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The impact of greenhouse gases on climate change

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Abstract. Climate change has become a threatening problem for all countries of the world. For Kazakhstan, one of the world's largest grain exporters, with its previously predominantly arid climate, developed mining industry, metallurgy and mainly coal-fired heat and electricity generation, slowing down warming is becoming an urgent task. The purpose of this study is to summarise various aspects of the impact of greenhouse gas emissions on climate change in the Republic of Kazakhstan and the possibilities of reducing greenhouse gas emissions through Kazakhstan's transition to a new economic model based on the use of renewable energy sources. During the study, various methods of analysis were used – analytical selection based on a given or identified feature, comparative analysis of similar characteristics of various objects, statistical analysis of dynamic series, synthesis, representing the primary theoretical generalisation of empirical data. As a result of the study, a noticeable dependence of changes in average annual temperature and precipitation on total greenhouse gas emissions was identified. Moreover, the identified similarity of the dynamics of the main climatic indicators with the dynamics of individual greenhouse gases in Kazakhstan requires further research. It is also concluded that individual innovations in the form of individual renewable energy power plants or a Quota trading system determined by the highest values will not lead to a noticeable reduction in greenhouse gas emissions. Only the transition to

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a green economy, which should become a state priority, and its principles and main characteristics should be the reference when making any government decisions. This study can become a starting point for many theoretical and practical studies and show the need to reduce greenhouse gas emissions not as a purely mechanical process, but in conjunction with other phenomena, which can be useful in making managerial decisions

Keywords: air temperature change; precipitation and the threat of desertification; emissions monitoring; green economy; alternative energy

INTRODUCTION

Climate change has become one of the most acute problems of humankind. The anthropogenic factor with the development of industrial production and the growth of emissions into the atmosphere has caused global warming. Back in the 70s, the UN drew attention to the potential threat of climate change and in 1992 adopted The Rumour Convention of the United Nations on Climate Change (1992), and subsequently The Kyoto Protocol to the United Nations Frame Convention on Climate Change (1997) to it, The Paris Agreement (2016) as documents containing mechanisms for reducing emissions and preventing the irreversibility of climate change. Solving problems related to climate change has become one of the global Sustainable Development Goals up to 2030 (2015).

The development and adoption of these documents have intensified the efforts of countries to reduce emissions in a coordinated manner. Greenhouse gases such as carbon dioxide CO_2, methane CH4, nitrous oxide N_2O, hydrofluorocarbon compounds, perfluorocarbon compounds, sulphur hexafluoride SF_6 should be noted among the emissions most affecting climate change (The Kyoto Protocol…, 1997). Most countries of the world, including the Republic of Kazakhstan, have joined these documents, committing themselves to reduce greenhouse gas emissions, which most affect the process of global warming. Pursuant to the Paris Agreement, the Republic of Kazakhstan has committed to reducing greenhouse gas emissions by 15-25% by 2030 compared to 1991, and to achieve carbon neutrality by 2060 (Luomi *et al.,* 2020).

Numerous studies conducted in the Republic of Kazakhstan due to the increased attention to the problem of climate change, as a rule, pay attention to certain aspects of the problem or solving problems of reducing greenhouse gas emissions in a particular industry. Thus, for example, A. Maldynova *et al.* (2022), M. Bekturganova *et al.* (2019), and a number of other researchers consider and justify possible transformations of the energy sector of Kazakhstan on the way to decarbonisation, based on industry positions. S.B. Kenenbayev and G.L. Yesenbayeva (2020), associate the success of the development of agriculture in Kazakhstan with adaptation to climate change through new technologies. K. Kaimuldinova *et al.* (2022) devoted their study to the inclusion of climate change and sustainable development issues in the educational programmes of the Republic of Kazakhstan.

This allows for accumulating a database, doing their primary analysis, and providing a basis for generalisations and further consideration of a specific problem in a complex. For example, the EU countries have gone through the evolution of approaches from environmental protection and reducing polluting emissions to linking these emissions with the problem of climate change, and seeing the main way to eliminate or stop the problem by reducing greenhouse gas emissions with a dominant carbon group, they came to the need to recognise the inevitability of replacing carbon energy sources with renewable sources. This has led to the fact that a whole revolution is taking place in the world in the field of energy and transport, supported by the course of transition to a new economic model – a model of sustainable economic development (other names, less capacious, but popular, are circular economy, green economy).

The main purpose of this study was to show the problem of the impact of greenhouse gas emissions on climate change in the Republic of Kazakhstan with its possible solution by changing the approach to the problem itself and moving to a new economic model that would maximally stimulate the reduction of emissions and eliminate the substantial detrimental effect of anthropogenic factors on the climate. In it, based on the analysis of international documents, legislation of the Republic of Kazakhstan, scientific publications and statistical materials of RSP "Kazhydromet", the Bureau of National Statistics of the Republic of Kazakhstan, the tasks were set to show the relationship of the problem of climate change in the Republic with the global problem of climate change; to indicate natural and economic factors of climate change at the level of primary generalisation; identify unresolved problems, show the connection between the desire of the Republic of Kazakhstan to decarbonise the economy and the development of alternative energy as the material basis for the transition of the economy to a new model.

Since 2013, the Republic of Kazakhstan has set a course for the transition to a green economy, adopting The concept of the transition of the Republic of Kazakhstan to the "Green Economy" (2013). However, the lack of a systematic approach is causing the transition to be slow and inconsistent. The attempt at primary generalisation and the application of an integrated approach to the problem undertaken in this study can

serve as a basis for further theoretical research, and the identified unresolved problems – become the subject of practical management decisions.

