



One hundred years of historical, political, and social changes: Is Central Asia ready for an energy transition, or is there no need to rush?

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ABSTRACT

The main goal of this paper is to present the historical context and current state, along with the prospects, of a sustainable energy future in one of the most traditionally isolated regions globally—Central Asia. From 1921 to 2025, the countries of this region experienced a series of complex social changes that were fundamentally evolutionary, although at times they occurred rapidly, resulting in enduring repercussions. The paper reviews the main features of the energy sector and society during the USSR era (large infrastructure projects, stability, and socioeconomic development); the post-independence period of Central Asian countries (instability and struggle for power); and the contemporary factors that will shape the region's energy, economic, and social future. The region has an outdated but operational energy infrastructure, rich energy resources, and large potential in renewable energy. Governance is centralized and largely non-transparent; energy markets and energy prices are state-controlled. Regional disputes over the use of hydropower have lasted for decades, hindering socioeconomic progress. The emigration rate is high. The main foreign investor in the sustainable energy transition is China. The sustainable transition of the energy sector has begun, but it is in the early stages. However, given the negative experiences of numerous countries in terms of social and environmental impacts of foreign investment, the region's slow progress should not be assessed as unfavorable. The main recommendations for governing the future sustainable energy transition of Central Asian countries are provided.

1. Introduction

The energy transition is a complex and long-term transformation process that involves substituting fossil fuels with renewable energy sources, more efficient use of energy resources, and modifying the economy and conventional consumer habits while minimizing pollution [1]. It requires substantial capital investments in new infrastructure [2, 3] and new technologies that facilitate the shift toward a low-carbon economy [4–6]. Additionally, a specifically designed governance system should be developed to ensure adherence to the principles of sustainable development, with the green energy transition as one of its major pillars [7,8].

The contemporary energy transition involves a multitude of high-intensity geopolitical risks [9,10]. The Russian-Ukrainian conflict has triggered complex geopolitical disturbances [11], while the disabling of Nord Stream 1 and 2—resulting from European Union (EU) sanctions against the Russian Federation (Russia)—prompted an urgent need to

diversify energy supply routes [12]. Furthermore, the 2024 decision to cease the supply of critical raw minerals, vital for decarbonization, from the People's Republic of China (China) compels the EU to seek alternative suppliers for these resources [13]. The United States of America (USA) also finds itself in an unfavorable position, as China imposed a ban in December 2024 on the export of certain rare earths—materials that are critical parts of high-tech products and defense industry items—as well as related technologies to the USA [14]. Recent conflicts in the Middle East emphasize the necessity of diversifying energy supplies and transitioning to alternative sources. This approach enhances security of supply and aligns with the principles of sustainability.

A green energy transition involves changes in how energy is exploited, transported, and utilized. It also requires the development and use of new infrastructure and equipment derived from the extraction of rare minerals, which are particularly valuable. The decarbonization efforts in the EU have significantly increased the demand for rare and critical minerals. These minerals were primarily sourced from China

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until the country imposed severe restrictions on their export. Therefore, countries pushing for decarbonization must find other sources of the necessary minerals. Given its abundant endowment of fossil fuels, critical raw materials, and renewable energy resources [15,16], Central Asia has emerged as a region of heightened strategic importance for major powers [17,18]. These dynamics carry major consequences for further development of the five Central Asian countries (Kazakhstan, the Kyrgyz Republic, Tajikistan, Turkmenistan, and Uzbekistan), which became independent after the dissolution of the Union of Soviet Socialist Republics (USSR) in 1991.

More than three decades after independence, however, Central Asia continues to exhibit relatively low levels of economic development alongside persistent poverty [19,20]. These structural constraints, compounded by the enduring legacy of the Soviet system, continue to shape key economic outcomes and influence the design and implementation of energy transition policies [21–24]. In addition, the region's landlocked geography has further reinforced its relative isolation and constrained its integration into global markets [25,26]. Against this backdrop, Central Asia confronts a complex interplay of internal and external challenges related to economic restructuring, institutional capacity, and the resolution of long-standing socioeconomic issues [27, 28]. As a result, the pursuit of energy transition pathways in the region is inherently more complex and demanding than in many other parts of the world [29,30].

Two perspectives are particularly important when examining Central Asian countries. First, they possess vast energy resources and substantial potential, encompassing both conventional and renewable energy sources. Second, these countries are seeking to implement the concept of sustainable development, within which the sustainable energy transition plays a crucial role. The interest of foreign entities in both aspects is undeniable. Contemporary geopolitical dynamics and the growing demand for resources create opportunities for the socioeconomic advancement of the Central Asian region; however, to identify feasible and context-specific solutions for the initial phase of the sustainable energy transition, it is essential to first examine the key prerequisites: infrastructure, regulatory framework, available resources, foreign influence, and governance.

There is a noticeable scarcity of scientific research on energy transition in the Central Asian region—its impacts and possible solutions that should serve as mitigation measures for sustainable energy development. For instance, a 2022 study revealed that over a 30-year period, only 33 studies (0.34%) addressing climate change in this region were published [31]. Existing studies indicate that research on the region has historically been dominated by fossil fuel-oriented analyses, while systematic investigations of renewable energy deployment, decarbonization pathways, and the broader sustainability transition remain limited and fragmented. At the same time, the region's structural characteristics—such as its resource dependence, landlocked geography, and complex geopolitical positioning—introduce additional layers of analytical complexity.

Consequently, the energy transition in Central Asia remains largely unexplored and represents a consolidated field of research, offering substantial scope for original contributions, particularly through integrative, data-driven, and comparative approaches. The recognized deficiency in the literature served as a primary impetus for this study, which seeks to deliver a comprehensive overview of Central Asia's progress in implementing the energy transition, with a particular emphasis on long-term country-level effects.

This paper primarily aims to address theoretical and practical gaps. The theoretical gap relies primarily on the modest scope of academic literature and official data but also on the approach to analyzing the observed issues. Namely, existing studies of the sustainable energy transition in this region (and beyond) mainly assess the potential for transitioning to renewable energy sources, reducing fossil fuel consumption, lowering pollution, or conducting a case study. This approach may be feasible in countries with a stable economic and political

environment; however, it is often inadequate and can be misleading in countries undergoing transition, such as those in Central Asia, which have vulnerable economies, low transparency in public policies, and limited reliable data.

