Energy Transition Pathways for the 2030 Agenda

SDG 7 Roadmap for Kazakhstan

Developed using National Expert SDG 7 Tool for Energy Planning (NEXSTEP)

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Acknowledgments

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Foreword: UNECE and ESCAP

The United Nations Economic Commission for Europe (UNECE) and the United Nations Economic and Social Commission for Asia and the Pacific (ESCAP) extend their gratitude to the Ministry of Energy for productive cooperation in shaping the SDG 7 Roadmap for Kazakhstan. This document has been developed in the framework of the United Nations Development Account (UNDA) project "Strengthening energy policies of Countries with Special Needs to build back better from COVID-19" and is a complement to the Government's commitment to achieving the ambitious targets of the Sustainable Development Goal 7 (SDG 7) and the Paris Agreement. The SDG 7 Roadmap has assessed existing policies and plans, identified gaps, and provided recommendations for an enabling policy framework and technological interventions to ensure the attainment of these targets.

The key objective of this SDG 7 Roadmap is to align and synergize the Government of Kazakhstan's energy policies and measures to achieve the SDG 7 and Nationally Determined Contribution (NDC) targets. The Roadmap contains a matrix of technological options and enabling policy measures for the Government to consider. It presents several scenarios that have been developed using national data, considering existing energy policies and strategies as well as reflecting on other development plans. These scenarios are expected to enable the Government to make an informed decision to develop and implement a set of policies to achieve SDG 7 by 2030, together with the NDC.

Kazakhstan has already achieved universal access to electricity and is very close to achieving universal access to clean cooking, which stood at 97.8 per cent in 2021. It is estimated that universal access to clean cooking will be achieved by 2030 under the current policy settings. Energy efficiency improvement needs to be boosted across different sectors in order to achieve a 3.4 per cent annual improvement, which would reduce energy intensity to 4.0 MJ/USD by 2030. There is significant scope to increase the efficiency of the country's energy system.. Concerted effort is needed to improve energy efficiency across the entire economy. The power sector is heavily reliant on coal leading to substantial GHG emissions. An increase in renewable energy-based power generation is essential to reduce emissions.

The Roadmap sets out the following four key policy recommendations to help Kazakhstan achieve the SDG 7 targets: 1) Improve energy efficiency across all economic sectors; 2) Proceed with electrification of the transport sector, which will reduce emissions and improve energy security; 3) Decarbonize the power supply, which is the key to achieving net zero emissions by 2050; and 4) Decarbonize the heating sector to reduce emissions and improve energy security.

UNECE and ESCAP express their unwavering commitment to assisting Kazakhstan in delivering a secure, resilient and sustainable energy future.

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Abbreviations and acronyms

BAU	business-as-usual
CBA	cost-benefit analysis
CO_2	carbon dioxide
CPS	current policy scenario
EC	European Commission
EE	energy efficiency
ESCAP	United Nations Economic and Social Commission for Asia and the Pacific
EV	electric vehicle
GDP	gross domestic product
GHG	greenhouse gas
ICS	improved cooking stove
IEA	International Energy Agency
IPCC	Intergovernmental Panel on Climate Change
IRENA	International Renewable Energy Agency
IRR	Internal Rate of Return
$MTCO_{2\text{-}e}$	million tonnes of carbon dioxide equivalent
ktoe	thousand tonnes of oil equivalent
kWh	kilowatt-hour
LCOE	Levelized Cost of Electricity
LEAP	Long-range Energy Alternatives Planning
LPG	liquefied petroleum gas
MCDA	Multi-Criteria Decision Analysis
MEPS	minimum energy performance standard
MJ	megajoule
MTF	Multi-Tier Framework
MW	megawatt
MWh	megawatt-hour
NDC	nationally determined contributions
NEXSTEP	National Expert SDG Tool for Energy Planning
PP	power plant
RE	renewable energy
SDG	Sustainable Development Goal
TFEC	total final energy consumption
TPES	total primary energy supply
UNECE	United Nations Economic Commission for Europe
US$	United States dollar
WHO	World Health Organization

Executive Summary

Under the Development Accounts project "*Strengthening energy policies of Countries with Special Needs to build back better from COVID-19*", ESCAP and the United Nations Economic Commission for Europe (UNECE) have collaborated to develop SDG 7 Road Map for Kazakhstan. The key objective of this SDG 7 roadmap[1] is to assist the Government of Kazakhstan in developing enabling policy measures to achieve the SDG 7 and NDC targets. This roadmap contains a matrix of technological options and enabling policy measures for the Government to consider. It presents several scenarios that have been developed using national data, and which consider existing energy policies and strategies as well as reflect on other development plans. These scenarios are expected to enable the Government to make an informed decision to develop and implement a set of policies to achieve SDG 7 by 2030, together with the NDC.

A. Highlights of the roadmap

Kazakhstan has already achieved universal access to electricity and is very close to achieving universal access to clean cooking, was 97.8 per cent in 2021. It is estimated that universal access to clean cooking would be achieved by 2030 under the current policy environment. Energy efficiency improvement needs to be boosted across different sectors in order to achieve a 3.4 per cent annual improvement, reducing energy intensity to 4.0 megajoules per the United States dollar by 2030. The country's energy system is currently highly inefficient. Concerted effort is needed to improve energy efficiency across the entire economy. The power sector is heavily reliant on coal leading to substantial GHG emissions. Increase in renewable energy-based power generation is essential to reduce emissions.

B. Achieving Kazakhstan's SDG 7 and NDC targets by 2030

1. Universal access to modern energy

Kazakhstan has made good progress in ensuring access to modern energy technologies. It has already achieved universal access to electricity and estimated to achieve universal access to clean cooking by 2030 under the current policy scenario.

2. Renewable energy

The share of renewable energy in the total final energy consumption (TFEC) was 1.9 per cent in 2021.[2] Based on current policies, the share of renewable energy is projected to increase to 6.3 per cent by 2030. The increase is due to the projected increase in renewable electricity and improvement in energy efficiency. In the SDG scenario, the share of renewable energy is projected to improve to 6.8 per cent of TFEC in 2030.

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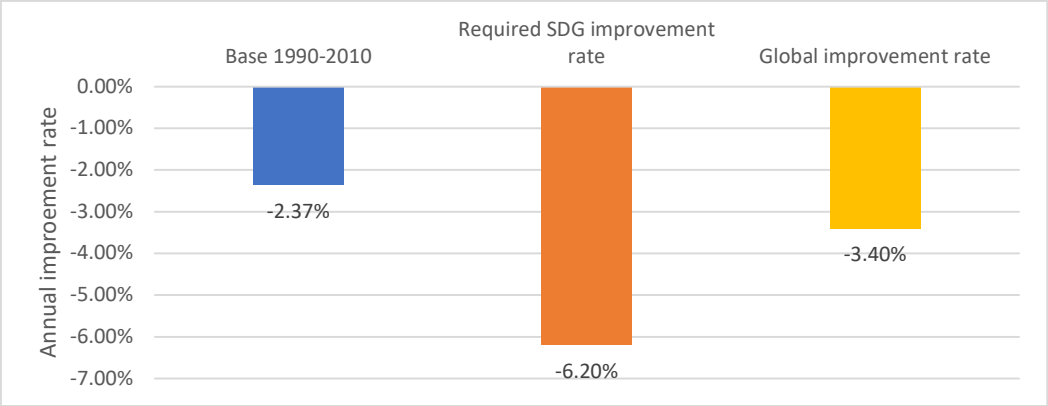
[1] This roadmap examines the current status of the national energy sector and existing policies, compares them with the SDG 7 targets, and presents different scenarios highlighting technological options and enabling policy measures for the Government to consider.

[2] Excluding traditional biomass usage in residential cooking and space heating.

3. Energy efficiency

Kazakhstan's energy intensity in 2021 is estimated to have been 5.8 MJ/US$$_{2017}$. Energy intensity in Kazakhstan declined at an average annual rate of 2.37 per cent between 1990 and 2010. A doubling of the 1990-2010 improvement rate is required in order to achieve the SDG 7.3 target, which requires an average annual rate increase of 4.74 per cent between 2010 and 2030. Such a high rate of energy efficiency improvement and a low energy intensity is challenging and unlikely to be achieved, even with ambitious energy efficiency improvement measures. Therefore, in consultation with stakeholders, NEXSTEP analysis suggests that Kazakhstan's energy intensity target be aligned with the global target of a 3.4 per cent annual improvement. This corresponds to a 2030 energy intensity target of 4.0 MJ/US$$_{2017}$, as shown in figure ES 1. Under the current policy settings, the energy intensity is projected to drop to 4.7 MJ/US$$_{2017}$. The energy efficiency target is met in the SDG scenario at 4.0 MJ/US$$_{2017}$.This is primarily due to the improvement of energy efficiency across different sectors.

Figure ES 1: Kazakhstan energy efficiency target[3]

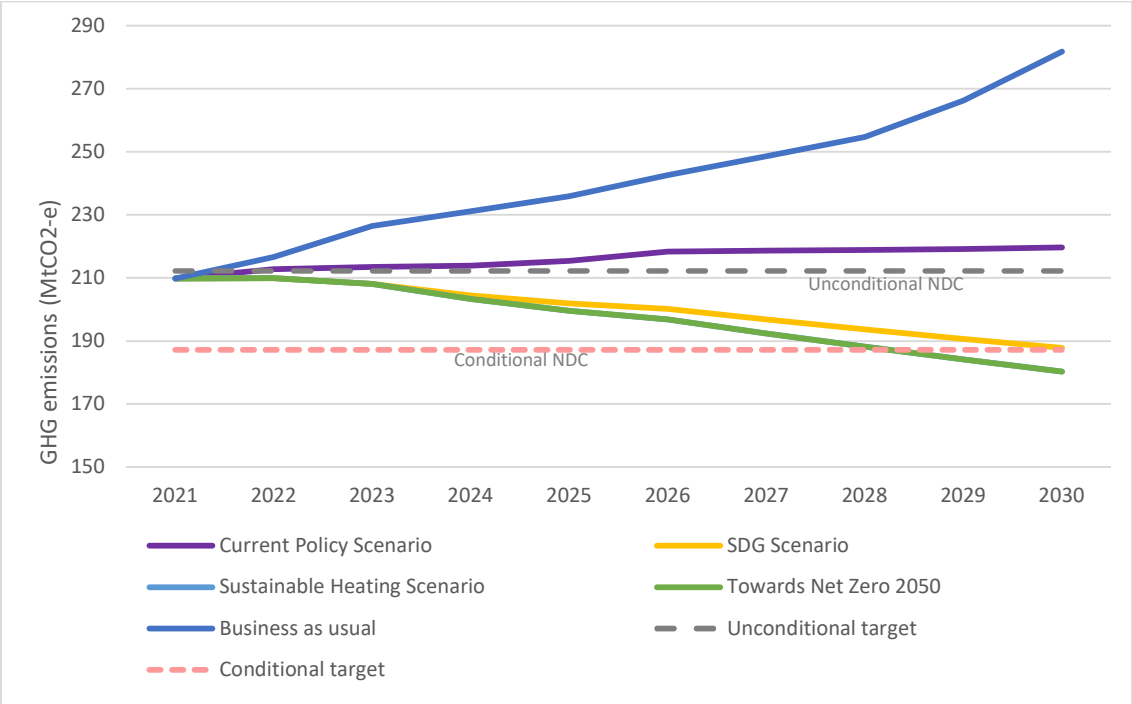


4. Nationally Determined Contribution

Kazakhstan's updated Nationally Determined Contribution stipulates the country's updated unconditional commitment to reducing its GHG emissions by 15 per cent of greenhouse gas (GHG) emissions by 2030. With the external support, Kazakhstan aims to reduce emissions by 25 per cent, which is the conditional NDC. Both unconditional and unconditional NDC targets are met in the SDG scenario, sustainable heating scenario and towards Net Zero scenario.

[3] Calculated based on data from the Asia Pacific Energy Portal.

Figure ES 2: Comparison of emissions, by scenario, 2021-2030



C. Important policy directions

The roadmap sets out the following four key policy recommendations to help Kazakhstan achieve the SDG 7 targets:

1. ***Improve energy efficiency across all economic sectors***. The residential sector is the highest energy consuming sector in Kazakhstan and therefore, requires the maximum focus. The utilization of improved heaters for space heating, aggressive adoption of MEPS and thermal insulation improvement in the residential sector are necessary to build sustainable heating environment. Energy efficiency improvement in the industry and service sectors can be obtained through deep retrofitting and motor replacement. Very high consumption of fossil fuel in the power sector and relatively low electricity prices may pose challenges in implementing ambitious energy efficiency measures. Policies to address these challenges should be developed.
2. ***Electrification of the transport sector will reduce emissions and improve energy security***. Accelerating the adoption of electric vehicles will reduce Kazakhstan's reliance on petroleum fuels. This measure is also critical to decarbonize the passenger transport sector by 2050. An adoption rate of 15 per cent of passenger cars, 5 per cent electric buses and 10 per cent of freight trucks by 2030 is highly recommended.
3. ***Decarbonization of the power supply is the key to achieving net zero emissions by 2050***. Decarbonization of the power sector is important to move towards net zero by 2050. This attempt will require a substantial increase in renewable capacities, which could be challenging but it will offer multiple benefits, including reducing emissions and improving energy security through the utilization of indigenous resources.

4. ***Decarbonize the heating sector to reduce emissions and improve energy security***. The sustainable heating scenario is set to offer a substantial GHG emission reduction through the implementation of an efficient and renewable energy-based heating system. While some sustainable heating technologies, such as heat pumps, could be challenging technically and economically, they will help improve energy security through the utilization of indigenous resources.

1. Introduction

1.1. Background

Transitioning the energy sector to achieve the 2030 Agenda for Sustainable Development and the objectives of the Paris Agreement presents a complex and difficult task for policymakers. It needs to ensure sustained economic growth, respond to increasing energy demand, reduce emissions, and consider and capitalise on the interlinkages between Sustainable Development Goal 7 (SDG 7) and other SDGs. In this connection, the United Nations Economic and Social Commission for Asia and the Pacific (ESCAP) has developed the National Expert SDG Tool for Energy Planning (NEXSTEP). This tool enables policymakers to make informed policy decisions to support the achievement of the SDG 7 targets as well as nationally determined contributions (NDCs). Under the Development Accounts project "*Strengthening energy policies of Countries with Special Needs to build back better from COVID-19*", ESCAP and the United Nations Economic Commission for Europe (UNECE) have collaborated to develop SDG 7 Road Map for Kazakhstan. This Road Map has been developed using the NEXSTEP framework and provides recommendations on technological options and enabling policy measures for Kazakhstan to achieve the targets of SDG 7 by 2030.

