ECONOMY-WIDE IMPACTS OF CLIMATE CHANGE AND ADAPTATION IN KAZAKHSTAN

Assessing the Macroeconomic Impacts of Climate Change and Adaptation in Kazakhstan with the e3.kz Model

Published by:

Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH

Supported by:

Federal Ministry for the Environment, Nature Conservation, Nuclear Safety and Consumer Protection

INTERNATIONAL CLIMATE INITIATIVE

based on a decision of the German Bundestag

As a federally owned enterprise, GIZ supports the German Government in achieving its objectives in the field of international cooperation for sustainable development.

Published by
Deutsche Gesellschaft für
Internationale Zusammenarbeit (GIZ) GmbH

Registered offices
Bonn and Eschborn, Germany

Address
Deutsche Gesellschaft für
Internationale Zusammenarbeit (GIZ) GmbH
Köthener Str. 2
10963, Berlin, Germany
T +49 61 96 79-0
F +49 61 96 79-11 15
E info@giz.de
I www.giz.de/en

Project description
Policy Advice for Climate Resilient Economic Development

Project manager
Dr. Sebastian Homm
sebastian.homm@giz.de

Authors
Dr Anett Großmann, Frank Hohmann | Osnabrück

Editor
Dana Yermolyonok, Karaganda

Design and layout
Alvira Yertayeva, Astana

Photo credits/sources
©pexels

This report was elaborated by the experts of the international consultancy Gesellschaft für Wirtschaftliche Strukturforschung | Institute of Economic Structures Research (GWS) within the global programme "Policy Advice for Climate Resilient Economic Development", implemented by the Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) on behalf of the Federal Ministry for the Environment, Nature Conservation, Nuclear Safety and Consumer Protection (BMUV).

On behalf of
Federal Ministry for the Environment, Nature Conservation, Nuclear Safety and Consumer Protection (BMUV)

Germany 2025

ECONOMY-WIDE IMPACTS OF CLIMATE CHANGE AND ADAPTATION IN KAZAKHSTAN

Assessing the Macroeconomic Impacts of Climate Change and Adaptation in Kazakhstan with the e3.kz Model

June 2025

TEAM

Dr Anett Großmann, Frank Hohmann (GWS)

Tel: +49 (541) 40933-180, Email: grossmann@gws-os.com
Tel: +49 (541) 40933-130, Email: hohmann@gws-os.com

Gesellschaft für Wirtschaftliche Strukturforschung (GWS) GmbH / Institute of Economic Structures Research

Heinrichstr. 30
49080 Osnabrück (Germany)

TABLE OF CONTENTS

List of figures

List of tables

Appendix

List of abbreviations

Bn	Billion
CA	Conservation Agriculture
CBA	Cost-Benefit Analysis
CGE	Computable General Equilibrium
CHP	Combined Heat and Power
COMSTAT	Committee of Statistics in Kazakhstan
CRED	Climate Resilient Economic Development
CRF	Common Reporting Format
CRR	Counter-Regulatory Reservoirs
DIW	German Institute for Economic Research (Deutsches Institut für Wirtschaftsforschung)
DIOM-X	Dynamic Input-Output Model in Microsoft Excel
EE	Energy Efficiency
ERI	Economic Research Institute
EWE	Extreme Weather Events
FAO	Food and Agriculture Organization of the United Nations
GDP	Gross Domestic Product
GEF	Global Environment Facility
GHG	Greenhouse Gas
GIZ	Deutsche Gesellschaft für Internationale Zusammenarbeit
GWS	Institute of Economic Structures Research (Gesellschaft für wirtschaftliche Strukturforschung)
ICT	Information and Communications Technologies
IEA	International Energy Agency
IMF	International Monetary Fund
INFORGE	INterindustry FORecasting GErmany
IO	Input-Output
IPCC	Intergovernmental Panel on Climate Change
JERP	Joint Economic Research Program in Kazakhstan
Ktoe	Kilo tons of oil equivalent
KZT	Kazakhstani Tenge
LEDS	Low-Emission Development Strategy
Mn	Million

MNE	Ministry of National Economy of the Republic of Kazakhstan
Mtoe	Million tons of oil equivalent
NAP	National Adaptation Plan
NPISH	Non-Profit Institution Serving Households
NPV	Net Present Value
OECD	Organisation for Economic Co-operation and Development
RCP	Representative Concentration Pathways
RE	Renewable Energy
REF	Reference Scenario
SDG	Sustainable Development Goal
SPM	Sustainable Pasture Management
SSP	Shared Socioeconomic Pathway
TFEC	Total Final Energy Consumption
TIMES	The Integrated MARKAL-EFOM System
Tn	Trillion
UN	United Nations
UNDP	United Nations Development Programme
UNFCCC	United Nations Framework Convention on Climate Change
VBA	Visual Basic for Applications

Glossary

Adaptation to climate change	Adaptation to climate change can be defined as a "set of organization, localization and technical changes that societies will have to implement to limit the negative effects of climate change and to maximize the beneficial ones" (Hallegatte et al., 2011). The United Nations Framework Convention on Climate Change (UNFCCC) defines adaptation as "adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities". (UNFCCC, 2013)
Climate change	Climate change "means a change of climate which is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and which is in addition to natural climate variability observed over comparable time periods." (UNFCCC, 1992).
Climate hazard	A physical process or event (hydro-meteorological or oceanographic variables or phenomena) that can harm human health, livelihoods, or natural resources. A hazard is not simply the potential for adverse effects. (https://climatescreeningtools.worldbank.org/content/key-terms-0).
Cost-benefit analysis	A systematic approach to estimate costs and benefits of a project. It compares the discounted value over the whole lifetime of the project – the net present value (NPV) – of the costs and the benefits. A project is recommended if the benefits outweigh the costs (NPV > 0).
Extreme weather events	"The occurrence of a value of a weather or climate variable above (or below) a threshold value near the upper (or lower) ends of the range of observed values of the variable" (IPCC, 2012, p. 117) with respect to a given reference period and a specific region.
Macroeconomic model	A macroeconomic model shows the economy and its interrelationships in a simplified way. It consists of variables which describe the economic actors (e.g. households) and sectors (e.g. agriculture) as well as their behavior (e.g. consumption). Model equations show the relationship between the variables. Results of a model can be forecasts of model variables or effects on model variables through shocks when conducting a scenario analysis.
Scenario	Scenarios are consistent sets of quantified assumptions describing the future development. Scenarios should not be considered as precise forecasts. Instead, they show possible development paths that are reactions to the assumptions made.

1 INTRODUCTION

Kazakhstan is facing the impacts of climate change such as increasing temperatures and more frequent and severe extreme weather events (EWE), i.e. droughts and floods. Another challenge is its commitment to achieving carbon neutrality by 2060 which involves a transformation of its resource-based economy to reduce Kazakhstan's contribution to global warming. During COP29, Mr. Tokayev reaffirmed this goal and reiterated the vulnerability of Kazakhstan to climate change (Caspian News, 2024).

Adaptation to and mitigation of climate change have to be integrated in long-term economic planning as climate change imposes substantial economic costs and affects key sectors such as agriculture, energy, and transport. Policymakers require robust tools to assess potential economic risks and benefits, as well as evaluate different adaptation strategies to initiate the transition to a climate-resilient economy. Understanding the economy-wide impacts of climate change and sectoral adaptation measures is crucial for Kazakhstan to develop climate-resilient economic strategies. Environmentally extended E3 models in combination with scenario analysis are effective tools to support policymakers with such issues.

The macroeconomic model e3.kz model has been developed as a cooperation of the Ministry of National Economy (MNE) of the Republic of Kazakhstan, the Institute of Economic Research (ERI), GWS and GIZ to accompany evidence-based policy-making on adaption to climate change.

From 11/2023 to 03/2024, the existing E3 model for Kazakhstan was extended, updated and applied to updated climate change scenarios (SSP1-2.6, SSP2-4.5 and SSP5-8.5) as well as adaptation measures based on more detailed cost-benefit analyses. This process was supported by national and international experts, e. g. ERI, AvantGarde Group, Berlin Economics and Earthyield Advisories.

The e3.kz model in combination with scenario analysis greatly helps to understand and quantify economic impacts of climate change and possible adaptation measures to it. By defining appropriate indicators, adaptation options can be evaluated towards their effect on the whole economy and the environment to identify favorable solutions. Classic CBA (cost benefit analyses) are usually limited to single-sector analysis.

By applying macroeconomic analysis with the e3.kz model, the evaluation comprises economy-wide climate change impacts and sector-specific adaptation measures. The analysis not only shows the direct effects but also reveals the indirect and induced macroeconomic effects (GDP, jobs, imports, sector-specific production) for Kazakhstan based on the inter-relationships within the economy. Furthermore, the results support awareness raising by showing what could happen given a certain climate change scenario. The results from adaptation measures also help to differentiate between more and less effective options and their varying impact on the economy, employment, and environment.

This report is an update of the preceding country study on the economic impacts of climate change in Kazakhstan (GIZ, 2022).

This report is organized as follows:

- Chapter 2 provides an overview of the methodology – the e3.kz model and scenario analysis – used for modeling the economy-wide impacts from climate change and adaptation in a nutshell.

- Chapter 3 describes briefly the assumptions and results of the reference scenario, which serves as a basis for the climate change and adaptation scenarios.
- Chapter 4 illustrates the results for the 3 E's (economy, energy and emissions) of three Shared Socioeconomic Pathways (SSP) scenarios.
- Chapter 5 presents four adaptation measures aiming to reduce or even avoid climate damages in the key sectors agriculture and energy. The macroeconomic impacts of the adaptation measures are quantified and provide economic arguments to support the selection of appropriate measures for the National Adaptation Plan (NAP) process. Chapter 6 concludes and provides an outlook.

2 MODELLING THE ECONOMY-WIDE EFFECTS OF CLIMATE CHANGE IN KAZAKHSTAN

2.1 The e3.kz model at a glance

During the first phase of the CRED project, an environmentally enhanced macroeconomic model for Kazakhstan – the **e3.kz (economy, energy and, emission model) model** – was developed from scratch jointly with the national partner ERI. In combination with **scenario analysis**, the model enables the evaluation of the economy-wide impacts of climate change and adaptation measures.

The e3.kz model depicts the Kazakh economy, energy system and CO_2 emissions based on a holistic, consistent modelling framework that calculates impacts simultaneously for each year until the end of the simulation period 2050 (Figure 1). Each module utilizes a dataset which is composed of comprehensive and up-to-date time series allowing for empirically-derived model relationships.

This model is fully developed in Microsoft Excel using the model building framework DIOM-X. The framework is built upon the Excel built-in programming language Visual Basic for Applications (VBA) and was developed for creating Dynamic Input-Output Models in Excel (Großmann & Hohmann 2019). Model users conduct scenario analysis by adjusting the values of model variables in one Excel worksheet which does not require any programming skills. The full model database, model equations and results are stored in a single Excel workbook to ensure that all aspects of the model can be examined, adjusted and extended.

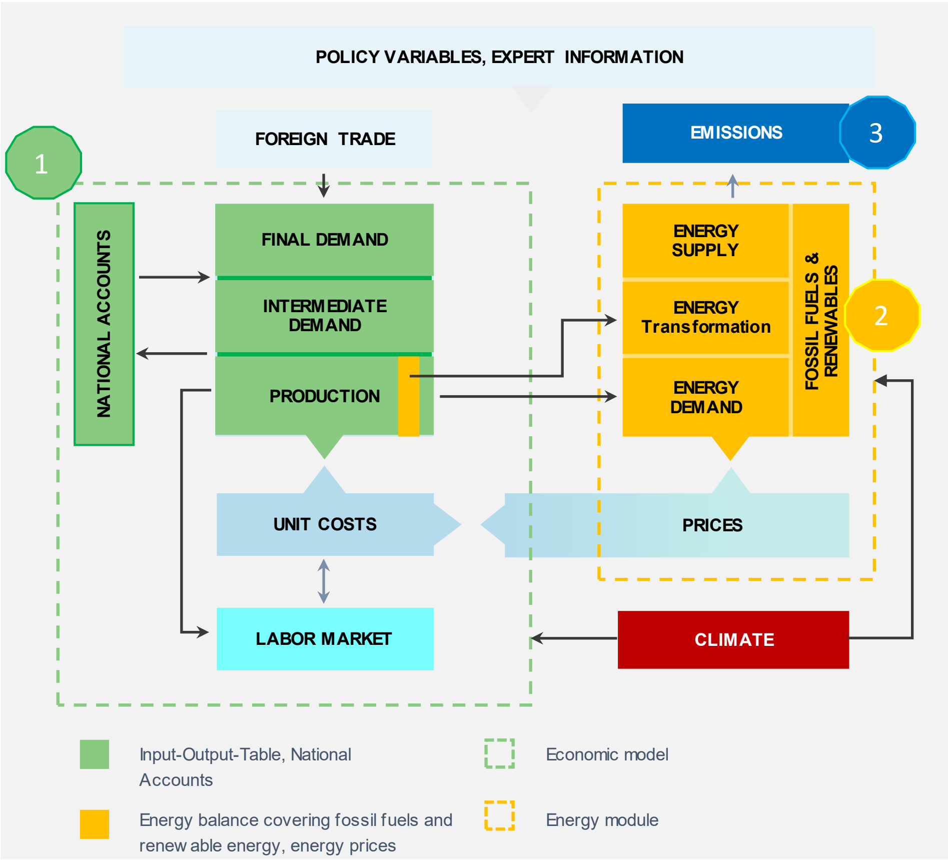


Figure 1 E3.kz model overview

Source: Own illustration based on GWS, 2022.

Within the second phase of the CRED project, e3.kz model was updated and applied for the analyses of new climate scenarios and additional adaptation measures.

For more detail on the e3.kz model and the methodology used, please refer to GIZ (2022).

2.2 Scenario analysis: The case of climate change and adaptation scenarios

2.2.1 Overview

Scenario analysis is a technique which tries to deal with the uncertainty of the future by analysing consistent sets of quantified assumptions regarding possible future developments. Scenario results depict different possible pathways, what and/or who is affected in which way, but they should not be considered exact forecasts. Such analysis starts by defining a reference (REF) scenario describing future developments based on continued behaviour that has been already observed in the past, plus some exogenous factors.

The REF scenario does not include climate change impacts and adaptation policies. It therefore provides the basis against which alternative scenarios are evaluated.

The e3.kz model is applied to simulate the economy-wide impacts of three climate scenarios (SSP1-2.6, SSP2-4.5 and SSP5-8.5) as well as the effects of climate change adaptation measures. Thus, climate scenarios take into account the sectoral impacts of the main climate hazards impacting the Kazakh economy the most which are not reflected in the REF scenario. Climate change adaptation scenarios build upon the climate scenarios and consider the sector-specific costs and benefits of adaptation measures as well. The scenario settings and required data for the scenarios have been jointly selected and collected with national, sectoral and climate experts.

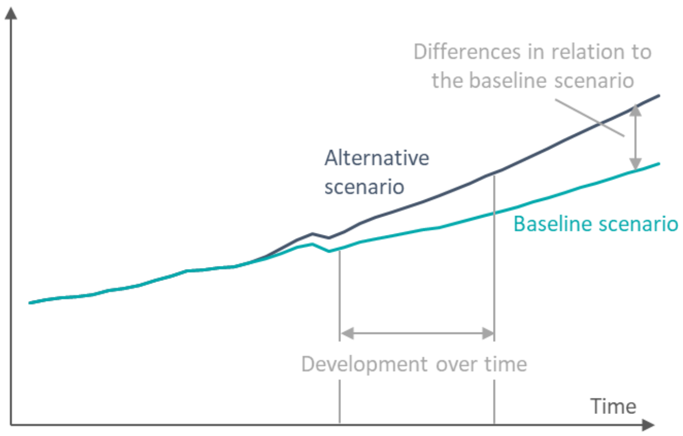


Figure 2: Scenario comparison

Source: Own representation by GWS.

The simulation of the climate scenarios and the adaptation scenarios with their respective scenario settings cause chain reactions in the e3.kz model resulting in an "alternative" future. To see the impacts of a climate change scenario, the results for relevant model variables such as employment, GDP or production are evaluated against the REF scenario (Figure 2). To see the effects of an adaptation measure, this scenario must be compared to the respective climate change scenario which includes climate change impacts but no adaptation policies.

With the help of the e3.kz model, not only direct, but also indirect and feedback effects of alternative scenarios can be evaluated which includes sectoral detail and an economy-wide analysis. The e3.kz model aims at helping model users to identify highly effective adaptation options with positive effects on the economy, employment, and the environment. This is only possible due to the modelled relationships between economic activity, energy, and the emissions as well as the implication of socio-economic relationships (so-called e3 modelling).

2.2.2 Procedure to implement climate change and adaptation into the e3.kz model

The starting point for the analysis of climate change and its impacts for Kazakhstan are the Shared Socioeconomic Pathways (SSPs[1]) which represent different climate policy choices at global scale impacting GHG emissions. The CRED II project focuses on the SSP1-2.6, SSP2-4.5 and SSP5-8.5 scenarios, which range from low to high emission scenarios. SSP suffixes with higher values representing stronger climate warming effects.

Climate models help to better understand how future GHG emissions and land use changes translate into responses in the climate system which can be seen in slow onset events and extreme weather events. Those climate projections, in particular the intensity and frequency of droughts, heatwaves and floods, are an important input for the climate scenarios that are simulated with e3.kz.

