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(Almaty, Kazakhstan)**FROM CAPACITY EXPANSION TO SYSTEM VALUE: COORDINATED
DEVELOPMENT OF RENEWABLE ENERGY, GRID FLEXIBILITY AND ENERGY
STORAGE IN KAZAKHSTAN**

Abstract. By the end of 2024, Kazakhstan had connected 3,038.6 MW of renewable capacity, which produced 7.5551 TWh or 6.4% of national generation. Consumption nevertheless exceeded domestic generation by 2.0801 TWh, and installed generation exceeded available capacity by 6,423.9 MW. These indicators show why the next stage should evaluate projects by power-system contribution as well as nameplate capacity and auction tariff. Using official secondary data, policy documents and a structured system-value framework, this paper examines adequacy, flexibility, transmission, balancing, storage and localization. The 2026 auction schedule represents progress because it differentiates technologies and zones and introduces battery requirements for selected solar lots. Coordinated planning remains necessary because renewable value can fall when output is concentrated in congested locations or hours with insufficient reserves. Four measures are proposed: locational procurement, anticipatory transmission, technology-neutral flexibility markets and phased localization tied to lifecycle capability. The analysis also distinguishes MW from MWh, the older 10% benchmark from the later 15% renewable-share instruction for 2030, and ordinary 20-year auction PPAs from project-specific 25-year arrangements. The framework supports a reliable, investable and locally beneficial transformation.

Keywords: Kazakhstan; renewable energy; system value; grid flexibility; energy storage; auctions; localization

JEL codes: Q42; Q48; L94; O33

1. Introduction

Kazakhstan has strong wind and solar resources, a renewable-energy support law, competitive auctions and long-term decarbonization objectives. At the end of 2024, 157 renewable facilities with 3,038.6 MW of capacity supplied 6.4% of national generation [6]. The 2026 auction schedule offers another 915 MW, comprising 450 MW of wind, 265 MW of solar and 200 MW of hydropower [9]. Capacity expansion remains necessary, although commissioned MW alone no longer provides a sufficient measure of success.

The operational context is demanding. Consumption reached 119.9955 TWh in 2024, compared with domestic production of 117.9154 TWh, and the 2.0801 TWh deficit was covered through net exchanges with Russia and Central Asia [6]. At the beginning of 2025, installed generation was 25,314.2 MW but available capacity was 18,890.3 MW [7]. Maintenance, fuel, technical and resource constraints explain this difference and demonstrate that installed MW, available MW and annual MWh represent different services.

This issue is especially important for variable renewable energy. A wind or solar plant contributes low-carbon electricity, fuel-price protection and investment, but its production depends on weather and time. When many projects produce simultaneously, their marginal market value can decline; when they are far from demand, network cost rises; and when forecast

errors increase, the system requires additional balancing resources [18,19]. The relevant policy question thus concerns the composition, location and operating capability of new capacity, together with the infrastructure and market arrangements that allow it to serve consumers reliably.

The objective of this paper is to develop a system-value approach for the coordinated development of renewable energy, grid flexibility and electricity storage in Kazakhstan. Three research questions are addressed. First, what do the official 2024 data reveal about the relationship among installed capacity, available capacity, energy production and cross-border balancing? Second, how does the 2026 auction schedule begin to incorporate location and storage, and what gaps remain? Third, which policy and investment measures can increase reliability, affordability and domestic industrial benefits during the next phase of deployment?

The paper applies system-value concepts to current official Kazakh data, integrates generation, networks, balancing and industrial policy, and converts the diagnosis into sequenced measures. Because annual secondary data cannot reproduce hourly dispatch, probabilistic adequacy or optimal storage sizing, the framework also identifies information required for subsequent project appraisal.