1.2. SDG 7 targets and indicators

SDG 7 aims to ensure access to affordable, reliable, sustainable, and modern energy production for all. It has three key targets, which are outlined below.

- Target 7.1. "By 2030, ensure universal access to affordable, reliable and modern energy services." Two indicators are used to measure this target: (a) the proportion of the population with access to electricity; and (b) the proportion of the population with primary reliance on clean cooking fuels and technology.
- Target 7.2. "By 2030, increase substantially the share of renewable energy in the global energy mix". This is measured by the renewable energy share in TFEC. It is calculated by dividing the consumption of energy from all renewable sources by total energy consumption. Renewable energy consumption includes consumption of energy derived from hydropower, solid biofuels (including traditional use), wind, solar, liquid biofuels, biogas, geothermal, marine and waste. Due to the inherent complexity of accurately estimating the traditional use of biomass, NEXSTEP focuses entirely on modern renewables for this target.
- Target 7.3. "By 2030, double the global rate of improvement in energy efficiency", as measured by the energy intensity of the economy. This is the ratio of the total primary energy supply (TPES) and GDP. Energy intensity is an indication of how much energy is used to produce one unit of economic output. As defined by the IEA, TPES is made up of production plus net imports, minus international marine and aviation bunkers, plus stock changes. For comparison purposes, GDP is measured in constant terms at 2017 PPP.

In addition to the above-mentioned targets, the SDG 7 goal also includes target 7.A – promote access, technology and investments in clean energy, and target 7.B – expand and upgrade energy services for developing countries. These targets are not within the scope of NEXSTEP.

1.3. Nationally Determined Contribution

NDCs represent pledges by each country to reduce national emissions and are the stepping-stones to the implementation of the Paris Agreement. Since the energy sector is the largest contributor to GHG emissions in most countries, decarbonizing energy systems should be given a high priority. For example, the global energy sector was responsible for 76 per cent of the global GHG emissions in 2018 (Climate Watch, 2021).

Kazakhstan's updated Nationally Determined Contribution (Government of Kazakhstan, 2023) sets a mitigation target of Kazakhstan's NDC that will be a 15 per cent reduction in total national greenhouse gas (GHG) emissions by 2030, compared to the 1990 emissions. Kazakhstan could achieve a 25 per cent emission reduction with additional international investments and green climate funds, along with access to the transfer of low-carbon technologies (conditional target).

2. NEXSTEP methodology

The main purpose of NEXSTEP is to help design the type and mix of policies that would enable the achievement of the SDG 7 targets and the emission reduction targets (under NDCs) through policy analysis. However, policy analysis cannot be done without modelling energy systems to forecast/backcast energy and emissions, and economic analysis to assess which policies or options would be economically suitable. Based on this approach, a three-step approach has been proposed. Each step is discussed in the following subsections.

2.1. Key methodological steps

(a) Energy and emissions modelling

NEXSTEP begins with energy systems modelling to develop different scenarios for achieving SDG 7 by identifying potential technical options for each scenario. Each scenario contains important information including the final energy (electricity and heat) requirement by 2030, possible generation/supply mix, emissions and the size of investment required. The energy and emissions modelling component uses Long-range Energy Alternatives Planning (LEAP). It is a widely used tool for energy sector modelling as well as for creating energy and emissions scenarios. Many countries have used LEAP to develop scenarios as a basis for their Intended INDCs. Figure 1 shows different steps of the methodology.

(b) Economic Analysis Module

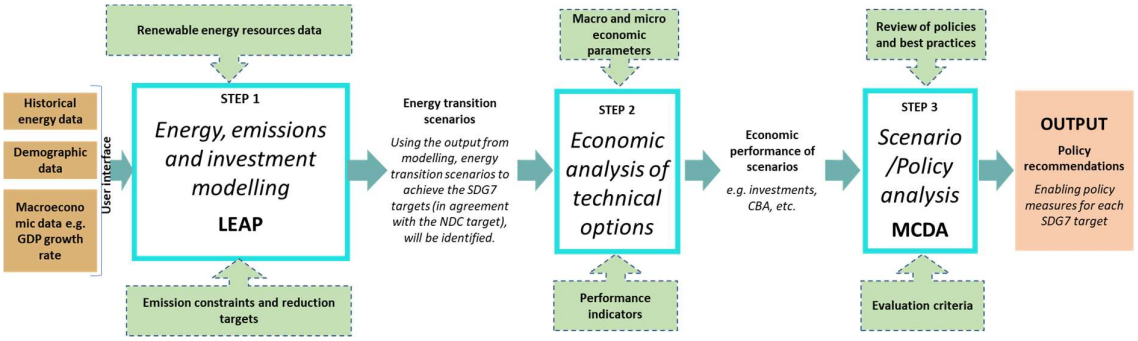
The energy and emissions modelling section selects the appropriate technologies, and the economic analysis builds on this by selecting the least cost energy supply mix for the country. The economic analysis is used to examine economic performances of individual technical options identified and to prioritize least-cost options. A comparative assessment of selected power generation technologies is done using the Levelized Cost of Electricity (LCOE) as an economic indicator. This will help policymakers to identify and select economically attractive technologies for better allocation of resources, and assist policymakers make an informed policy decision.

(c) Scenario and policy analysis

Using Multi-Criteria Decision Analysis (MCDA) tool, this prioritized list of scenarios is assessed in terms of their techno-economic and environmental dimensions to assess the comparative benefits of selecting a specific scenario over others. The top-ranked scenario from the MCDA process is used to inform the Government on the best possible energy transition pathway for the country.

This tool is unique, in that no other tools look at developing policy measures to achieve SDG 7. The key feature that makes it different is the back casting approach for energy and emissions modelling. This is important when it comes to planning for SDG 7 as the targets for the final year (2030) are already given; thus, the tool needs to be able to work its way backwards to the current date and identify the best possible pathway.

Figure 1: Different components of the NEXSTEP methodology



2.2. Scenario definitions

The LEAP modelling system is designed for scenario analysis, to enable energy specialists to model energy system evolution based on current energy policies. The baseline year, 2021, has been chosen, as it is the most recent year with sufficient data information for modelling. In the NEXSTEP model for Kazakhstan, five scenarios have been modelled. These include, three core scenarios (a) business-as-usual scenario; (b) current policy scenario (CPS); and (c) Sustainable Development Goal (SDG) scenario. In addition, two ambitious scenarios have been developed: (d) enhanced energy efficiency (EE) scenario and (e) renewable energy diversification scenario.

(a) The BAU scenario: This scenario follows historical demand trends, based on growth projections, such as using GDP and population growth. It does not consider emission limits or renewable energy targets. For each sector, the final energy demand is met by a fuel mix reflecting the current shares in TFEC, with the trend extrapolated to 2030. Essentially, this scenario aims to indicate what will happen if no enabling policies are implemented or the existing policies fail to achieve their intended outcomes. The main purpose of this scenario is to be able to compare the emissions trend with the baseline and estimate the emissions reduction target.

(b) Current policies scenario: Inherited from the BAU scenario and modified, this scenario considers relevant policies and plans currently in place.

(c) SDG scenario: This scenario aims to achieve the SDG 7 targets, including universal access to electricity and clean cooking fuel, by substantially increasing the renewable energy share and doubling the rate of energy efficiency improvement. For clean cooking, different technologies (electric cooking stove, LPG cooking stove, and improved cooking stove) have been assessed, with subsequent recommendation of the uptake of the most appropriate technology. Energy intensity has been modelled to help achieve the SDG 7 target. It also allows the achievement of the country's unconditional NDC target.

(d) Ambitious scenario: Like the SDG scenario, the ambitious scenarios aim to achieve the SDG 7 targets. In addition, these scenarios also look to increase the socio-economic and environmental benefits for the country from raising its ambition beyond just achieving the SDG 7 targets, such as by creating cost-effectiveness by further improving its energy efficiency beyond the SDG 7.3 target and meeting its conditional NDC target.

2.3. Economic analysis

(a) The economic analysis, in this roadmap, is aimed at assisting policymakers with information on costs and benefits of different measures as well as recommendations to assist in making informed policy decisions. While the economic analysis has been kept to a simple level, it contains enough information to support policy recommendations in this roadmap. Some key cost parameters that have been used in this analysis are capital infrastructure costs for technologies, which are based on country-specific data to improve the analysis. They include land, building, machinery, equipment and civil works.

(b) Operation and maintenance cost comprises fuel, labour, and maintenance costs. Power generation facilities classify operation and maintenance costs as fixed (US$/MW) and variable (US$/MWh) cost. Fixed O&M costs are incurred regardless of the energy produced by a process, and are entered per unit of capacity (e.g., per MW). Variable O&M costs are entered per unit of energy outputs, inputs, or losses.

(c) GHG abatement – the avoided cost of CO_2 generation is calculated in monetary value terms based on the carbon price. The 2016 Intergovernmental Panel on Climate Change (IPCC) Guidelines for National Greenhouse Gas Inventories is followed in the calculation of GHG emissions for the economic analysis. The sectoral analysis is based on the Tier 1 approach, which uses fuel combustion from national statistics and default emission factors.

2.4. Scenario analysis

The scenario analysis evaluates and ranks scenarios, using the Multi Criteria Decision Analysis (MCDA) tool, with a set of criteria and weights assigned to each criterion. Although the criteria considered in the MCDA tool can include the following, stakeholders may wish to add or remove criteria to suit the local context:

- Access to clean cooking fuel;
- Energy efficiency;
- Share of renewable energy;
- Emissions in 2030;
- Alignment with the Paris Agreement;
- Fossil fuel subsidy phased out;
- Price of carbon;
- Fossil fuel phase-out;
- Cost of access to electricity;
- Cost of access to clean cooking fuel;
- Investment cost of the power sector;
- Net benefit from the power sector.

This step is generally applied using the NEXSTEP online portal,[4] to suggest the best way forward for the countries by prioritizing the scenarios.

[4] Available at https://nexstepenergy.org/

3. Overview of Kazakhstan's energy sector

3.1. Current situation

Geography and climate: Kazakhstan (officially known as the Republic of Kazakhstan) is located in the Central Asian region is the largest landlocked country in the world,[5] bordered with Russian Federation, China, Kyrgyzstan, Turkmenistan and Uzbekistan. The country occupies a land area of 2.72 million km^2 with a total length of land border with other states amounts to 13,200 km. About 44 per cent of its territory is occupied by desert, 14 per cent by semi-desert, 26 per cent by steppes and only 5.5 per cent by forests. There are 8,500 rivers and 48,000 lakes in Kazakhstan. The remoteness of Kazakhstan from the oceans determines the continental climate of the country.

Population: The total population of Kazakhstan was around 19.8 million in 2021. with an annual growth rate of 1.3 per cent between 2020 and 2021. Over the ten-year period between 2012 and 2022, the annual population growth rate averaged 1.6 per cent. The percentage of urban population was estimated to be 67 per cent. Almaty, Astana, and Shymkent are three most populated cities in Kazakhstan.

Economy: Kazakhstan's economy is dominated by a large minerals sector. Its GDP in 2021 was estimated at US$ 197.1 billion. The GDP per capita has been increasing from just US$ 1,129 in 2000 to US$ 9,973 in 2021. The country's GDP relies heavily on the service sector (53.5 per cent), the industrial sector (35.3 per cent), and agricultural sector (5 per cent). The remaining goes to the other sectors.

Climate: Kazakhstan experiences an extreme continental climate, with long, hot summers and cold winters. Winter in the north of the country is long and cold – in some years the temperatures reached -52°C (Astana), but there are also thaws up to 5°C. The shortest season in the north is spring, which lasts 1.5 months, while summer lasts 3 months and winter extends from October to April. Snow primarily falls in November but can continue through April.

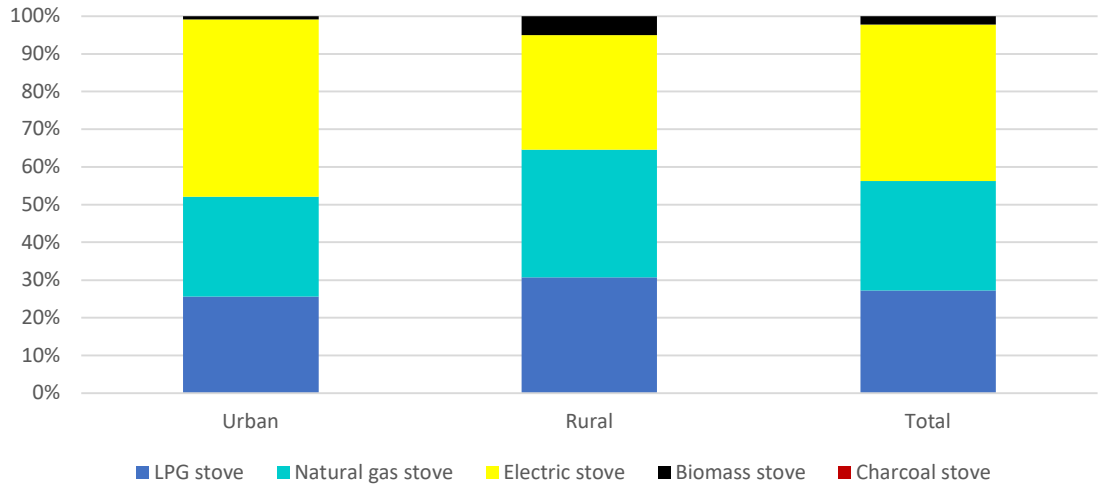
Energy governance: The energy sector in Kazakhstan is overseen by various government agencies, including the Ministry of Energy, the Ministry of Industry and Infrastructural Development, and the Ministry of Ecology, Geology, and Natural Resources. Some of the key organizations working in the energy sector in Kazakhstan include the state-owned energy company KazMunayGas, the national atomic company Kazatomprom, the Kazakhstan Electricity Grid Operating Company (KEGOC) and the Financial Settlement Center of Renewable Energy (FSC). The transport sector, including aviation, is overseen by the Ministry of Industry and Infrastructural Development. The extraction and production of petroleum, coal and uranium are also managed by ministries, governmental agencies, and national companies.

