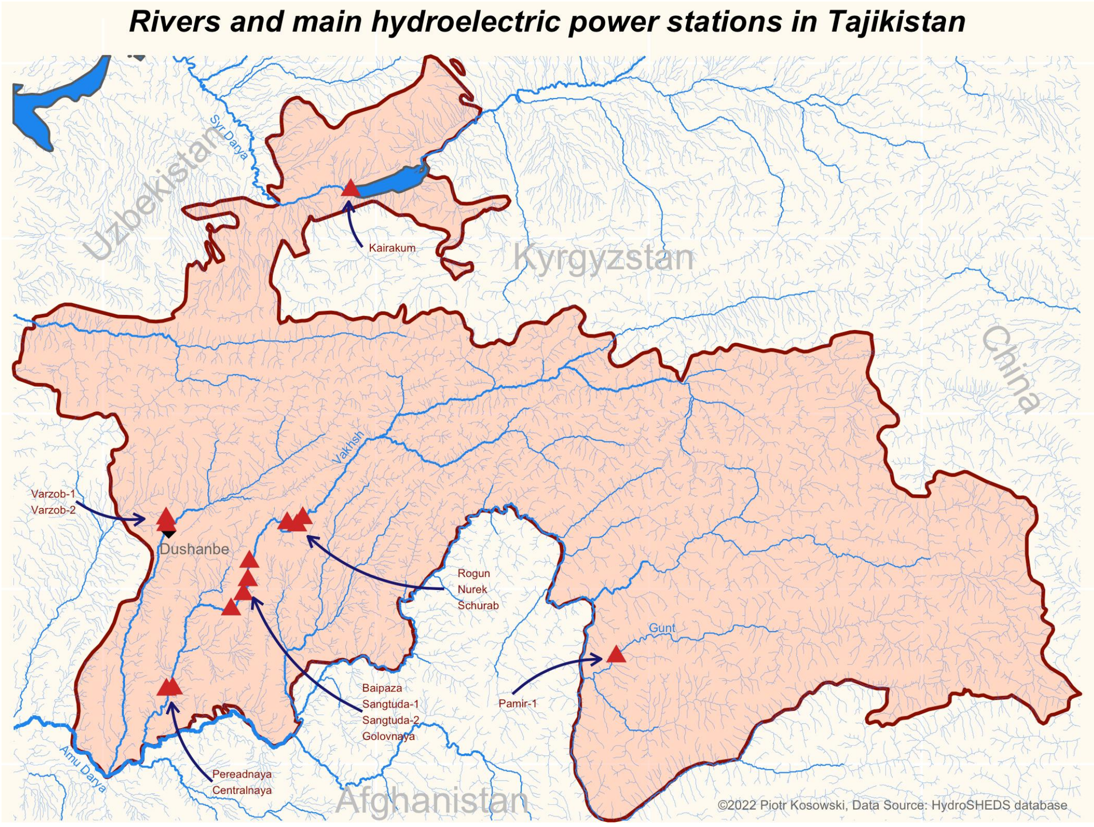

Figure 5. Rivers and main hydroelectric power stations in Tajikistan.

The country's enormous water potential became the basis of its first major hydropower projects—the first industrial hydroelectric power plant, Varzob HPP-1, was opened here in 1937 with a capacity of 7.1 MW and continues to operate successfully today. This was followed in 1946 by the Khorog HPP plant, with a capacity of 936 kW, and then two more in 1952, Varzob HPP-2 and Varzob HPP-3, with capacities of 15 MW and 3.5 MW, respectively [67]. The Pereadnaya HPP (29 MW) and Centralnaya HPP (15.1 MW) hydropower plants were then built in the 1950s. All Tajikistan's hydropower plants constructed before the 1960s are classified as small by today's standards, although in the past they were seen as large. A framework for the integrated use of large rivers for hydropower began to be developed in the 1950s, with an emphasis on building large plants—Kairakum HPP, with a capacity of 218 MW, Golovnaya HPP (210 MW), Nurek HPP (3000 MW), Baipaza HPP, Sangtuda HPP and others (Table 2, Figures 6–8).

Table 2. Biggest hydropower plants in Tajikistan.

Name	Owner	Capacity (MW)	River
Nurek HPP	Barki Tojik	3000	Vakhsh
Sangtuda HPP-1	Sangob (Iran)	670	Vakhsh
Baipaza HPP	Barki Tojik	600	Vakhsh
Golovnaya HPP	Barki Tojik	240	Vakhsh
Sangtuda HPP-2	Sangtudinskaya GES-1	220	Vakhsh
Kairakum HPP	Barki Tojik	126	Syr Darya
Pereadnaya HPP	Barki Tojik	29.95	Vakhsh Canal
Pamir-1 HPP	Pamir Energy	28	Gunt
Centralnaya HPP	Barki Tojik	15.1	Vakhsh Canal
Varzob HPP-2	Barki Tojik	14.7	Varzob
Varzob HPP-1	Barki Tojik	9.5	Varzob

Source: Tajikistan Energy Ministry: Jelektrojenergeticheskaja Sistema.

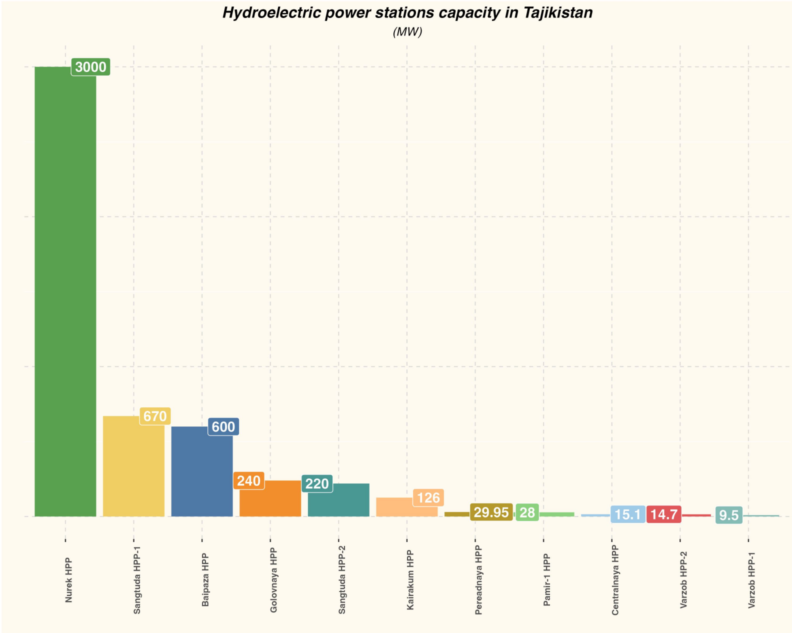

Figure 6. Hydroelectric power stations in Tajikistan and their capacities. Data source: Tajikistan Energy Ministry: Jelektrojenergeticheskaja Sistema.

