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GREEN ENERGY TRANSITION IN CENTRAL ASIA: CAPACITY GROWTH, TECHNOLOGICAL DIVERSIFICATION AND SYSTEM CONSTRAINTS

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Abstract. This study reassesses the green-energy transition in Kazakhstan, the Kyrgyz Republic, Tajikistan, Turkmenistan and Uzbekistan using the latest harmonised capacity data available in 2026 and a structured review of 17 Scopus-indexed studies published in 2020-2026. The empirical design separates scale, speed and technological composition rather than treating installed renewable capacity as a single measure of transition maturity. Three indicators are calculated for 2023-2025: compound annual capacity growth, each country's contribution to regional capacity additions, and a technology-concentration index based on hydropower, solar and wind shares. Regional renewable capacity rose from 17.636 GW in 2023 to 25.482 GW in 2025, an increase of 44.5%. Uzbekistan accounted for 86.4% of the net regional addition and reached 10.027 GW, while solar and wind represented 75.6% of its renewable portfolio. Kazakhstan retained the most technologically balanced portfolio, whereas the Kyrgyz Republic and Tajikistan remained strongly hydro-dependent. The results show that capacity expansion and transition quality are analytically distinct. A durable transition requires grid reinforcement, storage, flexible dispatch, competitive procurement, credible investment rules and regional electricity exchange. The article proposes a system-value framework in which new renewable capacity is evaluated by delivered generation, reliability, curtailment, carbon intensity and integration cost rather than by megawatts alone.

Keywords: Central Asia, renewable energy, energy transition, solar power, wind power, hydropower, grid flexibility, energy security, regional electricity trade.

Аннотация. В исследовании переоценивается траектория зелёного энергетического перехода в Казахстане, Кыргызской Республике, Таджикистане, Туркменистане и Узбекистане на основе последних сопоставимых данных о мощностях, доступных в 2026 году, и структурированного обзора 17 публикаций 2020–2026 годов из журналов, индексируемых в Scopus. Эмпирический дизайн разграничивает масштаб, темп и технологическую структуру перехода, не сводя зрелость энергетической трансформации к одному показателю установленной мощности ВИЭ. Для 2023–2025 годов рассчитаны три показателя: среднегодовой темп роста мощности, вклад каждой страны в региональный прирост и индекс технологической концентрации, основанный на долях гидро-, солнечной и ветровой энергетики. Совокупная мощность ВИЭ в регионе выросла с 17,636 ГВт в 2023 году до 25,482 ГВт в 2025 году, то есть на 44,5%. На Узбекистан пришлось 86,4% чистого регионального прироста, а совокупная мощность ВИЭ страны достигла 10,027 ГВт, при этом солнечная и ветровая энергетика сформировали 75,6% её возобновляемого портфеля. Казахстан сохранил наиболее технологически сбалансированную структуру, тогда как Кыргызская Республика и Таджикистан остались существенно зависимыми от гидроэнергетики. Результаты показывают, что расширение установленной мощности и качество энергетического перехода представляют разные аналитические категории. Устойчивый переход требует модернизации сетей, накопителей энергии, гибкого диспетчерского управления, конкурентных закупок, предсказуемых инвестиционных правил и развития регионального обмена электроэнергией. Предложена система оценки системной ценности, в рамках которой новые мощности ВИЭ





оцениваются по фактической выработке, надёжности, ограничениям генерации, углеродоёмкости и затратам на интеграцию, а не только по количеству введённых мегаватт.

Ключевые слова: Центральная Азия, возобновляемая энергетика, энергетический переход, солнечная энергетика, ветроэнергетика, гидроэнергетика, гибкость энергосистемы, энергетическая безопасность, региональная торговля электроэнергией.