2. Literature and Policy Review

2.1 From plant cost to power-system value

Levelized cost compares lifetime average technology costs but does not fully represent a plant's contribution to an interconnected system. The market value of variable renewables depends on the temporal and spatial correlation between output and prices, and coincident production can reduce the value factor as penetration grows [18]. System LCOE adds profile, balancing and grid-related costs to plant cost [19]. A low bid tariff therefore supports procurement efficiency, while consumer value also depends on when, where and how power is delivered.

System value has six connected dimensions: **energy value**, measured by useful MWh and displaced fuel; **capacity value**, meaning dependable contribution during scarcity; **flexibility value**, including ramps, reserves and frequency response; **network value**, determined by location, losses and congestion; **environmental and risk value**, including emissions and fuel-price exposure; and **industrial value**, covering domestic services, skills and maintenance. Joint assessment is necessary because performance differs across dimensions.

Flexibility manages supply-demand variability across seconds, hours, days and seasons at reasonable cost [15]. It can come from flexible generation, interconnection, demand response, storage, forecasting, networks and balancing. Batteries respond quickly, but their role depends on power, duration, cycling, location and dispatch rights [16,20]. Wind, solar and hydropower may also be complementary, subject to testing with synchronized resource and demand data [21].

International experience shows that auctions can incorporate connection readiness, location, delivery schedules and grid support if requirements are transparent and competition is preserved [17]. Unvalued obligations raise bids or reduce participation, while socialized grid costs without locational signals can produce sites that are cheap for the plant and costly for the system.

2.2 Kazakhstan's policy trajectory and target scopes

Kazakhstan's renewable-energy framework has evolved through several layers. The Law on Support of the Use of Renewable Energy Sources defines the principal support mechanism, while the Electric Power Industry Law establishes the wider sectoral and market setting [4,5].

The Green Economy Concept created a phased long-term direction and is widely restated as a renewable share in electricity production of 3% in 2020, 6% in 2025 and 10% in 2030, followed by 50% from alternative and renewable sources in 2050 [1]. The 2050 indicator has a broader technology scope than the renewable-only milestones and should be interpreted accordingly.

In May 2021, the President instructed the government to raise the share of renewable energy in electricity generation to 15% by 2030, explicitly identifying this as an increase from the earlier 10% goal [2]. The two figures should not be added, averaged or treated as simultaneous definitions of the same target. The 10% figure is the older benchmark embedded in the Green Economy policy trajectory; the 15% figure is the later presidential policy instruction for the same year and a more ambitious renewable-generation share. Separate from both, Kazakhstan's 2060 Carbon Neutrality Strategy establishes economy-wide decarbonization and states that long-term renewable development will be accompanied by electricity-storage systems [3]. Likewise, the strategy's 15% unconditional greenhouse-gas reduction by 2030 is measured against 1990 emissions and is a different indicator from a 15% renewable share in electricity generation.

Auctions introduced in 2018 improved price discovery and investor access, while long-term offtake and indexation supported bankability. The 2023 single-buyer and balancing reforms increased the importance of schedules and imbalance settlement [7]. Research emphasizes regulatory stability, spatial constraints, legacy thermal generation, combined heat-and-power operations and transmission limits [22-25]. Scenario work confirms that grids, flexibility and technology coordination affect the cost of deeper integration [26].

Policy has begun to move toward integrated projects: designated 2026 solar lots require batteries, while grid projects integrate the west and reinforce the south [8]. The interfaces among auctions, transmission, balancing and localization nevertheless require further definition because a plant auction alone cannot determine the least-cost system portfolio.

3. Data and Method

3.1 Data sources and unit discipline

The study uses secondary sources available as of August 2026. The principal quantitative source is KEGOC's 2024 Annual Report, including the national electricity balance, generation structure and investment program [6-8]. Auction information is taken from the official 2026 announcement, the published auction calendar and official KOREM conditions [9-11]. Policy interpretation relies on laws, presidential documents and the Carbon Neutrality Strategy [1-5]. International comparison and conceptual definitions are drawn from the IEA, IRENA and peer-reviewed literature [14-21].