As climate models and economic models are operating on different temporal and spatial scales and focusing on different indicators, a 4-step procedure (Figure 3) was followed to (1) integrate climate change impacts and (2) costs and benefits of selected adaptation measures (for a more detailed description see GIZ, 2022):

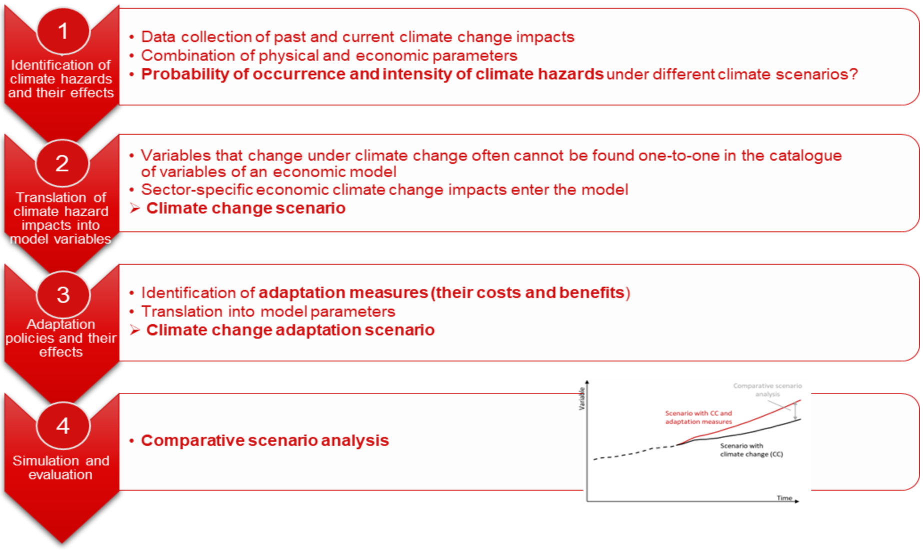


Figure 3: Four-step approach to implement climate change and adaptation in an economic model

Source: Adapted from GIZ, 2022

[1] https://climateknowledgeportal.worldbank.org/overview

For step 1 "Identification of climate hazards and their effects data from field experts are required (for more detail, please refer to GIZ, 2022). For a more detailed analysis of the economic impacts of climate change, the **probability of occurrence and the intensity of country specific climate hazards** (droughts, heatwaves and floods) are provided for **three SSP**[2] (SSP1-2.6, SSP2-4.5 and SSP5-8.5) **scenarios** by Earthyield Advisories (GIZ, 2025a). The frequencies of climate hazards by intensity (Low, Medium, High) differ and they are also different under the SSP scenarios.

Past and current sectoral damage / impact data for the climate hazards – if available differentiated for three intensity categories (low, medium and high) – are collected and serve as a benchmark for estimating future climate hazard impacts ("bottom-up" approach).

Currently, the classification of climate impacts into low, medium and high categories follows the size of damage assuming that low intensity climate hazards cause less damage. For each type of damage, the maximum damage in Tenge is determined from the damage database. The max. damage is divided by three to get three intensity classes (low, medium, high). For each class, the damages are summed up from the damage database and then divided by the number of climate hazards in that class to get the average. The average values in each class serve as benchmark damages by intensity.

Of course, the size of damage varies – even for the same climate hazard intensity – depending on the regional occurrence. If a climate hazard occurs in economically strong and / or populous regions, the economic damage is greater than in regions with smaller economic strength and populations.

In course of the CRED II project, the collection of past and current climate change impacts (GIZ, 2022, , 2023) has been updated including the most recent observed damages from the flood in 2024 and drought in 2021 by a national consultant (Appendix 2).

Adjustments are made to the benchmarks by assuming that, for example, the doubling of the probability of occurrence per year will also double the benchmark impacts (Figure 4).

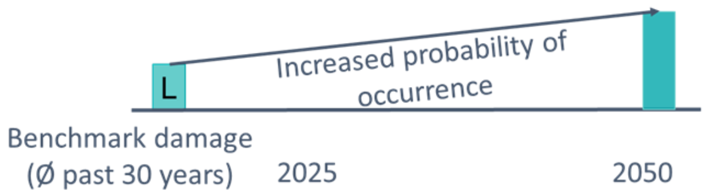


Figure 4: Exemplary projection of benchmark impacts into the future by applying the climate hazard probability of occurrence by hazard intensity (L-Low)

Source: Own illustration

The combination of the future evolution of climate hazards by intensities and observed climate hazard impacts by intensity category results in a time series of expected future impacts for the respective climate hazards.

[2] The SSPs represent different climate policy choices at global scale impacting GHG emissions pathways. SSP5-8.5 (SSP1-1.9) is the most pessimistic (optimistic) scenario assuming a global temperature increase of +4.8°C (+1.5°C) compared to the preindustrial level. (see e.g. climateknowledgeportal.worldbank.org/overview)

By using probabilities of occurrences, climate damages / impacts caused by irregularly occurring climate hazards are converted into a smooth curve (Figure 5). For example, damage caused by a climate hazard that occurs every ten years is distributed evenly over the decade.

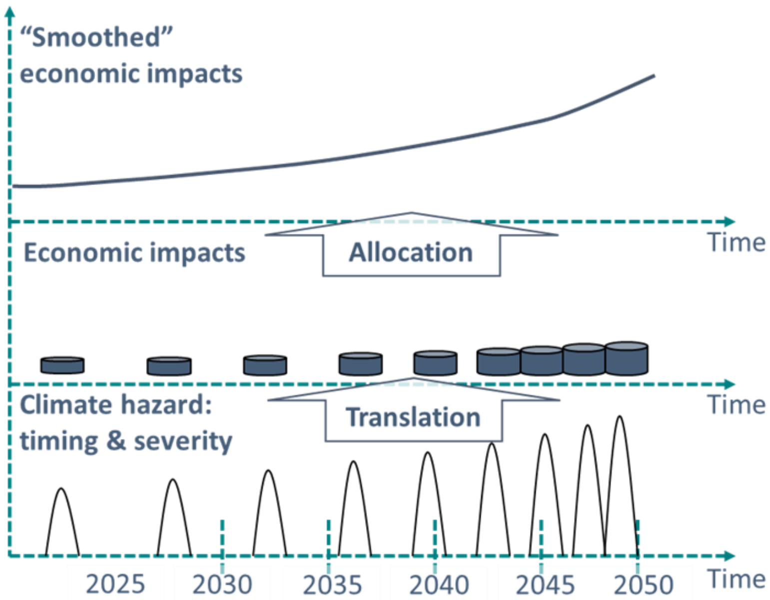


Figure 5: Conversion of irregularly occurring climate hazards into a smooth curve

Source: Own illustration based on Wolter et al. 2023

Other options are, if available, to rely on country-specific forecasts from sector models (e.g. yield forecasts from agriculture models, see UNDP, 2020) developed under different climate scenarios.

To complement the "bottom-up" approach, which cannot be considered a complete and systematic collection of data, other studies analyzing the macroeconomic impacts of climate hazards in Kazakhstan are reviewed ("top-down" approach). This provides (1) additional data of climate impacts in Kazakhstan (e.g. projections of labor productivity losses during heatwaves from Climate Analytics[3])), (2) helps to scale up "bottom-up" data, if not sufficient and (3) enables to compare own scenario results. For example, the World Bank (2022), Kahn et al. (2019) and Waidelich et al. (2024) publish GDP per capita losses for different SSP scenarios.

Other options are, if available, to rely on country-specific forecasts from top-down (e.g. projections of labor productivity losses during heatwaves from Climate Analytics[4]) or bottom-up resp. sector models (e.g. yield forecasts from agriculture models, see UNDP, 2020) developed under different climate scenarios.

[3] https://climate-impact-explorer.climateanalytics.org/impacts/?region=KAZ&indicator=ec1&scenario=rcp85&warmingLevel=3.0&temporalAveraging=annual&spatialWeighting=area&altScenario=rcp26&compareYear=2030

[4] https://climate-impact-explorer.climateanalytics.org/impacts/?region=KAZ&indicator=ec1&scenario=rcp85&warmingLevel=3.0&temporalAveraging=annual&spatialWeighting=area&altScenario=rcp26&compareYear=2030

In **step 2**, all data must then be implemented into e3.kz by finding appropriate model variables. The initial impacts of climate hazards can be implemented, for example, as effects to human behavior (increased demand for cooling and health care), as investments (reconstruction costs or adaptation investments), as price increases due to scarcities, lower labor productivity or changes in foreign trade (indicated by ● in Figure 6) which then cause chain reactions within the e3.kz model. The economy-wide impacts of three SSP scenarios are described in chapter 4.

In **step 3**, quantified sector-specific **costs and benefits of adaptation measures** are required to subsequently analyze the economy-wide impacts with e3.kz. Ideally, results from CBAs are available to be better informed about the specific costs and benefits which then serve as an input for the e3.kz model.

The costs of adaptation measures are usually implemented as investments and the benefits as reverse impacts of climate change. The results of four adaptation measures are part of chapter 5.

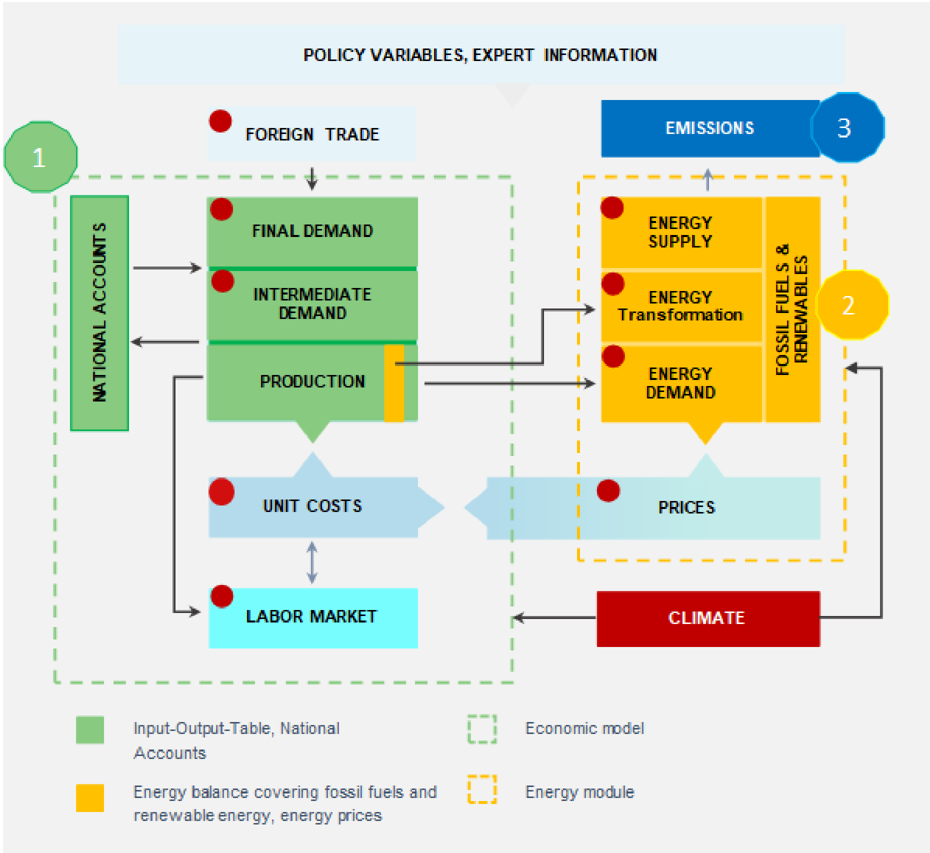


Figure 6: Implementing the impacts of climate change and adaptation measures into e3.kz

Source: GIZ, 2022

3 REFERENCE SCENARIO

3.1 Assumptions

In course of the CRED II project, the e3.kz model has been updated jointly with ERI to the most recent data (mainly 2023) from official statistics. All behavioral equations have been updated to reflect the new historical data. Exogenous projections for e.g. population and world market prices are revised as well to develop the reference (REF) scenario. The REF scenario does not include the latest updates of the "LEDS[5] models", which were still being processed when the reference scenario of the e3.kz model was already completed.

The LEDS models have a strong focus on simulating Kazakhstan's transition to climate neutrality by 2060 including a comprehensive representation of the energy sector. Aligning the exogenous assumptions and expectations for the development of the energy sector in the reference scenario of the e3.kz model and the LEDS models is advisable for comparability.

Thus, relevant e3.kz model indicators such as expectations in the energy sector (including production, exports, and renewable energy expansion) have been aligned as far as possible with previous LEDS projections (GIZ, 2022).

The REF scenario provides a projection of all model variables until 2050 presuming that – apart from a few exogenous assumptions – the economic relationships observed in the past are also valid in the future. The REF scenario is the benchmark to which other scenarios – such as the climate change and adaptation scenarios – are compared to.

3.2 Results

Economic development

In the REF scenario, the economy is expected to continue to grow until 2050 but a slower rate compared to the history (Table 1). In the first projection period, the average annual growth is 3% (2020-2030), followed by -0.3% (2030-2040) and 2.1% (2040-2050). The weaker GDP growth rate between 2030-2040 results from the export assumption.

The export development is driven by exogenous assumptions and shows accelerated growth between 2020-2030 of 3.2% also driven by higher crude oil exports following the Ministry of National Economy of the Republic of Kazakhstan (MNE) expectations. Afterwards, fossil fuel exports decrease according to the LEDS projections. In contrast, agriculture exports are assumed to grow steadily until 2050. For total

[5] The Low-emission development strategy (LEDS) modeling tools comprise a CGE, TIMES and System Dynamics model used to determine goals and tasks to achieve carbon neutrality in Kazakhstan by 2060.

exports, the growth rate to -2.2.% p.a. during the decade 2030-2040 and reaches 2.5% p.a. in the period of 2040 to 2050.

Household consumption is the main driver of GDP as in the past. More jobs and higher income have a positive impact on consumption expenditure decisions. The slower population growth compared to the past has the opposite effect. Consumer spending by private households continued the growth trend of the past starting with an annual average growth of 3.5% (2020 to 2030), slows down to 0.6% (2030-2040) and recovers afterwards reaching 2.3% in the period of 2040 to 2050.

The growth path of gross fixed capital formation follows the GDP growth. Investments are made to both maintain and expand production capacities to enable sufficient production to satisfy either domestic or foreign demand. Thus, investment will initially continue to grow at an average annual rate of 4.7% during 2020-2030, decelerate between 2030 and 2040 resulting in zero growth per year, and reach 1.3% p.a. in the period of 2040 to 2050.

Government consumption expenditure shows positive growth of up to 3% p.a., following GDP growth with a time lag.

Imports develop with the economic activity according to the import dependency of the economic sectors. In particular, the manufacturing sector (machinery, electrical equipment, computers) is highly import-dependent.

Table 1: REF scenario: Real GDP and components (expenditure approach), average annual 10-years growth rates in % (2000-2050)

	2000 – 2010	2010 – 2020	2020 – 2030	2030 – 2040	2040 – 2050
GDP	8.3%	3.9%	3.0%	-0.3%	2.1%
Final consumption expenditure: private households and non-profit institutions serving households (NPISH)	8.9%	5.6%	3.5%	0.6%	2.3%
Final consumption expenditure: government	6.7%	7.0%	3.0%	0.04%	1.3%
Gross fixed capital formation	14.0%	5.9%	4.7%	0.04%	1.3%
Export of goods and services	3.9%	-0.1%	3.2%	-2.2%	2.5%
Import of goods and services	2.8%	3.0%	4.6%	0.7%	1.6%

Source: Until 2023 historical data based on COMSTAT, e3.kz results (2024-2050).

Sectoral production follows the macroeconomic development considering inter-industry relationships. For the projection period, no structural changes or economic diversification of the economy are assumed except the developments in the energy sectors which follow LEDS growth assumptions.

Consumption-oriented sectors (e.g. service sectors, sectors providing essential goods for households) are more dependent on domestic demand while export-oriented sectors (agriculture and mining) generally show a stronger connection to foreign demand. Declining oil and gas exports are reflected in lower production in the mining sector in the period 2030 to 2050. Lower investments impact mainly manufacturing, construction, and related professional, scientific and technical activities. Figure 7 depicts the projections for real gross production by economic sectors.

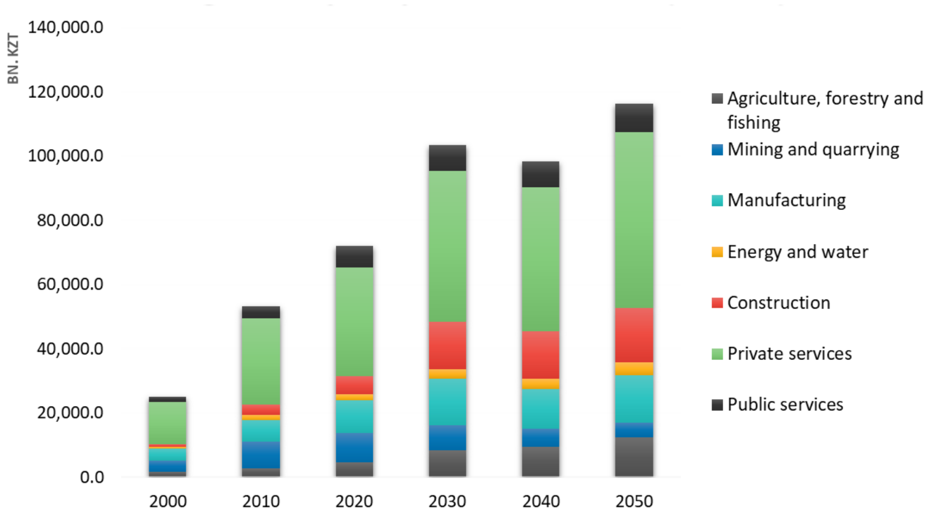


Figure 7: REF scenario: Real gross production by economic sectors in Bn. KZT (2000, 2010, 2020, 2030, 2040, 2050)

Source: Historical data until 2023 based on COMSTAT, e3.kz results (2024-2050)

Sectoral employment follows the sectoral economic activity considering the sector-specific labor productivity, real wages and partly population development. For example, population aged younger than 16 years is expected to be relevant for the number of teachers. In total, employment increases from 9.1 Mn. Persons to 10.3 Mn. By 2050. Most of the persons are employed in service sectors (e.g. trade, education, human health), agriculture and construction (Figure 8).

