UNITED NATIONS ECONOMIC COMMISSION FOR EUROPE

A Roadmap to Net-zero in Central Asia

UNECE

Contents

Acknowledgements

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Objectives

This report builds on the recommendations from UNECE Roadmap to Carbon Neutrality for Europe, North America, and Central Asia. The report builds upon a series of technology briefs that directly support the implementation of the Carbon Neutrality Project. The report also provides the basis for the further work on energy connectivity in Central Asia. The underlying objectives of this publication are to:

- **Inform policymakers about a range of options** and solutions to attain carbon neutrality.
- **Support countries' efforts to reach carbon neutrality and build resilient energy systems** and attract investments into clean infrastructure projects.
- **Build capacity in economies** across the UNECE region to reach common goals.

Executive Summary

Central Asia's energy systems, which are of significant environmental and climatic impact, are currently facing a necessary shift toward sustainability, carbon neutrality, and energy system resilience. This transition is driven by the Carbon Neutrality and Resilient Energy System Frameworks, which are anchored in the 2030 Agenda for Sustainable Development. These frameworks balance economic, social, and environmental factors, considering each country's unique endowments and historical patterns. A resilient energy system, per these frameworks, optimizes social, economic, and environmental contributions while ensuring fast recovery from unforeseen shocks.

Current Energy Supply and Need for Transition

To achieve carbon neutrality and resilience, Central Asian nations need to diversify their energy resources, promote regional connectivity, and ensure access to critical raw materials. Key actions also include prioritizing energy efficiency, digitalization, and low- and zero-carbon technologies. Furthermore, Central Asia's energy networks need to be interconnected to integrate renewable energy, ensuring a reliable, affordable, and sustainable energy supply. Deeper comparative analyses of energy systems will guide cost-effective and efficient pathways towards these goals.

Investment Requirements for Renewable Transition

Fossil fuels currently account for 95% of Central Asia's energy supply. The UNECE's Carbon Neutrality Toolkit suggests an investment of approximately $1.407 trillion is required between 2020 and 2050 to strengthen energy resilience under a business-as-usual scenario. However, harnessing the region's significant, untapped renewable energy potential (particularly hydro, wind, and solar power) would only necessitate a slight 2.15% increase in overall energy investment to reach net-zero emissions by 2050. The transition from fossil fuels to renewable sources necessitates an additional $255 billion investment in grid capacity to accommodate an expected 75% share of intermittent renewable energy by 2050. This would result in a 175% improvement in electricity transmission, distribution, and storage.

Achieving a Sustainable Future: Challenges and Opportunities

The shift towards a carbon-neutral, resilient, and sustainable energy system is complex but achievable. The roadmap to net-zero emissions by 2050 is not just a target, but a necessity for Central Asia's sustainable future. Despite the challenges posed by COVID-19, geopolitical crises, supply chain disruptions, and climate change, this transition provides an opportunity to fulfill both immediate energy needs and long-term

sustainability goals. The cost of inaction is too high, and the urgency of the climate crisis in Central Asia necessitates accelerated efforts.

Introduction

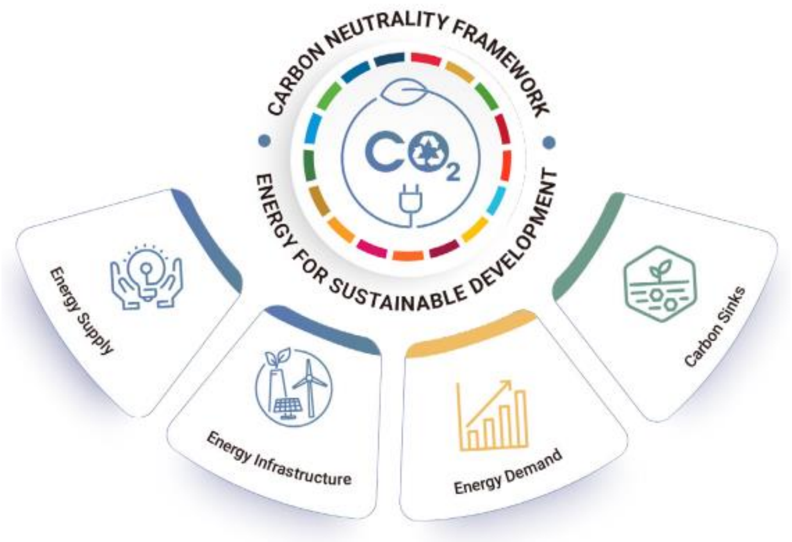
Energy systems in Central Asia have a significant impact on the environment and climate, leading to increased risks for society. Indeed, Central Asia's energy sector plays a significant role in the region's carbon dioxide (CO_2) emissions. According to the International Energy Agency (IEA), the sector's emissions amounted to 415.58 million metric tons (Mt) of CO_2. This figure highlights the substantial contribution of energy production and consumption, stemming from electricity & heat production, transport, industrial processes as well as residential & commercial uses to the region's greenhouse gas emissions.

Methane (CH_4) emissions from the energy sector in Central Asia also represent a significant environmental concern, with aggregated data from the World Bank indicating emissions amounting to 189,083.41 thousand metric tons of CO_2 equivalent (CO_2e). Methane is a potent greenhouse gas, with a global warming potential 82-87 times that of CO_2 over a 20-year period. Therefore, controlling methane emissions stemming from processes in the energy sector, notably natural gas production & distribution, oil production, and coal mining, is crucial for addressing climate change and shaping the road to net zero.

It is important to note that the data on methane emissions is thought to be underestimated, particularly in central Asia, where routine methane flaring and venting remains common practice. Indeed, standard methane accounting methodologies are often unreliable, leading to potential inaccuracies in reported emission levels. Inefficient detection and reporting systems, as well as the complex nature of methane emissions from various sources, contribute to this underestimation.