MATERIALS AND METHODS

In the course of this study, the initial international documents were analysed, such as "Agenda 21", (1992), The Framework Convention of the United Nations on Climate Change (1992), The Kyoto Protocol to the United Nations Frame Convention on Climate Change (1997), The Paris Agreement (2016), Sustainable Development Goals up to 2030 (2015), reports of the UN working groups preparing analytical information and conclusions for subsequent decision-making. These documents show and record the existing relationship between the changes that occur with the climate and greenhouse gas emissions. The Environmental Code of the Republic of Kazakhstan (2021), The concept of the transition of the Republic of Kazakhstan to the "Green Economy" (2013), Strategy "Kazakhstan-2050" (2019-2022) adopted by the Republic of Kazakhstan were also analysed as documents showing what actions the Republic of Kazakhstan assumes to implement The Kyoto Protocol to the United Nations Frame Convention on Climate Change (1997) and The Paris Agreement (2016).

After establishing a proven relationship between greenhouse gas emissions and climate change, documents containing quantitative data on climate change parameters such as atmospheric temperature, precipitation, extreme weather events and their frequency, greenhouse gas emissions according to the list defined by the Kyoto Protocol and in terms of carbon dioxide emissions (CO_2) were analysed. This is the National Report on the state of the Environment and on the use of Natural Resources of the Republic of Kazakhstan for 2021 (2022), The annual bulletin of monitoring the state and climate change Kazakhstan/RSP Kazhydromet. (2008-2021), which allowed making their statistical analysis. Based on these quantitative indicators, dynamic series of fluctuations in the average annual temperature and the average annual precipitation level by year were compiled, showed in Figures 1 and 2. Each of these figures shows the norm calculated by RSP "Kazhydromet" based on long-term data. This allows seeing both the trend in temperature and precipitation fluctuations and all deviations from the norm over the years simultaneously. Figure 3 shows the dynamic series of greenhouse gas emissions (in terms of CO_2) and greenhouse gas emissions from energy industry to trace their similarity/dissimilarity.

Based on the data of RSP "Kazhydromet", the dynamics of emissions of all greenhouse gases according to the list of the Kyoto Protocol for two-year periods and in general for 12 years (2010-2022) is calculated so that it is possible to compare the dynamics for each of the greenhouse gases with the dynamics of fluctuations in average annual temperatures. The analysis of such comparisons and a factor-by-factor analysis of the effect of each of the gases on the average annual temperature can be the subject of further research. The analysis of study materials by various authors containing a primary analysis of greenhouse gas emissions in certain industries based on the collection of arrays of primary empirical information gave the author the opportunity to identify common features of processes occurring in various industries.

That is, the use of various methods of analysis from an analytical selection of characteristics for sampling, statistical methods of analysis to the method of comparative analysis of process parameters in previously selected periods and regions became a preparatory stage for the initial theoretical generalisation of empirical materials selected by the author using analytical methods. The selected characteristics of the impact of greenhouse gas emissions on climate change were compared with the characteristics of new economic models of the economy, in particular, the green economy, which the Republic of Kazakhstan plans to transition to. Ultimately, the similarity and differences between the model of a sustainable economy, a green economy, a low-carbon, and a circular economy can also be an impetus for a new study.

RESULTS

For the Republic of Kazakhstan, about ninety per cent of the territory of which is located in the desert, semi-desert, and arid steppe zone with a predominance of flat terrain, the problem of climate change is very acute. In the last seventy-five years, an increase in surface air temperature has been recorded, and the deviation of the average annual air temperature in some years from the norm has increased to 2°C. (Seventh national communication…, 2017). Moreover, out of the ten warmest years in the period from 1936 to 2020, seven fall at the beginning of the 21st century. The average annual values for the period of 1961-1990, which are 5.4°C in air temperature and 317.7 mm in precipitation, are used as normative climatic indicators in the Republic of Kazakhstan.

According to the RSP "Kazhydromet", there has been a persistent warming trend since the 1960s. During the estimated period of 1976-2021, the average annual temperature increased by 0.32°C every ten years. The highest rate of warming was observed in the western and south-western regions (from 0.44°C/10 years to 0.54°C/10 years), the lowest – in the central, northern, and eastern regions (from 0.23°C/10 years to 0.29°C/10 years). Over the last decade of 2012-2021, the average annual air temperature was +6.61°C, exceeding the norm by 1.19°C, whereas, in the previous decade of 2001-2010, the average annual excess of the norm was 1.09°C. The warmest was the five-year period of 2017-2021 with an average annual air temperature of +6.69°C, exceeding the norm by 1.27°C. (The national report on the state…, 2022).

After the accession of Kazakhstan to the Kyoto Protocol, climate change and greenhouse gas emissions (primarily CO_2) began to be monitored in the republic, which is important for investigating their impact on climate change. The reasons for the reduction to the norm of average annual temperatures and their sharp increase in some years should be the subject of separate research. Moreover, it can be a combination of the influence of global climatic fluctuations and the anthropogenic factors on the territory of the republic itself. Figure 1 shows the changes in the average annual temperature for the period of 1990-2021, with the first two decades shown as single periods, and since 2010 annual values are given.

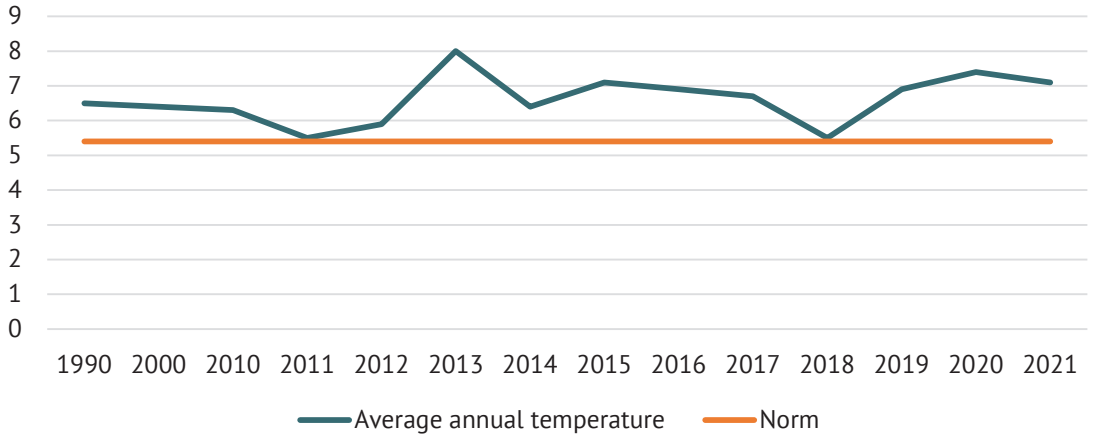

Figure 1. *Average annual temperature for 1990-2021 in the Republic of Kazakhstan, °C*
Note: *Norm – 5.4°C*
Source: *The annual bulletin of monitoring the state and climate change Kazakhstan/RSP Kazhydromet (2008-2021)*