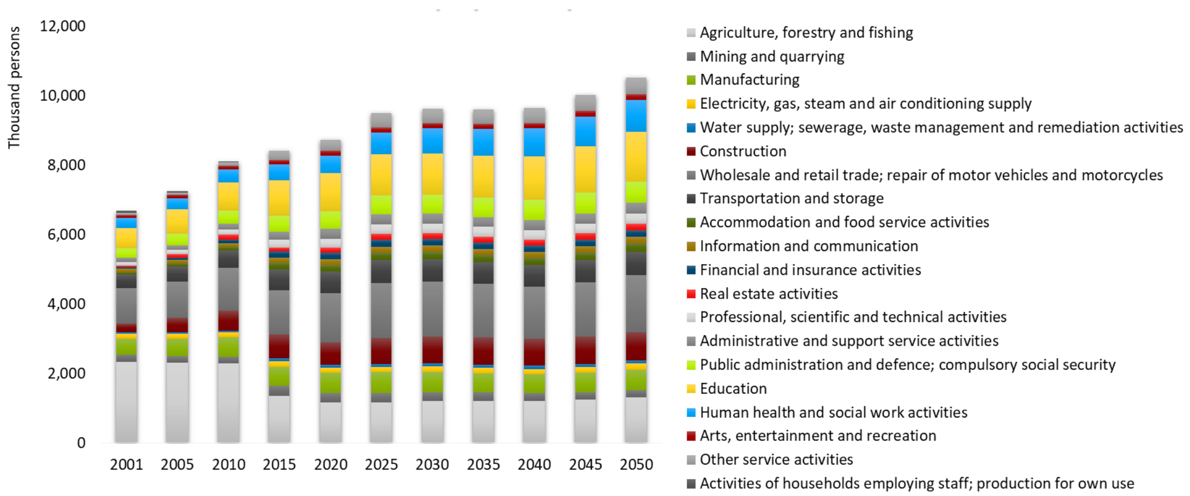


Figure 8: REF scenario: Employed persons by economic activity in 1,000 persons (2001-2050)

Source: Historical data until 2023 based on COMSTAT, e3.kz results (2024-2050)

In a gender-specific view of total employment, the distribution between women and men is largely equal (Figure 9). However, the differences can be seen for the different economic activities. Male employment dominates in construction (11% vs. 3% in respective total employment), transport (10% vs. 3%), mining (5% vs. 1%) and manufacturing (8% vs. 5%). In contrary, female employment is superior for education (19% vs. 7%) and human health (9% vs. 3%).

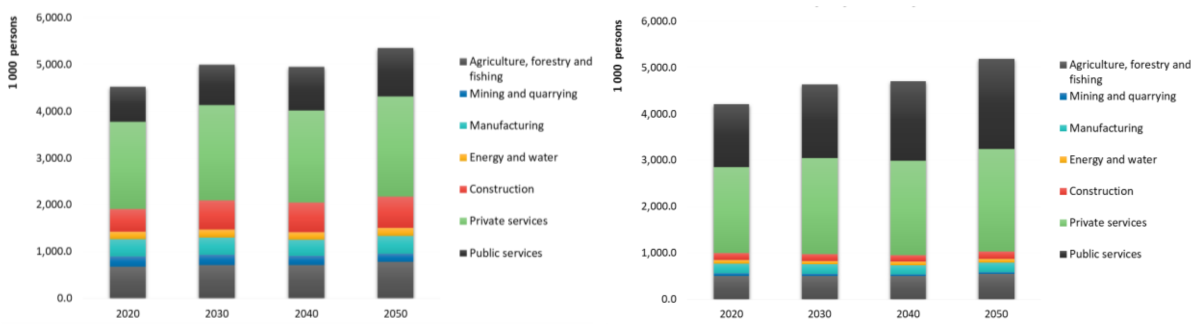
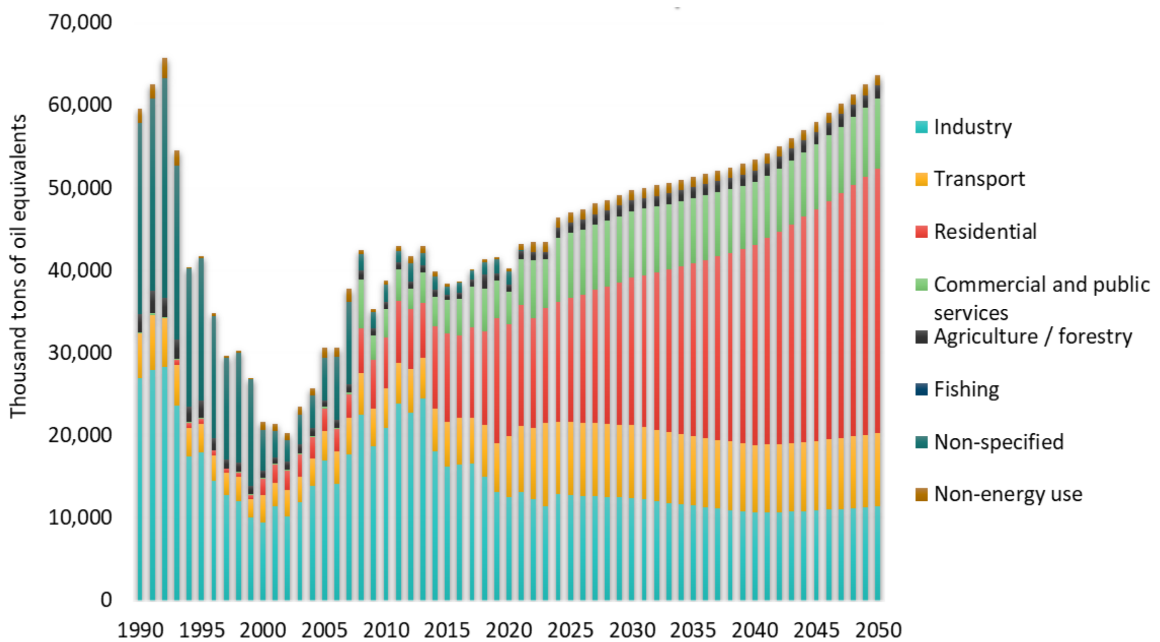


Figure 9: REF scenario: Employed persons by economic activity and gender in 1,000 persons (2001-2050), male (left figure), female (right figure)

Source: Historical data until 2023 based on COMSTAT, e3.kz results (2024-2050)

Energy demand and emissions

Total final energy consumption (TFEC) by sectors is driven by sectoral economic activity, or for the residential sector by population and trends (e.g., using more electrical appliances). Thus, TFEC will further increase reaching 61 Mtoe (Figure 10). The largest energy consumers in 2023 resp. 2050 are the residential (32% resp. 50%), industrial (26% resp. 18%), and transport sector (23% resp. 14%).



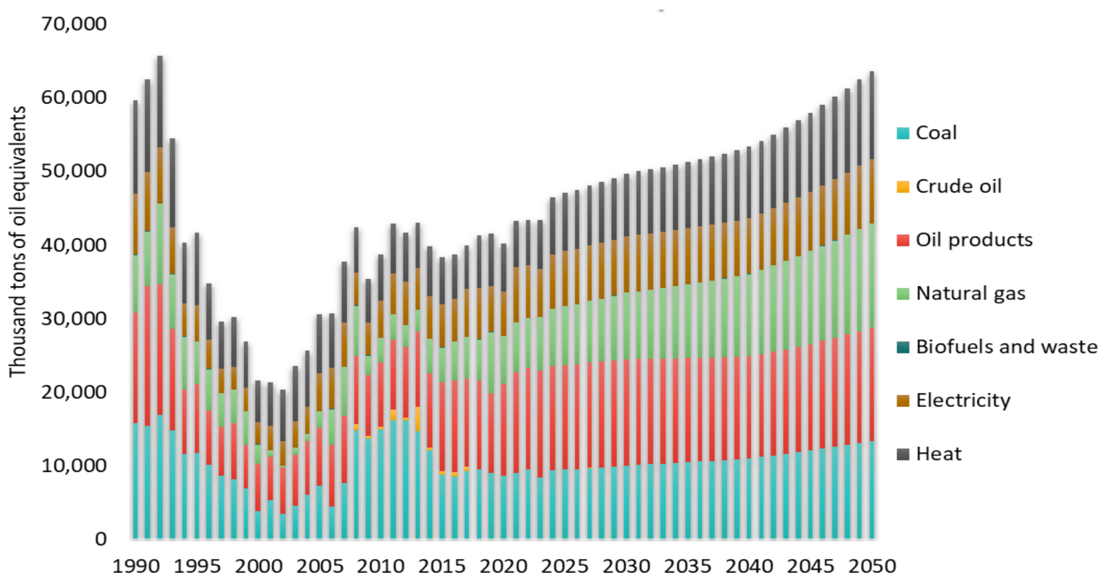


Figure 10: REF scenario: Total final energy consumption by sectors (top figure) and by energy carriers (bottom figure), 1990-2050

Source: Historical data until 2023 based on COMSTAT and IEA, e3.kz results (2024-2050)

The dependency on fossil fuels, in particular coal, oil products and natural gas, remains high. There is no switch from fossil fuels to renewable energy (RE) presumed for the final energy consumers (Figure 10). Similar applies to the energy sector: For generating heat and electricity, not much RE is used, mainly coal and gas. The expansion of RE follows LEDS projections resulting in an eight times higher electricity generation from wind and solar photovoltaic (DIW Econ, 2021). Wind power will remain more or less at the level of 2023.

The restrained expansion of RE and the modest energy efficiency improvements are leading to a further increase in combustion-related CO_2 emissions (Figure 11).

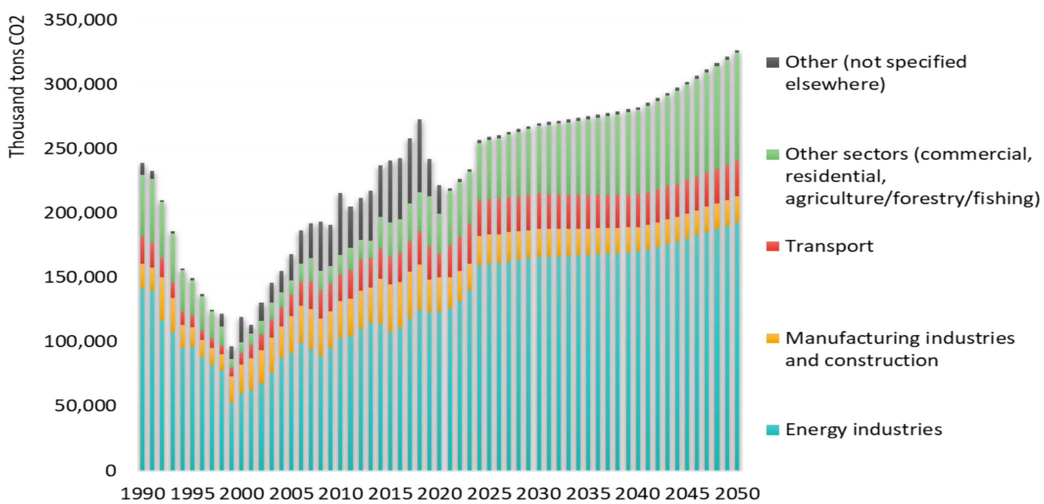


Figure 11: REF scenario: CO_2 emission by sectors, 1990-2050

Source: Historical data until 2021 based on UNFCCC, e3.kz results (2022-2050)

4 ECONOMICS OF CLIMATE CHANGE

In this chapter, the economy-wide impacts of three climate change scenarios are described regarding their impacts on economic growth, employment as well as for environmental indicators. As introduced in section 2.2.2, the future development of the main climate hazards under different climate change scenarios are required as well as the average sectoral benchmark impacts as observed in the past.

In the three examined climate change scenarios (SSP1-2.6, SSP2-4.5 and SSP5-8.5), the relevant key climate hazards and their impacts are combined to show the impacts on the 3 Es, namely the economy, energy system and emissions. These three SSP scenarios were selected to represent a range of possible global temperature increases and the associated extent (frequency and intensity) of climate hazards in Kazakhstan.

The desk research and exchanges with national climate experts during CRED I and II project revealed that floods, heatwaves and droughts are the most relevant climate hazards in Kazakhstan impacting people and key economic sectors either directly or indirectly (Ministry of Ecology, Geology and Natural Resources of the Republic of Kazakhstan, 2022; World Bank, 2021; UNESCAP, 2022). These climate hazards are therefore examined below.

4.1 Scenario settings – overview

This section gives an overview of the scenario assumptions for the three climate scenarios. The benchmark impacts as shown in Table 2 are the basis for all scenarios. The probability of occurrences for the climate hazards by intensity differs comparing the three SSP scenarios (Figure 12).

According to GIZ (2025a), the most relevant climate hazards are floods, droughts and heatwaves. In the future, climate hazards will occur even more frequently (i.e. flood and heatwaves) and more severely. In general, less intense climate hazards (red line in Figure 12) are expected to happen more often (approx. every two years) than those with high intensity (approx. every 14 years) and vice versa.

Furthermore, there is a tendency that the probability of occurrence of climate hazards (i.e. flood and heatwaves) is greater in Shared Socioeconomic Pathways (SSP) scenarios with higher warming potential due to higher emission pathways, e.g. SSP5-8.5 compared to SSP1-2.6 (GIZ, 2025a).

On average, floods occur every two (low hazard intensity), four (medium hazard intensity) to 27-40 years (high hazard intensity) resp. every three, 12 to 50-70 years for heatwave. Droughts are expected every three, four and 13-18 years. The difference in frequency for the climate hazard intensity between the SSP scenarios is similar except for high hazard intensity.

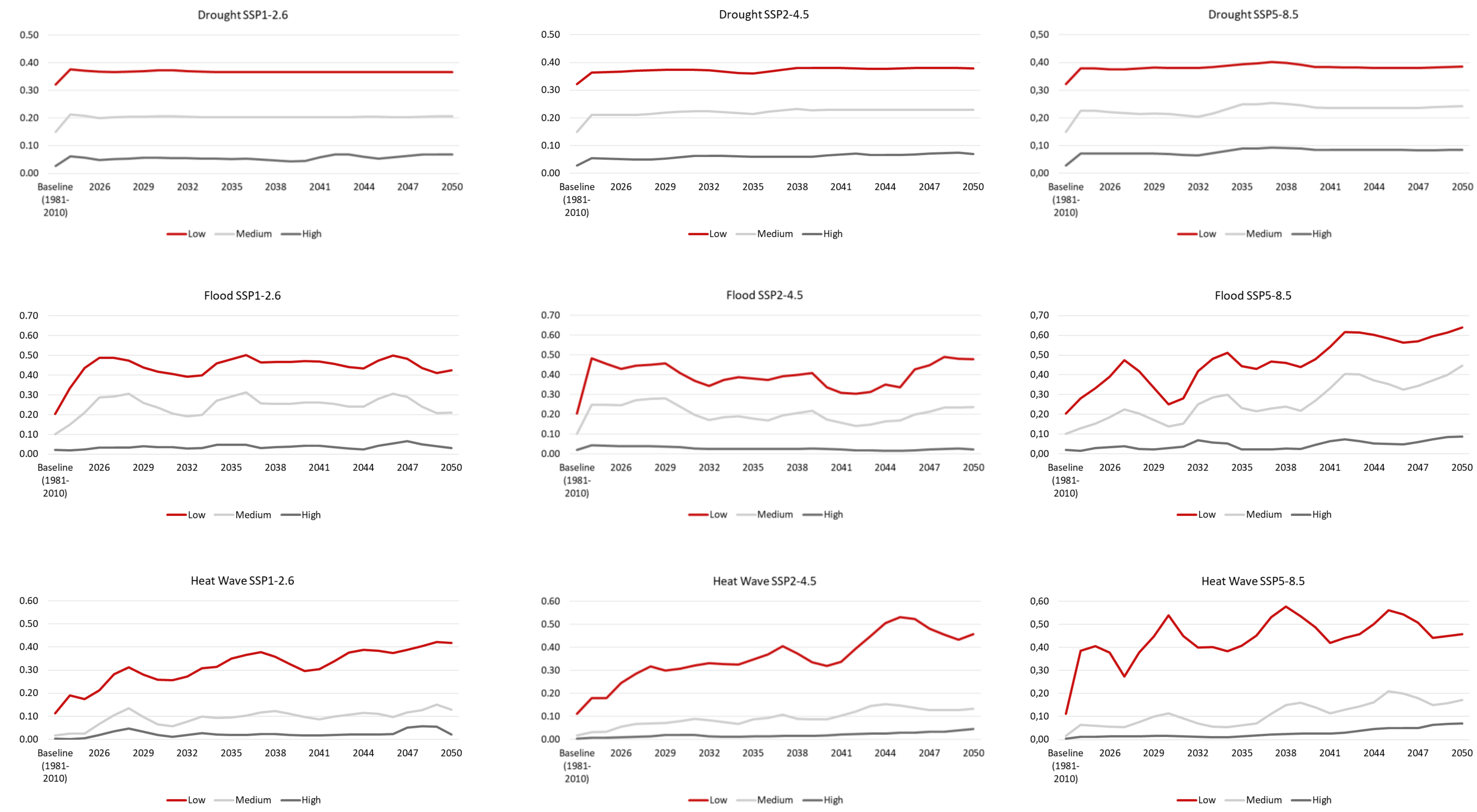


Figure 12: Probability of occurrence by intensity (low, medium, high) for droughts, heatwaves and floods under SSP1-2.6, SSP2-4.5 and SSP5-8.5 scenario

Source: GIZ (2025a)

The sectoral benchmark damages used in the scenarios are either collected by screening media, website etc. ("bottom-up" approach) or stem from analyses from sector-specific models such as the agricultural model (UNDP, 2020). Following, those data and information, the key climate hazards impacting mainly agriculture, energy and infrastructure (see Table 2). However, each climate hazard has different impacts on the economic sectors:

Floods cause damages mainly to infrastructure such as buildings, roads, bridges or energy infrastructure as the "bottom-up" data collection indicates. A minor share of the total damages is attributed to the agriculture sector, damaged cars, and household equipment. The total damage from flooding ranges from 468 Mn. KZT to 51 Bn. KZT which also includes the flooding from 2024 (Astana Times, 2024). Less severe events occurred more often than the very severe events, but the reported damage is lower. Results from "top-down" approaches – looking at GDP impacts – such as the AQUEDUCT Global Flood Analyzer from the World Resources Institute[6], indicated that the GDP impact could be 2.4 Bn. USD resp. 0.3% by 2050 under RCP8.5.

