

FROM WATER CRISIS TO ENERGY OPPORTUNITY: THE URGENT NEED FOR DIVERSIFICATION IN KYRGYZSTAN'S ENERGY SECTOR

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Abstract. Kyrgyzstan's electricity sector is overwhelmingly dependent on hydropower, which accounts for approximately 90 % of total electricity generation (International Energy Agency [IEA], 2023). While hydropower has historically underpinned energy security and enabled low-carbon electricity production, increasing water scarcity, seasonal variability, and climate-induced glacier retreat pose growing risks to system reliability (World Bank, 2022; UNECE, 2023). These vulnerabilities are particularly critical given rising electricity demand and limited flexibility within the existing generation mix.

This article argues for the urgent diversification of Kyrgyzstan's energy sector through the accelerated deployment of solar, wind, and hydrogen technologies. Kyrgyzstan possesses substantial untapped renewable energy potential, especially in solar and wind resources, which could significantly enhance system resilience and reduce dependence on hydrological conditions (IRENA, 2023). Diversification is further justified by rapid renewable energy development across Central Asia, where neighboring countries are expanding non-hydro renewables to strengthen energy security, attract investment, and meet climate commitments (ADB, 2023; EBRD, 2024).

Broadening the national energy mix would not only mitigate climate and seasonal risks but also support long-term economic stability, regional energy integration, and sustainable development, positioning Kyrgyzstan as an active participant in Central Asia's evolving clean energy transition.

Keywords: Paris Agreement, Nationally Determined Contribution (NDC 3.0), energy diversification, hydropower dependence, solar photovoltaic potential, wind energy development, energy security, climate resilience

1. Introduction

In recent years, the Kyrgyz Republic has committed itself to the global climate agenda through the ratification of key international climate agreements, most notably the **Paris Agreement** under the United Nations Framework Convention on Climate Change (UNFCCC). By joining the Paris Agreement, Kyrgyzstan acknowledged its responsibility to contribute to global efforts to limit the rise in average global temperature well below 2 °C and to pursue efforts to limit it to 1.5 °C, primarily through national actions aimed at reducing greenhouse



gas emissions and increasing the share of low-carbon energy sources (UNFCCC, 2015). As part of these obligations, Kyrgyzstan has developed and submitted its updated **Nationally Determined Contribution (NDC 3.0)**, which outlines the country's medium- and long-term climate mitigation targets in line with national development priorities. According to NDC 3.0, Kyrgyzstan aims to reduce net greenhouse gas emissions by **18 % by 2030 compared to the baseline level**, with a more ambitious target of **up to 30 % subject to international support**. By 2035, the reduction targets are set at **16 % unconditionally and up to 39 % with international assistance**, which would enable annual emission reductions of **8.5 million tons of CO₂-equivalent by 2030 and 13.1 million tons by 2035** (UNDP, 2023). Meeting these commitments requires a fundamental transformation of the national energy system. Historically, Kyrgyzstan has relied heavily on **hydropower**, which accounts for the majority of electricity generation. While hydropower is a low-carbon energy source, excessive dependence on it exposes the energy system to **hydrological and climate risks**, including seasonal water scarcity, droughts, and growing climate variability (World Bank, 2021). These vulnerabilities have already resulted in recurring electricity shortages, particularly during winter periods. In this context, the diversification of the energy system through the integration of **non-hydro renewable energy sources**, such as solar and wind power, becomes not only a climate obligation but also a strategic necessity. Expanding the renewable energy mix reduces reliance on water-dependent generation, enhances energy security, and supports sustainable economic development while aligning national energy policy with international climate commitments (IRENA, 2022). Therefore, diversification of Kyrgyzstan's energy system represents a key pathway for achieving both climate targets and long-term energy resilience.