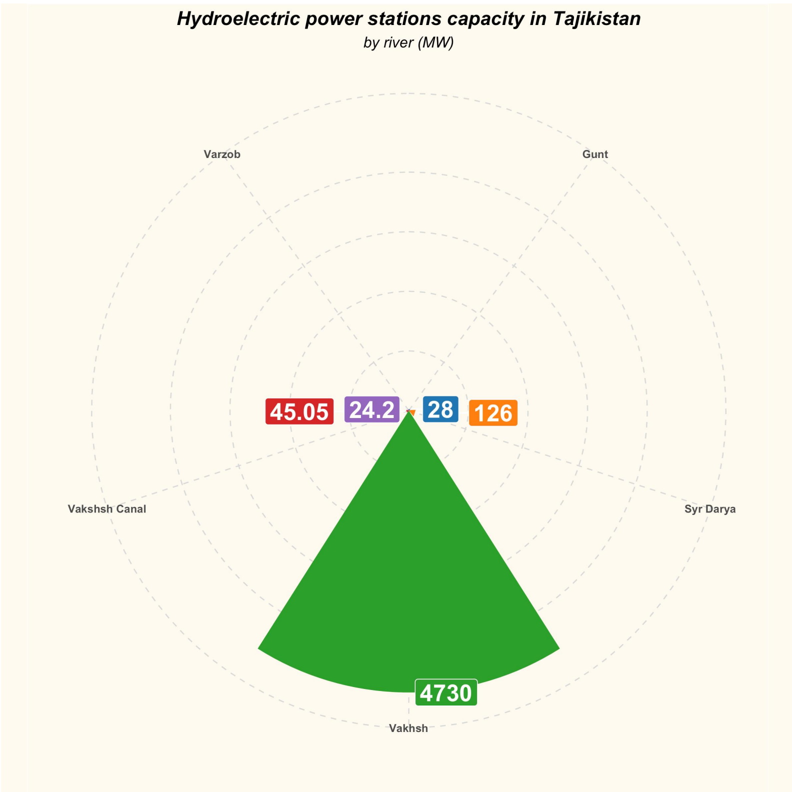

Figure 7. Hydroelectric power station capacities in Tajikistan by river. Data source: Tajikistan Energy Ministry: Jelektrojenergeticheskaja Sistema.

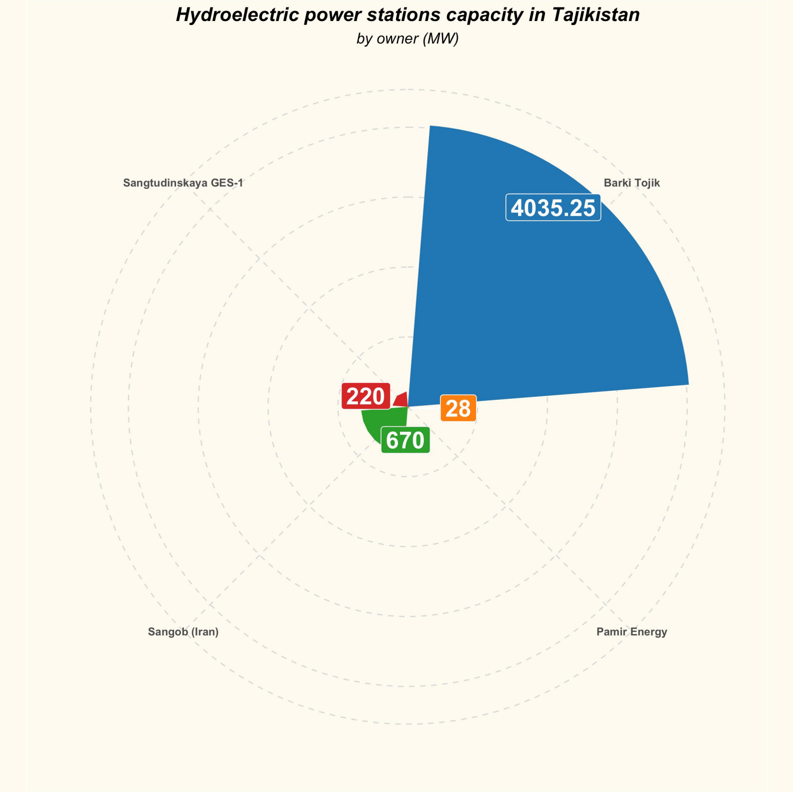

Figure 8. Hydroelectric power station capacities in Tajikistan by owner. Data source: Tajikistan Energy Ministry: Jelektrojenergeticheskaja Sistema.

4.2. Market Structure

The electrical energy sector is mainly owned and managed by Barki Tojik, a vertically integrated state company that is the main producer of electrical energy, operator of the transmission and distribution system and wholesaler [68]. Some hydropower plants are owned by foreign capital, including Sangtuda HPP-1, which is 75% Russian-owned, and Sangtuda HPP-2, which is owned and managed by Iranian companies (with a 12-year contract). Around two-thirds of small hydropower plants are privately owned. Distribution of hydroelectric energy in the autonomous region of Gorno-Badakhshan is handled by Pamir Energy [68].

4.3. Tajikistan's Energy Security

4.3.1. Security of Supply

A total of 14 large and medium-sized hydropower plants [69] and around 300 small ones currently operate in Tajikistan, with a combined capacity of 4953 MW. In 2009, a scheme for constructing small hydropower plants was adopted, undertaking the construction of 189 such plants with a combined capacity of 103.6 MW [70]. According to experts, exploiting energy from small rivers could satisfy 50–70% of the electrical energy demands—and in some cases, even 100%—of around 500–600,000 people living in remote regions of the country [70].

The capacity of Tajikistan's electrical energy system is 5190 MW, with hydropower plants accounting from 93.9% of the entire installed capacity. Thermal power stations have a capacity of 318 MW, or only around 6.1% of the total. The average annual electrical energy production in the Tajik energy system is 16.5 billion kWh. Over 98% of the electrical energy generated in Tajikistan comes from hydropower plants, 97% of it from large and medium-sized ones [70]. Historically, installed capacity was largely meant to satisfy the demand of the other Central Asian republics because, during the existence of the USSR, Tajikistan's development strategy was based on "export".

The main consumers of electrical energy in the country are public utility companies, which account for almost 47% of total electrical energy. Industrial enterprises, meanwhile, use 31% of electrical energy, with agriculture in third place, with 16% of the total consumption [71].

Seasonality of Supplies

The electrical energy produced in Tajik hydropower plants is seasonal in nature, depending on river flows. As a result, one of Tajikistan's main problems is water security. The lowest level of electrical energy production is observed in the autumn–winter period (October–April/May), whereas demand for electricity is highest in this period. At the same time, power is the most reliable in summer, with a surplus of electrical energy of 3–7 billion kWh [71]. The current objective of Tajikistan's energy policy is to mitigate the annual seasonal winter deficits and ensure uninterrupted access to energy for the population. The approach to the crisis has changed over the decades, depending on the domestic political situation and relations with the country's neighbours. At present, the government is planning to diversify energy sources (including introduction of non-hydro renewables), modernise the existing energy infrastructure, improve energy saving and increase regional integration [68].