[5] https://www.akorda.kz/en/republic_of_kazakhstan/kazakhstan

3.2. National energy profile

Kazakhstan has progressed well in providing energy access towards its citizens. The electrification rate in Kazakhstan was 100 per cent in 2021, and the clean cooking access rate was estimated at 97.8 per cent. The remaining 2.2 per cent of the population, which corresponds to 111,014 households, still relied on unclean and polluting solid fuel stove as their primary cooking technology. Overall, electric cook stoves were the most dominant primary clean cooking technology, with an estimated share of 41.3 per cent. This was followed by liquefied petroleum gas (LPG) stoves and natural gas stoves, which were estimated at 25.7 per cent and 27.1 per cent respectively (Figure 2).

Figure 2: Cooking stove distribution in 2021



Modern renewable energy delivered approximately 1.9 per cent of TFEC in 2021. This excludes traditional biomass usage in residential cooking and heating, which was low as the country is close to achieving universal access to clean cooking. While endowed with abundance of abundant renewable potential, Kazakhstan has a high reliance on fossil fuels (i.e., coal and oil products) to meet its stationary and mobile energy demands. The energy intensity, which is measured as the amount of primary energy required to produce one unit of GDP, was calculated aa 5.8 MJ/US$$_{2017}$ in 2021.

3.3. National energy policies and targets

Kazakhstan's energy sector development is guided by several national policies and legislations. These policies have been used as guiding references for the NEXSTEP modelling, to better understand the country's context and to provide recommendations in adherence to the national government's overarching direction. Where applicable, the currently implemented and adopted policies or regulations are considered in the current policy scenario, to identify gaps in achieving the SDG 7 targets. The following policies or strategic documents have been consulted.

- **Law on the Promotion of Renewable Energy Sources (Law No. 165-IV of 2009) (2020 Ed.)** (Office of the President of the Republic of Kazakhstan, 2009) proposes a long-term vision for the development of non-polluting energy sources – as a means of ensuring environmental

security, climate change mitigation, and attaining progress towards low-carbon, sustainable and eco-efficient economy. The proposed instruments aim to unleash the existing potential of renewable energy, while remaining barriers to renewable energy trade are expected to be removed. Emphasis is placed on improving renewable energy pricing mechanisms. Renewable energy shall account for five per cent in total energy mix by 2024.

- **Law No. 541-IV of 2012 on Energy Saving and Energy Efficiency (2019 Ed.)** (Office of the President of the Republic of Kazakhstan, 2012) is a strategic policy enacted to target significant decreases in industrial and municipal energy consumption. The law envisages establishing legal frameworks for improving energy conservation, energy efficient infrastructure development, shifting the national economy to green growth. The law proposes investments in refurbishing and modernization of existing energy infrastructure and programs on green technologies supported by the Government of the Republic of Kazakhstan.
- **Strategy Kazakhstan 2050** (Government of Kazakhstan, 2012) provides the direction of national environmental and energy policies by 2050, to address (1) the post-crisis Kazakhstan, (2) the top ten challenges in the 21st century, and (3) the future political direction in the fast-changing world. The policy has a target of providing half of Kazakhstan's total energy consumption by alternative and renewable energy sources in 2050.
- **The Concept on Transition towards Green Economy until 2050** (Office of the President of the Republic of Kazakhstan, 2013) **or Green Economy Concept** formulates long term priorities to increase efficiency in resources utilization, modernize existing infrastructure, protect environment, and enhance energy security. The first stage of the implementation was from 2013 to 2020 with the aims to start utilising natural resources optimally and efficiently and establishing green infrastructure. The second stage will be conducted up to 2030 focusing on the transformation of national economy by raising the uptake of renewable energy technologies as well as construction of energy-efficient facilities. The last stage from 2030 to 2050 will focus on the utilisation of natural resources on the condition of renewability and sustainability. There is a target to reduce energy intensity by 10 per cent in 2015, 25 per cent in 2020, 30 per cent in 2030; and 50 per cent in 2050 (aspirational target) compared to 2008 baseline. The share of alternative sources (solar, wind, hydro and nuclear) in electricity production will be at least 3 per cent by 2017; 30 per cent by 2030; and 50 per cent by 2050 (aspirational) over 2008 levels.
- **Concept for the Development of the Fuel and Energy Sector until 2030** (Government of Kazakhstan, 2014) is a strategic policy document developed in response to existing environmental concerns. Main objectives and areas of concern are represented by the development of an appropriate regulatory framework and incentives on sustainable and renewable energy, the adaptation to climate change and the addressing of the challenges associated with reducing carbon dependency.
- **Governmental Decree No. 264 validating the Concept for the development of energy saving and increasing energy efficiency of the Republic of Kazakhstan for 2023 2029** (Government of Kazakhstan, 2023) set a target by 2029 to reduce the energy intensity of the industry by 10 per cent and energy sector by 5 percent; the energy consumption per unit area

of premises by 10 percent; the energy consumption per capita by 5 per cent from the 2021 level.

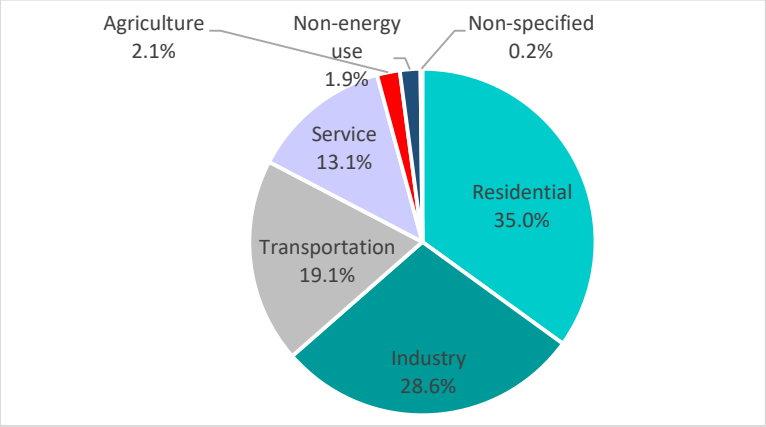
- **Kazakhstan's Updated Nationally Determined Contribution (NDC)** (Government of Kazakhstan, 2023) sets a mitigation target of Kazakhstan's NDC that will be a 15 per cent reduction in total national greenhouse gas (GHG) emissions by 2030, compared to the 1990 emissions. Kazakhstan could achieve a 25 per cent emission reduction with additional international investments and green climate funds, along with access to the transfer of low-carbon technologies (conditional target).

3.4. National energy balance 2021

The following details describe the estimated national energy consumption, using data[6] collected with a bottom-up approach, based on data such as activity level and energy intensity for the different sectors. The bottom-up estimation is generally in agreement with the national energy statistics, in terms of total energy supply and total final energy consumption by fuel type (ESCAP, 2024). It should be noted that biomass consumption data are not available from official sources and are estimated by using a bottom-up approach.

In 2021, the total final energy consumption (TFEC) was 42.1 Mtoe (Figure 3). Most of the demand came from the residential sector (35.0 per cent), followed by the industry sector (28.6 per cent), transport sector (19.1 per cent) and service sector (13.0 per cent). Agriculture and non-specific energy use accounted for 2.1 per cent and 0.2 per cent. Non-energy use accounted for 1.9 per cent.

Figure 3: Total final energy consumption by sector in 2021 – 42.1 Mtoe



The fuel mix in the residential sector was 27.9 per cent natural gas, 25.6 per cent coal, 19.2 per cent heat, 18.6 per cent oil products, 8.7 per cent electricity, and 0.1 per cent of biomass. Heating demand in Kazakhstan is quite high as the country experiences long and very cold winter season. Such a high share of residential heating demand was supplied mainly by district heating (55.5 per cent), gas boiler

[6] National data compiled by ESCAP's national consultant with reference to publicly available sources.

(17.9 per cent), mixed heating (13.5 per cent), coal boiler (12.2 per cent), and electric heater and other (0.9 per cent). Cooking activities consumed around 18.1 per cent of residential energy demand. The distribution of cooking technology will be discussed later. Around 1.3 Mtoe was utilized to power household appliances. Of this, oven and kitchen appliance consumed 46.5 per cent, lighting 17.3 per cent, refrigeration 15.7 per cent, washing machine 10.6 per cent, television 6.2 per cent, and the remaining 3.7 per cent was used for ironing, laptop, and other appliances.

There are three energy-intensive industries in Kazakhstan, which are (1) iron and steel, (2) non-ferrous metal, and (3) mining and quarrying. These industries together consumed 69.4 per cent of industrial energy demand. The remaining was consumed in food, beverages and tobacco, machinery and transport equipment, pulp and paper, wood and wood products, chemical and synthetic products, construction, textile and leather, and other processing industries.

Within the transport sector, 89.9 per cent of energy was consumed by road transport and 6.7 per cent by rail transport. The remaining went to the aviation and marine sector. Within the road transport category, 44.4 per cent energy was used by passenger cars. Trucks accounted for 49.1 per cent and buses accounted for 5.6 per cent of energy demand. The remaining went for motorcycles and tractor.

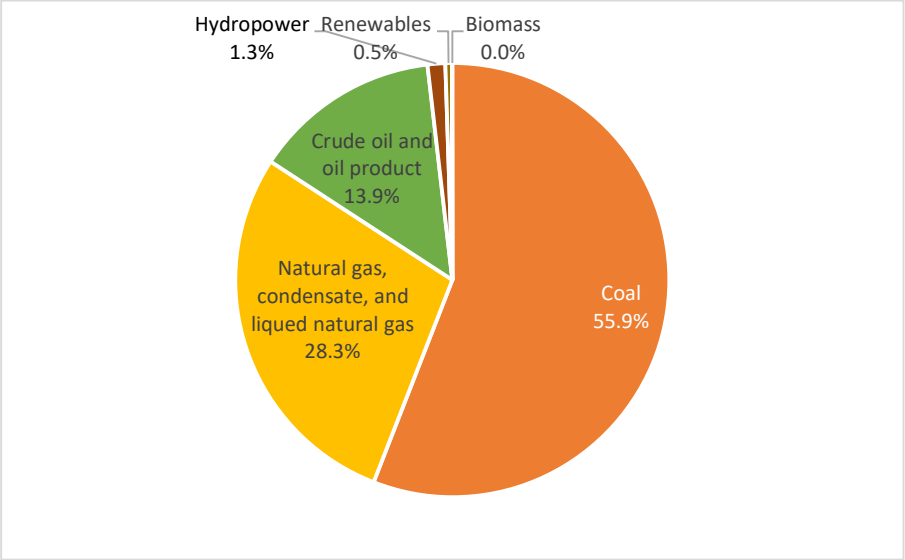
The service sector analysis is based on floor space occupied by the sector and the energy intensity per square metre. However, due to limited information, only the floor space for government building, hospital, and university that could be obtained. In the service sector, government buildings accounted for 27.4 per cent of the energy demand, healthcare facilities at 6.9 per cent, and educational institutions at 0.9 per cent. The remaining 64.8 per cent was used by other types of service sector buildings.

Energy supply: The total primary energy supply (TPES) in 2021 was 59.4 Mtoe, as shown in Figure 4. The energy supply mix was as follows: coal 33.2 per cent, natural gas 16.8 per cent, oil products including condensate 8.28 per cent, hydropower 0.8 per cent, wind and solar 0.3 per cent, and biomass 0.02 per cent.

Power generation: Total installed power generation capacity in 2021 was 23,96 MW. In terms of capacity mix, coal and gas accounted for 81.7 per cent of the capacity. Renewables[7] accounted for 18.8 per cent of capacity of which large hydropower was 10.6 per cent, solar 4.3 per cent, wind 2.8 per cent, and mini hydro was 1.1 per cent. Total electricity generation in 2021 was 114.5 TWh. Thermal power plants accounted for 89.0 per cent of power generation while the remainder came from renewable energy (large hydropower 8 percent, wind 1.5 per cent, and solar 1.4 per cent). Total heat generation in 2021 was 9.4 Mtoe coming from fossil-fuelled CHP and heat-only-boiler (HOB).

[7] Large hydropower is considered as renewables under the SDG 7.2 definition.

Figure 4: Total primary energy supply by fuel in 2021- 59.4 Mtoe



3.5. Energy modelling projections

The energy demand is estimated by using the activity level and energy intensity in the LEAP model. The demand outlook throughout the NEXSTEP analysis period is influenced by factors such as annual population growth and annual GDP growth. The assumptions used in the NEXSTEP modelling are further detailed in Annex II, while Table 1 provides a summary of the key modelling assumptions for the three main scenarios (i.e., BAU, CPS and SDG scenarios).

Table 1. Important factors, targets, and assumptions used in NEXSTEP modelling

Parameters	Business as usual scenario	Current policy scenario	Sustainable Development Goal scenario
Economic growth	3.2 per cent between 2021 and 2022,4.1 per cent between 2022 and 2023, 4.3 percent per annum from 2023[8]		
Population growth	1.6 per cent per annum*		
Urbanization rate	67 per cent in 2021, growing to 68 per cent in 2030[9]		
Service floor space	Assumed annual energy consumption increasing at the same growth as GDP		
Industrial activity	Assumed annual energy consumption increasing at the same growth as GDP		
Transport activity	Passenger transport activities and freight transport activities are assumed growing at a rate like the growth in GDP per capita		

[8] Historical data and estimation from Asian Development Bank
[9] This assumes that the urbanisation rate grows with an annual rate of 0.16 per cent, with reference to the national historical urbanisation growth from 2010 to 2020.

Residential activity	The appliance ownership for electrical appliances is projected to grow at a rate like the growth in GDP per capita.		
Access to electricity	The 100 per cent access to electricity has been achieved.		
Access to clean cooking fuels	Projected based on the historical penetration rate between the 2000-2020 period.100 per cent clean cooking access rate achieved by 2030		
Energy efficiency	Additional energy efficiency measures not applied	Improvement based on current policies	Global improvement in energy intensity adopted
Power plant	Considers 2021 RE share in power generation and grid emissions	Considers capacity expansion provided by national consultant	

3.6. Kazakhstan's energy system projections under the current policy settings

The CP scenario considers initiatives implemented or scheduled for implementation during the analysis period 2021-2030, considering the following two high-level strategies as they have been outlined in national policies. However, NEXSTEP modelling only considers policy measures that have come into force or already have a concrete implementation timeline within the analysis period.[10]

a) **Energy efficiency:** as per the **Governmental Decree No. 264**, reduce the energy intensity of the industry by 10 per cent and energy sector by 5 per cent; the energy consumption per unit area of premises by 10 per cent; the energy consumption per capita by 5 per cent by 2029 from the 2021 level.

b) **Power Generation:** The power capacity expansion plan, obtained from the Ministry of Energy, suggests reaching a total capacity built of 8,328 MW by 2030. This assumes that the expansion plan is carried out according to the planned timeline. The given capacity addition will increase the share of renewable (including large hydropower) in the total installed capacity to 37.6 per cent, where the share of wind generation will increase significantly from 2.8 per cent in 2021 to 16.8 per cent in 2030.