MW measures instantaneous power, whereas **MWh** measures energy delivered or stored. A 30 MW battery with 120 MWh of usable energy has four hours of nominal full-power duration. A disclosed 600 MWh energy capacity reveals neither the MW rating nor duration. Annual electricity is reported in TWh or GWh, and plant or network capability in MW or MVA.

3.2 Structured system-value assessment

The analytical framework evaluates a renewable project or portfolio (j) through six value channels and five enabling conditions. In conceptual form:

$$SV_j = EV_j + CV_j + FV_j + NV_j + ERV_j + IV_j - IC_j,$$

where (EV) is useful energy value, (CV) is dependable capacity value, (FV) is flexibility value, (NV) is network and locational value, (ERV) is environmental and risk value, (IV) is industrial value, and (IC) represents integration costs already not captured in the other terms. This expression is an accounting framework, not an estimated monetary equation in the present

paper. Monetization would require hourly prices, scarcity probabilities, nodal constraints, reserve procurement, curtailment, outage distributions and technology cost data that are not fully public.

The assessment proceeds in four steps: (1) diagnose the 2024 energy and capacity baseline; (2) map renewable additions against zones, connection arrangements and flexibility requirements; (3) test whether auction and market rules reward the relevant services; and (4) identify a staged set of institutional, infrastructure and industrial measures. The framework avoids double counting by treating a service as value only once and by separating project benefits from costs transferred to the grid or consumers.

System-value assessment framework for renewable investment

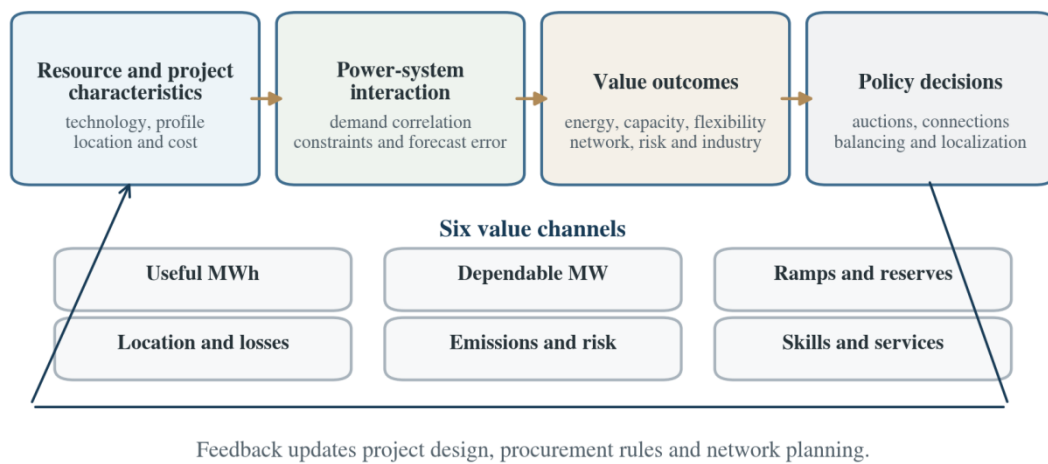


Figure 1. System-value assessment framework for renewable investment

Source note: Author's design based on the system-value literature [15,18,19] and auction-design guidance [17].

4. Kazakhstan's 2024 Power-System Baseline

4.1 Capacity, availability and energy

Table 1 presents the indicators most relevant to system value. Kazakhstan's 25,314.2 MW of installed capacity exceeded available capacity by 6,423.9 MW, meaning that 74.6% of nameplate capacity was categorized as available at the beginning of 2025. This ratio should not be interpreted as a universal plant-performance measure because availability definitions differ by technology. KEGOC's reported methodology credits 30% of run-of-river hydropower capacity, 20% of wind and 0% of solar in the available-capacity balance [7]. The methodology is conservative for adequacy planning and makes clear why nameplate additions cannot be directly substituted for dependable capacity.