Installed Capacity

Although Tajikistan is consistently striving to increase its installed capacity, it lags behind in terms of the diversification of the sources of electrical energy production, as well as suitable investment to cover the national electrical energy demand in the winter season, to the detriment of the security of energy services. Tajikistan's energy system is based on the Nurek power plant, with a capacity of 3000 MW, representing more than 60% of the total installed capacity. Built in 1961–1973 on the Vakhsh River, today it is the largest and second highest (300 m) dam in the world, with a reservoir with an area of 98 km^2 [72]. The opening of the Nurek hydropower plant contributed to an increase in the security of electrical energy supplies in Tajikistan. Increased security of supplies was also achieved in the case of the finalisation of the building of the Rogun hydropower plant, with a planned capacity of 3600 MW. Construction of this hydropower plant, at 355 m, the highest in the world, was launched in the 1980s. This extremely ambitious project was delayed for many years, however, by numerous factors: the collapse of the USSR, damage to the construction by a flood in 1993, the dispute with Uzbekistan over water resources, conflict with the investor—the Russian company, RusAl—about the ultimate size and type of dam, and later problems with funding of the project. The Tajik government has long been seeking international support for building the Rogan plant. According to estimates by experts in the country, its opening will double the total national electrical energy production and turn Tajikistan into a centre of the energy trade in Central Europe [68]. Most of the building costs are covered by loans, leaving the republic with an annual budgetary deficit of half its GDP. Following launch of the facility, which is still under construction, 90% of the country's entire electrical energy will come from two hydroelectric power plants—Nurek and Rogun [73].

4.3.2. Security of Services

In 2011, a uniform energy system was established for the country, combining the southern and northern energy systems. This all significantly improved the Tajik population's access to the electrical energy generated. According to Ministry of Energy data, 10% of the population of Tajikistan (around 1 million citizens) do not have access to electrical energy [74].

Tajikistan is currently positioned 163rd out of 190 countries in a "Getting electricity" ranking [75] and 107th out of 141 for "electricity supply quality" [76]. In the Doing Business "Reliability of supply and transparency of tariff index", Tajikistan scored 4 out of a possible 8—compared to an average for Europe and Central Asia of 6.2 [75].

In the winter season (November–February), the electrical energy deficit in Tajikistan is estimated at around 2–3 billion kWh [77]. The level of electrical energy deficits increased significantly in 2009, when the country suspended working with its neighbours in commercial electrical energy supplies through the Central Asia Power Grid. Energy shortages in the winter season affected around 70% of Tajikistan's population [56,68]. Currently, Tajikistan is forced to introduce restrictions on deliveries in the winter period, which has a particularly severe impact on rural inhabitants, comprising at least 70% of the country's total population [59,78]. Each year, limited electricity supply to rural areas results in a yield loss of crops of around 30% [70].

Curbs on electricity consumption in some areas of the country begin in October and last until around April. In this period, the population have access to electricity for around three to seven hours daily in all regions except the capital, where approximately 10% of the population live. Electrical energy used by the population comprises 40% of total usage. Energy supplies are the most reliable in summer, as there is an electricity surplus of 3–7 billion kWh in this season. Water surpluses lead to a significant level of inactive discharges, potentially meaning vast losses of electrical energy. Depending on the hydrological conditions in a given year, annual economic losses amount to USD 90–225 million [70]. In 2014, the economic losses associated with poor quality of energy supplies totalled 3% of GDP—around USD 200 million [79].

Electrical Energy Tariffs

Electricity tariffs for Tajikistan's population currently remain at the low level of 2.32 US cents/1 kWh. The state partly subsidises the tariff for the population while retaining a higher tariff for other categories of consumers. Tariffs for industry are 5.61 cents per 1 kWh, 2.4 times more than those for the population. Furthermore, every year, the country's government subsidises electricity consumption for low-income families from the state budget [70].

Reliability of Services

The energy infrastructure in Tajikistan is of poor quality, with the existing systems not operating efficiently. In 2013, 10% of businesses in the country identified outages in electrical energy delivery as the main factor hindering their work. They noted that electricity is switched off up to six times a month, and light might be turned off on average for up to four hours, causing them to lose over 4% of their income [80]. By 2019, the percentage of businesses experiencing losses due to power outages had been reduced to 8.6%. Yet despite the improvement, the result remains much higher than the average in Central and Asia and Europe, which is 3.8% [81].

The low quality of Tajikistan's electrical energy infrastructure and the lack of prospects for improvement stem from the poor financial state of the market operator, Barki Tojik. Despite its monopoly on Tajikistan's electricity market, in 2019, the company's debt amounted to around 12.5 billion somoni (USD 1.2 billion), representing 80% of the total debt of all state-owned companies to the Ministry of Finance. The problem of Barki Toki's huge debt results from the losses it has borne as a result of low electrical energy tariffs, consumers failing to pay bills (low revenue collection), electrical energy theft and technical losses in electrical energy transmission. In 2017, the average tariff for end users was 20% of the costs of energy production [82]. Current tariffs compensate for just 50% of energy production costs [83]. Moreover, for years Barki Tojik struggled with the problem of a low revenue collection rate for electrical energy. In 2000, the collection rate was around 30–40%.

In the second decade of the century, the situation improved markedly—in 2014–2020, collection of payments owed to the company rose from 70–80% to 85–90% (Figure 9) [82]. Debtors often included aluminium producers and Ministry of Water Resources pumping stations [84]. A separate category of losses borne by Barki Trojik is commercial losses popularly known as fraud, which, in Tajikistan, amount to 20–25%. "Untouchables" from the energy field do not pay for household electricity consumption or for electrical energy used in their businesses—and many of them have small branches of industry operating in the grey economy [84]. The final group comprises technical losses of electrical energy (those most commonly noted in official reports) at a level of 24% [82] of the total annual electricity production, which constitutes twice the acceptable rate of such losses for electrical energy systems of this age and configuration. Large amounts of electricity will continue to be wasted if the Tajik energy grids, built in the 1960s and 1970s, are not fully modernised [82]. All these categories of losses experienced by Barki Tojik leave the company facing unattainable objectives for exchanging and repairing equipment and improving the infrastructure and management of the entire sector.

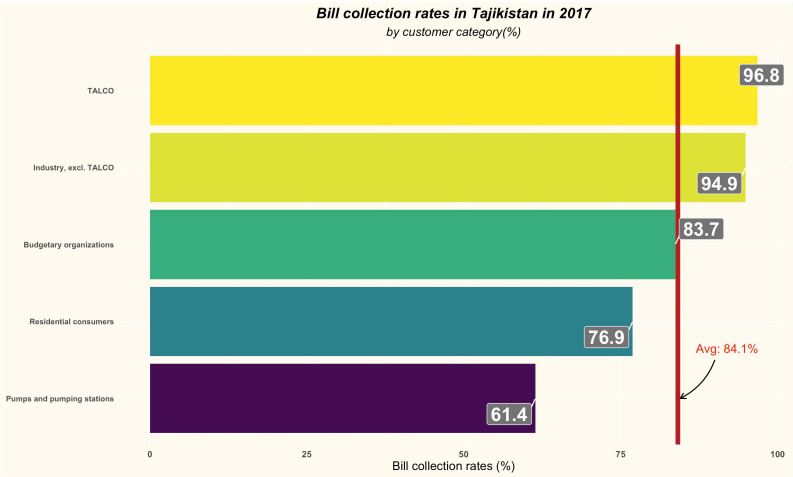

Figure 9. Bill collection rates in Tajikistan in 2017. Data source: World Bank.