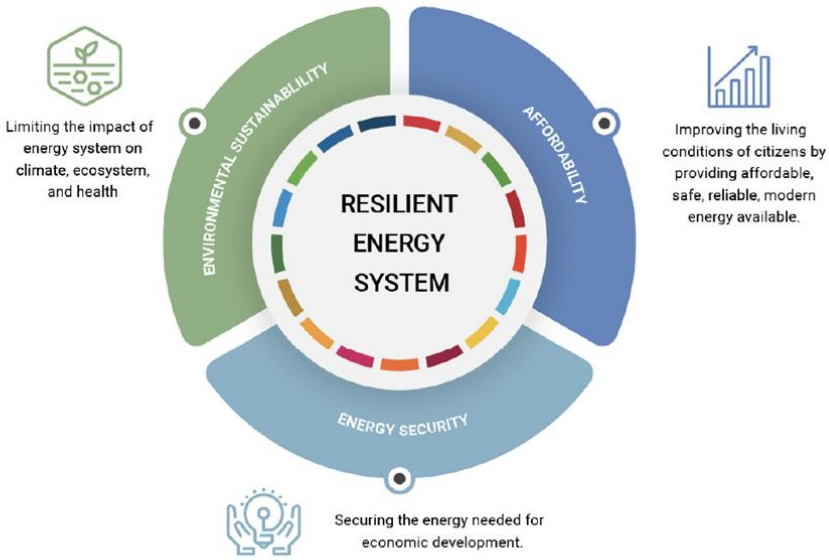
To combat these risks, experts have developed frameworks to transition towards a sustainable and carbon-neutral future while maintaining energy security and improving the quality of life.

The Carbon Neutrality Framework aims to find a balance between economic development, affordable energy for all, and environmental sustainability. This balance is essential to deliver on the universally agreed 2030 Agenda for Sustainable Development. Achieving this goal requires careful decision-making, considering each country's natural resource endowments, infrastructure, culture, and historical patterns of economic development.



Another critical framework is the **Resilient Energy System Framework**. This framework focuses on creating a system that contributes optimally to a country's social, economic, and environmental development while withstanding and quickly recovering from unforeseen shocks. The framework considers energy security, affordability, and environmental sustainability as the three pillars of a resilient energy system. It emphasizes that over-focusing on one aspect to the detriment of the others will lead to suboptimum results. The Resilient

Energy System Framework also acknowledges the potential impacts of climate change on energy resources and incorporates this into planning and operations to ensure long-term sustainability.



Ultimately, these frameworks serve as a guide for nations to identify trade-offs and synergies between the three pillars and work towards a sustainable future.

Modelling uses a simplified representation of real-life energy systems. This modelling aggregates geographical areas, economic sectors, and technologies to form judgments on required future technologies, lifestyle changes, and socio-political acceptance. The War in Ukraine is not reflected in the analysis. Furthermore, regional aggregates present limited understanding of the diversity and high level of variation of energy mixes in Central Asian nations.

Key Takeaways

- Use the UNECE Carbon Neutrality and Resilient Energy System Frameworks to balance economic, social, and environmental factors for a sustainable future.
- Diversify energy resources, promote regional energy connectivity, and ensure access to critical raw materials to enhance energy security in Central Asia.
- Prioritize energy efficiency, digitalization, and low- and zero-carbon technologies for a resilient energy system in Central Asia.
- Connect Central Asia's energy networks to integrate renewable energy and ensure a reliable, affordable, and sustainable energy supply.
- Conduct deeper comparative energy system analysis to identify cost-effective and efficient pathways to carbon neutrality and resilience in Central Asia, considering natural resources, infrastructure, culture, and historical patterns.

Building Resilient Energy Systems in Central Asia

Energy Security

Energy security ensures the availability of energy required for economic development. There are significant social, economic, environmental, and technological factors that affect energy security. Some countries might define energy security as energy independence, whereas others see energy security in a regional context, focusing on interconnectivity and trade.

To enhance energy security, there is a need to diversify energy resources, promote regional energy connectivity, and ensure access to critical raw materials.

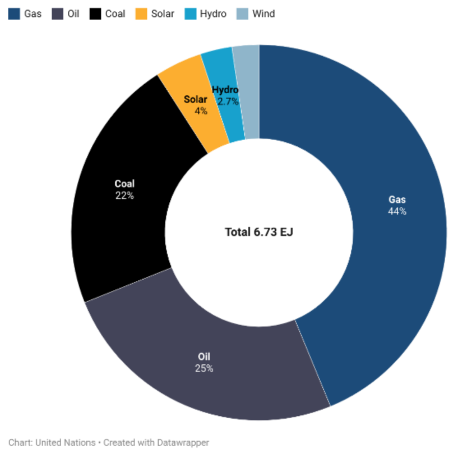


Figure 1 - Primary Energy 2050 Reference Scenario

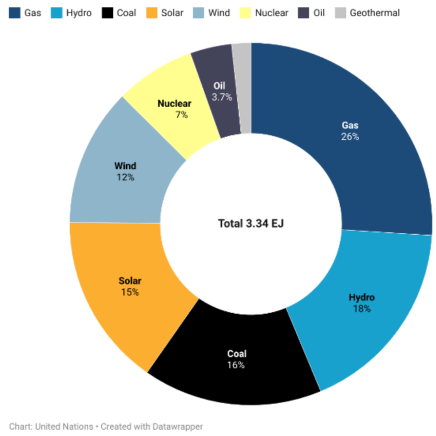


Figure 2 - Primary Energy 2050 - Carbon Neutrality Scenario

In the primary energy reference scenario for 2050, coal, oil, and gas dominate the energy mix with relatively high emissions. However, the primary energy carbon neutrality scenario presents a more sustainable and diversified future. It envisions significant reductions in carbon emissions across all energy sources.

To achieve carbon neutrality and resilience in the region's energy systems, several key measures are required. Firstly, there needs to be a shift towards diversified and efficient primary energy sources, with a strong emphasis on sustainable energy options. Energy efficiency must also be improved, aiming to reduce energy consumption from 6EJ to 3EJ.

While coal, gas, and oil will still have a role in the energy system, their presence will be significantly limited and redesigned to minimize their environmental impact. Simultaneously, there will be a massive expansion of solar, wind, and hydro power generation, harnessing the region's renewable energy potential. Additionally, oil will be primarily reserved for the transport sector.

Furthermore, the introduction of nuclear power in Uzbekistan and Kazakhstan will contribute to the carbon-neutral and resilient energy landscape.