To summarize, there is a clear theoretical gap between the needs (Central Asia's sustainable energy transition has begun, and the pressure to exploit its resources is increasingly pronounced) and the existing studies that can provide the necessary answers. This context reveals observable methodological and evidence gaps. From the methodological perspective, existing studies and academic literature are based mainly on the analysis of a single variable (most often resource potential and their availability), but a comprehensive multivariate analysis of the foundations for a future sustainable energy transition is rare. Studies that would take into account historical specificities that greatly influence the effectiveness of a sustainable energy transition in any sense are even rarer—and this study suggests that they need to be considered. The evidence gap becomes clear when closely examining existing studies. Some of them favor a sustainable energy transition through foreign investment, but recently studies have emerged that warn of the negative socioeconomic consequences of this approach. This study aims to analyze both perspectives and, by examining additional variables, provide answers to fundamental questions, offer policy recommendations, and suggest directions for further research.

A practical gap exists due to the discrepancy between established scientific findings and their application. While there is theoretical knowledge concerning the sustainable energy transition in Central Asian countries, professionals, industries, and policymakers fail to apply it effectively. This study examines the potential origins, dynamics, and reasons for this issue. This study strongly advocates the view that slow implementation of a sustainable energy transition in Central Asian countries is not necessarily a deficiency that should be removed. On the contrary, the study addresses this gap by advocating that a sustainable energy transition is a complex, expensive, and long-term process and must be carefully planned, especially in countries with rich resources but also with low socioeconomic indicators.

The theoretical and practical gaps outlined above establish the goal of this research: to conduct a multivariate examination of the prerequisites for a sustainable energy transition in the Central Asian region. This will be accomplished by addressing the following research questions.

RQ1: Have the countries of Central Asia adopted an adequate regulatory framework necessary for the implementation of a sustainable energy transition?

RQ2: To what extent is the existing energy infrastructure in Central Asian countries aligned with the requirements of a sustainable energy transition?

RQ3: Do Central Asian countries possess sufficient energy potential to support a sustainable energy transition?

RQ4: What is the role of foreign actors in the sustainable energy transition of the Central Asian region?

RQ5: How can the progress of the sustainable energy transition in Central Asian countries be assessed to date?

This study makes several significant contributions to the current corpus of knowledge. They are generally divided into three distinct types: empirical (what the data shows), theoretical (why and how things happen), and policy-based (what actions to take). In nearly all scientific and analytical pursuits, theory and empiricism are closely interconnected, but their peculiarities are further pointed out.

The empirical scientific contribution of this study is primarily evident in the novel insights that are derived from a methodological approach that investigates variables with mutual influences that are not fully quantifiable. Nevertheless, these influences are present and will have a substantial impact on the directions and dynamics of the sustainable energy transition in this region. The empirical contribution is

also evident in the perspective adopted for this research, which is uncommon in similar studies. This paper highlights the importance of paying greater attention to the observation of qualitative (measurable) data, which can either be constant or variable. For Central Asian countries, this matter holds greater significance than the wealth in resources required for their energy transition or for the decarbonization of other countries and regions. The study examines the historical context of Central Asia, noting that these countries had experienced economic momentum during the Soviet Union era. However, they also encountered a prolonged period of instability that persists to some degree. Additionally, their gradual integration with the outside world is a constant that evolves slowly. Furthermore, the study addresses the influence of foreign actors and investors, highlighting that their interrelationship, while sometimes difficult to discern, is nonetheless unavoidable.

The theoretical contribution discussed here differs from the previously mentioned empirical contribution, which is based on observations of selected variables. This theoretical contribution emphasizes ideas, concepts, and policy recommendations rooted in reasoning and logic. By examining the historical context and geopolitical perspective, this study contributes to the existing body of academic literature on the sustainable energy transition of Central Asia, including its main features, perspectives, and challenges. Exploratory in its nature, this study examines an emerging phenomenon of sustainable energy transition of Central Asia, which aims to discover patterns embedded in data, subject to subsequent scholarly validation, that could potentially provide insights for future theory development. This study can provide a new platform for further analysis and debate on the observed problem: how to initiate and govern sustainable yet just energy transition in countries rich in natural resources, prioritizing the well-being of both the countries and their citizens. The interests of foreign actors and investors should remain secondary, regardless of the extent to which they contribute to the decarbonization of other countries and regions.

Based on the empirical and theoretical research concerns outlined above, this study offers a policy-related contribution that calls for a necessary shift in focus regarding the observation of a sustainable energy transition and its main drivers. The study contributes to the body of knowledge on policy and governance from a specific perspective. While good governance and strong institutions are generally regarded as essential for a fair and sustainable energy transition worldwide, a different approach must be adopted for Central Asia. Governance in this region is largely different from Western governance models, and it is highly likely that this will continue in the future. Regardless of the universal importance of a sustainable energy transition, the countries of Central Asia have the right to forge their own path, set their own priorities, and be equal partners on the world stage, rather than being a region whose resources are exploited for decarbonization efforts taking place thousands of kilometres away. This study advocates a sustainable energy policy that respects the basic foundations of the existing governance system, which is deeply rooted in the region's history and tradition. Accordingly, it provides recommendations for improvement.

The paper is structured into sections. After the Introduction, Section 2 presents the Methodology of the research, which defines the purpose and objectives of the study and provides an explanation of the applied scientific method. Section 3 presents the Results, divided into five subsections related to the regulatory framework, energy infrastructure, energy potential, foreign actors, and energy transition results. Section 4 presents a discussion assessing the region's capacity for a sustainable energy transition in the future, followed by a set of recommendations primarily directed at policymakers. Finally, Section 5 provides a brief overview of the purpose and objectives of the study, summarizes the main findings, and provides recommendations for future research.

2. Methodology of the research

The research sample includes five Central Asian countries: Kazakhstan, Kyrgyz Republic, Tajikistan, Turkmenistan, and

Uzbekistan.

The study employs a qualitative analytical approach based on a structured comparative assessment of key determinants of the sustainable energy transition. Evaluating the Central Asian region's preparedness for a sustainable energy transition is a multifaceted endeavor that cannot be sufficiently analyzed using quantitative indicators or statistical analyses alone, as it necessitates the examination of several and diverse preconditions. In this context, qualitative analysis is not merely a methodological choice but reflects an effort to explore and interpret the subject in depth while capturing its contextual specificities. While grounded theory is characterized by methodological rigor in the systematic development of theory, general inquiry provides greater flexibility in understanding phenomena from multiple perspectives, without the constraints of adhering to or generating a formal theoretical framework [32].

Consistent with the research objectives and questions, five key variables were selected to assess the readiness of the Central Asian region for a sustainable energy transition. These variables can be defined and theoretically justified as follows.