Annotatsiya. Tadqiqot Qozog'iston, Qirg'iz Respublikasi, Tojikiston, Turkmaniston va O'zbekistondagi yashil energetika o'tishining amaldagi holatini 2026 yilda mavjud bo'lgan eng so'nggi taqqoslanadigan quvvat ma'lumotlari hamda Scopus bazasida indekslangan jurnallarda 2020–2026 yillarda chop etilgan 17 ta ilmiy maqolaning tizimli sharhi asosida qayta baholaydi. Empirik yondashuv o'tish jarayonining ko'lami, sur'ati va texnologik tarkibini alohida tahlil qiladi hamda qayta tiklanuvchi energiya manbalari bo'yicha o'rnatilgan quvvatni energetika transformatsiyasi yetukligining yagona mezonini sifatida qabul qilmaydi. 2023–2025 yillar uchun uchta ko'rsatkich hisoblandi: quvvatning o'rtacha yillik o'sish sur'ati, har bir mamlakatning mintaqaviy quvvat o'sishiga qo'shgan hissasi va gidroenergetika, quyosh hamda shamol energetikasi ulushlariga asoslangan texnologik konsentratsiya indeksi. Mintaqadagi qayta tiklanuvchi energiya quvvati 2023 yildagi 17,636 GVt dan 2025 yilda 25,482 GVt gacha oshib, 44,5% o'sdi. Sof mintaqaviy o'sishning 86,4% O'zbekiston hissasiga to'g'ri keldi va mamlakatning qayta tiklanuvchi energiya quvvati 10,027 GVt ga yetdi, quyosh va shamol energetikasining ulushi esa qayta tiklanuvchi portfelda 75,6% ni tashkil etdi. Qozog'iston texnologik jihatdan eng muvozanatli portfelni saqlab qoldi, Qirg'iz Respublikasi va Tojikiston esa gidroenergetikaga yuqori darajada bog'liq bo'lib qoldi. Natijalar o'rnatilgan quvvatning kengayishi va energetika o'tishining sifati alohida tahliliy kategoriyalar ekanini ko'rsatadi. Barqaror o'tish elektr tarmoqlarini kuchaytirish, energiya saqlash tizimlari, moslashuvchan dispetcherlik boshqaruvi, raqobatli xaridlar, barqaror investitsiya qoidalari va mintaqaviy elektr energiyasi almashinuvini talab qiladi. Maqolada yangi qayta tiklanuvchi quvvatni faqat megavattlar soni bilan emas, balki yetkazib berilgan elektr energiyasi, ishonchlilik, ishlab chiqarishni cheklash, uglerod sig'imi va integratsiya xarajatlari orqali baholaydigan tizimli qiymat yondashuvi taklif etiladi.

Kalit so'zlar: Markaziy Osiyo, qayta tiklanuvchi energiya, energetika o'tishi, quyosh energetikasi, shamol energetikasi, gidroenergetika, energiya tizimi moslashuvchanligi, energiya xavfsizligi, mintaqaviy elektr energiyasi savdosi.

INTRODUCTION

Central Asia entered a qualitatively different phase of renewable-energy development in 2024-2025. The region still combines fossil-fuel-intensive power systems in Kazakhstan, Uzbekistan and Turkmenistan with hydro-dominated systems in the Kyrgyz Republic and Tajikistan, yet the scale of new solar and wind investment has changed the structure of the regional portfolio. The analytical problem is therefore no longer whether Central Asia possesses renewable resources. The relevant question is whether additions of renewable capacity are being converted into reliable, flexible and economically sustainable electricity supply.

Earlier regional studies identified abundant technical potential alongside persistent barriers in regulation, infrastructure, finance, skills and data [1-3]. Subsequent research showed that governance quality, energy-water interdependence and investor confidence influence deployment at least as strongly as resource endowment [4-7]. Scenario analysis has also demonstrated a gap between announced climate ambitions and the long-term system changes needed for deep decarbonisation [8]. Recent empirical work adds a further point: renewable-energy consumption and green finance can improve sustainability indicators, but the effect differs across countries and depends on institutional and structural conditions [9-11].