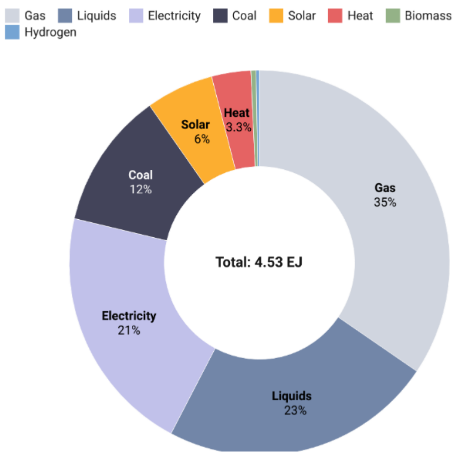


Figure 3 - Final Energy 2050 - Reference Scenario

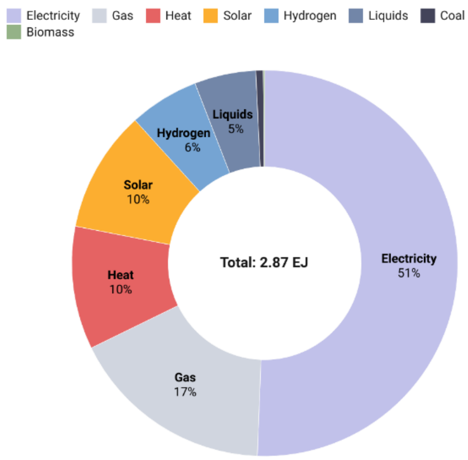


Figure 4 - Final Energy 2050 - Carbon Neutrality Scenario

The Final Energy Reference Scenario for 2050 reveals the current energy landscape, showcasing significant reliance on coal, liquids, and gas. However, the Carbon Neutrality Scenario envisions a transformative shift towards low- and zero-carbon technologies. In this scenario, coal and other fossil fuels are phased down to remarkably low levels, while renewable energy sources such as biomass, hydrogen, and solar power experience substantial growth.

To achieve carbon neutral and resilient final energy, key strategies and actions are required. The first imperative is the diversification of the energy system across all low- and zero-carbon technologies. This entails a comprehensive embrace of renewable energy sources, including biomass, hydrogen, and solar power, to replace the current reliance on coal and fossil fuels. Additionally, a significant retrofitting and redesign effort is needed to enhance the efficiencies of existing systems.

Furthermore, scaling up electricity grids is crucial, as electricity emerges as the primary driver in the pursuit of net-zero emissions. This expansion will facilitate the integration of renewable energy sources into the grid, ensuring a more sustainable and resilient energy system for Central Asia. Moreover, the introduction of hydrogen to the markets in the region holds immense potential, particularly in heating and transportation sectors, where it can be interlinked with renewable energy sources.

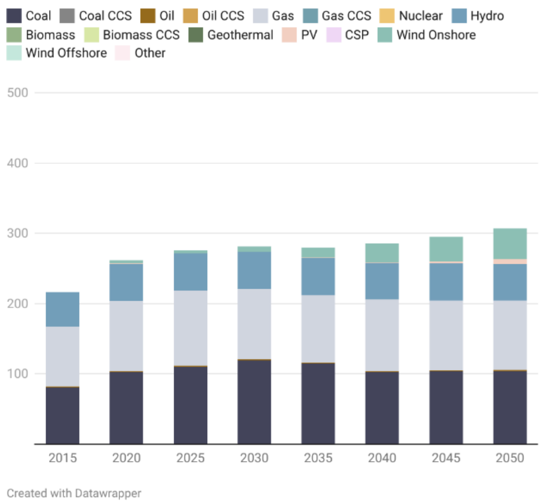


Figure 5 – Power Generation (TWh) Reference Scenario

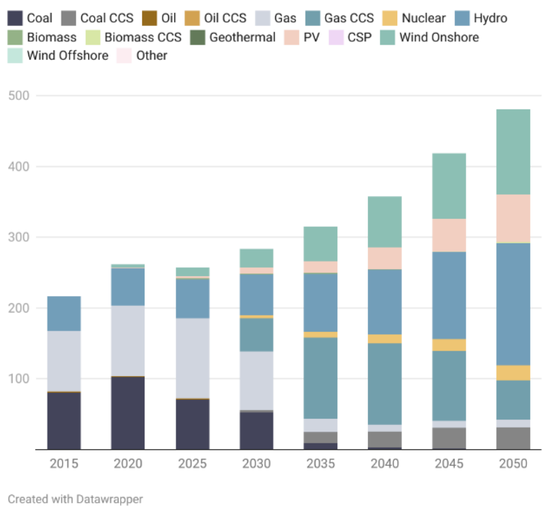


Figure 6 – Power Generation (TWh) Carbon Neutrality Scenario

The data highlights the need to scale up electricity generation at an unprecedented rate, accompanied by measures to ensure grid stability. Effective management of transmission and distribution systems is essential to support this expansion. Moreover, the utilization of electricity as a vector for energy plays a crucial role in enabling the substantial growth of renewable energy sources such as wind and hydro power.

Additionally, the transition toward carbon neutrality calls for the introduction of nuclear power and the implementation of Carbon Capture and Storage (CCS) technologies in countries that heavily rely on fossil fuels. These measures are crucial to mitigate the carbon emissions associated with the use of coal, oil, and gas in electricity generation.

Overview of Central Asian Renewable Energy Resources

Central Asia is a diverse region rich in natural resources and with vast potential to develop large scale renewable energy projects. However, despite a positive trend and increasing renewable energy capacity, the region still heavily depends on fossil fuels. Coal and natural gas still dominate the regional electricity generation mix and will continue meeting increasing regional energy demand. Nevertheless, the forecasted increase in regional electricity demand presents a significant challenge to the region, particularly considering the strain it places on fossil fuel reserves.

Uzbekistan's significant dependence on gas, accounting for 88 per cent of electricity production, and for 86 per cent of total energy supply in 2021, underscores the urgency for diversification[1]. This is especially the case given that Uzbek natural gas reserves are predicted to be depleted before 2040[2]. Investing in renewable energy sources can therefore provide a sustainable solution to bolster energy security by alleviating natural gas demand whilst also mitigating the environmental impact associated with fossil fuel consumption.

In Kazakhstan, coal constitutes the most significant energy source accounting for 49 per cent of total energy supply and 59 per cent of total electricity generation in 2021[3]. Consequently, given Kazakhstan's ambitious nationally determined contribution aiming to achieve a 25 per cent reduction in greenhouse gas emissions by 2030 and carbon neutrality by 2060, the Kazakh government aims to reduce coal-based power and heat generation by 50 per cent by 2030[4][5]. Nevertheless, electricity demand is expected to increase by 75 per cent by 2035, meaning that alternative energy sources, notably renewables, must be scaled up to fill the gap[6]. Thus, by effectively scaling renewable energy the region can not only meet its growing energy needs but also reduce its dependence on carbon intensive fossil fuel resources.

Kyrgyzstan and Tajikistan have a significant, still vastly untapped, potential of hydropower resources amounting to 158 and 527 TWh of annual electricity production, respectively[7]. Sustainable long-term management of these water resources is not only a prerequisite for domestic electricity supply but can also be a source of green energy in Uzbekistan and Turkmenistan, as well as across South Asia.

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[1] IEA, 2021. *International Energy Agency Countries & Regions: Uzbekistan.* Available at: https://www.iea.org/countries/uzbekistan
[2] bp, 2022. *bp Statistical Review 71st Edition*, London: bp.