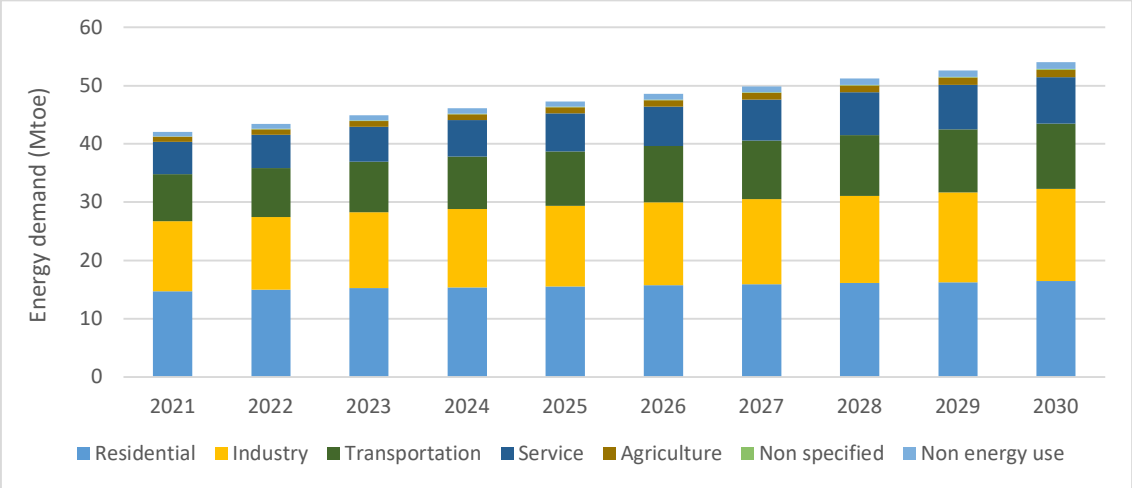
3.6.1. Energy demand outlook

The **total final energy consumption** in the current policy scenario is expected to increase from 42.1 Mtoe in 2021 to 54.04 Mtoe in 2030, an average annual growth rate of 2.8 per cent. TFEC is 2.8 Mtoe lower than the BAU scenario because of the planned implementation of energy efficiency measures in the industry, residential, and service sector as targeted under the energy efficiency concept. In 2030, the residential sector consumption will be the largest at 30.5 per cent, followed by the industrial sector 29.2 per cent, the transport sector 20.8 per cent, and the service sector 14.5 per cent. The agriculture

[10] Only policies with concrete and implemented measures are considered in the scenario modelling for the current policy scenario. To further explain, measures mentioned in strategy policy or planning documents that are yet to be enforced or implemented prior to October 2023 are not considered in the modelling of the current policy scenario.

sector will account for 2.4 per cent, while the remaining will go to non-specific energy use and non-energy use. Figure 5 shows the forecast of TFEC by sector under the CP scenario.

Figure 5. TFEC by sector 2021-2030, CP scenario



(a) Residential

Energy consumption in the residential sector will grow at 1.3 per cent per year to 16.5 Mtoe in 2030 from 14.7 Mtoe in 2021 and will represent 30.5 per cent of total TFEC. The urban and rural split of energy consumption would be 51.5 per cent and 48.5 per cent, respectively. In terms of fuel, natural gas will be the major energy source with 27.9 per cent, followed by coal at 25.6 per cent, energy consumption for heating (largely supplied by natural gas and coal) at 19.2 per cent, oil at 11.7 per cent, electricity 8.7 per cent, LPG at 6.8 per cent and biomass 0.13 per cent.

(b) Industry

TFEC share in the industry sector will be 29.2 per cent at 15.8 Mtoe in 2030. The sub-sectoral demand will be mainly dominated by iron and steel industry (29.2 per cent) and non-ferrous metal industry (25.3 per cent), followed by mining and quarrying industry (14.9 per cent), non-metallic minerals (9.4 per cent), construction industry and chemical industry (6.4 per cent each), food and beverages industry (4.5 per cent), and other industries, including pulp and paper, and machinery and transport equipment industries (3.9 per cent).

(c) Transport

Kazakhstan's transport sector consists of road transport, rail transport, aviation and marine transport. The total energy demand is projected to be 11.3 Mtoe in 2030. It will grow at an annual growth rate of 3.8 per cent per year. Road transport will consume the most 10.2 Mtoe (90.1 per cent), followed by rail transport 0.7 Mtoe (6.0 per cent), aviation 0.2 Mtoe (1.9 per cent) and marine transport 0.1 Mtoe (1.2 per cent). Among the passenger vehicle categories in 2030, private car will consume the most 4.5 Mtoe (87 per cent), followed by bus 0.6 Mtoe (11.1 per cent), tractor 0.06 Mtoe (1.1 per cent), and motorbike 0.04 Mtoe (0.8 per cent).

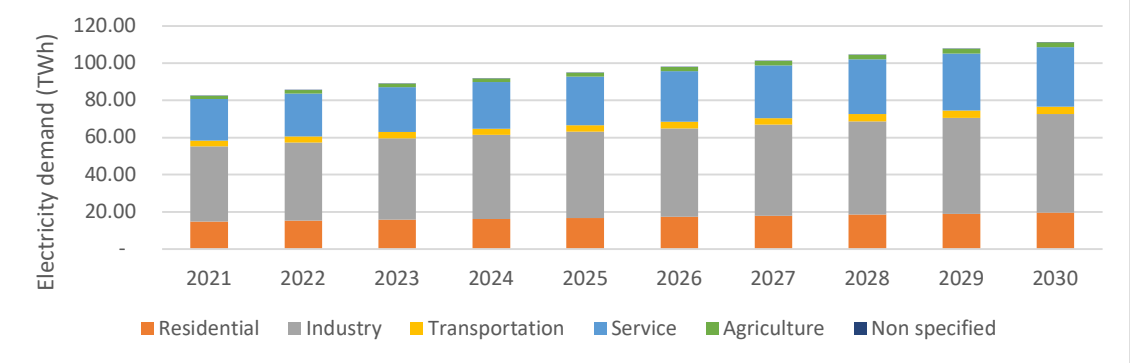
(d) Service and agriculture sectors

The service sector will be the fourth largest energy consuming sector in 2030. Its energy demand will grow from 5.5 Mtoe in 2021 to 8.0 Mtoe in 2030, at an average growth rate of 4.1 per cent per year. Energy consumption in the agriculture sector will grow from 0.9 Mtoe in 2021 to 1.3 Mtoe in 2030, growing at an average annual rate of 4.3 per cent. In terms of fuel, diesel will supply the most (56.5 per cent), followed by electricity (17.1 per cent), coal (10.7 per cent), and the remaining will be supplied by natural gas.

3.6.2. Power sector outlook

The electricity demand is expected to rise from 82.5 TWh in 2021 to 111.4 TWh in 2030 (Figure 6), increasing with an average annual rate of 3.4 per cent. Kazakhstan's electricity supply will be dominated by fossil fuel in 2030 with coal at 57.6 per cent, natural gas 22.4 per cent and the remaining (20.0 per cent) from renewables (mini hydro 8.25 per cent, hydro 4.0 per cent, solar 1.3 per cent, wind 6.3 per cent and biomass 0.1 per cent). The RE share of electricity supply increases from 5.6 per cent in 2021 to 20.0 per cent in 2030. The total electricity requirement (considering both final energy demand and transmission & distribution losses of 10 per cent) will be 230.0 TWh in 2030.

Figure 6. Electricity demand by sector 2021-2030, CP Scenario



3.6.3. Energy supply outlook

In the current policy scenario, TPES is forecast to increase from 67.6 Mtoe in 2021 to 79.1 Mtoe in 2030. The fuel shares in 2030 are projected to be coal 29.5 Mtoe, natural gas 21.3 Mtoe, oil products 21.6 Mtoe and renewables (including hydro, solar, wind and biomass) 3.9 Mtoe.

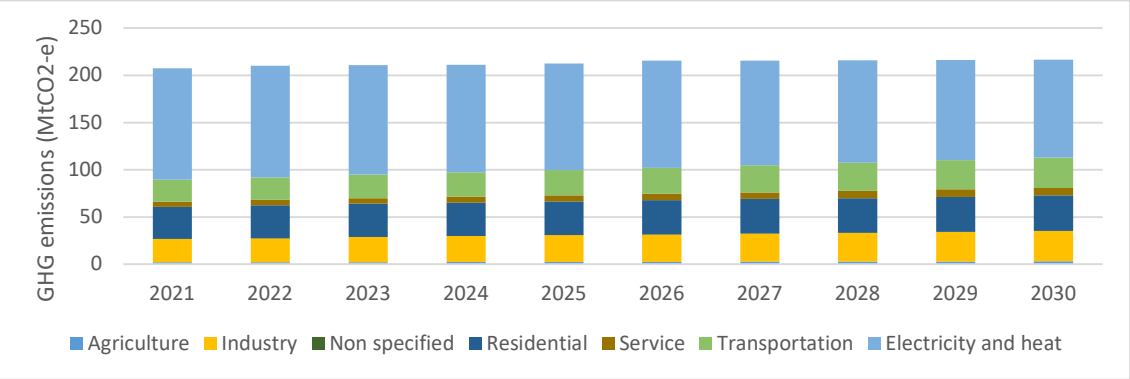
3.7. Energy sector emissions outlook

The energy sector emissions, from the combustion of fossil fuel, is calculated based on IPCC Tier 1 emission factors assigned in the LEAP model and expressed in terms of 100-year global warming potential (GWP) values. For the combustion of biomass and biomass products, the carbon emissions are not attributed to the energy sector but are accounted in the agriculture, forest and land use change

(AFOLU)[11] as per the accounting system suggested by IPCC. Nevertheless, the emissions of other GHGs such as methane and nitrous oxide are included in the total emissions in the energy sector.

GHG emissions from the energy sector are estimated to increase to 216.5 $MtCO_{2\text{-}e}$ in 2030. Power and heat generation emissions will be the largest at 103.4 $MtCO_{2\text{-}e}$. It is followed by the residential sector at 37.4 $MtCO_{2\text{-}e}$ coming from solid fuel combustions for cooking and space heating. The emissions attributable to the industrial sector are estimated at 32.3 $MtCO_{2\text{-}e}$ (Figure 7). The transport sector emissions will be 32.3 $MtCO_{2\text{-}e}$ arising from direct fuel combustions in internal combustion engines. The service and agriculture sector emissions together will be around 12.1 $MtCO_{2\text{-}e}$.

Figure 7. GHG emissions, CP scenario



[11] AFOLU sector is not within the scope of NEXSTEP.

4. SDG scenario – achieving SDG 7 by 2030

Access to affordable, reliable, sustainable and modern energy is essential to achieving the 2030 Agenda for Sustainable Development and the Paris Agreement on climate change. Kazakhstan has already achieved a 100 per cent access rate. Nonetheless, small gaps still need to be closed in order to allow the achievement of all SDG 7 targets, specifically the energy efficiency and clean cooking targets, with measures recommended in the SDG scenario.

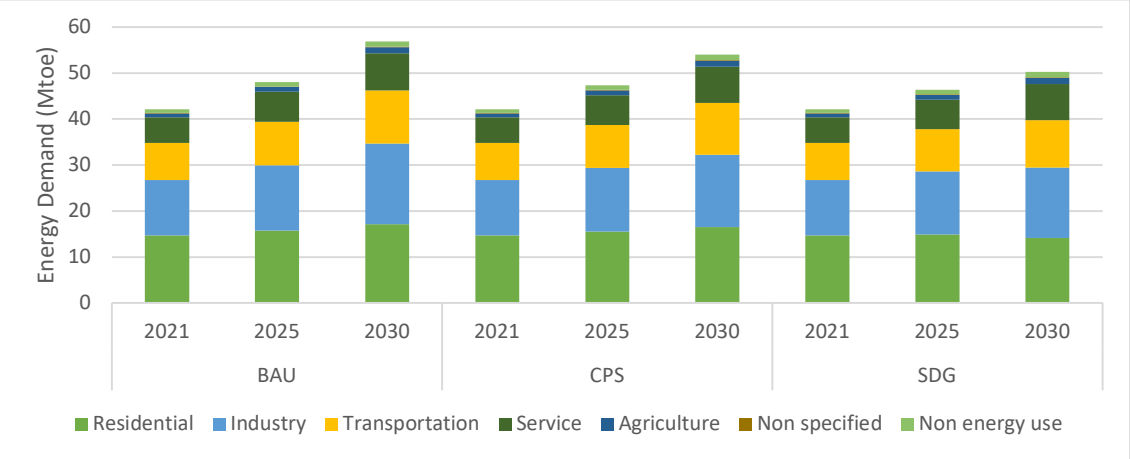
Additionally, it addresses the opportunities in phasing out unclean heating technologies in the residential sector. While clean heating is not specifically addressed in SDG 7 targets, yet it is an important issue in the Central Asian region, which contributes towards indoor air pollution and associated health impacts. A substantial amount of Kazakhstan's population relies on traditional solid fuel heating stove, particularly low-income households, making them susceptible to the consequences of inadequate heating and increased risks of respiratory illness (World Bank, 2014). The SDG scenario looks at two different clean heating technologies – High Efficiency Low Emissions (HELE) solid fuel stoves and heat pumps in achieving the goal. The following presents the main scenario findings considering the adoption of HELE stoves, unless stated otherwise (such as in Box 3).

This chapter further details the SDG scenario, starting with the energy demand forecast, and then discusses the energy sector in relation to SDG 7 targets.