The most recent literature has shifted from a simple deployment narrative toward system integration. Shadrina [12] examines how external partners can support transition strategies without displacing national institutional ownership. Zhakiyev et al. [13] show that ageing infrastructure and fossil-fuel dependence continue to sustain high carbon intensity in Kazakhstan, the Kyrgyz Republic and Uzbekistan. Aminjonov [14] argues that Central Asian states follow distinct strategic pathways shaped by state capacity and policy implementation. Studies published in 2026 further stress the importance of grids, human capital, financial innovation, hydrological resilience and regional coordination [15-17].

A weakness of many cross-country comparisons is the use of one headline indicator. Installed renewable capacity captures the stock of connected assets, but it does not reveal the technology mix, utilisation rate, curtailment, seasonal availability, network constraints or the cost of balancing. A country can therefore record a high renewable share while remaining exposed to hydrological shocks, or add large volumes of solar capacity while creating new requirements for evening flexibility and transmission. The present study addresses this measurement problem by separating scale, speed and structure.

The research objective is to identify the current configuration of Central Asia's green-energy transition using the latest comparable data available in 2026 and to determine which system constraints now limit the conversion of renewable capacity into energy-system value. Three research questions guide the analysis. RQ1 asks how the scale and speed of renewable-capacity expansion differed across the five countries in 2023-2025. RQ2 asks whether rapid growth was accompanied by technological diversification. RQ3 asks which policy and infrastructure mechanisms are required to translate new capacity into reliable low-carbon electricity.

Three propositions are examined. H1 states that regional growth is highly concentrated geographically, so the aggregate regional trend masks divergent national trajectories. H2 states that renewable-capacity scale and portfolio diversification produce different country rankings and should not be collapsed into a single leadership measure. H3 states that the next binding constraints increasingly concern integration - networks, storage, balancing, investment rules and cross-border trade - rather than renewable resource availability alone. The contribution of the article lies in combining updated capacity data with a transparent concentration metric and a system-value interpretation of transition progress.

LITERATURE REVIEW

The literature published since 2020 can be organised into four related strands. The first examines renewable deployment and policy design. Laldjebaev et al. [1] documented the region's large renewable potential but low utilisation outside Kazakhstan. Mouraviev [2] showed that Kazakhstan's formal policy framework did not automatically produce effective governance or investor confidence. Radovanović et al. [3] reached a similar regional conclusion: energy





transition is constrained by state-dominated markets, subsidised tariffs and weak implementation mechanisms. Shadrina [5] described this pattern as a paradox in which resource-rich systems possess both the need and the capability for diversification but retain institutional incentives favouring incumbent energy structures.

The second strand focuses on the water-energy nexus. Karimov et al. [4] demonstrate that irrigation, pumping and electricity production form linked systems in which energy and water savings can reinforce each other. Azimov and Avezova [6] extend this argument to small-scale hydropower, stressing modular technologies, storage and cross-border coordination. This evidence is important for the Kyrgyz Republic and Tajikistan, where hydropower dominates renewable capacity, but also for Uzbekistan and Kazakhstan because irrigation demand influences seasonal electricity and water management.

The third strand examines regional trade and decarbonisation. Rasoulinezhad et al. [7] find that geography, market space and institutional conditions shape Central Asian energy trade. Cassetti et al. [8] show that current policy trajectories are insufficient for ambitious long-term decarbonisation and argue for stronger regional planning. These studies imply that national self-sufficiency is not the only route to energy security. Differences in hydrology, wind regimes, solar profiles and peak demand can create economic gains from regional exchange when commercial rules and transmission capacity are credible.

The fourth strand links transition performance to sustainable development and finance. Filipović et al. [9] highlight persistent energy intensity and implementation gaps. Jie et al. [10] report that renewable energy, financial inclusion and fintech interact with environmental outcomes. He et al. [11] identify nonlinear relationships between renewable-energy consumption, energy intensity and carbon intensity. The 2025-2026 literature deepens this institutional interpretation. Shadrina [12] emphasises external cooperation and strategic complementarity; Zhakiyev et al. [13] focus on infrastructure and mitigation policy; Aminjonov [14] connects policy choices to state capacity; Khushvakhtzoda et al. [15] identify grids, finance and skills as major constraints; Liang and Morgan [16] examine synergies between green technology and financial innovation; and De Keyser et al. [17] show how hydropower expansion must be evaluated against basin-level environmental and governance constraints.