[3] IEA, 2021. *International Energy Agency Countries & Regions: Kazakhstan.* Available at: https://www.iea.org/countries/kazakhstan
[4] Kazenergy, 2023. *The National Energy Report 2023*, Astana: Kazenergy.
[5] IEA, 2022. *Kazakhstan 2022 Energy Sector Review*, Paris: International Energy Agency.
[6] UNECE, 2023. *Sustainable Hydrogen Production Pathways in Eastern Europe, the Caucasus and Central Asia,* Geneva: United Nations Publications.
[7] UNECE, 2023. *Sustainable Hydrogen Production Pathways in Eastern Europe, the Caucasus and Central Asia*, Geneva: United Nations Publications.

Kazakhstan's rich domestic natural resources, such as its vast uranium reserves, the second largest in the world, and uninhabitable land that provides space for large scale wind and solar power projects could make the country a green and low carbon energy powerhouse and drive the regional energy transition[8][9].

Uzbekistan is also endowed with significant uranium reserves, the thirteenth largest in the world, which is planned to be leveraged to build a 2.4 GW nuclear power plant[10]. Additionally, Uzbekistan has approved the construction of 10 solar power plants with a capacity totaling 2.0 GW and have taken preliminary steps to develop an additional 1.0GW of wind power capacity[11].

In addition to Turkmenistan's extensive gas resources, amounting to over 7.2 per cent of global proven reserves, which if coupled with carbon capture use and storage (CCUS) can provide low carbon baseload electricity to the region, Turkmenistan's climatic conditions also favor the production of solar power[12][13]. It is estimated that Turkmenistan's solar potential amounts to 4.4KWh/m, meaning that it would require 0.025 per cent of the country's territory to supply the nation's current electricity demand[14].

Strengthening Resilience: Connecting Central Asia's Energy Networks

Enhancing regional energy connectivity, integration and coordination of energy infrastructure, resources, and markets across regions, is critical to strengthening energy security and energy system resilience in Central Asia. An integrated and interconnected energy system, that encompasses both the electricity and gas grids, and which is also compatible for the transport and trade of low-carbon hydrogen, can help create a more reliable, affordable, and sustainable energy supply. Also, energy interconnectivity allows for deep decarbonization and more effective integration of scaled renewable energy capacity into the energy system.

The regional energy system in Central Asia is connected and a legacy of Soviet time planning[15]. However, despite the existing infrastructure, the current system is not ready for integration of large-scale renewable energy capacity and real-time power trading. The average electricity transmission losses for the region amount to 12.8 per cent, and inter regional blackouts, such as those of 2022 where a system malfunction induced a blackout in southern Kazakhstan consequently leading to power outages in Kyrgyzstan and Uzbekistan, have threatened regional energy security[16][17]. Consequently, to enhance the reliability of the regional electricity grids, significant investments are required to refurbish existing power lines and install new high-voltage power lines capable of enabling multilateral regional power trading and significant influxes of variable renewable energy.

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[8] IAEA, 2021. *Country Nuclear Power Profiles: Kazakhstan.* [Online]
Available at: https://www-pub.iaea.org/mtcd/publications/pdf/cnpp-2021/countryprofiles/kazakhstan/Kazakhstan.htm [Accessed March 2024].

[9] IEA, 2022. *Kazakhstan 2022 Energy Sector Review,* Paris: International Energy Agency.

[10] IEA, 2022. *Uzbekistan 2022 Energy Policy Overview,* Paris: International Energy Agency.

[11] UNECE, 2023. *Sustainable Hydrogen Production Pathways in Eastern Europe, the Caucasus and Central Asia,* Geneva: United Nations Publications.

[12] bp, 2022. *bp Statistical Review 71st Edition,* London: bp.

[13] UNECE, 2023. *Sustainable Hydrogen Production Pathways in Eastern Europe, the Caucasus and Central Asia,* Geneva: United Nations Publications.

[14] UNECE, 2023. *Sustainable Hydrogen Production Pathways in Eastern Europe, the Caucasus and Central Asia,* Geneva: United Nations Publications.

[15] UNECE, 2023. Energy Connectivity in Central Asia: An inventory of existing national energy systems, Geneva: United Nations Publications.

16 IEA, 2022. Kazakhstan 2022 Energy Sector Review, Paris: International Energy Agency.

17 World Bank, 2021. DataBank: World Development Indicators. [En ligne]
Available at: https://databank.worldbank.org/source/world-development-indicators
[Accès le March 2024].

In addition, the countries in the region are prone to developing their national energy strategies in isolation of each other, despite their energy systems already operating bilaterally with each other[18]. This is problematic as not only do their strategies fail to consider current mutual interdependencies shaping energy discourse, especially in the case of hydropower, where water resources are shared between Kazakhstan, Uzbekistan, Kyrgyzstan, and Tajikistan, but also because their strategies can fail to consider the economic and environmental benefits associated with regional energy cooperation and integration.

Enabling an integrated energy system capable of multilateral real time power trading would therefore grant each Central Asian nation access to a wider variety of renewable and low carbon energy sources, that, if operating in isolation of each other, they would not have access to. This is extremely beneficial to the region's energy security and decarbonization efforts, not only because it would maximize the consumption of renewable energy, but it would also enable regions facing power shortages or disruptions to receive power in real time from regions with power surpluses. Thus, Central Asia's power system will benefit from increased flexibility and redundancy planning which, in turn, will translate to a more stable and reliable power grid.

A unified power system would also lighten the implications to energy security associated to the intermittent nature of renewable energy, such as wind and solar power by providing scalable baseload low-carbon power, to the Central Asian region. Turkmenistan and Kazakhstan's extensive gas resources, if coupled with effective CCUS systems can provide flexible low-carbon baseload power. Kazakhstan and Uzbekistan's uranium resources can soon be leveraged to produce nuclear energy and, if their respective nuclear energy economy develops, will be capable of providing baseload nuclear power to the region in the future. Plans to substantial scale up hydropower capacity in Tajikistan and Kyrgyzstan by 2030, would enable Tajikistan and Kyrgyzstan to provide copious quantities of baseload hydropower to the region. An integrated power system would thus align each country's water management strategies, balancing national irrigation needs while maximizing hydropower output.

Moreover, an interconnected Central Asian power system would facilitate the integration of electricity markets in the region. A common integrated power market would, consequently, enable efficient resource allocation and promote market competition which is currently lacking due to the monopolistic structure of Central Asia's power sectors. Overall, market integration can lead to lower electricity tariffs for end consumers and boost efficiency in power production, transmission, and distribution.