1. Regulatory framework—defined as a structured system of laws, rules, guidelines, and administrative policies governing a specific domain [33]; in this case, the sustainable energy transition in Central Asian countries.
2. Energy infrastructure—a concept lacking a single universally accepted definition, as it is context-dependent [34]. For the purposes of this study, it is defined as the existing technical base that either enables or constrains the sustainable energy transition. In this regard, particular attention is paid to available thermal and hydropower plants, with hydropower considered a low-carbon energy source [35].
3. Energy potential—referring to the inherent capacity of natural resources, both renewable and non-renewable, to be converted into useful energy forms such as heat, electricity, or fuel [36]. For the purposes of this study, the analysis focuses on the availability of oil, gas, hydropower, and renewable energy potentials.
4. Foreign actors—defined as individuals, groups, or entities, including foreign governments, organizations, and citizens, that operate beyond their home country to influence the domestic politics, policies, or economy of a host nation [37], in this case, within Central Asian countries.
5. Outcomes of the sustainable energy transition—conceptualized as measurable progress in shifting from fossil fuel-based systems toward renewable energy sources, improving energy efficiency, and reducing carbon emissions [38], with a particular focus on developments since 2000.

The analysis of the above-defined variables provides the necessary inputs for addressing the research questions and formulating policy-relevant recommendations.

The data sources encompass both academic literature (primarily indexed in the Scopus database) and relevant professional reports, as well as official statistical and institutional data for the countries under study and the identified foreign actors.

The proposed methodological framework is transferable to the analysis of similar research problems in other countries where the academic and professional literature remains limited, particularly in the case of resource-rich economies endowed with energy resources and critical raw materials. In such contexts, the examination of research questions incorporates historical and broader socio-economic dimensions, thereby enabling the derivation of context-sensitive conclusions and policy recommendations, as well as identifying avenues for future research.

3. Results

3.1. Regulatory framework

The adoption of an adequate regulatory framework for a sustainable energy transition is closely linked to the broader state of the rule of law and legal regulation in Central Asian countries. It should therefore be examined as part of a wider historical context that has shaped the main features of governance to date and will continue to influence them in the future. All Central Asian countries experienced a severe crisis across all sectors due to the disintegration of the Soviet governance system, which had ensured and facilitated investments and advancements. The struggle for power was widespread across all countries and, in some of them, frequently escalated into violence [39,40]. Sporadic government upheavals occurred in Kazakhstan; the Kyrgyz Republic experienced three revolutions (2005, 2010, and 2020); the civil war in Tajikistan lasted from 1992 to 1997; yet, the government in Turkmenistan is described as one of the most durable totalitarian regimes.

In such conditions, a regulatory framework for a sustainable energy transition is being developed, which is currently based predominantly on general strategies. The sustainable energy transition began with the adoption of general regulations on sustainable development [41], initially focusing on establishing a regulatory framework for renewable energy production—laying the groundwork for the implementation of renewable energy projects. Regulatory documents regarding the sustainable energy transition have been implemented since 2010. The primary indicator of this trend is the adoption of national strategies that are designed to promote sustainable development, pollution reduction, and efforts to combat climate change.

Considered in more detail, the regulatory and strategic framework for implementing a sustainable energy transition in Central Asia is characterized by gradual development and considerable heterogeneity across the countries of the region, alongside a shared focus on decarbonization, improving energy efficiency, and increasing the share of renewable energy sources. Kazakhstan has implemented a sophisticated strategic framework via the *Concept for Transition to a Green Economy*, setting long-term goals to enhance the proportion of renewable energy sources and to introduce an emissions trading system (ETS), which is one of the most advanced regulatory mechanisms in the region. Uzbekistan has also established a strategic framework for transitioning to a green economy, focusing on diversifying the energy mix and attracting international investment via auction-based mechanisms and power purchase agreements (PPAs). By contrast, Kyrgyzstan and Tajikistan continue to rely predominantly on their hydropower potential, with regulatory frameworks primarily focused on energy security and the development of existing resources, while broader energy market reforms have seen limited progress. Turkmenistan is characterized by modest regulatory advancement and a pronounced reliance on natural gas, accompanied by minimal diversification within the energy sector.

Besides certain country-specific features pointed out above, at the regional level, common elements of the regulatory frameworks include the introduction of support mechanisms for renewable energy sources, the gradual liberalization of energy markets, and efforts to reduce state subsidies that sustain low energy prices. However, the execution of these policies is constrained by institutional deficiencies, outdated infrastructure, and significant state intervention in the energy sector. International financial institutions play a particularly important role in the development of regulatory and institutional capacities, most notably the European Bank for Reconstruction and Development (EBRD) and the World Bank, which—through financial and technical support—contribute to strengthening the regulatory framework and advancing market integration. However, the primary challenge lies in moving beyond declarative policy commitments toward effective, consistent, and enforceable implementation. In all countries of the region, the energy sector remains fully state-controlled.

Despite the extensive body of regulatory documents, it is important

to note that the full implementation of existing regulatory provisions in Central Asian countries is inadequate and hindered by widespread corruption in the energy sector, primarily manifesting as embezzlement of government funds, bribery, and abuse of office [42]. Governance in these countries remains centralized and often inefficient, marked by excessive bureaucracy [43] and ambiguous or inadequately measured objectives, which may change and consequently foster an adverse climate for executing a particular strategy.

In summary, the regulatory framework is either insufficiently developed or, where it exists, often poorly implemented. A notable practice is the frequent use of presidential decrees to override certain decisions—often with the specific aim of exerting control over developments in the energy market [44]. The latest OECD analysis from 2026 indicates that significant challenges persist in the implementation of adopted regulations, which continue to negatively affect foreign investor interest to a considerable extent [45].

3.2. Energy infrastructure

The energy infrastructure of Central Asian countries was established during the period when the region was part of the former Soviet Union.

As part of the USSR, the region developed within the framework of a centrally planned economic system [46,47] with a strong focus on industrialization and electrification. The Plan for the Electrification of Russia, adopted in 1920, envisioned the construction of 30 power stations (20 thermal and 10 hydroelectric), a goal that was fully achieved by 1931—four years ahead of schedule [48].

This document outlined a comprehensive development strategy for the Central Asian region, based on the region's extensive river systems and significant agricultural potential. The first hydropower plant in Central Asia was built in 1933 (*the Kadrynska hydropower plant*), and thereafter, another four big hydropower plants were built: *Buduarskaya*, *Komsomolskaya*, and *Tavakskaya* in Uzbekistan [49], as well as *Verhne-Varzobskaya* in Tajikistan [50]. Works on the electrification of the USSR did not stop even during the Second World War, when the largest thermal and hydropower plants were renovated and rebuilt. Electric power facilities in Central Asia were beyond the reach of the war, so they did not suffer any damage [51].