Table 1. Selected indicators of Kazakhstan's electricity system, 2024

Indicator	Official value	Derived interpretation
Total installed generation at 1 January 2025	25,314.2 MW	Nameplate capability across 233 plants
Available generation	18,890.3 MW	74.6% of installed capacity; gap of 6,423.9 MW
Renewable installed capacity	3,038.6 MW	12.0% of total installed capacity
Wind / solar / small hydro / bioenergy capacity	1,525.7 / 1,216.6 / 295.2 / 1.1 MW	Technology mix within reported RES fleet
National generation	117.9154 TWh	Increase of 4.5% year on year
National consumption	119.9955 TWh	Increase of 4.3% year on year
Generation-consumption balance	-2.0801 TWh	Domestic annual energy deficit
Renewable generation	7.5551 TWh	6.4% of national generation; increase of 12.5%
Wind / solar / small hydro / bioenergy generation	4.4976 / 1.8956 / 1.1613 / 0.0006 TWh	Implied annual capacity factors of about 33.7%, 17.8%, 44.9% and 6.2%
Net exchange with Russia	+3.4111 TWh	Imports exceeded exports
Net exchange with Central Asia	-1.3310 TWh	Exports exceeded imports

Source note: KEGOC 2024 Annual Report [6,7]. Percentages, capacity gaps, net exchanges and implied capacity factors are the author's calculations; a positive exchange indicates net imports into Kazakhstan.

Wind supplied 59.5% of reported renewable generation, solar 25.1% and small hydro 15.4%. The derived annual capacity factors shown in Table 1 indicate resource performance, but peak contribution requires several years of coincident hourly output, demand and outage data.

4.2 Geography, interconnection and balancing

Location is central because northern and central generation, southern load and solar potential, and the historically separate western zone create different network conditions. An annual national balance can coexist with regional scarcity, congestion or difficult ramps.

Cross-border exchanges provided a material balancing and energy function in 2024. Imports from Russia were 4.9260 TWh and exports to Russia were 1.5149 TWh, producing net imports of 3.4111 TWh. Kazakhstan simultaneously recorded net exports of 1.3310 TWh to Central Asia. The combined net position equals the 2.0801 TWh domestic generation deficit [6]. Interconnection creates economic and operational value, but long-term adequacy should not depend on unpriced or uncertain external flexibility. The IEA has previously observed that

Kazakhstan has limited flexible generation and uses parallel operation with Russia to manage imbalances and frequency, a challenge that increases as variable output grows [14].

KEGOC's investment program directly addresses several spatial constraints. The Western Kazakhstan integration project includes the 500 kV Karabatan-Ulke line of about 604.3 km and is intended to connect the western zone to the national system, thereby allowing the flexible capacity of the west to support the wider system. Southern-network reinforcement includes new lines and substation upgrades, while planned reconstruction covers thousands of kilometers of 220 kV and 500 kV assets [8]. These investments should be evaluated with renewable-auction decisions because a renewable plant's commissioning date and its connection asset form one delivery chain.