This literature establishes the relevance of institutional quality, but it leaves a narrower empirical gap. The exceptionally rapid capacity additions of 2024-2025 alter the comparative position of the five states, while older studies necessarily rely on pre-2024 data. The present analysis therefore updates the regional evidence and introduces a portfolio-concentration measure that distinguishes a large renewable stock from a diversified renewable structure.

METHODOLOGY

Research design. The study uses a comparative quantitative design covering Kazakhstan, the Kyrgyz Republic, Tajikistan, Turkmenistan and Uzbekistan. The





unit of analysis is the national renewable-power portfolio at the end of each calendar year. The quantitative window is 2023-2025 because it captures the recent acceleration while retaining a common IRENA statistical basis. The literature review includes 17 peer-reviewed journal publications indexed in Scopus and published from 2020 through 2026. Sources were selected for direct relevance to renewable deployment, transition governance, hydropower, regional electricity trade, sustainable development or green finance in Central Asia.

Data. Installed-capacity values are taken from IRENA Renewable Capacity Statistics 2026 and the IRENASTAT database, which report capacity connected by the end of 2025. The July 2026 Renewable Energy Statistics release is used as a consistency check for the distinction between capacity and generation. Capacity data are measured in MW. The analysis does not equate installed capacity with annual electricity production because capacity factors, hydrological conditions, outages and curtailment differ materially across technologies and countries. Statistical data source[18].

Indicators. Four measures are calculated. First, the two-year growth rate is $G_i = (R_{i,2025}/R_{i,2023} - 1) \times 100$. Second, compound annual growth is $CAGR_i = (R_{i,2025}/R_{i,2023})^{(1/2)} - 1$. Third, the country's contribution to regional net additions is $C_i = (\Delta R_i / \Sigma \Delta R) \times 100$. Fourth, technological concentration is measured by $HHI_i = s_H^2 + s_W^2 + s_S^2$, where s_H , s_W and s_S are the shares of hydropower, wind and solar in renewable capacity expressed as decimals. HHI approaches 1 when a portfolio is concentrated in one technology and falls as the portfolio becomes more balanced. Small residual technologies are immaterial at the reported precision and are excluded from the concentration calculation.

Analytical strategy. The first stage reconstructs national and regional capacity dynamics. The second stage compares technology structures. The third stage maps countries jointly by growth and solar-wind penetration and checks whether scale, speed and diversification lead to the same classification. The method is descriptive rather than causal. With five national observations, cross-sectional econometric inference would create false precision; the design therefore prioritises transparent indicators and mechanism-based interpretation.

Robustness and limitations. The principal robustness check is ranking stability across three non-equivalent measures: 2025 capacity, 2023-2025 growth and HHI concentration. Divergent rankings are treated as substantive evidence that transition performance is multidimensional. The main limitations are the absence of 2025 country-level generation data on a harmonised basis, incomplete information on curtailment and storage, and differences in national reporting of distributed generation. The conclusions therefore concern the structure and integration readiness of renewable assets, not a causal estimate of emission reductions.





RESULTS

Updated scale and composition of renewable capacity.

Regional renewable capacity increased from 17.636 GW in 2023 to 25.482 GW in 2025, a net addition of 7.846 GW or 44.5%. This aggregate result is highly concentrated. Uzbekistan added 6.777 GW and generated 86.4% of the region's total increase. Kazakhstan added 0.580 GW, the Kyrgyz Republic 0.384 GW and Tajikistan 0.105 GW. Turkmenistan remained statistically negligible. H1 is therefore supported by the descriptive evidence: the recent regional acceleration is primarily an Uzbek structural shift rather than a uniform Central Asian trend.