Just before the outbreak of the Second World War, industry was relocated from the European part of the USSR to regions beyond the Urals, accompanied by the construction of entirely new power plants to meet the industrial energy demands at the new locations. This huge undertaking was successfully implemented, whereby investment in the energy sector of Central Asia continued. First of all, the large hydropower plant *Farhadskaya* was built on the Syr Darya River at the time, as well as 40 smaller hydropower plants. The construction, operation, and maintenance of large hydropower plants and distribution networks in remote and roadless areas of Central Asia were the basis for the socio-economic development of this region.

The construction of major hydropower facilities and the implementation of a specialized management system that operated efficiently during the period of USSR governance effectively addressed the major challenges related to electricity and water supply. After the dissolution of the USSR, the integrated energy-water-agriculture governance system ceased to function. However, given its potential significance for the region's sustainable energy future, it is important to highlight its key features.

Since the rivers (Amu Darya and Syr Darya), on which the hydropower plants were constructed, played a crucial role in irrigation, a unique system for managing the water-energy complex was established in the southern part of Kazakhstan and administered from Uzbekistan. These two rivers record significant fluctuations in water levels between the winter and summer periods. During the winter, the Kyrgyz Republic and Tajikistan—where the upper courses of the two major rivers are located—stored water in large reservoirs while receiving electricity from other countries in the region, primarily Uzbekistan, Kazakhstan, and

Turkmenistan, with most of this electricity being produced by thermal power plants. During the summer, the Kyrgyz Republic and Tajikistan shipped the collected water to Uzbekistan, Kazakhstan, and Turkmenistan for agricultural and irrigation purposes. The issue of electricity shortage in that period was resolved by electricity supply from other parts of the USSR [52]. This governance model, established during the USSR era, ensured stability and the security of supply for both citizens and the economy at affordable prices [53].

After the Second World War, large-scale power infrastructure projects continued across the USSR, and the construction of nuclear power plants gained momentum. Specifically, electricity production from nuclear power plants amounted to 4 kWh per capita in 1921, increased to 250 kWh per capita by 1945, and reached 5200 kWh per capita by 1980. During that period, fossil fuel reserves were explored in the republics of Central Asia, but there was no significant extraction [54]. It was only after these countries achieved independence in 1991 that the intensity increased.

Until the dissolution of the USSR, the electric power system of Central Asian countries comprised 83 generation facilities, which were well interconnected and integrated into the unified electric power system of the USSR through Kazakhstan. The central dispatching center, which has remained to this day, is in Tashkent, the capital of Uzbekistan.

Table 1 presents an overview of all hydropower and thermal power plants constructed in the Central Asian region. In this context, thermal power plants in Turkmenistan and Uzbekistan primarily use natural gas as their fuel source, whereas in Kazakhstan they predominantly rely on coal.

The findings indicate that the largest number of hydropower plants were constructed during the period when Central Asian countries were

part of the USSR, within the framework of intensive electrification. Following independence, and despite the challenges that the countries of the region subsequently faced, six additional hydropower plants were built. All of the hydropower plants remain operational today and can be regarded as an important infrastructural foundation for the region's sustainable energy development [55]. However, there are significant issues hindering progress: the compromised energy-water management system, which has become increasingly non-transparent and closely tied to corruption since the dissolution of the USSR [56]. A distinct challenge specific to the countries of Central Asia concerns the supply of both water and electricity. For example, many large hydropower plants built during the Soviet era—designed to provide both water for agriculture and electricity—are located in one country, while the distribution networks for electricity and water are in another country. This situation has become a source of ongoing dispute [57,58], with issues that remain unresolved to this day.

Finally, it is important to note that the energy infrastructure inherited from the Soviet period has suffered from inadequate maintenance, while energy prices for domestic consumers remain heavily subsidized. Moreover, access to energy is often unreliable due to the vast geographical distances and the outdated condition of the network [59].

3.3. Energy potential

Geopolitical interests of global superpowers, especially those concerning access to natural energy resources, renewable energy potential, and strategic transit routes, will significantly influence the sustainable energy transition and its governance in the Central Asian region. The above points to the need to consider the potential of both conventional

Table 1
Hydropower and thermal power plants in Central Asia (1933–2025).

Country	Hydropower plant	Year of completion	Thermal power plants	Year of completion
Kazakhstan	Bukhtarma	1956	PlantUst-Kamenogorsk Power Plant	1947
	Oskemen	1959	Zhambylskaya Power	1967
	Kapshgay	1970	Aksu Thermal Power Plant	1968
	Shulbinks	1987	MAEC-3 CHP (Mangystau)	1983
Kyrgyz Republic	Al-Bashy	1970	Ekibastuz GRES-2 – 1990	1990
	Toktogul	1974	Bishkek Thermal Power Plant	1961
	Üch-Korgon	1974		
	Kurpsay	1976		
	Tash-Kömür	1987		
	Shamaldy-Say	1996		
	Kambar-Alta-2	2010		
Uzbekistan	Kadrynska	1933	Navoi Thermal Power Plant	1981
	Bozsuiskaya	1934	Angren Thermal Power Plant	1960
	Kadyrinskaya	1936	Talimarjan Thermal Power Plant	construction started in 1984 (continued in 1998)
	Burdjarskaya	1937	Syrdarya Power Plant	1981
	Tavakskaya - 1	1941	Tashkent Thermal Power Plant	1963
	Aktepinskaya	1943		
	Kibrayskaya	1943		
	Salarskaya	1944		
	Nizhne Bozsuiskaya - 1 - 6	1944		
	Kavakskaya - 2	1946		
	Kavakskaya	1951		
	Sheikhantaurskay	1953		
	Komsomolskaya	1956		
	Charvakskaya	1972		
	Khodjikentskaya	1976		
Gazalkentskaya	1981			
Tajikistan	Farkhad	1948	Dushanbe-2 Thermal Power Plant	2016
	Kayrakkum	1959		
	Golovnaya	1962		
	Nurek	1972		
	Baipaza	1985		
	Sangтуда - 1	2009		
Turkmenistan	Sangтуда - 2	2011		
	Ira-Turkmenistan Friendship dam	2005	Mary Thermal Power Plant	1987
			Ashgabat Power Plant	2006

Source: Authors, based on official records.

and renewable energy resources and their exploitation as two interconnected systems. The countries of the region have their own specificities in this regard. Table 2 presents a summary of several publications that offer an overview of the energy resource potential of Central Asian countries, with only minor variations in the reported data.