4.1. SDG energy demand outlook

In the SDG scenario, TFEC increases from 42.1 Mtoe in 2021 to 50.2 Mtoe in 2030. In 2030, the industry sector will become the largest energy consuming sector at 15.3 Mtoe (30.6 per cent), followed by the residential sector (14.1 Mtoe, 28.1 per cent), the transport sector (10.4 Mtoe, 20.6 per cent), the service sector (7.8 Mtoe, 15.6 per cent), the agriculture sector (1.3 Mtoe, 2.6 per cent), non-energy usage (1.2 Mtoe, 2.4 per cent), and non-specified sector (0.1 Mtoe, 0.3 per cent). Figure 8 shows the projected TFEC by sector under the SDG scenario.

Figure 8. Comparison of TFEC by sector 2021-2030 for BAU, CP and SDG scenarios



4.2. SDG 7 targets

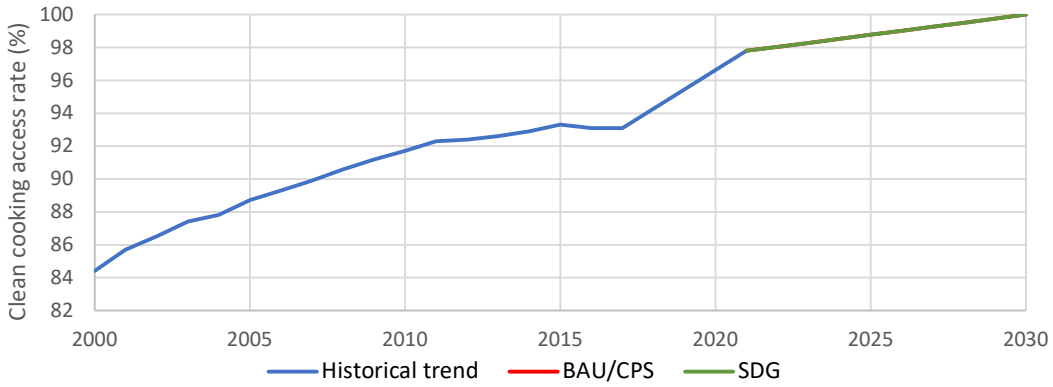
4.2.1. SDG 7.1.1 – access to electricity

Access to affordable, reliable, sustainable, and modern energy is essential to achieving the 2030 Agenda for Sustainable Development and the Paris Agreement on climate change. Kazakhstan has achieved a 100 per cent electricity access rate in the current policy scenario.

4.2.2. SDG 7.1.2 – access to clean fuels and technologies for cooking

As of 2021, 2.2 per cent of households relied on polluting cooking technologies, specifically solid fuel stoves (assuming biomass and charcoal as a primary fuel). This value is slightly lower compared to WHO data of 6 per cent in 2021. Assuming the growth rate is similar to the WHO rate, universal access to clean cooking fuels and technologies will be achieved in all scenarios by 2030 (Figure 9).

Figure 9 Kazakhstan's access to clean cooking in the BAU, CPS and SDG scenarios



Natural gas and LPG cook stoves will still play a role in Kazakhstan households since natural gas can provide the required heating energy. Electric cook stoves, however, provide the most appropriate solution for Kazakhstan in the long run due to cost and environmental effectiveness since the technology has been adopted widely in the country. Table 2 summarises the estimated annualized cost of different cooking technologies in Kazakhstan.

Table 2. The annualized cost of cooking technologies

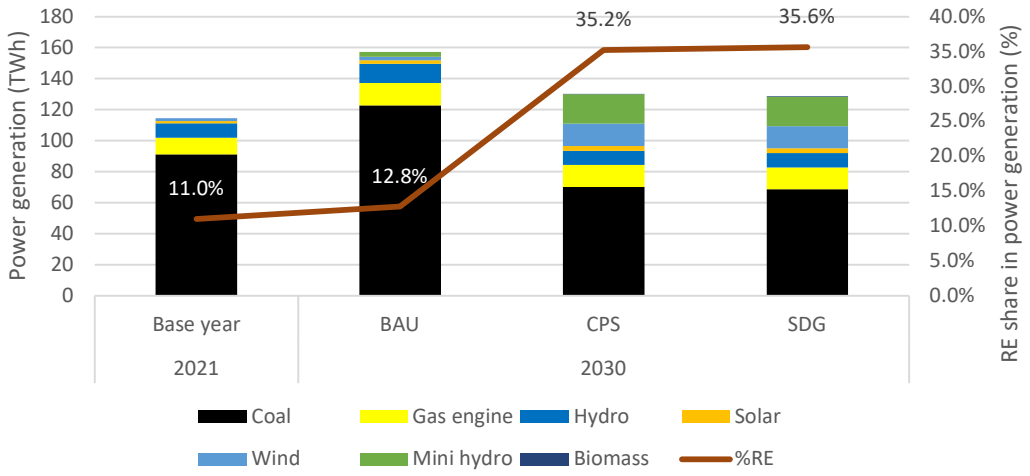
Technology	Annualized cost
Electric cooking stove	US$ 68
Natural gas stove	US$ 116
LPG stove	US$ 100

4.2.3. SDG 7.2 – renewable energy

SDG 7.2 does not have a quantitative target but encourages a "substantial" increase of **the renewable energy share in TFEC.** The share of renewable energy (excluding traditional biomass usage) in TFEC

in 2030 will be 6.3 per cent in the CP scenario. This increase is attributable to the higher share of renewable energy (including large hydropower) in power generation. Kazakhstan will be able to increase the renewable share in power generation from 11 per cent to 35.2 per cent as per capacity expansion plan (Figure 10). In the SDG scenario, the share of modern renewable energy in TFEC will increase slightly to 6.8 per cent due to the phasing out of traditional biomass, which will negatively impact on the RE share in TFEC.

Figure 10: power generation comparison in the base year, CPS and SDG scenarios 2030



4.2.4. SDG 7.3 – energy efficiency

A doubling of the 1990-2010 improvement rate is required to achieve the SDG 7.3 target. As discussed in Box 2, Kazakhstan is suggested to achieve a global improvement rate of 3.4 per cent between 2021 and 2030. Consequently, the energy intensity in 2030 would need to be 4.3 MJ/US$$_{2017}$.

Under the CP scenario, the energy intensity will be around 4.7 MJ/US$$_{2017}$, which is a 2.4 per cent average annual drop from the 2021 value of 5.8 MJ/US$$_{2017}$. This is a significant improvement due to the planned implementation of energy efficiency concept, which NEXSTEP projects that 3 Mtoe energy reduction can be achieved under the current policy scenario.

Box 2: Energy efficiency improvement target for Kazakhstan explained

Energy intensity under SDG 7.2 is defined as the ***total primary energy supply*** (TPES) in megajoules per US$ of gross domestic product in terms of power purchase parity in 2017. Kazakhstan's energy intensity in 2021 is estimated to have been 5.8 MJ/US$$_{2017}$. Energy intensity in Kazakhstan has declined at an average annual rate of 2.4 per cent between 1990 and 2010 from 13.9 MJ/US$$_{2017}$ to 8.6 MJ/US$$_{2017}$. A doubling of the 1990-2010 improvement rate is required to achieve the SDG 7.3 target, which requires an average annual rate increase of 4.7 per cent between 2010 and 2030 reaching 3.3 MJ/US$$_{2017}$ in 2030. However, between 2010 and 2021, the annual improvement rate was only around 3.5 per cent (Figure 11). To reach the required 2030 intensity, the annual

improvement rate between 2021 and 2030 would need to be around 6.2 per cent, which is quite challenging. Therefore, NEXSTEP analysis suggests that Kazakhstan's energy intensity target to be aligned with the global target of 3.4 per cent annual improvement (UNSD, 2022). This corresponds to a 2030 energy intensity target of 4.3 MJ/US$$_{2017}$$.

Figure 11: Kazakhstan energy efficiency target

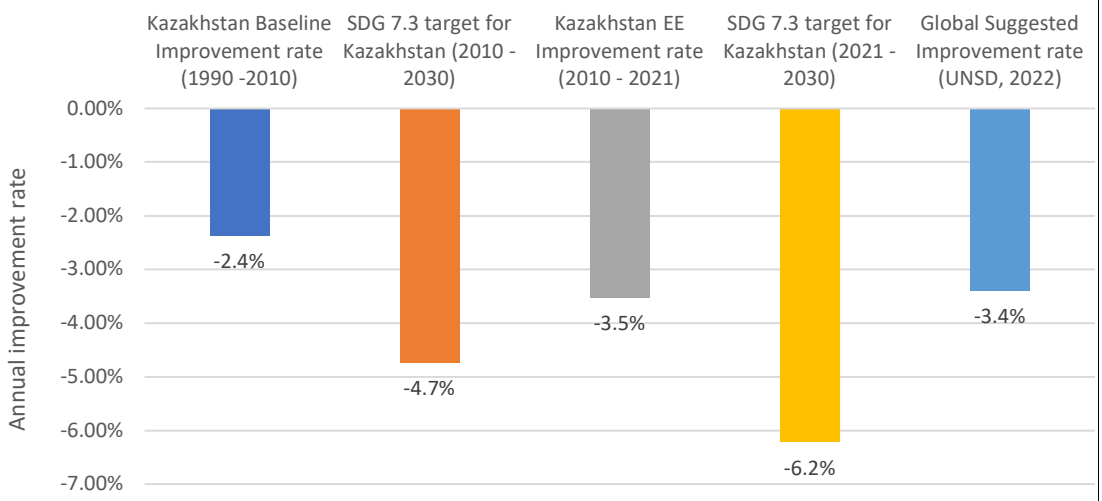


Table 3 lists different energy-saving opportunities measures under the CP scenario.

Table 3. Energy saving under the CP scenario compared to the BAU scenario.

Sector	Measure	Energy demand reduction in 2030 (Mtoe)
Residential	The development of energy-efficient building construction, for which the requirements for energy efficiency of building materials, products and structures will be revised and measures will be developed to stimulate the construction of high-class energy efficient facilities, simultaneously raising the awareness of citizens.	0. 65
Transportation	Updating the public vehicle fleet and increasing its number in the most densely populated cities of Kazakhstan while implementing eco-driving and operational transport monitoring system.	0.32
Industry	Financing measures for modernizing technological processes and equipment and introducing energy-saving measures in all industries, which will reduce physical wear and tear by at least 10 per cent and increase the efficiency of existing equipment.	1.75

Service	Increasing in the share of purchased energy efficient equipment will be ensured by monitoring public procurement of goods, works and services for compliance with energy efficiency requirements, as well as establishing administrative liability for their violation.	0.11
Total		2.84

This saving, however, fails to achieve the SDG 7 target by a small margin. NEXSTEP analysis finds that Kazakhstan can improve its energy intensity in 2030 further to 4 MJ/US$$_{2017}$, meeting the global energy efficiency target for SDG 7. An additional 3.9 Mtoe of energy demand reduction can be achieved through several measures, as discussed below.

Firstly, the adoption of minimum energy performance standards (MEPS) will be beneficial to reduce the electricity consumption for lighting, refrigeration, and television (the three appliances with the largest energy consumption). In terms of heating, further improvement of energy intensity in urban areas can be achieved by deep retrofitting while improvement of thermal efficiency in rural areas can also be introduced by improving insulation. In terms of residential heating technology, the utilization of coal-fired stove must be phased out in urban areas and replaced by more sustainable heating such as natural gas boiler and district heating. In rural areas, improved coal boiler with higher efficiency than coal-fired stove can be adopted. This will result in additional energy-saving opportunities in the residential sector under the SDG scenario, compared with the CP scenario, as shown in Table 5.

Table 4. Additional energy saving in the residential sector – SDG scenario compared to CP scenario

Sector	Measure	Energy demand reduction in 2030 (Mtoe)
Residential Heating	Deep thermal retrofitting in urban areas and insulation improvement in rural areas while simultaneously phasing out coal-fired stoves in urban area with district heating and natural gas heater. Introduction of improved coal boiler in rural areas to reduce coal and fuelwood heating.	2.17
Residential MEPS	Increase the adoption of energy efficient lighting, refrigeration, and television.	0.20
Total		**2.37**

According to the green economy concept document, recent energy audits demonstrated energy efficiency improvement potential of 15-40 per cent (Office of the President of the Republic of Kazakhstan, 2013). NEXSTEP found that at least 20 per cent heat reduction can be further achieved in both service and industry sectors (**Table *6***). In the service sector, further improvement of energy intensity in service buildings can be achieved by extensive deep retrofitting to the building. The same measures can also be implemented in the industrial sector. Furthermore, at least 15 per cent of

electricity savings can be achieved by just doing motor replacement, oversizing correction, variable speed driver (VSD) installation, and digitisation (de Almeida, Ferreira, & Fong, 2023).

Table 5. Additional energy saving in the service and industry sectors – SDG scenario compared to CP scenario

Sector	Measure	Energy demand reduction in 2030 (Mtoe)
Service	External insulation of service buildings to achieving at least 20 per cent energy saving in heating.	0.11
Industry	Improvement of 15 per cent efficiency of electricity and 20 per cent of thermal demand.	0.45
Total		**0.56**

The Government can significantly reduce the transport energy demand by promoting the utilization of electric vehicle in the country. NEXSTEP analysis suggests that at least 15 per cent of electric cars and 5 per cent electric buses penetration might reduce the energy demand by around 0.54 Mtoe. The target for passenger cars must be higher since a significant amount of energy demand is used by this category. The government may initially replace the government's fleet of cars with electric vehicle before promoting the electric vehicle to a wider public.

Additionally, since the energy consumption of freight trucks is also quite high, at least 10 per cent of electric trucks (as shown in Table 6) and 20 per cent of hybrid trucks might be introduced by 2030. Electrification of heavy trucks is challenging because of its competition with the long range of diesel trucks. However, it is expected that electrification of freight truck might also become an economically feasible option. In terms of infrastructure, the Government may start developing charging facilities in urban areas first since the mobility is concentrated in this area.