Physical damage to the capital stock may also cause further losses due to power disruptions, failures and delays in the supply chain (OECD, 2018; World Bank, 2019). Depending on the industry affected, that will cause higher imports or lower exports.

Heatwaves have consequences for many sectors: The energy sector is simultaneously affected through limited energy generation from hydro power and thermal combined heat and power (CHP) plants as well as an increased electricity demand. The agriculture sector faces wheat yield losses and a decline in livestock production due to lower pasture productivity. In contrary, sunflower yields are expected to increase (UNDP, 2020). According to international experience, higher beverage consumption of 3% (Mirasgedis et al., 2013) can be expected.

Average labor productivity declines due to heat stress between -0.95% (RCP2.6) and -1.9% (RCP8.5) until 2050 (Climate analytics[7]). Many sectors are affected, especially outdoor workers in agriculture and construction. The more (less) physical intense the labor in a sector is, the greater (lower) the labor productivity loss from the average. The productivity losses imply lower output in the affected sectors without heat-related suspension of staff.

Kazakhstan is also confronted with increasing heat-related health expenditures due to extreme heat, water-borne diseases, stunting and vector-borne diseases. The World Bank (2024a) publishes estimates of health costs until 2050 for the SSP2-4.5 of 4.9 Mn. USD.

Droughts mainly impact agriculture in the North of Kazakhstan where rain-fed wheat production is predominant. Depending on the severity of a drought, the crops are partially or even completely destroyed or the quality of the crops is inferior so that only lower prices can be obtained. From the "bottom-up" damage data collection, the average agricultural losses range from seven Bn. KAZ to 300 Bn. KZT depending on the intensity of a drought.

---

[6] https://www.wri.org/applications/aqueduct/floods/

[7] https://climate-impact-explorer.climateanalytics.org/impacts/?region=KAZ&indicator=ec1&scenario=rcp85&warmingLevel=3.0&temporalAveraging=annual&spatialWeighting=pop&altScenario=rcp26&compareYear=2030

Similar to heatwaves, droughts impact the energy sector as well. Lower water levels could create energy security concerns. Not only hydro power but also thermoelectric power plants are affected due to cooling needs.

In some sectors price increases are to be expected due to higher water demand during droughts. This aspect was discussed during the onsite training in Kazakhstan and implemented for coal mining, refrigerated steam and air conditioning services, agriculture and water transport. The price increases are caused either by greater demand for water or, in the case of water transport, by rising costs due to the lower capacity utilization of ships (Schattenberg, 2023).

Not all impacts from climate hazards are available, neither monetized nor in physical units. Thus, the macroeconomic analysis of climate change is limited to those damages that are quantified. Once, new quantified impacts from climate hazards become available, model users should update the climate change scenarios to reflect the most recent data.

Table 2: Quantifiable benchmark impacts from main climate hazards in Kazakhstan

	Agriculture	Energy	Infrastructure	Water	Health care	Cross-sectoral
Droughts	• Average agriculture losses from the past (7 Bn. KZT – 300 Bn. KZT)	• Decreased hydro power production due to lower water levels (-5% to -20%) • Limited energy supply from CHP plants due to insufficient cooling (-3.8% to 4.7%)	• Increased costs in water transport	• Increased water demand in agriculture, coal mining, steam and air conditioning services	-	-
Sources	• ClimateDamageDatabase_MapView_2024.xlsm	• IEA energy balance 1998 • Van Vliet et al., 2016	• Increased demand for wholesale services in water transport as observed during drought years	• Increased water demand in relevant sectors as observed during drought years	-	-
Heatwaves	• Wheat yield losses (457 bn. KZT until 2030, 608 bn. KZT until 2050) • Increased sunflower yields (1,8 bn. KZT until 2030, 0.9 bn. KZT until 2050) • Decline in livestock production (109 bn. KZT until 2030, 170 bn. KZT until 2050))	• Decreased hydro power production due to lower water levels (-5% to -20%) • Limited energy supply from CHP plants due to insufficient cooling (-3.8% to 4.7%) • Additional cooling demand: 0.5% to 8.5% per 1°C change in ambient temperature	-	-	• Higher health costs due to water-born and vector-borne diseases (SSP2-4.5: 4.9 Mn. USD by 2050)	• Average labor productivity losses due to heat stress (-0.95 to -1.9% by 2050) • Increased beverage consumption (3%-5%)
Sources	• UNDP, 2020	• IEA energy balance 1998 • Van Vliet et al. ,2016 • World Bank, 2021	-	-	• World Bank, 2024a	• Climate Analytics

	Agriculture	Energy	Infrastructure	Water	Health care	Cross-sectoral
						• Mirasgedis et al., 2013
Floods	• Killed livestock, flooded arable land (2% of total flood damages; 0.5 Bn. KZT -51 Bn. KZT)	• Damaged energy infrastructure (22 Bn. KZT -112 Bn. KZT) • Electrical outages causing sales losses in other sectors (0.5%-7.7%)	• Damages buildings and interior (87% of total flood damages; 0.5 Bn. KZT -51 Bn. KZT) • Damaged road infrastructure and cars (11% of total flood damages; 0.5 Bn. KZT - 51 Bn. KZT)	-	-	-
Sources	• ClimateDamageDatabase_MapView_2024.xlsm	• World Bank, 2019	• ClimateDamageDatabase_MapView_2024.xlsm	-	-	-

Source: Based on data collection during CRED I (GIZ., 2022) and data updates during CRED II (ClimateDamageData-base_MapView_2024.xlsm).

4.2 Results for the SSP5-8.5 scenario

The aforementioned benchmark damages and climate hazards with their respective probabilities of occurrences and intensities for all SSP scenarios are implemented into the e3.kz model and cause reactions in the whole economy. In this section, the results for the SSP5-8.5 scenario are described in more detail. The next section 4.3 provides a comparative overview of the macroeconomic results for all three SSP scenarios.

The economy-wide impacts are negative as long as no preventive adaptation measures are taken. Real GDP decelerates and is up to 6.5% resp. 4.9 Tn. KZT lower compared to the REF scenario (Figure 13).

Exports are restricted due to production losses in agriculture, metal production and mining. Agriculture is affected from the lower agricultural productivity during droughts and heat waves. The impacts on the mining sector stem from destroyed infrastructure during flooding. Many economic sectors are impacted from the reduced labor productivity during heatwaves (e.g. agriculture) and the losses due to electrical outages (e.g. metal production).

The import development is impacted by countervailing effects: On the one hand, imports accelerate due to constrained production capacities caused by electrical outages and damages as well as limited labor productivity in many sectors. It is assumed that imports replace (failed) domestic production to satisfy the demand. Depending on the duration of the production interruption, these can also be compensated for over the course of the year, which was not envisaged in this scenario. Contrary, imports are offset by decelerating GDP due to high import dependency i.e. in manufacturing.

With lower employment and income compared to the REF scenario, household consumption expenditures decelerate. Investments and government consumption expenditures follow the GDP.

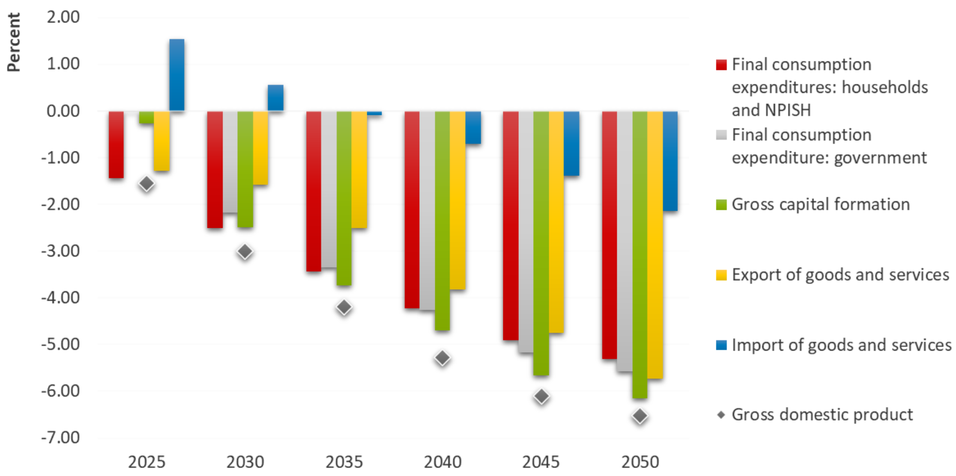


Figure 13: SSP5-8.5 scenario: macroeconomic effects, 2022-2050, deviations from a hypothetical "No climate change" (REF) scenario in percent

Source: Own illustration based on e3.kz results

Overall, total real production decelerates (-6.8% resp. 7.7 Tn. KZT, Figure 14) as the overall macroeconomic development. The impacts for the sectors differ: Agriculture suffers the most (-12% resp. 1.5 Tn. KZT), followed by construction (-8.3% resp. 1.4 Tn. KZT). The reduced labor productivity has an impact on many sectors, in particular those with outdoor activities like agriculture and construction.

The greater demand in the healthcare sector and in beverage production is more than offset by the less strong economic development. Other sectors such as the trade and service sectors are also impacted through intersectoral linkages. A positive development shows the water sector due to greater demand for water during droughts and heatwaves.

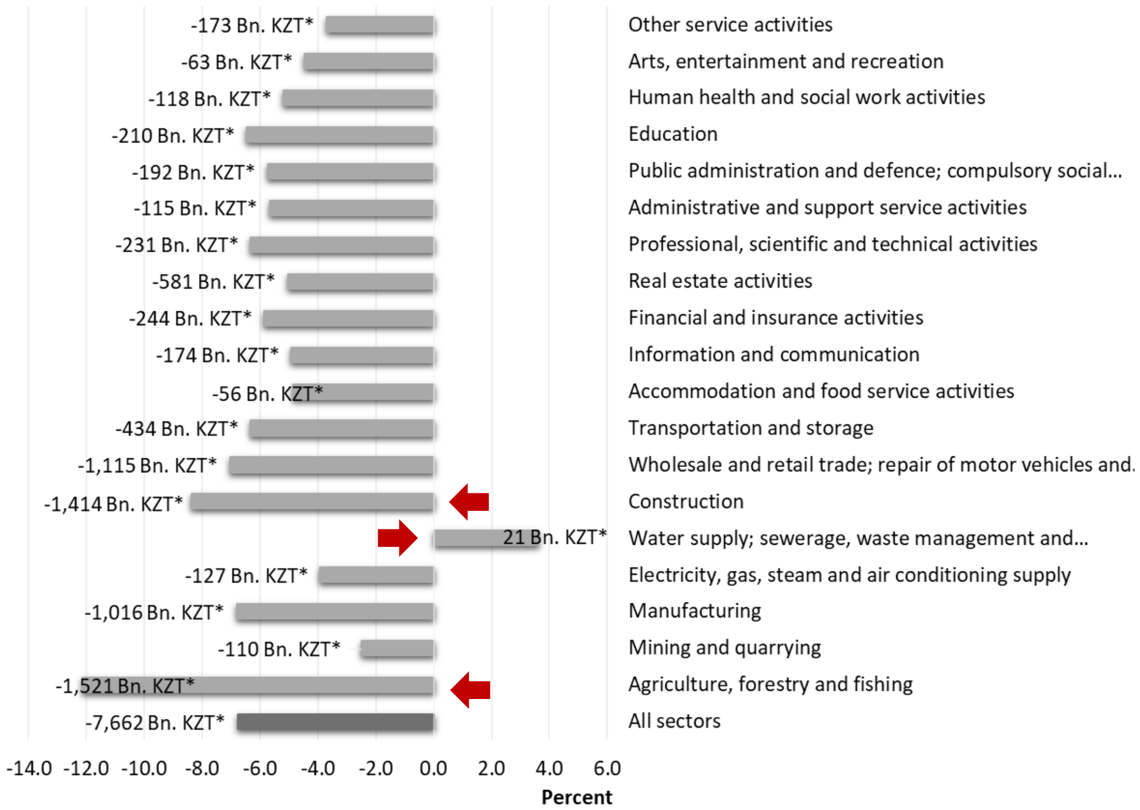


Figure 14: SSP5-8.5 scenario: real production by economic sectors in 2050, deviations from a hypothetical "No climate change" (REF) scenario in percent (x-axis) and Bn. KZT (*)

Source: Own illustration based on e3.kz results

Total employment is up to -1.8% resp. 187,000 employed persons lower in 2050 compared to a situation without climate change. It must be noted, that no heat-related suspension of staff is assumed but the aforementioned effects on sectoral production have an impact on employment. The greater the production effects and the higher the sectoral labor productivity, the greater the employment effects. As depicted in Figure 15, the agriculture sector and private sectors (including trade and transport) are affected the most. The water sector benefits in terms of jobs which is not visible in the graph as it is part of "energy and water" sector.

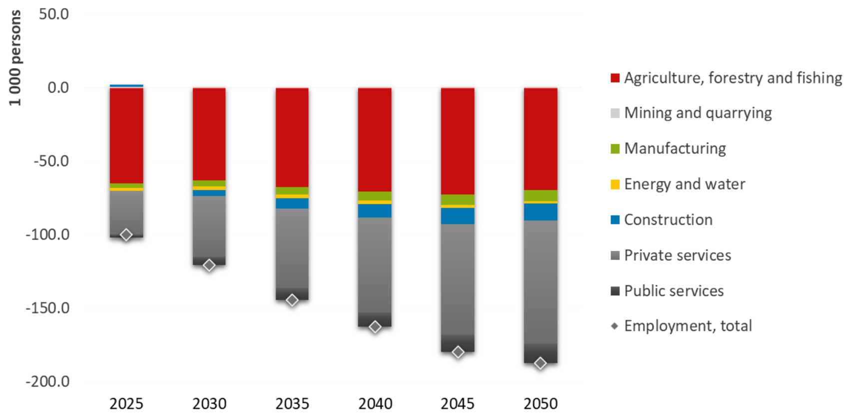


Figure 15: SSP5-8.5 scenario: employment by economic activities, 2025-2050, deviations from a hypothetical "No climate change" (REF) scenario in 1,000 persons

Source: Own illustration based on e3.kz results

The analysis of employment under a gender lens reveals that male workers are more affected than female workers because males dominate those economic activities such as construction, trade and manufacturing that are affected from climate change as considered under this scenario (Figure 16).

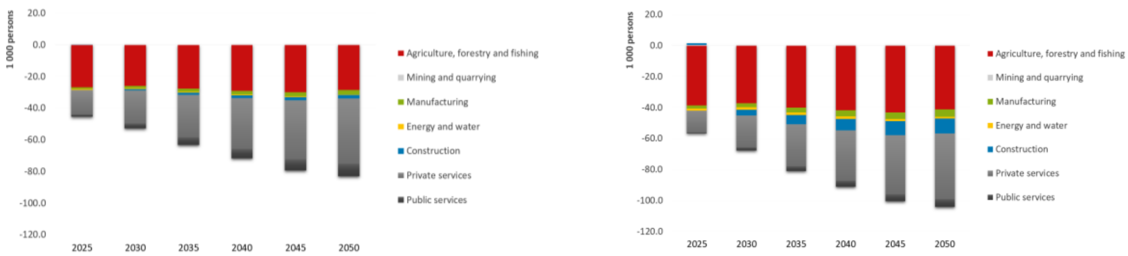


Figure 16: SSP5-8.5 scenario: employment by gender and economic activity (female: left figure, male: right figure), 2025-2050, deviations from a hypothetical "No climate change" (REF) scenario in 1,000 persons

Source: Own illustration based on e3.kz results

The limited economic growth results in lower total energy demand (1.8% resp. 1,150 ktoe) but the residential sector shows a higher cooling demand (up to 1.5% resp. 44 ktoe). In the public and commercial sectors, the additional cooling demand is overcompensated by the decelerated economic activity resulting in less total energy demand of up to -4.4% resp. 373 ktoe. Also other sectors like transportation shows less energy demand compared to a situation without climate change (-3.4% resp. 308 ktoe, Figure 17).

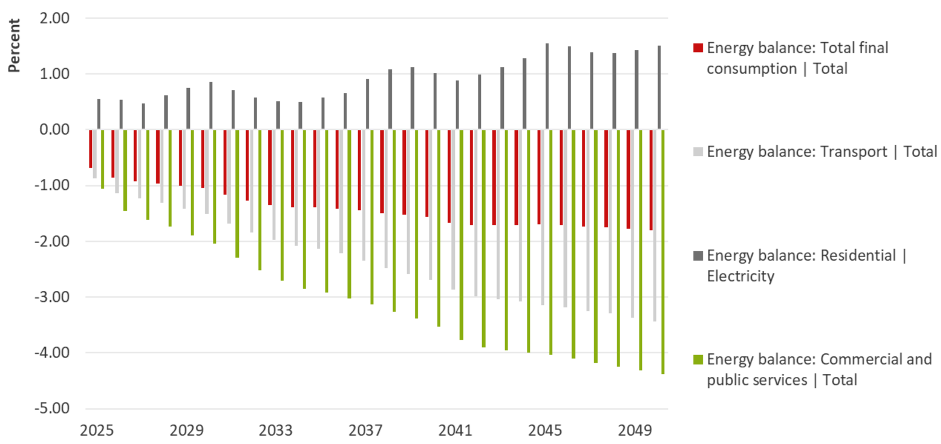


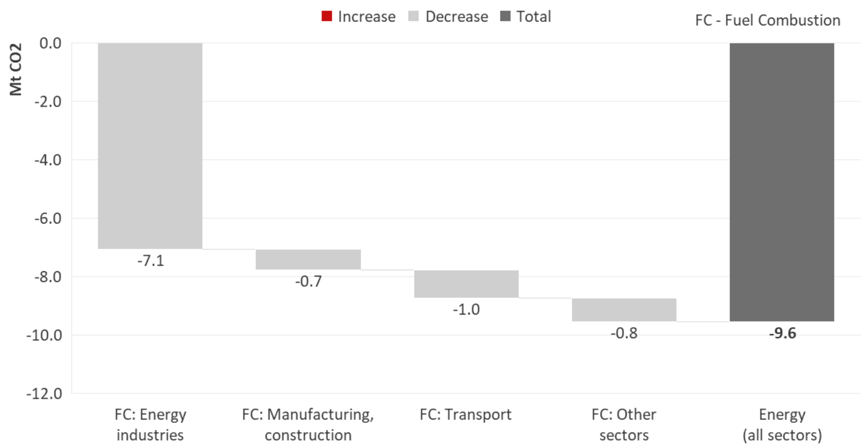
Figure 17: SSP5-8.5 scenario: energy demand, 2025-2050, deviations from a hypothetical "No climate change" (REF) scenario in percent

Source: Own illustration based on e3.kz results

Due to less energy demand, less fuels are needed for energy production such as heat, electricity and oil products. Although electricity demand is increasing during heatwaves, this is offset by lower energy demand needed during production processes.

