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Kazakhstan's Road to Net Zero GHG Emissions

Implementing Agency:

"National Conservation Initiative" Corporate Fund

Edited by: GianCarlo Tosato, Kanat Baigarin

Authored by:

Dauren Zhumabayev, Aidyn Bakdolotov, Rocco De Miglio, Vladimir Litvak, Assel Baibakisheva, Yerbol Sarbassov, Kanat Baigarin

March 2022

УДК 504.03
ББК 20.18
К 26

Editors: G. Tosato, K. Baigarin

Kazakhstan's Road to Net Zero GHG Emissions / Dauren Zhumabayev,
К 26 Aidyn Bakdolotov, Rocco De Miglio, Vladimir Litvak, Assel Baibakisheva, Yerbol Sarbassov, Kanat Baigarin – Nur-Sultan: 2022. – 92 p.

ISBN 978-601-08-1862-0

This work is aimed at studying ways for Kazakhstan to achieve carbon neutrality by 2060 – the course announced by the President of the Republic of Kazakhstan K. Tokayev. The first few chapters explore solutions in the energy, transport, agriculture and waste management sectors. The authors also analyze other issues, such as the carbon trading system, technology transfer, as well as transformation of the financial sector and attracting investment to achieve net-zero targets. Finally, regional cooperation options are being discussed.

The book is intended for experts, employees of scientific organizations and educational institutions, graduates, doctoral students and all those interested in the problems of climate change and carbon neutrality.

УДК 504.03
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ISBN 978-601-08-1862-0

9 786010 818620

ISBN 978-601-08-1862-0

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About Editors

GianCarlo Tosato has been the Operating Agent of the Implementing Agreement on the Energy Technology Systems Analysis Programme (ETSAP), in 2002-2013, within the framework of the International Energy Agency (IEA).

He was an expert at the original MARKal ALlocatian, in 1978. In Poland (1980), he was the first who guessed the partial equilibrium of the linear program, which was completed by Richard Loulou (2000). In 1998, he was a collaborator when the TIMES (The Integrated MARKAL-EFOM System) was presented. Amit Kanudia has, since then, kept alive the TIMES, with the VEDA (VErsatile Data Analyst), Front End (FE) and Back End (BE).

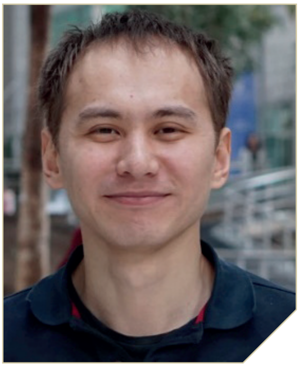
From 1978 up to now, he implanted MARKAL/TIMES programme in Australia, Japan, Kazakhstan, Korea, New Zealand, Russia, USA, and most European countries (Belgium, Denmark, Finland, France, Germany, Greece, Italy, Ireland, Netherland, Norway, Spain, Switzerland, UK).

Kanat Baigarin is currently an Advisor to the President of Nazarbayev University (NU). From 2009 and on he was the Managing Director of Nazarbayev University, Head of the Center for Energy Research founded by him within the new university, Director of the NURIS (NU Research and Innovation System) and Vice-President of NU. He is a member of the Board of Directors of the Kazakhstan Industry Development Institute (KIDI) under the Ministry of Industry and Investment of the Republic of Kazakhstan.

Dr. Baigarin was appointed UNFCCC and IPCC National Focal Point of the Republic of Kazakhstan in 1999. He was a leading negotiator on Kazakhstan's status under the UNFCCC and the Kyoto Protocol 1999-2010. He has been a member of TEC of UNFCCC. In 2001 Dr. Baigarin established "Climate Change Coordination Centre" (C4), which has a status of an observer organization to the UNFCCC.

He served as an international consultant on climate change policy, renewable energy sources issues in the national and regional projects of USAID, WB, UNDP, the Centre on Energy Research (Netherlands), and the Rockefeller Foundation. From 1975 till 1995 Dr. Baigarin had worked at the Russian Research Center: Kurchatov Institute in Moscow, Russia and holds a PhD degree from I.V. Kurchatov Institute of Atomic Energy. He graduated from the Moscow Physical and Technical Institute. Dr. Baigarin is a Fellow of the Leadership for Development and Environment Programme (LEAD) sponsored by the Rockefeller Foundation.

About Authors



Dauren Zhumabayev has MSc in Advanced computational methods for Aeronautics from Imperial College London (2012). Mr. Zhumabayev worked at Nazarbayev University in research laboratory of Energy, Ecology and Climate, where he was responsible for Climate Change in Central Asia research project; Worked in climate modeling and climate projections over Central Asia and Kazakhstan; Prepared Climate change projections over CA region. He also worked as national expert in LULUCF, Agriculture and Waste Management in UNDP Kazakhstan. He developed CBM CFS3 model to model forest GHG emission in Forest.

Aydin Bakdolotov is an experienced energy sector modelling expert with research interests in energy policy, climate change and economic development of Kazakhstan and the Central Asian region. During his professional career, he worked in many different areas such as power industry (combined power plant at Almaty CHP-2), academia (Nazarbayev University), government related bodies such as Economic Research Institute and Zhasyl Damu. He participated in many projects related to mitigation issues of the region, including preparation of nationally determined contributions (NDC), National communications, Biennial reports, Low carbon decarbonization strategy and pathways and many others. In these projects, he mainly took part in analysis, modelling and preparation of the scenarios of energy, climate policies with focus on GHG emissions, energy intensity of GDP, energy efficiency improvements and many others issues. In economic modelling he participated in research related to income, taxes, budget and many other macroeconomic parameters. Currently, he works as the Director of ESG expertise Center at the Economic research institute and participates in the elaboration of low carbon strategy of Kazakhstan. He has publications in national and international journals.

Rocco De Miglio is an Industrial and Management Engineer, with extensive experience in the development of decision support system tools, in the application of different modelling techniques and in the preparation and analysis of energy-climate strategies and plans. He also has long-term experience in the Central Asia Caspian area; he is the lead architect of the energy system model of Kazakhstan, of the multi-country energy system model of the CAC region, and of the associated dashboards. He is the author of a number of publications and studies about energy-related analyses of Kazakhstan and Central Asia, and the designer, administrator and moderator of the "CAC forum" (a knowledge sharing community about Energy and Climate in the Central Asia Caspian region). He is now working as an individual Senior International Expert for consulting services and technical assistances.

Vladimir Litvak is the Head of Carbon Markets and ESG, Climate & Sustainability Finance at VTB Capital, investment banking business of VTB Group. Mr. Litvak also has more than 25 years of experience in financing and managing renewable and clean conventional energy, sustainable infrastructure, environmental and climate change mitigation projects and investments, as well as in developing and implementing ESG, climate, energy, and environmental policies in the US, Russia, Central Asia, Central and Eastern Europe, and Asia. He is one of the pioneers of carbon markets and carbon finance and participated in setting up and sector. Reviewed National Inventory of Kazakhstan in LULUCF, gathered data, developed model and run simulations for CBM CFS3 together with international experts, managing several carbon and green energy funds and finance facilities.

Assel Baibakisheva has Master's degree in Public Administration from the University of Southern California, USA She was an expert at the WTO Department of the Center for Trade Policy Development and since 2012 has been working at Nazarbayev University first at the Central Research Office and later at the International and Research Projects Department of the "Kazakhstan National Geographic Society" Corporate Fund. In 2019 she was appointed as the Director of the "National Conservation Initiative" Corporate Fund.

Yerbol Sarbassov is a postdoctoral scholar at the Chemical & Materials Engineering Department of the School of Engineering and Digital Science at Nazarbayev University. He graduated with an engineering degree from Almaty Institute of Power and Telecommunications and worked in industry for 3 years mainly in the energy industry. He persuaded his MSc program at the University of Nottingham (UK) in 2010. Later completed his PhD degree at School of Engineering of Cranfield University (UK). Since, he has supervised MSc and BSc students at NU and has published 21+ publications. Yerbol also regularly acts as a reviewer for international journals such as Fuel Processing Technology, Journal of Cleaner Production and International journal of Energy & Research and has recently become a new member of the National Scientific Council for the Ministry of Education & Science. His expertise includes areas as clean coal technology, fluidized bed conversion, waste to energy and biomass energy.

Acknowledgement

The authors express acknowledgement to the British Embassy in Nur-Sultan and Nazarbayev University for their support of this project, also to the following experts who contributed to the first phase of the project: Ayimgul Kerimrai and Zhanna Kapsalyamova.

Editor's Note

The negotiation process under the Framework Convention on Climate Change (UNFCCC) on measures and actions to combat climate change is by far the highest achievement of interstate actions to combat the global threat to humanity. Climate change affects the interests of any state on the planet due to the lack of national boundaries for the greenhouse effect in the planet's atmosphere, which is the physical cause of the ongoing climate change.

Since gaining independence, Kazakhstan has faced more important tasks to ensure its own statehood and sustainable self-development. However, in 1995 the country acceded to the Framework Convention on Climate Change (UNFCCC) and in 1999 signed the Kyoto Protocol (KP). Thus, it demonstrated the willingness to participate in the global process of combating climate change. Moreover, in the same year, the country announced at the Conference of the Parties (COP-5) its desire to join Annex 1 of the UNFCCC, which includes only developed countries and a number of countries with economies in transition. This initiative found the support of most of the parties to the Convention, and as a result of difficult negotiations, Kazakhstan managed to determine its status, which was formulated in the decision of the COP-7 in Marrakesh on the status of Kazakhstan. The decision in case of ratification of the Kyoto Protocol opened before the country the prospect of attracting significant investments in the development of renewable energy sources, energy conservation and introduction of efficient technologies in industry and agriculture. Unfortunately, the process of ratifying the KP dragged on until 2009, and all the opportunities for a breakthrough decarbonization of the country's economy were lost. Obviously, this delay was not accidental. There was a tough lobby in the country that was not interested in a sharp change in macroeconomic priorities.

The country returned to this topic again at a high political level already in 2020, when President Tokayev announced Kazakhstan's aspirations for carbon neutrality and its achievement in 2060. Of course, now the conditions for achieving carbon neutrality have changed significantly, and it was necessary in the new conditions to consider scenarios for entering the trajectory of sustainable development within the framework of the Paris Agreement. Starting significant changes in the target macroeconomic guidelines of the state with a time delay of twenty years leads to significant shocks, both in socio-economic life and in the political system.

In September 2020, as a result of discussions on the preparations for COP26 in Glasgow, we, with the support of the British Embassy, decided to launch independent studies to find a zero emissions scenario for Kazakhstan. It was possible to assemble a team of experts and scientists with extensive experience, which studied the possibilities of achieving carbon neutrality. These are scientists and experts from the USA, Italy and Kazakhstan, including professors of Nazarbayev University. I have enjoyed working with this team for the past year and a half, although, of course, I have known each of them for many years and have no doubts about their sincerity towards this topic and their high competence. For the first time, we presented the results at the COP26 in Glasgow, where a side event was organized with representatives of many countries and international organizations. The research results are included here. Perhaps they will finally help to make a decision in favor of choosing a sustainable development strategy for Kazakhstan. And the declared goal of carbon neutrality will be transformed from the declaration into a political goal, a national idea and a practical program of action. Of course, today's price of a high quality of life and the transition to a clean economy is much higher than if we turned to it twenty years ago. And now we can't do without our own significant investments, along with the creation of favorable conditions for external ones.

Significant changes need to be made in the structure of energy production and consumption. In addition to a new approach to energy saving and efficiency, involving renewable energy, it is necessary to review the structure of transmission and distribution of energy resources, take a new approach to energy security and involve alternative energy sources. We cannot do without deeper integration of energy distribution with neighboring countries. It is necessary to reconsider the use of natural gas in the direction of increasing its share. If we are talking about carbon neutrality and «zero» emissions, it is necessary to use our obvious resource – this is the significant involvement of nuclear energy in the energy balance structure. Significant changes also need to be made on the energy consumption side. The analysis shows rather optimistic prospects for achieving carbon neutrality by Kazakhstan than forced pessimism.

Kanat Baigarin

Introduction

In December 2020 President of Kazakhstan Mr. Tokayev announced that Kazakhstan would become carbon neutral country by 2060. This work aims to investigate how to reach carbon neutrality in Kazakhstan and it is a continuation of the "Kazakhstan's Road to Net Zero GHG Emission Vision" project that was initiated when President had declared carbon neutrality aim.

This is a very ambitious aim given that considerable amount of energy in Kazakhstan is generated using coal power plants. The main challenges that are faced by Kazakhstan are high dependence on coal for electricity and heat generation, lack of funds to invest in renewable energy resources, transport, inefficiency of the government spending on mitigation activities, high emissions in cropland.

Kazakhstan will have to find money to cut off coal use and transit to carbon neutral technologies to produce energy in an efficient way with minimal damage to economy. This project investigates how to reach carbon neutrality in the most efficient and cost-effective way. The project develops Kazakhstan's carbon neutrality path using both short and long term vision.

In the context of the COP event held in Glasgow in November 2021, Kazakhstan's approach to carbon neutrality might be interesting to other countries. The results of this work were presented COP 26 in Glasgow, UK.

The report is divided into chapters. First several chapters investigate solutions in Energy, Transport, Agriculture and Waste sectors. Further general issues such as carbon trading system, technology transfer and financial topics are analyzed. And finally regional cooperation options are discussed.

Kazakhstan – Country Profile

Kazakhstan is the ninth largest country in the world that covers more than 2700 million square kilometers [1]. Kazakhstan is bounded by Russia to the North and West, China to the East, Uzbekistan, Kyrgyzstan and Turkmenistan to the South [47]. The area is mostly covered by valleys and steppes. There are mountains in the South-East and East parts of Kazakhstan and there is the Caspian Sea in the West. The population of the country is more than 17 million with about 53.2% living in the urban centers [47].

Considerable remoteness from the oceans and large area makes climate in Kazakhstan be continental with cold winters and hot summers. The average temperature in winter is – 18 °C in the North and – 3 °C in the South. In summer, the temperature changes from +19 °C in the North to +29 °C in the South. Annual precipitation rate varies from 1500 mm in mountainous regions to 200-500 mm in the steppes and 100-200 mm in the deserts. According to the National Meteorological Service [14], the average temperature in Kazakhstan has risen with the rate of about 0.28 degrees Celsius per decade since 1941. The maximum value of 0. 37°C per 10 years is observed in the West Kazakhstan, whereas the least increase is in the South Kazakhstan region (0.24°C every 10 years). Meanwhile the precipitation rate has not changed. Currently the average annual temperature in Kazakhstan is about 0.7 degrees Celsius.

1. Climate Change in Central Asia and Kazakhstan

1.1 Literature Review on Climate Change in Central Asia

Central Asian countries have encountered climate change challenges such as a warming temperature trend and an increased number of weather anomalies [9].

Problems with water resources associated with both poor use and management, precipitation and water discharge changes have already caused the almost total drying up of the Aral Sea [3] and may cause hydropower generation problems [19]. Since agriculture in Central Asian countries is strongly dependent upon precipitation [13], it is considerably sensitive to the consequences of climate change.

National governments in Central Asia have developed adaptation strategies [4]. Kazakhstan’s government has adopted a «green economy» model until 2050 in order to meet the climate change challenges, what involves transition to low carbon development of the economy and use of renewable energy sources [10]. This fact proves the necessity of reliable future climate change projections for policy and decision makers [6].

To the best of authors’ knowledge, there have been few attempts to generate high resolution climate projections using regional climate models over Kazakhstan and Central Asia [16, 15, 11, 12).

Small analyses a precipitation simulation performance of the RegCM2 model over Central Asia [16]. The model captures precipitation anomalies, but it may under-predict or over-predict the mean precipitation. Even though thorough statistical analysis were conducted the simulation spanned across only five years, which considering the year of conduction, gives quite outdate results.

Schiemann [15] systematically compare seasonal mean precipitation between different observational datasets and the regional CHRM model. They conclude that model may capture spatial distribution of precipitation but this differs from seasonal variability of precipitation. It gives a good understanding of performance of the datasets and model; however, no future projections of CHRM are considered.

Mannig [11] assessed the performance of REMO regional climate model (RCM) over the same region. In particular, the annual temperature and precipitation were compared to gridded observations for 1971-2000 periods. The mean summer and winter projections of temperature and precipitation are provided for the three last decades of the twenty first century (2071-2100).

Ozturk [12] validated regional RegCm4.3.5 driven by HadGEM2-ES and MPI-ESM-MR global models against Era-Interim reanalysis dataset. Projections have shown relatively high increase in temperature and decrease of precipitation in all seasons.

Hu et al studied precipitation change in CA. It was found that there is increasing annual precipitation trend for 1951-2013 at about 2mm per decade and correlation with El-Nino-Southern Oscillation (ENSO).

Song and Bai analyzed both gridded and station observations [17]. Overall slight increase in precipitation during 1960-2013 was observed, mostly due to increase in winter precipitation.

About 80% percent of CA's land was found to be very sensitive to precipitation anomalies (Gessner et al).

Historical precipitation trends were analyzed in Song and Bai [17]. Stations data for 1960 to 2013 from Global Historical Climatology Network (v.3.02) and China Meteorological Administration as well as gridded observations from GPCC, CRU, MERRA and TRMM were analyzed. No significant trend was found except for Southeast Central Asia and winter precipitation moderate increase.

1.2 Data and Methods

This report uses the regional model PRECIS (Providing REgional Climates for Impact Studies), developed by the Met Office Hadley Centre [65]. PRECIS simulations were driven by global climate model HadGEM ES2 for two historical time periods: from 1960 to 2004 and for the future period from 2005 to 2099 under RCP2.6 and RCP8.5 emission scenarios. Additionally, A1B scenario driven by Echam and HadCM3 global climate model is presented for the same time periods. In this report 1980 to 2004 time period was considered as the recent past and 2025 to 2049 and 2050 to 2074 as the future time periods. The resolution of the simulation is by which allows for good spatial details to be obtained over the region. The model domain includes includes all Central Asian countries: Kazakhstan, Uzbekistan, Kyrgyzstan, Turkmenistan and Tajikistan.

1.3 Climate Projections

As climatic scenarios daily precipitation data and seasonal mean changes of temperature and precipitation for the period 2025-2049 and the 2050-2074 have been used in these reports [61].

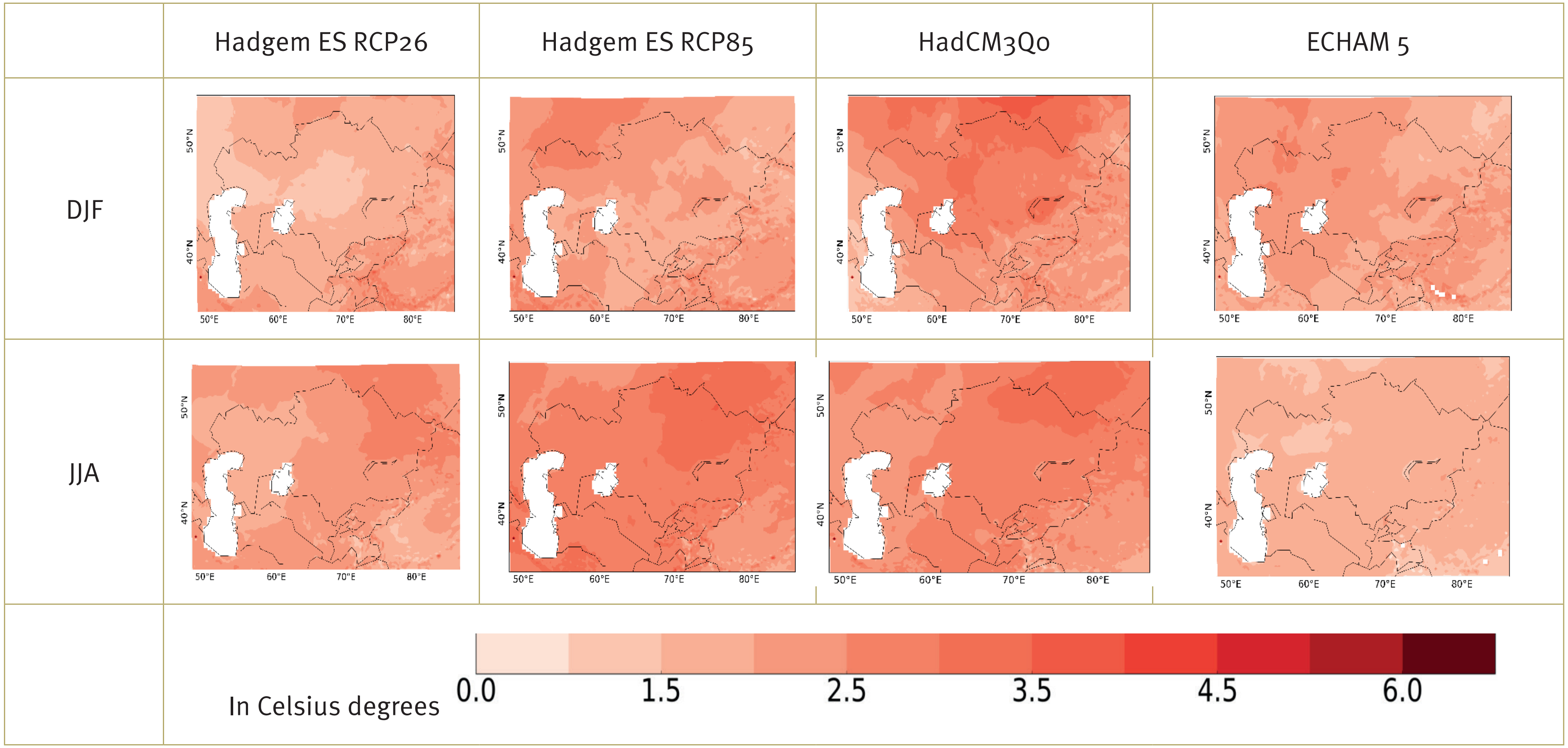


Figure 1.1 – Air temperature projections (in Celsius) for the domain for 2025-2049 relative to 1980-2004 according to PRECIS driven by different GCMs. Here DJF-mean for winter, JJA-mean for summer months.

Nearest 25 years show moderate temperature increase from 2 to 4 degrees Celsius depending on the area. But the trend tends to be that north areas will experience higher temperature raise.

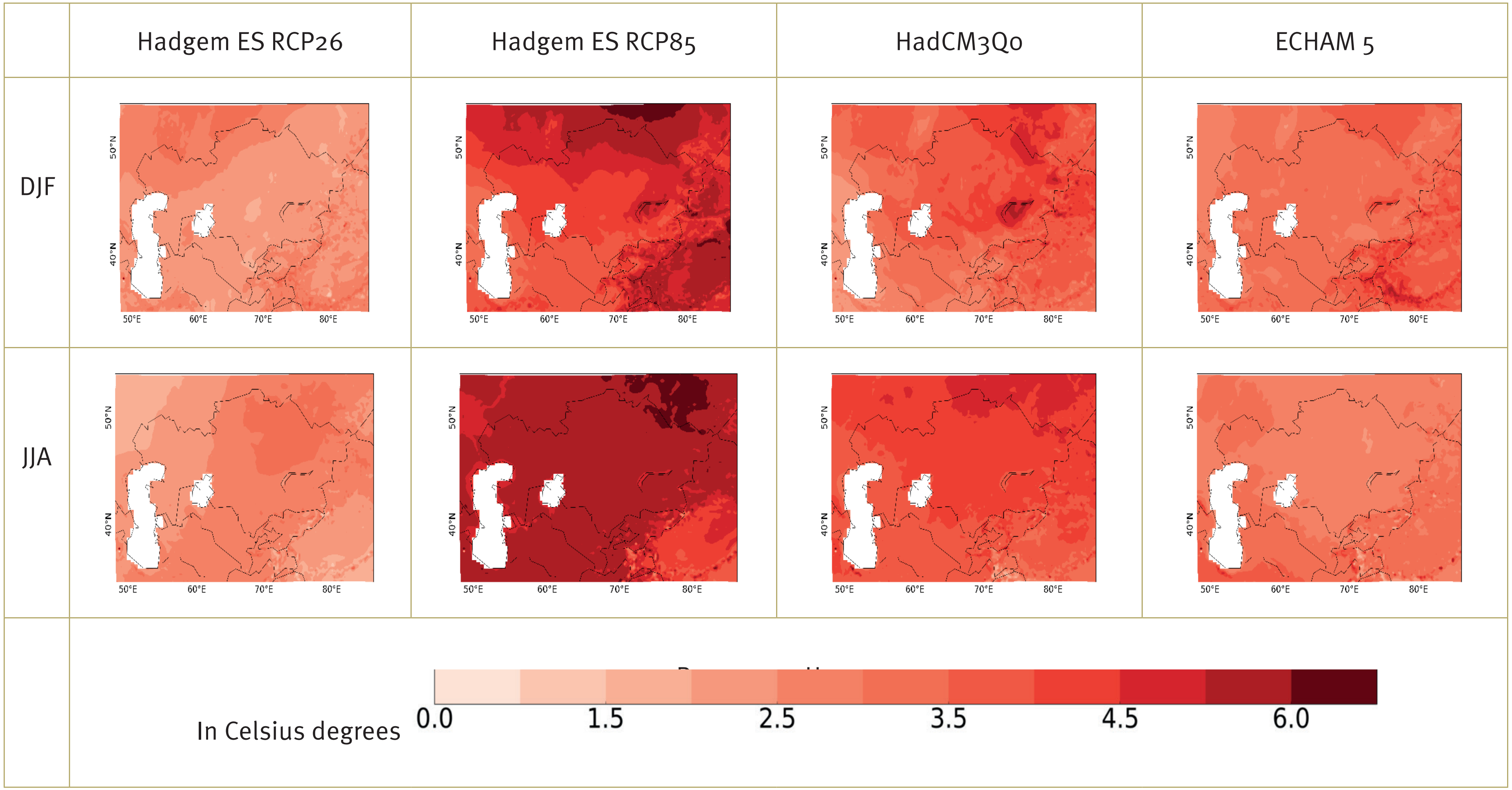
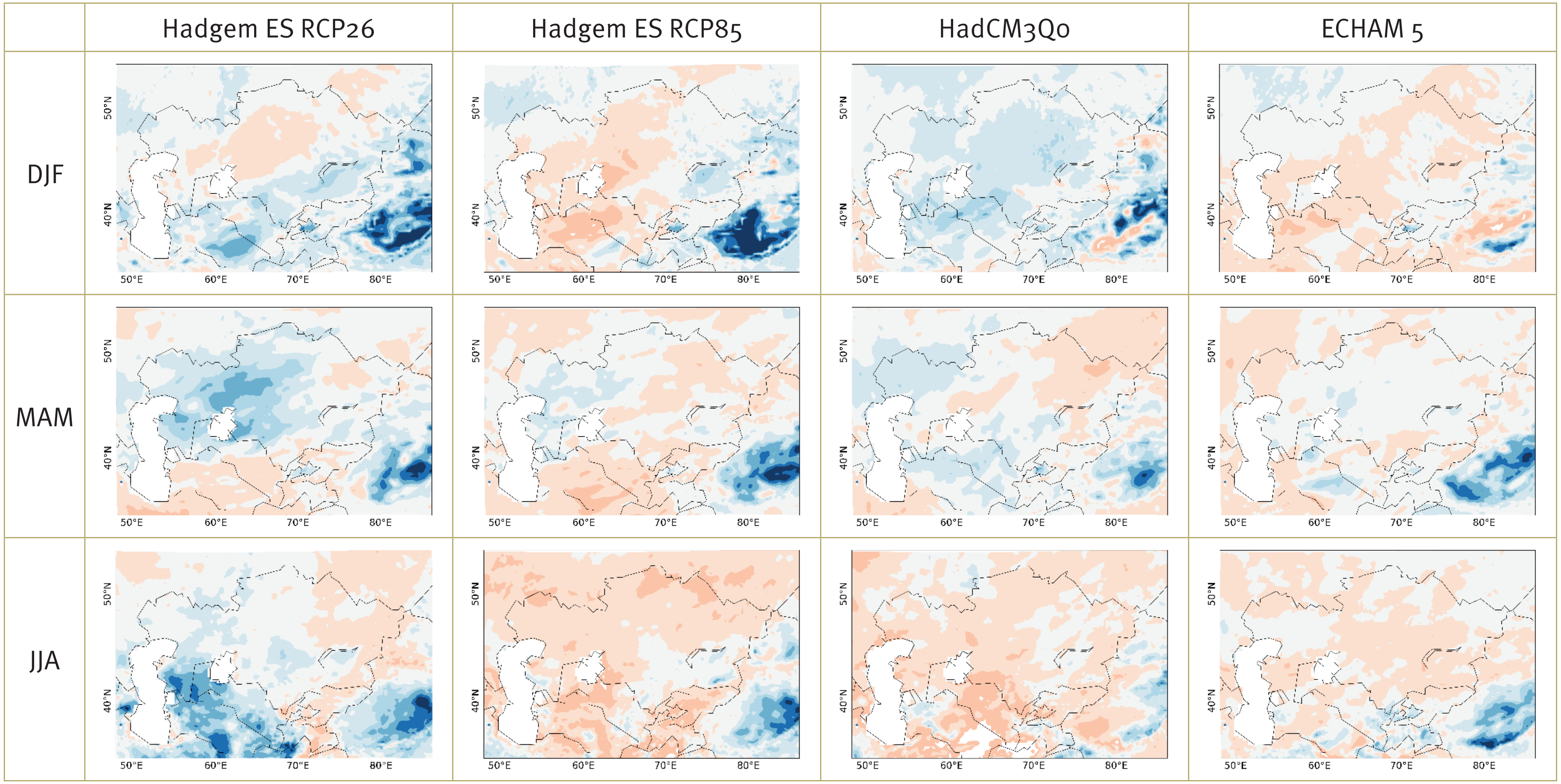


Figure 1.2 – Air temperature projections (in Celsius) for the domain for 2050-2074 relative to 1980-2004 according to PRECIS driven by different GCMs. Here DJF-mean for winter, JJA-mean for summer months.

