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Energy Potential of Central Asian States: Prospects for Nuclear Power Development

Khalova Gyulnar Osmanovna[1], Arslanov Magomed Arslanovich[2], Bagyev Isa Rakhmanovich[3]

[1]Center for Central Asian Studies, Institute of China and Contemporary Asia of the Russian Academy of Sciences, Russia, [2]Graduate Student at the Center for Central Asian Studies, Institute of China and Contemporary Asia of the Russian Academy of Sciences, Russia, [3]Graduate student at the Center for Central Asian Studies, Institute of China and Contemporary Asia of the Russian Academy of Sciences, Russia. *Email: khalova@iccaras.ru

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ABSTRACT

This study offers a comprehensive analysis of the pressing challenges and strategic prospects for developing the energy potential of the Central Asian region. The research begins with the acknowledgment of the region's growing geopolitical and energy significance, which is nonetheless offset by substantial internal asymmetries. The investigation identifies a number of fundamental structural imbalances, including the stark disparity in the distribution of hydrocarbon reserves and hydropower resources, the extensive physical and moral obsolescence of generation and transmission infrastructure, systemic seasonal energy deficits, and persistent conflicts of interest over the use of transboundary waterways. A significant portion of the analysis focuses on assessing the potential of nuclear energy as a strategic instrument for overcoming electricity generation shortfalls, reducing environmental burdens, and stimulating long-term economic growth in Central Asian countries. Based on a detailed review of the national energy sectors across the region, the article outlines pathways for multilateral cooperation. The central conclusion of the analysis is that only a coordinated and strategically sound energy policy can serve as the primary driver for ensuring sustainable socioeconomic development and strengthening the sovereignty of Central Asian states amid deepening global instability.

Keywords: Energy Security, Central Asia, Regional Integration, Energy Sector, Geopolitics, Energy Industry
JEL Classifications: Q3, Q4

1. INTRODUCTION

The Central Asian region, situated in the interior of the Eurasian continent and covering an area of approximately 4 million square kilometers, constitutes a geopolitical entity comprising five sovereign republics: Kazakhstan, Kyrgyzstan, Tajikistan, Turkmenistan, and Uzbekistan. Owing to its pivotal geostrategic location at the heart of the continent, the region has historically served as a critically important node along transcontinental trade routes and as a cultural bridge linking Eastern and Western civilizations. In the contemporary era, its geopolitical relevance has been significantly reinforced by the ongoing transformation of global energy markets and the structural reshaping of the international order.

Within the global geopolitical framework, Central Asia's influence is steadily increasing, driven primarily by the region's substantial natural resource endowments. Kazakhstan, the Kyrgyz Republic, the Republic of Tajikistan, Turkmenistan, and the Republic of Uzbekistan have become focal points attracting the strategic interests of major global powers and multinational corporations. Amid escalating turbulence in world politics, countries of the region face external pressures aimed at revising their traditional foreign policy alignments and trade-economic orientations. The People's Republic of China views Central Asia as a crucial corridor for diversifying its energy imports and facilitating goods transit along historic overland routes. The Russian Federation remains a strategically vital partner in the energy domain—a role underpinned not only by historically entrenched ties but also by the operation of major pipeline infrastructure and the active involvement of Russian companies in developing the region's resource base and modernizing its energy sector. This constellation of factors establishes a robust foundation for prospective and mutually beneficial cooperation.

Nevertheless, despite their considerable resource potential, Central Asian countries confront a range of structural constraints. The most significant among these are the critical level of wear and tear affecting energy infrastructure and the persistent reliance of their economies on raw material exports. Addressing these challenges necessitates comprehensive analysis and the formulation of coordinated measures designed to fully leverage the region's comparative advantages and enhance its economic, political, and energy security.