However, during heatwaves and droughts energy production is constrained due to insufficient cooling and lower water level. Thus, electricity generation from hydro power and CHP must be compensated for by imports (as presumed in this scenario) or by electricity generation from gas-fired power plants if capacity is sufficient.

All sectors decelerate emissions due to limited economic growth and energy demand resulting in lower CO_2 emissions (-2.8% resp. 9.6 Mt CO_2, Figure 18).



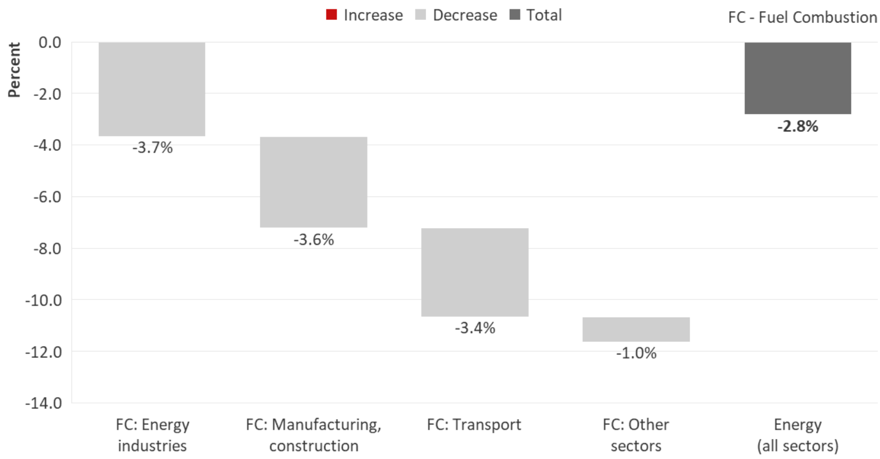


Figure 18: SSP8-8.5 scenario: CO_2 emissions, 2025- 2050, deviations from a hypothetical "No climate change" (REF) scenario in Mt CO_2 (top figure) and percent (bottom figure)

Source: Own illustration based on e3.kz results

4.3 Comparative presentation of results for SSP1-2.6, SSP2-4.5 and SSP5-8.5 scenario

The comparative representation of the three SSP scenarios and their economy-wide impact show differences driven by the frequencies and intensities of floods, droughts and heatwaves. As shown in Figure 12, droughts at all three intensity categories (low, medium and high) are expected to occur more or less with the same frequency and intensity. For heatwaves, the frequency differs slightly for medium and high intensity events. For low intensity events the differences are more obvious within the next decades but until 2050 they become more similar. For floods, the differences between SSP1-2.6 and SSP2-4.5 are somewhat different but interestingly, the frequency for medium and high intensity events is higher for SSP1-2.6 compared to SSP2-4.5. The frequency of low intensity events is expected to increase with less global climate protection ambitions.

As expected, the implications for the macroeconomy and the economic sectors are greatest for the SSP5-8.5 which show a continuously worsening impact on GDP until 2050 reaching -6.5% in real GDP compared to a hypothetical situation without climate change (Figure 19 bottom left). Agriculture, construction and private services are impacted the most mainly from negative impacts in agriculture and the labor productivity implications in many sectors, in particular in sectors with outdoor activities.

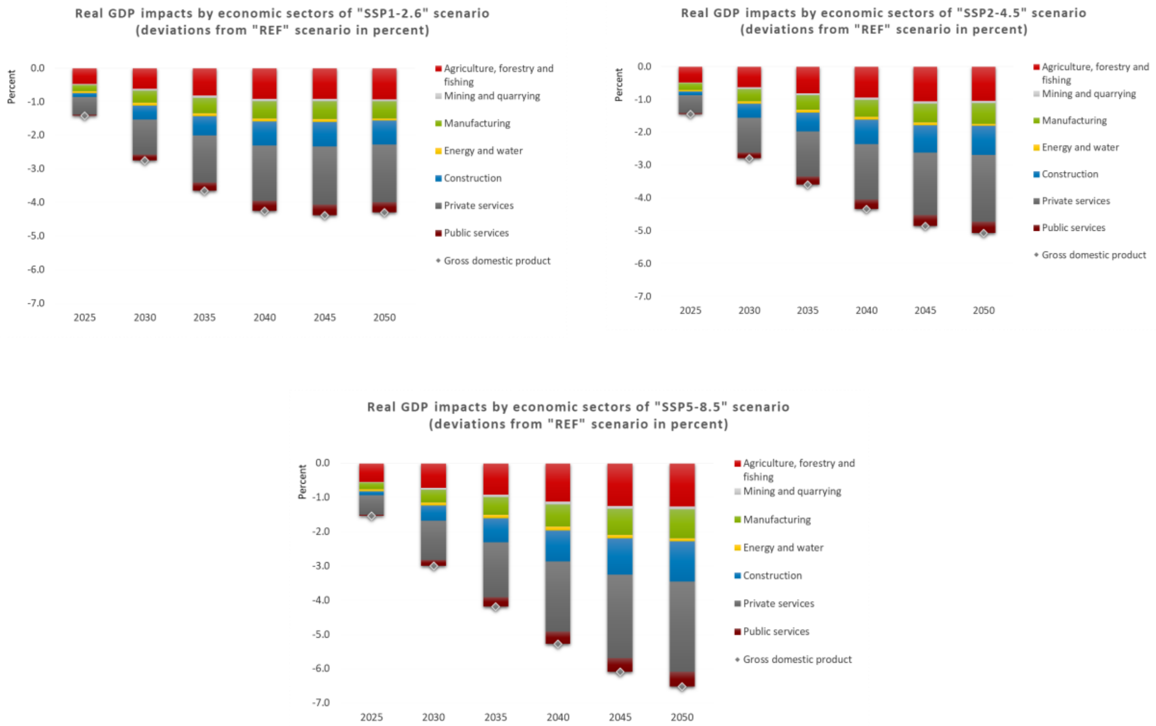


Figure 19: SSP1-2.6, SSP2-4.5 and SSP5-8.5 scenarios: Real GDP impacts by economic sectors, 2025-2050, deviations from a hypothetical "No climate change" (REF) scenario in percent

Source: Own illustration based on e3.kz results

To summarize, climate change impacts key economic sectors which endangers food and energy security. Exports are constrained and impaired production processes in Kazakhstan result in increased imports which increases the dependency from other countries. Apart from negative economic impacts, also people will suffer from heat stress, heat strokes and other heat-related illnesses and death. Thus, government should prevent recurring climate hazards to avoid renewed expenditures on damage control and to protect Kazakh people and the economy.

The lowest economic impact is expected for scenario SSP1-2.6, which assumes global climate protection activities and thus lower greenhouse gas concentrations in the atmosphere. It also shows decelerating economic activity which stabilize somewhat from 2040 onwards at -4.4% (Figure 19 upper left).

The macroeconomic results for the SSP2-4.5 scenario are between the two other SSP scenarios. Real GDP decelerates and reaches -5.1% by 2050 (Figure 19 upper right).

Regarding the GDP impacts, the results for SSP2-4.5 and SSP 5-8.5 are within the range of other studies analyzing the economic effects of climate change (Table 3). For SSP1-2.6, the GDP impacts are greater which is mainly driven by the fact, that the frequency of the climate hazards under consideration are broadly similar in 2050.

Table 3: GDP per capita losses in % in 2050

Source	SSP1-2.6	SSP2-4.5	SSP5-8.5
Kahn et al., 2019	-1.5%	-	-4.7% to -9.3%
Waidelich et al., 2024	-	-4.1% to -5.5.%	-7.3%
World Bank, 2022	-1%	-1.2%	-1.6%

Source: Kahn et al., 2019; Waidelich et al, 2024, World Bank, 2022

Figure 20 shows key results for all SSP scenarios in 2050 in comparison to the REF scenario. The stronger the effects on GDP and economic sectors, the greater the reactions for employment, total final energy demand and CO_2 emissions. From a gender perspective, climate change impacts male employment more than female employment.

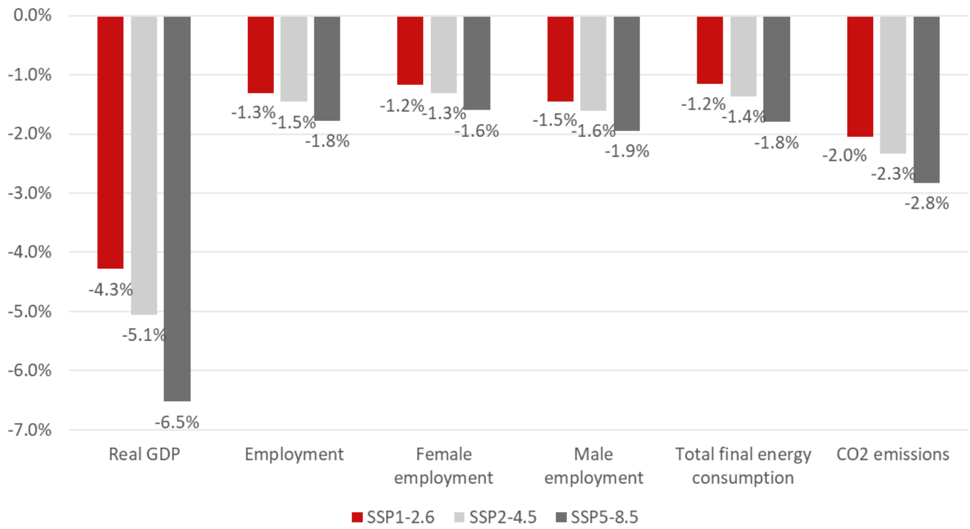


Figure 20: SSP1-2.6, SSP2-4.5 and SSP5-8.5 scenarios: Key impacts, year 2050, deviations from a hypothetical "No climate change" (REF) scenario in percent

Source: Own illustration based on e3.kz results

5 ECONOMICS OF ADAPTATION TO CLIMATE CHANGE

The explanations in the previous section have shown that Kazakhstan is highly vulnerable to climate change, in particular droughts, floods and heatwaves, which impacts the agriculture, energy and infrastructure sectors (e.g. buildings) the most.

It is important that Kazakhstan is well-prepared to reduce the impacts of climate change which will become even more frequent and intense in the future by taking appropriate adaptation measures. Various adaptation options exist (e.g., World Bank 2024b). Jointly with Kazakh experts and political partners, the most relevant were selected and, first, examined in great detail by conducting sector-specific costs-benefit analyses (CBA).

Subsequently, the results of the CBA were fed into the e3.kz model analyzing the economy-wide impacts of the adaptation option. The results of the macroeconomic analyses do not only show the direct impacts but also the indirect and (unwanted) feedback effects for the macroeconomy and various economic sectors. Thus, decision-makers can identify those measures that are highly effective and are expected to have positive effects on the economy, on employment and the environment (win-win-options).

The selected adaptation options for which the results are presented below are:

- Energy efficiency improvements of public and residential buildings
- Enhanced flood protection through the development of counter-regulatory reservoirs with application in agriculture
- Conservation agriculture
- Incentives for sustainable pasture management

5.1 Energy efficiency improvements of public and residential buildings

Kazakhstan is increasingly vulnerable to extreme temperatures – very low in winter season and very high in summer season – resulting in a growing demand for air conditioning systems and electricity in the cooling season, and high heat demand in the roughly six month long heating season (GIZ, 2025b; World Bank & ADB, 2021).

Due to ageing and energy-inefficient buildings, energy demand of Kazakhstan's building stock consumes 270 kWh / m^2 which is more than doubling European average of 100-120 kWh / m^2 (World Bank, 2022). Over 90% of public buildings fail to meet the required energy efficiency standards, and over half of residential buildings are inadequately insulated (BE, 2025c). This results in total final energy consumption of 14 Mtoe for the residential sector and of 6 Mtoe public and service sector as of 2023 (QAZSTAT, 2024).

Improving the energy efficiency of buildings helps to decrease heat stress and reduces the energy costs for heating and cooling buildings, and it ensures compliance with Kazakhstan's Law on Energy Savings and Energy Efficiency Improvements. Furthermore, energy efficiency improvements provide win-win solutions for mitigation and adaptation in the context of rising energy demand and respective supply constraints due to climate change.

Climate change mitigation aims at reducing CO2 emissions through increased energy efficiency and / or replacing fossil fuels by renewable energy in various sectors. If energy efficiency measures are taken in the building sector, they support climate change adaptation and mitigation action simultaneously. Labor productivity losses can be reduced during heat waves and health issues can be minimized during extreme temperatures. Furthermore, during periods of extreme cold and extreme heat, energy demand can be limited which also helps to better balance energy demand and supply. Water demanding power plants such as hydro power and thermal power plants which rely on (cooling) water, show a lower energy generation potential during extreme heat.

5.1.1 Scenario settings

The assumptions of this energy efficiency improvement in the buildings scenario "EE" are taken from the CBA conducted by AvantGarde (2025) who analyzed in greater detail the costs and benefits for public and residential buildings.

The results of the CBA – which are summarized in Table 4 – are implemented into the e3.kz model to analyze the economy-wide impacts of this adaptation measures which goes beyond the single sector analysis.

Table 4: Summary of the CBA results for energy efficiency (EE) improvements in the building sector based on climate scenario SSP1-2.6

Adaptation measures	Cumulated investment	Cumulated adaptation benefits (otherwise indicated)
Energy efficiency improvements in residential buildings	• Capital investments for renovation (2.6 Tn. KZT; government bears the costs by 50% of the investment)1 • Operational costs (70 Bn. KZT) 1	• Less heat consumption in winter (-7,069 ktoe) 1 • Less electricity consumption in summer by 2050 (-0.5%)2, 3, 4 • Fossil fuel savings provide export opportunities (1.4 Tn. KZT) 1 • Costs savings on healthcare (500 Bn. KZT) 1 • Less repair and replacement of machinery due to the upgrade (871 Bn. KZT) 1
Energy efficiency improvements in public buildings	• Capital investments for renovation (0.28 Tn. KZT; government fully bears the costs of the investment)1 • Operational costs (11 Bn. KZT) 1	• Less heat consumption in winter (-984 ktoe) 1 • Less electricity consumption in summer (-0.5%)2, 3, 4 • Fossil fuel savings provide export opportunities (35 Bn. KZT) • Costs savings on healthcare (30 Bn. KZT) 1 • Less repair and replacement of machinery due to the upgrade (210 Bn. KZT) 1 • Less labor productivity losses in public sector due to insulation (50%)

Source: [1] AdvantGarde (2025), [2]Zhaosong et al (2014), [3]GIZ (2025b), [4]Considering an assumed share of 1/3 of electricity consumption attributed to air conditioning.

The costs and benefits of this adaptation option have been calculated under the assumption of an SSP1-2.6 scenario which is the less severe scenario regarding GHG emission concentration and temperature increase. The assumptions regarding the benefits assuming the same investments (costs) must therefore be adjusted for the SSP2-4.5 and SSP5-8.5. As there is no or little evidence, the following assumptions on the benefit-adjustments were made (Table 5):

Table 5: Benefit adjustments under different climate scenarios

Adaptation benefit	SSP1-2.6 (basis for CBA)	SSP2-4.5	SSP5-8.5
Less heat consumption in winter	100%	101.5%	105%
Less electricity consumption in summer	100%	95%	82.6%
Fossil fuel savings provide export opportunities	100%	100%	100%
Costs savings on healthcare	100%	110%	120%
Less repair and replacement of machinery due to the upgrade	100%	100%	100%
Labor productivity in public sector	100%	95%	82.6%

Source: Own assumptions

Under SSPs expecting an increase in temperature, heat savings are expected to be even higher compared to the SSP1-2.6. The heating degree days decline under the SSP2-4.5 and SSP5-8.5 by up to 1.5% resp. 4.9% compared to the SSP1-2.6 scenario for the period 2040-2059. In contrast, electricity savings from cooling will be lower as cooling degree days will increase by up to 5.1% resp. 17.4% for the period 2040-2059 (World Bank[8]). Depending on the fossil fuel savings, export opportunities arise.

Labor productivity is expected to follow the development of cooling degree days resulting in smaller benefits with increasing temperatures.

Healthcare expenditures are expected to be lower compared to SSP1-2.6 due to improved quality of life. Repair and replacement of machinery due to the upgrade will stay at the same level as it is related to the investments in energy efficiency improvements which will be the same as assumed for the CBA under SSP1-2.6 scenario.

The next section describes the results of this adaptation measure under SSP1-2.6 because this was the basic assumption for the CBA. Afterwards, the results are presented in a nutshell for SSP2-4.5 and SSP5-8.5.

5.1.2 Model results under SSP1-2.6

The macroeconomic effects of energy efficiency improvements in residential and public buildings are positive reaching up to 0.2% per year. Investments increase by up to 0.16% p.a. due to the refurbishment of public buildings and the overall higher economic activity. As residential buildings are almost fully owned by private households, private household consumption expenditures by purpose are reshuffled. Expenditures for thermal insulation activities increase during the implementation of the measure. After successful implementation private households profit by spending less for energy as well as repair and

[8] https://climateknowledgeportal.worldbank.org/country/kazakhstan/climate-data-projections (downloaded February 12th, 2025)

replacement of machinery due to the upgrade of the building. Overall, private household consumption expenditures are up to 0.25% resp. 88 Bn. KZT higher due to more jobs and income compared to a scenario with climate change (SSP1-2.6) and without adaptation (Figure 21). Assuming that the government's financial support for the adaptation measure comes at the expense of the government budget elsewhere, government consumption expenditure will be lower by a maximum of 0.8% resp. 60 Bn. KZT. However, government profits also from lower energy costs in public buildings, health cost savings and higher energy prices at the world market compared to lower domestic tariffs which compensate governments financial support for climate protection over time.