Table 6. Additional energy saving in the transport sector – SDG scenario compared to CP scenario

Transport category	Measure	Energy demand reduction in 2030 (Mtoe)
Passenger transport	Electric cars penetration by 15 per cent and electric buses penetration by 5 per cent in 2030.	0.54
Freight Transport	10 per cent of electric trucks penetration in 2030.	0.36
Total		**0.90**

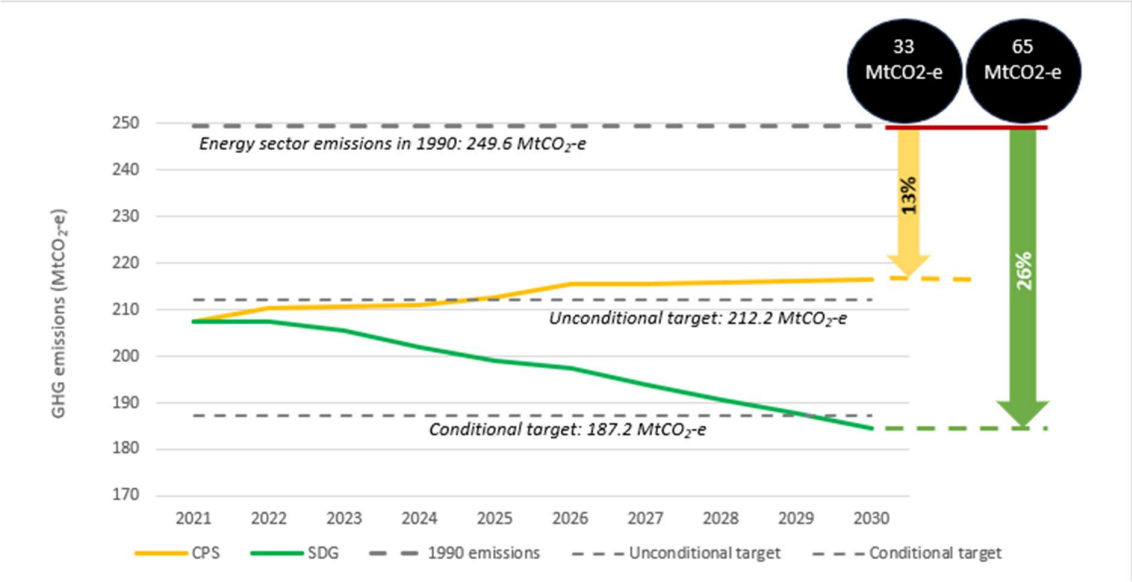
4.2.5. GHG emissions

Emission analysis in this study suggests that the BAU emission in 2030 will be 278.3 $MtCO_2$-e. Kazakhstan has committed to reducing GHG emissions by 15 per cent unconditionally (without international aid) and 25 per cent conditionally compared to 1990 level. In 1990, the energy sector's

emission was 249.6 $MtCO_2$-e. This translates to a cap of 212.2 $MtCO_2$-e for unconditional target and 187.2 $MtCO_2$-e for conditional target. Under the current policy setting, the total emissions are expected to grow to 216.5 $MtCO_2$-e (Figure 12) or a 13 per cent emission reduction compared to 1990 level, falling short by a small margin to achieve the unconditional NDC target despite a significant decrease in GHG emissions, relative to the BAU scenario, due to increase of renewables share in electricity supply as per the capacity expansion plan.

Kazakhstan can further enhance its efforts to achieve the unconditional NDC target by accelerating the implementation of energy saving measures in order to align with the global improvement target of 3.4 per cent discussed in the previous section. In the SDG scenario, total emissions are expected to further decrease to 184.6 $MtCO_2$-e by 2030 or an emission reduction of 26 per cent compared to 1990 level, which meets the unconditional NDC target in the energy sector.

Figure 12: Emissions comparison for CP and SDG scenarios

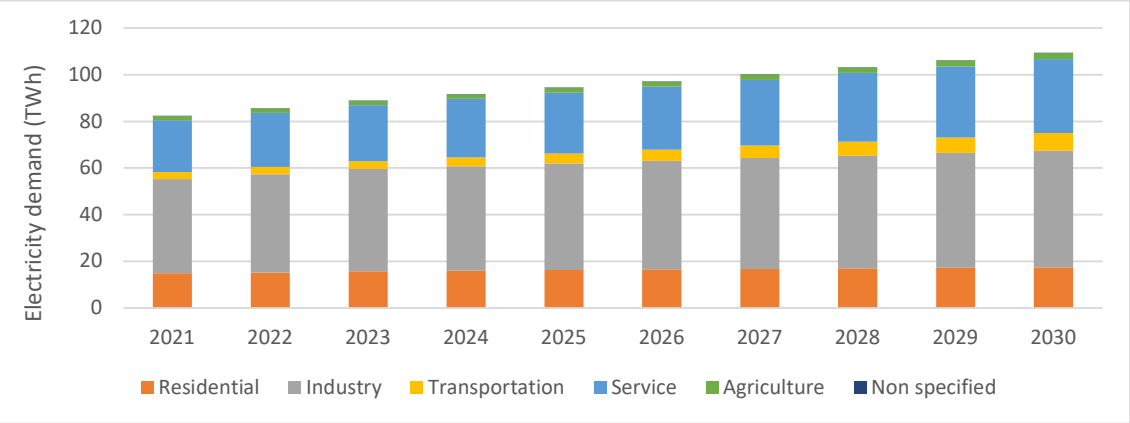


4.3. Power generation in the context of SDG 7

The electricity demand is expected to rise from 82.5 TWh in 2021 to 109.4 TWh in 2030 (

Figure ***13***), increasing with an average annual rate of 3.2 per cent. The power capacity expansion is modelled similar to the CP scenario with expected increase in wind power capacity to 5.4 GW during the analysis period. The total electricity requirement (considering both final energy demand and transmission & distribution losses of 10 per cent) will be 121.6 TWh in 2030.

Figure 13. Electricity demand by sector 2019-2030, SDG scenario



Nuclear power: According to the Concept on Transition towards Green Economy, Kazakhstan considers nuclear power plant as a potential source of power supply. According to the results of Republican referendum on approval of construction of nuclear power station in Kazakhstan held on 6 October 2024, 71.12 per cent of population of Kazakhstan voted for construction. Taking into account that the Road Map considers 2021 as a base year for modelling, nuclear power has not been considered/calculated in this document.

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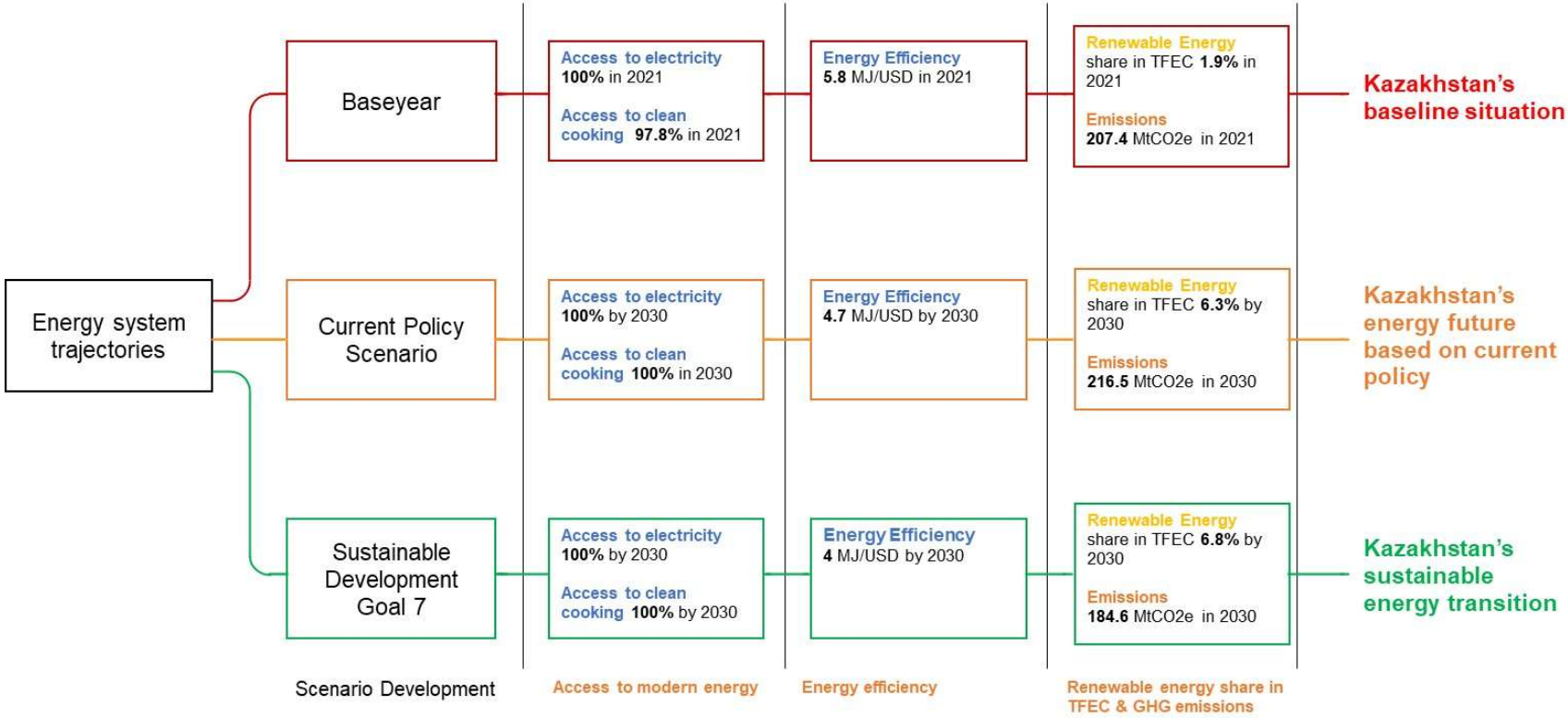
Figure 14 Summary of SDG 7 indicators for CP and SDG scenarios



5. Energy transition pathway with increased ambitions

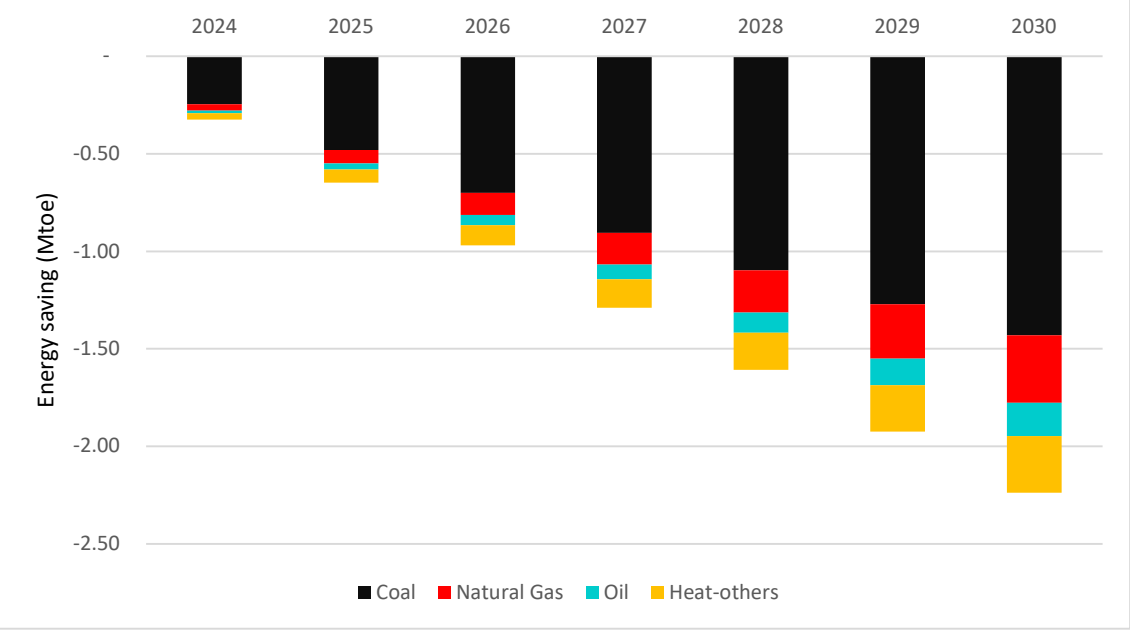
The SDG scenario builds on the current policy settings to provide recommendations for achieving the SDG 7 targets. Further analysis shows that there are ample opportunities for Kazakhstan to raise its ambition beyond just achieving the SDG 7 targets. For example, additional energy efficiency measures can substantially increase energy savings and reduce fuel imports.

5.1. Adoption of sustainable and clean heating in the residential sector

Due to its climatic condition, a significant amount of heat is consumed in Kazakhstan. Most of the demand, however, is supplied from fossil fuel based heating technology. Building on the SDG scenario, the sustainable heating scenario further explores how the country can transition its heating demand and supply side towards cleaner technologies.

Under the SDG scenario, it is expected that at least 14.4 percent of the rural population will still use coal boiler technology by 2030. In this sustainable heating scenario, NEXSTEP suggests phasing out of the remaining inefficient heating technology in the residential sector by promoting electrical heaters and natural gas boilers. In both urban and rural areas, the average natural gas boiler efficiency can also be improved from 75 per cent to 84 per cent (IEA, 2020). Additionally, actual thermal savings may be maximized, up to an estimated 15 per cent, by further insulation measures in roof spaces, basements and windows through deep retrofitting. This will result in 2.2 Mtoe energy saving in the residential sector (Figure 15).

Figure 15 Energy saving in the residential sector through efficient heating system, 2021-2030



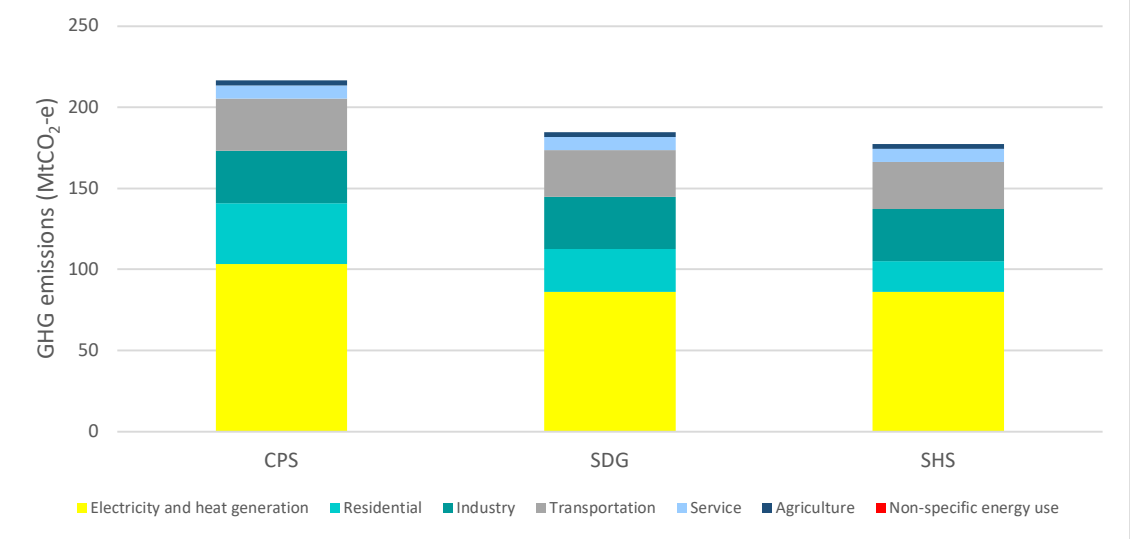
In the supply side, it is also critical to increase the share of renewable energy in heating generation. In 2021, the heating demand is supplied mainly by fossil-fuelled CHP and coal HOB. NEXSTEP analysis

suggests adding of 2.5 GW heat pump to reduce the heat generation from fossil fuel. As a result, this scenario will improve the following indicators:

a) increase the share of renewable energy in heating generation to 20 per cent by 2030, compared to zero per cent in the SDG scenario;
b) increase the share of renewable energy in TFEC to 10.6 per cent by 2030, compared to 6.8 per cent in the SDG scenario;
c) reduce the energy intensity to 3.9 MJ/US$$_{2017}$$ by 2030, compared to 4 MJ/US$$_{2017}$$ in the SDG scenario; and
d) reduce GHG emission to 177.2 $MtCO_2$-e or a reduction of 72.4 $MtCO_2$-e (29 per cent) compared to 1990 level exceeding the conditional NDC target.