Achieving regional energy connectivity can henceforth enhance the availability and affordability of low-carbon energy and accelerate the utilization of renewable energy over time. Interconnectivity enhances economies of scale of large green infrastructure projects, translated into lower overall system investment and operating costs. Furthermore, greater energy connectivity allows for improved resource planning, energy pooling and resource diversification. Consequently, interconnectivity enhances energy security by connecting countries or sub-regions facing energy deficits to markets with surpluses of energy. It is also expected that interconnectivity will positively contribute to the Central Asian economies, generating new jobs and improving gender parity.

This objective can be achieved by conducting comparative energy system analyses, organizing regional workshops and policy dialogues, developing a roadmap, policy recommendations, and identifying projects of common interest aimed at improving regional energy connectivity and energy system resiliency.

[18] UNECE, 2023. Energy Connectivity in Central Asia: An inventory of existing national energy systems, Geneva: United Nations Publications.

Harnessing Hydro: The Food-Water-Energy Nexus in Central Asia

Central Asia faces several challenges in achieving sustainable development in the energy, water, and agricultural sectors. However, there is increasing recognition that integrated planning and cooperation between sectors can facilitate progress towards environmental and economic objectives. The United Nations Special Programme for the Economies of Central Asia (SPECA) has recommended that participating states prioritize "green" projects and regularly assess their progress in water, energy, and environmental policies while strengthening collaboration with partner institutions. The UNECE Sustainable Energy Division invites water experts to continue cooperation with the Group of Experts on Renewable Energy to design effective policies that consider the water-energy nexus. Through multi-stakeholder *Hard Talks*, the nexus approach can harness hydro power to achieve economic, social, and environmental sustainability while improving the quality of life in Central Asia.

The Value of Vital Resources: Critical Raw Materials in Central Asia

Critical raw materials (CRMs) are essential for the achievement of the Paris Agreement and Sustainable Development Goals. In Central Asia, the demand for CRMs such as lithium, nickel, copper, cobalt, manganese, graphite, and rare earth elements is expected to skyrocket in the coming years due to increased renewable energy use, battery production, and the shift to electric vehicles. Meeting this demand sustainably is a major challenge that requires billions of dollars in financing and careful attention to environmental, economic, and social considerations. Nevertheless, as illustrated by table 1, the Central Asian region is already a significant producer of many critical raw materials that are essential for the global energy transition. Additionally, as table 2 highlights, Central Asia's vast reserves of many critical raw materials can be leveraged to meet Central Asia's CRM needs and generate novel export revenue streams and business models capable of driving economic growth in line with the energy transition. Thus, frameworks, notably the United Nations Framework Classification for Resources (UNFC)[19] and the United Nations Resource Management System (UNRMS)[20], play a crucial role in promoting the sustainable and responsible development of CRMs. Considering the intricate interplay between the production, utilization, and recycling of CRMs and their impact on society, the environment, and the economy, comprehensive systems like UNFC and UNRMS are imperative for effective and integrated natural resource management.

[19] UNECE, 2009. United Nations Framework Classification for Fossil Energy, Mineral Reserves and Ressources: Incorporating Specifications for Its Application , Geneva: United Nations Publications.

[20] UNECE, 2022. United Nations Resource Management System: Principles and Requirements , Geneva: United Nations Publications.

Table 1: Production of Critical Materials in Central Asia, 2019[21]

Critical Material	Annual Domestic Production (Metric Tons)	Share of Global Production (%)	Global Production Rank
Chromium	5,191,920	12.73	2
Cadmium	1,573	6.15	2
Selenium	150	3.91	6
Zinc	710,253	5.71	6
Lead	88,500	2.47	7
Silver	1,307.7	4.98	7
Copper	883,554	4.29	7
Bauxite	6,104,200	1.87	8
Tellurium	48	9.16	8
Manganese	1,674,145	3.16	9
Iron	32,670,543	1.12	11
Molybdenum	750	0.27	11
Rhenium	900	5.80	11
Aluminum	365,700	0.57	22
Titanium	13,712	0.14	24

Table 2: Proven Reserves of Critical Materials in Central Asia (metric tons) and Total Share of Global Reserves (%), 2019[22]

Critical Material	Proven Reserves in Central Asia	Share of Global Reserves (%)
Manganese	951,564,557	38.6
Chromium	230,390,000	30.07
Lead	25,927,215	20
Zinc	46,009,736	12.6
Titanium	395,608,070	8.7
Aluminum/Bauxite	1,351,999,294	5.8
Copper	40,114,164	5.3
Cobalt	209,139	5.3
Molybdenum	855,350	5.2

Critical Material	Proven Reserves in Central Asia	Share of Global Reserves (%)
Nickel	121,700	1.2
Silver (kg)	146,525	1.2
Tin	433,636	0.9
Lithium	72,257	0.4
Graphite	8,360,615	0.3
Silicon	5,102,000	0.01
Tellurium	2,623	0.01
Cadmium	85,587	-
Germanium	4,552	-
Indium	2,617	-

[21] Vokulchuk, R. & Overland, I., 2021. Central Asia is a missing link in analyses of critical materials for the global clean energy transition. One Earth, 4(12), pp. 1678-1692.

[22] Vokulchuk, R. & Overland, I., 2021. Central Asia is a missing link in analyses of critical materials for the global clean energy transition. One Earth, 4(12), pp. 1678-1692.

Affordability

A resilient energy system improves the living conditions of citizens by providing access to safe, sustainable, reliable, modern, and affordable energy for all. This includes physical access to electricity networks and stand-alone grids, and the quality, reliability and affordability of access to the broader concept of energy services. It is important to consider costs and the need to ensure uninterrupted availability of energy services, including electricity, heating, cooling, and transport when assessing the resiliency of an energy system.

To enhance energy affordability, there is a need to distribute investments across the energy sectors to scale up all low- and zero-carbon energy sources.