Table 1

Renewable capacity and technology structure in Central Asia, 2023-2025

Country	2023, MW	2024, MW	2025, MW	Growth 2023-25, %	Hydro in RES, %	Solar + wind in RES, %
Kazakhstan	5,504	5,561	6,084	10.5	46.8	53.2
Kyrgyz Republic	3,143	3,314	3,527	12.2	97.2	2.8
Tajikistan	5,737	5,738	5,842	1.8	100.0	0.0
Turkmenistan	2	2	2	≈0	≈100	≈0
Uzbekistan	3,250	6,079	10,027	208.5	24.3	75.6
Central Asia	17,636	20,694	25,482	44.5	57.3	42.7

Source: author's calculations from IRENA Renewable Capacity Statistics 2026. Values are rounded; minor residual renewable technologies account for small differences in individual country totals.

Uzbekistan is now the largest renewable-capacity market in Central Asia. Its 2025 portfolio consisted of 5.934 GW of solar, 1.652 GW of wind and 2.441 GW of hydropower, giving 10.027 GW in total. The structural change is material: solar and wind together account for 75.6% of renewable capacity. This reverses the historical hydro dominance visible in the region and creates a new operational problem - matching variable daytime and weather-dependent supply with demand, reserves and transmission availability.

Kazakhstan reached 6.084 GW and retained the most balanced technology structure. Hydropower represented 46.8%, while wind and solar jointly represented 53.2%. The country's growth rate was much lower than Uzbekistan's, yet the distribution of capacity across technologies reduces exposure to a single renewable resource. This distinction is central to H2: a ranking by absolute capacity favours Uzbekistan, whereas a ranking by diversification favours Kazakhstan.

The Kyrgyz Republic and Tajikistan remain hydro-dependent. Their large renewable shares should therefore be interpreted with hydrological risk in mind. New solar capacity in the Kyrgyz Republic is an early diversification signal, but hydropower still accounts for 97.2% of renewable capacity. Tajikistan's renewable portfolio remains almost entirely hydroelectric. De Keyser et al. [17] reinforce this interpretation by showing that hydropower is regionally important





but exposed to water-management trade-offs, sedimentation, ecological constraints and climate-driven variability.

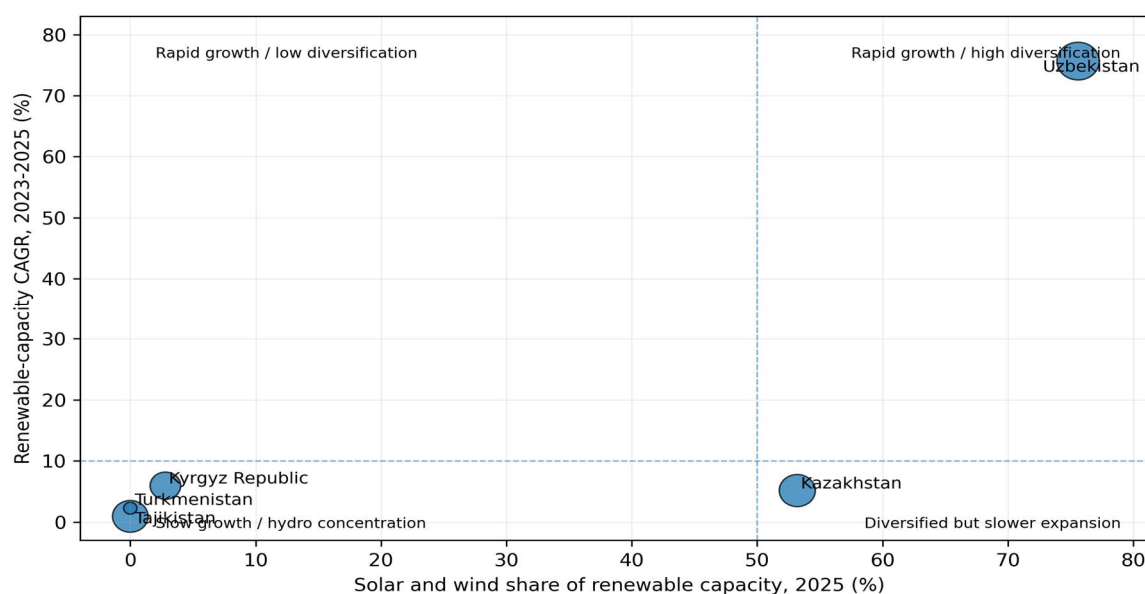
Growth, concentration and national transition trajectories.