The above data show that the energy resource potential of Central Asian countries is very significant on a global scale. The region is endowed with abundant reserves of natural gas, oil, and uranium—key resources whose export can generate essential revenues for the region's overall development, as well as for financing the sustainable energy transition. Looking at countries, Turkmenistan possesses substantial natural gas reserves—an energy source considered relatively environmentally friendly—and is ranked as the country with the sixth largest proven gas deposits in the world.

The low cost and wide availability of coal make it the most used energy source for both residential and industrial needs. However, the experiences of Kyrgyzstan [61], Tajikistan [62–64], and Kazakhstan [65,66] demonstrate that dependence on coal leads to considerable environmental degradation [67].

The potential for renewable energy sources is also significant, yet unevenly distributed across countries [68,69]. Table 3 summarizes data retrieved from UNDP.

All countries demonstrate significant potential for harnessing solar energy. This potential is followed by a considerably lower capacity for wind energy generation. Small hydropower plants, despite their limited potential, play a crucial role in supplying energy to remote areas of this vast region. In contrast, the potential of biomass is the least significant and can be regarded as negligible.

Kazakhstan has the highest potential for investment in renewables, particularly in solar and wind energy [71,72]. Kazakhstan is the leader in the production of energy from renewable energy sources, with over 120 smaller active renewable energy projects today, but the progress is still burdened with several administrative restrictions [73,74]. Kazakhstan has outperformed other countries in the region when it comes to the energy transition [75].

3.4. Foreign actors

Foreign investor activity has increased substantially across all Central Asian countries in the field of renewable energy, with projects predominantly concentrated in hydropower, wind, and solar energy, alongside the growing importance of battery storage systems and hybrid power plants. The most prominent investors in the energy transition are

Table 2
Energy resource potential of Central Asian countries.

	Resource potential	Hydropower (bill. KWh/year)	Oil reserves (million tons)	Gas reserves (billion m ³)
Kazakhstan	Oil and petroleum products, natural gas, coal, uranium	40,2	4000	6800
Kyrgyz Republic	Gold, hydropower	142,5	5	6
Turkmenistan	Oil and petroleum products, natural gas	2	300	23,000
Tajikistan	Uranium, coal, hydropower	527	2 (53 ^a)	-(3.000 ^a)
Uzbekistan	Gold, oil, coal, natural gas, uranium	15	250	5900
TOTAL		726,7	4557	37,706

^a Estimates made by research companies, based on [60].

Table 3
Technical potential for installed renewable electricity capacity in Central Asia (MW).

	Kazakhstan	Kyrgyz Republic	Tajikistan	Turkmenistan	Uzbekistan
Small hydro	4800	1800	23,000	1300	1800
Wind	354,000	1500	2000	10,000	1600
Solar	3,760,000	267,000	195,000	655,000	593,000
Biomass	300	200	300	Negligible	800

Source [70].

outlined in the following section.

3.4.1. International financial organizations

International financial institutions have played a pivotal role in initiating reforms and fostering development within the energy sector of Central Asia [76], among which are the EBRD and the World Bank. In this context, the EBRD primarily dominates in the direct financing of energy transition projects, whereas the activities of the World Bank are more focused on the development of institutional and regional frameworks for long-term decarbonization and the integration of energy systems.

No single aggregate figure can capture the total volume of investments by the EBRD and the World Bank in the energy transition of Central Asia, as funding is distributed across diverse programs, sectors (including infrastructure, renewable energy, and energy efficiency), and time horizons. From a cumulative perspective, the EBRD has invested more than €21 billion in the region across over 1250 projects, with more than one-third allocated to energy infrastructure development, renewable energy projects, energy efficiency improvements, and broader “green economy” initiatives. Over the past 30 years of EBRD engagement in the region, Uzbekistan and Kazakhstan received the largest share of funding.

According to data from the World Bank, Kazakhstan and Tajikistan are Central Asian countries that have attracted the largest number of financial resources for sustainable energy transition and mitigating climate change. In addition, the World Bank financed the development of regulations, tariff reforms, renewable energy projects, and an investment strategy, mostly in Uzbekistan.

A major investor in climate-related projects is the Global Environmental Fund, along with the newer financial mechanism, the Green Climate Fund, which supports fewer projects but on a significantly larger scale.

3.4.2. The People's Republic of China

An analysis of the principal investors in the Central Asian region since the post-Soviet era indicates that China has emerged as the most prominent, with a growing focus on investing in renewable energy sources. China's motivation to invest in Central Asia has been driven not only by the intention to allocate excess capital but also by political considerations [77] and the strategic goal of securing and diversifying access to energy resources essential for sustaining its economic growth [78]. Given Central Asia's abundance of energy resources and its geographic proximity to China, the region became a primary target for China's initial investments under the framework of the One Belt One Road Initiative, launched in 2013. Around 80% of Chinese investments in that region are directed to Kazakhstan and Turkmenistan [79–81] in large infrastructure projects that ensure oil and gas supply for their domestic markets [82–84].

The most recent information indicates that, after 2023, Central Asian countries and China have signed numerous agreements concerning future cooperation in renewable energy production [85–87].

3.4.3. The Russian Federation

Although Chinese investments dominate Central Asia's energy

industry, Russia's influence continues to be significant over thirty years post-USSR disintegration, as indicated by a strong rise in its investments in the region's energy sector [88].

There are certain arguments in favor of the fact that Russia will participate in the development of Central Asian countries, primarily for two reasons. Firstly, there are clear historical ties between Russia and Central Asian countries. Secondly, in accordance with Russia's foreign policy strategy adopted in 2000, the post-Soviet states have been designated as countries of the highest foreign policy priority [89,90]. The strategic documents adopted thereafter do not show changes in this respect [91,92].

In the post-Soviet period, Russian investments in Central Asia were limited and focused almost exclusively on the traditional energy sector [93,94]. However, following 2022, a shift became evident, marked by Russia's growing interest in energy sector investments across Central Asia. In the Central Asian region, Russia has participated in several joint investment projects, primarily in the construction of large hydropower plants [95] and nuclear power facilities in Uzbekistan and Kazakhstan [96]. Additionally, Russia has also announced plans for joint investments in renewable energy across the region.