Figure 16 compares emissions of different sectors and electricity generation for the current policy scenario, SDG scenario and the sustainable heating scenario.

Figure 16 Comparison of emissions, by scenario, 2030



5.2. Transitioning towards Net Zero by 2050

This scenario explores challenges and opportunities for the Government of Kazakhstan to align its energy sector in line with the global ambition of achieving net zero emissions by 2050. Various stringent measures across different sectors will need to be implemented as we move beyond 2030. The first step would be to plan for full decarbonization of the power sector by 2050. In the demand side, the utilization of 100 per cent electric cooking stove will be needed to achieve by 2050 to fully decarbonize the residential sector. The transport sector will need the adoption of 100 per cent e-mobility. In the service and industrial sectors, fuel switching has a significant role, particularly the switching from fossil-fuel to electricity.

This scenario would save energy demand by around 25.5 Mtoe compared to the CP scenario. However, this scenario requires 678.3 TWh of electricity by 2050, an additional 430.3 TWh, compared to the CP

scenario (Figure 17). Further implementation of energy efficiency would help reduce this electricity demand. In terms of supply, it is estimated that 276 GW of wind power capacity, 15 GW solar power capacity, 4 GW hydropower, and 2.2 GW mini hydro on top of 2.7 GW gas engine are required to fulfil the electricity demand by 2050. In addition to this, 18 GW heat pump will be required to fulfil heat demand.

Figure 17 Comparison of energy demand by scenario in 2050

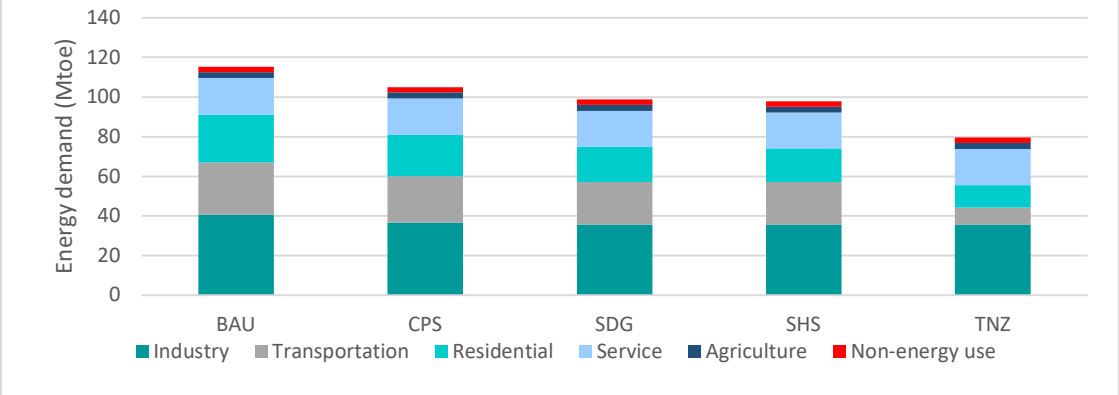
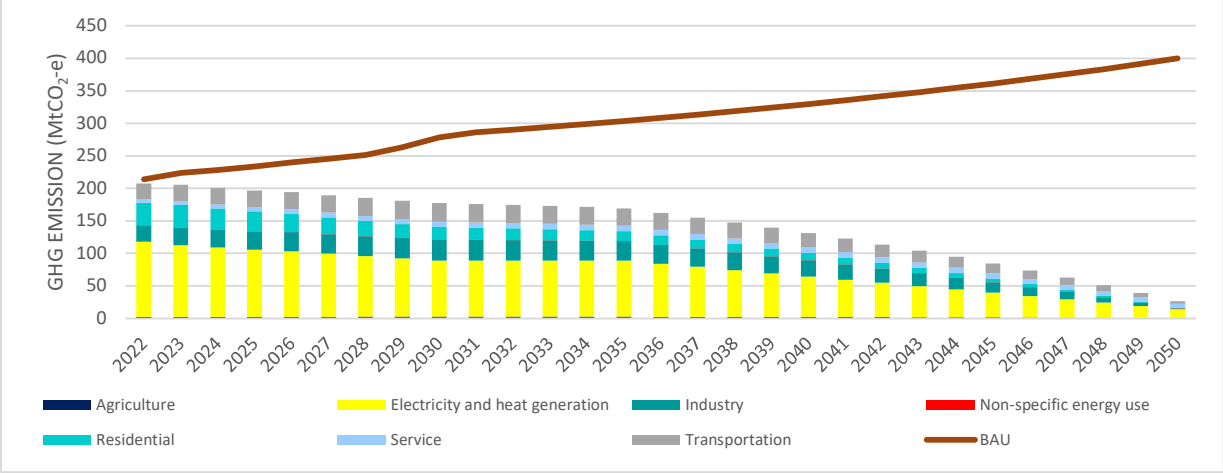


Figure 18 illustrates GHG emission under this scenario. It appears that there will be a significant emission reduction. However, due to certain limitations to implementing measures in the transport sector, a small amount of emission would still be produced. Therefore, carbon sinks, such as reforestation or forest management, or other carbon capture technologies should be considered to absorb the remaining carbon emissions.

Figure 18 GHG emission in the demand sector 2022-2050 by sector, decarbonisation of whole economy scenario



5.3. Policy recommendations to raise ambitions beyond SDG and NDC targets

5.3.1. Increase the efficiency of energy use in all economic sectors

The presence of energy efficiency concept will help Kazakhstan reduce its energy intensity by 2030. Kazakhstan can further increase its energy reduction by 2030 through additional measures under the SDG scenario. The residential sector is the highest energy consuming sector in Kazakhstan. Therefore, the utilization of improved heaters for space heating will significantly help improve energy efficiency and reduce emissions. The more aggressive MEPS adoption and thermal insulation improvement in the residential sector can be implemented to achieve a more sustainable heating system. In addition to the residential sector, industry and commercial service sectors might have significant energy saving potential through deep retrofitting and motor replacement. Very high consumption of fossil fuel in the industry sector will pose a major challenge should the country wishes to pursue the net zero emissions pathway. In terms of decarbonization of the whole economy by 2050, the industrial sector might be a challenge for Kazakhstan since the consumption of fossil fuels is quite high. Therefore, fuel-switching options need to be considered.

5.3.2. Accelerate electrification of the transport sector to reduce emissions and improve energy security

Vigorous adoption of electric vehicles reduces the demand for oil products, hence reducing Kazakhstan's reliance on imported petroleum fuels. At the same time, it can contribute to climate mitigation and improve local air quality. Transport electrification would be critical to decarbonize the passenger transport sector by 2050. An adoption rate of 15 per cent of passenger cars, 5 per cent electric buses and 10 per cent of freight trucks by 2030 has the potential to save energy by 10.92 Mtoe and reduce emissions by 34.5 MtCO2-e.

5.3.3. Decarbonization of the power supply is the key to achieving net zero emissions by 2050

Decarbonization of the power sector is important to prevent shifting of emissions from one sector to the other when implementing policies, particularly on clean cooking and electric vehicles. This would be also needed if the country plans to move towards net zero by 2050. Decarbonization efforts will require a substantial increase in renewable capacities, which could be challenging but it will offer multiple benefits, including reducing emissions and improving energy security through the utilization of indigenous resources. In terms of electricity supply, it is estimated that 276 GW of wind power capacity, 15 GW solar power capacity, 4 GW hydropower, and 2.2 GW mini hydro are required to fulfil the rising electricity demand.

5.3.4. Decarbonize the heating sector to reduce emissions and improve energy security

As can be noted in the sustainable heating scenario, substantial GHG emission reduction is possible through the implementation of efficient and renewable energy-based heating system. Although the required additional capacities could be challenging technically and economically, they will help improve energy security through the utilization of indigenous resources. NEXSTEP analysis suggests 2.5 GW of heat pumps be introduced by 2030, which should increase to 18 GW by 2050.

6. Building back better in the recovery from COVID-19 with the SDG roadmap

Energy plays a key role in rebuilding better in the recovery from the COVID-19 pandemic. Energy services are essential to supporting health-care facilities, supplying clean water for essential hygiene, enabling communication and IT, and off-grid renewables refrigeration for vaccine storage. Economic challenges resulting from the pandemic have the potential to force countries in the Asia-Pacific region to focus on short-term fixes to revive GDP growth, potentially undermining long-term sustainable development. In the energy sector, this can result in the decline of investment in clean energy development – slowing progress on renewable energy and energy efficiency, and eventually, impeding national economic growth.

The COVID-19 pandemic has caused social and economic devastation globally, including in Kazakhstan. Kazakhstan GPD shrank in 2020 due to the COVID-19 pandemic (Asian Development Bank, 2022). While grappling with the devastation caused by pandemic, Kazakhstan should not lose sight of its progress and ambitions towards achieving the SDGs and NDC targets. Kazakhstan should build back better from this crisis, to become more resilient to face future challenges such as climate change.

Thus, it has never been more important to design a well-planned energy transition pathway that enables the country's energy sector to shield itself from the likely impacts of the COVID-19 pandemic and helps in the recovery to build back better. The SDG 7 roadmap has identified several key areas that will assist policymakers in strengthening policy measures to help recover from the COVID-19 impact while maintaining the momentum to achieving the 2030 Agenda for Sustainable Development and the Paris Agreement.

6.1. Accelerating access to clean and modern energy services

Access to clean and modern energy services is essential in helping rural populations to combat challenges related to COVID-19. Relying on traditional and hazardous technologies for cooking increases their susceptibility to the effects of the virus. It is important to consider how these seismic shifts in the energy sector from COVID-19 affect the most vulnerable people.

Kazakhstan had around 2 per cent of the population lacked access to clean cooking fuel in 2021. In addition to that, a substantial number of populations is relying on unclean heating solutions. One medium-term impact of COVID-19 could be decreased investment in energy access, as national budgets come under strain and priorities shift. Additionally, access to clean cooking and heating technologies is a major development challenge that is often forgotten. WHO has warned about the severity of health impacts arising from the exposure to traditional use of biomass for cooking and space heating, and is encouraging policymakers to adopt measures to address this challenge.

The SDG 7 roadmap has analysed and identified technical options for connecting the remaining population to cleaner fuel for cooking and heating. The benefits resulting from this measure, in the form

of reduced mortality and health impact, will exceed the needed investment to advance the clean cooking rate and clean heating rate to 100 per cent.

6.2. Savings from the energy sector will help to build other sectors

The NEXSTEP analysis shows that there are ample opportunities for Kazakhstan to save energy by improving energy efficiency beyond the current practices. Several of these measures also provide cost savings and strengthen the country's energy security, making it less susceptible to fuel supply and price shocks. Savings from this improvement can help investment in other sectors, such as health, social protection, and stimulus, which are critical in responding to, and recovering from the COVID-19 pandemic. Increasing renewable power capacity with the aim of cross-border power trade also provides new sources of income for the country. Such measures are very important to solidifying the pathway to recovery from COVID-19 and building back better.

6.3. Long-term recovery planning to build back better while ensuring sustainable growth

The COVID-19 pandemic has caused unprecedented socio-economic impacts around the world. On the brighter side, many countries have taken this opportunity to "reset" their economies. For example, the World Economic Forum has launched the Great Reset initiative, to encourage economic transformation and building a better society as the world recovers from the global health-care crisis (World Economic Forum, 2020), and the European Commission has placed the European Green Deal at the heart of their long-term sustainable recovery from the pandemic (European Commission, 2020b). This may be an opportunity for Kazakhstan to re-examine its economic structure and leverage the potential of climate-smart sectors.

7. Scenario ranking

The current policy, SDG and the ambitious scenarios have been evaluated and ranked, using the Multi Criteria Decision Analysis (MCDA) tool, with a set of 12 criteria and weights assigned to each criterion (Table 7). While the criteria and weights have been selected based on expert judgement, ideally the process should use a stakeholder consultation. If deemed necessary, this step can be repeated using the NEXSTEP tool in consultation with stakeholders where the participants may want to change weights of each criterion. The following factors have been considered to assume comparative weights across the set of criteria, where the total weight needs to be 100 per cent:

(a) Universal access to electricity to be achieved.
(b) Universal access to clean cooking fuel to be achieved.
(c) Renewable energy share in the total final energy consumption to increase.
(d) Energy efficiency improvement should be doubled, and where there is an economic benefit it should be further enhanced.
(e) The unconditional NDC target should be achieved. Where possible, the conditional target should be achieved and, if it is economically viable.
(f) Total investment should be kept low, but the net benefit should be high. This was done by assigning both indicators the same weight to ensure that a scenario is chosen on the value-for-money basis.
(g) Carbon pricing should be introduced to encourage investments in clean energy.

Table 7. Criteria with assigned weights for MCDA

Criterion	Weight
Access to clean cooking fuel	10%
Energy efficiency	10%
Share of renewable energy	11%
Emissions in 2030	10%
Alignment with PA	10%
Fossil fuel subsidy phased out	5%
Price on carbon	5%
Fossil fuel phase-out	5%
Cost of access to electricity	7%
Cost of access to clean cooking fuel	7%
Investment cost	10%
Net benefit from the power sector	10%

Table 8 shows the summary of results obtained through this evaluation process. The scenario recommendation suggests that the ambitious scenario, “renewable energy diversification” scenario, is the highest-ranked energy transition pathway for Kazakhstan.