Under pressure from international organisations, reforms in Tajikistan's energy sector are taking place, but progress is too slow. The country's government is endeavouring to optimise Barki Tojik's structure by dividing the production, transmission and distribution of electrical energy between separate companies. It is also gradually increasing tariffs and earmarking additional funds for the modernisation of electrical energy lines [85]. However, despite official agreements on energy sector reform, Tajikistan's leaders attach greater importance to electrical energy exports, which they see as the solution to the problem of lack of profit in the energy sector. This is demonstrated by the situation from autumn–winter 2021, when the Tajik population was unhappy with constant electricity outages and high costs resulting from alternative home heating methods. Residents of rural regions had access to electricity for seven to eight hours daily. Barki Tajik blamed the electricity outages on renovation work within the sector, while at the same time increasing electrical energy exports to neighbouring countries [86].

4.3.3. Security of Demand

Tajikistan became an exporter of electrical energy in Soviet times, when it used CAPS to export surplus processed electricity in summer and import energy in winter. The collapse of the Soviet Union brought an end to regional agreements on energy exchange, with the new situation forcing Tajikistan to seek new export opportunities. In economic terms, electrical energy exports were supposed to generate financial income for the republic's budget, while in political terms, Dushanbe was endeavouring to emphasise its position in the region.

The situation was complicated in 2009, when Uzbekistan blocked Tajikistan's participation in CAPS owing to conflict over the region's water resources. Tajikistan's access to the regional electrical energy market was therefore cut off, although energy cooperation between the countries was renewed in 2018 [87].

There are 13 electrical energy lines of varying voltages between the Republic of Tajikistan and neighbouring states. Electrical energy surpluses of up to around 1–2.5 kWh are currently exported to Kyrgyzstan, Afghanistan and Uzbekistan. In 2018, the volume of electricity exports was 1.44 billion kWh [88].

In 2019, renewed exports to Uzbekistan meant that electrical energy exports grew from 1350 GWh to almost 2875 GWh. Further growth in electricity exports is expected as a result of:

- Synchronisation of the Tajik grid with CAPS in 2022, permitting supplies of electrical energy to all Central Asian countries without management of the grid and other operational problems;
- The launch in 2022 of the Central Asia–South Asia (CASA-1000) transmission system, with a capacity of 1300 MW [89].

Tajikistan is actively supporting the CASA-1000 project, whose objective is to build a transmission line in the region of Central and South Asia. The CASA-1000 power transmission line will stretch 970 km from Kyrgyzstan and Tajikistan to Afghanistan and Pakistan [90], exporting surplus electricity from these Central Asian countries to their neighbours in the summer season. The project is expected to enable exports up to 5 TWh annually from large hydropower plants in Central Asia (Nurek in Tadjikistan and Toktogul in Kyrgyzstan) to the energy-intensive Pakistani and Afghan markets [91]. The aim is to ensure the countries a constant income source that can be used to alleviate the severe winter energy shortages and improve their economic security [92].

In 2019, a record amount of more than USD 90 million bolstered Tajikistan's budget from electricity exports to neighbouring Uzbekistan and Afghanistan. By comparison, the equivalent amount in 2017 was just USD 53.5 million. Uzbekistan's share in Tajik export supplies is around 56%. In the income received by Tajikistan in 2019, this share will correspond to USD 51.128 million. A reduced tariff operates for Uzbekistan—2 cents per kWh [93]. The Afghan market is furnished with electrical energy at much higher tariffs, which amounted to 4.11 cents per kWh in 2018. In 2019, Afghanistan accounted for 44% of Tajik exports. The main reason for the doubling of electricity exports in 2019 was the resumption of energy collaboration between Tajikistan and Uzbekistan (suspended a decade earlier.) At presents, deliveries are based on mutual settlements with a considerable price discount—Uzbekistan receives Tajik electrical energy at preferential rates, and in return supplies natural gas to the Tajik market at a price of USD 120 per 1000 m^3, half of the export rate [93].

5. Kyrgyzstan

5.1. General Information

Kyrgyzstan is a small, landlocked Central Asian state that borders with Kazakhstan, Uzbekistan, Tajikistan and China. Around 85% of the country's territory comprises high mountains, in which glacier and snow melt produces more than 30,000 watercourses. Kyrgyzstan's total freshwater flow makes up around 50% of all freshwater resources in Central Asia [94]. Like Tajikistan, Kyrgyzstan is among Central Asia's poorest countries, with a mainly agriculture-based economy, a GDP of USD 7.7 billion (2020) and a population of 6 million [94]. The Kyrgyz economy is susceptible to external shocks owing to its dependence on one gold mine, Kumtor, providing around 10% of the GDP. The republic is also dependent on money remittances from economic migrants, which in 2011–2015 comprised approximately 30% of the GDP [94].

One of the most important branches of Kyrgyz industry is energy, generating 3.9% of the country's GDP and constituting 16% of industrial production [95]. Kyrgyzstan's energy sector comprises two segments: extraction of fuels (coal, crude oil and natural gas) as well as electrical energy production. Both industries work on behalf of other industrial sectors, as well as providing energy for households, agriculture and transport.

The dominant subsector of the Kyrgyz energy industry is hydroelectric power, owing to the country's vast water energy resources (Table 3, Figures 10 and 11). The average annual flow of rivers and other water in Kyrgyzstan is around 45–50 km^3. Of this, some 75% comes from the Syr Darya River (27–28 km^3), and 2% from the Amu Darya (1.9 km^3)—the region's two main water arteries. Owing to the mountainous terrain, much of the water is directed to neighbouring areas—lower-lying states, mainly Uzbekistan and Kazakhstan, and to a lesser extent, China and Tajikistan [96]. Kyrgyzstan's hydro resources put it in third place among the Commonwealth of Independent States countries, behind Russia and Tajikistan [97].

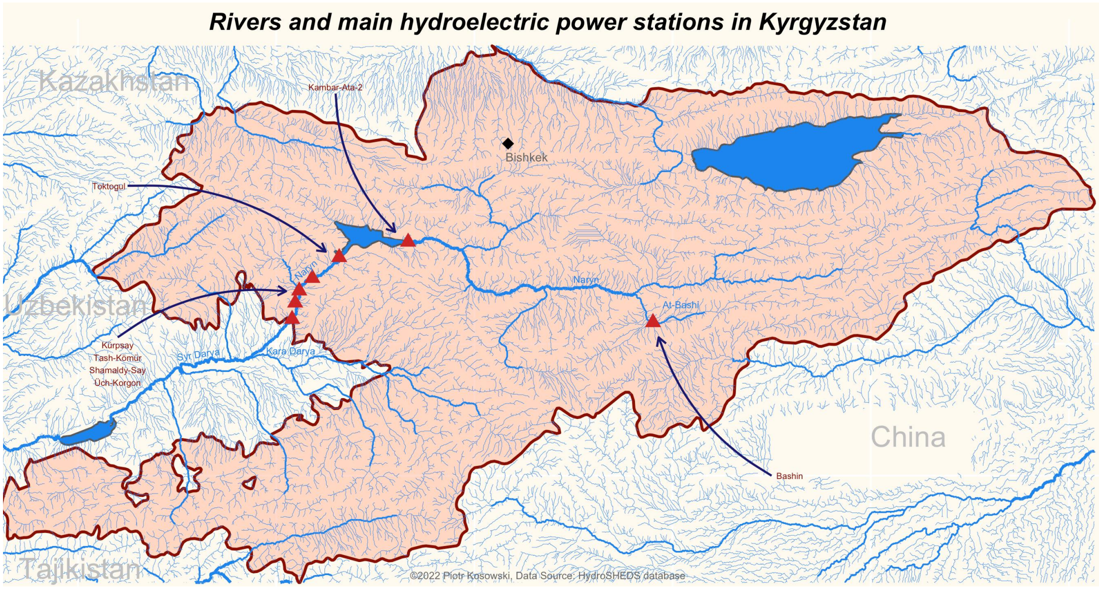

Figure 10. Rivers and main hydroelectric power stations in Kyrgyzstan.