Table 2

Analytical indicators of transition speed, concentration and regional contribution

Country	CAGR 2023-25, %	Share of regional additions, %	Technology HHI	Trajectory	Binding system issue
Kazakhstan	5.1	7.4	0.365	Diversified expansion	Grid reinforcement; coal-system flexibility
Kyrgyz Republic	5.9	4.9	0.946	Hydro-dependent diversification	Seasonal balancing; solar/storage complementarity
Tajikistan	0.9	1.3	1.000	Hydro-concentrated	Hydrology; winter reliability; basin coordination
Turkmenistan	≈0	≈0	≈1.000	Inertial / gas-centred	Market rules; data transparency; project pipeline
Uzbekistan	75.6	86.4	0.437	Accelerated solar-wind transition	Storage; transmission; balancing; curtailment control

Source: author's calculations from IRENA 2026 data. HHI = sum of squared hydropower, wind and solar shares; lower values indicate greater technological balance.



Source: author's calculations from IRENA Renewable Capacity Statistics 2026. Bubble size is proportional to 2025 renewable capacity. The embedded figure contains a vector SVG layer with a high-resolution fallback for compatibility.

Figure 1. Transition map: renewable-capacity growth and solar-wind diversification, 2023-2025





The concentration metric changes the interpretation of leadership. Kazakhstan records the lowest HHI (0.365) and therefore the most balanced portfolio among the five countries. Uzbekistan's HHI is higher at 0.437 because solar is already the dominant technology, despite the presence of sizeable wind and hydro capacity. The Kyrgyz Republic and Tajikistan are close to complete concentration. These results support H2: capacity scale, deployment speed and technological balance capture different dimensions and should be reported separately.

Figure 1 makes the divergence visible. Uzbekistan occupies a distinct high-growth, high-solar-wind position. Kazakhstan is located in the diversified but slower-growth quadrant. The Kyrgyz Republic and Tajikistan remain near the hydro-concentration axis. The figure also illustrates why a single regional average is misleading: the five national systems face different marginal policy problems.

DISCUSSION

From megawatts to system value.

The results confirm the central argument of recent literature that renewable deployment is necessary but insufficient for an energy transition. Studies published in 2021-2024 mainly described weak deployment, governance barriers and limited diversification [1-11]. The 2025-2026 literature increasingly addresses implementation quality, grids, hydrology, finance and strategic coordination [12-17]. The updated capacity data show why this shift matters. Once solar and wind additions accelerate, the policy problem moves from project procurement toward integration.

For Uzbekistan, the critical issue is the speed at which complementary assets can catch up with generation capacity. A solar-heavy portfolio creates a pronounced intraday profile. Additional value from new PV therefore depends on transmission reinforcement, storage, flexible thermal or hydro operation, demand response and cross-border exchange. Competitive procurement should gradually move from isolated energy-only contracts toward products that reward availability during system-stressed hours and explicitly price storage or flexibility where these services reduce total system cost.

Kazakhstan faces a different transition problem. Its renewable portfolio is technically diversified, but the wider electricity system remains strongly linked to coal generation and geographically separated load and resource centres. The policy challenge is not simply to add wind and solar capacity. It is to coordinate transmission expansion, retirement or flexibility of legacy thermal assets, reserve procurement and investment signals. Mouraviev [2] and Shadrina [5,12] indicate that investor participation depends on governance credibility as much as on nominal targets.