In 2021, the average annual precipitation in Kazakhstan amounted to 85.5% of the norm or 272 mm. Thus, the greatest shortage of precipitation was observed in the Mangystau and Kyzylorda regions, where an average of 29.9% and 64.1% of the norm fell, respectively. A 20-40% precipitation deficit of the norm was observed in Atyrau, Kostanay, North Kazakhstan, Akmola, Karaganda, Turkestan, Zhambyl, and Almaty regions. In the last two decades, there has been a tendency to increase the monthly precipitation deficit in April-May and August-October, and to exceed the norm in February and March. An increase in the proportion of liquid precipitation creates problems with snow accumulation and the creation of a moisture charge for the soil for the growing season, which is important for the development of agriculture (Annual Bulletin of monitoring the state and climate change of Kazakhstan: 2021, 2022). In the period 2011-2021, six out of ten years were marked by a deficit of the average annual precipitation in relation to the climatic norm, as shown in Figure 2.

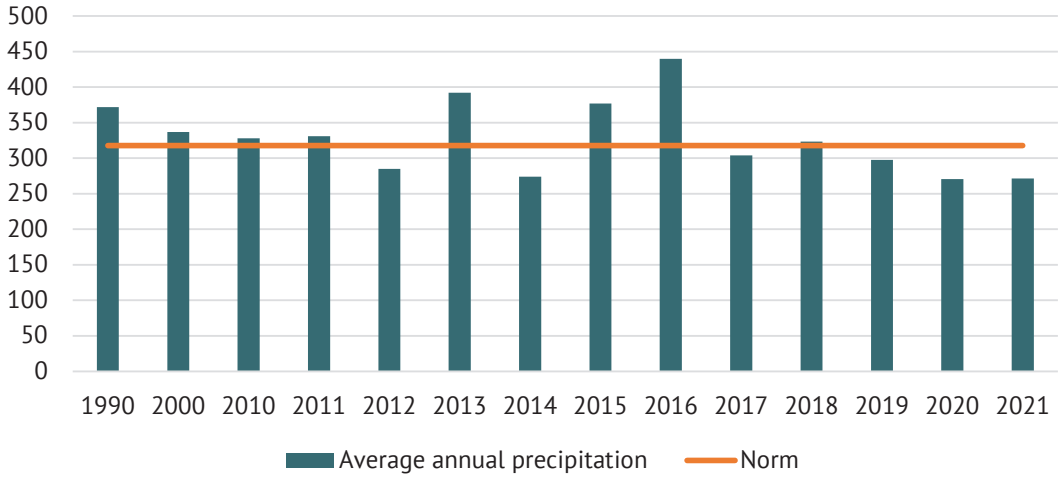

Figure 2. *Average annual precipitation for 1990-2021 in the Republic of Kazakhstan, mm*
Note*: Norm – 317.7 mm*
Source: *The annual bulletin of monitoring the state and climate change Kazakhstan/RSP Kazhydromet (2008-2021)*

In addition, precipitation has increasingly become extreme. The number and frequency of extreme weather events have also increased, which was highlighted by The national report on the state of the environment and the use of natural resources of the Republic of Kazakhstan for 2021 (2022). Moreover, Almaty and the Almaty region account for 38.7% of all registered cases, Zhambyl region – 7%. The most frequent natural hydrometeorological phenomena in Kazakhstan are heavy rainfall, strong wind, heavy blizzard and heavy snow, floods, abnormal cold, abnormal heat, drought, ice, hail, and dust storms. There were 46 more cases of such phenomena in 2021 than in 2020. The abundance of heavy rainfall, the rapid melting of glaciers due to the increase in average annual temperatures pose a threat of mudslides and landslides. Thus, over the past five years, the number of landslide-prone areas amounted to 390 and increased by 43%, and the number of mudslide-prone areas increased by 80% and amounted to 729 in 2021 (Almaty region – 243, Almaty – 195, Zhambyl region – 140, Turkestan region – 100, East Kazakhstan region – 23, Shymkent – 28).

An increase in average daily temperatures and a shortage of precipitation in early spring are also one of the main causes of forest and steppe fires that cause substantial material damage. In 2021, it amounted to KZT 6.138 million, which is almost three times more than in 2020. The same reasons create conditions for the occurrence of spring and autumn droughts. A precipitation deficit of 80-100% with an air temperature exceeding 1.6-3.7°C compared to the norm caused an autumn drought in Almaty, Zhambyl, Turkestan regions in 2021 (The national report on the state…, 2022; Kaimuldinova *et al.,* 2022). All these phenomena and the increase in their intensity indicate the existence of a persistent trend towards climate change in Kazakhstan.

Since climate change is a global problem, researchers from many countries have been investigating its causes. The results of the work of specially created intergovernmental working groups showed that the intensity of climate change is a consequence of anthropogenic activity, pointing to one of the main factors – greenhouse gas emissions. The physical mechanisms of impact and models of possible scenarios are presented in the Reports of these working groups. The same issues of the impact of greenhouse gases on atmospheric air circulation in global and regional aspects are also considered in the long-term studies of S. Manabe (2019), in which, based on modelling, a direct link between greenhouse gas emissions and climate change is proved.