The economic systems of Central Asian states exhibit marked structural heterogeneity, yet they share a common dependence on raw material exports. In Kazakhstan and Turkmenistan, export revenues are generated predominantly through the exploitation of vast oil and natural gas reserves. Uzbekistan's economic model demonstrates a relatively higher degree of diversification, although it remains fundamentally anchored in stable income from natural gas production and agricultural output, with cotton cultivation retaining particular importance. Kyrgyzstan and Tajikistan, possessing more modest natural resource endowments, sustain their economies through remittances from labor migration, agricultural development, and the utilization of hydropower resources—thereby securing a distinct niche within regional economic cooperation.

According to statistical data for 2024, the region's total population stands at nearly 81 million people. The distribution across individual states is as follows: Kazakhstan—20.1 million, Kyrgyzstan—7.1 million, Tajikistan—10.2 million, Turkmenistan—6.6 million, and Uzbekistan—36.9 million (International Monetary Fund, 2025). Consequently, since the dissolution of the USSR in 1991, the demographic potential of Central Asia has grown by a factor of 1.6 (Table 1).

This demographic trend creates what is commonly referred to as a "demographic dividend" for Central Asia—a phenomenon that opens avenues for intensive economic development over the long term. This effect stems from the fact that the working-age population significantly outnumbers the non-working segments (children and elderly individuals). The realization of this demographic potential—and its conversion into sustained economic growth—depends directly on the implementation by regional governments of balanced socio-demographic and economic policies aimed at the productive employment of the expanding young labor force.

Regarding current economic indicators, the combined gross domestic product (GDP) of the five Central Asian states, measured at purchasing power parity (PPP), is estimated to reach USD 1,564.6 billion in 2024. Within the regional economic structure, Kazakhstan holds a dominant share of 53.7%, amounting to USD 840.9 billion in absolute terms—an objective confirmation of its status as the region's economic leader. Uzbekistan ranks second, with a PPP-adjusted GDP of USD 432.2 billion. The economies of Kyrgyzstan (USD 57.9 billion), Tajikistan (USD 57.2 billion), and Turkmenistan (USD 177.3 billion) are considerably smaller in scale, reflecting their more limited production capacities and resource bases (Table 2) (International Monetary Fund, 2025).

The significant disparity in demographic potentials and the highly uneven distribution of natural resources in Central Asia are directly reflected in macroeconomic indicators. A key consequence of this structural asymmetry is profound economic stratification, which sharply distinguishes energy-exporting states from those facing a deficit in raw material endowments—a division clearly evidenced by per capita GDP statistics (Table 3).

Kazakhstan's and Turkmenistan's economic development is fundamentally based on a strategy aimed at maximizing revenues from the exploitation of natural resources, a strategy implemented through transport infrastructure inherited from the Soviet era that facilitates raw material exports (Khalova and Illeritsky, 2024).

Thus, the Central Asian macroregion is characterized by three key features: profound resource asymmetry, a substantial yet spatially uneven demographic potential, and a high degree of vulnerability to fluctuations in the external economic and geopolitical environment. The countries of the region exhibit clear economic stratification, driven by divergent growth models. Kazakhstan and Turkmenistan anchor their economic development on hydrocarbon rents as the primary source of income. In contrast, Kyrgyzstan and Tajikistan build economic resilience primarily through labor migration and the development of their hydropower potential. Uzbekistan occupies an intermediate position, systematically pursuing economic diversification by expanding processing industries and high-tech sectors.

Table 1: Population dynamics of Central Asian States, 1992-2024 (in million people)

Year	Kazakhstan	Kyrgyz republic	Tajikistan	Turkmenistan	Uzbekistan
1992	17,05	4,41	5,54	4,11	21,36
1995	15,68	4,53	5,67	4,36	22,69
2000	14,88	4,88	6,22	4,68	24,49
2005	15,15	5,14	6,85	4,94	26,02
2010	16,32	5,42	7,64	5,27	28,00
2015	17,54	5,90	8,55	5,77	31,02
2020	18,76	6,52	9,48	6,25	33,91
2024	20,13	7,08	10,19	6,60	36,93

Source: Compiled by the authors based on (International Monetary Fund, 2025)

2. ANALYSIS

The energy framework of Central Asia is shaped by substantial—but extremely unevenly distributed—natural resource endowments (Table 4). The region's distinguishing characteristics include.