Kazakhstan power-system baseline, 2024

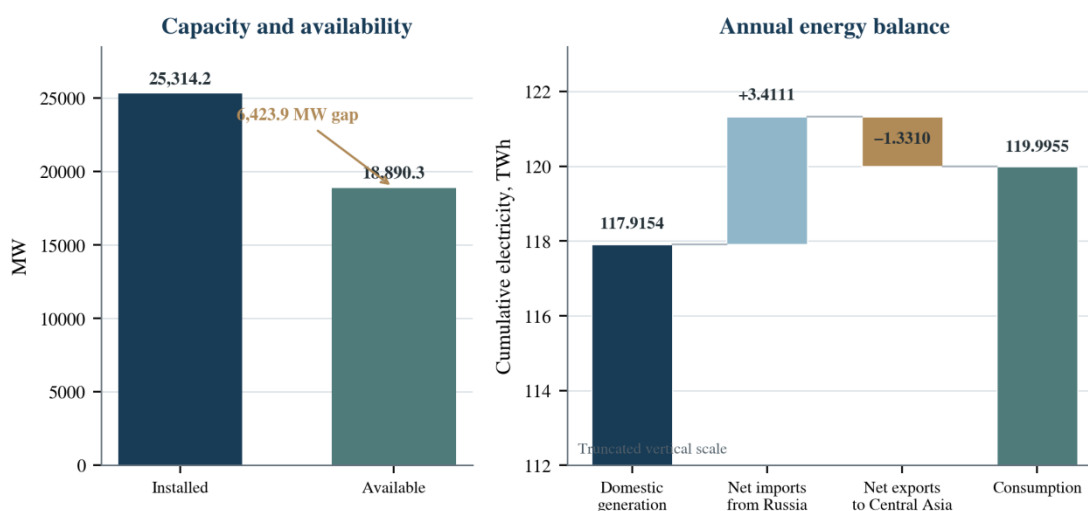


Figure 2. Kazakhstan power-system capacity and annual energy baseline, 2024
Source note: Author's visualization specification using official KEGOC data [6,7].

5. The 2026 Auction Schedule and the Emerging Role of Storage

5.1 What the schedule contributes

The Ministry of Energy approved a 915 MW renewable-auction program for 2026. The program is differentiated by technology and zone and combines open auctions, in which bidders may bring their own land and connection point, with auctions linked to specified zones or connection arrangements [9,10]. This differentiation is meaningful. It can reduce speculative project selection, align capacity with regional needs and reveal the value of prepared grid access.

Table 2. Kazakhstan's 2026 renewable-energy auction schedule

Date in 2026	Technology	Zone or region	Offered capacity	Published commissioning period	Storage condition	Ordinary PPA term
27 April	Wind	Western zone, Atyrau	250 MW	36 months	No explicit battery condition reported	20 years
28 April	Solar	Southern zone, Turkestan	50 MW	24 months	Battery requirement applies under solar open-auction conditions	20 years

29 April	Solar	Almaty region	100 MW	24 months	Battery power at least 30% of plant MW and energy for at least 4 hours	20 years
30 April	Solar	Almaty region	50 MW	24 months	Same minimum battery condition	20 years
18 May	Solar	Kyzylorda region	65 MW	24 months	Same minimum battery condition	20 years
19 May	Wind	Northern zone	100 MW	36 months	No explicit battery condition reported	20 years
20 May	Wind	Northern zone	100 MW	36 months	No explicit battery condition reported	20 years
21 May	Hydropower	All zones	150 MW	60 months	No explicit battery condition reported	20 years
22 May	Hydropower	All zones	50 MW	60 months	No explicit battery condition reported	20 years
Total			915 MW			

Source note: Official aggregate program and support terms [9]; detailed calendar and regions [10]; official KOREM solar-auction storage condition [11]. “No explicit battery condition reported” means that the cited schedule did not state one and does not prove that no other technical obligations apply.

5.2 Interpreting the battery requirement

The storage condition in selected solar auctions illustrates why MW and MWh must remain distinct. The requirement states that battery power should be at least 30% of the solar plant’s installed MW and that stored energy should sustain this power for at least four hours [11]. For a 100 MW solar plant, the minimum implied battery specification is 30 MW and 120 MWh. For 50 MW of solar, it is 15 MW and 60 MWh; for 65 MW, it is 19.5 MW and 78 MWh. These are minimum arithmetic implications. Usable energy, degradation reserve, temperature derating, auxiliary consumption and grid-code performance may require a larger nominal design.

Such a battery can shift midday output, reduce ramps, improve schedules and provide fast response. The highest-value service still depends on location. Contracts should define dispatch control, state-of-charge management, grid charging, loss settlement, degradation compensation and whether balancing revenue can be combined with the PPA.