Documents adopted within the framework of the UN, such as The Rumor Convention of the United Nations on Climate Change (1992), The Kyoto Protocol to the United Nations Frame Convention on Climate Change (1997), Strategy "Kazakhstan-2050" (2016) have become binding documents on reducing greenhouse gas emissions for countries that they were joined. The Republic of Kazakhstan is one of them. Kazakhstan is one of the thirty countries – the largest sources of greenhouse gas emissions in the world, ranks eleventh in the world in terms of the carbon intensity of GDP and is one of the 15 countries with the highest CO_2 emissions per capita. The main sources of greenhouse gases in the Republic of Kazakhstan are energy, industry, and transport. 82% of all greenhouse gas emissions in Kazakhstan are related to energy production, of which 31% is the result of fuel combustion directly in the energy sector, 9% in manufacturing and construction, 7% in transport (Barlybaeva *et al.,* 2021). In addition, specific sources of influence on the climate are deserts, as a source of dust storms, and the Aral Sea, from where millions of tonnes of aeolian dust, consisting of fine particles of sand and salt, rise in strong winds. The direct relationship between the total amount of greenhouse gas emissions without land use, land use change, and forestry (LULUCF) in Kazakhstan and the amount of emissions from energy industry is shown in Figure 3.

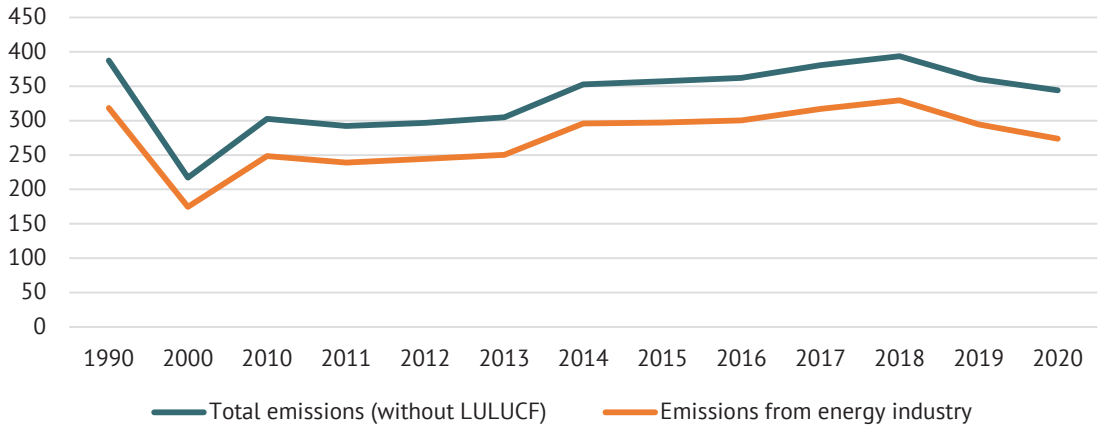

Figure 3. *Total greenhouse gas emissions (without LULUCF) and emissions from energy industry for 1990-2020 by sector in the Republic of Kazakhstan, thousand tonnes CO_2-eq*

Source: *The national report on the state of the environment and the use of natural resources of the Republic of Kazakhstan for 2021 (2022)*

For example, the lack of monitoring associated with global databases makes it impossible to include most cities of Kazakhstan in global air quality ratings. The differences between WHO air quality standards and standards in the Republic of Kazakhstan make existing national indicators incomparable with international ones, which makes it difficult to really assess the situation with atmospheric air, and in general with the trends of anthropogenic impact on climate change in the country. Kazakhstan uses only one-time maximum values for PM 10 (PM is a term for a mixture of solid particles and liquid droplets in the air), PM 2.5, and NO_2 to assess air quality and does not use the average annual MPC, whereas WHO uses average daily and annual limit values, which implies constant monitoring of the entire spectrum of emissions in the atmosphere. For example, the standard of the maximum one-time value for PM 2.5 applied in Kazakhstan is sixteen times higher than the average annual WHO standard (Assanov *et al.,* 2021).

The monitoring system needs to be expanded, especially in cities and at facilities that are major sources of emissions. The lack of the necessary amount of information distorts the real picture. Examples of the shortcomings of the existing monitoring system are given by D. Assanov *et al.* (2021). They note that all coal-fired power plants in Kazakhstan (except one) do not use installed emission control equipment. Monitoring stations are located 3 and 30 km from the largest power plants in Aksu and Ekibastuz, respectively, and record relatively low levels of atmospheric air pollution there, and the Pavlodar aluminium plant with CHP-1 is not included in the monitoring network. In addition, reports of the Republic of Kazakhstan on the implementation of international commitments to reduce greenhouse gas emissions are given according to one universal indicator – emissions recalculated by CO_2 equivalent, whereas The Kyoto Protocol to the United Nations Frame Convention on Climate Change (1997) assumes monitoring and reduction of emissions for the entire list of greenhouse gases defined in it. The importance of such detail is demonstrated in Table 1.

Table 1. *Dynamics of greenhouse gas emissions 1990-2020 by period*

	2000 in % to 1990	2010 in % to 2000	2012 in % to 2010	2014 as % of 2012	2016 as % of 2014	2018 as % of 2016	2020 in % to 2018	2020 in % to 2010	2020 in % to 1990
Carbon dioxide (CO_2)	52.9	167	98.76	122.02	102.42	108.85	83.9	112.72	99.86
Nitrous oxide (N_2O)	81.61	109.1	92.71	101.59	106.12	108.12	105.5	114.0	101.52
Methane (CH_4)	60.32	67.33	97.31	105.05	103.13	109.27	106.12	122.23	49.64
HFC	-	410.64	108.54	113.77	106.69	97.76	100.43	129.34	531.1 (by 2000)
PFU	-	-	109.52	84.16	112.43	109.7	102.59	116.63	249.55 (by 2008)
Sulphur hexafluoride (SF_6)	-	-	105.78	109.84	102.49	104.37	107.44	133.53	140 (by 2007)
Total emissions (in CO_2 equivalent) excluding LULUCF	56.07	139.15	98.29	118.87	102.68	108.82	87.3	113.97	88.92

Source: *The annual bulletin of monitoring the state and climate change Kazakhstan/RSP Kazhydromet (2008-2021)*

The key year is 2010, as from this year emissions of certain greenhouse gases are monitored by The Kyoto Protocol to the United Nations Frame Convention on Climate Change (1997). The table shows that the emissions of hydrofluorocarbon (HFC), perfluorocarbon (PFC) compounds, and sulphur hexafluoride SF_6 for the period 2010-2020 have greater dynamics compared to carbon dioxide, whose emissions were monitored in previous periods. It was this decade that was recognised as the warmest in the history of observation.