First, the presence of large, yet geographically concentrated, oil and natural gas fields.

Second, considerable—though seasonally variable—hydropower potential in mountainous areas, as well as promising wind energy resources in desert zones.

Third, a strategic location at the crossroads of overland transport corridors linking China, South Asia, and Europe.

These factors give rise to a systemic challenge: hydrocarbon-exporting countries such as Kazakhstan and Turkmenistan face acute water scarcity, while Kyrgyzstan and Tajikistan—despite their abundant hydropower resources—experience chronic electricity shortages during the winter months.

As of 2025, proven oil reserves in the region exceed 4 billion tonnes (equivalent to more than 30 billion barrels), with nearly 95% of these reserves concentrated in the Republic of Kazakhstan. The country hosts several giant fields: Tengiz, with estimated recoverable reserves of approximately 1.5 billion tonnes of oil (Tengizchevroil, 2025), Kashagan, holding around 0.8 billion tonnes (Tyurin, 2015) and Karachaganak, with reserves estimated at 0.25 billion tonnes of oil (Caspian Barrel, 2024).

Natural gas constitutes a cornerstone of Central Asia's energy structure. The region's total proven gas reserves surpass 16.7 trillion cubic meters, of which Turkmenistan accounts for 81.4%. This positions Turkmenistan as one of the world's leading gas-rich nations, ranking fourth globally in terms of gas reserves. The primary outlet for Turkmen gas exports is the "Central Asia-China" pipeline, through which annual deliveries exceed 30 billion cubic meters (Grozin, 2018). Such vast resources create favorable conditions for establishing stable baseload power generation capacities. Moreover, Turkmenistan's potential integration into a prospective Unified Central Asian Power System could significantly enhance the overall balance, reliability, and resilience of regional energy supply.

In addition to its substantial oil reserves, Kazakhstan also possesses significant natural gas deposits, primarily located in the western regions of the country. Its gas transportation infrastructure is actively utilized to export gas to both Russia and China. For both Kazakhstan and Turkmenistan, priority strategic objectives for

Table 2: Dynamics of GDP (PPP) of Central Asian States, 1992-2024 (in billion USD)

Year	Kazakhstan	Kyrgyz republic	Tajikistan	Turkmenistan	Uzbekistan
1992	116,41	10,98	7,07	16,54	46,61
1995	90,55	7,74	4,61	12,20	45,67
2000	111,23	11,04	5,77	16,17	59,94
2005	204,29	14,91	10,11	38,36	87,23
2010	303,60	20,20	15,30	73,41	142,40
2015	415,07	27,82	23,30	100,10	218,91
2020	565,76	34,83	35,62	119,91	283,86
2024	840,09	57,87	57,21	177,29	432,19

Source: Compiled by the authors based on (International Monetary Fund, 2025).

Table 3: Dynamics of GDP per Capita (PPP) in Central Asian States, 1992-2024 (in USD)

Year	Kazakhstan	Kyrgyz republic	Tajikistan	Turkmenistan	Uzbekistan
1992	6828	2490	1277	4023	2182
1995	5777	1709	814	2799	2013
2000	7473	2265	928	3451	2448
2005	13487	2903	1475	7764	3352
2010	18601	3727	2002	13935	5085
2015	23661	4719	2726	17359	7056
2020	30165	5345	3760	19185	8372
2024	41735	8176	5615	26870	11704

Source: Compiled by the authors based on (International Monetary Fund, 2025)

Table 4: Proven reserves of oil, natural gas, and coal in central Asian countries as of End-2023, and their share of global reserves (%)

Country	Oil, billion tonnes	Percentage of global reserves	Gas, trillion m^3	Percentage of global reserves	Coal, million tonnes	Percentage of global reserves
Kazakhstan	3.9	1.7	2.3	1.2	25 605	2.4
Kyrgyz republic	*	*	*	*	*	*
Tajikistan	*	*	*	*	*	*
Turkmenistan	0.1	0.03	13.6	7.2	*	*
Uzbekistan	0.1	0.03	0.8	0.4	1375	0.1

* - Minor reserves. Source: Compiled by the authors based on (Energy Institute, 2024)

the transformation of their gas sectors include diversifying export routes—particularly through the development of liquefied natural gas (LNG) production facilities—and strengthening their roles within international energy distribution networks.