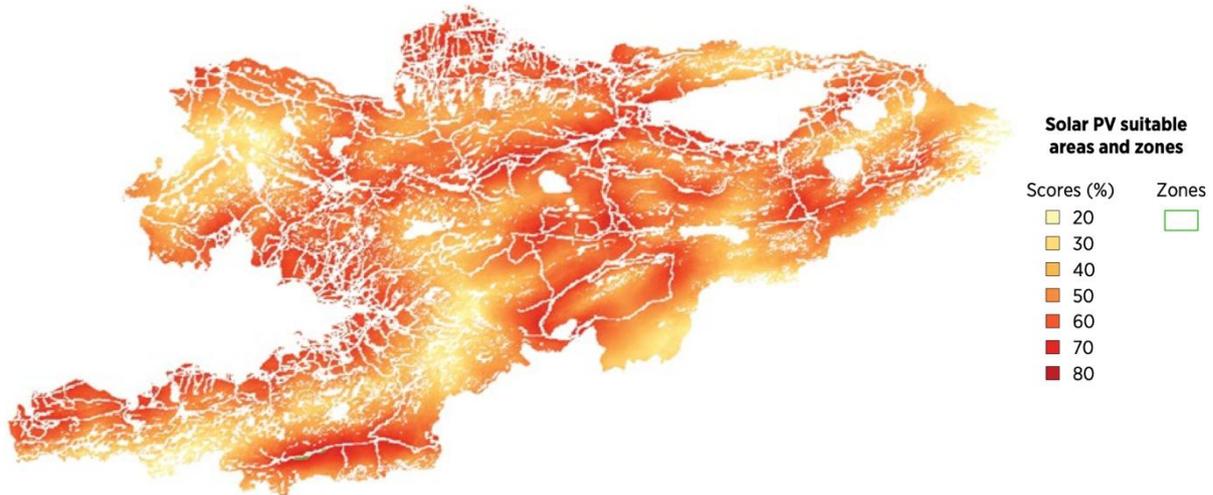
2. Institutional Support for Renewable Energy Development

To support the diversification of the energy sector and accelerate the deployment of renewable energy technologies, the Government of Kyrgyzstan has established the Green Energy Fund, a state institution operating under the Cabinet of Ministers. The Fund plays a central role in facilitating investment, allocating land, and coordinating renewable energy projects across the country. In a recent initiative, the Green Energy Fund announced a tender for the allocation of land plots for renewable energy development, signaling a shift toward more proactive state involvement in the energy transition. The tender includes seven designated sites located in the Osh and Jalal-Abad regions, of which five are intended for small hydropower plants (HPPs) and two for solar power plants (SPPs) (The Caspian Post). The creation of the Green Energy Fund and the launch of targeted tenders demonstrate a growing institutional framework aimed at attracting private and foreign investment, reducing administrative barriers, and advancing Kyrgyzstan's long-term goals of energy security, climate resilience, and compliance with international climate commitments.

Kyrgyzstan benefits from **high solar irradiation**, particularly in its **southern and high-altitude regions**, making solar power a promising alternative that can complement hydropower and contribute to diversification of the national energy system. Unlike hydropower, whose generation capacity can fluctuate significantly with seasonal water availability, solar energy provides a more predictable generation profile during dry seasons and can help **smooth seasonal gaps in electricity supply**, enhancing energy security and grid resilience. Reflecting this potential and growing investor interest, Kyrgyzstan recently inaugurated its **first large-scale solar power plant** in the **Kemin district of the Chui Region** on **24 December 2025**. The facility has an installed capacity of **100 megawatts**, covers about **230 hectares**, and was developed with the participation of a Chinese investor, with a **total investment of**

approximately \$56 million. According to official reports, the plant is expected to generate around 210 million kWh of clean electricity annually, enough to supply the needs of one district and significantly reduce carbon dioxide emissions, marking one of the largest private investments in solar energy in the country's history. President Sadyr Japarov highlighted that the launch of the plant represents "an important step in strengthening energy independence and developing renewable energy sources," and noted that Kyrgyzstan is consistently developing solar and wind projects alongside traditional hydroelectric generation. The commissioning of this plant illustrates Kyrgyzstan's concrete efforts to diversify its energy mix, reduce dependence on hydropower alone, and align its energy strategy with broader climate and development goals (DuCray, 2024).