Export opportunities may arise for the freed-up energy – mainly coal and gas – which increases total exports by up to 0.1% resp. 16 Bn. KZT. Imports are slightly higher compared to a scenario with climate change (SSP1-2.6) and without adaptation by 2050 which results from economic growth and the import dependency.

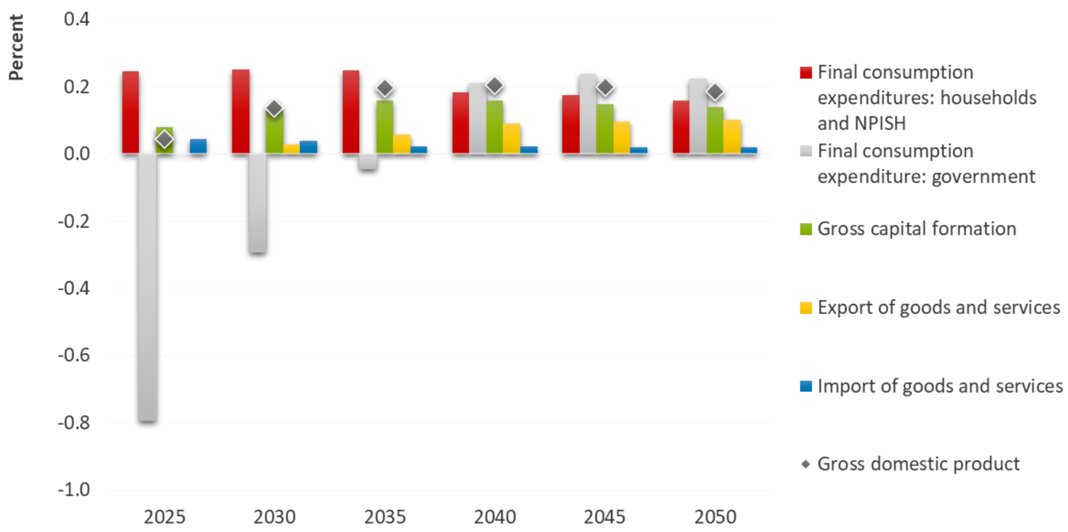


Figure 21: Macroeconomic effects of the "SSP1-2.6_EE" scenario , 2025-2050, deviations from a "SSP1-2.6" scenario in percent

Source: Own illustration based on e3.kz scenario results

The impacts on real production for the economic sectors are diverse (Figure 22): during the implementation period the construction sector and economic sectors along the supply chain (e.g. manufacturing of non-metallic minerals) benefit from the increased refurbishment activities. After successful implementation, the energy demand in the refurbished buildings as well as demand for machineries (part of "Manufacturing") and human health services decelerates which is intended by the measure. The latter gives financial scope for the government to increase spending for public administration and defense services; compulsory social security services. Furthermore, due to better insulation of public buildings, labor productivity in the public sector improves during heatwaves.

Additionally, expenditure on refurbishment activities by private households can increasingly be offset by lower energy expenditure, leaving also financial scope for additional non-essential activities (here accommodation and food service activities).

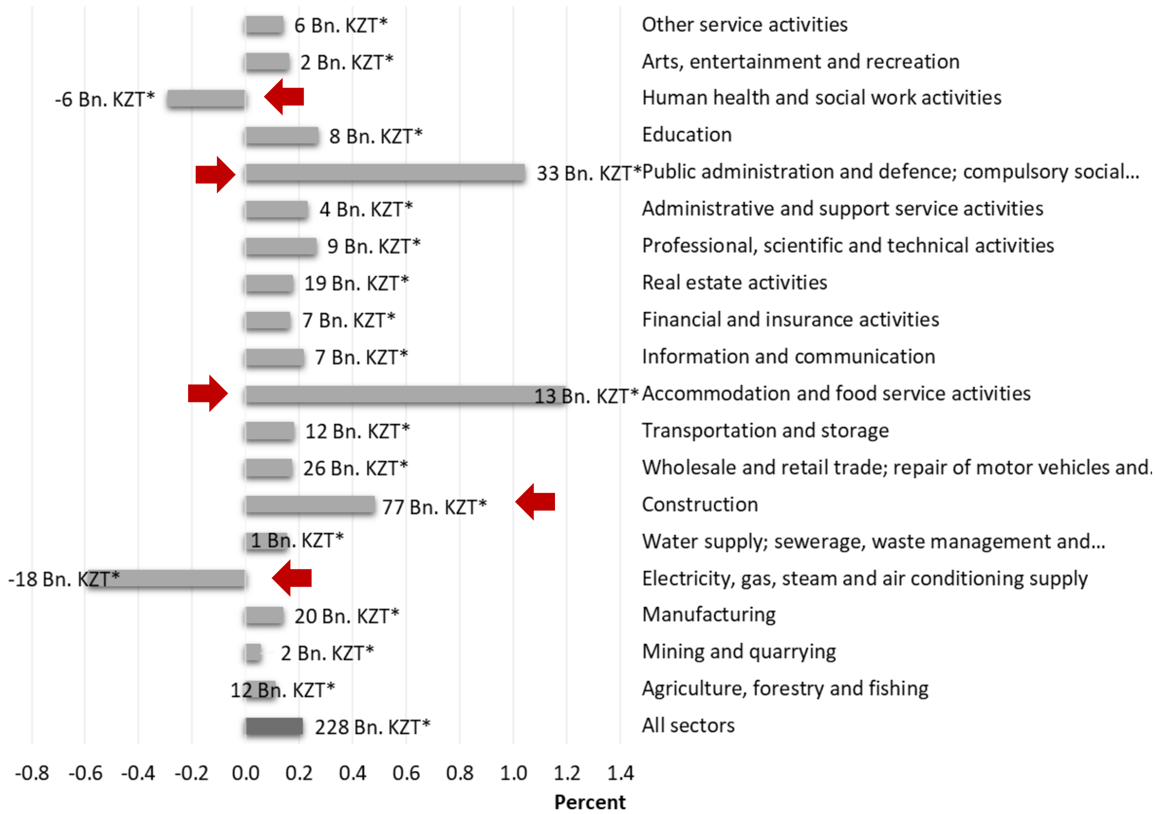


Figure 22: Effects of the "SSP1-2.6_EE" scenario on real production by economic sectors, 2050, deviations from the "SSP1-2.6" scenario in percent (x-axis) and respective bn. KZT (*)

Source: Own illustration based on e3.kz scenario results

Following the economic activity, employment accelerates resulting in up to 8,700 employed persons p.a. compared to a situation without adaptation and climate change under SSP1-2.6 (Figure 23). Persons employed in construction benefit the most, while jobs in public administration (part of "Public services") and private services decelerate in particular at the beginning of the simulation period. At that time, the financial support from the government is at the expense of public administration which leads to lower expenditure and thus decelerated activity and jobs. Similarly, private households shift their expenditures from non-essential activities such as accommodation and food services activities (part of "Private services") to those needed for refurbishment activities. These effects will be reversed by 2050. Persons working in accommodation and food service activities profit over time from the released money due to energy savings which is assumed to be spend for non-essential expenses.

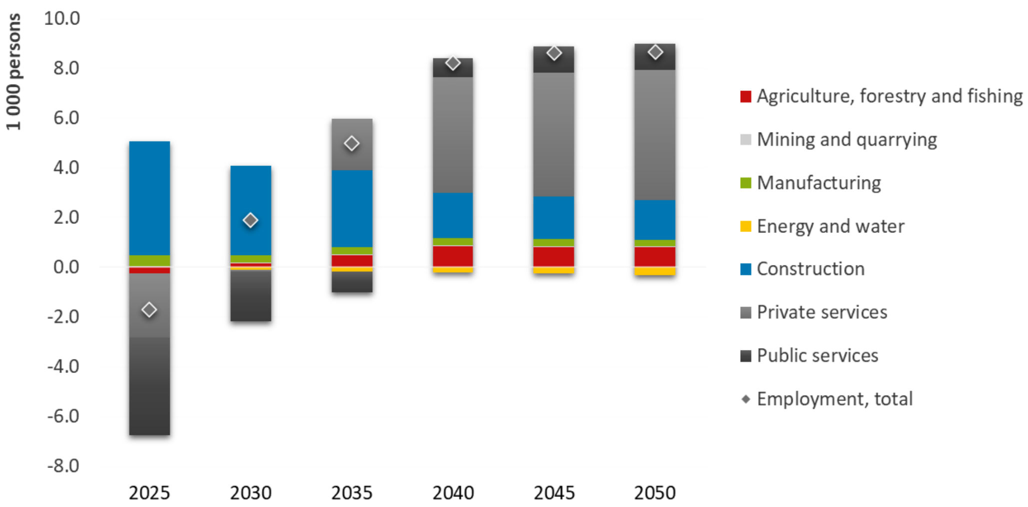


Figure 23: Effects of the "SSP1-2.6_EE" scenario on employment by economic sectors, 2025-2050, deviations from the "SSP1-2.6" scenario in 1,000 persons

Source: Own illustration based on e3.kz results

First, female employed persons are negatively affected as they are in particular employed in the service sector which shows a deceleration in the first decade but then recovers. Male persons are mainly employed in construction leading to positive effects for them over the whole simulation period (Figure 24).

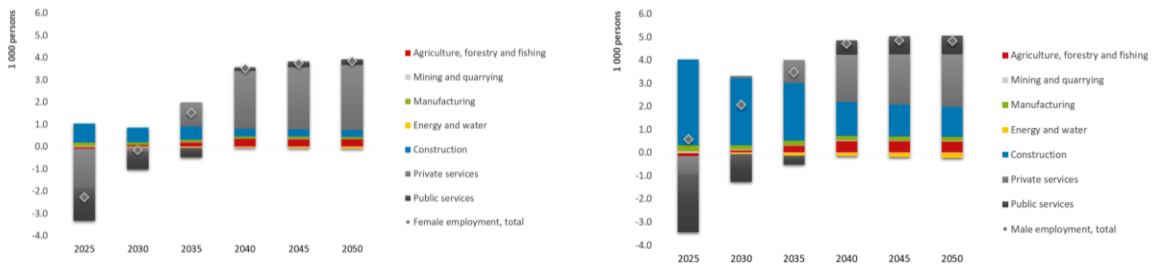
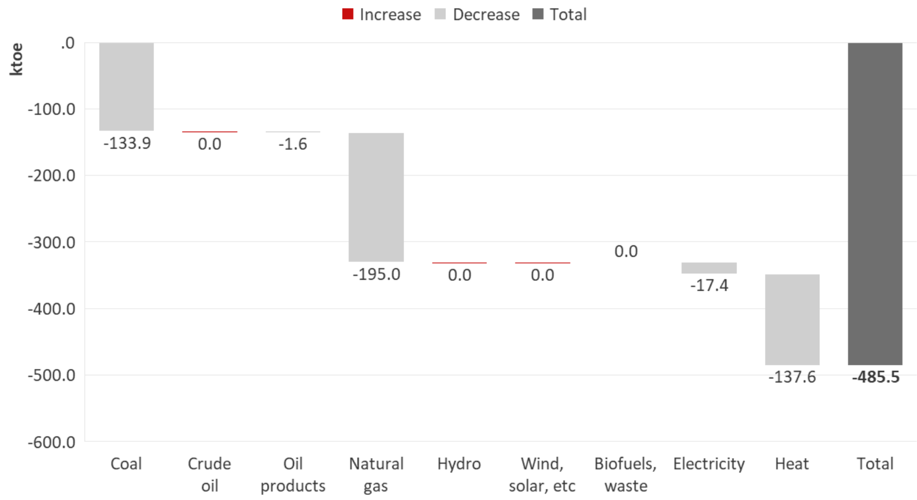


Figure 24: Effects of the "SSP1-2.6_EE" scenario on employment by gender and economic activity (female: left figure, male: right figure), 2025-2050, deviations from the "SSP1-2.6" scenario in 1,000 persons

Source: Own illustration based on e3.kz results

Energy efficiency improvements in the residential and public sector decelerate electricity consumption from air conditioning in particular during heat waves and also reduce heat demand in winter (-0.5% for commerce and public services and -1.4% for the residential sector). Other sectors such as construction and manufacturing show a slight increase in energy demand due to higher economic activity that impairs the reduction in residential and public sector. Total final energy consumption is up to 0.8% resp. 486 ktoe lower compared to a scenario with climate change (SSP1-2.6) and without adaptation. In particular, the demand for natural gas, coal and district heat can be reduced (Figure 25).



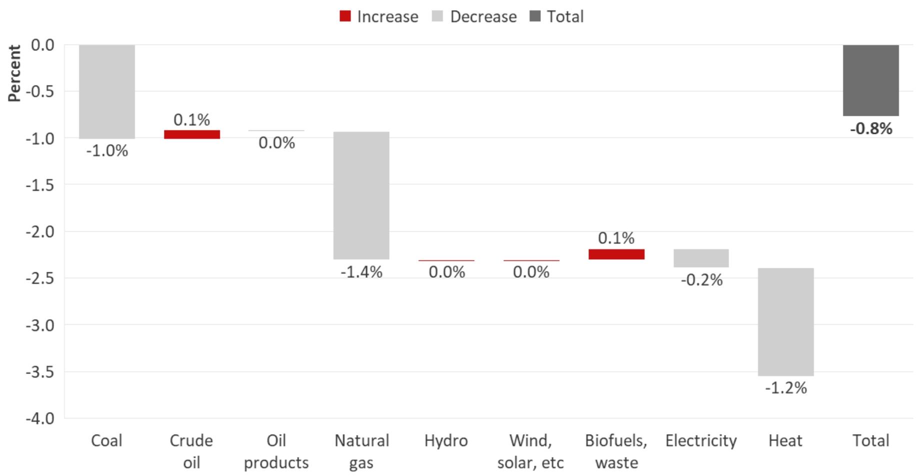


Figure 25: Effects of the "SSP1-2.6_EE" scenario on TFEC, 2050, deviations from the "SSP1-2.6" scenario in ktoe (top figure) and percent (bottom figure)

Source: Own illustration based on e3.kz results

The decelerated energy results in positive effects for CO_2 emissions which are decelerating as well and resulting in -0.6% resp. -1.9 Mt CO_2 contributing the overall emission reduction target. Other sectors including the residential sector contribute the most, followed by energy industries (Figure 26). As the demand for district heat and electricity is lower compared to a situation without adaptation, energy industries need less fossil fuels to generate heat and electricity. CO_2 emissions in the construction, manufacturing and transport sectors slightly increase following the economic activity. For those sectors, no climate protection measures are adopted.

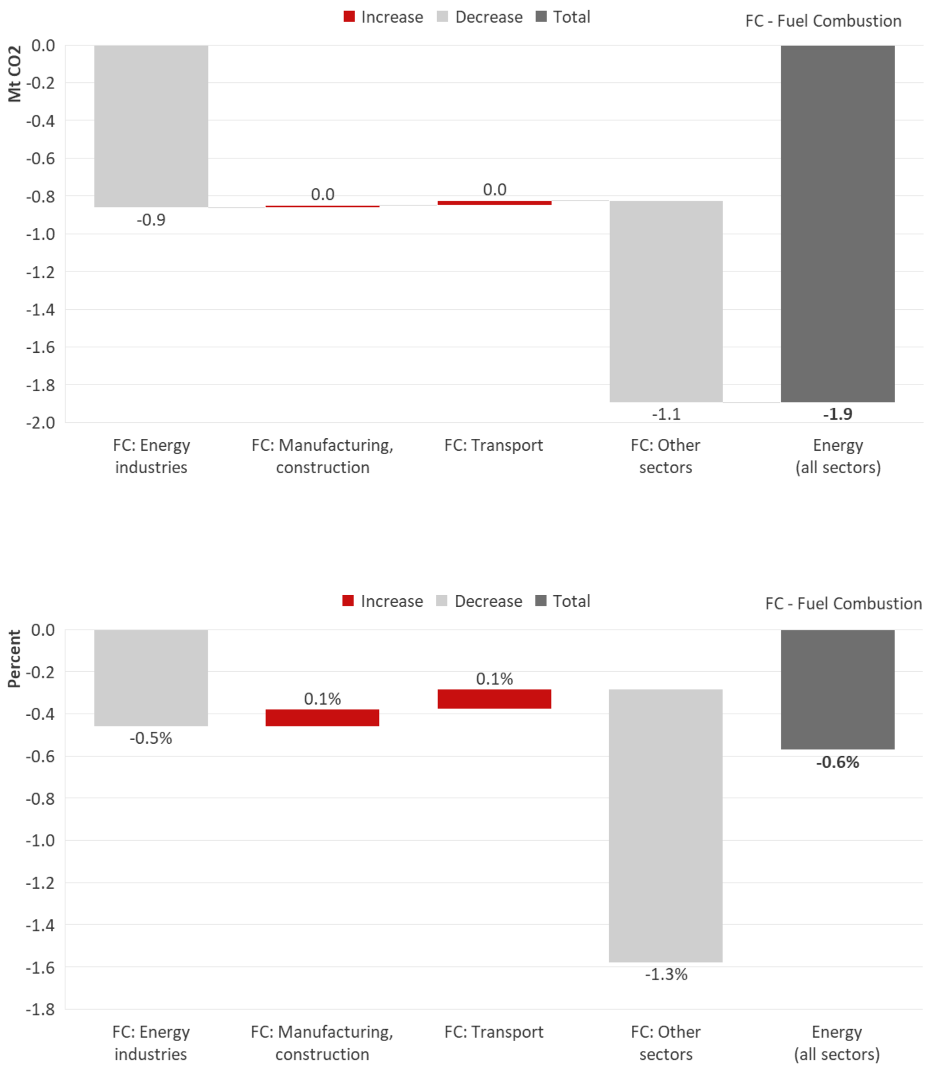


Figure 26: Effects of the "SSP1-2.6_EE" scenario on CO_2 emissions, 2030, deviations from the "SSP1-2.6" scenario in kt CO_2 (top figure) and percent (bottom figure)

Source: Own illustration based on e3.kz results

5.1.3 Model results overview for SSP1-2.6, SSP2-4.5 and SSP5-8.5

Depending on the climate scenario, the intensity and frequency of climate hazards differs and thus, the economic impacts (c.f. section 4). Similarly, an adaptation measure yields different benefits given an investment under different climate scenarios. Figure 27 summarizes the results for GDP by economic sectors for all SSP_EE scenarios.