Temperature change projections were presented for summer and winter.

As it can be seen from temperature projections RCP 8.5 scenarios show the highest temperature increase due to higher GHG emissions in this scenario. According to RCP8.5 scenario temperature will raise for 4-6 degrees Celsius compared to reference time period. All models show that northern territories will have stronger temperature increase. Precipitation change projections are presented for all seasons.



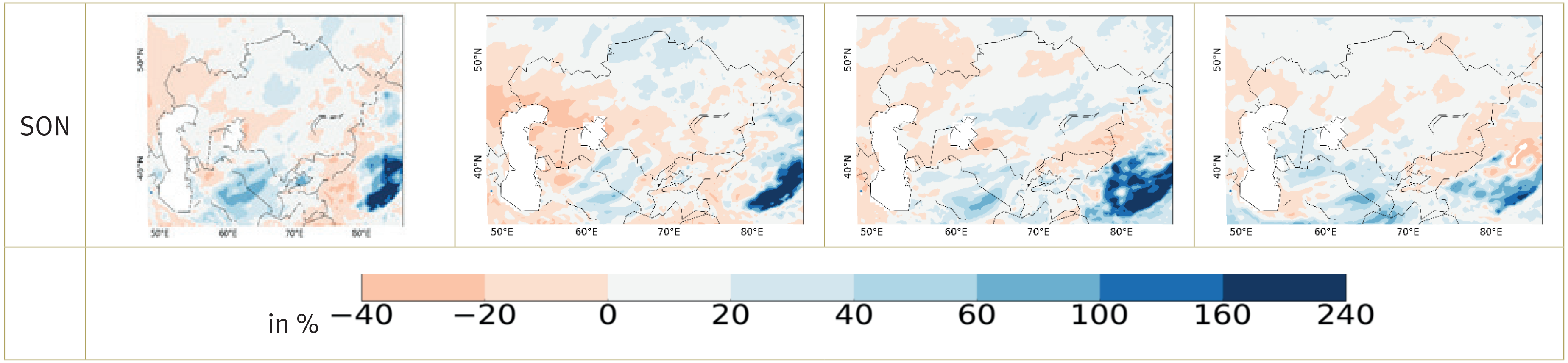
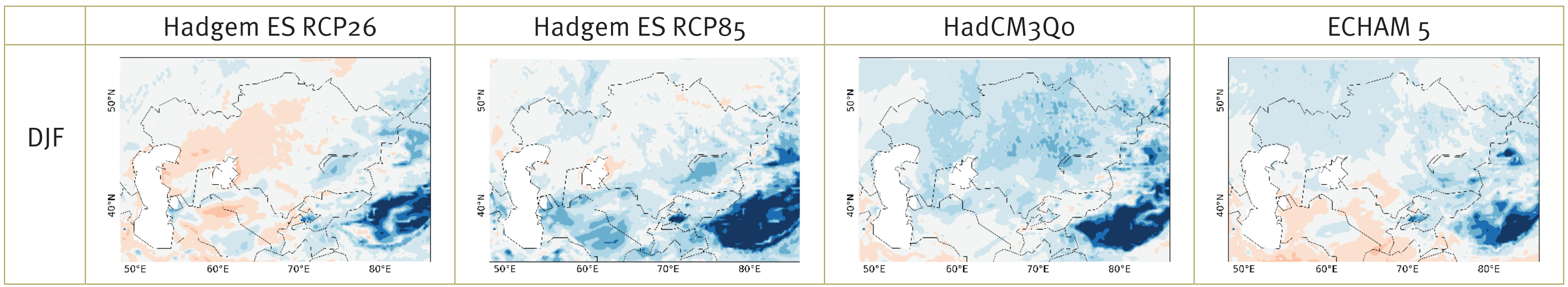


Figure 1.3 – Precipitation projections (in %) for the domain for 2025-2049 relative to 1980-2004 according to PRECIS driven by different GCMs. Here DJF-mean for winter, JJA-mean for summer, MAM-mean for spring, SON-mean for autumn months.

Precipitation projection does not reveal any clear trend. Models vary from changing location and magnitude. Many researchers conclude that roughly precipitation level in Central Asia will remain the same. It can be seen however, that Precis does not model precipitation in the mountains in the southeast.



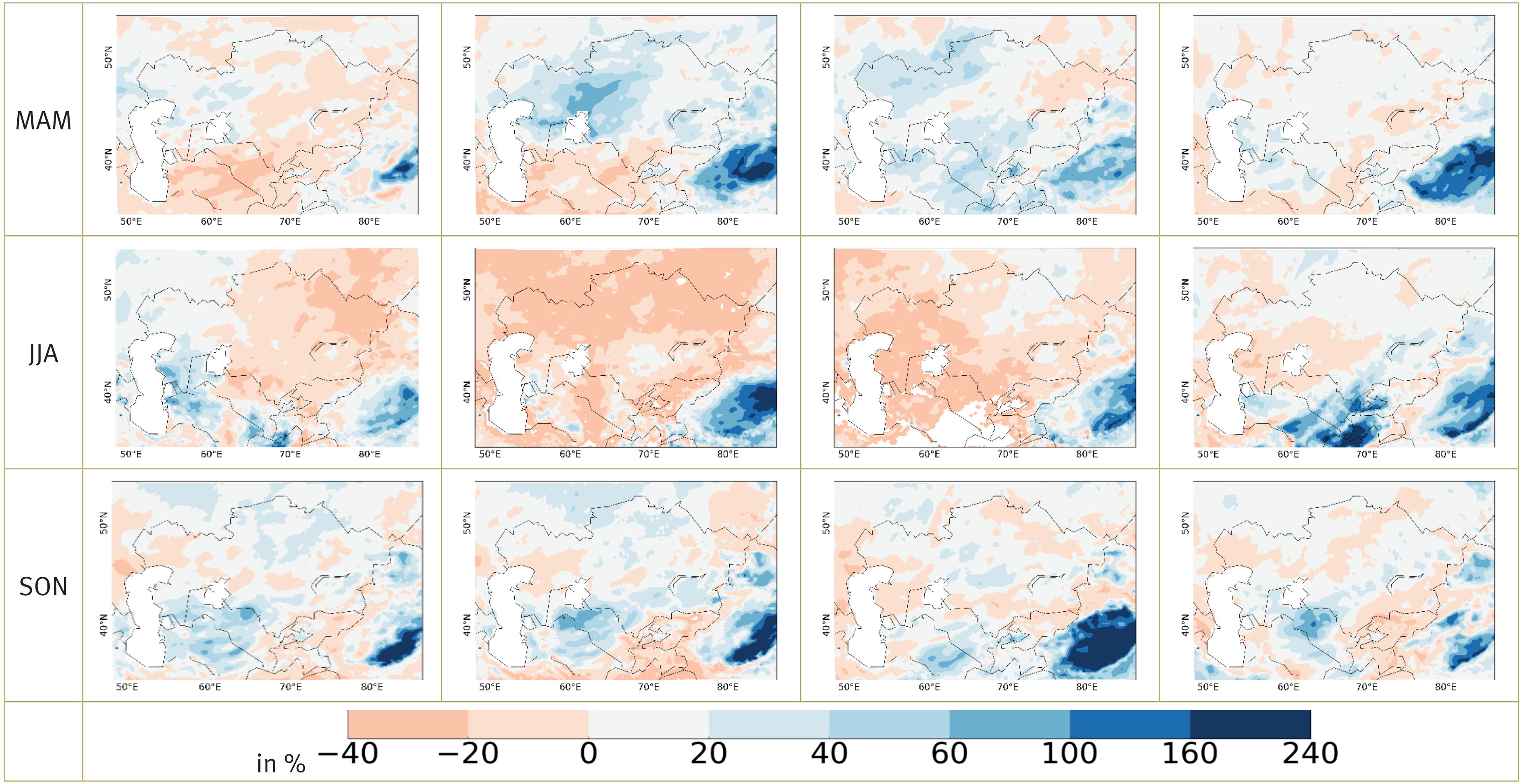


Figure 1.4 – Precipitation projections (in Celsius) for the domain for 2050-2074 relative to 1980-2004 according to PRECIS driven by different GCMs. Here DJF-mean for winter, JJA-mean for summer, MAM-mean for spring, SON-mean for autumn months.

Similarly, 2050-2074 precipitation projection varies by season and location. However, summer precipitations in all models tend to reduce over major part of Kazakhstan. Summer precipitation is very important for agricultural wield production. Reduction of precipitation may significantly reduce agricultural output. Further investigation and additional research are needed to assess precipitation change and its impact in Kazakhstan and Central Asia.

2. Projection

2.1 Energy Sector [48] [49]

The energy sector in this chapter includes all sectors where energy resources are burned and fugitive emissions occur. Energy activities are the main source of greenhouse gas emissions in the Republic of Kazakhstan, accounting for about 80% of all GHG emissions. According to the 2006 IPCC Guidelines, the "Energy Activities" include the following categories: Energy, Manufacturing and Construction, Transport, Other Sectors, Other Sources, and Fugitive Emissions.

2.1 a Historical Dynamics of Greenhouse Gas Emissions in the Energy Sector

The historical dynamics of GHG emissions in the energy sector is based on the report on the National Greenhouse Gas Inventory of Kazakhstan. In 2019, total GHG emissions in the "Energy activities" sector amounted to 261.231 Mt of CO2-eq. which is less than the level of 1990 by 8.5% and 6.1% less than the emissions of 2018.

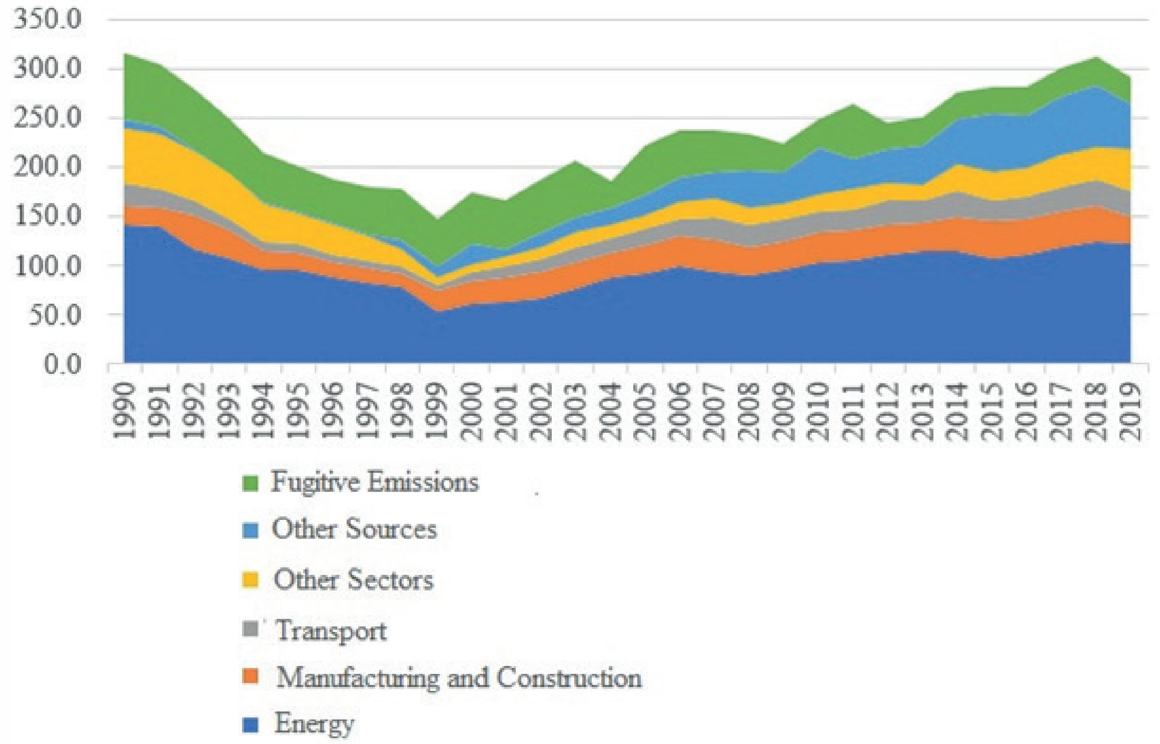


Figure 2.1 – Historical dynamics of GHG emissions in the energy sector, Mt of CO2-eq

The largest GHG emissions in the energy sector are produced by the Energy Industry, which accounts for at least 42.4% of all GHG emissions. This category includes industries such as the production of heat and electricity, oil refining and the production of oil, gas and solid fuels. This is due to the current structure of the energy system of Kazakhstan, based on the use of coal and a continental climate with clearly defined seasons. GHG emissions in the Energy Industry category in 2019 amounted to 123.6 Mt of CO2-eq., which is 13.2% less than in 1990 and 1.3% less than in 2018.

The second largest contributor to total GHG emissions in the energy sector is the Manufacturing and Construction category. In 2019, the contribution of this category amounted to 8.8%, compared to 2018, GHG emissions in 2019 decreased by 28.6% and amounted to 25.6 Mt of CO2-eq and, compared to the base year 1990, exceed by 23.3%. This sector is important for the country's economy and is also characterized by a significant use of solid fuel for its needs in such industries as ferrous and non-ferrous metallurgy.

The third largest contributor to total GHG emissions is the "Transport" category, its share in 2019 was 9.1%, or 26.6 Mt of CO2-eq. Emissions in this category exceed the base year 1990 by 16% and the previous year 2018 by 1.7%. This sector is one of the key ones for the country's economy. However, GHG emissions in this sector are growing not only due to economic growth, but also due to an increase in the share of aging fleet, and, as a result, an increase in GHG emissions and pollutants per unit of mileage, passenger traffic and freight traffic.

2.1 b Greenhouse Gas Emission Scenarios in the Energy Sector

To study the possibility of achieving carbon neutrality, the TIMES (The Integrated MARKAL-EFOM system) energy system model was used, which was developed as part of the ETSAP (The Energy Technology Systems Analysis Program) of the International Energy Agency and is used in many countries to study energy and climate policies. This model covers the sectors of the energy system, from the extraction of fossil resources, through transformation, transportation, distribution and to final consumption.

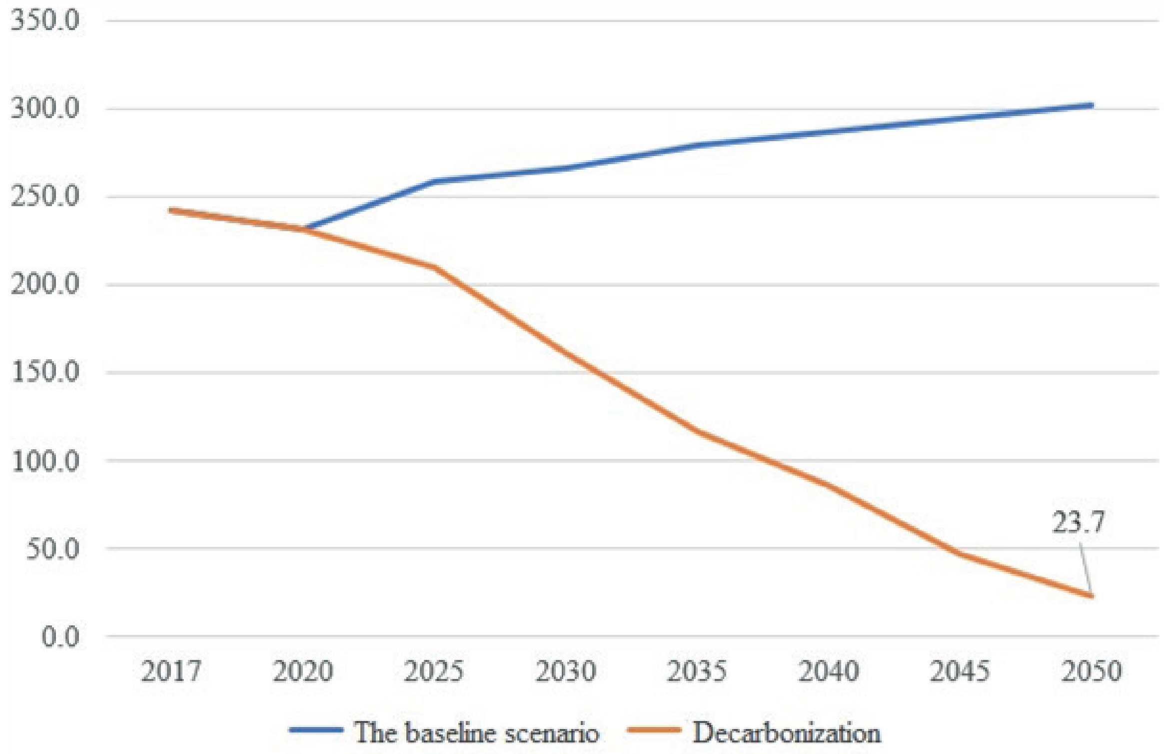
Calculations were carried out for two scenarios – the baseline scenario and the decarbonization scenario. The baseline scenario does not contain restrictions on GHG emissions and develops in accordance with the continuation of the historical dynamics of economic development. The decarbonization scenario explores the potential for maximizing GHG reductions that the model provides, taking into account the possibility of using clean energy technologies. That is, the model chooses such a structure of energy sectors, which, firstly, allows to satisfy the final demand for energy, and secondly, reduces GHG emissions.

In addition to limiting GHG emissions, the decarbonization scenario includes the introduction of nuclear power plants (NPPs) at a capacity level of 1.2 GW in 2030, 1.2 and 0.6 GW in 2035, and 0.6 GW in 2040. This procedure is associated with the assumption of commissioning a nuclear power plant in the amount of two units of 1.2 GW in the Ulken village, and two units of 0.6 GW each in the cities of Kurchatov and Aktau. Since these capacities cannot be built and commissioned at the same time, their commissioning was extended for 10 years. A scenario without nuclear power plants was also developed, where decarbonization was implemented through the introduction of traditional sources of renewable energy. This did not lead to significant changes in electricity tariffs compared to nuclear energy.

The following chapters present the results for GHG emissions and for the corresponding generation mix and capacities.

2.1 c Greenhouse Gas Emissions

The GHG emissions in the baseline and decarbonization scenarios are presented below. As can be seen, in the baseline scenario the GHG emissions from the energy sector are increasing. In the case of the decarbonization scenario, the GHG emissions are decreasing to 23.7 Mt of CO2-eq. This amount of emissions, over the next 10 years, from 2050 to 2060, with the help of new technologies must be further reduced in order to achieve carbon neutrality.

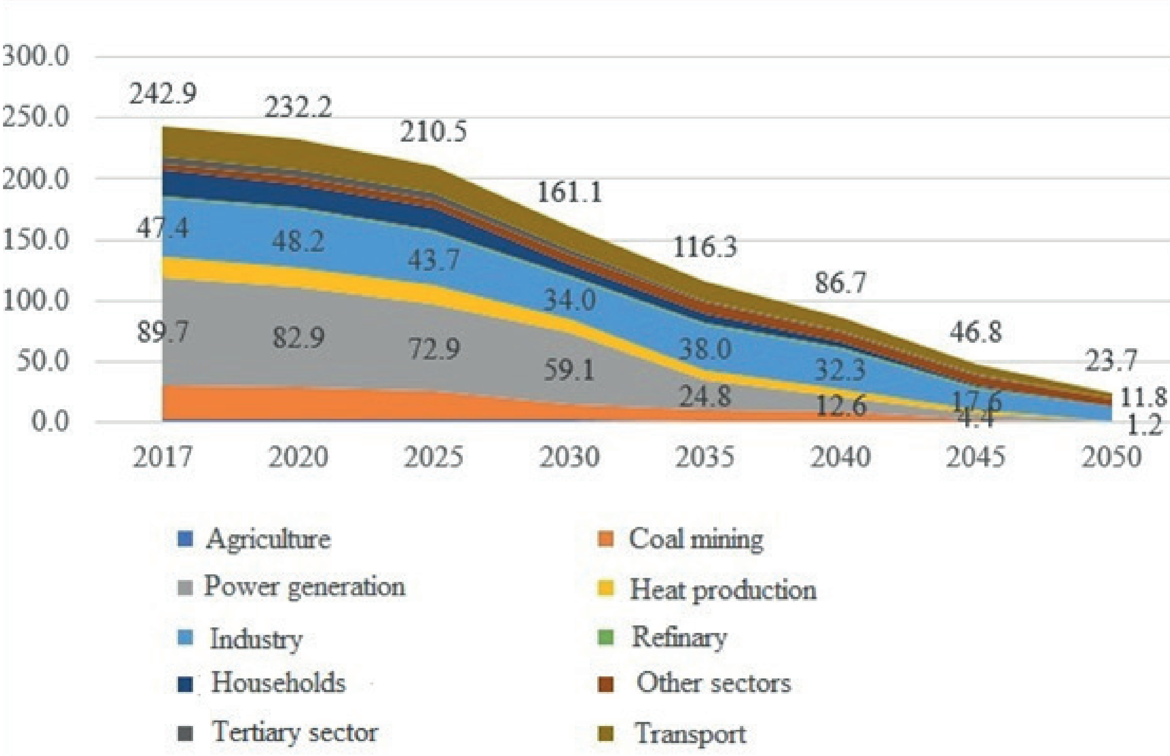


Picture 2.2. – Greenhouse gas emissions in the energy sector by scenarios, Mt of CO2-eq.

Below are the GHG emissions by energy sector in a more detailed breakdown for the decarbonization scenario.

By 2050, the electricity generation sector will account for 21.4 Mt CO2-eq, of which 20.2 Mt CO2-eq will be absorbed by CCS (carbon capture and storage) technologies, leaving 1.2 Mt CO2-eq on the balance sheet. Electricity generation will increase from 108.1 million kWh in 2020 (with 82.9 Mt of CO2-eq) to 320.6 million kWh in 2050.

GHG emissions in 2050 in this sector will come from the use of natural gas, which is necessary for the maneuvering of capacities, compensating for the instability of production from RES (renewable energy sources).



Picture 2.3 Greenhouse gas emissions from the energy sector, Mt of CO2-eq.

Table 2.1 – Greenhouse gas emissions from the energy sector, Mt of CO2-eq.

	2017	2020	2025	2030	2035	2040	2045	2050
Agriculture	2.4	2.4	2.2	1.9	1.4	1.0	0.5	0.0
Coal Mining	27.7	26.1	23.0	12.7	8.8	8.0	1.9	0.1
Electricity Generation	89.7	82.9	72.9	59.1	24.8	12.6	4.4	1.2
Heat Generation	16.8	15.0	15.0	11.4	7.9	5.7	2.9	0.0
Industry	47.4	48.2	43.7	34.0	38.0	32.3	17.6	11.8
Refineries	1.4	1.4	1.2	1.1	1.1	1.2	1.2	0.9
Households	22.1	19.8	18.1	10.1	7.6	5.0	2.5	0.0
Other Sectors	4.9	5.9	7.4	8.0	8.7	7.7	7.6	6.1
Tertiary Sector	6.6	5.5	5.1	3.4	2.6	1.7	0.9	0.0
Transport	23.8	25.1	21.8	19.4	15.4	11.5	7.6	3.6
Total	242.9	232.2	210.5	161.1	116.3	86.7	46.8	23.7

2.1 d Electricity

The decarbonization of the power sector is one of the main policies first considered when decreasing the GHG emissions in the country. The electricity and heat generation is important in mitigation of GHG, as the share in the GHG emissions in 2019 was 30.1% and it is 2.3% less than the level in 1990.

The cost of decarbonization of the power sector depends on many factors mainly on the future generation technology structure. Costs of renewables will go down each year and their share will increase in the future structure. At the same time gasification will take place in the power sector to mitigate the GHG emissions and maneuver the intermittent nature of renewables.

According to the results, the electricity generation will increase from 108.1 million kWh in 2020 to 320.6 million kWh in 2050, by more than 3 times. Thus, this indicates the importance of electrification of the energy system and the economy on the way to decarbonization.

Coal in electricity generation will be nullified, reaching almost zero by 2050. It should be noted that the decline in the role of coal is supposed to be a natural decline in capacities, which at the moment have already exhausted the park resource in most cases, and for many it is extended periodically. That is, there comes a time when it is necessary to replace the existing capacities with new ones. At the same time, whether they will be of the same type, that is, on coal, or on clean forms of energy, in any case, such a replacement will require financial resources for investment. This, in turn, will lead to the need of increasing tariffs to attract investment. The social significance of the issue of tariff increases entails the question of the right policy in relation to the tariff policy, that is, the increase should be smooth and the pace should be slower than the growth rate of household incomes.

Another point related to the increase in tariffs relates to the creation of a common electricity market within the Eurasian Economic Union (EAEU). This union will be accompanied by the harmonization of tariffs with other countries, that is, an increase in tariffs to the level of neighboring countries, members of the EAEU.

On one hand, the increase in tariffs entails the possibility of introducing the necessary new capacities, on the other hand, it will allow considering the issue of importing electricity in case of a lack of capacities during the transition to a new structure of the electric power industry. The common electricity market will also allow for lower tariff regulatory capacity from the Russian Federation and the Central Asian countries, and to deal more effectively with the instability of the growing share of RES.

As can be seen from the figure, natural gas is increasing in use for electricity generation in the interim period and further, closer to 2050, and will be used more at maneuvering capacity to support compensation for RES instability. At the same time, GHG emissions from them will be captured by CCS technologies.

Generation of clean renewable energy will expand. Generation from hydroelectric power plants increases slightly. Solar power generation is growing at a fast pace, and wind power generation is growing at a faster pace.

Nuclear power plants will appear in 2030, which is assumed by the prerequisites of the decarbonization scenario.