Zoning assessment for solar PV



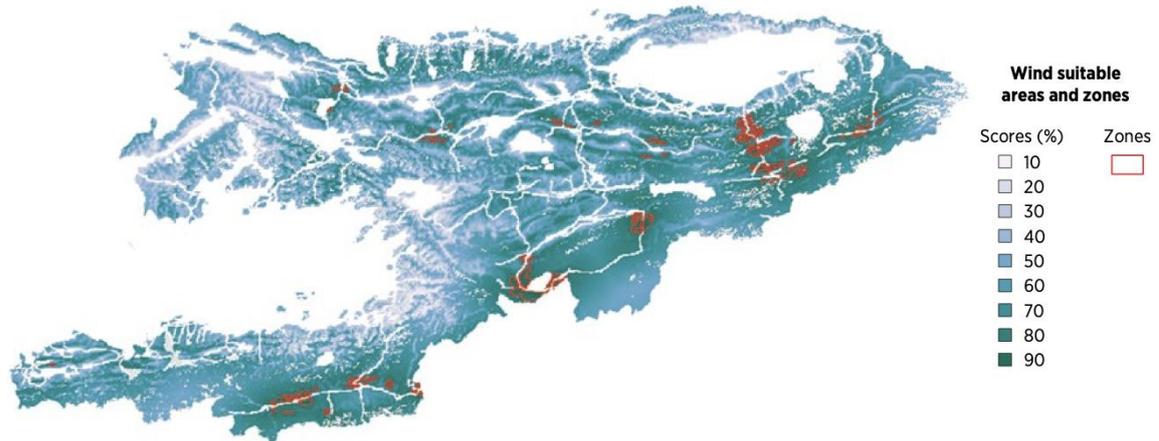
Source: Global Atlas (2022) <https://globalsolaratlas.info/map?c=11.609193,8.349609,3>

In addition to recent project-level developments, resource mapping assessments further confirm Kyrgyzstan's strong solar energy potential. According to a preliminary assessment conducted by the International Renewable Energy Agency (IRENA), more than 3,645 km² of land area in Kyrgyzstan exhibits good suitability for solar photovoltaic (PV) deployment, defined by a suitability score exceeding 50 percent (IRENA 2021b). Within this broader potential, the assessment identifies three high-priority zones with suitability scores above 75 percent, covering a combined area of approximately 26 km². These zones alone could support the deployment of up to 650 MW of utility-scale solar PV capacity, representing a substantial contribution to the national electricity system.

Spatial analysis reveals that the most suitable solar PV zones are concentrated in the southern Osh region, particularly along the Kyzyl-Suu river corridor. This geographic clustering is especially significant from a system-planning perspective, as the zones are located in proximity to the city of Osh, one of the country's largest urban and economic centers. Their closeness to existing demand hubs could reduce transmission losses, limit the need for costly grid extensions, and enhance the feasibility of integrating solar power into the national grid. Moreover, deploying solar PV capacity in southern Kyrgyzstan would help balance the current north-south asymmetry of electricity generation and reduce pressure on hydropower resources during periods of low water availability. Overall, IRENA's assessment underscores that solar

energy is not only technically viable in Kyrgyzstan, but also strategically positioned to support energy diversification, urban energy security, and climate resilience (IRENA 2021b).

Zoning assessment for wind power



Source: Global Atlas (2022) <https://globalsolaratlas.info/map?c=11.609193,8.349609,3>

In addition to solar resources, wind energy represents a major untapped opportunity for large-scale energy diversification in Kyrgyzstan. According to a preliminary assessment by the International Renewable Energy Agency (IRENA), approximately 94,000 km² of the country's territory demonstrates good suitability for onshore wind development, defined by a suitability score exceeding 50 percent (IRENA 2021b). Within this area, the assessment identifies 77 high-quality wind zones with suitability scores above 83 percent, covering a total of approximately 2,304 km². These priority zones alone could support the deployment of up to 5.8 gigawatts (GW) of onshore wind capacity, far exceeding Kyrgyzstan's current installed electricity generation capacity.