For the Kyrgyz Republic and Tajikistan, diversification has a seasonal dimension. Hydropower provides large volumes of low-carbon electricity, yet dependence on river flow can produce winter shortages and interannual volatility. Solar generation, storage and regional exchange can complement

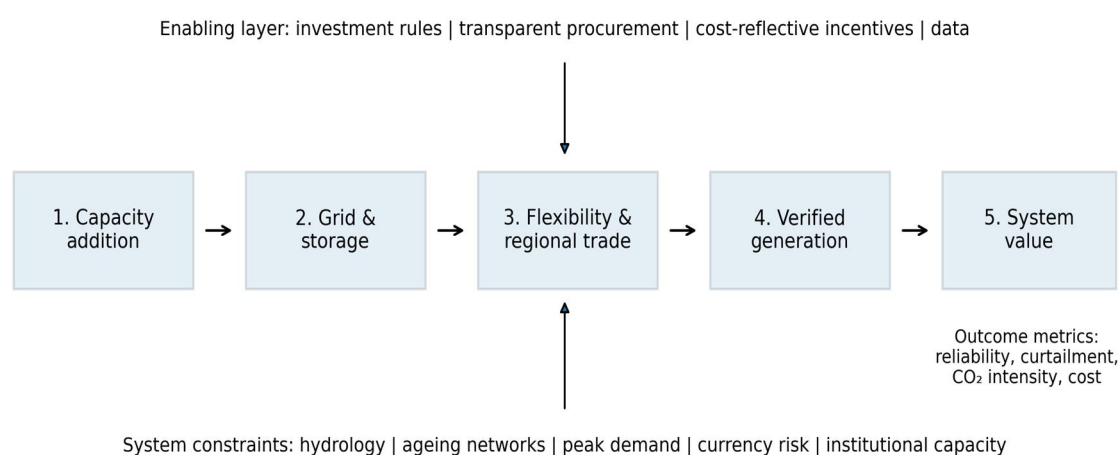




hydropower without requiring the countries to abandon their comparative advantage in water resources. The water-energy literature [4,6,17] shows, however, that new hydropower must be assessed at basin scale because electricity benefits interact with irrigation schedules, ecosystem requirements and downstream commitments.

Turkmenistan remains analytically distinct. Its near-zero non-hydro renewable capacity is not explained by resource scarcity. The more relevant constraints are the absence of a mature procurement pipeline, limited market transparency, administered energy prices and a gas-centred political economy. A credible first stage would consist of transparent resource and grid data, standard connection rules, a pilot competitive procurement round and publication of actual generation data. This is a sequencing problem rather than a technology problem.

A system-value framework for 2026-2030.



Source: developed by the author from the empirical results and the mechanisms identified in [2-17]. The embedded figure contains a vector SVG layer with a high-resolution fallback for compatibility.

Figure 2. System-value framework for converting renewable capacity into reliable low-carbon electricity

Figure 2 reframes transition policy as a conversion chain. Capacity addition is only the first stage. New assets create system value after grids and storage can absorb output, flexible resources and trade can respond to variability, actual generation is verified, and the resulting electricity improves reliability or reduces carbon intensity at an acceptable cost. The framework also clarifies why policy failure can occur after successful procurement: a project may be built on time but deliver less value than expected because of congestion, curtailment, weak dispatch incentives or seasonal mismatch.

The framework supports four regional priorities for 2026-2030. First, planning should integrate generation, transmission and storage rather than approve them as separate portfolios. Second, procurement should disclose expected connection dates, curtailment rules, indexation and allocation of





balancing risk. Third, each country should publish a common set of operational metrics: renewable generation, curtailment, storage power and energy capacity, network losses, outage duration, reserve availability and cross-border flows. Fourth, regional trade should move toward shorter settlement intervals and transparent capacity-allocation rules so that complementary national resource profiles can substitute for duplicated reserves.

Financial design is equally important. Jie et al. [10] and Liang and Morgan [16] imply that finance and technology are complementary, but concessional capital should not replace project discipline. Guarantees, blended finance and development-bank participation are most useful where they reduce risks that private investors cannot efficiently control, such as early-stage grid uncertainty or regulatory transition. Currency risk, construction risk and performance risk should remain visible in project appraisal rather than being absorbed implicitly by public balance sheets.