Kyrgyzstan's water potential has a positive impact on the development of the national electric power industry. More than 80% of the country's electricity is generated by hydropower plants, with thermal power stations using coal, gas or mazut accounting for the rest (Table 4). The Kyrgyz annual hydropower potential is estimated at 163 billion kWh, of which only 10% is currently being exploited [98].

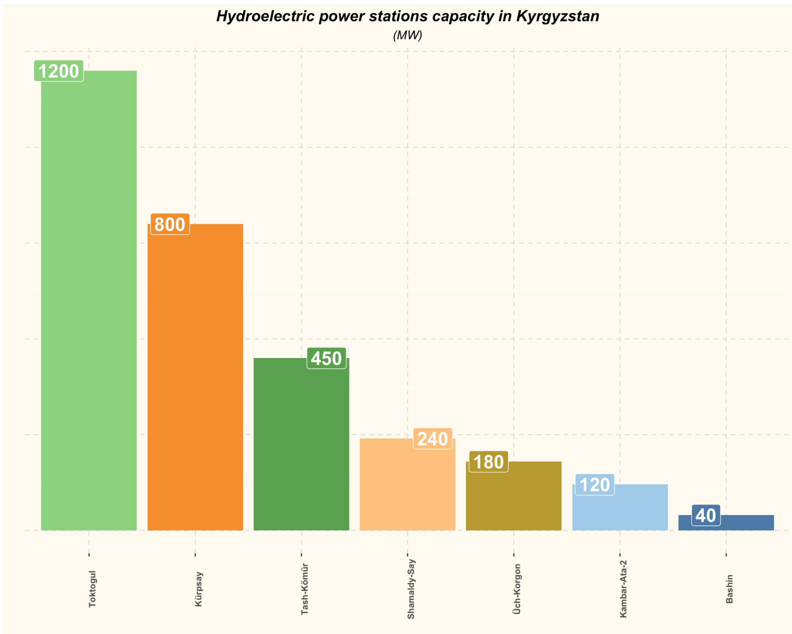

Figure 11. Hydroelectric power stations in Kyrgyzstan and their capacity. Data source: Elektricheskie Stantsii company website, http://www.energo-es.kg, accessed on 16 July 2022.

Table 3. Kyrgyzstan's biggest hydropower plants.

Name	Capacity (MW)	River
Toktogul Hydropower plant	1200	Naryn
Kürpsay Hydropower plant	800	Naryn
Tash-Kömür Hydropower Plant	450	Naryn
Shamaldy-Say Hydropower Plant	240	Naryn
Üch-Korgon Hydropower Plant	180	Naryn
Kambar-Ata-2 Hydropower Plant	120	Naryn
Bashin Hydropower Plant	40	At-Bashy

Source: own elaboration based on the Elektricheskie Stantsii company website, http://www.energo-es.kg, accessed on 16 July 2022.

Table 4. Thermal power stations in Kyrgyzstan.

Name	Capacity (MW)	City
Bishkek Power Plant	812	Bishkek
Osh Power Plant	50	Osh

Source: own elaboration based on the Elektricheskie Stantsii company website, http://www.energo-es.kg, accessed on 16 July 2022.

5.2. Market Structure

The Kyrgyz electric power industry underwent restructuring in the late 1990s. The KyrgyzEnergo Denationalisation and Privatisation Programme, adopted by the government in 1999, had the objective of increasing the efficiency of companies in the state electric power sector. At the time, KyrgyzEnergo was a state-owned electricity giant controlling the entire chain of energy production and transmission. The restructuring programme comprised four stages, envisaging the division of the energy sector into several parts and their further privatisation. The first three stages were concluded around 2001 with KyrgyzEnergo's separation into six joint-stock companies: Electric Stations, National Electric Network of Kyrgyzstan, SeverElectro, VostokElectro, OshElectro and JalalabadElectro. The Kyrgyz government's shares in the electric power industry companies amounted to almost 95% [99].

5.3. Kyrgyzstan's Energy Security

5.3.1. Security of Supply

Kyrgyzstan's electrical energy sector is made up of nine power plants with a combined capacity of 3646 MW. Seven of these are hydropower stations with a capacity of 2918 MW, and the remaining two are thermal stations. The largest hydropower plants were built on the River Naryn, the country's strategic asset, generating 97% of hydro energy (Figure 12) [100]. The remaining 3% is covered by nine mini-hydropower plants located on other, smaller rivers.

For years, annual electricity production of 14–15.5 billion kWh [101] enabled Kyrgyzstan to satisfy its own demand, sending the remaining electricity for export. This was received by Russia, China, Kazakhstan, Uzbekistan and Tajikistan. Total annual exports were in the region of 2–2.5 kWh. Growing domestic consumption (around 4–6% a year) along with losses resulting from an antiquated electricity grid meant that, in 2014–2016, the country underwent a transformation from an exporter to an importer of electrical power. This means that the annual increase in electricity consumption exceeded the level of its production, forcing Kyrgyzstan to import electrical power several years in a row [102]. In order to meet the growing electricity demand, annual electrical energy production should reach a level of 18 billion kWh [103].