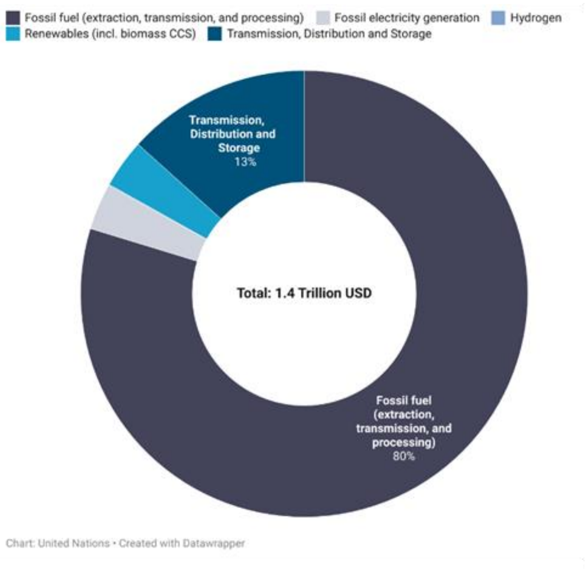

Figure 7 - Cumulative Investment 2020-2050 Reference Scenario

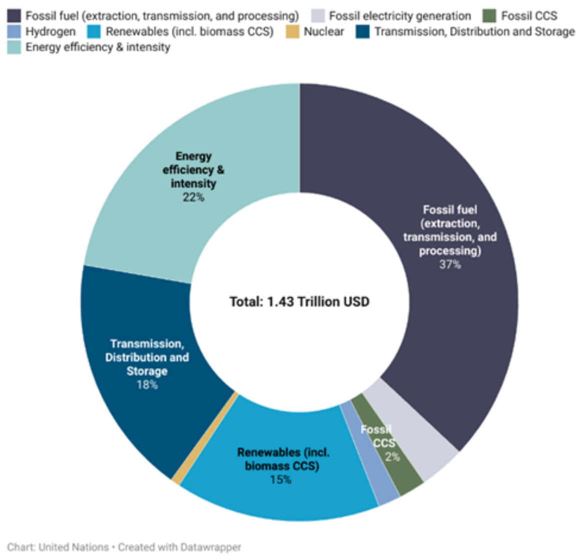

Figure 8 - Cumulative Investment 2020-2050 Carbon Neutrality Scenario

The region's current energy landscape relies heavily on fossil fuels, with a significant investment of 1.1 trillion USD in fossil fuel extraction, transmission, and processing, along with 47.2 billion USD in fossil electricity generation.

In the Carbon Neutrality Scenario, analysis underscores the importance of redirecting investments towards expanding energy governance and promoting sustainable practices in underdeveloped areas such as energy transmission, distribution, and storage. Technology transfer plays a pivotal role in facilitating the growth of low-zero carbon technologies, enabling a transition towards cleaner energy sources. Notably, energy efficiency emerges as a critical investment instrument, requiring serious attention and mainstream adoption.

Expanding renewable energy across all countries in the region is a key priority. The deployment of renewable technologies, including biomass carbon capture and storage (CCS), is crucial to mitigate greenhouse gas emissions and foster sustainable energy production. Additionally, the introduction of fossil carbon capture and storage (CCS) technologies can help reduce emissions from fossil fuel-based energy systems.

To achieve these goals, there is a necessity to implement robust policy frameworks and effective energy governance mechanisms. These measures would encourage financial flows towards low and zero-carbon technologies, supporting the development and adoption of sustainable energy solutions throughout Central Asia.

Creating Opportunities: How Carbon Neutral Energy Systems Drive Economic Growth in Central Asia

The transition to carbon-neutral energy systems in Central Asia presents a remarkable opportunity for sustainable economic growth and development in the region. By embracing renewable energy sources, promoting energy efficiency, and adopting low- and zero-carbon technologies, Central Asian nations can unlock tremendous potential for innovation, job creation, and improved energy security.

A shift towards cleaner energy not only mitigates the adverse effects of climate change but also enhances energy system resilience, attracting investments and fostering regional cooperation. The development and utilization of renewable energy resources, such as solar, wind, and hydro power, will reduce reliance on fossil fuels, diversify the energy mix, and promote a sustainable future. Furthermore, investing in expanded electricity grids, integrating hydrogen technology, and securing critical raw materials will further stimulate economic growth while ensuring access to reliable and affordable energy.

Environmental Sustainability

Building Resilient and Carbon Neutral Energy Systems in Central Asia will require a comprehensive approach with clear strategies for CO2 mitigation. Implementation of scaled-up carbon capture and storage (CCUS) infrastructure will play a vital role in capturing and storing emissions from biomass, coal, and gas combustion and conversion processes.

Additionally, the region will undergo a significant transition in its energy supply chains. The focus will be on adopting low-carbon alternatives such as renewables, nuclear power, and implementing demand changes that account for most avoided emissions. Central Asia's industrial sector will play a crucial role in CO2 mitigation by accelerating the substitution of traditional fossil fuels with low-carbon alternatives, including electricity, hydrogen, and district heating systems. This shift will not only contribute to reducing carbon emissions but also scale-up low-energy intensity in industrial production processes.

Addressing the carbon footprint of buildings will require prioritizing the refurbishment and replacement of existing housing stock with energy-efficient buildings. Replacing gas-based heating systems with heat pumps, biofuels, and solar thermal heating systems will lead to significant reductions in CO2 emissions. Finally, the transportation sector will undergo a major transformation, with a focus on replacing combustion engines with electric vehicles through lifestyle changes and efficiency improvements.

In Central Asia, a combination of different technologies and solutions can contribute to decarbonizing the entire energy system. All low and zero-carbon technologies can be utilized in all sectors.

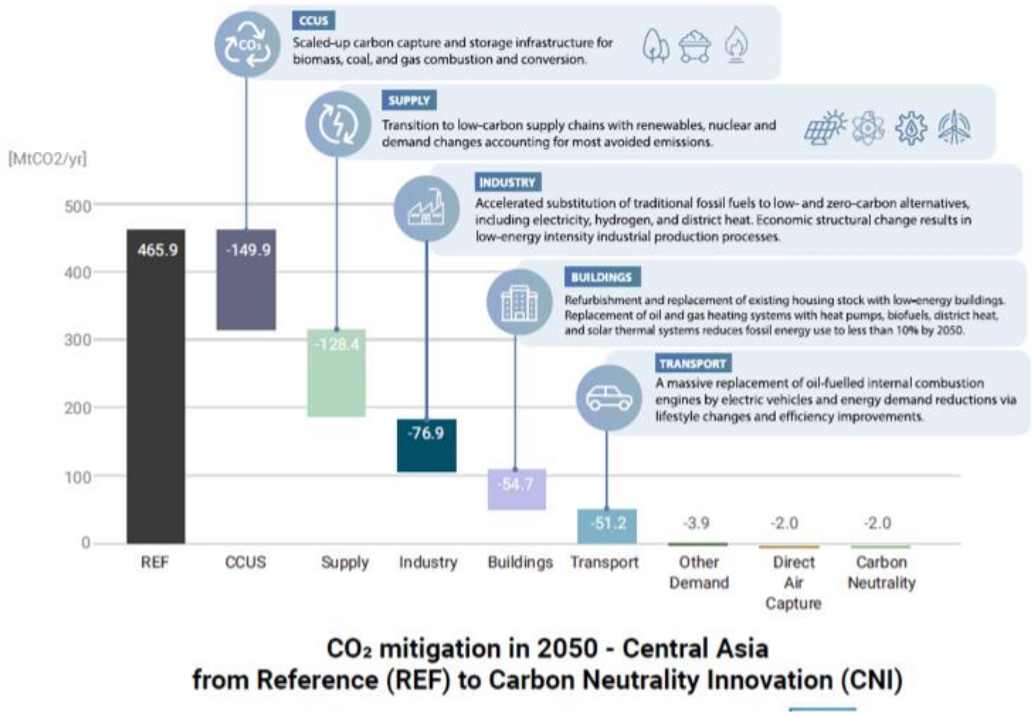

Figure 9 - CO2 mitigation [MtCO2/yr.] in Central Asia, Carbon Neutrality Innovation vs Reference Scenarios