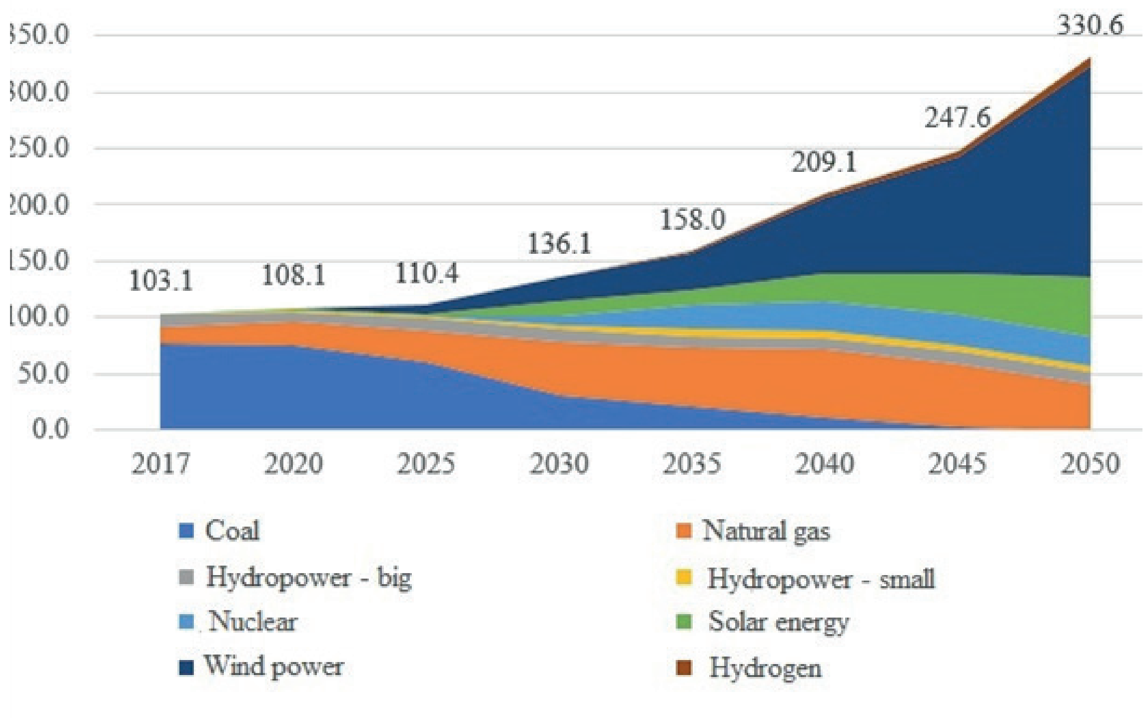


Figure 2.4 – Electricity generation by fuel type, bln kWh

Table 2.2 – Electricity generation by fuel type, bln kWh

	2017	2020	2025	2030	2035	2040	2045	2050
Coal	76.3	74.5	60.9	30.3	20.5	10.2	2.8	0.0
Natural gas	15.3	21.7	27.6	48.4	52.1	60.9	56.4	40.4
Hydropower – big	11.2	8.7	11.2	11.2	11.2	11.2	11.2	11.2
Hydropower – small	0.0	0.8	1.1	2.7	5.2	5.2	5.2	4.8
Nuclear energy	0.0	0.0	0.0	8.9	22.3	26.8	26.8	26.8
Solar energy	0.0	1.3	1.9	13.7	13.7	24.7	37.2	51.9
Wind energy	0.3	1.1	7.7	21.0	31.4	67.2	102.7	188.5
Hydrogen	0.0	0.0	0.0	0.0	1.5	2.9	5.3	7.1
Total generation	**103.1**	**108.1**	**110.4**	**136.1**	**158.0**	**209.1**	**247.6**	**330.6**

Table 2.3 – Power generation structure, %

	2017	2020	2025	2030	2035	2040	2045	2050
Coal	74.0	68.9	55.2	22.2	13.0	4.9	1.1	0.0
Natural gas	14.8	20.1	25.0	35.5	33.0	29.1	22.8	12.2
Hydropower – big	10.8	8.1	10.1	8.2	7.1	5.3	4.5	3.4
Hydropower – small	0.0	0.8	1.0	1.9	3.3	2.5	2.1	1.4
Nuclear energy	0.0	0.0	0.0	6.6	14.1	12.8	10.8	8.1
Solar energy	0.0	1.2	1.7	10.1	8.7	11.8	15.0	15.7
Wind energy	0.3	1.0	7.0	15.4	19.9	32.1	41.5	57.0

	2017	2020	2025	2030	2035	2040	2045	2050
Hydrogen	0.0	0.0	0.0	0.0	0.9	1.4	2.1	2.1
Total generation	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**

The electricity generation from coal will decrease from 74.0% in 2017 to 0.0% in 2050. The share of natural gas in generation in 2030 will be 35,4% which is more than 25.0% that set in the "green" concept of Kazakhstan and it highlights the importance of natural gas for the purpose of decarbonization. In 2050, its share will be 12.2% and it will fall on maneuvering capacities.

The hydropower will be increasing by absolute value, however, due to lower growth rates in comparison with the total generation, its share will decrease.

Most of the share of renewables in 2050 will come from wind generation, it will account for more than half of the electricity – 57,0%.

The share of the nuclear power first increases until 2035 (14.1%), but by 2050 it decreases down to 8.1%.

The levels by installed capacity are shown below.

Table 2.4 – Installed capacity by type of fuel, GW

	2017	2020	2025	2030	2035	2040	2045	2050
Coal	16.3	13.4	15.5	15.2	12.5	8.5	5.0	3.5
Natural gas	3.1	6.0	5.5	10.5	11.7	17.8	21.2	19.8
Hydropower – big	2.6	2.6	2.6	2.6	2.6	2.6	2.6	2.6
Hydropower – small	0.0	0.1	0.3	0.6	1.2	1.2	1.2	1.1
Nuclear energy	0.0	0.0	0.0	1.2	3.0	3.6	3.6	3.6
Solar energy	0.1	1.0	1.1	7.8	7.8	14.1	21.3	29.7
Wind energy	0.1	0.5	2.6	7.1	10.7	28.5	46.9	79.7
Hydrogen	0.0	0.0	0.0	0.0	0.3	0.3	0.3	0.3
Total capacity	**22.2**	**23.6**	**27.6**	**45.1**	**49.9**	**76.8**	**102.1**	**140.4**

According to the results of the decarbonization scenario, the design capacity of electricity generation will increase from 23.6 GW in 2020 to 45.1 GW in 2030, and will be 76.8 GW in 2040 and 140.4 GW in 2050 (5.9 times more compared to the capacity in 2020).

2.1 e Heating

The heating sector is one of the essential sectors in Kazakhstan due to the cold climate in most of the country. One of the ways to decarbonize the heating sector is to electrify it to the maximum.

According to the estimated results of the decarbonization of the centralized heating sector, the GHG emissions will decrease from 16.7 MtCO2eq in 2017 to 0.3 MtCO2eq in 2050 (due to the use of natural gas in heating).

According to the results, the decarbonized heat supply in 2050 will consist of heat from centralized and individual heat pumps, as well as electric heaters combined with air conditioning.

Table 2.5 – Heat production by type of fuel, PJ

	2017	2020	2025	2030	2035	2040	2045	2050
Coal	136	117	79	0	0	0	0	0
Gas	146	159	185	167	110	54	11	0
Oil products	19	0	0	0	0	0	0	0
Biofuel	2	8	5	0	0	0	0	0
Electricity	3	7	8	25	40	58	67	70
Centralized heating	149	155	151	146	139	136	152	161
Total	455	446	429	339	290	248	230	231

The heating sector is seeing a decline in coal, an increase in the use of natural gas in the interim, and an increase in the use of electricity.

2.1 f Coal

Currently, Kazakhstan is dominated by coal power which accounted for 74.07% of the total electricity generation in 2017.

The decarbonization of the power sector begins with the decarbonization of this type of power. The coal capacities cannot be decommissioned right away easily now and a clear policy on this should be developed and formulated in a short term. There are plans and indicators on gasification and alternative energy in the medium and long terms, however, there are no clear plans for coal share in electricity output.

However, more and more natural phase out of coal is being discussed at many levels of communication platforms across the country. It means no new coal capacity and phasing out of existing coal capacities in all sectors starting with power and heat sectors.

According to the modelling results for the sector coal decarbonization will occur in the following dynamics (see Figure and Table below).

Most of the coal is used in energy and its decarbonization will take place throughout the period until 2050. A small use of coal in 2050 will remain in industry, 5.1 PJ, and it is due to the use of coke in metallurgy.

The coal decarbonization in agriculture, households and the tertiary sector will occur in the decade till 2030.

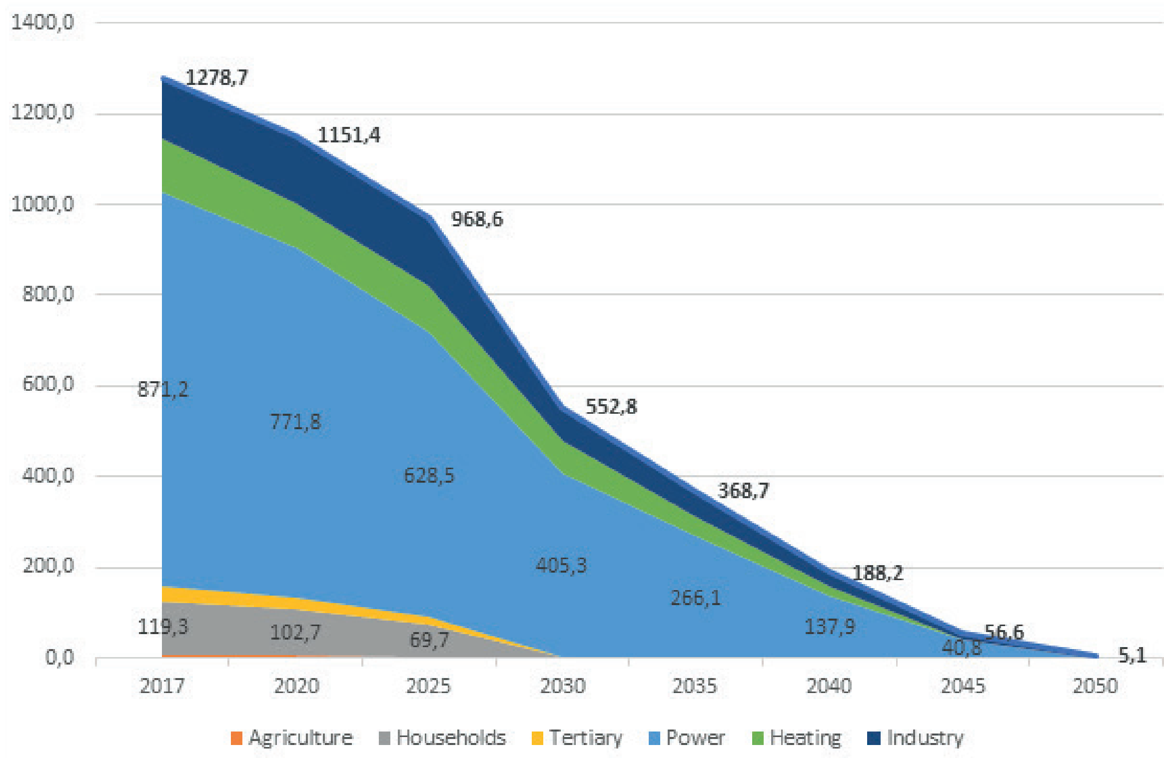


Figure 2.5 – Phasing out of coal by sectors, PJ

Table 2.6 – Phasing out of coal by sectors, PJ

	2017	2020	2025	2030	2035	2040	2045	2050
Final consumption of coal	**1278.7**	**1151.4**	**968.6**	**552.8**	**368.7**	**188.2**	**56.6**	**5.1**
Agriculture	7.3	5.9	2.7	0.8	0.0	0.0	0.0	0.0
Households	119.3	102.7	69.7	0.0	0.0	0.0	0.0	0.0
Tertiary	30.0	25.5	16.9	0.5	0.1	0.0	0.0	0.0
Power	871.2	771.8	628.5	405.3	266.1	137.9	40.8	0.0
Heating	117.4	98.1	102.9	73.6	44.2	22.0	0.0	0.0
Industry	133.4	147.4	147.8	72.7	58.3	28.2	15.8	5.1

In the sectors directly related to the population, the coal phasing out is associated with the electrification of energy services.

2.2 Transportation [50]

Transportation in this work refers to vehicles, aviation and navigation and GHG emissions from it are direct emissions from fossil fuel combusted during their operation.

According to the recent report by the International Energy Agency (IEA) Net Zero by 2050: A Roadmap for the Global Energy Sector [8], the global transport sector emitted over 7 Gt CO2 in 2020, and nearly 8.5 Gt in 2019 before the Covid-19 pandemic. In the Net-Zero Emission (NZE) scenario from the report, the transport sector CO2 emissions will be slightly more than 5.5 Gt in 2030 and

0.7 Gt in 2050 – a 90% drop from the level of 2020. Even though, the transport modes do not decarbonize at the same rate due to the technology specifics.

In Kazakhstan, according to the last inventory, the total net GHG emissions were 364.48 MtCO2eq which is 2.39% less than in 1990, among them the GHG emissions from the transport sector (including the pipeline transport) amounted to 26.60 MtCO2eq which is 19.19% higher than the same category in 1990. Most of the emissions came from road transport and it has the most emissions from cars.

Table 2.7 – GHG emissions in the transportation sector in Kazakhstan, ktCO2eq [51]

	2017	2018	2019	2019
	GHG (ktCO2eq)			Share
Total GHG net emission	**371064.1**	**388019.1**	**364483.1**	**100%**
Transport	**23622.8**	**26127.6**	**26597.7**	**7.30%**
Domestic aviation	986.0	1083.2	1192.6	0.33%
Road transportation	20221.6	21861.7	22351.8	6.13%
Cars	13094.0	14381.2	14345.5	3.94%
Light duty trucks	2290.4	2397.7	2654.9	0.73%
Heavy duty trucks and buses	4817.7	5062.2	5331.4	1.46%
Motorcycles	19.5	20.6	20.1	0.01%
Railways	1502.7	1611.2	1604.5	0.44%
Domestic Navigation	8.7	9.9	7.0	0.00%
Other transportation	903.7	1561.6	1441.8	0.40%
Pipeline transport	749.2	1383.6	1248.3	0.34%
Other	154.5	178.0	193.5	0.05%

The main indicators of transport statistics are provided in the table below.

Table 2.8 – The main indicators of the transport sector in Kazakhstan [52]

	Transportation of goods		Freight turnover		Transportation of passengers		Passenger turnover	
	mln tons	%	bln tkm	%	mln persons	%	mln pkm	%
	4 222.7	**100.0**	**597.6**	**100.0**	**23 835.8**	**100.0**	295 517	**100.0**
Rail	397.0	9.4	286.7	48.0	22.4	0.1	17 721	6.0
Car and electric urban	3 550.5	84.1	173.5	29.0	23 804.7	99.9	260 909	88.3
Water domestic	1.3	0.0	0.01	0.0	0.0	0.0	0.7	0.0
Pipeline	273.0	6.5	136.7	22.9				0.0
Sea	0.8	0.020	0.7	0.1	0.1	0.0		0.0
Air	0.027	0.001	0.1	0.0	8.6	0.0	16 886	5.7

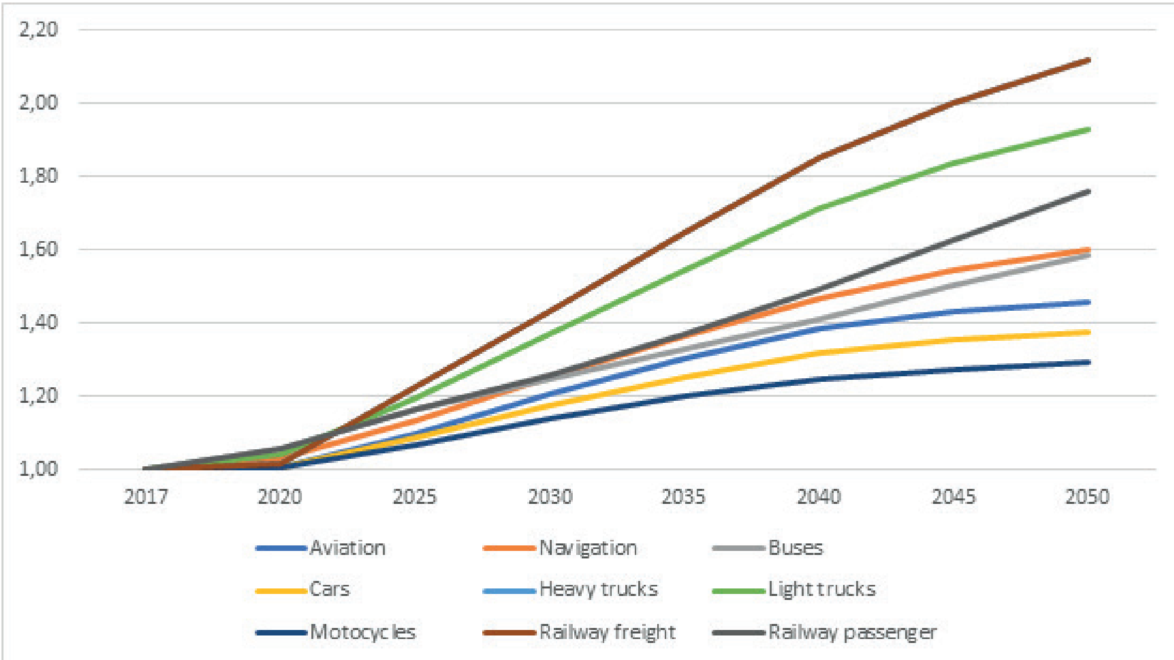
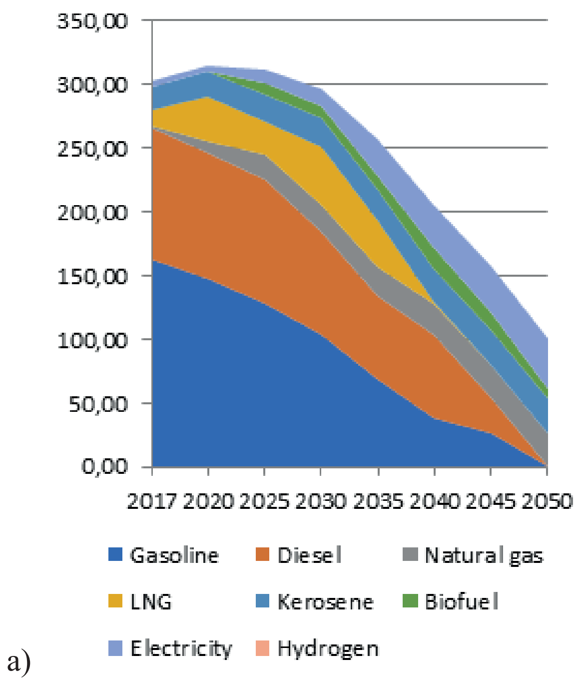


Figure 2.6 – Dynamics of the demand projections by transport modes

The decarbonization of the transport sector depends on the shifts of fuels used and modes of transport.

The types of fuels used in the transport sector and its structure are shown below. By 2050 all the gasoline and diesel will disappear from the structure.



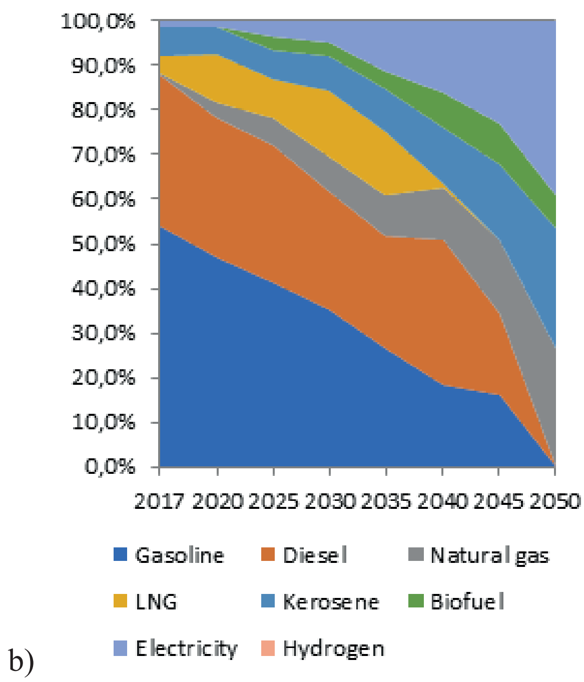
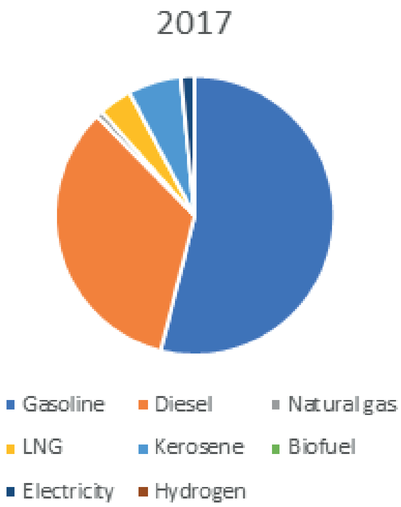
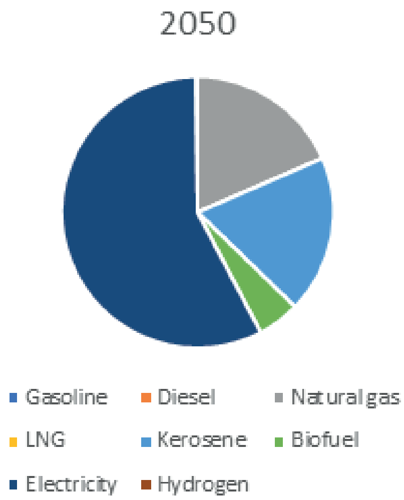


Figure 2.7 – Fuels used in the transport sector: a) values in PJ, b) shares in %



a)



b)

Figure 2.8 – Structure of fuels used in transport: a) 2017, b) 2050

The GHG emissions dynamics are shown below. There is a decrease from 24.5 MtCO2eq in 2017 to 3.63 MtCO2 in 2050. The remnant emissions in 2050 will be due to aviation and heavy trucks.

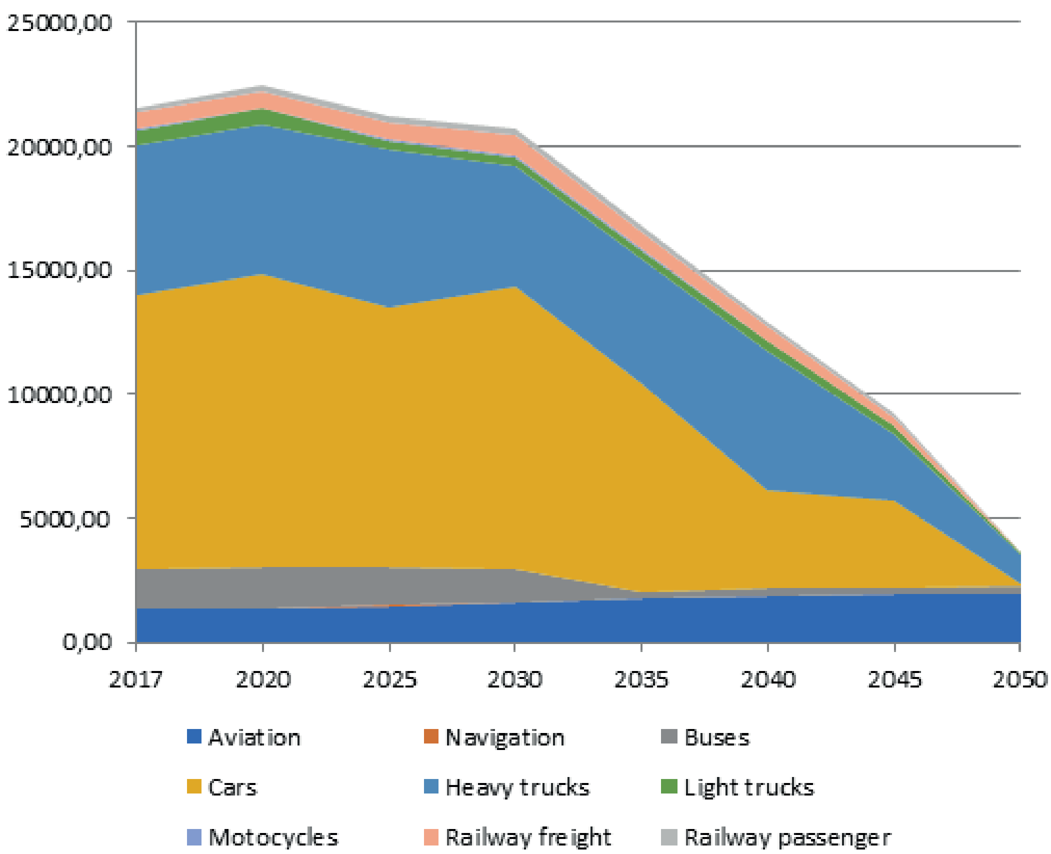


Figure 2.9 – GHG emissions dynamics

2.3 Agriculture [53]

Agriculture in this chapter includes land use management, livestock, and pasture management. These subsectors were put together for simplicity of analysis and understandability to general public, even though IPCC guidance places land use management and livestock in different sectors.

To understand current situation in Agriculture emission trends are presented since base year of 1990. Emission trend analysis is based on latest available Kazakhstan's National Inventory Report [41]. The latter is structured according to IPCC guidance with Land Use, Land Use Change and Forestry (LULUCF) sector and Agriculture.

Trend analysis helps to understand what causes key emissions in the sector and points direction to GHG emissions mitigation policies. GHG emission trend analysis mitigation includes livestock, cropland, and forestry. Key problems and opportunities are discussed in the second half of this chapter.

2.3 a Emission Trends Analysis

Trend analysis is based on Kazakhstan National GHG inventory report. Fists emissions caused by livestock and mineralization of nitrous dioxide in processed soil are presented below (Figure 2.10)

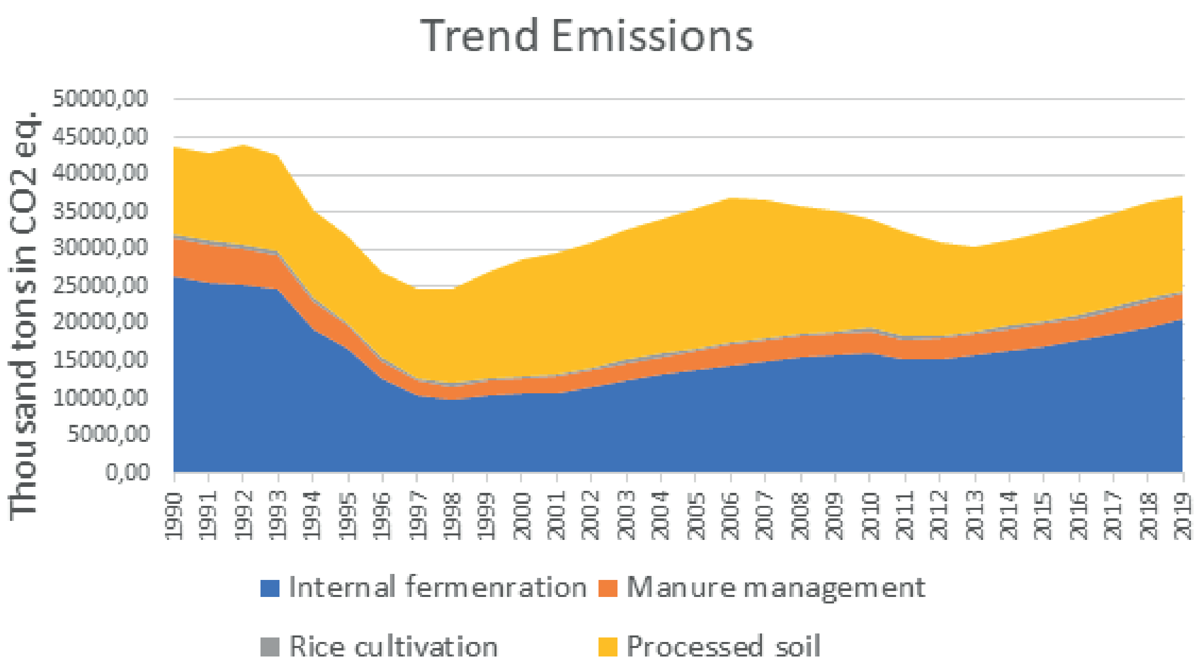


Figure 2.10 – Emission trends in Livestock and soil mineralization

Emission trend in figure above is mainly driven by number of cattle. Nitrous dioxide emission in soil and rice cultivation emissions is roughly fixed since 1990. A little can be done to reduce meat consumption in Kazakhstan in the future, because people are used to eat a lot of meat. It can be however assumed that the emissions level presented in the figure above will level out and amount to about 45 million tons per year.