The regional dimension also has distributional implications. Cross-border trade can improve system efficiency, yet gains will be uneven unless transmission costs, reserve contributions and water-related externalities are explicitly allocated. Rasoulinezhad et al. [7] show that trade patterns depend on institutional and spatial factors, while Cassetti et al. [8] demonstrate the value of regional planning under ambitious decarbonisation scenarios. A credible market architecture must therefore combine technical interoperability with rules for settlement, congestion revenue and dispute resolution.

Scientific contribution and policy implications.

The scientific contribution is threefold. First, the article updates the quantitative baseline to the end of 2025, capturing the largest recent structural change in the region. Second, it distinguishes scale, speed and concentration with reproducible metrics instead of assigning a single country ranking. Third, it links the capacity evidence to a system-value framework that identifies the mechanisms through which renewable assets affect reliability and decarbonisation.

The results also refine the concept of transition maturity. A mature transition cannot be inferred from the share of renewables in installed capacity alone. It requires evidence that variable generation is absorbed with limited curtailment, that reliability is maintained, that investment obligations are transparent, and that the carbon intensity of delivered electricity declines. Under this definition, hydropower-rich systems are not automatically mature, and rapidly expanding solar systems are not automatically integrated.

For measurement, national authorities should publish technology-specific capacity and generation, hourly or sub-hourly system load, curtailment, storage utilisation, transmission constraints and outage metrics. These data would permit future research to estimate system integration costs and causal effects. They would also allow policymakers to distinguish a shortage of generation from a shortage of flexibility, a distinction that is essential for efficient capital allocation.





CONCLUSION

Central Asia's green-energy transition accelerated sharply in 2024-2025, but the acceleration was geographically concentrated and technologically uneven. By the end of 2025, renewable capacity in the five countries reached 25.482 GW, 44.5% above the 2023 level. Uzbekistan generated 86.4% of the region's net additions and transformed its portfolio toward solar and wind. Kazakhstan expanded more slowly but retained the most balanced renewable technology mix. The Kyrgyz Republic and Tajikistan continued to rely overwhelmingly on hydropower, while Turkmenistan remained outside the region's measurable solar-wind expansion.

The comparison confirms that no single indicator provides a defensible ranking of transition quality. Absolute capacity identifies scale. CAGR identifies speed. The solar-wind share and HHI identify technological structure. These indicators lead to different assessments because they answer different questions. The practical implication is straightforward: governments and international institutions should stop treating installed renewable megawatts as a sufficient proxy for energy-system transformation.

For Uzbekistan, the next stage centres on storage, transmission, flexible dispatch and curtailment management. For Kazakhstan, the priority is to integrate diversified renewables into a coal-intensive system through network investment and credible flexibility signals. For the Kyrgyz Republic and Tajikistan, diversification should reduce seasonal hydrological exposure while preserving the economic value of hydropower. For Turkmenistan, institutional entry conditions - data, procurement rules, connection procedures and an investable project pipeline - precede scale.

At regional level, electricity trade offers a mechanism for converting structural differences into mutual resilience. Hydropower can provide flexibility during periods of high solar and wind variability, while solar and wind can reduce pressure on water resources and stored hydro energy. This complementarity requires modern interconnections, commercial metering, shorter-term trading arrangements and enforceable settlement rules. Regional cooperation is therefore an economic infrastructure project as much as a diplomatic objective.

The article's main conclusion is that Central Asia has moved from a resource-availability problem toward an integration problem. The region already has sufficient evidence of renewable potential and, in several markets, sufficient investor interest. The binding constraint increasingly lies in the institutions and infrastructure that convert capacity into dependable low-carbon electricity. Policy for 2026-2030 should therefore evaluate projects by delivered system value: verified generation, reliability, curtailment, carbon intensity, integration cost and cross-border substitutability.

Further research should use hourly dispatch data, project-level procurement terms and storage operation to estimate marginal integration costs. A panel combining capacity, generation, network congestion, reserve prices and outage indicators would permit stronger causal testing of whether diversification





improves reliability and reduces carbon intensity. Such evidence is necessary before attributing macroeconomic or emissions outcomes to capacity additions alone.

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