Spatial analysis indicates that the most promising wind zones are concentrated in strategically important regions, including the southern Osh region along the border with Tajikistan, as well as the northern and southern parts of Naryn oblast and additional southern high-altitude areas. These regions are characterized by open terrain, elevated altitudes, and consistent wind patterns, making them particularly suitable for utility-scale wind development. Importantly, many of these zones are located near existing or planned transmission corridors, which could facilitate grid integration and reduce infrastructure costs.

The scale of identified wind potential highlights wind power's ability to play a transformational role in Kyrgyzstan's energy system. If even a fraction of the estimated 5.8 GW potential were developed, wind energy could significantly reduce seasonal electricity deficits, complement hydropower during dry periods, and support the country's climate mitigation objectives under its updated Nationally Determined Contribution. IRENA's findings therefore confirm that wind energy is not only technically feasible but also strategically essential for strengthening energy security, improving system flexibility, and advancing Kyrgyzstan's long-term energy diversification strategy (IRENA 2021b).

In addition to solar energy, **wind power is emerging as a key pillar** of renewable energy diversification in Kyrgyzstan, helping reduce dependence on hydropower and improve energy security. After years of planning and preparatory work, the country has begun moving from concept to implementation of industrial-scale wind projects. One of the most significant developments is the construction of **Kyrgyzstan's first modern wind farm** in the **Balykchy**



area of the Issyk-Kul Region. Construction began in 2025, and the first turbine has already been installed, marking a historic milestone in the nation's renewable energy efforts. The project, developed by the local company **Metrum TEK**, aims for a total capacity of **100 megawatts**, implemented in two phases the first phase with 21 turbines totaling 50 MW and a second phase adding additional turbines to complete the full capacity. Once fully operational, the facility is expected to generate up to **250 million kWh of electricity annually**, providing a stable source of clean energy and reducing pressure on hydropower generation during periods of low water availability. In parallel, **international cooperation and investment** are supporting wind energy development. A major agreement was signed between the **Government of the Kyrgyz Republic and Rosatom Renewable Energy** for the construction of a **100 MW wind power station in the Issyk-Kul region**, representing one of the first large-scale foreign wind power investment projects in the country. Equipment components for this project have already been delivered, and construction is progressing toward commissioning between 2025 and 2027. These initiatives demonstrate Kyrgyzstan's **practical steps to harness wind potential** across suitable high-altitude and open regions, expanding the renewable energy portfolio and complementing hydropower and solar generation. By integrating wind power into the national grid, the country can better address seasonal variability, improve grid reliability, and advance toward its broader climate and energy diversification goals outlined in its updated climate commitments (Kwan, *The Times of Central Asia*).

As of 2024, the electricity sector of Kyrgyzstan remains heavily dominated by hydropower generation. Hydropower plants produced approximately **12.77 billion kWh of electricity**, while **thermal power plants**, primarily coal- and gas-fired, generated only about **1.76 billion kWh** during the same year (24.kg; IMF). This production structure reflects a long-standing dependence on water-based electricity generation.

Electricity Consumption Trends and Implications for Energy Diversification in Kyrgyzstan

Electricity consumption trends in Kyrgyzstan provide important insight into the structural challenges facing the national energy system and reinforce the urgency of diversification. According to data from the National Statistical Committee of the Kyrgyz Republic, total electricity consumption in the country reached 13,839 million kWh in 2023, reflecting a slight decrease compared to 13,883 million kWh in 2022 (National Statistical Committee of the Kyrgyz Republic 2024). While this decline may appear marginal, long-term consumption patterns reveal significant volatility driven by economic cycles, demographic changes, and climatic conditions.

Between 1990 and 2023, average annual electricity consumption in Kyrgyzstan amounted to approximately 11,891 million kWh, with a historical peak of 15,728 million kWh in 2018. This peak coincided with periods of higher industrial activity and relatively favorable hydrological conditions. In contrast, the lowest recorded consumption 9,392 million kWh in 1990 reflects the economic contraction following the dissolution of the Soviet Union. These fluctuations demonstrate the sensitivity of electricity demand to both economic and environmental factors, underscoring the vulnerability of the existing energy system (CEIC 2024).