The relationship between the increase in the number of emissions of these compounds and their impact on climate change in Kazakhstan (Figures 1 and 2, reflecting the main climate parameters – air temperature and precipitation), and identification of their main sources require further special studies. The need for detailed monitoring of emissions in all regions of the Republic of Kazakhstan can be shown by comparing the emission situation for 2021 in two neighbouring regions — Almaty and Zhambyl. Notably, despite the proximity, their very geographical location has an impact on the features of climate change. A substantial part of the territory of the Zhambyl region is occupied by the Betpak-Dala and Moyinkum deserts, therefore, the already arid region undergoes rapid desertification with climate warming. More protected by the Alatau mountains, the Almaty region, due to intensive economic activity, is more susceptible to extreme weather events. Thus, Almaty and Almaty region account for 38.7% of all registered cases, Zhambyl region – 7%.

The main sources of atmospheric air pollution in Zhambyl region are stationary sources – power plants

and industrial enterprises. There are 5,380 of them in the region, with total emissions of 30.8 thousand tonnes per year. The structure of emissions in the cities of Taraz, Zhanatas, Karatau, Shu and the village of Kordai consists mainly of suspended particles of PM5 and PM10, sulphur dioxide, gaseous compounds not included in the list of greenhouse gases under the Kyoto Protocol, and particles of heavy metals. This indicates that the main sources of atmospheric air pollution are industrial enterprises of the region and power plants. The transport factor is present but does not play such a substantial role as the two above-mentioned sources of pollution. The emission monitoring system in the Zhambyl region does not cover all sources of pollution. It has only ten units, of which there are five observation posts in Taraz, including one automatic station, one automatic station in Zhanatas, one automatic station in Karatau, one automatic station in Shu, and one automatic station in Kordai (Newsletter of the state of the environment of the Zhambyl region 2021). With existing emission standards focused on the highest possible level and insufficient monitoring, the emission data provided in the bulletin cannot be called such that they record all emissions produced even by stationary sources. Thus, unlike the Almaty region, the Zhambyl region does not fall under the effect of heat supply emissions. Exceeding the maximum permissible concentrations of pollutants in five positions were recorded in Taraz, assumably, due to the larger number of monitoring stations than in other cities of the region. However, this issue requires additional research. Greenhouse gas emissions in the Zhambyl region are not monitored by monitoring stations.

The Almaty region is home to the metropolis of Almaty, which affects the structure and volume of emissions of pollutants into the atmosphere. The main sources of emissions are stationary sources – power plants and industrial enterprises. Motor transport provides a substantial part of emissions. Thus, there are 25,380 stationary sources of emissions in the Almaty region, of which 10,359 are in Almaty. The total emissions of enterprises in Almaty amounted to 46,060 tonnes. In Almaty, 151 sources of heat supply are among stationary sources of emissions. Such information is not recorded for the region. Kazhydromet calls the thermal power plants, road transport, and agricultural and construction facilities the main sources of air pollution in the Almaty region. The total emissions of pollutants in the Almaty region amounted to 2,800 tonnes in 2021. Motor transport in Almaty amounted to 517,500 units in 2021, and annually its number increases by more than 1,700 units. Motor transport in the Almaty region amounted to 119 thousand units in 2021. Monitoring of atmospheric air pollution in Almaty is conducted at 16 observation stations, 11 of which are automatic. In addition, there is a mobile environmental laboratory that occasionally monitors the state of the air at ten points. There are four observation stations in the Almaty region in Taldykorgan, Talgar, and Zharkent (Information Bulletin of the State of the Environment of the Almaty region 2021). The monitoring is conducted according to the list of substances, among which there are no greenhouse gases, named in the Kyoto Protocol.

The analysis of the list of indicators that are regularly monitored by the observation stations of the RSP "Kazhydromet" showed that greenhouse gas emissions from these observation stations are not included in the area of their constant attention. Greenhouse gas emissions are also not included in the nomenclature of environmental statistics indicators and even green economy indicators, which are regularly monitored and submitted in their bulletins by the Bureau of National Statistics of the Republic of Kazakhstan. Information on greenhouse gas emissions appears only in the section on the implementation of the Sustainable Development Goals up to 2030 (2015) of the Bureau of National Statistics, and regular information on primary observations in the data of Kazhydromet and the Bureau of National Statistics is not identified.

The Strategy "Kazakhstan-2050" (2019-2022) and The concept of the transition of the Republic of Kazakhstan to the "Green Economy" (2013), adopted in the Republic of Kazakhstan, involve the development of energy-saving technologies, carbon capture and storage, and the transfer of the electric power industry to renewable energy sources. In the context of decarbonisation, they aim to increase the share of renewable energy sources in the Republic of Kazakhstan to 10% by 2030 and to 50% by 2050 of the total electricity production. Therewith, these documents suggest a reduction in greenhouse gas emissions in Kazakhstan by 2030 by 31% below the level of 1990, by 2060 – by 97%. However, in fact, these documents are more of a tribute to involvement in international processes, and not strategic documents for the development of the Republic of Kazakhstan, on the implementation of which all government activities would be based. Apparently, there is still inertia in the attitude towards the environment as something secondary, to which attention is paid according to the residual principle. Therewith, climate change has become an acute problem for the whole world and for Kazakhstan itself. Fixing the parameters of climate change and the factors influencing this process, and the adoption of legislative and regulatory documents in the Republic of Kazakhstan in the context of fulfilling international obligations are certainly positive phenomena. However, in practice, there is a lack of actions to implement them. Some positive examples only emphasise this trend.