The impact chains described in the previous section are the same. The main difference is that the specified benefits defined in the CBA under SSP1-2.6 are either greater or smaller depending on the benefit (c.f. Table 5). Due to opposing adjustments of benefits, the differences between the different SSPs are small.

Figure 27 shows key results for all SSP_EE scenarios in 2050 in comparison to the resp. SSP scenario. The socio-economic effects are very similar. Minor differences can be observed for total final energy consumption and CO_2 emissions. With increasing temperatures, more energy savings in winter can be expected. The effect from cooling related electricity demand in summer time is limited due to a cooling period of only three months and not many installed air-conditioning systems. However, the latter effects are hard to estimate as no reliable data is available (AvantGarde, 2025).

To summarize, investing in energy efficiency improvement of buildings is beneficial for the economy and the environment. The promotion of domestic activities, such as construction, creates jobs during the implementation period. Such a measure creates co-benefits for mitigation and adaptation: It helps to stabilize energy demand during extreme heat and extreme cold and thus supports energy security under climate change. Additionally, it contributes to Kazakhstan's Climate Pledges to reduce CO_2 emissions.

Upgrading the infrastructure is time-consuming and thus, only a certain share of buildings can be renovated per year (AvantGarde, 2025). On the one hand, this limits the positive effects per year but on the other hand, the positive effects are stretched over a longer period of time, especially in view of the insufficient number of qualified workers required to carry out the activities (Tengrinews, 2025).

Although refurbishment activities come at costs, these investments are likely to be "anyway" costs that Kazakhstan will have to spend on replacing outdated infrastructure. The economic impacts would be even better, if international donors would financially support the mitigation and adaptation ambitions of Kazakhstan. Considering carbon taxation could also create additional money for financing adaptation but the carbon tax scheme must take care of the financial burdens for the people and industry.

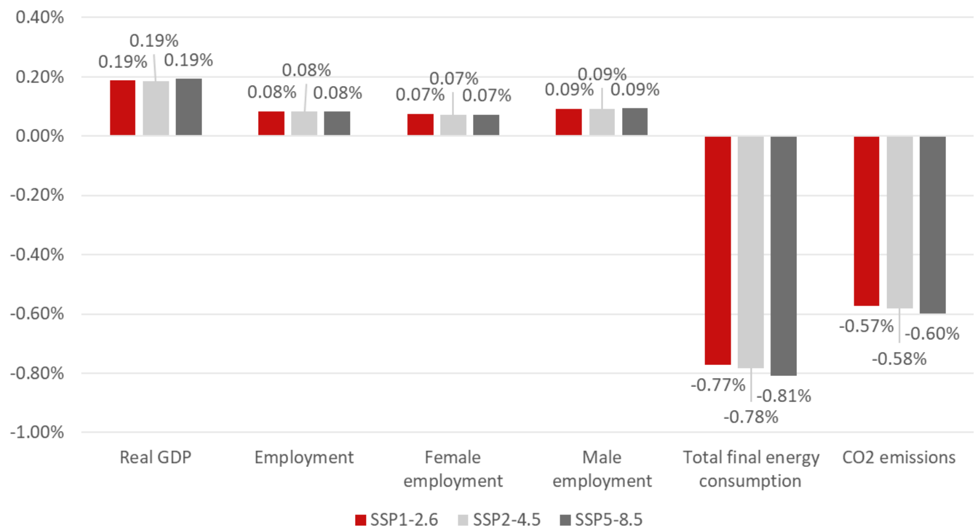


Figure 27: "SSP1-2.6_EE", "SSP2-4.5_EE" and "SSP5-8.5_EE" scenarios: Key impacts, year 2050, deviations to the respective SSP scenario in percent

Source: Own illustration based on e3.kz results

5.2 Enhanced flood protection through the development of counter-regulatory reservoirs with application in agriculture

Extreme precipitation and glacier melt are the major reasons for the intensified flooding in Kazakhstan which is the major risk for the people and the economy. Flooding is expected to become more frequent and more intense in particular under the most severe climate scenario SSP5-8.5. Many sectors are affected: Soil erosion and land degradation affect the productivity in agriculture and livestock drown in flooded areas. Floods also damage infrastructure such as buildings, bridges, roads and physical infrastructure relevant for energy generation and transmission. The disruption of energy supply may trigger economic losses in other sectors due to power outages.

Various options to prevent from flooding exist such as investments into protective infrastructure e.g. dams, water reservoirs and drainage structures. In the following scenario, multi-purpose water infrastructure, such as reservoirs, are under consideration. On the one hand, they reduce the risk of being flooded by collecting excess water. On the other hand, multi-purpose water reservoirs can be beneficial for agriculture by increasing water availability for irrigation during droughts and for additional cultivable land.

This adaptation option was selected for further analysis, as the Kazakh government and the Islamic Development Bank, for example, have planned such "grey" infrastructure solutions. However, nature based ("green") solutions should be considered as well, as they also provide ecological benefits. "Green" and "grey" infrastructure adaptation options should first be analyzed individually regarding their impacts on the ecosystem, including strategic environmental assessments. Subsequently, the can by analyzed in terms of the economy-wide impacts, for which quantified costs and benefits are essential.

A detailed analysis of the costs and benefits has been carried out by national experts with support from the Kazakh Economic Research Institute (ERI). Then, the results of the CBA (section 5.2.1) are implemented into the e3.kz model to evaluate nationwide socio-economic benefits (section 5.2.2).

5.2.1 Scenario settings

The results of the CBA – which are summarized in Table 6 – are implemented into the e3.kz model to analyze the economy-wide impacts of this adaptation measure which goes beyond a single sector analysis.

According to this CBA, it is planned to build up 42 new reservoirs. Additionally, investments in irrigation infrastructure are planned to increase the irrigated land. The total investments amount to additional 311 Bn. KZT. For operation and maintenance additional costs occur over the lifetime of the reservoirs and irrigation systems which amounts to a total of 46 Bn. KZT.

Given the promise of the Islamic Development Bank at COP29 to support climate resilient water resources development projects in Kazakhstan with 1.15 Bn. USD, it is presumed that CAPEX and OPEX are fully paid by international donors and do not cause a financial burden in Kazakhstan.

The benefits of this adaptation measure can be seen in avoided damages to infrastructure during flooding and the higher agricultural productivity due to additional irrigated land.

Table 6: Summary of the CBA results for "Counter-regulatory reservoirs with application in agriculture (CRR)" based on climate scenario SSP2-4.5

Adaptation measure	Cumulated investment	Cumulated adaptation benefits (otherwise indicated)
Construction of multi-purpose water reservoirs with application in agriculture	• Investment costs for building reservoirs and installing irrigation infrastructure (311 Bn. KZT) • Operational costs for building reservoirs (46 Bn. KZT)	• Reduced damage from flooding (-50%) • Increased agricultural productivity due to better irrigation and more irrigated land (946 Bn. KZT)

Source: Calculations by AvantGarde and ERI.

The costs and benefits of this adaptation option have been calculated under the assumption of an SSP2-4.5 scenario which is the medium severe scenario regarding GHG emission concentration and temperature increase. The assumptions regarding the benefits assuming the same investments (costs) must therefore be adjusted for the SSP1-2.6 and SSP5-8.5. The CBA tool allows for adjusting the probability of floods under different SSP scenarios. The probability is taken as the average (2024-2050) from Earthyield Advisories. The resulting benefits – meaning the avoided damage from floods – are as follows (Table 7):

Table 7: Benefit adjustments under different climate scenarios

Adaptation benefit	SSP1-2.6	SSP2-4.5 (basis for CBA)	SSP5-8.5
Damage reduction from flooding	1,710 Bn. KZT	1,368 Bn. KZT	1,778 Bn. KZT
Higher agricultural output due to better irrigation and new irrigated cultivated land	100%	100%	100%

Source: Calculations by AvantGarde and ERI.

The higher agricultural output due to better irrigation and new irrigated cultivated land is a climate-independent benefit und thus is the same for all climate scenarios as for SSP2-4.5.

The next section describes the results of this adaptation measure under SSP2-4.5 because this was the basic assumption for the CBA. Afterwards, the results are presented in a nutshell for SSP1-2.6 and SSP5-8.5.

5.2.2 Model results under SSP2-4.5

The macroeconomic impacts of the "SSP2-4.5_CCR" scenario are positive. GDP accelerates and is up to 0.14% p.a. higher compared to a situation with climate change (SSP2-4.5) and without adaptation (Figure 28). The investments are up to 0.2% higher and a result of countervailing effects: While the investments in water reservoirs and irrigation infrastructure are beneficial for the investments, the avoided damages from floods to infrastructure reduce the involuntary investments to rebuild the infrastructure such as roads, buildings and bridges.

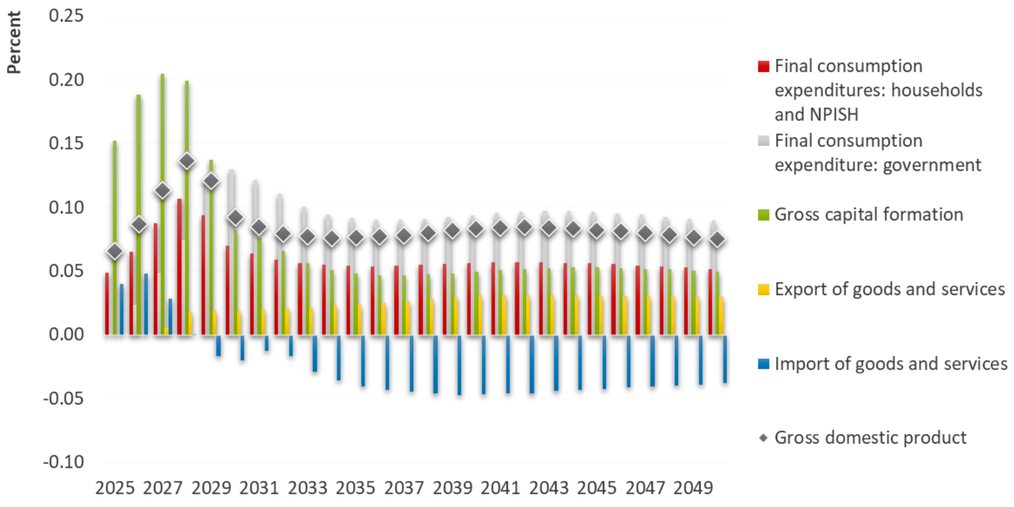


Figure 28: Macroeconomic effects of the "SSP2_4.5_CRR" scenario, 2025-2050, deviations from the "SSP2-4.5" scenario in percent

Source: Own illustration based on e3.kz scenario results

The positive impacts for agriculture, which profits from additional irrigated land and better irrigation, increase the export opportunities of agricultural goods, reduce the dependency from imported livestock and other agricultural products and thus, supports food security.

Although this proactive adaptation measure is initially associated with higher investment costs, the benefit is a permanent reduction in expenditure on repairing flood damage. Both the government and the people are beneficiaries in a sense that they can avoid involuntary and defensive spendings and spend the money for other purposes.

The government consumption expenditures are up to 0.13% p.a. higher than in a situation without adaptation and climate change. Household consumption expenditures increase by up to 0.1% which results from an increase in income and jobs.

The impacts on the economic sectors mirror the overall economic development, the shift in household and government consumption expenditures and the positive impacts on the agriculture sector: Overall, the impact in real production is positive (0.07%, Figure 29).

It is presumed that the government used the freed-up money for additional consumption expenditures in "Public administration, defense and compulsory social security services". Less involuntary spending by private households is assumed to increase non-essential spending for food services. Thus, real production in those sectors accelerates. For construction the economic activity changes over time: At the beginning, the impact from building reservoirs is positive but is overcompensated until 2050 due to avoided reconstruction activities.

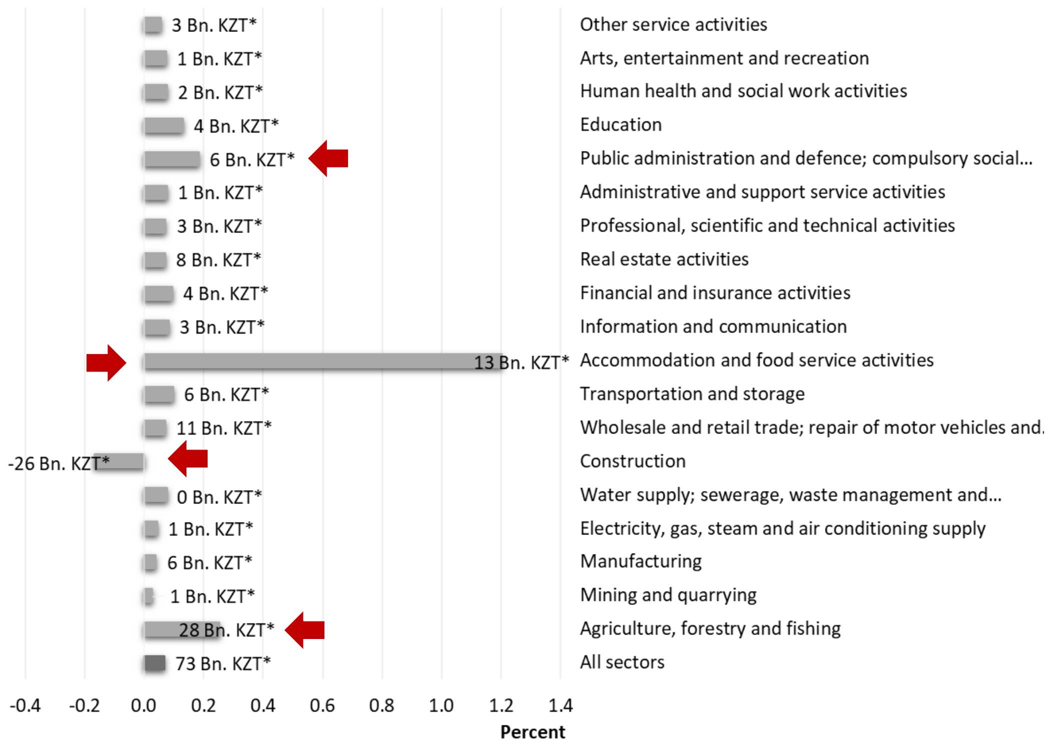


Figure 29: Effects of the "SSP2-4.5_CRR" scenario on real production by economic sectors, in 2050, deviations from the "SSP2-4.5" scenario in percent (x-axis) and Bn. KZT (*)

Source: Own illustration based on e3.kz scenario results

The employment impacts result from the economic activity in the sectors and their labor intensity. In total, employment is up to 6.9 thousand persons resp. 0.1% higher than in the SSP2-4.5 scenario (Figure 30). During the construction period of reservoirs, the demand for workers in construction accelerates. Afterwards, the impacts from avoided reconstruction activities and the benefits in agriculture (up to 2.639 persons p.a.) are visible. Private services profit as well due to higher expenditures for food service activities (part of private services).

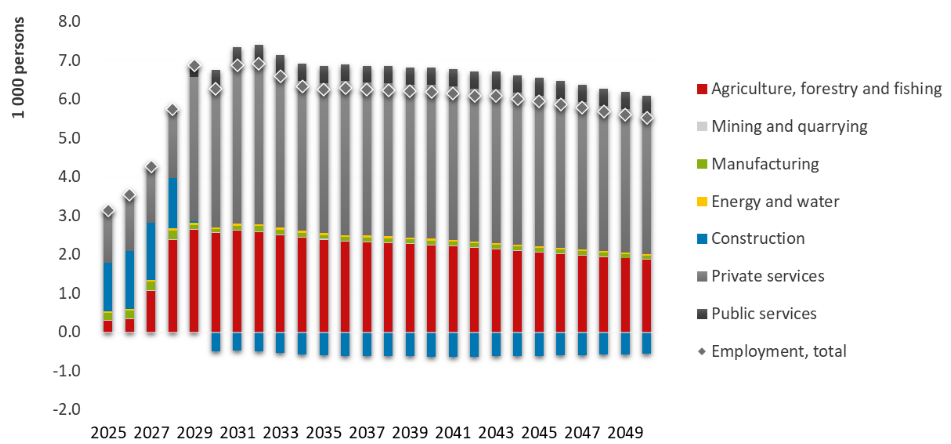


Figure 30: Effects of the "SSP2-4.5_CRR" scenario on employment by economic activity, 2025-2050, deviations from the "SSP2-4.5" scenario in 1,000 persons

Source: Own illustration based on e3.kz results

The employment figures are also positive from a gender perspective (Figure 31). Males and females benefit more or less equally from the job creation. Female employment profits mainly from the development in the food service activity sector (part of private sector), while males are mainly affected from higher construction activity at the beginning and also from agriculture over the whole period.

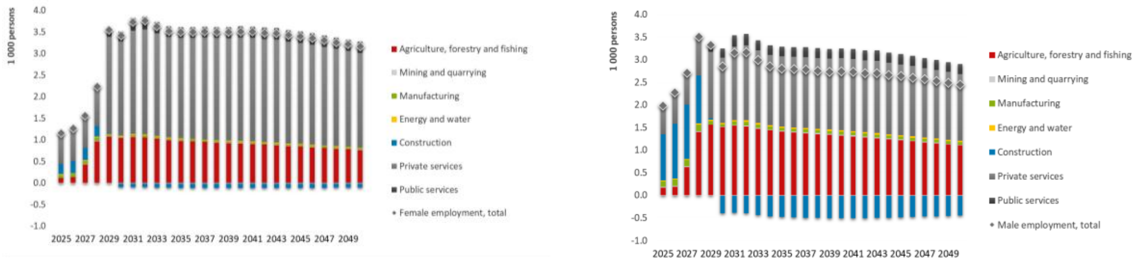


Figure 31: Effects of the "SSP2-4.5_CRR" scenario on employment by gender and economic activity (female: left figure, male: right figure), 2025-2050, deviations from the "SSP2-4.5" scenario in 1,000 persons

Source: Own illustration based on e3.kz results

The energy demand and CO_2 emissions follow the economic activity which increases only slightly during the implementation period of the adaptation measure and then slows down (Figure 32). Overall, both effects are small, as is the economic impact.