Uzbekistan's energy potential, by regional standards, is characterized by relatively modest hydrocarbon reserves. Its proven natural gas reserves are estimated at approximately 800 billion cubic meters. Consequently, the republic's current policy prioritizes securing reliable domestic supply. High levels of internal energy consumption—peaking during the autumn–winter period—pose significant constraints on expanding export volumes. Nevertheless, Uzbekistan remains an influential player in the regional energy market while simultaneously advancing a strategy to modernize its national energy mix through the systematic development of renewable energy sources (Ismatillaeva, 2025).

As for Tajikistan and Kyrgyzstan, the absence of significant industrial oil and gas deposits is offset by their strategic dominance in Central Asia's hydropower sector. In Tajikistan, over 93% of domestically consumed electricity is generated from hydropower resources (International Energy Agency, 2024). The centerpiece of the country's national energy strategy is the under-construction Rogun hydropower plant (HPP), with an installed capacity of approximately 3.6 GW. Once commissioned, the Rogun HPP is expected not only to fully meet domestic electricity demand but also to significantly expand summer-season electricity exports. Nevertheless, both countries continue to face acute challenges related to seasonal energy deficits during the winter months and remain dependent on imported fossil fuels.

A similarly pronounced structural imbalance characterizes Kyrgyzstan's power sector, where the cascade of hydropower stations on the Naryn River—led by the Toktogul HPP—plays a pivotal role. The national power system exhibits a stable seasonal cycle: surplus generation in summer enables electricity exports to Uzbekistan and Kazakhstan, whereas winter months bring a pronounced deficit, necessitating reverse imports of both electricity and fossil fuels. This persistent asymmetry poses a systemic challenge to regional energy security and underscores the urgent need to strengthen mechanisms for interstate coordination.

To date, the installed capacity of renewable energy sources (RES) in Central Asia remains disproportionately low relative to the region's objective potential. The greatest prospects are associated with solar and wind power development. Wind energy is advancing most dynamically in Kazakhstan and Uzbekistan, both of which possess extensive territories with average annual wind speeds reaching 6-7 m/s. In Kazakhstan, this momentum is materializing through large-scale projects such as the 100 MW Zhanatas Wind Farm, financed with foreign investment. Uzbekistan, for its part, has officially embraced a transition toward a "green" economy, setting a short-term target of achieving an 18% share of renewables in its energy mix (Sputnik Uzbekistan, 2024). Solar energy also holds considerable growth potential due to the region's exceptionally high number of sunny days per year—exceeding 300. According to expert assessments, by 2035 solar generation could account for 10-15% of the electricity supply in certain Central Asian countries.

The current architecture of energy consumption in Central Asia exhibits marked structural heterogeneity, manifested in the dominance of different generation sources across countries. The region demonstrates a polarized model: Kazakhstan and Turkmenistan rely primarily on fossil fuels; Tajikistan and Kyrgyzstan on hydropower; while Uzbekistan is actively advancing renewable energy deployment. This diversification of national energy profiles not only shapes individual countries' energy policies but also determines specific formats of regional cooperation. Kazakhstan, Uzbekistan, and Turkmenistan function as net exporters of hydrocarbon resources, whereas Kyrgyzstan and Tajikistan export electricity during the summer months. However, the regional energy balance undergoes a radical reversal in winter, compelling hydropower-dependent countries—including Uzbekistan—to import energy resources. This cyclical pattern not only intensifies seasonal vulnerabilities but also creates conditions conducive to the destabilization of regional energy dialogue.