3.4.4. The European Union

Although the EU did not initially consider Central Asian countries to be a region of particular interest—mainly due to their geographical distance [97,98]—the outbreak of the Ukrainian crisis prompted a surge of EU initiatives in the energy sector. In November 2022, the EU launched a project with the aim of supporting the sustainable energy transition of Central Asian countries, with an emphasis on better connectivity. The EU plans to invest EUR 6.8 million from 2022 to 2026 in the sustainable energy transition of this region [99].

Accordingly, the first EU–Central Asia summit was held in Uzbekistan on April 4, 2025. The meeting resulted in a series of agreements designed to foster collaboration across various sectors. In the context of sustainable energy development, two initiatives stand out: the EU–Central Asia Declaration of Intent on Critical Raw Materials and the 2025–2026 roadmap under the EU–Kazakhstan Memorandum of Understanding on critical raw materials, batteries, and green hydrogen. Additionally, cooperation is intensifying with the EU in the field of green hydrogen production [100].

3.4.5. The United States of America

The interests of the USA in the Central Asian region are primarily geopolitical, driven by its strategic proximity to Russia, China, Iran, and Pakistan. A 1995 study indicates that, although the countries of Central Asia do not threaten its vital interests, U.S. foreign policy will seek to support democratization, denuclearization, and the reduction of terrorist threats coming from this region [101].

The diplomatic platform of the USA is based on joint work and the improvement of cooperation, primarily in the domain of developing democracy, reducing the threat of terrorist activities, and opening the region to the world [102], as well as advancing energy development [103].

There is a lack of academic literature offering a comprehensive analysis and concrete examples of the US' influence in the Central Asian region, beyond the available strategic documents and isolated expert opinions. The most recent available data on U.S. investment in the region pertains to USAID, which allocated USD 39 million for supporting the sustainable energy transition in Central Asia for the period from 2020 to 2025 [104].

3.5. Outcomes of the sustainable energy transition to date

The implementation of sustainable energy transition measures has been formally acknowledged in Kazakhstan, where notable steps have been undertaken; however, the overall results remain modest [105]. Key constraints to accelerating sustainable energy transition include

subsidized energy prices, an unfavorable investment climate, outdated infrastructure, and insufficiently developed strategic and legal frameworks. There is also a prevailing perception that the country's future development should continue to rely on the exploitation of its abundant energy resources, a stance that is not fully aligned with the objectives of a clean energy transition [106]. Furthermore, decision-makers appear to prioritize regional geopolitical considerations over sustainable energy transition goals.

Kyrgyzstan represents a case in which the sustainable energy transition is closely intertwined with adverse socioeconomic conditions. As the country exhibits the highest poverty rate in the region and lacks adequate access to energy, addressing these challenges tends to overshadow energy transition and environmental concerns within the hierarchy of sustainable development priorities [107]. Consequently, progress in the sustainable energy transition remains limited, further constrained by weak institutional efficiency, high levels of corruption, and structural inefficiencies within the energy sector [108].

To date, there is also limited evidence of meaningful progress toward a sustainable energy transition in Tajikistan. In addition to challenges similar to those observed in Kyrgyzstan, existing environmental regulations are often inadequately enforced [109]. Demographic trends further exacerbate these challenges, while insufficient regional cooperation in energy and water resource sharing represents a critical barrier [110].

Tajikistan and Uzbekistan have only partially resolved the ongoing tensions regarding the shared use of the Rogun hydropower plant, despite donor-supported efforts [111]. Collectively, these factors point to limited institutional readiness and commitment to advancing a sustainable energy transition.

The transition to renewable energy remains negligible in Turkmenistan, which, despite being one of the economically strongest countries in the region, continues to rely heavily on its fossil fuel base [112]. In 2015, Turkmenistan joined the TAPI pipeline project, aimed at transporting natural gas, which is considered relevant for both sustainable energy transition and regional cooperation [113]. However, as construction remains ongoing, its impacts cannot yet be fully assessed [114]. Empirical evidence suggests that while the country possesses significant wind energy potential, its realization depends on stronger political commitment and openness to foreign direct investment.

In Uzbekistan, similar to other Central Asian countries, substantial progress in the deployment of renewable energy remains limited and is unlikely to accelerate in the near term, largely due to highly subsidized electricity prices [115,116]. Existing studies indicate that the construction of a nuclear power plant could significantly enhance the country's energy security [117], although potential environmental implications are often insufficiently addressed.

In general, sustainable energy transition in countries of Central Asia is at early stages, with all countries in the region facing the challenge of meeting internationally accepted climate agreements; it is expected that this trend will continue due to the interdependence of economic, social, environmental, and policy concerns [118].

4. Discussion

The study encompassed a review of prior research findings alongside an analysis of five selected variables, thereby providing a more comprehensive understanding of the process of implementing the sustainable energy transition in the region. The results indicate that there has been no substantial progress in the sustainable energy transition across Central Asian countries, which is consistent with the findings of the limited number of existing studies.

The analysis identified the fundamental preconditions necessary for a sustainable energy transition in the Central Asian region. Tables 3 and 4 present the authors' assessment of the key factors, along with brief descriptions and prospects, organized into three distinct but interconnected historical periods.

Table 4
The most important preconditions for a sustainable energy transition: energy resources and infrastructure of Central Asian countries (1920–ongoing).

Factor	During the USSR era (1920–1991)	After the dissolution of the USSR (1991–2023)	Situation in 2025	Prospects
Natural gas (relevant for Turkmenistan)	Exploitation, infrastructure construction, progress	Exploitation, without maintaining old and building new infrastructure	Progress	Favorable, primarily due to the fact that 90% of electricity is produced from natural gas
Coal and uranium (relevant for Kazakhstan)	Exploitation, infrastructure construction, progress	Exploitation, without maintaining old and building new infrastructure	Minimal progress	Moderately favorable due to planned construction of nuclear power plants to generate electricity
Renewable energy sources	Not relevant	No investments	Initial estimates indicate significant potential, with minor investments	Favorable, due to the significant potential—particularly in the event of securing advantageous export contracts
Hydropower	Big investments, progress in electrification	No investments in existing infrastructure, devastation, grid losses, and theft	Minor investments in existing infrastructure, devastation, grid losses, and theft	Moderately favorable, due to substantial potential but requiring large investments and the resolution of ongoing regional disputes
Clean technologies	Not relevant	No investments	Minor investments	Unfavorable, primarily due to the high cost of investment, shortage of qualified workforce, lack of transparency, and weak institutional capacity
Sustainable energy transition monitoring system	Not relevant	The system did not exist	System declaratively exists, but it is incomplete and unreliable	Unfavorable, due to the lack of qualified human resources and a policy that does not prioritize the aforementioned issues

Source: Authors.