As such small examples, the work on decarbonisation and reduction of greenhouse gas emissions in the Zhambyl region in 2019 can be noted. Kazphosphate LLP, disposing of 21-22 thousand tonnes/ "boiler" dust per year. The processing of "boiler" dust yields

1-1.5 thousand tonnes/year of phosphorus-potash fertilisers. There is also the introduction of a GHG emissions accounting system, thanks to which emissions are reduced by 18-21 thousand tonnes of carbon dioxide per year by reducing the consumption of natural gas during the production of phosphorite agglomerate (Abdildin *et al.,* 2021). The general trend, with the exception of some positive examples, is generally opposite to the objectives set in the Strategy and other documents, which does not contribute to reducing greenhouse gas emissions. Thus, D. Assanov *et al.* (2021) note that investments in atmospheric air protection decreased 2.6 times in 2018 compared to 2013. The main reason for the lack of systematic work to reduce greenhouse gas emissions is the low degree of interest of enterprises in implementing green technologies. Thus, for enterprises in Kazakhstan, the MPC (maximum permissible concentrations) of emissions are set based on the highest level of emissions measured during the maximum production volume. This allows enterprises not to reduce the amount of emissions, and to preserve outdated technological processes without violating legislation. The Republic of Kazakhstan was the first in Central Asia to introduce an emissions trading system (ETS) and suggests its improvement to stimulate the transition to a low-carbon economy (decarbonisation) or green economy (which is similar, but not identical). The introduction of a carbon tax is currently being discussed.

Thus, relying on the research of other authors concerning certain issues of climate change, reduction of greenhouse gas emissions, transition to the green economy and its parameters, and transition tools, the author in this study made an attempt to show a holistic picture consisting of the relationship of physical and meteorological processes with the state and structure of the economy of Kazakhstan today and the transition to new models of the economy of the future (sustainable, green, low-carbon). This paper can become the basis for higher-level generalisations in further investigations. Conventional models of economic development are focused mainly on the consumption of natural resources and do not have built-in mechanisms to stimulate the reduction of greenhouse gas emissions, which is noted in some fragments of this study. At this stage, it is of utmost importance to develop a step-by-step plan for the transition from the existing technologically and economically outdated model of the economy to the model of sustainable development of the Republic of Kazakhstan, based on the analysis of the experience of the European Union and individual European countries, its adaptation to the conditions of the republic.

DISCUSSION

The link between greenhouse gas emissions and climate change towards its warming is considered scientifically proven by the work of Intergovernmental Groups under the auspices of the United Nations and numerous independent researchers. This resulted in a number of international documents obliging the signatory countries to reduce greenhouse gas emissions, mainly of carbon origin. The reduction of emissions has inevitably led to the emergence of new technologies and concepts for the development of energy based on renewable energy sources.

Greenhouse gas emissions are the result of human economic activity. Recognising this indisputable fact and the need to reduce greenhouse gas emissions, a number of researchers raise the question of the need for further investigation of greenhouse gas emissions and suspended particles of natural origin, for example, as a result of volcanic activity, and natural cycles of climate change. This will allow for the further evaluation of the ratio of all factors and correctly choosing methods to mitigate the consequences of their negative impact on human life (Hegerl *et al.,* 2019). They also highlight the fact that the issue of other products of anthropogenic impact, for example, aerosols, remains poorly investigated.

Chinese researchers Y. Sun *et al.* (2022), analysing the anthropogenic impact on climate change, note that so far it is possible to talk about a clear relationship between the impact of greenhouse gas emissions and urbanisation on the increase in air temperature. However, a clear correlation between human activity and the total amount of precipitation has not yet been established, although the results of numerous experiments indicate the connection of extreme precipitation with human activity. The question of the impact of the anthropogenic factor on the extreme wind remains poorly investigated. There is also no comprehensive vision of the human impact on the various manifestations of climate change, which makes it difficult for governments to make the right policy choices regarding the mitigation of the consequences of such changes. Each country solves these issues based on the current situation and the degree of understanding of the problems related to climate change.

In the Republic of Kazakhstan, the main sources of greenhouse gas emissions are energy, industry, and transport. The basis of the energy of the Republic of Kazakhstan consists of thermal power plants operating on local coal and generating 60.5% of electricity. The burning of coal as the main fuel for the production of electric and thermal energy is the main source of greenhouse gas emissions and a factor of climate change in Kazakhstan. Naturally, it is impossible to solve this problem without radical reform of the entire energy sector. Despite the fact that the production of electricity at gas turbine power plants is growing, and the share of its production at hydroelectric power plants, wind, solar, and biogas power plants increased from 9.1% in 2011 to 10.4% in 2019, coal-fired power remains the backbone of the industry. Moreover, the capacity of power plants commissioned more than 30 years ago is 54.3% of the total installed capacity (Maldynova *et al.,* 2022).

Outdated equipment for burning high-ash coal gives the bulk of greenhouse gas emissions, and the system of standards and regulations that currently exists in the Republic of Kazakhstan, inherited from the USSR, gives little incentive to economic entities to reduce emissions and use new technologies in the electric power industry and metallurgical industry (Assanov *et al.,* 2021). The need for a more stringent approach to the establishment of MPC and the provision of emission quotas to enterprises is also indicated by M. Bekturganova *et al.* (2019), A. Barlybaeva *et al.* (2021). The application of strict emission standards for coal-fired power plants has been successful in China, which has largely similar climate change trends (Sun *et al.,* 2022). After the introduction of ultra-low emission standards for coal-fired power plants in China in 2014, almost all coal-fired power plants in 2017 were equipped with emission management equipment, primarily CO_2. In the period from 2014 to 2017, annual emissions by Chinese power plants of all types of pollutants, including particulate matter, decreased by 60-72%, depending on the type of emissions.