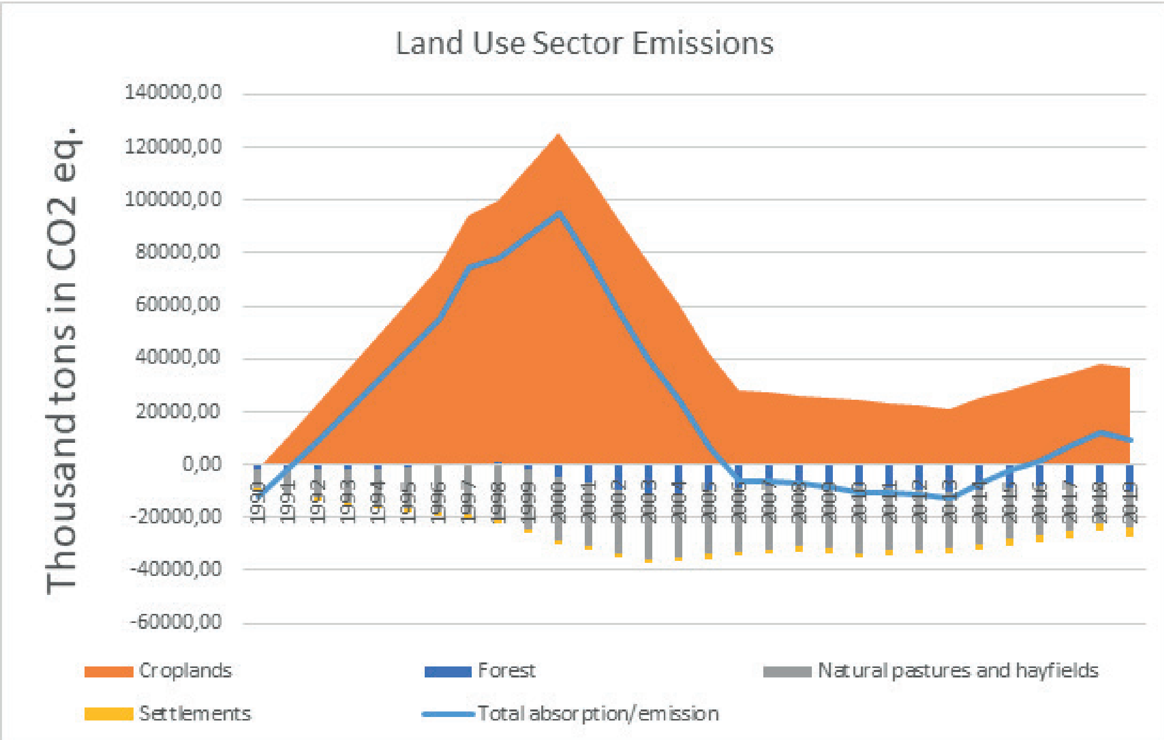


Figure 2.11 Emission trends in Land Use, Land Use Change and Forestry (LULUCF)

Overall LULUCF was sink in 1990, but in 2019 it became a net emitter of GHG emissions. Main changes occurred in cropland management. Other land categories do not emit, but oppositely sink GHG emissions. Emissions from settlements and wetlands can be considered as fixed based on historical emission trend [41]. Natural pastures and forest increased sink since 1990 level.

2.3 b Cropland Management

As it can be seen from the figure above cropland emissions were zero in 1990 and have risen dramatically since 1990. According to the national inventory report today the humus reduction speed is around 1 percent per year. As a result, emissions in 2019 reached more than 35 million tons of CO2 which is around 10% of the total GHG emissions of Kazakhstan. Humus reduction is caused by lack of fertilizers, crop rotation and other needed agricultural activities during crop production. Today humus level in cropland is reducing at a speed around 1% per year [41].

The solution to humus reduction could be introduction of carbon tax in agriculture which will be connected to the humus level in cropland's soil. Even though the humus level is measured only once in several years, nevertheless, is possible to tax farmers according to the level of humus reduction on their fields. This carbon tax policy in agriculture does not require any significant investment from government but provides clear signal to farmers to use soil efficiently and sustainably. Maintenance of humus level is reasonable from GHG emission reduction as well as from economic point of view because humus level directly effects productivity of land. For example, if humus level reduces by 10% in 10 years, then productivity of wheat production may fall by 10% from 1 hectare. The recent measured level of humus may be fixed as 100% and further humus change may be taxed according to humus reduction percentage. Money from carbon tax may be returned to agriculture as subsidies to fertilizer subsidies.

Carbon tax policy may be implemented in next 5 years, because it only requires improvement of legislation. Of course, legislation should consider validation and confirmation of humus measurements. Carbon tax may be set at the level starting from 1000 tenge (2$) per 1% reduction on 1 hectare per year. Tax value may then adapt depending on efficiency of initial tax value.

2.3 c Forest Sector

Forest can be planted on huge areas of Kazakhstan to make carbon balance neutral. For these purposes large areas of reserve and partly agricultural land can be used.

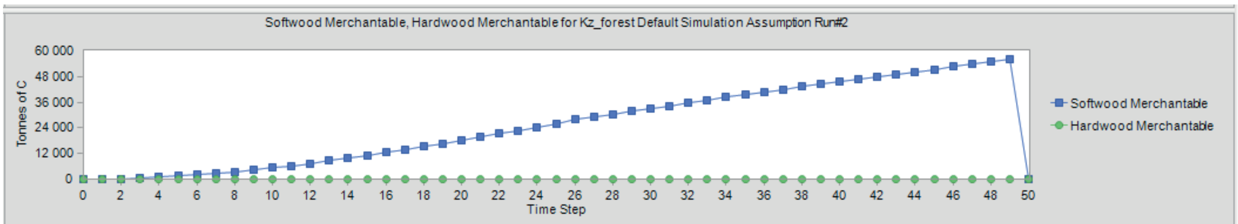
Kazakhstan has unique conditions, because of large areas free from agriculture. Overall Kazakhstan's territory covers 272 million hectares, of which around 100 million are so called reserve land. According to the definition in the Land Code "Reserve lands are all lands that are not owned or used which are under administration of district executive bodies".

The main areas of reserve land were formed during the land reform in connection with the reform of large state agricultural enterprises. During this period, the land area of the reserve increased from 19.0 million hectares in 1991 to 125.6 million hectares – in 2005, when it reached its maximum value. At the same time, significant areas of not only low-productive pastures located in desert and semi-desert zones were transferred to the reserve lands, but also more fertile lands in the developed agricultural regions of the republic. The structure of the reserve land is dominated by former agricultural land -78.3 million ha (81.9%), including 51.7 thousand ha of arable land, 2,011,3 thousand ha of deposit, 2,146,0 thousand ha of hayfields and 74,119,9 thousand ha of pastures. In other words, out of 95 million hectares of reserve land 78 million were former pastures. The rest can be considered as semideserts and deserts. Thus around 78 million of hectares can be potentially used to grow forest. Additionally, agricultural land which is not properly used by farmers can be returned to State and then also used to grow forest [42].

Afforestation of 1 hectare of plain land and GHG emissions uptake was modeled using CBM-CFS3 model fully adapted to Kazakhstan conditions. The development of this model for Kazakhstan was supported by UNDP Kazakhstan. The work carried out resulted in a database that best describes the climate conditions, soils, trees species' growing curves of the Kazakhstan forests, based on available data [41].

To assess the potential of forest plantation pine forest growing was simulated on CBM-CFS3 model. Pine was selected, because it is one of the most spread tree species along with birch, spruce and fir. Model shows different parameters as outputs starting from CO2 uptake and ending by available commercial wood after 50 years.

Newly planted pine forest will uptake on average around 7 tons of CO2 annually from plantation date during next 50 years according to CBM-CFS3 model. Consequently, plantation of 80 million hectares of pine or similar tree species would sink around 560 million tons of CO2 annually. To maintain such level of GHG uptake, the tree species should not be bush like saxaul, which is wide spread in South Kazakhstan. Tree species should be among main forest tree species such as pine.



	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
Softwood Merchantable	0	62	239	525	918	1 412	2 006	2 694	3 474	4 341	5 290	6 317	7 417	8 586	9 817	11 105	12 446	13 833	15 261	16 725	18 218	19 737
Hardwood Merchantable	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Figure 2.12 – Accumulation of commercial wood in tons of carbon by 1 hectare of forest.

Today, if someone grows forest, then according to Kazakhstan’s constitution it will belong to the State. According to paragraph 3 of Article 6 of the Constitution of the Republic of Kazakhstan “land and its subsoil, water, plant and animal world, other natural resources are under state ownership. The land may also be privately owned on grounds, conditions and within the limits established by law.” Thus, according to the law, forests grown under commercial projects will be considered state property. T*he Forest Code* acknowledges both forms of forest ownership, namely public and private forest funds. As a result, there are only 500 hectares of forest privately owned in Kazakhstan. Legislation needs to be amended to allow tenants on long-term leases for forest cultivation to harvest business wood and to obtain all other commercial benefits, subject to the standards to be established for commercial forestry. Additionally, government may improve legislation to allow national and international companies to invest in GHG mitigation through forest planting actions. Reserve land for those purposes could be given to long-term lease via auctions.

Roughly, in 30 years forest will accumulate around 30 tons of carbon or 100 m3 of commercial wood (Figure 2.12). If current price will raise according to inflation rate of 5%, then the average price per m3 at the end of 30 years will be around 400$. As a result potential revenue from 1 hectare can be 40 000 $. For 30 years initial investment will grow 4 times, given that bank interest is also 5%. As a result, plantation cost per 1 hectare and maintenance during should be less than 40 000/4 = 10 000$ to be economically reasonable. Some estimates show that 1 hectare of forest plantation costs around 2500$.

Additional benefits of forest plantation include improvement of climate, biodiversity, soil productivity and reduction of desertification processes.

3. Technology Transfer

Below is the list of possible technologies that may be applied and transferred to Kazakhstan to mitigate GHG emissions. It is important to note that the government of Kazakhstan should not invest in these projects directly or indirectly. The reason for this is the extremely inefficient spending of funds by the government of Kazakhstan on projects to reduce GHG emissions and protect the environment. Another example is the government's investment in a solar panel plant through the national company Kazatomprom. The solar panel plant operated for two years and went bankrupt. More than 100 million US dollars were invested in one of them – "Kazakhstan Solar Silicon" [54]. Similar investments were made in other plants. In 2021, two out of three solar plants were sold for less than 1 million US dollars each [55].

Government should only create conditions and encourage business and private households to be interested in implementing these technologies from economic point of view. For example, government may introduce carbon tax on GHG emissions or reduce tax for carbon neutral businesses.

3.1 Household Renewables [56]

3.1 a Roles of Households in a Net-zero Emissions Society

Achieving net-zero emissions requires almost full decarbonization across most sectors. Active engagement from households to reduce their carbon footprint will be vital to achieve this goal:

• **Heating.** Almost all household heating will need to be low-carbon. This will involve changes to the way houses are heated: – Low-carbon heating systems will replace the natural gas boilers used in most homes today. Heat pumps, heat networks and hydrogen boilers could be used. Solutions will depend on factors including location (e.g. in urban and therefore heat-dense areas district heating could be a good solution) and home type (e.g. in homes with space constraints solutions such as smart electric heating, which takes up less space than heat pumps, may be preferable). – Improvements to the fabric of homes (e.g. insulation, draught proofing, new windows) can reduce the rate of heat loss from the building, thereby reducing the amount of energy required to maintain a comfortable temperature. Improvements could be combined with other home improvements, and energy savings can outweigh costs.

• **Electricity.** Household electricity emissions will also need to be very low. Many of the changes to continue reducing electricity emissions will occur on the supply side (e.g. more deployment of offshore wind) but households can take action by installing *renewable technologies (e.g. solar PV)*. It will also be important to ensure that electric cars and/or heat pumps consume electricity smartly, in response to the needs of the grid – with *smart systems in the home and across the grid*, this can be automated based on price signals driven by supply and demand.

• A clear trajectory of *standards* covering owner-occupied, social– and private-rented homes and non-residential buildings, announced well in advance. This includes standards for energy efficiency, detailed plans on phasing out the installation of high-carbon fossil fuel heating and improvements in the efficiency of existing heating systems. Energy efficiency is the key precursor to low-carbon heat and delivers most benefits when deployed early.

Energy efficiency improvements by replacing appliances, lights and boilers at the end of their lives with the latest equivalent models.

3.1 b Optimizing the Energy Efficiency of Buildings

Overall, buildings are responsible for a large part of total energy consumption. Some startups offer energy performance auditing tools for existing buildings. However, most focus on optimising the energy efficiency of new buildings. BIM (building information modelling) technology is increasingly used in the construction industry. It provides access to data, information and tools for planning and designing buildings. These tools help construction players optimise the energy efficiency of buildings upstream. For example, they can:

- determine the best orientation in relation to the sun to benefit from natural light;
- select the most insulating materials; and
- choose the best interior room layout for ventilation flows.

3.1 c Leveraging the Potential of Renewable Energy

One of the solutions is to produce renewable energy (geothermal, wind, solar...) within the building themselves. *Solar panels* can be integrated on the roof or on the facades. The integration takes place either at the time of construction or later to make an existing building greener. The panels produce clean energy as close as possible to the consumption site and limit transport-related losses.

3.1 d Energy-friendly Systems

Lastly, buildings must incorporate equipment and devices that are more energy-efficient, especially for heating. ***Condensing boilers*** collect the exhaust gases from the combustion of natural gas. They cool the fumes to create steam and condense it to generate thermal energy. These boilers consume 12 to 20% less energy than conventional oil-fuelled systems.

Electrical equipment must also be more efficient, as lighting and household appliances represent 15% of the energy consumption in the residential sector. ***Energy-saving lamps (fluorescent or LED)*** consume 50% less energy than incandescent light bulbs. As for household appliances, energy labels guide consumers to identify the most energy-efficient appliances.

3.2 Monitoring and Adjusting Energy Consumption with Intelligent Systems [57]

Start-ups are offering tools to people to easily monitor their consumption and adopt more eco-friendly behaviours. In addition to monitoring energy consumption, some start-up solutions allow for optimal control.

3.2 a Tapping into Waste Heat

Qarnot Computing, a French start-up, has developed *the first computing heater*. Its solution consists of embedded microprocessors that remotely perform computations via the Internet for banks, industrial players, 3D animation studios... The heat generated by these calculations is then used to heat the building. This solution greatly reduces the computing carbon footprint while providing free and eco-friendly heating.

Swedish startup Enjay, on the other hand, has created the Lepido *heat exchanger for restaurant and food factory ventilation*. Its solution is protected by two exclusive patents and prevents grease and soot particles from getting stuck in the heat exchanger. The recovered energy can then be used for heating and cooling processes.

3.2 b Control Systems Save Energy [58]

Manufacturers worldwide are introducing a variety of innovative technologies, new business processes and management techniques to increase their energy efficiency. One approach involves leveraging the capabilities of ***control systems to optimize energy use.***

Automated machine energy-monitoring and information technologies help manufacturers capture the value of industrial costs like energy. Controls and automation allow managers to diagram energy use and flow through computer modelling techniques. They also collect up-to-date and up-to-the-minute statistics on energy activity by automatically monitoring and metering with database technology platforms. Management teams can monitor energy spikes, peak hours, weekend use, wasted hours and more. By establishing an energy baseline by which improvements can be measured, the systems signal the need to investigate lapses in machine performance based on parameters that are set to define "normal" results.

3.3 Waste Water Treatment [59]

Fresh water quality and supply, particularly for domestic and industrial purposes, are deteriorating with contamination threats on water resources. Multiple technologies in the conventional wastewater treatment (WWT) settings have been adopted to purify water to a desirable quality. However, the design and selection of a suitable cost-effective treatment scheme for a catchment area are essential and have many considerations including land availability, energy, effluent quality and operational simplicity. Three emerging technologies, including anaerobic digestion, advanced oxidation processes (AOPs) and membrane technology hold great promise to provide integrational alternatives for manifold WWT process and distribution systems to mitigate contaminants and meet acceptable limitations.

3.3 a Anaerobic Digestion (Ad) Process

In this process, a large fraction of the organic matter (cells) is broken down into carbon dioxide (CO_2) and methane (CH_4), and this is accomplished in the absence of oxygen. About half of the amount is then converted into gases, while the remainder is dried and becomes a residual soil-like material.

The AD technology has encountered significant recognition in the last few decades with the applications of separately configured high rate treatment processes for industrial wastewater streams. In the wastewater treatment settings, the AD has been employed in several instances throughout the world for bioremediation and biogas production.

Biogas, a well-known and common renewable source of energy, is produced via the AD process, consisting largely of CH_4 and CO_2. As an alternative source of energy, the AD process produces biogas that can be chiefly used as fuel in combined heat and power gas engines. There has also been a rapid adoption of anaerobic co-digestion, where two or more different feed stocks are digested together in anaerobic biodigesters with the core aim of improving the biogas yield. Other advantages ensured in the anaerobic systems include lower energy requirements, a safer and more convenient way of converting "waste" to useful products associated with urbanization, being a predictive tool for the fulfilment of the UN Sustainability Goal to meet Global standards, having excellent nutrient recovery and high organic removal efficiencies. Drawbacks include longer hydraulic retention times (2–4 months) and high alkalinity requirements. The aerobic system presents merits such as high organic removal efficiencies, excellent effluent quality and shorter start-up times (2–4 weeks). Demerits include longer hydraulic retention times, pretreatment requirements for delignification of lignocellulosic biomass, odor built-up in bioreactors, costs associated with CO_2 upgrading, no nutrient recovery and high energy requirements. It presents advantages such as a lower consumption of energy, low chemical consumption, low sludge production, its enormous potential for the recovery of resources, simplicity of the operation and the requirement of less equipment. Some advantages of the biological treatment method over other treatment techniques such as thermal and chemical oxidations are capital investments required and costs in operation of the processes.

3.3 b Advanced Oxidation Process

Basically, there are two stages which are usually employed in wastewater treatment settings via a pre-treatment step involving mechanical and physicochemical systems to reduce the heterogeneous components of the effluents followed by an advanced treatment process. The physiochemical process enhances the efficiency of the advanced treatment by agglomerating the containments into a larger size for easy filtration or removal. However, degradation of emerging recalcitrant components with membrane and bioremediation in advanced treatment processes attests to be complex. So, in addressing this problem, advanced oxidation process (AOP) has gained much attention due to its potential to degrade a wide range of organic micro-pollutants. This process involves the generating of potent reactive hydroxyl radicals (E_0 = 2.8 eV) with photon energy and without further additional chemical treatment. Examples are chemical oxidation (O_3, Fenton reagents), photochemical oxidation (Ultraviolet-UV/O_3, UV/H_2O_2), heterogeneous photocatalysis (UV/TiO_2), electrolysis and sonolysis. These technologies use UV-A with long wavelengths of 315–400 nm, and UV-C with short wavelength radiation of 100–280 nm for degradation of most environmental contaminants. Generally, UV/O_3 and UV/H_2O_2 processes consume large amounts of oxidant, which makes them uneconomical to operate. On the other hand, the hazards associated with ozone being an unstable gas limits its application and is usually coupled with an ozone-water contacting device to convert the ozone into its liquid phase thus increasing the cost of production. However, the considerable operational conditions of ambient temperature and pressure and the use of a low-cost and chemical stable catalyst (TiO_2) are predominantly attractive for complete mineralisation of contaminants and by-products. This makes heterogeneous photocatalysis techniques to be advantageous over other AOP's. Other advantages include no sludge production, quick reaction rate, low cost and operating well at ambient temperature and pressure conditions.

3.3 c Membrane Technology

Membranes, as a thin layer barrier for size differential separation, are usually integrated with chemical and biological treatment or standalone systems in secondary treatment of wastewater settings. In a typical membrane mechanism, there is usually a driving force, such as a semi-permeable barrier which controls the rate of movement of components by fractional permeation and rejection through pores of different sizes. The permeation and selective rejection is a function of the membrane pore size and chemical affinity, which helps to have a product stream devoid of target components. Due to the relatively low energy requirement and wastewater treatability efficiency, membrane technology has tremendously improved by the development of new materials and configurations for industrial applications. Some of these applications include microbial fuel cells, removal of organic and inorganic components, disinfection, pathogen removal and desalination.

Generally, the major driving force for selective filtration is a potential gradient of variables such as hydrostatic pressure, electrical voltage, temperature, concentration or a combination of these driving forces. These variables including nature (natural and synthetic) and structure (porous or non-porous and heterogeneous or homogenous) have been used in the classification of membranes. However, most commercially available and industrially used membranes are pressure-driven and energy driven (electrodialysis and electrodialysis reversal) membranes. Pressure driven types are namely microfiltration (MF), ultrafiltration (UF), reverse osmosis (RO) and nanofiltration (NF).

3.4 Fertilizer Production from Sewage Sludge [60]

A lot of attention has been paid to sewage sludge due to its increasing amount and problem with its disposal. In the age of expensive energy sources and depletion of natural feedstocks it is necessary to find ways of reusing and recycling waste. Sewage sludge has a high valuable fertilizing potential. It is known as a rich source of nutrients. In addition, it includes a large amount of organic matter, which could facilitate the bioavailability of macro– and micronutrients and improves the soil structure.

On the other hand, untreated sewage sludge contains a high concentration of heavy metals and pathogenic microorganisms. Different alkali compounds (lime, kiln dust, potassium hydroxide, sodium hydroxide) or acids (sulphuric acid, phosphoric acid or its mixture) are usually used in fertilizer production process in order to disinfect and deodorize sewage sludge. The technology of organo-mineral fertilizer production from sewage sludge often includes an addition of mineral fertilizers or other wastes (gypsum, cement kiln dust, lime kiln dust, waste phosphoric acid) as sources of N, P, K, Ca, Mg, etc. It allows to obtain balanced fertilizers with an optimal N:P:K ratio. Basaltic detritus and coal waste can be added to sewage sludge in order to adsorb heavy metals and transform them into hardly soluble compounds. After the sterilization and modification of product composition usually granulation and drying occur. Granulated or pelleted fertilizers are easy for spread, transportation and storage.

Organo-mineral fertilizers can be produced by mixing sewage sludge with additives in pug mill, plow mixer or other vigorous mixers and also by coating the granulated sewage sludge with melted urea. As a result gradual-release NPK organo-mineral fertilizers are obtained. Physical characteristics of a product allow for using standard equipment for application to the soil.

OMFs give similar crop yield responses to conventional fertilizers. OMFs application to the soil increases soil organic matter and soil mineral nitrogen, yet it does not influence significantly heavy metals contents in the soil.

Biosolids used for fertilizer production can reduce the costs of sewage sludge disposal and reliance on mineral fertilizers. It is a step towards a Circular Economy policy focused on environmentally-friendly and resource-efficient society by re-using and recycling materials and making a closed-loop system.

4. Other Elements

4.1. Waste Management

4.1 a Description of the Current State of Waste Management System in Kazakhstan

As in many developing countries, the disposal of the municipal solid waste (MSW) in Kazakhstan still dominantly relies on the landfilling. The main reason for that is explained with the available open space and relatively low disposal cost for MSW in comparison to other treatment methods [1]. Based on the data from 2019, the cost of MSW disposal including the separation and landfilling at the MSW polygon was estimated at 5.4 euro/t in Nur-Sultan city, while this value is expected to be lower in other cities [2]. The low cost of disposal is explained by the relatively low tariffs paid by the population and the norms (tariff) for collection of MSW are controlled by the local municipalities.

Roughly 94-97% of MSW is disposed in the authorized landfills and uncontrolled dumps without processing and recycling [3-5]. These MSW disposal values can be compared with those Eastern European countries such as Poland and Russian Federation with recycling rate of 90% and 95%, receptively. In the outside of major cities, only one-quarter of the population has an access to MSW collection services. In 2015, there were in total 4284 landfills including site dumps, and only 459 met needed requirements [3, 6] In 2017, there were 546 operating communal enterprises in total, 55 of which were state owned and 488 private [7]. Annual production of MSW is varying between 4-5 Mt, and this value is expected to reach 7 Mt by 2030 [8-9]. If this current MSW production rate continues to remain, all landfills in the country are expected to be saturated within next decades. As a result, construction of new regional sanitary landfills will be required shortly, while gas collection should be facilitated in existing landfills to mitigate GHG emissions. At present, waste recycling section has attracted private investments and there are more than 130 small and medium sized enterprises dealing with sorting and recycling more than 20 types of materials [7]. Promising attempts of public-private collaboration are in place like Raduga firm, which processes household products from recycled polymers in North Kazakhstan, the Non-Woven Fabric Factory in the Kostanay region, the Hill Corporation in Shymkent, and KazRecycleService waste recycling plant in Nur-Sultan. The higher recycling rate of MSW was observed in Nur-Sultan city by reaching 13% in 2018. However, based on the latest data, an average recycling rate of MSW in the country has increased to 18.3% [10]. Another waste recycling project is to be launched in the city of Semei in collaboration with a Greek company which projects to increase the recyclable fraction to 30% [62]. A pilot project was also implemented in Nur-Sultan city for separate collection of wet and dry solid waste, thus green and yellow containers were placed partially near residential buildings. According to the new concept on green economy, the country targeted to increase the recycling rate of municipal solid waste to 40% by 2030 and 50% by 2050. At the same timw, by 2030, 100% sanitary disposal of MSW should reach 95%. This means that all relatively new landfills will need to be refurbished and planned landfills should should be built on the best environmental practices. To achieve this target, Ministry of Environment along with environmental agencies has developed a concept to build 6 waste-to-energy plants in largest cities of the country such as Aktobe, Almaty, Ust-Kamenogorsk, Nur-Sultan, Karaganda and Shymkent. It is reported that the recycling of waste to energy will help to increase recycling rate of MSW to 30% by 2025.

According to IPCC report, wastewater is the second largest source of GHG emissions (CH_4 and N_2O) after MSW landfills [11]. Similarly lower levels of upgrading in waste water treatment facilities are also reported. According to the Ministry of Environment and Natural Resources, there are 180 waste water treatment plants in the country, of which 71 are located in the cities/towns and other 109 are in industrial areas [12]. Most of wastewater treatment plants in Kazakhstan use mechanical and biological treatment method followed by tertiary treatment with sand filtration and UV disinfection. During the treatment processes, large amounts of dewatered and un-stabilized sewage sludge are produced and transported by tracks to the landfills [13]. In total, 583 million tons of wastewater was treated as example in 2016, which led to the production of 52 million tons of sewage sludge in cities and towns in Kazakhstan. Only in the capital Nur-Sultan alone, between 250-300 tons of sewage sludge is produced daily with a moisture content of more than 70%. With ever-increasing city residency, new wastewater treatment plant will be required in the near future. As a result, this will lead to further increase the production of sewage sludge waste and GHG emissions. The only sustainable project was launched in the wastewater treatment plant of Shymkent city (South Kazakhstan region) for treatment of sewage sludge in 2017; however, no operational data are available from this project. Mostly, the generated sewage sludge waste in Kazakhstan is currently stored in open sludge drying beds and further disposed in the sanitary landfills [13]. Table 4.1 presents the potential cut of GHG emissions from sewage sludge landfills, in case of the implementation of the thermal treatment method [12].