Within the fuel and energy balances of individual Central Asian countries, coal continues to play a significant—though uneven—role. This trend is most pronounced in Kazakhstan, where coal-fired power plants account for more than 54% of total electricity generation. This reliance stems from the country's vast proven coal reserves—25.6 billion tonnes, representing 2.4% of global resources—as well as from historically established mining and combustion infrastructure. However, the dominance of coal-based generation entails substantial environmental costs: Kazakhstan ranks among the region's top emitters of greenhouse gases, jeopardizing its ability to meet international climate commitments and pursue a credible decarbonization pathway.

It must be emphasized that the technological obsolescence of existing coal-fired capacity—much of which was commissioned during the Soviet era—results in low energy efficiency and high specific CO_2 emissions per unit of electricity generated. Consequently, maintaining the current coal-based generation model not only exacerbates environmental burdens but also undermines the competitiveness of the national power system amid the accelerating global energy transition.

At the same time, in the context of regional energy security, coal continues to serve as a strategic reserve, providing baseload generation when the intermittency of renewable sources and the seasonality of hydropower limit system flexibility. Yet, in the long term, this role can—and should—be progressively redefined through the phased replacement of coal infrastructure with zero-emission technologies, primarily nuclear power and gasification coupled with carbon capture and storage (CCS). Thus, coal in Central Asia's energy sector should not be viewed as a cornerstone of sustainable development, but rather as a transitional energy resource requiring a deliberate, managed phase-out within a balanced strategy of energy modernization and environmental responsibility.

In summary, the realization of Central Asia's energy potential hinges on a set of interrelated factors. Key among them are, first, the establishment of effective transboundary water resource management; second, the development and modernization of cross-border energy infrastructure; third, the active integration of renewable energy technologies into national and regional power systems; and finally, the diversification of export routes to reduce dependence on individual external partners.

The development of nuclear energy in several Central Asian states is fundamentally driven by the presence of a substantial raw material base. Historically, Kazakhstan and Kyrgyzstan formed the core of the Soviet Union's uranium supply chain for its nuclear industry. In the current era, Kazakhstan maintains global leadership in the uranium sector: it holds the world's second-largest proven reserves and ranks first in annual production (Figure 1), accounting for approximately 45% of global output (World Mining Data, 2024).

In 2023, Kazakhstan produced 21,819 tonnes of uranium, accompanied by positive growth in its conversion capacities for manufacturing nuclear fuel (Neftegaz.ru, 2024). At the Ulba Metallurgical Plant, production of fuel pellets enriched to 4.5% in the isotope U-235 has been successfully established. The energy content of each pellet is equivalent to burning approximately 700 kg of hard coal. In the absence of domestic nuclear power plants, up to 90% of the mined uranium is exported, with key destinations being China, Russia, and European Union member states.

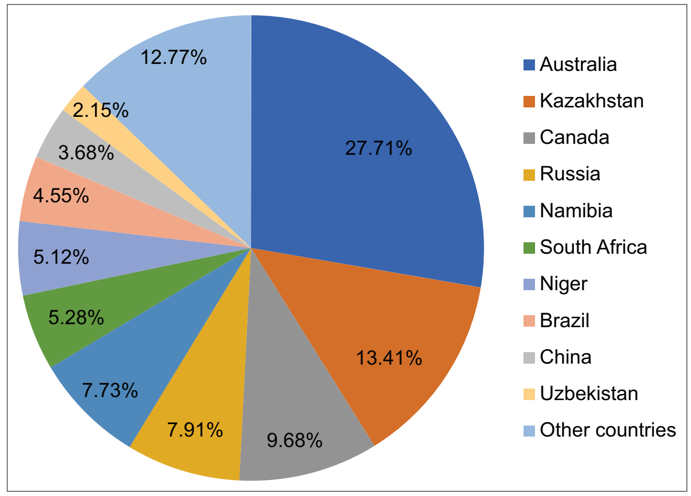
The global uranium market is experiencing sustained demand growth, most notably in the People's Republic of China, where consumption has risen by 18% since 2020, and in India, which has recorded a 12% increase. These trends are directly linked to ambitious national programs in both countries aimed at expanding nuclear power generation. Simultaneously, Eastern European nations plan to commission up to ten new reactor units by 2030. Collectively, these developments—coupled with the gradual depletion of major uranium deposits in Canada and Namibia—are expected, according to industry experts, to create a structural supply deficit in the global uranium market by 2035.