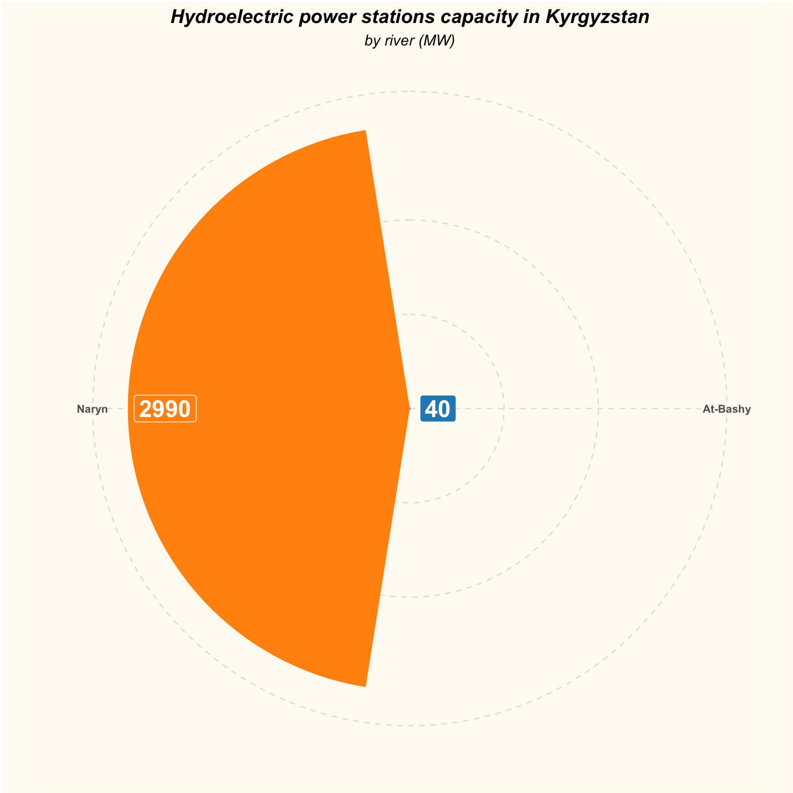

Figure 12. Hydroelectric power station capacities in Kyrgyzstan by river. Data source: Elektricheskie Stantsii company website, http://www.energo-es.kg, accessed on 16 July 2022.

The main consumer of electrical energy in Kyrgyzstan is industry, at 53% of the total. Agriculture is in second place, with 26% of the total consumption, while other sectors account for 21% [101].

Seasonality of Supplies

Electricity production in Kyrgyzstan's hydropower plants is characterised by seasonal fluctuations, which has a significant impact on reliability of supplies. Electricity supplies are most reliable in spring and summer, in which period domestic demand is fully satisfied and energy surpluses were exported for many years. Low river water levels in autumn and winter result in a sharp drop in electrical energy production in hydropower stations.

Installed Capacity

The foundation of Kyrgyzstan's energy system is the Toktogul hydropower plant on the River Naryn. Put into operation in 1975, today, it is one of Central Asia's biggest hydropower plants, with a capacity of 1200 MW. The plant's reservoir, with a maximum capacity exceeding 19 billion m^3, was used to generate electricity for the needs of Kyrgyzstan as well as regulate the flow of the Naryn to ensure water for the neighbouring republics in summer [104]. Currently, Toktogul produces approximately 6000 GWh of electrical energy annually, providing around 40% of electricity in Kyrgyzstan. The plant's regular technical problems (in 2015–2016) forced the Kyrgyz government to decide to modernise it. After work is completed, Toktogul's capacity is expected to increase to 240 MW, with the total exploitation time extended by 35–40 years [105]. The plant's reconstruction is being overseen by foreign experts, with planned costs exceeding USD 400 million.

Increased security of supply was to be assured through the implementation of new hydropower projects. An agreement was signed between Russia and Kyrgyzstan in 2021 on the construction of dams on the River Naryn. The project was supposed to improve the country's energy security as well as reinforce the Kyrgyz position in contacts with the region's richest countries. The agreement envisaged the building of the Kambar-

Ata 1 hydropower plant, as well as a cascade of hydropower plants in the upper course of the Naryn. The Russian company Inter RAO was responsible for implementing the Kambar-Ata 1 project, with a value of USD 400 million, while the construction of four hydropower stations on the River Naryn was to be entrusted to the Russian holding RusHydro. The costs of building the Naryn cascade, with a capacity of 1860 MW, were estimated at USD 727 million [106]. Owing to unfavourable economic conditions and budgetary problems in 2015, the Russian side announced that it would not be possible to finance electricity projects in Kyrgyzstan. In 2016, the Kyrgyz parliament annulled the agreement on the investments in question. A year later, the Czech company Liglass Trading CZ expressed an interest in building a cascade of 10 hydropower plants on the Naryn. The project, valued at USD 500 million, was to be operational in 2020 [107]. In less than a year, however, the agreement with Liglass Trading was also terminated, as the Czechs did not pay off the Kyrgyz obligations to the previous investor, RusHydro, amounting to USD 37 million.

5.3.2. Security of Services

Kyrgyzstan currently lies 143rd out of 190 countries in the "Getting electricity" ranking [108] and 115th out of 141 for "electricity supply quality" [76]. In the Doing Business "Reliability of supply and transparency of tariff index", the country scored 4 out of a possible 8—compared to an average for Europe and Central Asia of 6.2 [108].

A characteristic of the Kyrgyz energy system is the fact that 90% of electric power comes from hydropower plants located in the southern part of the republic, while 70% of electricity is used in the northern region [109]. Nonetheless, the developed electricity grid provides access to electrical energy to the vast majority of the population. Kyrgyzstan has an electrification rate of 99% [110]. In terms of electricity use per inhabitant, however (1809 kWh), the country lags behind the world average (2972 kWh), as well as the rates in neighbouring countries: Kazakhstan (5085 kWh) and Tajikistan (2172 kWh) [109].

In the autumn–winter period, shortage of electrical energy in Kyrgyzstan is currently estimated at around 6 billion kWh [103]. The problem of a serious electricity deficit in Kyrgyzstan first reared its head in winter 2007/2008, when the water level in the Toktogul reservoir (the main reservoir in the country) dropped significantly. The state authorities gave the main reason for the water shortage, and the subsequent electricity deficit, as excessively cold winters in 2008–2009, as well as a series of exceptionally dry summers. To solve the problem, Kyrgyzstan's government decided to limit energy consumption for both industry and the population. It also announced a rise in electricity prices and made attempts to increase the capacity of the thermal power stations in Bishkek and Osh [111]. The problem of the deficit in electrical energy in the winter period remains unresolved today—in 2020–2021, the water level in the Toktogul reservoir dropped significantly to 12.5 billion m^3 (the optimal level is 16–17 billion m^3), which curbed electricity production and prompted the introduction of restrictions on supplies [102]. In winter, Kyrgyzstan is forced to import electrical energy, mainly from Kazakhstan [102].

Reliability of energy supplies therefore becomes especially problematic in the winter period, when the gulf between the supply of electrical power and growing demand widens. Demand among households varies greatly by season. In 2016, household consumption was an average of 286 kWh/month in summer and 721 kWh/month in winter. Winter consumption constitutes 67% of total use. Use of electricity for heating is the main reason for the seasonality of the structure of consumption.

Electrical Energy Tariffs

In the electrical energy sector, average tariffs for end users remain below the level of costs, mainly because of low household tariffs. Expenditure on electric power comprises a relatively low proportion of total household spending, fluctuating between 2.3% and 2.6% [102]. Tariffs for other groups of consumers, however, are higher than the level of the cost of electricity generation, which has a positive impact on the entire sector's financial condition. In 2014, Kyrgyzstan's Ministry of Energy and Industry introduced a monthly limit on household electrical energy usage of 700 kWh. After exceeding this level, the electricity price is the same as that paid by commercial consumers, i.e., the real market value. More than 80% of citizens do not exceed this limit [112].