Main findings from Table 3 indicate that Central Asia is richly endowed with energy resources and maintains a highly centralized and state-controlled energy sector. A large share of the energy infrastructure dates back to the Soviet era, rendering it outdated and unreliable. Addressing this issue has emerged as a strategic priority across all countries in the region; however, the concrete steps taken thus far remain insufficient (for reasons that are numerous and beyond the central scope of this study), resulting in the postponement of comprehensive infrastructure modernization into the foreseeable future. The postponement is likely to significantly impede the sustainable energy transition, as secure and uninterrupted energy supply continues to be regarded as a fundamental development priority, supported by substantial investments. In this context, it is critical to acknowledge that, more than three decades after the dissolution of the Soviet Union, regional disputes over the use of transboundary river resources continue to exist, and these issues remain unresolved.

An additional constraint on the sustainable energy transition in the region is continuous emigration, which contributes to a shortage of skilled labor and limits the capacity to effectively implement transition-related measures. This situation represents a complex socioeconomic

challenge that, although not the primary focus of this study, will significantly shape not only the sustainability trajectory but also the broader development prospects of the region.

After examining energy infrastructure and potential, it is necessary to consider political and socioeconomic factors. Table 5 presents the authors’ perspective on the key factors from this group, that have shaped the countries of Central Asia since 1920, along with an assessment of their prospects for achieving a sustainable energy transition.

According to the findings of both previous and this research, the economic and governance crisis that followed the dissolution of the USSR [119] led to a rapid decline in living standards, heightened tensions, and political instability. Under such circumstances, the countries of Central Asia were unable to plan for or achieve stable development. It was not until 2010 that these nations commenced the restoration of their developmental levels from the era preceding the dissolution of the USSR.

In these circumstances, it was expected that a sustainable energy transition would be recognized, but not on the priority list. Nevertheless, a sustainable energy transition has begun, and certain results are known. Previous experiences in the region have demonstrated that the main obstacles to investment in sustainable energy transition are weak

Table 5
The most important preconditions for a sustainable energy transition: political and socioeconomic factors in Central Asia (1920–ongoing).

Factor	During the USSR era (1920–1991)	After the dissolution of the USSR (1991–2024)	Situation in 2025	Prospects
International pressures on the region	Did not exist	Isolation, emergence of pressures	Increased pressures	Unfavorable
Cooperation between Central Asian countries	In the days of the united USSR, there were no problems	The crisis arose immediately after the dissolution of the USSR	Not at the required level	Unfavorable
The state of democracy	Not relevant	Cannot be assessed	Cannot be assessed	Cannot be assessed
State of institutions	Strong institutions	Weak institutions	Unclear	Cannot be assessed
Model of governance	Centralist, socialist	Crisis	Centralist	Centralist
Regulatory framework for sustainable development	Not relevant	Progress after 2010	It exists and is mostly declarative in nature	Slow progress
Quality of life	Constant improvement	Decline up to 2010	Minor progress	Slow progress
Education	Constant improvement	Cannot be assessed	Lack of experts in all fields, closely tied to increased emigration rates	Cannot be assessed
Energy market	Centralized; no electricity supply crises	Centralized; electricity supply crises	Centralized; regulatory progress	State-regulated; energy is considered a social category
Investments	Centralized, planned with secured funds, implemented	Legally regulated framework; minor investments	Legally regulated framework; beginning of significant investments	Favorable
Foreign direct investments	None	After 2010 China and EBRD are leading the way	EBRD, World Bank, China, the Russian Federation, Turkey, France, South Korea	Favorable
Corruption	Minimal	Widespread	Unfavorable	Unfavorable
Energy and water resources management	Centralized and efficient	Centralized and inefficient	Crisis, unsolved disputes	Unfavorable

Source: Authors.

administrative capacity, lack of transparency, and unreliable, outdated infrastructure [120]. The World Bank identifies political factors as a frequently cited key obstacle to advancing energy transformation based on renewable sources [121]. Further issues encompass a lack of expertise, inadequate data and information availability, and the lack of necessary support across all system levels.

The countries of the Central Asian region also face challenges in independently financing projects related to the sustainable energy transition. As a result, support from international financial institutions is essential, and there is a growing presence of both foreign direct investment and joint ventures in the sector. Various actors are active in the region in this regard, with China's influence becoming increasingly dominant, while the presence of Russia and the EU is also steadily growing [122]. The reasons for this trend are numerous, and the interests of foreign actors are not always fully understood (though they certainly extend beyond a sustainable energy transition). However, it is reasonable to expect that this trend will persist.

4.1. Policy recommendations for initiating a comprehensive sustainable energy transition

Despite numerous challenges and regional specificities, it is essential to consider the possibilities for Central Asia to advance toward a sustainable energy transition—an aspect of sustainable development that is arguably among the most complex and demanding to achieve. The process of defining goals should be grounded in evidence-based research, while the formulated policies must be aligned with broader policy frameworks [123]. Although the region possesses substantial resources that serve as a key prerequisite for the energy transition, it is essential to assess the possibilities for their sustainable exploitation, which inherently involves certain risks. The fundamental prerequisites for initiating a just and sustainable energy transition should be built upon the following key foundations.

- a) Stability amid geopolitical pressures. Geopolitical developments since 2022 have triggered significant disruptions in global energy markets and supply chains. Given that the region is endowed with both renewable and non-renewable energy resources, regulators may prioritize investment projects that are aligned with sustainable energy transition principles. Given the changing dynamics in global competitiveness [124], especially concerning emerging green technologies, the region should pursue stable and sustainable partnerships that facilitate the transfer of knowledge and technology, thereby contributing to its overall development.
- b) Strengthening cooperation between the countries of the region. After the dissolution of the USSR, internal conflicts and the struggle for power within countries were frequent and diverse but poorly studied. Inadequate regional cooperation remains a persistent issue that continues to significantly hinder the development of the region to this day.
- c) Developing an efficient energy governance system. Strengthening institutions, reducing corruption, and ensuring investment security constitute essential prerequisites for a long-term sustainable energy transition while duly accounting for social and environmental considerations [125]. The countries of Central Asia have experienced a decades-long period of turbulence; however, it can now be considered that they have entered a phase of relative stabilization in this regard. Considering the specific characteristics of these countries and their current economic conditions, it is therefore essential to identify appropriate models of operation and cooperation that can facilitate progress toward a sustainable energy future.
- d) Defining a regulatory framework that provides and encourages a sustainable energy transition. Despite the adoption of regulations related to energy and sustainability, the absence of concrete action plans remains evident, giving the impression that the decisions are rather declarative in nature.