In 2023, the Republic of Kazakhstan exported 20,000 tonnes of uranium out of a total production volume of 22,000 tonnes. Export flows were heavily oriented toward the Chinese market (45%) and the European Union (30%). Kazakhstan's main competitors in the global uranium market are Canada and Namibia, which primarily supply the United States, the EU, and China (Table 5).

Regarding the downstream segment, Kazakhstan's processing capacity—represented by the Ulba Metallurgical Plant with an annual throughput of 190 tonnes of nuclear fuel in pellet form—remains substantially limited compared to Russian facilities, particularly the Novosibirsk Chemical Concentrates Plant, which has an annual capacity of 600 tonnes.

Uzbekistan, despite its minimal presence in the global uranium market, possesses a considerable domestic resource base, estimated at 131,200 tonnes of uranium (World Nuclear Association, 2024) (Figure 1). This resource potential creates favorable conditions for launching national nuclear energy development programs. Utilizing indigenous uranium would enable both Uzbekistan and Kazakhstan to significantly reduce the fuel component in the cost structure of electricity generation, thereby enhancing the economic viability of nuclear power. Constructing nuclear power plants (NPPs) based on domestically sourced uranium could lower electricity tariffs by 30-40%, a factor of particular strategic importance amid intensifying competition among various generation technologies—including renewables and gas-fired power plants.

Figure 1: Share of global uranium reserves by country, %



Source: Compiled by the authors based on (World Nuclear Association, 2024)

Table 5: Comparison of uranium production and exports by country in 2023

Country	Production	Export	Main sales markets
Kazakhstan	21,819	19,500	China (45%), EU countries (30%)
Canada	4,693	3,800	USA, EU countries
Namibia	5,753	5,200	China, France
Russia	2,635	2,400	China, India

Source: Compiled by the authors based on (World Mining Data, 2024)

The existence of a domestic uranium resource base in Kazakhstan and Uzbekistan alone cannot be considered a sufficient or rational justification for the development of nuclear energy. Currently, neither country possesses a complete technological cycle required for the autonomous design, construction, and operation of nuclear power facilities. This creates an objective necessity to engage foreign technological partners. In this context, Russia's state nuclear corporation Rosatom plays a pivotal role, notably through its participation in the project to construct Kazakhstan's first nuclear power plant in Ulken.

The functional evolution of the energy systems in Kazakhstan and Uzbekistan is accompanied by deep structural imbalances and strategic challenges arising from the interplay of economic, technological, and environmental factors. Most acutely, both countries face a trend of rapidly growing electricity demand—

driven by economic expansion and intensified urbanization—which imposes increasingly stringent requirements on the reliability and scale of their generation capacity. In Kazakhstan, annual electricity demand is rising by an estimated 3–4%, objectively necessitating the commissioning of substantial new generating capacity. Uzbekistan, meanwhile, regularly experiences seasonal electricity shortages, particularly during the winter months.

Despite the considerable potential of renewable energy sources (RES)—notably solar and wind power—their contribution to the national energy mix remains limited in both countries. This constraint stems from the high cost of energy storage systems and insufficiently developed grid infrastructure. Moreover, the inherent weather dependency of these generation sources causes significant output fluctuations, introducing additional risks to the uninterrupted power supply required by industrial consumers who demand high levels of delivery stability.