Kyrgyzstan has the fourth lowest electric power tariffs in the world, with one kilowatt-hour costing an average of USD 0.017. Similar tariffs can be found in African countries such as Libya (USD 0.007), Angola (USD 0.013), Sudan (USD 0.014) and Zimbabwe (USD 0.021). In countries in the post-Soviet region, meanwhile, they are considerably higher: Russia (USD 0.05), Kazakhstan (USD 0.039), Tajikistan (USD 0.023), Uzbekistan (USD 0.027), Armenia (USD 0.007) and Belarus (USD 0.069) [113,114].

Given the limited monetary income sources of households, an increase in the electrical energy tariffs could have a major impact on the quality of life of people with a low income, especially in rural areas. Moreover, given the seasonal nature of income from agriculture, households in the countryside earn the least in winter, when energy use and electricity bills are highest [102]. Kyrgyzstan's former energy minister, Osmonbek Artykbayev, believes that a solution is needed to deal with price increases, following extensive analysis of the problem from the government: "Electrical energy should not be sold at a price below cost. Electricity producers should be able to support themselves and develop. On the other hand, tariffs should be fixed taking into account the level of prosperity of society [...]. Without profits, electricity companies will not improve" [115].

The Kyrgyz authorities are trapped in their own social policy, which, at present, does not allow it to introduce market mechanisms to the country's energy system. The government must subsidise tariffs and deal with energy firms' debts, running into the billions.

Reliability of Services

Reliability of supply refers, among other things, to the frequency and length of power outages. Reliability of supply in Kyrgyzstan's electrical energy system is low, especially in the winter months. In 2009–2012, distribution companies recorded an average of 43 outages per day. In 2013, commercial firms announced a monthly average of 0.9 outages, meaning a loss of 4% of total sales [116]. In December 2012, a fault at Toktogul HPP caused interruptions to energy supplies throughout the republic [117]. A further failure at Toktogul HPP in winter 2015 limited electricity use in the north and south of the country. Shortages of electrical energy in periods of the winter peak and disruptions in the energy grid, as well as breaks in electricity supply, produce social tensions and curb development of industry and small- and medium-sized enterprises [118]. The situation worsened dramatically in the 2020–2021 heating season. The National Electric Network of Kyrgyzstan company announced that overload of electricity grid facilities had been observed in all regions of the country [119]. A particularly high increase in electricity usage was recorded in Bishkek, where a third of the electric power generated is used. The grids in the capital were operating at their limits or were overloaded, and the power outages were caused by an equipment failure in a transformer [120].

A threat to the reliability and quality of supplies is posed by the fallible electric power infrastructure and high level of losses during electricity transmission. Almost all of Kyrgyzstan's entire current infrastructure was inherited from the USSR. Most of the energy lines constructed in the 1960s and 1970s are now in poor condition. In international practice, fixed asset consumption at a level of 30% is regarded as critical, and anything above 30% as unreliable. In Kyrgyzstan's energy market, depreciation of fixed assets exceeds 60%, putting it at a dangerous level.

A total of 98% of electric power in Kirgizstan is produced by the company Electric Stations, which owns seven Kyrgyz hydroelectric power plants and the country's two thermal stations. The rate of their usage is currently 80% and 60%, respectively [121]. The entity responsible for transporting electric power is the National Electric Network of Kyrgyzstan. The company has a total of 7548 km of high-voltage lines, with the extent of their depreciation estimated at 69% [122]. The firm also supplies electrical energy directly to large companies and sells to intermediaries [123]. Electricity losses during transport amount to 5–6%. Further distribution to the end client results in increased losses [124]. After supplying electricity to the regions, it is distributed to end users. Four companies are involved in this: SeverElectro [125], VostokElectro, OszElectro [126] and JalalabadElectro [127]. The level of usage of the distribution grids administered by these firms is 57%, 56%, 73% and 50%, respectively [122]. The low quality of transmissions and distribution networks results in high technical losses at a level of 20% [102] and increases the risk of failures [128]. In 2016, for example, the largest distribution firm, SeverElectro, announced the urgent need to exchange 40% of the 928 km of underground cables in Bishkek [102]. The poor quality of power is also a problem. More than half of respondents in a study from 2013 reported problems with low voltage, and almost one-fifth said their household appliances had been damaged by a low quality of services [129].

At the same time, the electric power sector is one of Kyrgyzstan's most indebted. In the last 15 years, the country has taken out almost USD 2 billion in loans for electrical energy projects [124].

The low quality of the electricity infrastructure and services (power outages, poor quality) is a consequence of the financial weakness of the electrical energy sector. In 2017, the energy sector's debt was in excess of 96.7 billion som, around 20% of the GDP [128]. The sector's income in 2016 was 21% lower than energy production costs, meaning that energy companies are experiencing a shortage of the funds needed to modernise antiquated infrastructure and improve the quality of services and investments in the sector [102].

Uncontrolled growth of electricity consumption (4–6% annually) has made it essential to increase the system's energy output to meet the population's needs. Building new infrastructure demands major financial injections, and electricity tariffs in Kyrgyzstan are unable to cover such costs. The lack of funds in the energy sector makes modernisation of the main energy facilities difficult, which could lead to further failures and power outages and, ultimately, to an energy crisis, according to representatives of the KyrgyzEnergo energy firm [130].

The Kyrgyz energy sector is also seen as problematic in terms of corruption. In accordance with the president's 2014 decree, "Measures for eliminating the causes of the political corruption system in government bodies", the 15 most corrupt ministers and department were identified, including the Ministry of Energy and Industry. Audits revealed that officials open to bribery were working in the distribution companies themselves, with corrupt practices present in tendering processes, electrical energy exports, issuing of licenses and setting tariff policy. In 2011, a case of large-scale electricity theft in the SeverElectro company was exposed. The firm added non-existing clients to its database and attributed stolen quantities of electrical energy to them [131]. The public procurement sector also has a high level of corruption. Officials cancel procedures or they turn out to be just a formality as the successful tenders are arranged in advance. Corruption crimes also take place during electricity exports, sold via private intermediary firms.

5.3.3. Security of Demand

Kyrgyzstan's electrical energy has a decisive impact on the condition and prospects of the national economy, equal to more than 3% of GDP and around 15% of industrial production as well as over 5% of income to the country's budget (2019). A developed electricity grid provides access to electrical power to the vast majority of the population [109]. Kyrgyzstan's energy potential is enormous. Its water resources are almost entirely formed in its own territory. Dozens of hydropower plants of varying sizes could be built on the main rivers, but to date, only a tenth of the country's potential has been realised. In 2020, electrical energy exports from Kyrgyzstan were 300.1 million kWh, 11.4% more than the previous year. According to data from the National Statistical Committee, between 1994 and 2019 Kyrgyzstan exported electric power for more than USD 900 million [132]. The country gained its lowest income from electricity sales, at USD 32,000, in 2015, and the highest amount, USD 83.2 million, in 1997.