Large project-specific arrangements require equally careful unit and contract interpretation. TotalEnergies’ Mirny project combines a 1 GW wind plant with 600 MWh of battery energy and a 25-year power-purchase agreement [12]. The disclosed 600 MWh is an energy quantity; absent a disclosed MW rating, battery duration cannot be inferred. The 25-year term is linked to a specific large-scale project arrangement and should not be presented as the ordinary auction rule. The standard 2026 framework provides 20-year PPAs [9]. Maintaining this distinction is important for investor expectations, procurement comparability and public communication.

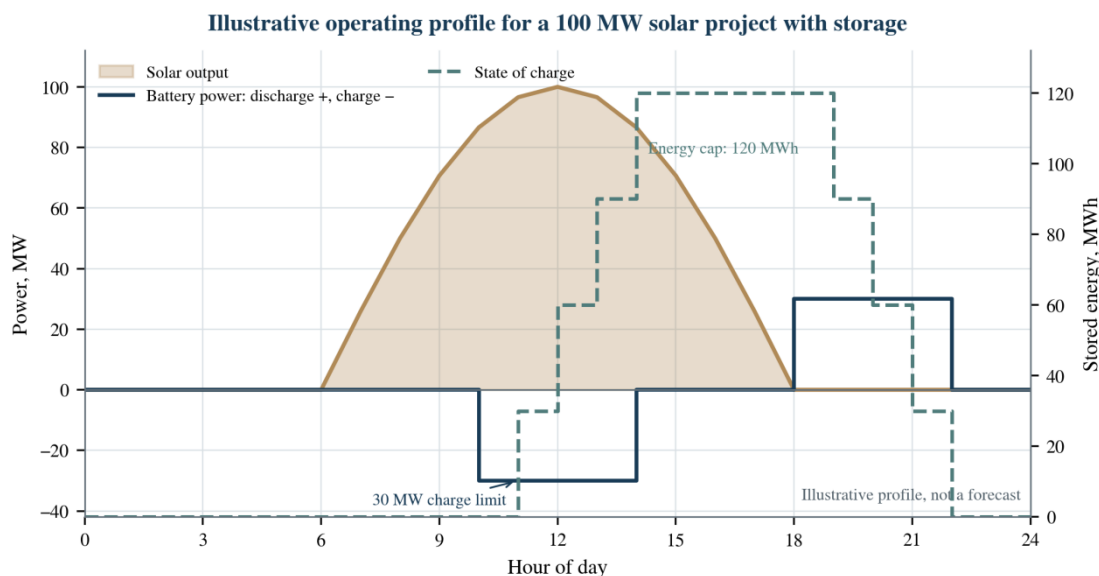


Figure 3. Illustrative operating profile for a 100 MW solar project with storage

Source note: Author's conceptual specification based on the minimum solar-auction storage ratio reported by KOREM [11] and battery-system principles summarized by the IEA [16].

6. A Coordinated Development Strategy

6.1 Procure renewable energy according to value and location

Competitive auctions should add transparent system-value signals. A multi-year procurement map should identify technology, zone, connection point, delivery window and system need, allowing lots to be classified as energy, peak-support, congestion-relief or flexibility products. Price competition would continue within each defined product.

Later, a published value-adjusted tariff could reflect losses, system-funded connection cost, delivery profile and committed services. In the near term, separate locational products are simpler and auditable. Prepared-site auctions can serve strategic corridors, while open auctions can discover developer-led sites [9]. Both require aligned milestones for land, permits, network studies, financing and equipment delivery.

6.2 Treat transmission as an anticipatory transition asset

Transmission should be planned before congestion delays investment. Generation and network projects need integrated schedules and named responsibility for critical interfaces. Priorities are to complete western integration, synchronize southern reinforcement with solar and demand growth, and reconstruct aging 220 kV and 500 kV corridors with justified digital protection and monitoring [8].