Analysis by Sector

Central Asia is facing a pressing issue in decarbonizing all sectors in the region. There is urgency for bold and immediate action to decarbonize energy and subsequently all sectors powered by energy. International cooperation is crucial to support all countries in the UNECE region to build resilience and accelerate the energy transition. Policymakers must work towards a cross-sectoral approach to raise awareness, develop policies, and create a level-playing field to build resilient carbon-neutral energy systems.

Industry

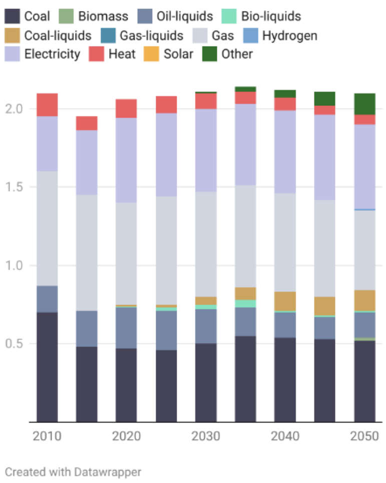

Figure 10 – Industry Final Energy Reference Scenario (EJ)

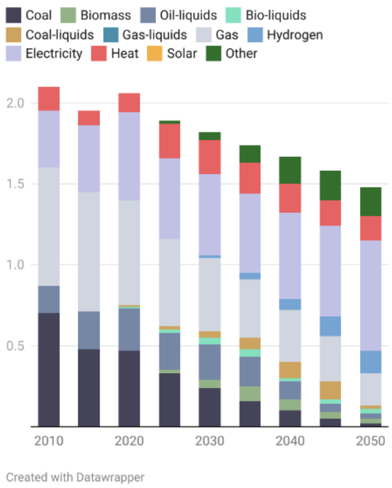

Figure 11 – Industry Final Energy Carbon Neutrality Scenario (EJ)

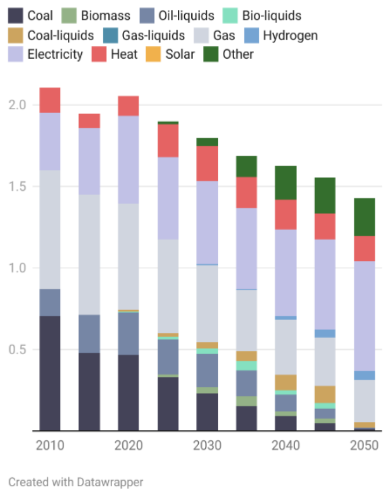

Figure 12 – Industry Final Energy Carbon Neutrality Innovation (EJ)

The reference scenario reveals a gradual transition in the region's industry sector's final energy sources from coal and oil to natural gas and electricity. Coal's share diminishes steadily over time, reaching a mere 0.52 by 2050, while gas becomes the dominant fuel, albeit declining to 0.51EJ by the same year. The integration of renewable energy sources, such as biomass and solar, remains marginal in this scenario.

In the carbon neutrality scenario, the industry sector of Central Asia exhibits a more ambitious transformation. Notably, there is a substantial reduction in final energy derived from coal and oil, reflecting the region's commitment to curbing greenhouse gas emissions. By 2050, coal's share drops to a mere 0.02, while oil's contribution diminishes to 0.03. This decline is offset by the increased utilization of natural gas, which remains the primary energy source, albeit significantly cleaner, with a final energy share of 0.20. The scenario also underscores the crucial role of renewable energy, with biomass, bio-liquids, and hydrogen contributing a notable share. Furthermore, the expansion of electricity as a final energy source supports the region's transition away from fossil fuels, demonstrating a commitment to sustainable and resilient energy systems.

The data highlights the pivotal steps Central Asia is taking to reshape its energy landscape. By reducing reliance on coal and oil, increasing the use of natural gas, and expanding renewable energy sources, the region is actively pursuing carbon neutrality and building resilience. The integration of hydrogen underscores the significant expansion of electricity as a final energy source.

Buildings

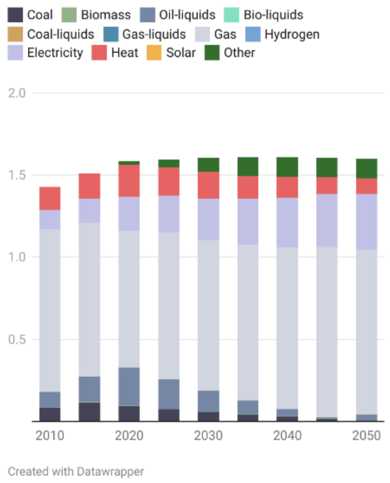

Figure 13 – Buildings Final Energy Reference Scenario (EJ)

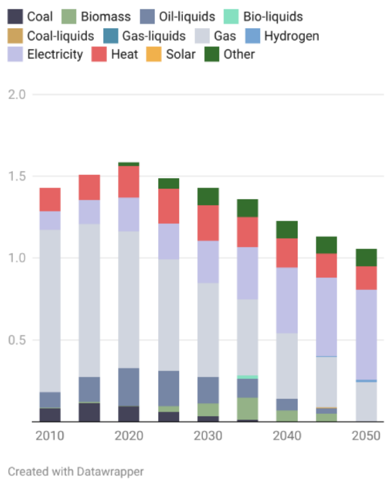

Figure 14 – Buildings Final Energy Carbon Neutrality Scenario (EJ)

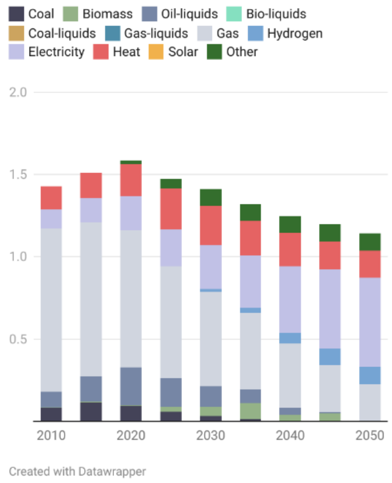

Figure 15 – Buildings Final Energy Carbon Neutrality Innovation (EJ)

In the reference scenario, data indicates that gas will continue to dominate the energy mix without substantial changes and remains a viable source in carbon neutrality scenarios. While this maintains stability, it also highlights the need for diversification and reduced reliance on a single energy source.