Both Kyrgyzstan and Tajikistan should begin exporting electrical energy to Pakistan and Afghanistan as part of the CASA-1000 project. What obligations will Kyrgyzstan have in supplying electricity? This issue is particularly concerning given the fact that the country is today facing a deficit of electric power, which it is forced to import. During the first stage, exports are to take place in the summer period, when Kyrgyzstan has an electricity surplus. According to the CASA-1000 contract, the country's obligations in supplying electrical energy to South Asia are divided into two levels. The first concerns the minimum amount of guaranteed exports, and the second the amount of additional ones. Kyrgyzstan has the right to spread the guaranteed export amounts over separate years [90]. Annual electricity supplies in the summer season (May to September) from Kyrgyzstan to Pakistan and Afghanistan should average between 500 million and 1.5 billion kilowatt-hours, which is 40% of the total. The remaining 60% is Tajikistan's exports. The tariff for electricity exports will be much higher than for the domestic market, amounting to 5.15 cents per kWh for Pakistan and 5.10 per kWh for Afghanistan [90]. The annual electricity exports are estimated to bring Kyrgyzstan an income of around USD 80 million, which will be possible thanks to higher electricity tariffs than those on the domestic market [90].

6. Discussion

In accordance with the adopted research methodology, Tadzykistan and Krigistan have been analyzed for energy security in the fields of:

- Security of supply;
- Security of services;
- Security of demand.

The comparison of the results for both countries is presented below.

6.1. Security of Supply

Both of the Central Asian countries—Kyrgyzstan and Tajikistan—analysed in terms of energy security, are producers of hydropower. Both countries have a large hydropower potential, the use of which is able to cover the domestic demand for electricity and ensure exports to neighboring countries. Electricity exports can be a valuable source of government revenue that should be invested in improving existing infrastructure, building new generation capacity and supporting economic growth by increasing electricity supply at affordable prices.

In the case of both countries, the hydropower potential is several times higher than the current electricity production and consumption. Each republic has its flagship power plant—the Toktogul power plant in Kyrgyzstan and the Nurek power plant in Tajikistan—underpinning the entire power system. In the area of security of supply, the main threat is the seasonality of deliveries. Electricity supplies are most reliable in spring and summer—during this period, the demand of the domestic market is fully met. On the other hand, in the autumn and winter, when the demand reported by energy consumers is the highest, Kyrgyzstan and Tajikistan face the problem of electricity shortage. This problem affects the lion's share of the population of both countries and has not been solved to this day. The power system of Kyrgyzstan and Tajikistan today offers low reliability of supply, especially during the winter months. Due to electricity shortages during the winter peak and disruptions in the power grid, power outages create social tensions and hamper the development of industry and small- and medium-sized enterprises. At this stage, the energy policy of Tajikistan and Kyrgyzstan aims to alleviate the annual seasonal winter shortages and ensure uninterrupted access to energy for the population.

6.2. Security of Services

Both Tajikistan and Kyrgyzstan occupy distant places (compared to European countries or the average for Central Asia) in the "Doing Business" ranking of access to electricity, in terms of electricity supply quality or reliability of supply and transparency of tariff index. The main threat to the reliability and quality of supply is the unreliable power infrastructure (inherited from the USSR) and the high losses incurred during the transmission of electricity. The poor quality of the electricity infrastructure of Tajikistan and Kyrgyzstan is due to the poor financial condition of the energy companies of both countries. Despite their strong position on the electricity market, energy sector companies are experiencing a shortage of the financial resources needed to modernize outdated infrastructure, improve the quality of services provided and invest in the development of the energy sector. Modernization or construction of new infrastructure facilities requires large investment outlays, and extremely low electricity tariffs in Kyrgyzstan and Tajikistan do not allow them to be financed. The lack of funds in the energy sector and inadequate energy policy hinder the modernisation of major energy infrastructure, leading to further power failures and outages. The financial problems of the hydropower sectors of both countries are also conditioned by the non-payment of energy bills by the recipients, theft of electricity, technical losses during the transmission of electricity and a high level of corruption in both the energy sector and the entire economy. Currently, the power systems of Kyrgyzstan and Tajikistan are working at the limit of their capabilities, and the risk of further failures is increasing.

6.3. Security of Demand

Security of demand in the case of Tajikistan and Kyrgyzstan is guaranteed by agreements signed with neighboring countries. Both Central Asian countries are actively supporting CASA-1000, a project to build an electricity transmission line from Kyrgyzstan and Tajikistan to Afghanistan and Pakistan to export surplus electricity during the summer season. CASA-1000 is intended to provide Tajikistan and Kyrgyzstan with a steady source of income that can be used to alleviate severe winter energy shortages and improve the level of economic security of both countries.

7. Conclusions

Among renewable energy sources, hydropower is and will remain the very important source of electricity generation worldwide. Although the importance of cross-border hydroelectric power plants operating for more than a century is invaluable, this topic is still poorly analysed. This article was intended to fill part of this gap. The conclusions of the conducted research indicate that the number and size of dams and the potential of hydropower resources are important for the energy system of a given country. On the other hand, however, it is not enough for a country to have huge hydropower potential and large installed capacities to improve its energy security in all three dimensions analyzed. Today, the hydropower sectors of Kyrgyzstan and Tajikistan are quite controversial parts of the economy of both countries: they are referred to as the flagship sectors of the economy, while they are characterised by worn-out and unreliable infrastructure. They are supposed to give the impression of being investor-friendly, while it will be extremely difficult to ensure the profitability of electricity production. They pretend to be an energy exporters to Pakistan and Afghanistan, while they themselves are forced to import electricity from neighboring countries.

The problems of the energy sectors of Kyrgyzstan and Tajikistan are a consequence of the structural weakness of governments in both countries and their dependence on the Russian Federation in the political and economic dimensions. Despite more or less formal declarations about the modernisation of the power sector, both governments do not have enough will to carry out the necessary reforms. The second important issue that has been inhibiting the development of the hydropower sector of Tajikistan and Kyrgyzstan for years is the problem of cross-border rivers—Syr-Daria and Amu-Daria—whose water resources are crucial for the economies of other Central Asian countries.

It is difficult to expect the possibility of improving the energy security of both countries in the context of the hydropower sector due to the political and economic weakness of Kyrgyzstan and Tajikistan. In the economic field, we are dealing with economies based mainly on the Soviet way of management: inefficient, small and very underdeveloped economies with a high level of corruption. The political system in both Central Asian countries is not conducive to reforming the economic system. Three decades of authoritarian rule by Emomala Rahmon in Tajikistan allowed the president and his relatives to take control of every branch of the national economy. In turn, the imperfect democracy of Kyrgyzstan is characterized by frequent violations of the law in the name of the personal interests of the current president and the regional clan represented by him.

A small chance for a lasting change may be the weakening of the protectorate of the Russian Federation over this area. This weakening may result from the crisis in the Russian state caused by the attack on Ukraine, which turned out to be a catastrophic mistake. However, it should be remembered that Russia guaranteed the stability of this region, in which there are still many unresolved ethnic, economic and territorial conflicts. On the other hand, it hampered necessary reforms that were not in Russia's interest. The weakening of Russia may destabilize this region, which will not be conducive to reforms in the energy systems of the analyzed countries, at least in the short term. Paradoxically, however, this may be an opportunity for a change in the long term, as long as the situation in the region does not become out of control. Additionally, in the face of the crisis of the Russian Federation, China's influence in this region may increase significantly.

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Abbreviations

The following abbreviations are used in this manuscript:

IEA	International Energy Agency
GDP	Gross Domestic Product
CAPS	Central Asian Power System
ESS	Energy Security Services
CASA	Central Asia–South Asia

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