Risk allocation should distinguish dedicated connection assets, normally paid by the project, from shared reinforcement recovered through the regulated network. Locational auction signals can maintain discipline. Curtailment rules should separately address grid unavailability, project non-compliance and emergency system action.

6.3 Build a portfolio of flexibility and balancing services

Flexibility procurement should define services, such as frequency response, reserves, ramps and multi-hour energy, and permit competition among batteries, hydropower, flexible thermal units, demand response and interconnection. Renewable producers and aggregators also need timely data, intraday schedule updates and bankable imbalance settlement. Aggregation can reduce individual forecast error.

Storage should be procured by use case: short duration for fast response, four hours for solar shifting, and longer duration for extended adequacy. Every project should disclose rated MW, usable MWh, duration, efficiency, availability, degradation, connection and control rights, together with safety, climate performance, cybersecurity and end-of-life plans. KEGOC's earlier storage feasibility work can be updated with current costs and balancing data [13].

6.4 Link localization to capability, quality and scale

Localization can create employment and maintenance capability, but poorly sequenced mandates can raise tariffs or create shallow assembly. Initial emphasis should be on civil works, structures, cabling, substations, logistics and operations. Subsequent phases can deepen engineering, digital monitoring, equipment repair, battery diagnostics and testing, followed by component production only where demand, quality assurance, export potential and recycling justify scale [2].

Auction documents should request a localization and skills plan rather than rely solely on a percentage. Verifiable commitments may cover domestic expenditure, training, supplier development, local engineering, warranties and lifecycle service centers, announced early enough for credible partnerships with Kazakh firms and universities.

Table 3. Proposed policy matrix for coordinated system-value development

Area	Near-term action, 2026-2028	Medium-term action, 2029-2035	Principal indicator
Renewable procurement	Publish zonal products, connection data and delivery windows; retain price competition	Introduce value-adjusted evaluation informed by hourly and nodal analysis	Useful delivered MWh, curtailment, connection readiness
Transmission	Integrate auction and KEGOC schedules; complete priority western and southern projects	Develop anticipatory corridors and digital network capability	Transfer capacity, congestion hours, project delay
Balancing and flexibility	Define products for reserves, ramps and fast response; improve data access	Enable aggregation, demand response and multi-service storage participation	Reserve sufficiency, imbalance volume and cost
Storage	Specify MW, usable MWh, duration and dispatch rights for every project	Procure multiple durations by system need and location	Availability, cycles, response, avoided curtailment
Localization	Focus on construction, engineering, O&M, training and verifiable suppliers	Deepen repair, testing, components and recycling where scale is proven	Domestic value added, certified personnel, lifecycle capability
Governance and data	Publish auction, grid and balancing performance dashboards	Conduct periodic integrated resource and network planning	Timeliness, data completeness, forecast accuracy

Source note: Author's recommendations based on the diagnostic results in Sections 4 and 5, Kazakhstan's policy objectives [2,3,8,9] and international guidance [15-17].

7. Discussion

The proposed transition from capacity expansion to system value has several implications. First, it changes the meaning of a successful auction. A low tariff remains essential

because consumers should receive the benefit of competition, but success also requires on-time grid connection, predictable output, manageable balancing exposure and durable equipment performance. Procurement reports should therefore track delivery, curtailment, forecast error, local capability and network readiness in addition to the winning tariff and awarded MW.

Second, the framework distributes responsibility more clearly. Developers are responsible for compliant assets, credible forecasts, agreed grid services and delivery milestones. KEGOC is responsible for transparent connection studies, system operation, transmission planning and reliable data. The single buyer and balancing settlement institutions are responsible for bankable contracts and accurate settlement. The Ministry of Energy is responsible for aligning targets, auction volumes, capacity adequacy and industrial policy. Regional authorities, universities and suppliers have roles in land, permitting, skills and local economic development. Coordination requires a formal process because no individual participant can optimize the whole system.