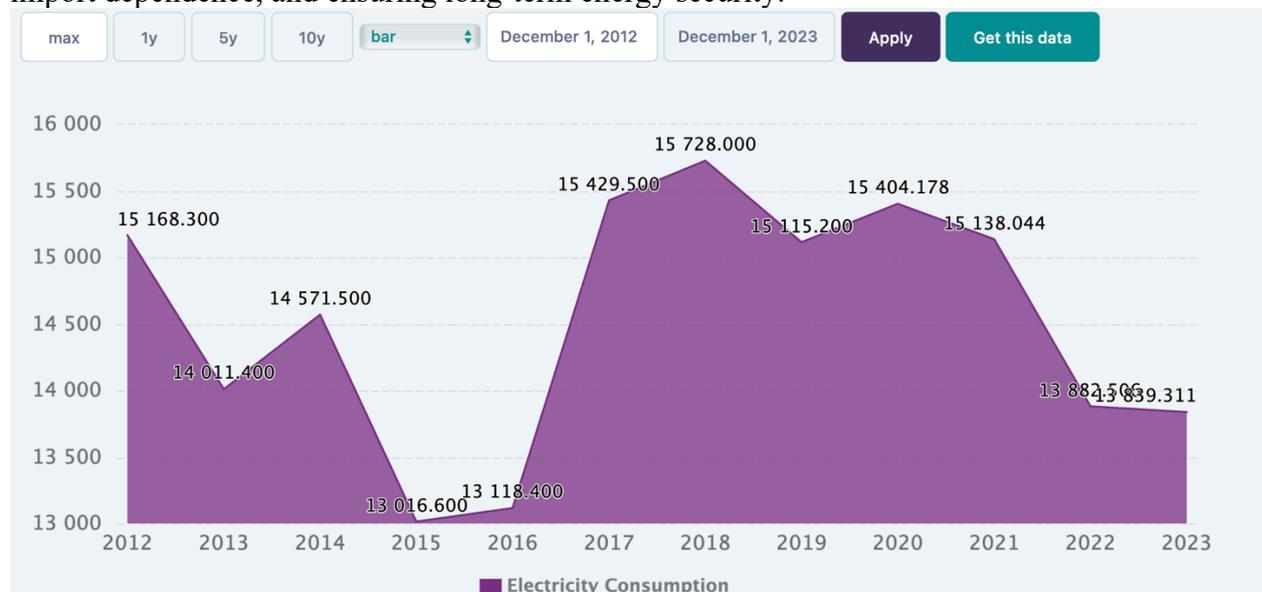
The sharp increase in electricity consumption observed between 2016 and 2018, followed by a gradual decline after 2020, highlights the structural imbalance between demand growth and supply reliability. This imbalance is particularly problematic given Kyrgyzstan's

heavy reliance on hydropower, which accounts for over 90 percent of electricity generation. During years of low water availability, electricity shortages intensify, especially in winter, when demand peaks but hydropower output declines. As a result, the country increasingly relies on electricity imports and thermal generation, undermining both energy security and emissions reduction goals.

Moreover, the recent stabilization and slight reduction of electricity consumption should not be interpreted as a long-term decline in demand. Urbanization, population growth, electrification of heating, and economic modernization are expected to drive future increases in electricity use. Without diversification, rising demand will place additional pressure on hydropower reservoirs, exacerbating seasonal shortages and increasing the risk of supply disruptions.

In this context, the integration of solar, wind, and waste-to-energy generation becomes critical. Diversified renewable sources can complement hydropower by supplying electricity during dry seasons and peak demand periods. Solar generation, for example, aligns well with summer demand and high irradiation levels, while wind energy offers potential in mountainous and southern regions. Waste-to-energy projects, such as the Bishkek solid waste recycling and power generation facility, can provide stable baseload electricity while addressing urban waste management challenges.