Quite rightly, the above-mentioned researchers talk about the need for an inventory of emissions, analysis of their sources, expansion and optimisation of the monitoring system, harmonisation of all indicators and standards with international analogues. The transport sector is one of the largest sources of direct greenhouse gas emissions, accounting for about a quarter of global greenhouse gas emissions, which are still rising. In Kazakhstan, greenhouse gas emissions in the transport sector account for 7% of the total. With the current trend towards an increase in the number of motor vehicles, this share may increase, especially in large cities. In such densely populated cities as Almaty and Astana, the largest number of cars are registered, respectively, more than 500 and 300 thousand. The increase in the number of motor transport in Kazakhstan is largely caused by the inefficiency of public transport and the lack of alternatives for the population (Assanov *et al.,* 2021).

The spread of electric vehicles covers all countries of the world. Many states aim to gradually replace cars with internal combustion engines with electric cars. For example, there is no federal policy in the United States to encourage the introduction of electric vehicles, but some states have set a goal of reducing greenhouse gas emissions from vehicles to zero by 2050. Japan intends to sell only electric vehicles by 2050. India has pledged to stop selling fossil fuel-powered cars by 2030. China is developing a plan to stop the production and sale of vehicles with internal combustion engines. Noting this global trend as mitigating the intensity of climate change, researchers R. Zhang and S. Fujimori (2022) argue that the development of electric transport without the transition of the electric power industry to renewable sources does not solve the problem of the total amount of greenhouse gas emissions affecting global climate change. The combination of electrification of transport with an energy policy to reduce carbon emissions can contribute to the transition to a low-carbon future.

Even though the Republic of Kazakhstan is located mainly in arid climatic zones, it is one of the largest producers and exporters of grain in the world. Climate change is seriously affecting agriculture. The main grain-producing regions of Kazakhstan are increasingly covered by severe droughts, leading to a decrease in grain yields by more than 50%. They are especially often repeated in the Aktobe, West Kazakhstan, Karaganda, and Kostanay regions (Kaimuldinova *et al.,* 2022). The increase in average annual temperatures, droughts, increased winds and dust storms creates conditions for land desertification and undermines the functioning of one of the most important sectors of the economy of the republic, threatening not only the food security of Kazakhstan but also the whole world. The main problem of crop production in Kazakhstan has always been the lack of moisture in the soil, which has worsened due to climate warming. The availability of water will become a serious limiting factor in the development of the economy of Kazakhstan in the future, so it is necessary to make every effort to adapt crop production to the changed conditions. This can be achieved by resource-saving technologies with the most rational use of moisture, soil, and energy. The main direction should be the transition to the development and implementation of adaptive landscape farming systems (ALFS) in agricultural production (Kenenbayev & Yesenbayeva, 2020).

The waste management sector is in fourth place in the list of global greenhouse gas emissions sources since solid household waste accounts for 5% of such emissions. Mainly this is about such greenhouse gases as CH_4 and N_2O, formed at landfills without gas utilisation and open landfills, where the final disposal of solid household waste takes place. This is currently the main waste management practice in Kazakhstan. As a positive example, in 2017, the amount of greenhouse gas emissions (in CO_2 equivalent) generated daily in Tehran as a result of incineration became almost 17 times less compared to the practice of waste disposal. The EU example also shows that efficient waste management can reduce greenhouse gas emissions (Temireyeva *et al.,* 2022).

Having joined international documents such as Agenda 21, The Rumor Convention of the United Nations on Climate Change (1992), The Kyoto Protocol to the United Nations Frame Convention on Climate Change (1997), and The Paris Agreement (2016) since 1992, the Republic of Kazakhstan has adopted a number of laws and programmes for implementation of commitments, such as Environmental Code of the Republic of Kazakhstan (2021), Strategy "Kazakhstan-2050" (2019-2022), and The concept of the transition of the Republic of Kazakhstan to the "Green Economy" (2013). Kazakhstan became the first country in Central Asia and Asia to introduce a system of trading quotas for

greenhouse gas emissions (Bekturganova *et al.,* 2019). Decarbonisation implies a reduction in carbon dioxide (CO_2) emissions per unit of GDP (tonnes/USD/capita) for the economy in general and reduction of CO_2 emissions per unit of energy produced (kg/barrel) for the economy of the energy system. Such decarbonisation directions as electrification, decarbonisation, electricity production, and energy efficiency were identified to achieve progress on these targets in the Republic of Kazakhstan (Maldynova *et al.,* 2022).

Currently, Kazakhstan exceeds the level of carbon intensity of the gross domestic product of the Organisation for Economic Cooperation and Development by 3-5 times (Bekturganova *et al.,* 2019). In 2018, the production of environmentally friendly products in Kazakhstan decreased by 4.4% compared to 2014. A. Kazhmuratova *et al.* (2020) indicate the low efficiency of investments in environmental innovations, despite the actualisation of this problem in Kazakhstan. Therewith, the share of environmental innovations from 2014 to 2018 decreased from 12.7% to 7.8% in the total number of innovations. A study on the introduction of green technologies by enterprises of Kazakhstan in the context of industries and regions conducted by Abdildin *et al.* (2021) showed that the main sources of emissions (mining, metallurgical, oil, and gas industries) reduced the number of green technologies used.

Freshwater sources, food security, ecosystems, human habitat and infrastructure are most affected by the climate risks of global warming, according to S. Fawzy *et al.* (2020). This can cause an increase in poverty and changes in the social structure of society. Ultimately, climate change affects the physical and psychological health of a person, which in the future will require not only work on reducing emissions but also preparing the entire healthcare sector for new conditions and needs (Ebi *et al.,* 2021). The risks are primarily associated with extreme weather events, which are becoming more frequent, and the consequence of which is a tendency to increase the number of victims.

Reducing emissions and decarbonising the economy are necessary, but not the only measures to mitigate climate change. The second promising method is the method of capturing and binding CO_2. The third method that can be applied without reducing the concentration of greenhouse gases is the use of geoengineering technologies to stabilise or reduce air temperature (Fawzy *et al.,* 2020). The latter method is applicable for a short period since it does not eliminate the causes of temperature rise inherent in the first two methods. Governments should prepare appropriate tools for the possibility of their application and promotion of their application to apply various measures to mitigate the effects of climate change.