Table 4.1 – Potential reduction of GHG emissions from sewage sludge landfills, 2016 (taken from inventory of GHG emission, IPCC, 2006) [12]

City	Net CH_4 emissions from sludge deposits (kt CO_2 eq)	Emissions from CH_4 combustion (CO_2 kt)	Potential reduction of GHG emissions (CO_2 kt)
Aktobe	13.95	1.45	12.5
Almaty	59.73	6.20	53.5
Oskemen	10.97	1.14	9.9
Taraz	11.95	1.24	10.7
Oral	7.90	0.82	7.1
Karaganda	16.74	1.74	15.0
Kostanay	8.00	0.83	7.2
Aktau	6.12	0.64	5.5
Petropavl	7.25	0.75	6.5
Shymkent	33.41	3.47	29.9
Nur-Sultan	34.49	3.58	30.9
Total	**211**	**22**	**189**

4.1 b Composition of Municipal Solid Waste Produced in Kazakhstan, Based on Case Study Conducted in Nur-Sultan City

The capital city of Nur-Sultan has experienced a typical development spurt due to population growth and economic progress. Between 1998 and 2019, the population of the city has increased from 327 000 to over 1 078 000 [15]. This exponential population growth of the city has made an existing waste management system more challenging to deal with. On a daily basis, roughly 1300-1400 tons of MSW are generated in the capital which gives around 1.47 kg per capita per day. Some investments were made during these two last decades in waste management by constructing two cells in MSW landfill. The first MSW cell in Nur-Sultan city was in operation between 2006 and 2018, and has received more than 4 mln tons of MSW (while a projected capacity was 3.2 mln tons). A new MSW cell started to accept MSW volumes from 2019, however without significant improvements on recycling rate, separate collection services, and the environmental awareness of citizens on waste management, this new cell is expected to be filled out in 2025. In this regard, a research project was implemented at NU between 2017 and 2019 on an assessment of refused derived fuel which can be extracted from MSW. The project has conducted several MSW sampling campaigns of the city at MSW landfill of Nur-Sultan city. Following sampling procedure was performed which represents typical MSW mechanical and biological sorting plant. According to the ASTM D5231-92, two step sampling procedure was applied for MSW sampling as illustrated in Figure 4.1. Large pieces of waste including recyclables were separated during the first step sorting, which included paper (cardboard, paper, Tetrapak), plastic (HDPE LDPE, PET, other plastics), metals (Fe and non-Fe), glass, wood, textile and leather, waste electrical and electronic equipment (WEEE), construction and demolition (CDW), and others. During the second sorting step, non-recyclable fractions were further sorted as potential source for RDF (combustible fractions) such as mixed paper, mixed plastic, textile and leather, and wood, as well as non-combustible smaller items as metals (Fe and non-Fe), glass, and WEEE. The remaining waste after second step sorting contains fine fractions with particle size less than 12 mm and organic fraction.

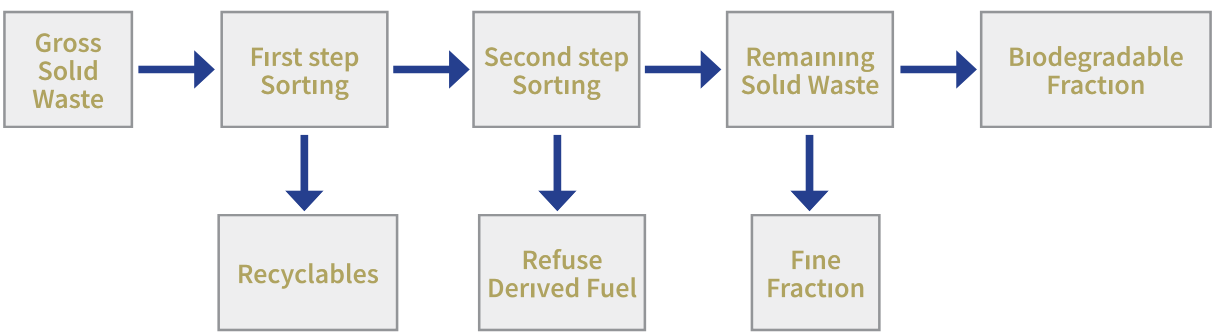


Figure 4.1 – Sampling steps for MSW

Table 4.2 shows the average compositions of MSW for the period for 2018 and 2019. Major fractions of MSW consists of organics (47%), plastics (15.2%), paper (12.08%), and diapers (5.9%). The difference between 2018 and 2019 did not show a significant fluctuation and was in an acceptable range. Based on the results on the MSW sampling, the fraction of the refuse-derive fuel from MSW was found at around 10%, however with further improvements on current sorting plant at landfill and establishment of source separation system in place, the RDF share can be increased up to 15%. A decreasing trend on the plastics and paper fractions at the gate of landfill are anticipated as the sorting of MSW at the source will become a common trend in the cities and small improvements from the behavior of the citizens. One of the tasks within the project was dedicated for the analysis of population behavior and relevant survey conducted on the waste sorting at the source. The survey has showed that around 24% of people showed their readiness to perform sorting the source if MSW facilities are available [16].

Table 4.2 Municipal solid waste composition in Nur-Sultan city [17-18]

Fractions	Average of 2018, %	Average of 2019, %
Paper	12.5	12.8
Plastic	15.4	15.2
Fe Metals	2.0	1.9
Non-Fe Metals	0.7	0.1
Glass	6.2	4.9
Wood	0.8	0.8
Textile & Leather	3.4	3.7
WEEE	0.6	0.7
Construction & Demolition waste	0.9	3.2
Organics	47.2	46.3
Fine (<12 mm)	3.5	3.5
Diapers	6.2	5.9
Miscellaneous	0.8	1.0
Total	**100**	**100**

4.1 c Waste Management Scenarios & Recommendations Towards Reduction of GHG Emissions

Landfills became one of the important sources of GHG emissions and contribute around 5% of global GHG emissions [19]. According to the National Inventory report, GHG emissions of the waste management sector have reached in total 6788.78 kt of CO2-eq and contributed roughly 1.7% of the country's GHG emissions. This includes the controlled and uncontrolled landfills/ dumps, wastewater treatment plants, industrial wastewater and medical wastes [20]. The share of medical wastes is minor and therefore, it is excluded in the base year 1990.

In summary, following possible pathways are recommended on waste management:

1. Methane collection system in all existing landfills should be built urgently for energy recovery purposes, while planned sanitary landfills should be designed with methane collection system.

2. Quality of MSW fractions entered to MSW sorting plant has to be improved significantly by integrating the separate sorting of MSW at the source and facilitating the separate tracks for those sorted fractions. The current pilot project with wet and dry separation of MSW placed in Nur-Sultan, so far did not show any significant pro-

gress. Based on our study, the recycling rate of MSW can go up to 30-33%.

3. Almost half of MSW in Kazakhstan mainly consists of an organic fraction. Thus, composting of organic wastes and utilization of methane looks more promising rather than incineration of major MSW fraction.

4. There is a potential to extract 10-15% of refused derived fuel from gross MSW which can easily be co-fired in the existing coal-fired power plants for energy recovery purposes. This will mitigate the GHG emissions notable by replacing the coal utilized in power plants.

Name of a measure	Combustion of MSW
Description	Construction of 6 incinerators (MSZ) with electricity production at a price of 172 tenge/kWh and/or incineration of MSW in furnaces of cement plants to replace coal.
Key reasons	The Department of State Policy and Waste Management of the Ministry of Civil Affairs of Kazakhstan to solve the growing problems of MSW management proposed the construction of 6 MSW in large cities of Kazakhstan, which will produce electricity. Amendments to the Environmental Code of the Republic of Kazakhstan, allowing the energy utilization of solid waste, were adopted by the Parliament of the Republic of Kazakhstan at the end of 2020. Earlier, the Environmental Code prohibited the burning of solid waste in Kazakhstan. It should be noted that the experience of using MRZs in the world has shown their dangerous effects on human health and the danger of food grown within a radius of many thousand kilometers from the MRZ. Therefore, MRZs are currently banned in many developed countries. Currently, only previously built plants are operating, new plants are not being built.
Promotion of the achievement of the SDGs by 2030	The construction of the MRZ does not meet any of the 17 UN sustainable development goals
Minimum Data Requirements for MRV	Volumes of incinerated MSW, tons per year
Frequency of data collection for MRV	once a year
Potential to reduce greenhouse gas emissions, million tonnes of CO2-eq	0,5
for 2021-2025 years	1
for 2026-2035 years	2,5
Investment requirement (cost) for realization of the specified potential of GHG emission reduction, million dollars. USA [63]	
for 2021-2025 years.	500
state	500
business	
international donors, investors	-

Name of a measure	Combustion of MSW
for 2026-2035 years.	1500
state	1500
business	0
international donors, investors	-
ecological	Reduction of new volumes of MSW disposal at landfills
social	Increase in cancer and cancer mortality among the population in the MRZ emission zone

In July 2021 new auction was organized the Ministry of Energy, where 6 Waste incineration plants were contracted to be built in the next 5 years. Overall capacity of these plants is 100 Mwt. It is planned that these plants will burn new waste as well as accumulated waste in major Kazakhstan cities to produce electricity. The price of electricity per kilowatt from waste incineration plants will be around 172 tenge.

The authorized bodies in the field of municipal waste management in Kazakhstan are the Department of State Policy and Waste Management of the MEGPR of the Republic of Kazakhstan (it is responsible for the development and improvement of sectoral policy), as well as the Committee on Construction and Housing and Communal Services of the IIR of the Republic of Kazakhstan (responsible for the implementation of the policy).

According to the Concept for the Transition of the Republic of Kazakhstan to Green Economy (2013), the volume of solid domestic waste (MSW) processing should be 40% by 2030.

According to Article 301 of the Environmental Code of the Republic of Kazakhstan, from January 1, 2019, a ban on the burial of paper, plastic and glass at landfills of the Republic of Kazakhstan entered into force. There is also a ban on the burial of metal, tires and their fragments. On January 1, 2021, a ban on the disposal of food waste and waste of building materials entered into force. Local executive bodies are responsible for implementing these changes. They must allocate land and build facilities for their placement. However, local authorities are currently experiencing difficulties in implementing burial especially in villages, since there is no necessary logistics infrastructure and there is no established transfer of collected waste to enterprises for sorting and processing of these components of solid domestic and industrial waste. Therefore, the requirements of the Environmental Code are currently being violated in many regions.

Systems for monitoring and evaluation of progress are dynamics on the introduction of modern methods and technologies for waste [64].

4.1 d Results and Discussion

According to the information provided in this chapter there is high GHG mitigation potential to process wastewater in Kazakhstan. The reason of that is high amount of sewage sludge in wastewater. Additionally, up to a half of the MSW consists of organic waste. The latter opens an opportunity to install garbage disposal units in households. Further organic content in wastewater could be processed using anaerobic methods to produce agricultural fertilizers. This makes all process economically sensible given that fertilizers will be sold in the market. The legislation and standards to process wastewater in Kazakhstan need to be updated to include anaerobic process of wastewater. Up to a half of emissions in waste management may be reduced by introduction of this policy, because waste water and organic content in MSW produces considerable amount of GHG emissions.

In summer 2021 Kazakhstan's government contracted to build 6 waste incineration plants in 6 largest cities of Kazakhstan. The fuel for these plants will be provided from waste storage landfills, which accumulated more that 100 million tons of MSW. The government will pay 172 tenge (0,4$) per kilowatt hour of electricity from waste incineration plants. The full capacity of 6 plants is 100 Mwt. If these plants will work at full capacity, then annual production of electricity will be around 876 million kwt/h. As a result annual investment will require 350 million US dollars and around 3 million tons of waste will be required. The effect from waste incineration may be both positive and negative. For example if 1 tone of paper is incinerated then 230kg of CO_2 is saved, but if 1 tone of plastic is burnt, then 1500 kg of CO_2 is emitted. On average one tone of MSW saves around 180 kg of CO_2 [18]. Consequently around 540 thousand tons of CO_2 will be saved. If we compare investment needed then one tone of CO_2 will costs about 650$. That makes the whole project ineffective and irrelevant to reduction of GHG emissions. Additionally, it proves the government is ineffective in funds management of GHG mitigation activities.

4.2 New Approach in Legislation and Regulation Mechanisms: Carbon Trading and Carbon Tax

In Kazakhstan, the State partially regulates greenhouse gas emissions through the establishment of a market mechanism for trading carbon units. The market mechanism for trading carbon quotas is carried out in accordance with the Environmental Code [65] and the rules of government regulations [66] in the field of greenhouse gas emissions and removals [67].

Legislation in the field of environmental protection was updated in early 2021. Changes in greenhouse gas regulation have affected the Environmental, Administrative Codes [68]. In particular, the Environmental Code was amended to monitor emissions of pollutants, and the concept of offset projects was introduced into the greenhouse gas trading system of the Republic of Kazakhstan. The administrative code introduced a fine in the environmental code for GHG emissions in excess of the authorized quota in the amount of 5 month calculated indicators (MRP) or 14585 tenge per ton of CO_2. Despite the updating of carbon trading legislation, the greenhouse gas trading system has a number of shortcomings.

According to article 285 of the Environmental Code, State regulation in the field of greenhouse gas emissions and removals is carried out using the following tools:

1) establishing a carbon budget;
2) carbon quota arrangement;

Article 286 of the Environmental Code defines the carbon budget for 2021 to be at least 1.5 per cent lower than the 1990 carbon balance, and in subsequent years to be at least 1.5 per cent less annually than the previous year's carbon budget. For the carbon budgeting period from 2026 to 2030, the carbon budget for each calendar year decreased by at least 1.5 percent of the level of the carbon budget of the previous year. For further periods of carbon budgeting, the carbon budget for each calendar year was at least fifteen per cent below the 1990 carbon balance.

However, what the 1990 carbon balance means in the figures is undefined. Does the 1990 carbon balance mean total emissions of RCs in 1990 without land use, land use change and forestry (LULUCF)? If the latter is true, then the 1990 carbon balance according to the latest inventory report of RK [69] is 385 million tons in CO_2 equivalent. But according to article 289 of the Environmental Code, the electric power, oil and gas, mining, metallurgical and chemical industries, as well as the manufacturing industry in terms of cement, lime, gypsum and brick production (hereinafter referred to as regulated sectors of the economy) are subject to carbon quota, which corresponds to the sectors of energy and industrial processes in the national report of the GHG inventory. According to the Inventory Report, energy emitted 249.6 million tons of CO_2, and industrial processes emitted 19.4 million tons of CO_2. Together, energy and industrial processes emitted 269 million tons of CO_2.

We now look at the National Greenhouse Gas Emissions Allocation Plan for 2021 [70]. The total greenhouse gas emissions in 2021 was 169 187 227 tons of CO_2. Here, 1 carbon quota is 1 ton of CO_2. The greenhouse gas emission quota reserve for 2021 is 11,500,000. The number of carbon quotas together with the reserve in 2021 amounted to 180,687,227 tons of CO_2. It remains equally unclear what the 1990 carbon balance is.

Moreover, if we look at carbon quotas for 2018-2020 years [71] were 485909138 units + reserve 35273634 units of quotas. That is, on average, quotas per year were 161,969 + reserve 11,757,878. Thus, it turns out that the number of quotas on average for 2018-2020 was less than 2021, when a decrease in quotas of 1.5% per year was announced. The Emissions Trading (ETS) system has no logic and consistency in the implementation of carbon policies.

An enterprise in the ETS system can develop and implement a so-called offset project aimed at generating clean energy or absorbing GHG emissions. Article 298 of the Carbon offset refers to reductions in greenhouse gas emissions and/or increases in greenhouse gas uptake resulting from activities or activities in any sector of the economy in the Republic of Kazakhstan aimed at reducing greenhouse gas emissions and/or increases in greenhouse gas uptake.

Offset units are indefinite in terms of validity, except when their validity period is limited at the time of issuance.

However, clear rules are not given on how to determine GHG reductions in offset projects. Only a general indication is given that this project will be considered by an authorized body from the Ministry of Ecology, Geology and Natural Resources. It would be a good improvement of ETS generating a library of offset projects.

Example 1kWh hour of renewable electricity is equivalent to receiving 1 kWh from a coal power plant where 350 grams of coal is burned, or 1 kg of CO_2 is emitted (evaluation is based on Ekibastuz GRES 1 [72]). Thus, an offset project in the field of renewable electricity generation can be reduced to counting the generated kilowatt hours and converting them to CO_2 equivalent, according to the proposed example.

Similarly, planting 1 hectare of forest annually, for example, absorbs 3 tons of

CO_2 per year. Creating a library of offset projects and assessing their absorption of GHG, facilitates the implementation of offset projects by enterprises, and also gives enterprises confidence in the validity of investments.

The mechanism for allocating reserve quotas is not clear. For example, Ekibastuz GRES 1 exceeded carbon quotas in 2020 by 8.587 million tons in CO_2 equivalent [8]. GRES 1 requested additional quotas from the ministry in the amount of 8.587 million and received them. How does the allocation of reserve quotas affect the ETS market, is it positive or negative? Judging by the practice established in Kazakhstan, this has a negative effect.

Another point regarding ETS is that enterprises themselves submit an inventory report of GHG. It will be difficult to validate how much the enterprise burned, for example, fuel. Therefore, there is a possibility that the enterprise will falsify and underestimate its emissions.

All the above-mentioned factors, as well as the Non-elaboration and uncertainty of ETS, lead to the fact that enterprises are reluctant to implement projects to reduce ETS, rather, according to the inventory, annual GHG emissions are growing. According to the commodity exchange, the volume of GHG trade is very insignificant. The price is 500 tenge per ton of CO_2, which seems to be an artificial price.

As a solution, this report proposes to curtail ETS and replace ETS with carbon tax. If you introduce a carbon tax per ton of CO_2 according to the price formed on the exchange per ton of CO_2, that is, 500 tenge per ton, then taxing 180 million tons of emissions you can get about $200 million per year in the form of taxes for GHG emissions.

The carbon tax can also and should be extended to cultivated land, which will stop GHG emissions and reduce emissions by 30 million tons of CO_2 equivalent per year.

Also, the carbon tax plans to introduce the European Union regarding products that were created using energy intensive processes. To begin with, the European carbon tax will affect metals, and then oil and gas. A logical step in this case would be the introduction of a carbon tax on oil and coal production. The amount of tax should be set at 1% of the revenue per ton of oil or coal. As a result, carbon tax revenues from oil production, according to the author, would have ranged from $200 to $500 million. Financial flows from the carbon tax would give the Government resources to decarbonize the economy of Kazakhstan. For example, this money could be used for the sale of auctions on renewable energy.

4.3 Short-lived Climate Pollutants (SLCP)

This section is focused on methane as the most important SLCP from the prospective of accelerated action to combat climate change.

Accelerated reduction of methane emissions across all sectors of the economy has been increasingly recognized by the international community in the run up to COP-26 as a very high priority policy and action required to achieve stated goals of the Paris Agreement. The US, European Union, the UK, and six other significant methane-emitter countries have committed to the Global Methane Pledge to reduce methane emissions by 2030 by 30% compared to 2020 levels [73].

There are also various international initiatives and partnerships involving industry, international organizations, and NGOs aiming at accelerated reduction of methane emissions such as:

- Global Methane Initiative [74],
- The CCAC Oil and Gas Methane Partnership [75],
- IEF Methane Initiative [76],
- UNEP/CCAC Global Methane Alliance [77],
- One Future [78].

Methane emissions in Kazakhstan amount to almost 42 mt of CO2eq, out of which about more than 20 mt are emitted in the energy related activities. Agriculture accounts for roughly 16 mt. [79].

In the energy sector, fugitive coalmine methane is responsible for 76% of all sector emissions with fugitive methane in the oil and gas production, processing, transport, and distribution accounting for most of the rest.

Technologies for capture and utilization of coalmine methane from operating and closed coal mines are well developed and easy to deploy, their use is widespread in many coal-producing countries. Unit abatement costs of such technologies are low. At the same time, in the context of coal phaseout, captured coalmine methane could be a valuable local substitute fuel resource, primarily for industry and residential needs. Reduction and/or utilization of nearly all fugitive coalmine methane emissions should become a near term policy priority by requiring all coal mine operators to capture and destroy/ utilize fugitive methane.

Fugitive methane emissions in the oil and gas sector could also be relatively easily reduced and managed. It also makes economic sense for the companies to do so. Regulations on this need to be introduced as soon as practicable. International industry initiatives and partnerships such as above should be engaged and joined.

The Government of Kazakhstan, in its turn, needs to quickly create a robust regulatory and incentive framework to accelerate reduction of fugitive methane emissions, including special provisions for dedicated "transition" finance instruments.

Abandoned and improperly closed wells present an important source of methane but are difficult to tackle. At the same time a program to deal with this issue could become a new driver of economic activity and alternative employment during this crucial decade of accelerated action. Speedy resolution of outstanding legal and regulatory issues and creating a public-private partnership undertake proper plug-in of the above wells, supported by an appropriate financial framework, including use of market mechanisms, would help to liquidate this source of leakage.

Agricultural methane emissions are more difficult to tackle. Cardinal reductions currently are conceivable only through drastic changes in the existing food production system and reduction of cattle stock and meat consumption. Still improvements in cattle productivity can go a long way in reduction of agricultural methane. There are also significant ongoing R&D efforts to develop advanced ruminant dietary additives that would be able to significantly remove enteric methane emissions [80].

Methane digesting and biogas production is also widely available technology that has significantly advanced in the recent decades and could be deployed in several regions of Kazakhstan, providing an alternative source of fuel for heating and other uses.

Policymakers should:
- Stimulate entrepreneurship in better cattle productivity and methane digestion/biogas use (substitute for coal for heat in the rural areas)
- Increase investments in R&D related to advanced dietary supplements, better breeding strategies, and methane digestion technologies
- Facilitate technology transfer and adoption, partnerships with the leaders in this field

Significant reductions in agricultural methane emissions would have an added effect of sizable reduction of N2O emissions as well.

Solid and liquid waste management is in this area should include:

- Spread of separate collection of organic waste, prevention of its disposal at solid waste landfills
- Production of new products including biofuel
- Transition to maximum possible use of biodegradable waste to produce saleable compost and biogas
- Increase of recycling, reprocessing, reuse, and utilization
- Collection and utilization of methane/biogas generated at landfills and wastewater treatment facilities and its use as renewable fuel

There is clearly a case for a regional Central Asia methane public-private partnership bringing together the governments, national and international companies active in the region, international and bilateral development finance organizations, leading business and trade associations, and science and technology research institutions. Such partnership could provide a synergistic multiplying effect and become a meaningful contribution to solving this important global climate mitigation issue.

4.4 Finance Sector and International Finance

Transformation of the financial sector is critical and central to achieving net-zero targets. Financial flows should be cardinally redirected from financing business-as-usual projects and technologies to low-carbon and zero-carbon solutions. There has been some initial progress in Kazakhstan but this transformation needs to be scaled up dramatically.

There is a range of measures and instruments that are available to all financial sector institutions, from the National Bank to the Ministry of Finance to development finance institutions to commercial banks, investment companies, and venture funds. What needs to happen is for the National Bank and Ministry of Finance to move from a neutral-positive stand on green, transition and sustainable development finance to proactive position spearheading financial sector transformation, providing framework for a radical transformation of finance – capital markets, investment, corporate, SME, and retail finance.

National Bank should focus on the following policies and operations:
- climate risk disclosures
- more liberal risk provisions and reserve requirements for green, transitional, and SDG finance
- allowing use of carbon assets as reserves
- robust green finance taxonomy and guidance compatible with the best international practices
- potential purchases of green bonds, sustainability-linked bonds etc, as part of future stimulus programs

Ministry of Finance and national development finance institutions can and should:

- issue sovereign and quasi– sovereign green bonds and other similar instruments
- provide green/sustainability credit and credit enhancement instruments for low-carbon projects and technologies
- provide green venture catalyst capital to leverage private capital flows

Banks, exchanges, investment companies and other financial services and markets institutions should respond to regulatory incentives and business sense in the new regulatory environment to dramatically expand green, transition, and SDG banking and finance in order to mobilize.

International finance. While Kazakhstan is a middle-income country and can't count on large volumes of financial aid from developed countries, there are many sources of international public and private finance to support transition available provided that the right policy framework exists and is enforced and "green" investment climate is attractive. Public finance should serve as a catalyst for leveraging very substantial private finance flow needed to underwrite transition to net 0. In addition to public institutions, such as:

- Bilateral (US Development Finance Corporation, KFW etc.),
- Multilateral (IBRD, IFC, EBRD, ADB, EuDB, AIIB etc.),
- Hybrid (GEF, GCF, CIFs etc.);

private climate-tech venture funds, such as:

- Bezos Earth Fund, Breakthrough Catalyst Fund;

and private equity climate funds and asset managers should also be engaged. Private climate finance will inevitably outpace the public sources but Kazakhstan needs to be in a good competitive position to attract the above financial flows.

Some key questions need to be addressed. How to put Kazakhstan on the investors radar screen? Why would they invest in Kazakhstan? What will make a difference are the conducive investment regime and capacity to prepare and execute investments in an efficient and transparent manner. This would make Kazakhstan a winner in the new green finance race.

4.5 Hard-to-abate Industries

Kazakhstan is home to a diversified industrial base providing substantial share of its GDP and export earnings. Decarbonizing hard-to-abate industries such as metals, cement, glass, and chemicals will be challenging and must rely on international partnerships and government support to develop and deploy new technologies. At the same time there are many options, given appropriate incentives and tools, to make existing technological processes more energy– and resource-efficient, or use alternative fuels such as renewables or RDF.

Kazakhstan-produced metals are providing a valuable contribution to the global energy transition as demand for copper, cobalt, and other metals is growing in this context. The challenge is to produce and use them in the most climate-benign way.

Still new technologies will need to be developed and deployed. For example, in steel making, according to ArcelorMittal, global steel group with significant presence in Kazakhstan, there are currently two main decarbonization pathways:

- Direct reduced iron/hydrogen and
- Use of circular carbon, carbon waste streams, sustainable biomass, carbon capture and utilization, and carbon capture and storage

Incidentally, ArcelorMittal committed to reaching groupwide target of net-zero emissions by 2050 setting a good example for other Kazakhstan industrial companies or international corporations with Kazakhstan operations.

4.6 Socio-economic Mitigation of Accelerated Coal phase-out – Just Transition

Given Kazakhstan's dependence on coal, energy sector transition away from coal will be very challenging. Equally challenging will be a just socio-economic transition in the communities and regions with heavy concentration of coal mining works and coal-fired power plants. Such just transition will require careful re-development planning, significant financial investment resources, and participatory and responsive community engagement.

Just transition from coal should become a matter of a very high priority for the Government and regional/local authorities in Karaganda, Ekibastuz, and other coal-producing basins. As one American NGO has put it, "...we should abandon coal, not coal workers." [81].

Kazakhstan should draw lessons from other countries that went through the coal sector restructuring, downsizing, and closure earlier. The World Bank [82] [83], with its experience of many coal sector adjustment lending projects and globally sourced knowledge of several country-level coal sector transitions could become a valuable partner in developing, financing, and executing just transition plans based on such pillars as:

I. Governance structure
II. People and communities
III. Land and environmental reclamation

European Just Transition Mechanism, as well as many other national and subnational initiatives are also worth studying and engaging with to develop the most appropriate national scheme.

Kazakhstan should also engage with other most heavily coal-dependent countries and international financial institutions to form a partnership or platform to generate and exchange knowledge and attract long-term concessionary and innovative finance. Mobilization of international private impact capital in the redevelopment projects should also be explored.

5. International Cooperation

5.1 A Net-zero Kazakhstan in 2060 [84]

Regional/international cooperation generally refers to the political and institutional mechanisms that actors of a region use to "imagine and plan a joint development" while promoting national interests at the same time.

In the framework of this chapter, we look at "regional cooperation" (in the energy and climate field) as a multifaceted concept that can potentially be translated into "co-design of policies" (e.g. standards), "co-development of technologies/solutions", "co-financing of projects and measures", "rational exchanges of surpluses", "sharing experiences, practices or lesson learned", and "dialogue", to find and strengthen common interests.

From a geographical and geopolitical perspective, the "region" around Kazakhstan has always been a crossroad for the movements of goods and people between Europe and East Asia (China), as well as between Russia and West/South Asia, thus (often) being seen as a land of strategic opportunities as well as of complexities. Furthermore, because of the crossroad nature of the region, the borders of the Central Asian system themselves are somehow "fuzzy", and several neighbours such as Azerbaijan [85], Mongolia [86], Afghanistan [87], may be also considered important actors of a bigger and even more complex regional game [88].