Overall, electricity consumption data clearly indicate that Kyrgyzstan's energy transition must focus not only on expanding generation capacity but also on building a resilient, diversified, and climate-adaptive energy system. Aligning consumption trends with renewable energy deployment will be essential for meeting national climate commitments, reducing import dependence, and ensuring long-term energy security.



Source: CEIC <https://www.ceicdata.com/en/kyrgyzstan/electricity-generation-consumption-and-trade/electricity-consumption> National statistical committee of the Kyrgyz Republic

Historically, **more than 90 % of total electricity generation in Kyrgyzstan has relied on hydropower**, making the country one of the most hydropower-dependent energy systems in the region (Wikipedia; Trade.gov). Despite this dominance, the country has utilized only



a **small share of its technically estimated hydropower potential**. Total hydropower potential is estimated at approximately **142 billion kWh per year**, yet current exploitation remains limited due to infrastructural, financial, and institutional constraints (Trade.gov).

While hydropower has provided Kyrgyzstan with a low-carbon electricity base, its overwhelming dominance has created **structural vulnerabilities** within the energy system. Electricity supply is highly sensitive to **seasonal water availability**, and periods of drought, reduced river inflows, or changing climate patterns significantly affect generation capacity. These risks are particularly pronounced during **winter months and dry years**, when electricity demand peaks but hydropower output declines, resulting in shortages and increased pressure on thermal generation and imports (IMF; cawater-info.net).

Overall, these trends demonstrate that although hydropower has long served as the backbone of Kyrgyzstan's energy system, **over-reliance on a single renewable source poses growing risks** under conditions of climate variability, rising electricity demand, and aging infrastructure. This underscores the urgent need for **diversification of the energy mix**, including the integration of solar and wind power, to enhance energy security and system resilience.

The recent development of large-scale renewable energy projects, including the 100 MW wind power initiative, demonstrates that Kyrgyzstan has clear potential to attract substantial foreign investment into its energy sector. However, the successful scaling of such projects depends on the establishment of a supportive and predictable policy environment, including transparent regulatory frameworks, secure land-use arrangements, and long-term power-purchase agreements that reduce investor risk and ensure financial viability (greenenergy.gov.kg). Without these institutional foundations, investor confidence may remain limited.

Beyond generation capacity, the transition toward a diversified and low-carbon energy system presents several structural, technical, and institutional challenges. Integrating variable renewable energy sources such as solar and wind requires significant modernization of transmission and distribution networks, improved grid flexibility, and the deployment of energy storage technologies to maintain system stability. Kyrgyzstan's electricity infrastructure, historically designed around centralized hydropower generation, may struggle to accommodate decentralized and intermittent renewable sources without substantial upgrades.

Financial and governance-related constraints also pose challenges. High upfront investment costs, limited domestic financing, regulatory uncertainty, and gaps in technical expertise may slow implementation. In addition, social and environmental issues including land allocation, public acceptance of new facilities, and environmental impact management must be carefully addressed to ensure a just and sustainable energy transition.

At the same time, energy diversification in Kyrgyzstan is expanding beyond solar and wind power. The Bishkek waste recycling and waste-to-energy plant project represents an important step toward integrated and innovative energy solutions. The project has been developing rapidly, with the first test waste delivery conducted in November 2025, and the facility is now preparing for full-scale operation. Once commissioned, the plant will process municipal solid waste while simultaneously generating electricity, becoming a key infrastructure component for both urban waste management and energy supply. This project highlights the potential of non-traditional renewable energy sources to address multiple policy

challenges simultaneously, including waste reduction, urban environmental protection, and electricity generation.

Despite existing challenges, the combination of foreign investment, technology transfer, and institutional support mechanisms such as the Green Energy Fund provides Kyrgyzstan with a realistic pathway toward building a diversified, resilient, and future-proof energy system. If effectively implemented, these efforts can reduce dependence on hydropower, enhance energy security, support climate mitigation commitments, and contribute to long-term sustainable development.