In addition to the efforts of governments, various non-state subjects are also involved in reducing emissions and mitigating the effects of climate change – cities, regions, entrepreneurs, and public organisations, the actions of which should complement national policy. A study by T. Kuramochi *et al.* (2020), conducted in ten countries, showed that the actions of non-state actors can reduce emissions by 3.8-5.5% more compared to the envisaged irrational programmes by 2030. However, the effectiveness of their actions, especially in cities and regions, depends on the accuracy of information on emissions (Gurney *et al.,* 2021). This is especially important for cities where the main sources of emissions are concentrated. Therewith, it should be considered that the established technological and managerial order of things can slow down the necessary changes.

CONCLUSIONS

The Republic of Kazakhstan is one of the largest producers of grain crops, has a developed mining and metallurgical industry, and is among the countries with the highest greenhouse gas emissions in absolute terms (CO_2-equivalent) and in terms of emissions per capita and per unit of GDP. Provoked by emissions from large enterprises, climate changes occur towards warming, snow cover decrease in winter, and extreme droughts, winds, and rains become more frequent. Frequent sandstorms together with desert sands carry small salt particles. All these phenomena pose a threat to the agriculture of Kazakhstan and cause great damage.

The fixation of greenhouse gas emissions is poorly organised. The most well-established is the system for monitoring CO_2 emissions. But this system also does not cover many large sources of emissions (power plants, large enterprises). Emissions of other greenhouse gases are even more insufficiently monitored. Accordingly, in the reports of the Republic of Kazakhstan to international organisations, greenhouse gas emissions are represented by the only calculated indicator of CO_2. The dynamics of emissions of other greenhouse gases and their impact on climate change remain little-known, incomplete, and poorly investigated. The main source of greenhouse gas emissions in Kazakhstan is thermal power plants powered by local coal, equipped mainly with physically and morally obsolete equipment installed more than thirty years ago. Technical re-equipment of these facilities with just more modern equipment is impractical. There is a need for a complete technical reform of the energy industry and its transfer to renewable energy sources. This will also be a conceptually novel approach to the construction of energy networks.

Since 1992, the Republic of Kazakhstan has signed a number of international documents on climate change and environmental protection, adopted documents, such as Strategy "Kazakhstan-2050". The concept of the transition of the Republic of Kazakhstan to the "Green Economy", indicates intentions to join the global processes of changing the economic model from one based on the consumption (burning) of non-renewable resources to a model based on its energy and industry

on renewable resources, a model of waste-free production when it returns to the natural environment a minimum of substances that do not pose threats to people and the environment. Naturally, this represents a change in all sectors of the economy, management systems, and social life. This process will take place gradually, and its speed depends not only on the objective need for changes but also on the degree of awareness of the importance of the transition to a new economic model for the survival of humanity in general, each nation, and each locality.

In the meantime, the accepted documents are poorly executed. According to the old Soviet approach, environmental issues, and other issues of the environment and human living conditions, were considered something secondary, optional, and even frivolous, which can be ignored. Inertia has persisted, and the introduction of green technologies is slow, especially in polluting industries. Even a promising emissions trading system suffers from this approach. Quotas are set at the highest level of emissions, not at the lowest, which creates little incentive to change anything in production technologies. Until the subject of sustainable development (green economy, decarbonisation, circular economy as its sides) becomes the main one for the government of the country, through the prism of which all processes will be considered – not a single issue of a seemingly technical nature can be solved, including the issue of reducing the emission of greenhouse gases, which most provoke climate warming in arid Kazakhstan.

This study is an attempt to summarise the materials of various researchers concerning various aspects of the problems of climate change, reducing greenhouse gas emissions, and stimulating economic entities to reduce emissions, into a more holistic picture on the example of the Republic of Kazakhstan. It may become the subject of other studies concerning the development of elements of a new model of the economy or a higher level of generalisation. In addition, this study may be of interest to people making managerial decisions, as it shows the relationship of many processes that are not apparent at first glance.

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CONFLICT OF INTEREST

The authors declare no conflict of interest.

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Вплив парникових газів на зміну клімату

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Анотація. Зміна клімату стала загрозливою проблемою для всіх країн світу. Для Казахстану, одного з найбільших світових експортерів зерна, з його раніше переважно посушливим кліматом, розвиненою гірничодобувною промисловістю, металургією і переважно вугільною генерацією теплової та електричної енергії, уповільнення потепління стає нагальним завданням. Метою цього дослідження є узагальнення різних аспектів впливу викидів парникових газів на зміну клімату в Республіці Казахстан і можливостей скорочення викидів парникових газів шляхом переходу Казахстану до нової економічної моделі, заснованої на використанні відновлюваних джерел енергії. Під час дослідження були використані різні методи аналізу – аналітичний відбір на основі заданої або ідентифікованої ознаки, порівняльний аналіз схожих характеристик різних об'єктів, статистичний аналіз динамічних рядів, синтез, що представляє собою первинне теоретичне узагальнення емпіричних даних. В результаті дослідження було виявлено помітну залежність змін середньорічної температури та кількості опадів від загальних викидів парникових газів. Крім того, виявлена схожість динаміки основних кліматичних показників з динамікою окремих парникових газів в Казахстані вимагає подальших досліджень. Також зроблено висновок, що окремі інновації у вигляді окремих електростанцій на відновлюваних джерелах енергії або системи торгівлі квотами, що визначаються за найбільшими значеннями, не призведуть до помітного скорочення викидів парникових газів. Лише перехід до зеленої економіки, який має стати державним пріоритетом, а його принципи та основні характеристики – орієнтиром при прийнятті будь-яких державних рішень. Це дослідження може стати відправною точкою для багатьох теоретичних і практичних досліджень і показати необхідність скорочення викидів парникових газів не як суто механічного процесу, а в комплексі з іншими явищами, що може бути корисним при прийнятті управлінських рішень

Ключові слова: зміна температури повітря; опади та загроза опустелювання; моніторинг викидів; зелена економіка; альтернативна енергетика