Achieving carbon neutrality in the region requires a focus on energy efficiency. The reference scenario shows that incremental improvements can lead to a gradual reduction in carbon-intensive sources such as coal. In carbon neutrality and carbon neutrality innovation scenarios, data suggests that by the 2030s, there will be greater penetration of electricity mainly through the application of heat pumps, and some integration of hydrogen as an alternative energy source.

Both the carbon neutrality and innovation scenarios present a brief introduction of biomass as an alternative to coal. This highlights the potential of biomass as a renewable energy source that can contribute to carbon neutrality efforts in the region.

Transport

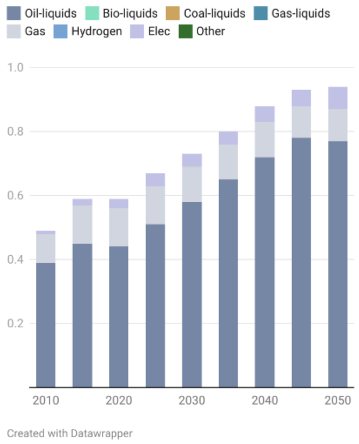

Figure 16 – Transport Final Energy Reference Scenario (EJ)

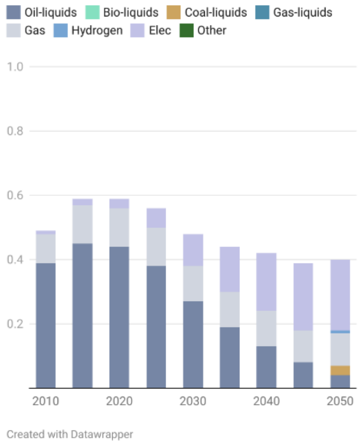

Figure 14 – Transport Final Energy Carbon Neutrality Scenario (EJ)

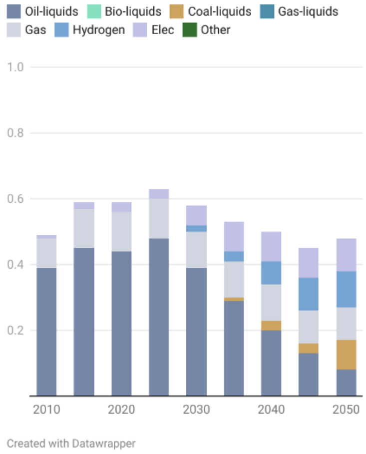

Figure 15 – Transport Final Energy Carbon Neutrality Innovation (EJ)

Oil currently dominates the transport landscape in the region. However, in order to achieve carbon neutrality, a remarkable reduction in overall transport consumption is essential. The Carbon Neutrality scenario depicts a substantial decline in the use of oil-liquids, leading to a notable shift in the energy mix.

A massive uptake of electric vehicles leads to the share of electric energy in the final energy consumption of the transport sector reaching 55% by 2050. Moreover, the Carbon Neutrality Innovation scenario envisions the emergence of diverse technologies in the transport sector. Alongside electric vehicles, hydrogen-powered solutions are expected to enter the market.

Policy Checklist

1. **Enhance Energy Efficiency:**
    - Prioritize and maximize energy efficiency solutions across sectors.
    - Increase systemic efficiencies in industry, buildings, and transport.
    - Improve energy system resilience through enhanced efficiency.
2. **Digitalize Energy Systems:**
    - Capitalize on digital solutions and improved digital literacy.
    - Reduce energy demand and enhance energy system resiliency through digitalization.
3. **Accelerate Fuel Switching:**
    - Replace carbon-intensive fuels with low- and zero-carbon solutions over time.
    - Maintain economic stability and energy security while transitioning.
4. **Manage Resources and Circularity:**
    - Implement UNFC and UNRMS to improve resource management.
    - Integrate circular carbon considerations into decision-making.
    - Promote repairability and recyclability of goods.
5. **Deploy Low- and Zero-Carbon Technologies**:
    - Scale up renewable energy deployment.
    - Replace carbon-intensive fuels with low- and zero-carbon technologies.
    - Reduce carbon footprint through CCUS deployment.
    - Foster cooperation and develop regulatory frameworks for investments.
6. **Diversify Energy Resources:**
    - Prioritize renewable energy sources (solar, wind, hydro) to reduce reliance on fossil fuels.
    - Promote a sustainable energy mix.
7. **Promote Regional Energy Connectivity:**
    - Enhance cooperation and infrastructure connectivity.
    - Integrate renewable energy sources.
    - Ensure a reliable, affordable, and sustainable energy supply.
8. **Ensure Access to Critical Raw Materials:**
    - Secure supply of critical raw materials for renewable energy technologies and electric vehicles.
    - Support the transition to a carbon-neutral energy system.
9. **Expand Electricity Grids:**
    - Invest in expanding and upgrading electricity grids.
    - Accommodate intermittent renewable energy sources.
    - Enable efficient transmission, distribution, and storage.

10. Integrate Hydrogen Technology:

- Explore the potential of low carbon hydrogen as a clean energy carrier.
- Reduce carbon emissions and diversify energy sources.
- Enhance energy system resilience.

11. Strengthen Energy Security:

- Diversify energy mix and foster regional cooperation.
- Ensure stable and reliable energy supply.
- Work towards energy independence.

12. Increase Investments in Low- and Zero-Carbon Technologies:

- Redirect investments towards clean technologies.
- Support renewables, energy efficiency, and CCS technologies.
- Create policy frameworks and financial incentives.

13. Promote Cross-Sectoral Collaboration:

- Adopt a comprehensive cross-sectoral approach to the energy transition.
- Coordinate efforts across industries, buildings, and transport.
- Create a level-playing field for clean energy technologies.

14. Foster International Cooperation:

- Engage in international cooperation and knowledge sharing.
- Collaborate with organizations, neighbouring countries, and global partners.
- Access expertise, technology transfer, and financial resources for a resilient and carbon-neutral energy system.