To illustrate the (identified) most relevant elements of regional and international cooperation, the chapter is organized in paragraphs as follows:

- Methodological approachs,
- Kazakhstan and the Central Asia region,
- Kazakhstan and the Russian Federation,
- Kazakhstan and China,
- Kazakhstan and other (Western) players (focus on the EU),
- Kazakhstan and all: digitalisation,
- Key conclusions.

5.2 Key Messages from the G20 on Environment, Climate and Energy [89]

Energy and environment ministers from the Group of 20 rich nations have met in July 2021 in Italy to discuss on the formulation of "key" climate change commitments. The G20 meeting can be considered as a major step ahead of United Nations climate dialogue, known as COP 26, which will take place in Glasgow in November 2021.

Ministers could not manage to find a complete agreement on "two" disputed issues in July 2021 (leader summit). The two key contested points [90] are: the phase-out of coal power timeline (some countries pushed towards an early retirement by 2025); and the reinforcement/acceleration of the Paris Agreement (cap temperature at 1.5 degrees that some countries would push to reach in the next decade [91]), due to their respective policy costs.

Despite the points of disagreement, Italy's Ecological Transition Minister said "this is the first time that the G20 has accepted that climate and energy policies are closely interconnected".

Some of the "pillars" discussed during the G20 are summarized below. They will form the basis of the transition towards a climate neutral world, and will provide the "keywords" for the present chapter.

- The energy system is key in the path towards climate neutrality and net-zero emissions by 2050.
- A systemic view is needed to ensure sustainable, resilient, accessible, and just energy system development: all layers must be considered.
- A climate neutral and sustainable energy system relies on the integration of the different energy sectors at any scale and considering the most cost-effective ways.
- Three pillars underpin the transition to a climate-neutral energy-system, namely: "Sustainable Input", "Flexibility" and "Decentralization".
- Limiting warming to 1.5°C implies reaching net zero CO2 emissions globally by 2050, and concurrent deep reduction of non-CO2 emissions, particularly methane.
- The SARS-Cov2 pandemic has caused a shock to economies at the global level, but it represents an unprecedented opportunity to accelerate the transition towards a climate-neutral, and sustainable economy.
- International cooperation and multilateral action shall continue providing a platform to share best practices, align ambitions, harmonize standards, maximize and capitalize R&I efforts and support investment at scale.

Sustainable Input

Renewable energy (the IEA Sustainable Development Scenario (SDS) to 2070 reports that the share of renewables in the global power generation mix needs to reach 86%) and electrification (transport sector, industry, building) are key to meet the neutrality goal. Decisive technological and socio-technical actions need to be taken "jointly" to promote the potential of renewable energies to meet electricity, mobility, heating. Research activities, country and cross-country infrastructures, digitalisation, involvement of consumers/local communities are important tools to trigger the change.

Key words:

- Large-scale renewable energy
- Electrification

Flexibility

The integration into power systems of high shares of vRES poses significant challenges to the system operation. Several solutions for flexibility services to the system are available or are being developed. Energy storage can provide multiple services to the electric grid by storing the energy produced in excess and delivering it on demand (e.g. power and thermal storage). Hydrogen as a vector allows to decouple the dynamics of energy generation from that of demand. Moreover, powerful interconnections, with special reference to high voltage direct current (HVDC) systems, leverage the potential of different renewable energy sources, technologies, time zones, load characteristics, also located far from one another thus ensuring the overall balance along the entire energy system. Lack of production in one area can be compensated by surplus in another one.

Key words:

- Storage
- Hydrogen
- Interconnections

Decentralization

From "centralised" to decentralised "generation", exploitation of renewable energy resources available locally (biomass, biogas, geothermal, waste, small hydro) to allow more circularity, sustainability, inclusive and community-based, and a more efficient use (less losses) of energy. Digitalisation (ICT architectures, IT techniques, gamification) and energy efficiency are also key to foster decentralisation.

Key words:

- Small-scale renewable energy
- Energy efficiency
- Community engagement
- Digitalisation

5.3 Methodological Approach

Kazakhstan is one of the middle-income countries that heavily rely on direct rent from carbon intensive activities to continue developing, building necessary infrastructures, and running the basic public services such as education and health (export revenues from oil as a share of total export revenues is greater than 50%). A first step to move along the "value chain", from a pure extraction industry to the manufacturing, has led to a relatively high concentration of carbon-intensive industries (e.g. metallurgy and chemicals) which are generally still quite low-value added sectors. The "intrinsic" quantity of GHG emissions embedded into the commodities/goods destinated to export is therefore among the highest in the world.

Figure below shows a simple framework to assess the level of "exposure" of the country to a "world low carbon transition". It is based on four main indicators monitoring (in a quantitative [92] or semi-qualitative manner) the current and expected/projected economic dependency of the country on the fossil fuel (bottom), and the already built and planned/under consideration captive assets (top). Both the "type" and the "timing" of the exposure are evaluated.

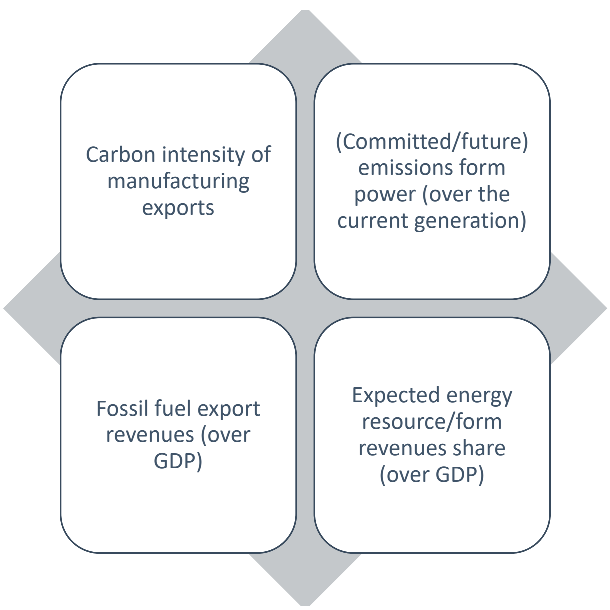


Figure 5.1 – Author' elaboration, adjusted from World Bank.

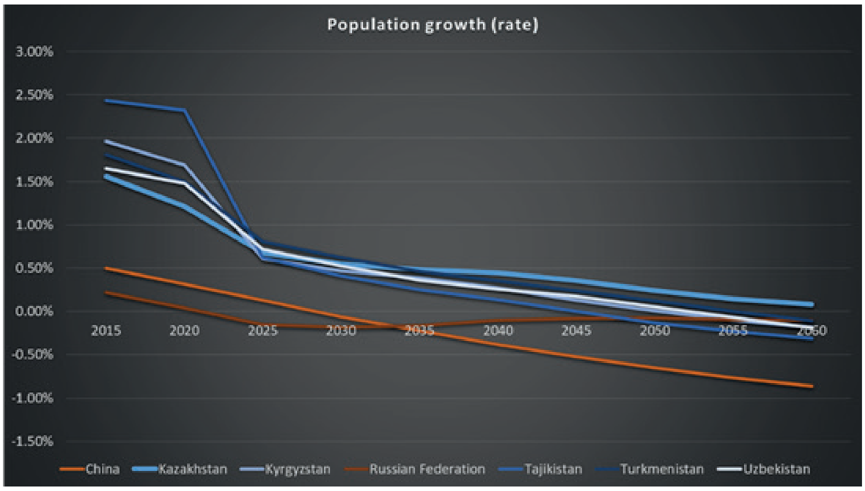
Kazakhstan has a large share of fossil fuel export revenues, and quite high carbon intensity of the exported goods. It has huge reserves of coal [93] (R/P >200 years) that is in part exported (13 Mtoe) and in part used in for internal consumption (mainly) in the power sector and industry, and significant reserves (R/P >45 years) and export (71 Mtoe) of oil. In a low carbon transition world perspective, demands and prices of both the commodities are most likely expected to decrease thus (potentially) leading to significant reduction of revenues from direct export [94]. Moreover, trade measures/ instruments [95] of importing regions may soon introduce some (minimum) "standards" about the embedded carbon content of the traded goods, thus posing an additional high risk for the market position of the products manufactured in Kazakhstan. The (economic and social) cost of *inaction* can potentially be even higher than the cost of transition to a net-zero economy, Kazakhstan should try to maximize the benefits of cooperation not to lose the momentum.

In the framework of this "net-zero emissions vision" for Kazakhstan, and of the potential benefits of regional/international cooperation to achieve climate neutrality in the next 40 years, the following key "players" are taken into consideration: the Central Asian region [96], Russia, China, and other relevant (Western) actors (focus on the EU).

Figure 5.2 – Kazakhstan (blue); Central Asian countries (dark blue); big neighbours (dark orange), rest of the world (light grey)

This chapter aims mainly to provide a "descriptive analysis" of the space (and trade-offs) of regional and international cooperation relevant to the climate neutrality vision of Kazakhstan. It also aims to highlight players and areas of such a complex game (with Kazakhstan as a "centroid" of the game), identify and describe potential opportunities for synergies, collect and share a few basic quantitative information inherited by other studies [97], and ultimately give food for thoughts and elements for decision makers, analysts, and stakeholders in Kazakhstan, in order to ease a just and timely achievement of the vision.

In this regard, it is also worth noting that the "net zero vision to 2060" of Kazakhstan is embedded in a regional socio-economic perspective that foresees positive rates of population growth (with the exception of China, after 2035), and that expects / aspires to relatively high GDP growth rates for all the countries involved, thus posing additional concerns and complexities for future energy demands and competition for resources and market shares.



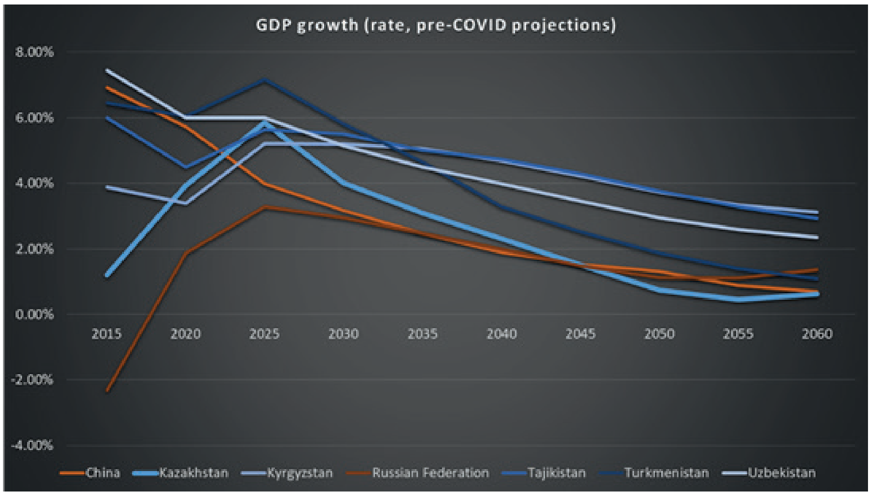


Figure 5.3 – Population growth rate and GDP growth rate

Table 5.1 provides an overview of the "possible" space for regional and international cooperation; the most relevant areas and topics are further explored in this chapter.

Table 5.1

Kazakhstan – Cooperation on/with:	Central Asia	Russia	China	EU	Others Western
Large-scale renewable energy	3	2	3	2	2
Electrification	2	2	3	3	2
Storage	3	2	3	3	2
Hydrogen	1	3	3	2	3
Interconnections	3	3	3	1	1
Small-scale renewable energy	3	1	2	3	2
Energy efficiency	2	1	2	3	2
Community engagement	3	1	1	3	1
Digitalisation	3	3	3	3	3
Non-CO2 emission cut	1	3	1	2	1
Research and Innovation	3	2	2	3	2

Qualitative (indicative) color-gradient scale

5.4 Kazakhstan and the Central Asia Region

Central Asian countries, namely Kazakhstan, Kyrgyzstan, Tajikistan, Turkmenistan and Uzbekistan, have a cumulative population of about 70 million people that is expected to grow to something like 90 million by 2050, still an incomplete market-based development of the economies and old and inefficient energy-related physical assets, all factors posing important obstacles to the low emission development of the region. Natural and energy resources are shared unevenly among the countries with hydrocarbon resources [98] concentrated in Kazakhstan, Turkmenistan, Uzbekistan, and hydropower resources [99] concentrated in Kyrgyzstan, Tajikistan.

Figure 5.4 – Kazakhstan and Central Asia on the map

A (simplified) version of the regional "strategic game", in light of the net-zero vision for Kazakhstan, is presented and illustrated below (in an extensive-tree format). Four players are taken into consideration with a number of moves/strategies per each player (representing possible country-specific priorities and choices), the combination of which is expected to lead to very different outcomes for Kazakhstan. Potentials for "cooperative equilibria" (pure or mixed strategies) need to be carefully analysed in order to move towards "win-win" outcomes (to make use of each other strengths, and try to stand in the international negotiations as one player), as non-cooperative decisions are easily estimated to be expensive and risky under several criteria [100].

Kazakhstan (3 Exemplificative Strategies, Light Blue)

Move 1: rely on CO2 free energy import (electricity, biofuels, H2) from other Central Asia countries, investments in the required interconnections, modernization of the industrial sector while keeping the existing economic structure (with the exception of the oil and gas industry, due to lower international demand);

Move 2: massive exploitation of domestic renewable energy (wind and solar, with the associated backups) and of the national afforestation potential, structural change of the national economy to self-sustain the transition to a climate-neutral 2060;

Move 3: development of H2 industry/chain, blue hydrogen surplus (in combination with CCS) to other Central Asia countries in exchange of electricity (and as part of the minimum water flows negotiation), modernisation of the industrial sector while keeping the existing economic structure (with the exception of the oil and gas industry, due to lower international demand).

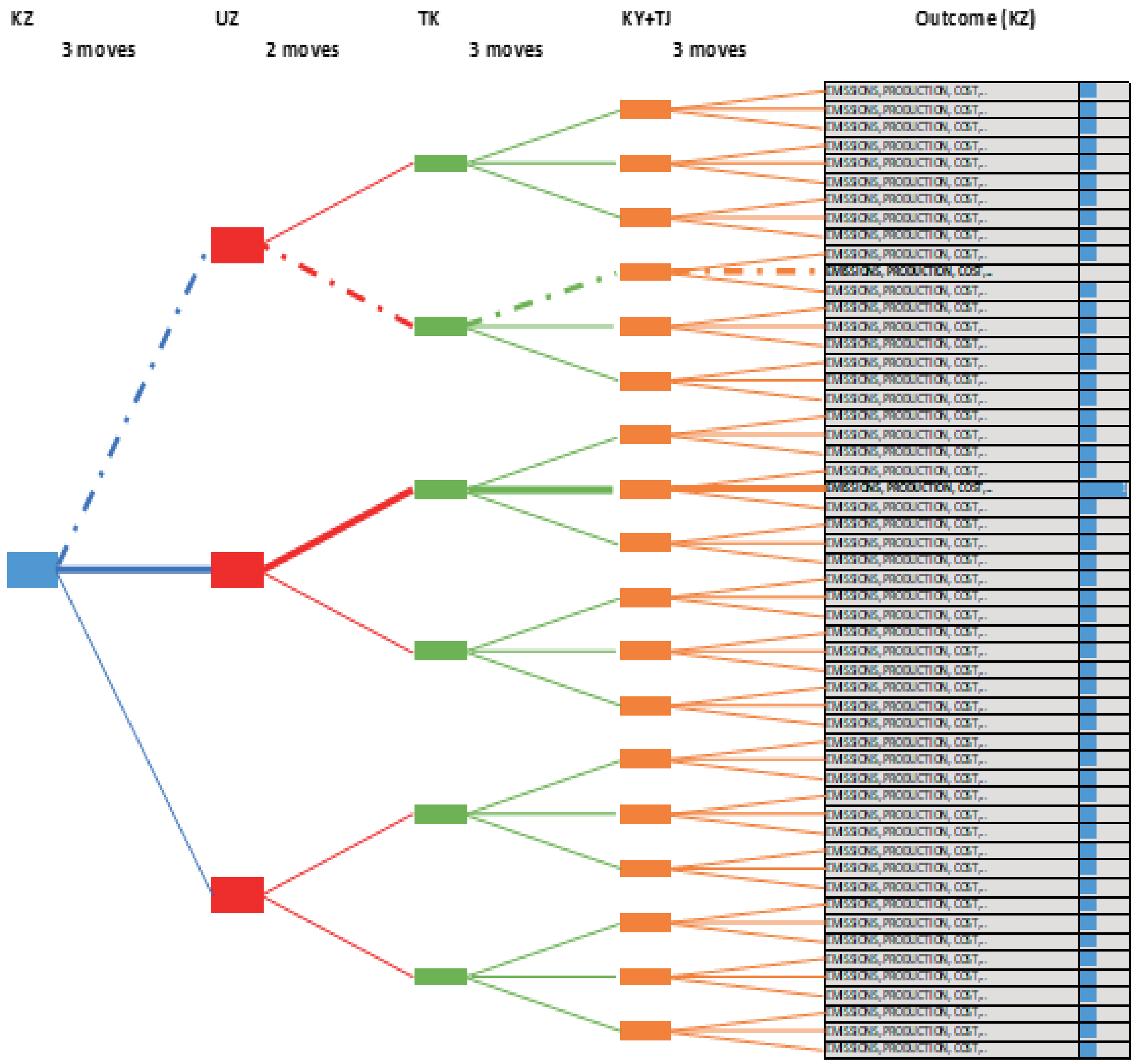


Figure 5.5 – Kazakhstan (KZ), Uzbekistan (UZ), Turkmenistan (TK), Kyrgyzstan + Tajikistan (KY+TJ), Central Asia (CA) [101].

Dashed-dotted branch: most risky wrt the net zero vision; solid weighted: most likely to succeed wrt the net zero vision.

Uzbekistan (2 Exemplificative Strategies, Red)

Move 1: exploitation of domestic renewable energy and nuclear energy to generate surplus of electricity to other Central Asia countries (in particular to Kazakhstan);

Move 2: delayed carbon neutrality transition, rely on CO2 free energy import (electricity, biofuels, H2) from other Central Asia countries.

Turkmenistan (3 Exemplificative Strategies, Green):

Move 1: energy and climate autarchy (limited cooperation in the context of Central Asia);

Move 2: massive exploitation of domestic renewable energy (solar with the associated backups) to generate electricity for the domestic use and some surplus for the regional market (in particular to Kazakhstan);

Move 3: development of H2 industry/chain, blue hydrogen surplus (in combination with CCS) to other Central Asia countries in exchange of electricity (and as part of the minimum water flows negotiation).

Kyrgyzstan + Tajikistan (3 Exemplificative Strategies, Orange):

Move 1: increase of the internal consumption (priority) and electrification of the domestic system, limited electricity surplus to Kazakhstan.

Move 2: delayed domestic electrification, more electricity available for export (lower downstream water flow but more hydropower to Kazakhstan);

Move 3: electricity surplus to other Southern countries (high internal consumption and electrification, and significant reduction of hydropower to Kazakhstan).

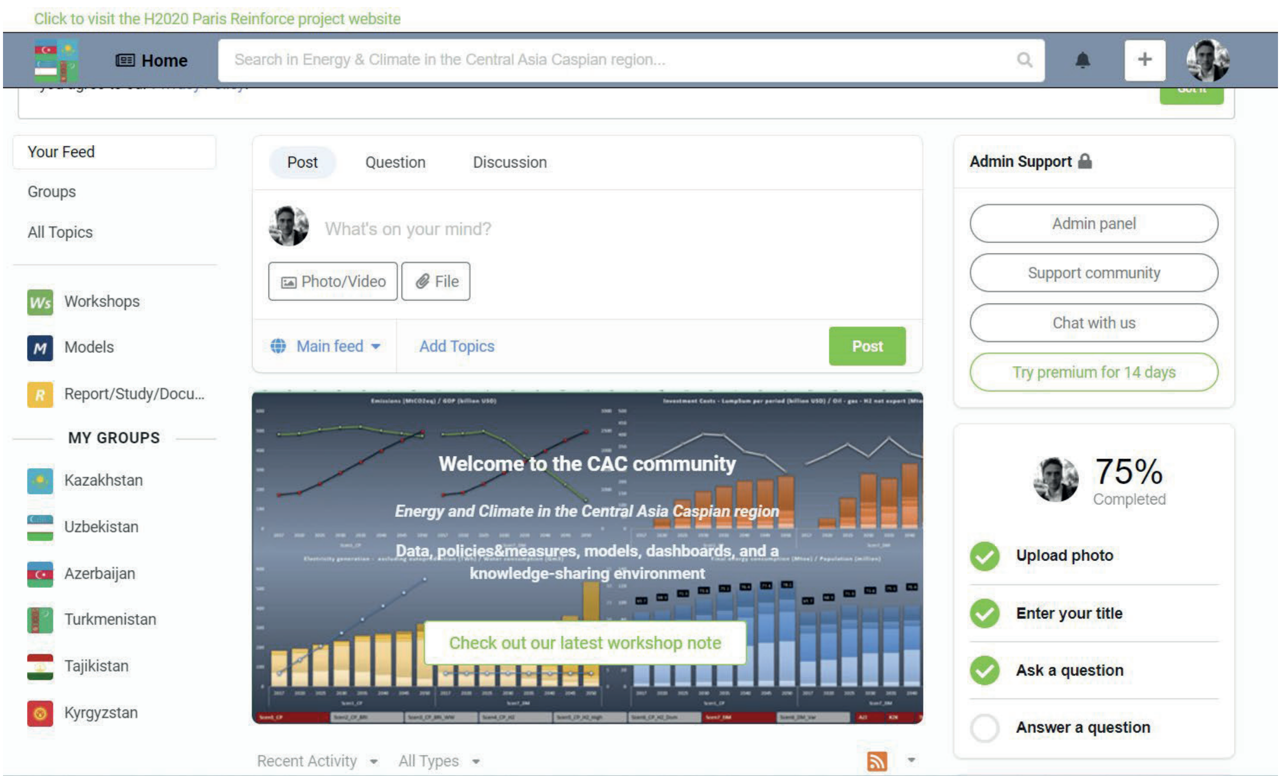
<u>The water and energy nexus</u>

Among the river basins, the Amu Darya and Syr Darya river basins provide 90% of the region's river water. Balancing the needs of hydroelectricity generation (upstream) and agriculture (downstream) is a key issue (with high demand and prices of electricity in winter and high demand and water volume obligations in the Spring/Summer).

Source: author' elaboration

Furthermore, the pressure on the region's water resources is expected to continue increasing due to climate change, and to extra agreements with other countries (e.g. Pakistan) about water-related projects and infrastructures.
Cooperation on a "good/fair" allocation of water resources in the region, as well as on the sustainable exploitation of the hydropower of TJ and KY is fundamental to meet the multiple contrasting needs and wishes, and to turn the region towards a decarbonized future.
Countries involved: Kazakhstan, Kyrgyzstan, Tajikistan, Turkmenistan and Uzbekistan (others, indirectly)

In the framework of a recent stakeholder engagement exercise in the area, a first regional "cooperation community" (named "CAC forum") was designed with the aim to gather experts of Central Asia, discuss hot topics in the energy and climate areas, facilitate the cross-country dialogue, sharing international and local experience, findings, and material, and organise polls/surveys. Forum can be developed in a virtual "platform" to coordinate actions and decisions at regional level in the broad and integrated field of energy and climate.



CAC.tribe.so

Figure 5.6 – CAC Forum [102]

The forum is organized as follows:

– One common group: where the aim is to discuss regional issues with all the participants and share comments, ideas, material. This is in fact the "homepage" of the platform.

– Country groups: where the aim is to discuss more country-specific issues (not relevant for other countries or a bit more confidential). Country-specific information and posts are stored here, access is limited to country-specific experts and international experts/modellers.

– Moderators also play the role of "trigger", to stimulate the discussion and the sharing experience.

The Integrated Energy System of Central Asia

The TIMES-CAC model is designed as a single, multi-regional model, based on four structurally-consistent and interconnected country energy systems (Azerbaijan, Kazakhstan, Turkmenistan, Uzbekistan) combined with an implicit representation of water and hydropower from Tajikistan and Kyrgyzstan. It covers the period 2017 (BaseYear) – 2050 with the aim to analyse alternative developments of the regional system under different scenarios in a medium-to-long time horizon. It describes the entire energy chain (from the mining/extraction to the final uses) with high capability to represent technologies, mitigation options and measures, energy efficiency and fuel switches, so as to cover the large part of the GHG emissions reported in the national inventories.

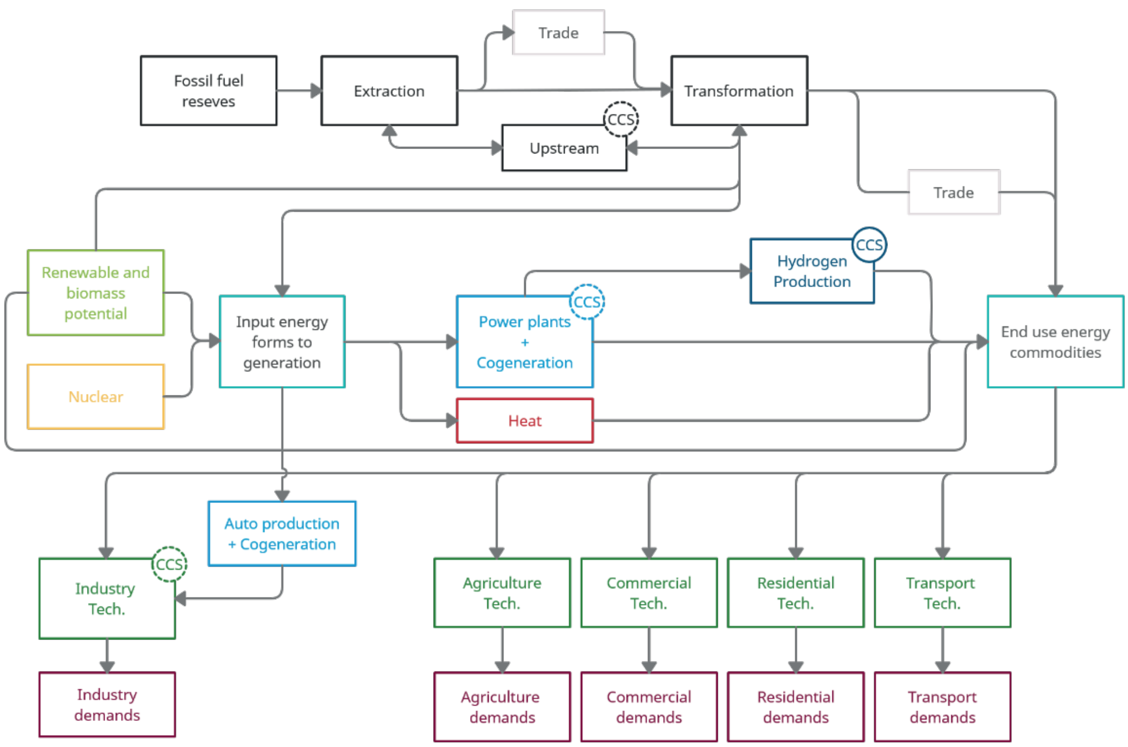


Figure 5.7

The model makes use of a partial equilibrium paradigm (TIMES-based) and it is formulated as a mixed-integer linear programming problem (MILP) as some variables (size of “power plants”) are restricted to be integer. Integer linear programming formulations provide a more accurate tool for the representation of specific investment decisions/installations at the cost of higher computational efforts.
In order to model the time variation of key energy flows demands within a year and the time variation of energy production from variable renewable energy sources, the year has been divided into a number of “time slices” (24: 4 seasons * 6 intraday slots) by grouping hours with similar characteristics (load). The current intra-annual representation of the flows does allow to better represent key technologies such as wind, solar, advanced heaters, storage systems, peak needs, etc.
The TIMES-CAC model represents the trades with the rest of the world by mean of exogenously defined supply/demand cost curves (Azerbaijan is the region’s link westward). Particular attention is dedicated to the trade of electricity with Kyrgyzstan and Tajikistan (water-energy nexus), and to the design of a new cross-national “market” for hydrogen (specifically designed for testing cooperative strategies in the region).
The key data, scenario factors and outcome of the model have been recently presented and discussed in a stakeholder engagement series with local experts [103].
The TIMES-CAC embeds the energy system model of Kazakhstan presented in this document (as an advanced version of the model designed and used for the Low Emission Development Strategy of Kazakhstan).