Third, investment certainty must be preserved while rules evolve. Kazakhstan's 20-year ordinary auction PPA is a core bankability instrument [9]. Additional performance requirements should be standardized before bidding and supported by contractual definitions. Large strategic projects may use special arrangements, including a 25-year term such as the Mirny agreement [12], when justified by scale, storage, investment structure and negotiated obligations. Such exceptions should be communicated as project-specific and assessed for value, since investors otherwise may assume that the special term is generally available or that ordinary projects face comparable obligations.

Fourth, storage should be valued through the service it provides. A mandatory ratio is a practical early-stage instrument and can accelerate learning. Over time, however, storage quantity should be derived from adequacy, ramping, congestion and reserve needs. A four-hour battery paired with solar provides a specific daily-shifting capability; it does not solve seasonal deficits, prolonged low-wind periods or all transmission constraints. Conversely, a smaller fast-response battery may create significant frequency value even if its stored MWh are limited. Technology-neutral service markets and location-specific procurement can reveal these differences.

Fifth, localization should be connected to long-term operating quality. Wind turbines, inverters, transformers and batteries require decades of inspection, software support, spare parts and skilled maintenance. Domestic capability in these functions can be more economically valuable than nominal assembly that remains dependent on imported engineering and warranties. For Chinese and other international investors, joint development with Kazakh enterprises and educational institutions can combine global supply-chain scale with local execution, environmental knowledge and workforce development. This model is consistent with Kazakhstan's investment objectives and can improve project resilience.

The analysis also highlights a data agenda. Public hourly demand, zonal generation, curtailment, congestion, reserve activation, imbalance prices and outage statistics would allow researchers and investors to estimate marginal system value. Standardized interconnection queues and hosting-capacity maps would reduce duplicated development expenditure. Storage registers should report MW and MWh separately. These improvements would support the spatial and dispatch modeling already developed for Kazakhstan [25,26] and permit policy to move from qualitative screening to quantitative optimization.

8. Conclusion, Policy Implications and Limitations

Kazakhstan has made substantial progress in renewable-energy development. The 2024 fleet of 3,038.6 MW generated 7.5551 TWh and supplied 6.4% of national electricity. The next phase will occur in a system that also recorded a 2.0801 TWh annual domestic energy deficit and a 6,423.9 MW difference between installed and available generating capacity. These conditions strengthen the case for renewable expansion and require that new projects be coordinated with dependable capacity, grid development and operational flexibility.

The 2026 auction program provides a constructive foundation. Its zonal and technology differentiation can improve portfolio composition, while battery requirements for selected solar lots introduce dispatch capability into procurement. The framework should now be deepened through four measures: procure clearly defined locational products; treat transmission as an anticipatory transition asset; establish transparent markets for balancing and flexibility services; and implement phased localization based on verifiable capability and lifecycle quality.

Three distinctions must remain explicit in policy and investment practice. MW measures power and MWh measures energy, so a storage project requires both values for meaningful evaluation. The older 10% renewable benchmark for 2030 and the later 15% policy instruction refer to alternative ambition levels for a renewable share in electricity generation, while other 15% climate indicators may have entirely different denominators. Ordinary 2026 auction projects receive 20-year PPAs, whereas the cited 25-year term belongs to a special large-project arrangement and is not the general auction standard.

This study is limited by its reliance on annual official statistics and publicly available program documents. It does not estimate hourly curtailment, effective load-carrying capability, probabilistic loss of load, nodal prices, optimal battery duration or the consumer cost of proposed measures. Annual data also cannot capture seasonal hydrology or coincident wind and solar events. Future research should combine at least three to five years of hourly weather, demand, outage and network data in a co-optimized generation-transmission-storage model, test alternative auction and balancing designs, and assess distributional effects on households, industry and regions. Subject to these limitations, the system-value framework offers an implementable direction: renewable capacity, grids, flexibility, storage and local capability should advance as one coordinated investment program.

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