Environmental concerns represent another critical dimension. The dominance of fossil fuels in the generation mix results in substantial greenhouse gas emissions and adverse ecological impacts. In Kazakhstan, over 70% of electricity is produced by coal-fired power plants, making the country one of the region's largest CO_2 emitters. Uzbekistan, while relying heavily on natural gas—which is cleaner than coal—faces its own constraints due to the finite nature of its proven gas reserves.

3. DISCUSSION

Under these conditions, modern nuclear power emerges as a system-forming element capable of ensuring the sustainable development of Central Asia's energy sector. The primary argument in its favor is the high reliability of supply: nuclear power plants operate in base-load mode with a capacity factor[1], exceeding 90%—a performance level fundamentally superior to that of renewable energy sources and one that provides a dependable foundation for industrial growth.

Equally significant is the environmental advantage of nuclear generation: it produces virtually no CO_2 emissions during operation. Commissioning a single 1 GW nuclear unit can prevent the annual release of 5–6 million tonnes of carbon dioxide compared to an equivalent coal-fired plant, thereby establishing a rational core for national decarbonization strategies.

However, implementing nuclear projects in the region entails addressing several objective constraints. The construction of a single reactor unit requires capital investments ranging from USD 6 to 9 billion. A major additional barrier is water scarcity: given that up to 80% of the region's water consumption is allocated to agriculture, securing sufficient water for cooling large-scale power plants becomes a technologically and economically complex challenge.

1 The ratio of the actual amount of electricity generated by a power plant over a specific period (typically one year) to the maximum possible output that could have been achieved if the plant operated continuously at its installed (rated) capacity throughout that entire period.

Furthermore, Central Asia is characterized by high seismic activity, necessitating the deployment of reactor technologies with enhanced safety features. In this context, the VVER-1200 reactor design, developed by Russia's State Atomic Energy Corporation Rosatom, appears particularly promising. These units incorporate passive safety systems capable of preventing accident escalation—even in the event of a complete loss of external power and failure of active control systems (AtomMedia, 2024).

Given these challenges, the most viable pathway for nuclear development in the region appears to lie in Small Modular Reactors (SMRs). Their principal advantage is significantly lower capital intensity—approximately USD 1–2 billion per project—making the technology accessible to countries with constrained investment capacity. Equally important is the logistical flexibility of SMRs: the ability to transport core modules by rail opens prospects for electrifying remote and isolated areas with underdeveloped infrastructure.

According to analytical estimates by the International Atomic Energy Agency (Kindra et al., 2024), the specific capital costs for constructing Small Modular Reactors (SMRs) range from USD 3,000 to 6,000 per kilowatt of installed capacity—20-30% lower than those for large-scale nuclear power plants, which typically cost USD 5,000–8,000/kW. The economic viability of SMRs is further corroborated by ongoing international projects: the U.S.-based NuScale plant, with a total capacity of 720 MW, demonstrates specific capital expenditures of approximately USD 5,000/kW; Russia's RITM-200 reactor falls within the USD 4,000-5,000/kW range; and China's high-temperature gas-cooled reactor HTR-PM is estimated at around USD 6,000/kW.

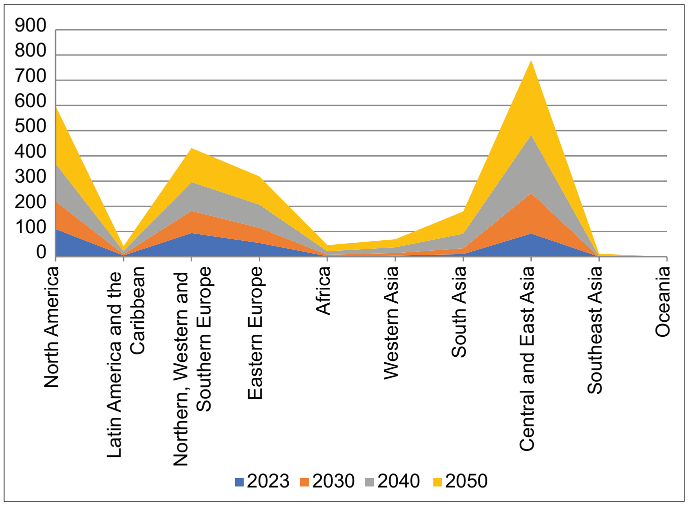
The projected levelized cost of electricity (LCOE) from SMRs is estimated at USD 60-80 per megawatt-hour, making it competitive with gas-fired generation (USD 50-70/MWh) and significantly more cost-effective than coal-based power (USD 70-100/MWh). Although electricity from renewable energy sources remains cheaper (USD 30-50/MWh), the key technological advantage of SMRs lies in their dispatchability—that is, their ability to provide stable, predictable, and controllable power output.