5.5 Kazakhstan and the Russian Federation

The development of an international climate agenda can bring both opportunities and risks for the economy of Russia. Among the opportunities is the possibility to gain new market shares through competitive advantages associated with the low carbon intensity of Russian goods [104] (especially in the non-EU market) and to play a leadership role in the global transition; among the risks are the possible expenses under European Carbon Border Adjustment Mechanism (CBAM) [105], and the possible growth in tariffs for heat and electricity for all types of domestic consumers when deep mitigation / de-carbonization targets are transferred to the national system.

Energy (and economic, and social) interdependence between Russia and Kazakhstan is historically rooted and can be well-captured by simply looking at the electricity grid and at the oil & gas pipelines maps of Kazakhstan (the border between the countries is the second longest continuous in the world). Both countries have to deal with critical “characteristics/challenges” like the high heating demand, the relevance of heavy industry (mining, oil and gas) in the economic structure, potential stranded assets [106], long distances (risk of losses), etc.

To what extent competitive behaviours (or on the other side, cooperative actions) in the energy and climate fields can potentially affect the transition of the energy-economic system of Kazakhstan is something worth to be deeply evaluated, and it is likely to be very relevant.

Figure 5.8 – Kazakhstan (KZ), Russian Federation (RF)

Pillars of the long-term energy and climate policies in Russia

Russia is estimated to have around 35% – 40% of the total carbon stock of the world's boreal forest ecosystems. According to current official estimates, Russian forests (LULUCF sector) compensate for 26.6% of national greenhouse gas emissions [107].

Having huge reserves of forests is considered the most important natural advantage of Russia for the future competitiveness of the national economy; to date the implementation of measures to exploit and increase carbon sequestration by forest ecosystems is the key policy element of the country.

Nuclear power is considered the first option to decarbonise the power sector; it is a well-developed domestic industry providing the full cycle of equipment production and construction of nuclear power plants as well as their fuel supply. Local experts expect a 15%-20% decrease of CAPEX due to the technological learning and transition to the fast reactors from 2040 [2].

Most of renewable energy resources (hydro, wind, solar with higher capacity factors) are located in the North and East of Russia, far away from the load centers (80% of the electricity demand is currently in the European part of the country), and therefore the massive penetration of renewable is generally associated with higher costs and subject to the construction of very long HV transmission lines (thousands km).

In July 2021, the President signed a long-awaited law limiting GHG emissions to oblige the enterprises (whose work produces high amount of emissions) to record and monitor emissions with respect to specific targets.

On August 2021, the Russian Concept of Hydrogen Economy Development came out with some indications of the role of hydrogen in the future years:

– hydrogen is viewed as a "hedging tool" that can help reduce the carbon intensity of Russian exports with a view that transboundary carbon mechanisms (eg CBA) will be introduced in other countries (EU);

– as for domestic uses, hydrogen is especially prospective for far North regions, improving their access to low – carbon energy;
– Russia primarily bets on hydrogen using natural gas and coal with CCUS, and nuclear energy.
– Russia plans to create and develop "three" hydrogen production clusters: NorthWestern, for EU exports; Eastern for Asian exports, and the Arctic cluster for domestic consumption in far north regions and/or exports. Potentially, a Southern cluster will be developed as well (of interest for Kazakhstan).
– Russia plans to develop a unified international hydrogen classification system that will include the assessment of the carbon footprint when using each of the available technologies for the production of hydrogen.

A (simplified) version of the regional "strategic game", in light of the net-zero vision for Kazakhstan, is presented and illustrated below (in an extensive-tree format). Here the two players are taken into consideration with a number of moves/ strategies per each player (representing possible country-specific priorities and choices), the combination of which is expected to lead to very different outcomes for Kazakhstan. The integration of different country-strategies reveal risks and opportunities for Kazakhstan with respect to the economic/social indicators as well as to the country climate ambitions.

Kazakhstan (3 Exemplificative Strategies, Light Blue)

Move 1: immediate join the "race to zero" (massive investments in clean energy and modernization of the heavy industries in compliance with international best available technologies (CBAM) standards);

Move 2: delayed transition and rely on CO_2 free energy import (electricity, biofuels, H_2) from other countries in the region (free-riding), and on technology/standards developments from neighbours.

Move 3: energy and climate plan inspired by the Russian pillars (e.g. nuclear, afforestation [120]), standards (e.g. energy intensity per unit of output), practices (e.g. gas flaring).

Russian Federation (2 Exemplificative Strategies, Red/Blue)

Move 1: current lines of priorities (carbon sequestration and nuclear);

Move 2: much larger exploitation of renewable energy forms, hydrogen, and construction of HV transmission lines and trans-country "corridors".

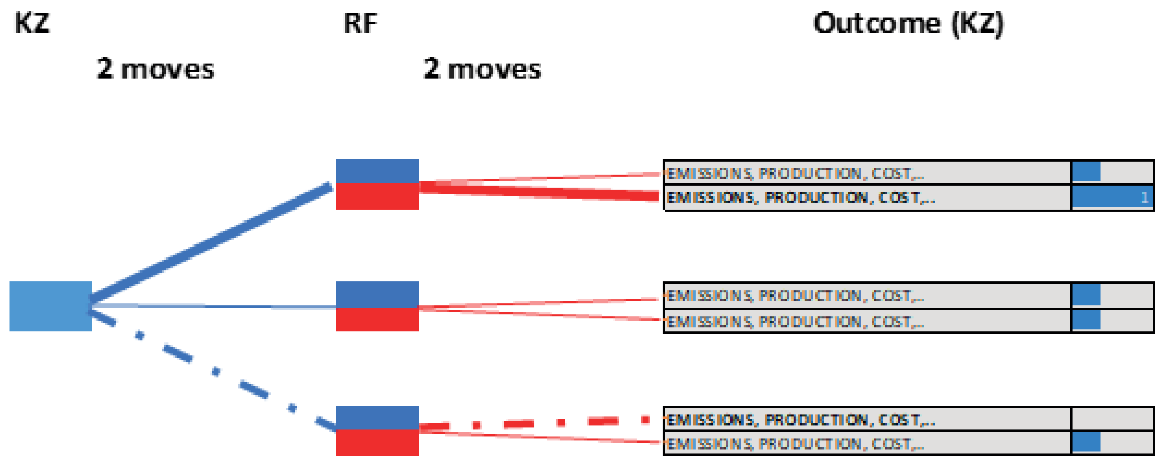


Figure 5.9 – Kazakhstan (KZ), Russian Federation (RF).
Dashed-dotted branch: most risky wrt the net zero vision; solid weighted: most likely to succeed wrt the net zero vision.

5.6 Kazakhstan and China

Likely, the Chinese announcement of net-zero emission by 2060 (even more than the equivalent commitment of the EU by 2050) has played the role of *real trigger for the neutrality vision of Kazakhstan*.

Chinese GHG emissions alone account for around 26% of the global GHG emissions (Climate Gap Report, 2020). Current policies and targets in place have the potential to (relatively easily) meet the Chinese NDC target (65% reduction in *emissions intensity* of GDP relative to 2005) and to peak the emission level some time in between 2030 and 2040 [108]. But *significant* additional efforts are needed to turn the NDC pathway to a net-zero pathway after 2035-2040, in particular in the power sector and industry and transportation.

Pillars of the carbon neutrality goal in China

Although no clear and official pattern has emerged so far, and no precise mechanism has been presented for the achievement of the neutrality goal, a number of studies [1] and modelling exercises (and actual physical projects, in China) seem to suggest that:

– from 2050 and beyond the power sector is seen to be strongly dominated by renewable energy and nuclear;

– the electrification of the energy services in the building sector (coupled with smart-enabling technologies) is seen as one of the fundamental steps to achieve the goal;

– electricity, biofuels, and hydrogen are all seen to contribute for a low-carbon transportation sector in combination with intelligent transportation systems (providing innovative services for different modes of transport);

– high electrification rates in modern industrial activities, and large use of hydrogen and biomass (with CCS) for industrial process heat (in substitution of coal and natural gas) are key.

Aside from the domestic ambition of neutrality and the changes to achieve the target, it is a fact that nowadays China become one of the leading countries in development and manufacturing of "clean" technologies and that will therefore play a pivotal role in the global challenge to decarbonise the energy sector (with potentially huge economic competitive advantages).

A talk about the introduction of a domestic "CBA-like" mechanism (against the carbon intensive import products) is at a very initial stage.

Figure 5.10 Kazakhstan (KZ), China (PRC)

The extent to which the net-zero ambition of Kazakhstan is in synergy or (somehow) in competition with the climate neutral goal of China is a complex and multifaceted issues. In this paragraph a possible space of cooperation, in the framework of the Chinese "green BRI" initiative, is briefly presented [109].

The Belt and Road Initiative [110] is a complex China transcontinental long-term policy and investment program (2013). Its aim is to develop infrastructures and accelerate the economic integration of countries along the route(s) of the historic Silk Road (Silk Road Economic Belt (land routes) comprising six development corridors).

Figure 5.11 – "The Bridgeland theory"

It can be considered a controversial program, a mix of opportunities and risks. It can bring significant amount of money in the region (dozens of billions USD), currently the large share of which has been allocated to the oil and gas sector and to (heavy) industries, and therefore it can be seen as an opportunity to modernize the old-fashioned and inefficient infrastructures of the Central Asian countries and in particular in Kazakhstan [111]. At the same (if not properly controlled/used) such an opportunity can be "turned" into a re-location program of heavy industries from China to Kazakhstan, with very negative impacts on the GHG mitigation ambition.

More recently, it is getting more attention the expression "Green BRI", namely the interpretation of the program under a sustainable lens. The idea would be to invest/construct/finance green-related projects (renewables, transmission grids, modern railways, hydrogen) only, in order to "tie" the green development of China with green developments of the rest of the regions, over the economic corridors. Under the above described framework, making use of the two stand-alone explorative analyses (for China and for Central Asia / Kazakhstan) and of the corresponding key elements and outcomes, a possible design of cooperation has emerged. The key pillars of such a cooperative behaviour being the following:

- in the case of a Chinese net-zero emission transition, some "spare hydrogen production" results from the analysis (driven by the huge wind penetration) in the long-term, especially in the Western regions (which border with Kazakhstan);
- such amount of hydrogen can be seen as a "surplus" of a CO_2-free energy form that cannot contribute to the domestic (further) reduction of GHG emissions, and that therefore can potentially be used to supply neighboring regions (Kazakhstan);
- in the framework of the "Belt and Road Initiative" projects, such a hydrogen surplus can play the role of "green-maker" of the Chinese captive investments in the energy systems of the region, thus enhancing the "attractive power" of foreign projects in the country;
- the "lag" between timelines and pathways of the Chinese decarbonization plan (publicly announced) and the possible/future decarbonisation plans of Kazakhstan [112] may create the condition for stimulating and facilitating the use of clean energy in the country (free-riding) [113], as shown by the "Deep Mitigation" profile in the white area of the figure below.

The quantitative analysis (undertaken for a different research [114]) of the above described storyline shows that the mitigation potential of this CO_2-free energy supply, from China to Kazakhstan (mainly used for transport and industrial processes), is equivalent to the reduction needed to meet the NDC target of the country in the long-term.

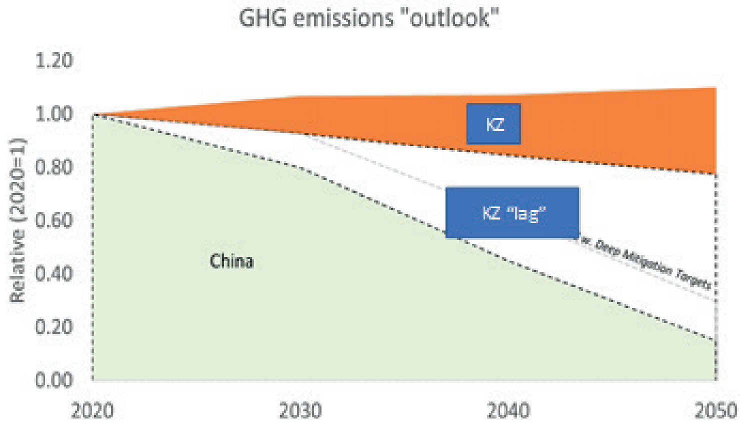


Figure 5.12 – GHG emissions "outlook"

A (simplified) version of the regional "strategic game", in light of the net-zero vision for Kazakhstan, is presented and illustrated below (in an extensive-tree format). Here, the two players are taken into consideration with a number of moves/strategies per each player (representing possible country-specific priorities and choices), the combination of which is expected to lead to very different outcomes for Kazakhstan. The combinations of different country-strategies reveal risks and opportunities for Kazakhstan with respect to the economic/social indicators as well as to the country climate ambitions.

Kazakhstan (3 Exemplificative Strategies, Light Blue):

Move 1: immediate join the "race to zero" (massive investments in clean energy and modernization of the heavy industries in compliance with international best available technologies (CBAM) standards);

Move 2: delayed transition and rely on CO2 free energy import (electricity, H2) from other countries in the region (free-riding), and on technology/standards developments from neighbours;

Move 3: development of H2 industry/chain, generation of blue hydrogen surplus (in combination with CCS) for export to China (West) in exchange of technology and modernization of the industrial sector (to keep the existing economic structure (with the exception of the oil and gas industry, due to lower international demand).

China (2 Exemplificative Strategies, Yellow/Red):

Move 1: delayed transition to a climate neutral economy (delayed generation of potential surpluses), more standard development of BRI projects in Kazakhstan) [115];

Move 2: early exploitation of renewable energy forms (and hydrogen surplus) to meet the domestic ambition before 2060, and massive investments in the "green BRI" [116] (standard and principles in accordance with the 1.5 degree target).

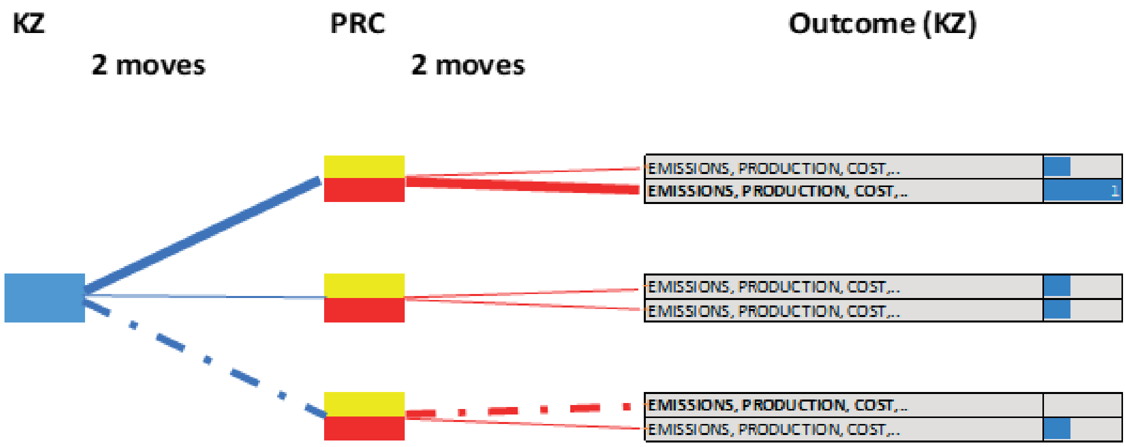


Figure 5.13 – Kazakhstan (KZ), China (PRC).

Dashed-dotted branch: most risky wrt the net zero vision; solid weighted: most likely to succeed wrt the net zero vision.

5.7 Kazakhstan and Other (Western) Players (Focus on the Eu)

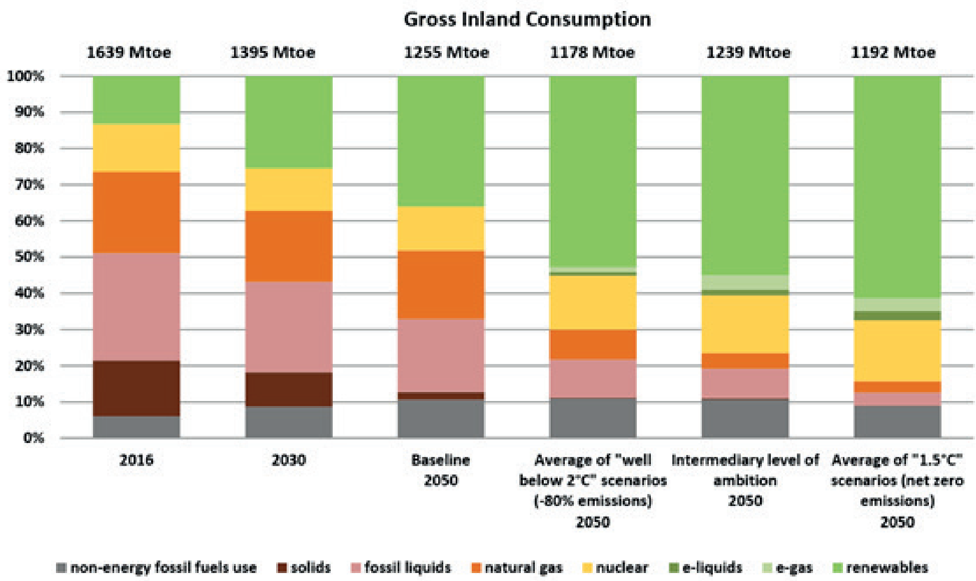
The European Union aims to be climate-neutral – an economy with net-zero greenhouse gas emissions – by 2050. This objective is at the heart of the European Green Deal and in line with the EU's commitment to global climate action under the Paris Agreement. The transition to a climate-neutral society is considered both an urgent challenge and an opportunity to build a better future for all, and all sectors of the society and economy are called to play an important role: from the power sector to industry, mobility, buildings, agriculture, and forestry [117].

The EU is set to take the "lead" in climate policy action among the world's biggest greenhouse gas emitters, and can therefore be seen as the "benchmark / reference" for all other players with similar ambitions.

Figure 5.14 – Kazakhstan on the map

Through the proposed new EU program “SECCA” (expected to begin at the end of 2021), the EU aims to promote a more sustainable energy mix in the Central Asia region in line with EU “best practices”. EU Support to Sustainable Energy Connectivity in Central Asia (SECCA), built on the experience of the INOGATE program, and of the most recent the EU4Energy program, will work through a range of activities to achieve concrete outputs to strengthen public capacity (institutional, human and regulatory, financial), raise awareness, improve data and modelling, improve the identification of bankable projects, and boost regional cooperation, eventually setting the seed for connectivity.

The Eurpean Commission’ vision for a climate-neutral EU was prepared in late 2018 (on March 2020 the EC proposed the first European Climate Law), based on the exploration and analysis of multiple transition pathways. The vision is in line with the Paris Agreement objective to keep the global temperature increase to well below 2°C and pursue efforts to keep it to 1.5°C.



Fuel mix in Gross Inland Consumption

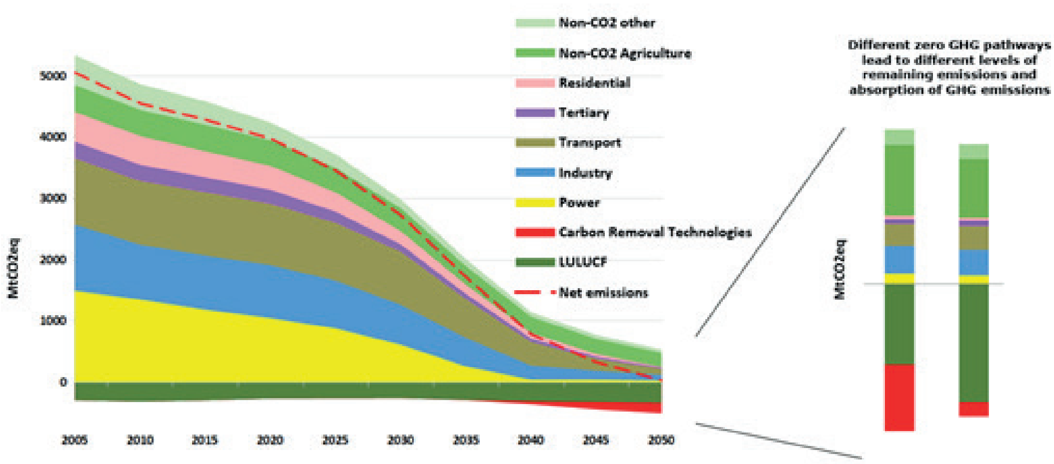


Figure 5.15 – GHG emissions trajectory in a 1.5°C scenario

Highlights (potential lessons / food for thoughts for Kazakhstan and other players):

- massive investments/penetration of renewable, electrification of the end-uses;
- phase-out of solid fuels, nearly-zero oil products use in transport;
- exploitation of e-fuels (for hard-to-electrify services);
- development of carbon removal technologies (hard-to-abate emissions, e.g. non-CO_2 agriculture)

The EU can lead the way by investing into realistic technological solutions, empowering citizens and aligning action in key areas such as industrial policy, finance and research, while ensuring social fairness for a just transition.

As part of the international cooperation process, an EU-Central Asia Sustainable Energy Centre will be developed (in the framework of the SECCA project) and operated. Such Centre would facilitate regional cooperation and harmonisation on EU energy efficiency and renewable deployment approaches, methodological and regulatory standards, technologies, and gender related issues as well as facilitating financing of investment projects.

Beyond the EU, the recent G7 initiative called "Build Back Better World" ("B3W") proclaims a goal of G7 countries to provide an alternative to the Belt and Road Initiative for green and sustainable development in emerging countries. The G7 partners agree to provide and mobilize financing to close the USD 40 trillion dollar infrastructure gap, based on multilateral agreed standards, and align their outbound investment with the Paris Agreement. The overall goal of the initiative is in fact defined as the global infrastructure development for a "green growth" (climate, digital-, equality-, transparency– related values and criteria).

5.8 Kazakhstan and All: Digitalization

Recently, the Climate Action Tracker estimated that climate policies implemented across the world at present (Summer 2021), including the effect of the pandemic, will lead to a temperature rise of 2.9 °C by the end of the century. Despite the declared commitments/efforts of many players, it might be that policy packages under design will not be able to meet the net-zero targets.

In this context, and in accordance with the concept of social "responsibility" [118], the introduction of behavioural-related instruments, like the "personal carbon allowance" (PCAs) as a complementary mitigation measure, re-gained attention in some countries. In short, such types of schemes aim (in their basic design) to link personal actions with emission reduction targets through the introduction of tradable (personal) carbon allowances that can be "spent" for transportation, space heating, electricity services, and that can be sold/ purchased in a market-like environment in case of surplus/deficit. Instruments like the above one are meant to create a direct and perceptible "incentive" to have more virtuous energy behaviours and reduce emissions.

Digitalization, and recent development of big data and artificial intelligence technologies, can provide the bed for the practical implementation of such a measure. Moreover, the experience of tracking apps, during the COVID-19 pandemic, has probably broken a “psychological barrier” and made people more willing to accept [119] behavioural tracking associated to private and public benefits (common good).

Climate-ambitious technologically advanced countries are more likely to succeed in similar attempts (USA, EU) and play the role of pioneers in this field. At the same time countries with a high share of young population and high digital literacy (India), or big manufacturers of IT devices (China), can develop innovative tools/standards/games with the same purpose for the country-specific social and geographical context.

Cooperation in the framework of IT and digital technologies is therefore potentially open at 360 degrees for Kazakhstan that can capture the best practices from all foreign experiences, and process, adapt, improve the approaches for a possible internal utilisation and benefit (in light of the climate neutrality target).

5.9 Key Conclusions

To conclude this short essay about the possible opportunities of “cooperation” with key regional and international players, in view of a net-zero transition of Kazakhstan, a few more quantitative considerations and information can be added.

As said at the very beginning of this chapter, cooperation generally refers to the political and institutional mechanisms that actors of a region use to “imagine and plan a joint development” while promoting national interests at the same time. Therefore, cooperation is a strategic element / asset that can be developed to follow multiple (sometimes conflicting) objectives subject to a number of conditions, information and actions of all other parts involved, that need to be taken into consideration and to be investigated.

Aside from, and in addition to, the synergies in country policies and visions (presented above), a quantitative indicator about the “innovation capacity” of relevant country players, related to strategic energy-related technologies, is presented below to help Kazakhstan navigating its space for useful cooperation.

The number of patents is a reliable and often-used indicator to describe the absolute innovation potential and the country strength, as it provides a proof of product/process novelty, that reflects knowledge, capacity, and reliability, without the bias of personal opinions or idealised expectations. Making use of a research (policy report) [120] undertaken in the framework of an EU-funded project [121], the key insights about the technology-specific “know-how” of key countries are reported. Data were extracted from the European Patent Office: Global Patent Index (EPO GPI); charts report the number and ratio of patents by country and category of key technologies.

Decision makers in Kazakhstan can use this (and similar KPIs) to explore the room for (technological) cooperation for an imaginary net-zero emissions 2060, in accordance with the domestic priorities and the most-promising identified national technology-pathways.