References

1. SE4ALL / UNECE Report on Kyrgyz energy mix. [unece.org](https://www.unece.org)+1
2. Asian Development Bank (ADB). *Managing Climate Risks in Central Asia's Power Sector*. Manila: Asian Development Bank, 2021.
3. Asian Development Bank (ADB). *Scaling Up Renewable Energy in Central Asia*. Manila: Asian Development Bank, 2023.
4. Asian Development Bank (ADB). *Public-Private Partnerships in Renewable Energy*. Manila: Asian Development Bank, 2024.
5. DuCray, Jennifer. "Why Switching to Solar Power Is Good for Business." *Kemin Industries Blog*, 2024. <https://www.kemin.com/na/en-us/blog/corporate/solar-panels>.
6. European Bank for Reconstruction and Development (EBRD). *Renewable Energy and Grid Integration in Emerging Markets*. London: EBRD, 2024.
7. Government of the Kyrgyz Republic. *National Development Program of the Kyrgyz Republic until 2030*. Bishkek, 2023.
8. Green Energy Fund of the Kyrgyz Republic. "100 MW Wind Power Station Land Agreement." Bishkek, May 30, 2025. <https://www.greenenergy.gov.kg>.
9. International Centre for Integrated Mountain Development (ICIMOD). *Hindu Kush Himalaya Assessment: Mountains, Climate Change, Sustainability*. Kathmandu: ICIMOD, 2020.
10. International Energy Agency (IEA). *Energy Security and Clean Energy Transitions*. Paris: IEA, 2022.
11. International Energy Agency (IEA). *Central Asia Energy Outlook*. Paris: IEA, 2023.
12. International Monetary Fund (IMF). *Kyrgyz Republic: Selected Issues—Energy Sector Challenges*. Washington, DC: IMF, 2019.
13. International Renewable Energy Agency (IRENA). *Renewable Energy Market Analysis: Central Asia*. Abu Dhabi: IRENA, 2022.
14. International Renewable Energy Agency (IRENA). *World Energy Transitions Outlook*. Abu Dhabi: IRENA, 2023.
15. Kwan, Sergey. "Rosatom to Build 100 MW Wind Farm in Kyrgyzstan." *The Times of Central Asia*, December 2024.
16. United Nations Development Programme (UNDP). *Kyrgyz Republic: Updated Nationally Determined Contribution (NDC 3.0)*. Bishkek: UNDP, 2023.
17. United Nations Economic Commission for Europe (UNECE). *Climate Change Impacts on Water Resources in Central Asia*. Geneva: UNECE, 2023.
18. United Nations Environment Programme (UNEP). *Waste-to-Energy: Considerations for Sustainable Development*. Nairobi: UNEP, 2021.



19. United Nations Framework Convention on Climate Change (UNFCCC). *The Paris Agreement*. Paris, 2015. <https://unfccc.int>.
20. United Nations Human Settlements Programme (UN-Habitat). *Integrated Waste Management for Sustainable Cities*. Nairobi: UN-Habitat, 2023.
21. U.S. Department of Commerce. *Country Commercial Guide: Kyrgyz Republic – Energy*. Washington, DC: Trade.gov, 2024. <https://www.trade.gov>.
22. World Bank. *Central Asia Water and Energy Program: Climate Risks and Energy Security*. Washington, DC: World Bank, 2021.
23. World Bank. *Climate Risk Country Profile: Kyrgyz Republic*. Washington, DC: World Bank, 2022.
24. World Bank. *Power System Flexibility for Variable Renewables*. Washington, DC: World Bank, 2023.
25. World Bank. *What a Waste 2.0: A Global Snapshot of Solid Waste Management*. Washington, DC: World Bank, 2018.
26. National Statistical Committee of the Kyrgyz Republic. 2024. *Electricity Generation, Consumption and Trade*. CEIC Global Database, Table KG.RB001.
27. CEIC. 2024. *Kyrgyzstan Electricity Consumption Data (1990–2023)*. CEIC Data Global Database.
28. International Renewable Energy Agency (IRENA). *Renewable Energy Market Analysis: Central Asia*. Abu Dhabi: IRENA, 2021.