This attribute fundamentally distinguishes SMRs from weather-dependent and intermittent renewables and positions them not as competitors, but as complementary components of a modern power system. As the share of variable renewable generation increases, SMRs can serve as a reliable backbone, enabling load balancing, frequency and voltage regulation, and enhanced resilience of the grid against external disturbances. This functional role endows SMRs with strategic importance in shaping a flexible, balanced, and resilient energy architecture for the future[2].

As demonstrated by studies from NuScale Power and IAEA reports (2022), the economic efficiency of Small Modular Reactors (SMRs) stems from standardized factory-based module production and optimized construction timelines. Together, these

2 For example, in the United States, the cost of electricity from NuScale is estimated at USD 65 per MWh, whereas in China, the cost of electricity from the HTR-PM reactor is approximately USD 70 per MWh.

Figure 2: Projected nuclear power capacity for electricity generation by 2050, by World Region (Optimistic Scenario)



Source: Compiled by the authors based on (International Atomic Energy Agency, 2023)

factors reduce specific capital expenditures by 20-30% compared to conventional nuclear power plants.

In this context, IAEA analysts anticipate that countries in Central and East Asia will become the primary drivers of global nuclear power expansion in the medium term (Figure 2).

According to the optimistic scenario, the region could face an almost threefold increase in electricity consumption by 2050, driven both by objectively rising energy demand and by deliberate national efforts to strengthen energy security.

Under these circumstances, nuclear power presents a balanced combination of economic viability, reliable baseload generation, and environmental acceptability. This unique set of advantages is particularly relevant for Central Asian countries, which confront a systemic deficit in baseload generation capacity amid steadily growing electricity demand. Consequently, the establishment of a nuclear energy sector in the region should be regarded not merely as an option, but as a strategic necessity.

The development of nuclear energy offers Central Asia long-term prospects, transforming energy independence into a sustainable foundation for economic growth and assured energy security.

4. CONCLUSION

In conclusion, it is essential to emphasize that Central Asia—possessing some of the world's largest uranium reserves—occupies a strategically significant position within the global nuclear fuel cycle architecture. These resources create not only the conditions for maintaining the region's role as a raw material exporter but also open pathways toward a more advanced and economically advantageous development model based on deep uranium processing and the production of high-value-added nuclear products.

Kazakhstan, in particular, stands out as especially promising in this regard, holding approximately 15% of the world's proven uranium reserves. This resource endowment provides a unique window of opportunity to transform the country from a commodity supplier into a technological player in the global nuclear industry. Targeted investments in domestic uranium enrichment and nuclear fuel fabrication capacities—alongside the deployment of Small Modular Reactor (SMR) infrastructure—will enable Kazakhstan to address critical domestic energy challenges, including reliable electrification of remote and energy-deficient regions, while simultaneously securing a competitive foothold in the high-tech nuclear product market across the Asia-Pacific region.

Given the projected structural uranium deficit on the global market after 2030—driven by the depletion of major deposits in Canada and Namibia—the timely diversification of the economic model from raw material exports toward integration into the upper segments of the nuclear fuel cycle is no longer merely a strategic option. It has become a necessary precondition for ensuring long-term energy security, technological sovereignty, and sustainable economic growth for Kazakhstan and the Central Asian region as a whole.

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