- e) Reaching a time of stable economic development—free from significant volatility and uncertainty—is crucial for enabling effective planning and implementation of sustainable energy transition plans [126]. In this regard, it is necessary to enhance policy transparency and to design and implement appropriate incentive measures and mechanisms to support green transition investments and innovation [127].
- f) Achieving an adequate level of quality of life. For a long time, the population was deprived of electricity and water supply, and the poverty rate was high. It was only after 2010 that the situation began to improve; however, the data thereof remain unreliable or inaccessible. Reducing poverty and improving the social position of citizens remain the top priorities for the countries of the region, resulting in the sustainable energy transition being set aside for now. On the other hand, investing in energy exploitation projects can generate the income needed for the country's overall development and improve the social position of the population.
- g) The liberalization of the energy market is essential for achieving a sustainable energy transition; nonetheless, its full implementation remains lacking. In all Central Asian countries, the energy market is monopolized, and prices are subsidized. Therefore, it is important to assess whether a sustainable energy transition—which requires investment and a return on capital, preconditioned by market-regulated prices—is feasible for domestic or foreign investors. Nevertheless, examples of investments in renewable energy projects indicate that such transitions are possible. However, due to insufficient transparency, it is not possible to assess the contractual commitments and the associated benefits for the countries of Central Asia.
- h) Development of public–private partnership (PPP) models, which represents a particular challenge in countries where the energy sector is under state control. PPPs should be designed to ensure transparency and deliver benefits to all citizens.
- i) Developing a comprehensive system for monitoring the effectiveness of the sustainable energy transition. The issue of data availability poses a significant challenge in assessing the situation, as data are often inaccessible and their credibility is frequently questionable. The development of a monitoring system, along with data collection, processing, interpretation, and the use of results, requires a significant enhancement of expertise in this field.
- j) The integration of energy and water management systems is closely linked to the resolution of interstate disputes. The region possesses significant hydropower potential, which necessitates the use of major rivers and existing hydropower plants to meet both energy and agricultural needs.

Achieving the above goals requires a clear and unified commitment from decision-makers in Central Asian countries to pursue the path of sustainable development. Given the acknowledged potential, strategic documents, and previous collaboration with international investors on projects in this domain, it appears that there is a genuine commitment to move forward. However, given the region's numerous specificities and the challenges it faces, the future development, scope, and effectiveness of the sustainable energy transition remain difficult to predict.

5. Conclusions

This paper examined the fundamental prerequisites, opportunities, and challenges associated with the sustainable energy transition in Central Asia, focusing on the evolution of the region's energy sector, the condition of energy infrastructure, resource availability, governance capacity, and the influence of foreign actors. The findings reveal that, despite increasing political commitment to sustainability and renewable energy development, the region remains at an early stage of a systemic energy transition.

The historical legacy of the Soviet energy system continues to shape

the region's development trajectory. While large-scale electrification and industrialization established an extensive energy infrastructure, decades of underinvestment following independence have resulted in aging facilities, inefficiencies, and limited modernization. Although all countries have adopted strategic documents and regulatory frameworks related to sustainable development and energy transition, implementation remains uneven, and tangible progress is still limited. Kazakhstan has advanced furthest in this regard, while the remaining countries continue to face significant institutional and financial constraints.

The analysis demonstrates that the transition cannot be understood solely as a technological challenge. Rather, it is deeply embedded in broader socioeconomic and political realities, including poverty, governance weaknesses, corruption, insufficient institutional capacity, and demographic challenges associated with high emigration rates and shortages of qualified professionals. These factors significantly influence the pace and effectiveness of energy reforms. At the same time, unresolved disputes over the management of shared water resources continue to constrain the expansion of hydropower, despite its considerable potential to support decarbonization and regional energy security.

Nevertheless, the region possesses substantial comparative advantages. Central Asia is endowed with abundant conventional and renewable energy resources, significant hydropower potential, and globally important reserves of critical raw materials and rare earth elements that are increasingly important for the global low-carbon transition. These assets create opportunities for economic diversification, technological modernization, and greater integration into emerging clean energy value chains. However, they also intensify geopolitical competition among major external actors, including China, Russia, the EU, and the USA, each seeking access to strategic resources and influence in the region.

The findings suggest that a successful sustainable energy transition in Central Asia requires country-specific pathways rather than the direct adoption of models developed in advanced economies. Strengthening regulatory and institutional frameworks, improving transparency and governance, investing in human capital, promoting regional cooperation in water and energy management, and establishing balanced partnerships with international investors will be essential for long-term success. Ultimately, the transition should not be viewed solely as an environmental objective but as a broader development strategy aimed at enhancing economic resilience, energy security, and societal well-being. The future sustainability of the region will depend on its ability to balance domestic development priorities, geopolitical pressures, and the opportunities arising from the growing global demand for clean energy and critical minerals.

The novelty of this paper is reflected in its conceptual framing, methodological approach, and empirical insights. First, while the majority of existing studies focus on the current state of the energy sector or short-term developments, this study adopts a long-term perspective by examining a century of energy sector evolution in Central Asian countries. Building on the identification of key structural changes and persistent challenges, it advances context-specific policy recommendations. Second, the study argues that assessing the prospects of a sustainable energy transition requires moving beyond a conventional data-driven approach. It emphasizes the need to capture and integrate broader dynamics shaping the region, particularly those related to natural resource economics, the social environment, and geopolitical factors. Third, the findings demonstrate that foreign direct investment, in itself, does not guarantee progress in the energy transition. Instead, the study suggests that a deeper, more nuanced analysis is necessary to understand the conditions under which such investments contribute to sustainable outcomes. Finally, the research highlights that the success of a sustainable energy transition should not be evaluated solely on the basis of predefined targets, such as reductions in carbon emissions or the share of renewable energy in total energy production. Given the structural and contextual specificities of Central Asian countries, monitoring

progress requires a more comprehensive and multidimensional framework that extends beyond purely quantitative indicators.

Given these factors, this study ultimately proposes a set of prerequisites essential for creating a more conducive environment that enables an effective sustainable energy transition—one that, above all, serves the interests of Central Asian countries and their citizens. Future research should prioritize detailed assessments of how the sustainable energy transition impacts citizens' well-being, as populations are directly affected by the consequences of both favorable and inadequate policy decisions. Therefore, future research efforts should be intensified to enable in-depth analysis of specific challenges and the development of targeted, actionable recommendations.

Declaration of competing interest

Authors declare no conflict of interest.

Data availability

Data will be made available on request.

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