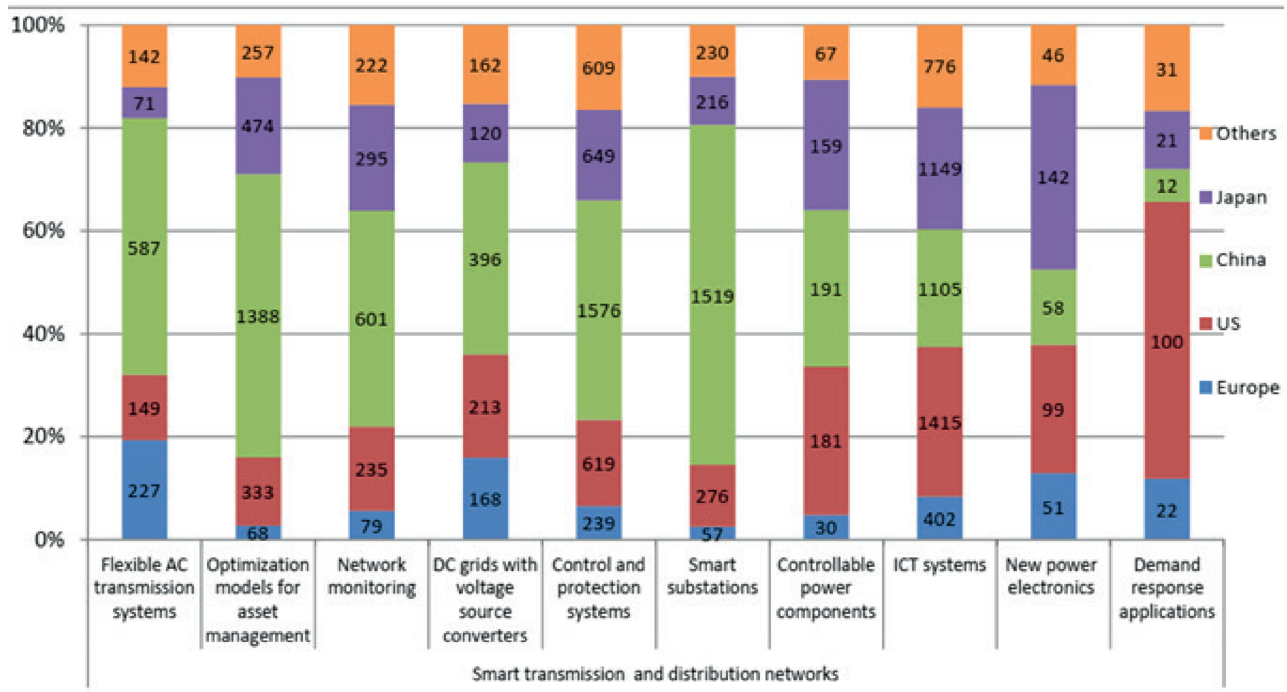


Figure 5.16

Top 3 industrial players (by number of patents): grid networking systems

1. GEN ELECTRIC USA
2. ITRON INC USA
3. HONEYWELL INT INC USA

Top 3 industrial players (by number of patents): demand-response applications

1 Toshiba Japan
2 Schneider Electric France
3 Emerson Electric USA

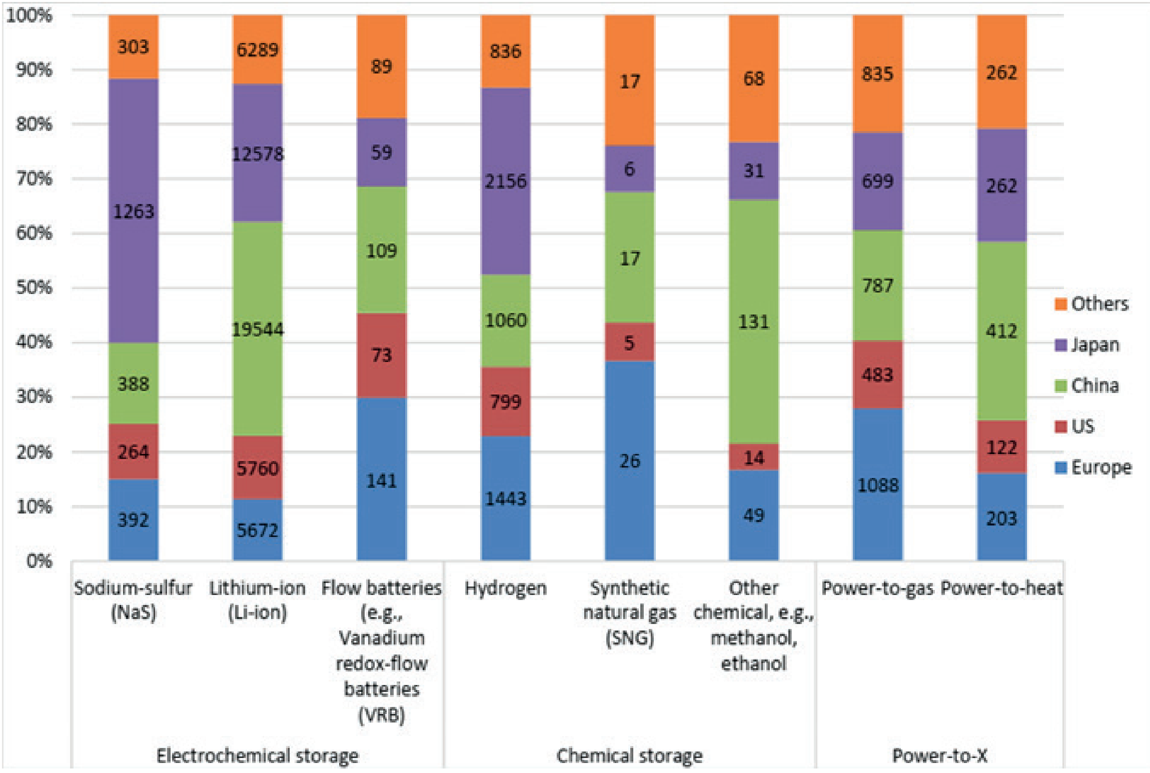


Figure 5.17

In the large-scale energy storage field, it is Japan who comes first in the ranking by number of patents (Figure III-IX) for large-scale batteries and hydrogen, due to the activity of its two leading companies: Panasonic and Hitachi the pioneer of lithium ion batteries for automobile use. China published the most patents about compressed air.

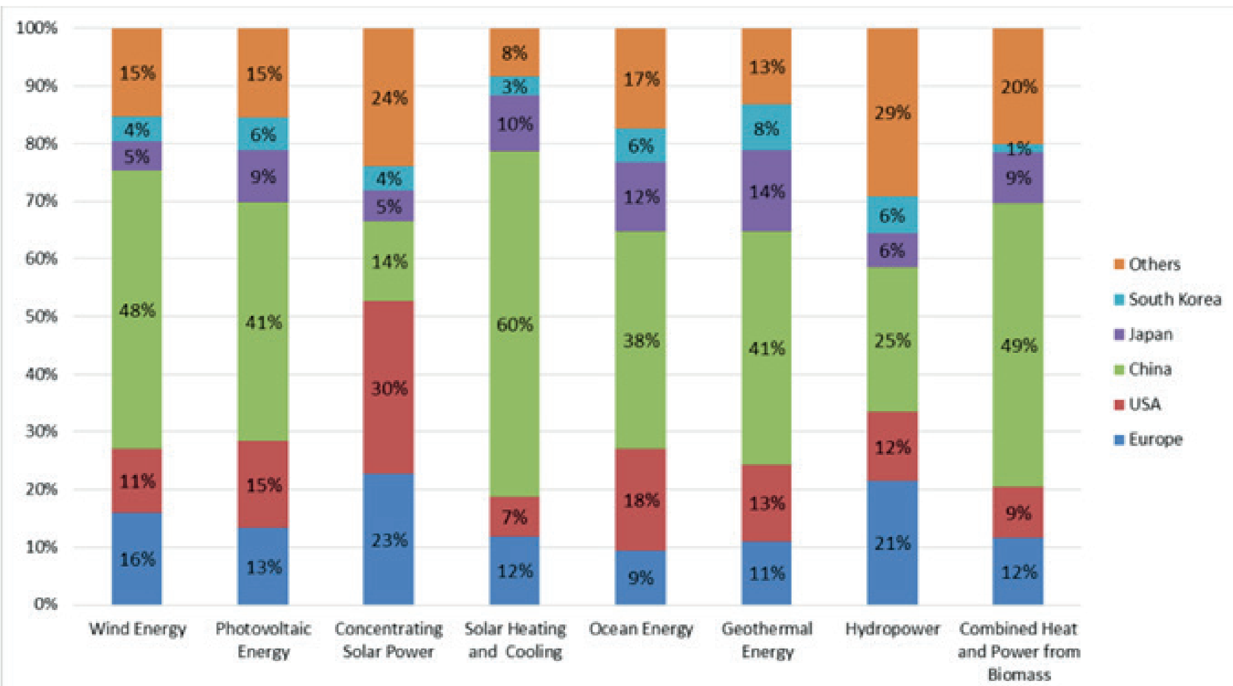


Figure 5.18

Top 3 industrial players (by number of patents): wind energy
1. WOBBEN ALOYS EU
2. VESTAS WIND SYS AS EU
3. GEN ELECTRIC USA

Top 3 industrial players (by number of patents): photovoltaic energy
1. CANON KK Japan
2. COMMISSARIAT ENERGIE ATOMIQUE EU
3. DU PONT USA

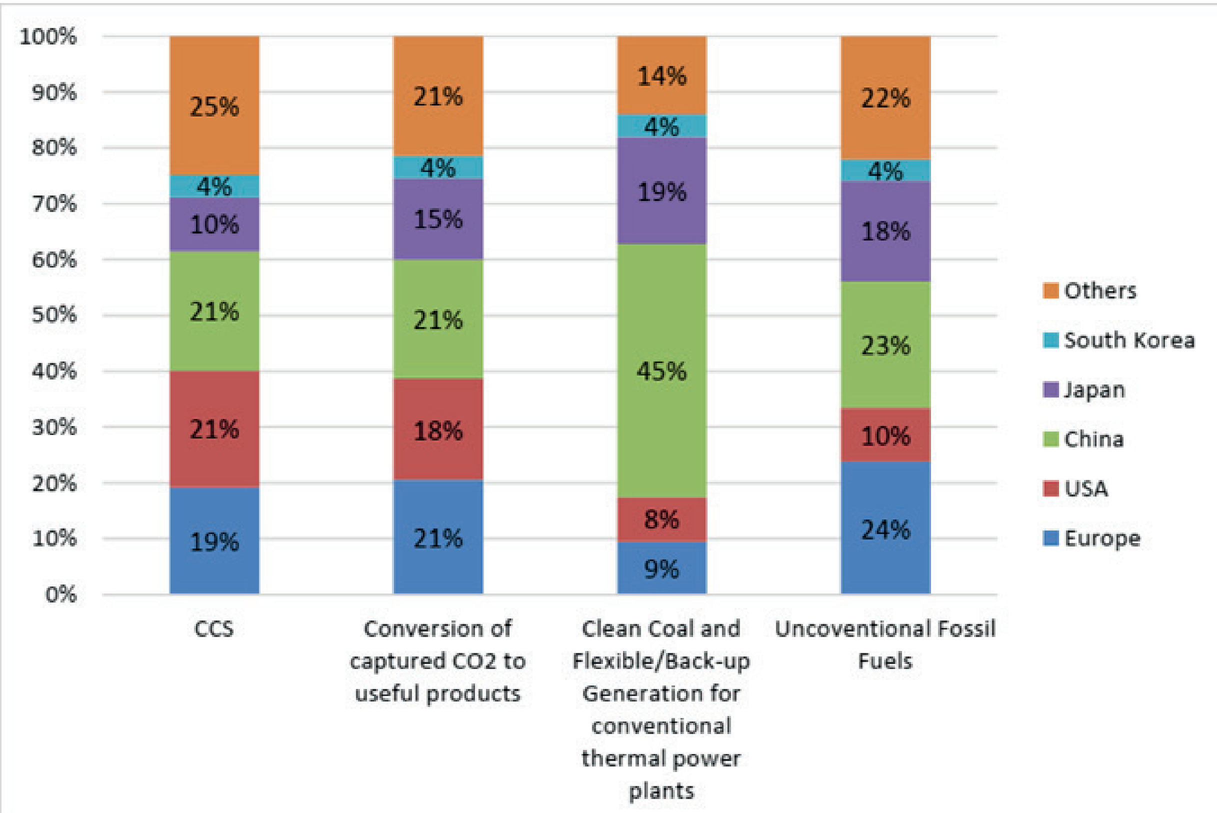


Figure 5.19

Top 3 industrial players (by number of patents): CCS
1. ALSTOM TECHNOLOGY LTD EU
2. CALERA CORP USA
3. GEN ELECTRIC USA

KVASENKOV OLEG IVANOVICH (Russia) is ranked in the top 10 for the Unconventional Fossil Fuels

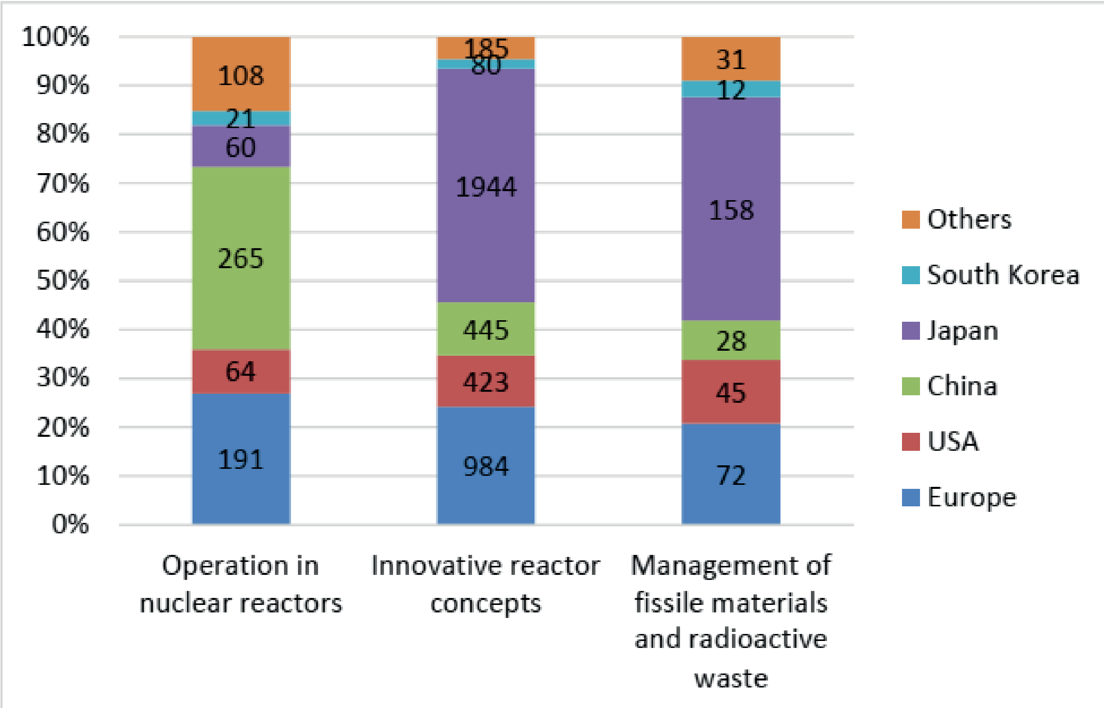


Figure 5.20

Top 3 industrial players (by number of patents): Nuclear reactors

1. Areva Europe
2. Westinghouse –GE US
3. Atomstroyexport Russia

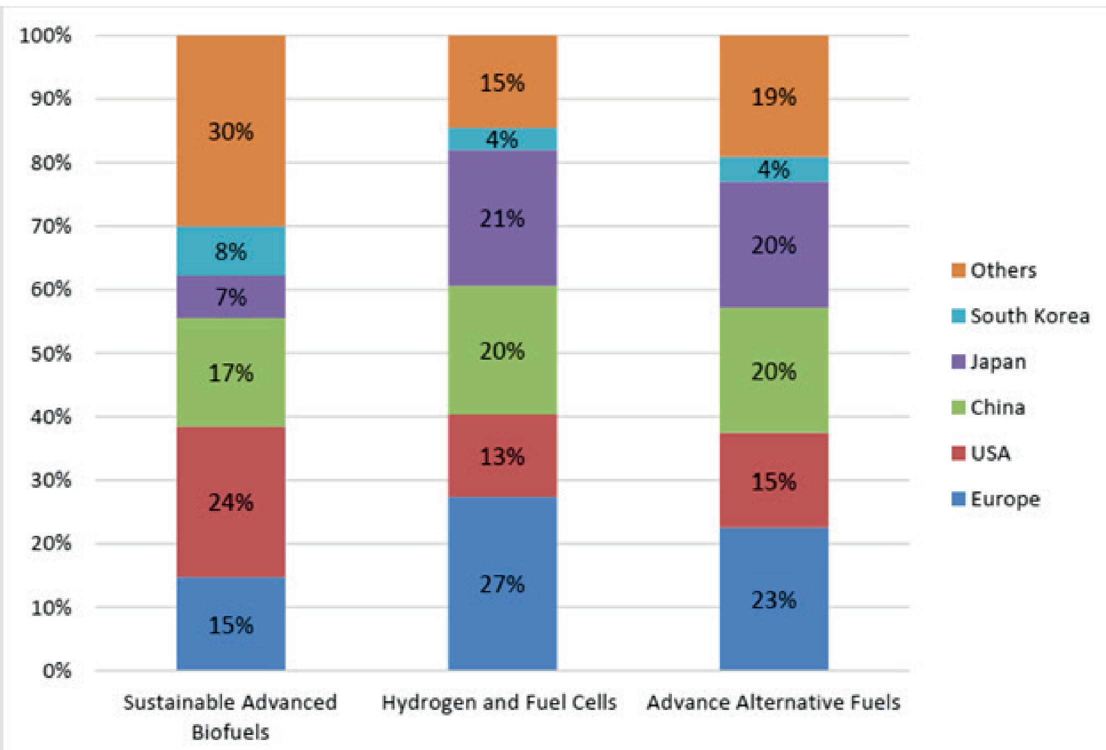


Figure 5.21

Top 3 industrial players (by number of patents): Hydrogen and Fuel Cells

1. MATSUSHITA ELECTRIC IND CO LTD Japan
2. SIEMENS AG EU
3. HITACHI LTD Japan

Top 3 industrial players (by number of patents): Advanced Alternative Fuels

1. ALSTOM TECHNOLOGY LTD EU
2. ASHLAND OIL INC USA
3. SNAM PROGETTI EU

Summary

In December 2020 President of Kazakhstan Republic Mr. Tokayev announced that Kazakhstan will become carbon neutral by 2060. "Kazakhstan's road to net zero GHG emissions" report is one of the first attempts to understand how to reach that ambitious goal.

Around 80% of GHG emission comes from Energy generation. Republic's main source of energy generation is coal. Electricity and centralized heating system are mainly based on coal combustion. Population growth will further increase energy demand. Kazakhstan's decarbonization way may be interesting to other countries in the context of COP26 held in Glasgow.

The authors team have diverse background and experience. They are local and international experts in GHG emissions calculation and mitigation measures.

Climate Change

Climate change seems to be inevitable to Kazakhstan. Over the next 25 years, temperatures will rise 2-3 degrees above the 1980-2004 average. Further in next 50 years temperature will rise by 5-6 degrees Celsius. In the north temperature raise will be higher compared to South Kazakhstan.

Precipitation level will remain approximately at the same level as it is now. However, most of climate models used in this report show considerable reduction of summer precipitation in high GHG emission scenario.

Glaciers melting will cause reduction of water availability and consequently energy generation shortage in neighboring Kyrgyzstan and Uzbekistan. These countries are highly dependent on hydro power stations. As a result, electricity shortage and lack of water for agricultural purposes in these countries and in South Kazakhstan is expected. Water availability and food security will be negatively impacted by climate change in Central Asia's region.

Agriculture

Kazakhstan's emissions from cropland raised considerably adding almost 10% or 35 million tons of CO_2 to Republic's total GHG emissions. This increase is caused by absence of crop rotation, lack of fertilizers and lack of other agricultural techniques to maintain productivity of soil. Kazakhstan's cropland area is from 20 to 25 million hectares.

Introduction of carbon tax seems the only and very effective measure to stop incredible humus reduction in cropland soil at speed of about 1% per year. Other options will require a lot of investment mainly from the government of Kazakhstan. The latter seems to be ineffective in money distribution and spending effectiveness.

Unique condition of Kazakhstan is that there are over 100 million hectares of land in reserve, which means that it is a State property and not used. Around 80 million out of 100 are former agricultural land. Potentially this land may be used to grow forest for commercial

purposes and as a carbon sink. Land may be given for long term rent to international and local companies through auctions. Other option could be emission of carbon emission allowances futures to raise money on forest plantation on reserve land.

Emission Trading Scheme

Kazakhstan's emission trading scheme is not effective as expected. Carbon budget or allowances cover only half of total emissions. Emissions are often not properly validated, enterprises fear to invest in renewable energy.

Waste Management

Kazakhstan's government in summer 2021 introduced waste sorting system. The latter implies separate waste boxes for wet and dry waste. It is assumed that paper, plastic, metal, food would be gathered in separate boxes and then transported to the waste processing plants to recycle it. However people's mentality is not ready for these changes. People continue to gather mixed waste in one box. This measure lacks promotion and incentives for people.

Very promising measure seems introductions of food disposal systems in households and then gather carbon in sewage system. Captured carbon could then be processed anaerobically to produce agricultural fertilizers.

Background on the Vision for Achieving Carbon Neutrality in the Energy Sectors of Kazakhstan

GHG emissions during 2017-2050 will decrease from 242.9 MtCO2eq to 30.6 MtCO2eq 2050 or 7.9 times lower. Remaining 30.6 MtCO2eq will be further reduced in the next decade until 2060.

Table – GHG emissions from energy sectors, MtCO2eq

	2017	2020	2030	2040	2050
Agriculture	2.4	2.4	1.9	1.0	0.0
Coal mining	27.7	26.1	12.7	4.9	0.1
Electricity generation	89.7	82.9	64.8	32.2	1.2
Centralized heat generation	16.8	15.0	12.7	6.5	0.3
Industry	47.4	48.2	34.0	26.2	18.2
Oil refinery	1.4	1.4	1.0	0.9	0.7
Residential	22.1	19.8	10.1	5.3	0.5
Other sectors	4.9	5.9	9.0	13.1	6.1
Tertiary	6.6	5.5	3.4	1.7	0.0
Transport	23.8	25.1	19.4	11.5	3.6
Total	**242.9**	**232.2**	**168.9**	**103.4**	**30.6**

Electricity Generation

By 2050, the electricity generation sector accounts for 21.4 MtCO2eq, of which 20.2 MtCO2eq is absorbed by CCS technologies, leaving 1.2 MtCO2eq in the balance. Emissions in the sector come from the natural gas used, which is necessary for maneuvering capacities that compensate for the instability of production from renewables.

Electricity generation will increase from 108.1 bln kWh in 2020 to 329.8 bln kWh in 2050, more than 3 times. Thus, this indicates the importance of electrification for decarbonization. The electricity generation with coal is nullified, almost reaching zero by 2050. Natural gas is used at maneuvering capacities to support compensation for renewables instability. Around 2035, a nuclear power plant appeared in the structure of the electric power industry.

The decarbonization of the heat sector is based mainly on the heat pumps on centralized level and individual level as well.

The decarbonization of electricity and heat generation sectors, as main users of coal lead to phase out of coal usage and mining. The use of natural gas in the intermediate term and electricity in long-term lead to decarbonization of the other sectors.

The transport sector by 2050 has small usage of oil products due to aviation and heavy trucks, the entire sector is electrified.

Finance Sector and International Finance

Transformation of the financial sector is critical and central to achieving net-zero target. Financial flows should be cardinally redirected from financing business-as-usual projects and technologies to low-carbon and zero-carbon solutions. There has been some initial progress in Kazakhstan but this transformation needs to be scaled up dramatically.

There is a range of measures and instruments that are available to all financial sector institutions, from the National Bank to the Ministry of Finance to development finance institutions to commercial banks, investment companies, and venture funds. What needs to happen is for the National Bank and Ministry of Finance to move from a neutral-positive stand on green, transition and sustainable development finance to proactive position spearheading financial sector transformation, providing framework for a radical transformation of finance – capital markets, investment, corporate, SME, and retail finance.

International Cooperation for a Net-zero Kazakhstan in 2060

In the framework of this “net-zero emissions vision” for Kazakhstan, and of the potential benefits of regional/international cooperation to achieve climate neutrality in the next 40 years, the following key “players” are taken into consideration: the Central Asian region, Russia, China, and other relevant (Western) actors (focus on the EU), Kazakhstan; Central Asian countries; big neighbours, rest of the world.

This chapter aims mainly to provide a

"descriptive analysis" of the space (and trade-offs) of regional and international cooperation relevant to the climate neutrality vision of Kazakhstan. It also aims to highlight players and areas of such a complex game (with Kazakhstan as a "centroid" of the game), identify and describe potential opportunities for synergies, collect and share a few basic quantitative information inherited by other studies, and ultimately give food for thoughts and elements for decision makers, analysts, and stakeholders in Kazakhstan, in order to ease a just and timely achievement of the vision.

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84. Disclaimer: the aim of this “chapter” is to offer national and international stakeholders, decision makers, researchers, analysts and citizens, a ground for imagining, exploring and debating in the field of a climate neutral future of Kazakhstan. Hence, this work is not intended to be a quantitative “analysis” per se, or a statement of commitment, rather it aims to trigger the interest towards the green transition of Kazakhstan and to highlight the huge possibilities (and some trade-offs) offered by regional/international cooperation. The ideas, perspectives, outlooks, and interpretations expressed and reported in this section are those of the author(s) only and do not necessarily reflect the view of the Institutional Bodies.
85. Azerbaijan shares cultural and linguistic traits with Central Asia, it is the region’s link westward and plays a key role in the transit of hydrocarbons from Central Asia to international (Western) markets.
86. East-West economic integration and transport corridors.
87. North-South economic integration and energy and transport corridors.
88. Energy Efficiency and circularity in a post pandemic economy. Developed by the Italian G20 Presidency 2021 in collaboration with ENEA and RSE.
89. In July 2021, in Italy (Naples).
90. In the end China and India had declined to sign the two contested points.
91. As currently, they are on track to exceed the 1.5-2 degree ceiling.
92. World Bank. doi:10.1596/978-1-4648-1340-5
93. Coal has the highest carbon content among fossil fuels.
94. The European Union is studying long-term strategies to de-carbonize the system by 2050, with limited/no use of oil products in transportation. China announced an ambitious and stimulating goal to hit peak carbon emissions before 2030 and achieve carbon neutrality before 2060.
95. EU initiative (CBAM, under design) to counteract the risk of low climate ambitions of international trade partners, by “adding” a carbon-related “penalty” on import of certain goods produced outside the EU.

96. Uzbekistan, Turkmenistan, Tajikistan, Kyrgyzstan.
97. This chapter is not based on quantitative/modelling work. Some regional (quantitative) explorations have been recently launched and analysed making use of the TIIME-CAC model in the framework of the ongoing H2020 Paris Reinforce project. See box: The integrated energy system of Central Asia.
98. Max R/P (oil) of the region: Kazakhstan 45 years; Max R/P (gas) of the region: Turkmenistan: >>200
99. Maximum hydropower potential of the region: Tajikistan 40 GW; minimum hydropower potential of the region: Turkmenistan <2 GW.
100. Quantitative models and tools can be used to estimate advantages and disadvantages of each strategy.
101. All Central Asian countries are already members of Central Asia Regional Economic Cooperation (CAREC). The CAREC new long-term strategic framework program is anchored on a broader mission to connect people, policies and projects for shared and sustainable development, serving as the premier economic and social cooperation platform for the region. Central Asia can also benefit from the ASEAN's experience in the development of a core of solidarity among regional members, in order to prevent foreign powers from playing ASEAN members against each other.
102. To join the CAC Forum, please contact the Administrator at: rocco.demiglio@gmail.com
103. https://paris-reinforce.eu/
104. Structural features and the implementation of targeted measures allow oil and gas Russian companies to be in an advantageous position relative to competitors from other countries (in terms of kg CO_2eq per barrel, scope1 emissions).
105. In particular for iron and steel, oil and gas, and chemical industries.
106. Russian energy exports can be up to 20% lower (with respect to the reference projections) in 2030 if the signatories of the Paris Agreements carry out their obligations/plans.
107. Due to the high level of statistics and policy impacts uncertainty, some sort of coordination/cooperation on standards, methods, practices, and measurement techniques, of the potential LULUCF carbon sink, would also be very important.
108. In September 2020, at the 75th Session of the United Nations General Assembly, President Xi claimed that China is going to have its CO_2 emissions peak before 2030 and achieve carbon neutrality before 2060. China's national ETS (an intensity-based system with the cap adjusted ex-post based on the actual production level) is expected to be one of the key policy instruments to achieve the short-medium term ambition (emission peak by 2030).
109. See the following for a more detailed analysis covering China and Central Asia: https://papers.ssrn.com/sol3/papers.cfm?abstract_id=3858058
110. Rocco De Miglio, Gabriele Cassetti (2020), The BRIDGELAND "the Belt and Road Initiative in Different Green Economies – a Long-term Analysis of its Novel Development". https://www.linkedin.com/posts/rocco-de-miglio_the-bridgeland-activity-6706581226733600768-e0AD

111. The total amount (in million US dollars) of financed projects (per subsector, in the 5 years plan 2015-2020) in Kazakhstan was around 12 billion, the majority of which in oil and gas and other industry projects.
112. In 2021, Kazakhstan has started to investigate a net-zero GHG emissions “vision” by 2060.
113. This is key. The entire narrative is based on the assumption that China will “move first” in the decarbonization transition, so as to generate the conditions for an early uptake of hydrogen in the Kazakhstan (not driven by domestic goals or policies, but as a result of an “opportunity”).
114. Based on strong statistics and decision support systems (models), a quantitative assessment of the indicators can be undertaken.
115. Yang, Xi and De Miglio, Rocco and Cassetti, Gabriele, Greening China’s BRI in Central Asian Countries: The Role of Hydrogen Towards Net-Zero Future. Available at SSRN: https://ssrn.com/abstract=3858058
116. According to the China Belt and Road Initiative Investment Report H1 2021 released by the International Institute for Green Finance, 2020 was the first year when renewable investments in the Belt and Road countries (not only Kazakhstan) exceeded investments in coal, while in the first half of 2021, no coal-related financing went into the Belt and Road countries.
117. A European strategic long-term vision for a prosperous, modern, competitive and climate neutral economy (https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:52018DC0773)
118. We all have a duty to ensure sustainable development.
119. Provided that other important, social, and political barriers are overcome, and private freedom respected.
120. Among the key indicators used in this study, to track innovation capacity (see references), are: the R&D expenditure and the Import/Export Volumes
121. Insight_E, http://www.insightenergy.org/.