Table 8. Scenario ranking based on MCDA

Scenarios	Weighted scores	Rank
Net Zero by 2050 scenario	52.2	1
Sustainable heating scenario	46.8	2
SDG scenario	45.0	3
Current policy scenario	43.4	4
Business-as-usual scenario	17.0	5

8. Conclusion

The 2030 Agenda for Sustainable Development and Paris Agreement provide a common goal for all countries to achieve sustainability and climate objectives. Achieving the SDG 7 and NDC targets is not an easy feat, but it will help to create a more sustainable and resilient society. This roadmap has presented several different scenarios together with their technical feasibility, investments, benefits, challenges and opportunities to inform policymakers of different pathways to energy transition. NEXSTEP has also looked beyond just achieving SDG 7 targets and have explored the full potential of the country in relation to advancing energy efficiency and achieving the country's conditional national target.

Kazakhstan has already achieved 100 per cent electricity access rate and is very close to achieving the same for clean cooking. The major concern of the energy sector of Kazakhstan is the heavy reliance on coal-based power generation. More than three quarters (77 per cent) of electricity was generated from coal in 2021 and another 17.4 per cent was generated from natural gas. This puts a challenge to achieving the unconditional NDC by 2030 under the current policy scenario. To address this challenge, in the SDG scenario, enhanced energy efficiency measures have been suggested along with the increase in renewable energy-based electricity generation target.

Ample opportunities exist in the residential, industrial, commercial, and agricultural sectors to save a substantial amount of energy through the implementation of energy efficiency measures. The residential sector provides the biggest energy saving potential and should be the focus, particularly via deep thermal retrofitting in urban areas, insulation improvement in rural areas, replacing coal-fired stoves with district heating in urban areas and introducing improved coal boiler in rural areas. The adoption of higher energy efficiency measures in the industrial sector would help save about 450 ktoe by 2030 in the SDG scenario, compared to the current policy scenario.

Kazakhstan has the potential to increase its ambition beyond what is needed for the SDG 7 energy efficiency target and to further reduce energy consumption and emissions. The sustainable heating scenario suggests replacing inefficient heating technologies in the residential sector with electric heaters and natural gas boilers. Some low and no-cost measures, such as by installation of insulation in roof spaces, basement and windows through retrofitting, have the potential reduce energy consumption by 15 per cent. Looking beyond 2030 and moving towards Net Zero by 2050, Kazakhstan would be able to save 25.5 Mtoe energy. The Net Zero approach will require (a) decarbonisation of the power sector and (b) converting all energy consumption to electricity. This will require an additional 478 TWh electricity by 2050, compared to the CP scenario. This additional electricity supply will require 276 GW of wind power capacity, 15 GW solar power capacity, 4 GW hydropower and 2.2 GW of mini hydro. In addition to this, 18 GW heat pump will be required to fulfil heat demand.

Finally, the energy transition pathway presented in this SDG 7 roadmap will support rebuilding better after the COVID-19 pandemic. The proposed energy transition presents opportunities to reduce

economic risks, both for public and private investment, and identifies areas for financial savings in the energy sector that can support the recovery of other critical sectors, such as the health sector.

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Annexes

I. National Expert SDG 7 tool for energy planning methodology

The analysis presented in this national roadmap is based on the results from the National Expert SDG 7 Tool for Energy Planning (NEXSTEP) project. NEXSTEP is an integrated tool for assisting policymakers make informed policy decisions that will help in achieving SDG 7 and NDC targets by 2030. The SDG 7 and NDC targets are integrated in the LEAP energy model and backcasted from 2030, since the targets for 2030 are already defined.

Annex table 1. Targets and indicators for SDG 7

Target	Indicators	2021	2030
7.1. By 2030, ensure universal access to affordable, reliable, and modern energy services.	7.1.1. Proportion of population with access to electricity.	100%	100%
	7.1.2. Proportion of population with primary reliance on clean fuels and technology for cooking.	97.8%	100%
7.2. By 2030, increase substantially the share of renewable energy in the global energy mix.	7.2.1. Renewable energy share in total final energy consumption.	1.9% (excluding traditional biomass)	6.8% (excluding traditional biomass)
7.3. By 2030, double the global rate of improvement in energy efficiency.	7.3.1. Energy intensity measured as a ratio of primary energy supply to gross domestic product.	5.8 MJ/US$ (2017) PPP	4.0 MJ/US$ (2017) PPP

SDG 7.3. Energy Efficiency. "By 2030, double the global rate of improvement in energy efficiency", as measured by the energy intensity of the economy. This is the ratio of the total primary energy supply (TPES) and GDP. Energy intensity is an indication of how much energy is used to produce one unit of economic output. As defined by the IEA, TPES is made up of production, plus net imports minus international marine and aviation bunkers plus stock changes. For comparison purposes, GDP is measured in constant terms at 2017 PPP.

$$Primary\ energy\ intensity = \frac{Total\ Primary\ Energy\ Supply\ (MJ)}{GDP\ (USD\ 2017\ PPP)}$$

$$CAGR = \left(\frac{EI_{t2}}{EI_{t1}}\right)^{\frac{1}{(t2-t1)}} - 1$$

where EI_{t1} is energy intensity in year t1 and EI_{t2} is energy intensity in year t2.

Base period improvement rate for Kazakhstan (1990 – 2010): 2.37 per cent.

SDG 7.3. improvement rate for Kazakhstan (suggested global improvement rate): 3.4 per cent.

SDG 7.2. Renewable Energy

Methodology: Share of renewable energy in total final energy consumption, where TFEC is total final energy consumption, ELEC is gross electricity production and HEAT is gross heat production.

$$\%TFEC_{RES} = \frac{TFEC_{RES} + \left(TFEC_{ELEC} \times \frac{ELEC_{RES}}{ELEC_{TOTAL}}\right) + \left(TFEC_{HEAT} \times \frac{HEAT_{RES}}{HEAT_{TOTAL}}\right)}{TFEC_{TOTAL}}$$

II. Key assumptions for NEXSTEP energy modelling

(a) General parameters

Annex table 2. GDP, PPP, and growth rate

Parameter	Value
GDP (2021)	197.1 million
Growth rate[12]	2021 - 2022: 3.2%; 2022 - 2023: 4.1%; 2023 - 2030: 4.3%

Annex table 3. Population, population growth rate and household size

Parameter	Value
Population (2021)	19.8 million
Population growth rate	1.6 %
Number of households (2021)	5.08 million
Household size (constant throughout the analysis period)	3.89

(b) Demand-side assumptions

(i) Industry

- The industry sector is further differentiated into 12 sub-categories. The fuel consumption by industry sub-categories is as detailed in the table below.
- The industrial GDP is assumed to grow at an annual rate similar to the national GDP growth rate. The energy intensity is assumed constant throughout the analysis period in the absence of energy

[12] Following historical and projection data up to 2022 using Asian Development Bank data. From 2023 onwards, following the projected GDP on the Industrial Scenario under National Development Strategy

efficiency interventions (i.e. as explored in the Current Policy Scenario and Sustainable Development Goal Scenario).

Annex table 4. Fuel consumption by industry sub-categories in 2021

Industry	Fuel consumption (Mtoe)						
	Coal	Natural Gas	Biomass	Electricity	Oil Products	Heat	Total
Food Beverages and Tobacco	0.04	0.18	-	0.14	0.08	0.14	**0.60**
Chemical and Synthetic Products	0.20	0.31	0.00	0.21	0.02	0.11	**0.84**
Non-Metallic Minerals	0.66	0.15	-	0.15	0.23	0.04	**1.23**
Iron and Steel	1.20	0.31	-	1.23	0.41	0.68	**3.83**
Pulp and Paper	0.00	0.04	-	0.11	0.01	0.02	**0.18**
Textile and Leather	0.00	0.01	-	0.01	0.00	0.00	**0.02**
Mining and Quarrying	0.47	0.32	-	0.51	0.51	0.14	**1.95**
Machinery and Transport Equipment	0.03	0.03	-	0.08	0.01	0.04	**0.19**
Wood and Wood Products	0.00	0.00	0.00	0.01	0.00	0.00	**0.01**
Construction	0.05	0.05	-	0.20	0.50	0.04	**0.83**
Non-Ferrous Metal	1.79	0.01	-	1.10	0.24	0.19	**3.32**
Non-Specified Industry	0.00	0.00	0.00	0.03	0.00	0.07	**0.11**
Total	4.44	1.41	0.00	3.78	2.01	1.46	**13.11**

(ii) Transportation

- Land transport sector consumption is estimated using the vehicle statistics, load factor, annual travel mileage and estimated fuel economy as shown in Table 5. The factors are based on vehicle statistics compiled by the local consultant and assumptions made by ESCAP and the local consultant, as local specific data is scarce.
- Transport activities in 2021 are estimated at 376 billion passenger-kilometres and 243.5 billion tonne-kilometres. The growth in both passenger transport and freight transport activities is assumed growing at the same rate as the population, i.e., 1.6 per cent per annum.

Annex table 5. Transport sector fuel consumption

Passenger Transport	No. of vehicles	Annual mileage (km)	Load Factor (pass-km/veh-km)	Fuel consumption	%share of passenger-km
Passenger Car	3,343,736 (gasoline) 73,867 (diesel) 3,886 (CNG) 491 (electric)	20,000 20,000 20,000	2.5	9.20 km/l 9.20 km/l 9.20 km/l 5.00 km/kWh	45.45%
Bus	52,839 (gasoline) 27,427 (diesel) 2,513 (CNG)	49,500	50	8.50 km/l 8.30 km/l 8.30 km/l	54.42%
Tractor	148,000 (diesel)	1,900	1.8	6.00 km/l	0.13%
Freight Transport	No. of vehicles	Annual mileage (km)	Load Factor (tonne-km/veh-km)	Fuel consumption	%share of tonne-km
Freight Truck	213,322 (gasoline) 225,700 (diesel) 124 (electric) 3,672 (CNG)	50,000	11	5.30 km/l 5.30 km/l 2.0 km/kWh 5.30 km/l	100%

(iii) Commercial sector

- The total annual energy consumption in the service sector is 5.52 Mtoe in 2021. It is projected to grow at an annual rate similar to the national GDP growth rate in the BAU scenario.

Annex table 6. Commercial sector fuel consumption in 2021

Category	Fuel Consumption (ktoe)				
	Coal	Natural Gas	Oil Products	Electricity	Heat
Service	737.6	660.9	352.2	1,908.1	1,856.5

(iv) Residential:

- The residential sector is further divided into urban and rural households. Both urban and rural households have achieved a 100 per cent electricity access rate.
- About 78 per cent of residential demand can be attributed to residential heating. The residential appliance ownership data, and energy use intensity in the baseline year are provided by the ministry through the national consultant.
- The appliance ownership is projected to grow a rate similar to the growth in GDP per capita. The average electrical demand per owning household for the different appliances are assumed constant throughout the analysis period, unless further energy efficiency measures are implemented.

(v) Other sectors

- The remaining demand sectors are 1) non-specified use, 2) agriculture and 3) non-energy use. The energy consumption in 2021 is as detailed in the following table. The consumption growth is projected to grow at an annual rate similar to the national GDP growth rate.

Annex table 7. Consumption from other sectors in 2021

Category	Fuel consumption (ktoe)					
	Coal	Natural Gas	Oil products	Electricity	Heat	Total
Non-specified use	2.0	-	-	9.0	74.0	85.0
Agriculture	104.1	74.7	549.1	166.2	77.2	971.3
Non-energy use	-	224.7	584.4	-	-	809.1

III. Power Technologies Cost and Key Assumptions

The cost parameters considered for the power technologies are as follows:

Annex table 8. Power technologies key assumptions

Technologies	Capital Cost (US$/kW)	Fixed O&M (US$/kW-year)	Variable O&M (US$/MWh)

Coal	2,100	24.6	3.1
Gas	950	12.9	1.3
Solar PV	830	15.0	-
Wind	1,500	60.0	-
Hydro	1,730	34.5	-
Mini hydro	2,222	44.4	-
Biomass	2,420	182.0	-

IV. Economic analysis data for clean cooking technologies

The NEXSTEP economic model utilizes the technological and cost parameters to estimate the. annualised cost of clean cooking technologies. The calculation assumes an annual cooking thermal energy requirement of 3,840 MJ per household (Putti and others, 2015). In addition, a discount rate of 5.37 per cent is assumed.

Annex table 9. Technology and cost data for clean cooking technologies

Technologies	Efficiency[13] (%)	Lifetime[14] (years)	Stove Cost [15](US$)	Variable O&M [16](US$/year)	Fuel Cost[17] (US$)
ICS	35	4	35	10	0.03 per kg
LPG Stove	56	7	56	10	1.05 per kg
Biogas Digester	50	20	950	50	-
Electric Stove	84	15	40	10	0.02 per kWh

V. Summary results for the scenarios for 2030

	CPS Scenario	SDG Scenario	Sustainable heating	Towards Net Zero by 2050
Universal access to electricity in 2030	100%	100%	100%	100%
Universal access to clean cooking in 2030	100%	100%	100%	100%

[13] Sourced from: ICS – own estimation, LPG stove and biogas digester efficiency ranges - (World Bank, 2014), electric cookstove (induction stove) - (IEA, 2012)
[14] Sourced from: ICS – own estimation, LPG stove – (Clean Cooking Alliance, 2021), biogas digester - (Wang & Zhang, 2012), electric stove - (IEA, 2012)
[15] Sourced from: ICS – own estimation, LPG stove and biogas digester – (IRENA, 2017), electric cookstove cost range
[16] Variable O&M is based on own assumptions, with the exception of biogas digester (IRENA, 2017)
[17] Wood cost is assumed opportunity cost related to wood collecting activities, LPG price is based on price quoted for 2020, Electricity price is based on the average residential tariff for 2020

GHG emissions in 2030	216.5 $MTCO_2$-e	184.6 $MTCO_2$-e	177.2 $MTCO_2$-e	177.2 $MTCO_2$-e
Net benefits from the power sector by 2030	US$ 3.46 billion	US$ 3.50 billion	US$ 3.50 billion	US$ 3.50 billion
Total investment for the power sector 2021-2030	US$ 12.99 billion			