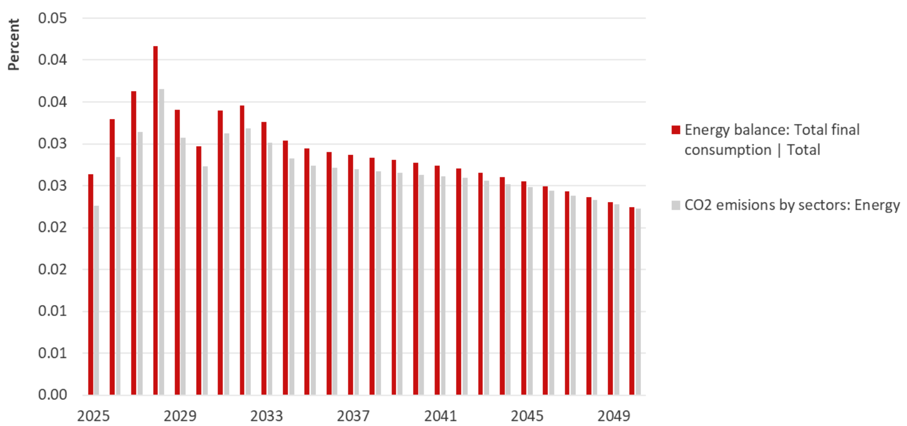


Figure 32: Effects of the "SSP2-4.5_CRR" scenario on TFEC and CO_2 emissions, 2025 - 2050, deviations from the "SSP2-4.5" scenario in percent

Source: Own illustration based on e3.kz results

5.2.3 Model results overview for SSP1-2.6, SSP2-4.5 and SSP5-8.5

Depending on the climate scenario, the intensity and frequency of climate hazards differs and thus, the economic impacts (c.f. section 4). Similarly, an adaptation measure yields different benefits given an investment under different climate scenarios. Figure 33 summarizes the results for GDP by economic sectors for all SSP_CRR scenarios which are broadly similar due to the assumptions made for the benefits (c.f. Table 7). Subsequently, the impacts for other key model variables are also not very different. From a gender perspective, female workers benefit slightly more from this adaptation measure than male workers. The impacts on energy consumption and CO_2 emissions are more or less on the level of the respective SSP scenario.

Overall, counter-regulatory reservoirs need no high investment but it is beneficial for the people and in particular agriculture. Additionally, involuntary (defensive) spendings can be avoided due to damage reduction. Taking into account the increasing scarcity of water in some regions and excess water in other regions, the collection of surplus water in reservoirs for later use, e.g. in agriculture, is a sensible investment.

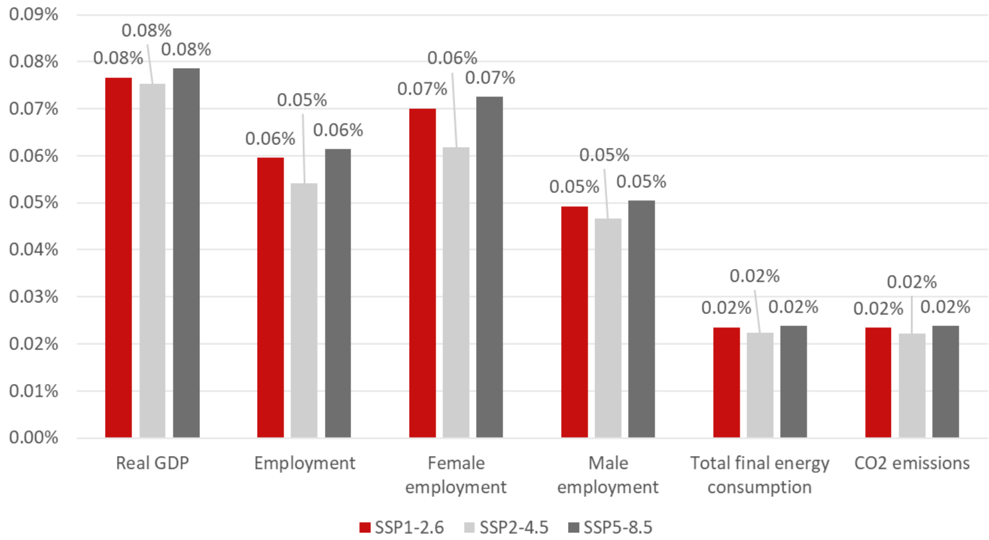


Figure 33: "SSP1-2.6_CRR", "SSP2-4.5_ CRR" and "SSP5-8.5_ CRR" scenarios: Key impacts, year 2050, deviations to the respective SSP scenario in percent

Source: Own illustration based on e3.kz results

5.3 Conservation agriculture

Kazakhstan's agricultural sector is substantially influenced by climate hazards such as drought and heatwaves. In particular seasonal crops such as cereals, rice, legumes etc. accounting for 57% of total agricultural output are highly vulnerable to climate change and should be protected by suitable adaptation measures (GIZ, 2025b).

Possible options include the use of water-saving technologies, leakage control, restoring of water infrastructure and cultivation of more water-efficient crops. Using moisture saving technologies (conservation agriculture, no-till farming) could help to conserve soil (UNDP, 2020; Broka et al., 2016, see Table 17). Each of these individual techniques can at least partially offset yield losses caused by climate change.

Conservation agriculture (CA) is already adopted in Kazakhstan (2.6 out of 21.3 Mn. ha) but there is still room for improvement (Polo et al., 2022). CA means minimal and no tillage, crop diversification and soil cover with crop residue. It requires investment in new machinery and equipment, knowledge, and training which comes at costs but is also beneficial (World Bank, 2024b).

5.3.1 Scenario settings

According to the World Bank (2024b), the following targets can be defined in using "water-conserving" technologies resp. CA technologies:

- Northern-Kazakhstan can expand its CA area by 25-50% within 5 years
- Eastern and western zones of Kazakhstan may reach 50% CA area after 5 to 7 years
- South-Eastern and Southern zones of Kazakhstan may reach 25-30% CA area within 5 years
- Thus, after five to seven years, additional 9.6 Mn. hectare are expected to adopt CA technologies. The estimated costs and benefits of CA technologies as shown in Table 8 are specified for a hypothetical farm with 10,000 ha. Considering the additional hectares on which CA technologies are applied, the resulting costs and benefits are implemented into the e3.kz model to quantify the economy-wide impacts. It is presumed that the adaptation measure is financed by the investing sector who passes the costs onto the consumers via higher prices for agricultural products.

Table 8: Assumptions for "Conservation agriculture (CA)" based on climate scenario SSP5-8.5

Costs (in USD per 10,000 ha)	Benefits (in USD per 10,000 ha)
• Investments in new machinery for CA practices (1.2 Mn. USD); replacement investment after approx. 10 years • Information campaigns for farmers on CA (0.05 Mn. USD) • Costs for additional crop residue distributed on the soil (0.1 Mn. USD) • Purchase of herbicides, including glyphosate (0.3 Mn. USD.)	• Increased agricultural yields (0.15 Mn. USD p.a.) • Elimination of fallow and additional crops (0.7 Mn. USD p.a.) • Reduction of field staff operating soil tillage and related equipment; saving on fuels (0.3 Mn. USD p.a.) • Sale of machinery for deep tillage (0.6 Mn. USD)

Source: World Bank 2024b, p.32.

The costs and benefits of this adaptation option are supposed to be calculated under the assumption of an SSP5-8.5 scenario which is the most severe scenario regarding GHG emission concentration and temperature increase. The assumptions regarding the benefits assuming the same investments (costs) must therefore be adjusted for the SSP1-2.6 and SSP2-4.5. The benefits are adjusted by reflecting the frequency of droughts under the three SSP scenarios. According to this, droughts are less frequent (-5% resp. -16%) in SSP2-4.5 resp. SSP1-2.6 compared to SSP5-8.5 which results in higher benefits (Table 9).

As there is no or little evidence, the following assumptions on the benefit-adjustments were made:

Table 9: Benefit adjustments under different climate scenarios

Adaptation benefit	SSP1-2.6	SSP2-4.5	SSP5-8.5 (basis for CBA)
Increased agricultural yields	116%	105%	100%

Source: Own assumptions

The next section describes the results of this adaptation measure under SSP5-8.5 because this was the basic assumption for the CBA. Afterwards, the results are presented in a nutshell for SSP1-2.6 and SSP2-4.5.

5.3.2 Model results under SSP5-8.5

Improving CA in Kazakhstan has positive impacts for the economy. GDP accelerates compared to a situation with climate change (SSP5-8.5) but with no adaptation by up to 0.45% p.a. (Figure 34). At the beginning, the positive effects of the investment in machinery predominate, while after the implementation period, the full benefits can be observed in agriculture.

The additional investments in CA practices are assumed to be paid by the agricultural sector. However, the financial burden can be limited because the measure itself provides cost reduction potential, for example, through less fuels, labor and the sale of the no longer used agricultural machinery.

The increased agricultural yields are expected to increase exports (up to 0.3% p.a.) and limit imports. An opposing impact on imports have the necessary investments in minimal and no-till machinery which is mainly imported. More general, the import-dependency of the various economic sectors determines the overall imports with increasing economic activity leading to higher imports of up to 0.3%.

Economic growth has positive impacts on income and expenditures of private households resulting in more consumption of private households (up to 0.36% p.a.). Also government expenditures and investments of companies increase accelerated economic activity.

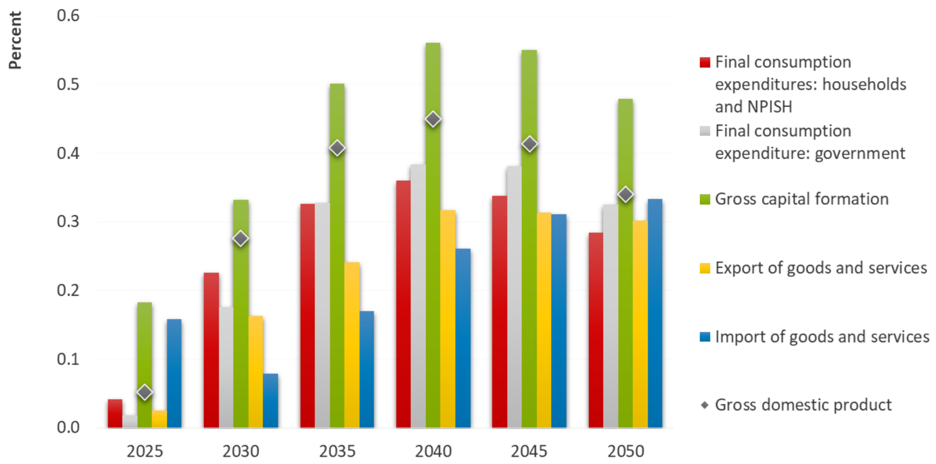


Figure 34: Macroeconomic effects of the "SSP5_8.5_CA" scenario, 2025-2050, deviations from the "SSP5_8.5" scenario in percent

Source: Own illustration based on e3.kz scenario results

The overall positive GDP impact can be observed for ~~the~~ real production as well (0.5% p.a. in 2050, Figure 35): In particular agriculture profits (1.7% p.a. in 2050). The need for training farmers in adopting CA practices is visible in "education" (0.5% in 2050) which is not only related to educating young people but also for further education of adults. The impacts in manufacturing are divers: for the subsector "manufacturing of machinery", the additional demand for minimal and no-till machinery is to a limited extent beneficial. The manufacturers of chemical products profit from the increased demand for herbicides. Contrary, CA practices are expected to reduce demand for fuels which impacts manufacturers of oil refining products negatively. Overall, for manufacturing the shift impact is positive (0.4% in 2050).

Apart from the economic sectors that are directly impacted from the measures, other sectors such as trade, transport and service sectors that are part of the value chains are influenced as well.

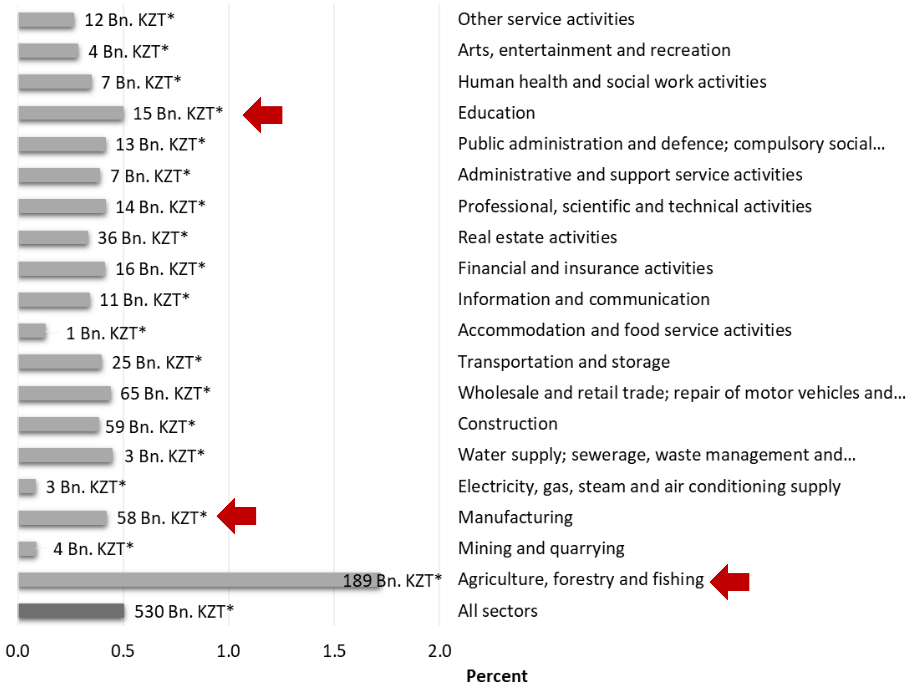


Figure 35: Effects of the "SSP5_8.5_CA" scenario on real production by economic sectors, in 2050, deviations from the " SSP5_8.5" scenario in percent (x-axis) and Bn. KZT (*)

Source: Own illustration based on e3.kz scenario results

Jobs are created during the implementation period to a limited extent and reach the maximum after the full benefits are exploited. Overall, up to 0.2% resp. additional 18 thousand people are employed (Figure 36). Agriculture benefits the most (8 thousand employed persons), followed by private services (7.4 thousand employed persons).

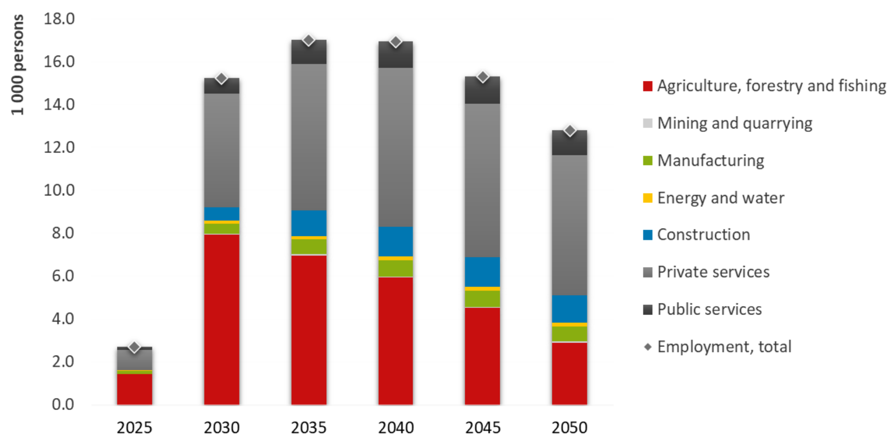


Figure 36: Employment effects of the " SSP5_8.5_CA" scenario, 2025-2050, deviations from the "SSP5_8.5" scenario in 1,000 persons

Source: Own illustration based on e3.kz results

Overall, male workers (up to 0.2% p.a. resp. 10 thousand) benefit more than female workers (0.17% p.a. resp. 8 thousand). In private services the allocation is more or less equal. In construction, agriculture and manufacturing the share of male workers is greater than for female workers.

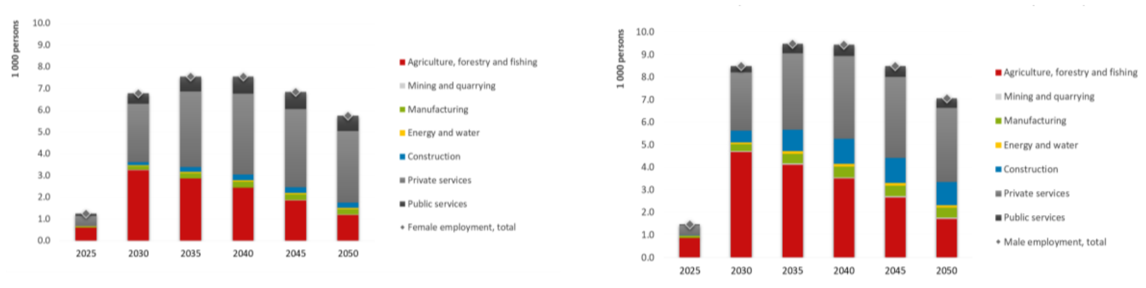


Figure 37: Employment effects of the "SSP5-8.5_CA" scenario: employment by gender and economic activity (female: left figure, male: right figure), 2025-2050, deviations from the "SSP5_8.5" scenario in 1,000 persons

Source: Own illustration based on e3.kz results

Economic growth increases energy demand and CO_2 emissions as long as no additional climate protection measures are considered. Thus, in the industrial and transport sector as well as commercial and public services energy demand increases between up to 0.25% and 0.37% p.a. (Figure 38). Due to the presumed fuel savings in agriculture, energy demand (mainly for oil products) is up to 10.8% resp. 138 ktoe lower than without this adaptation measure. Overall, energy demand is slightly decelerating.

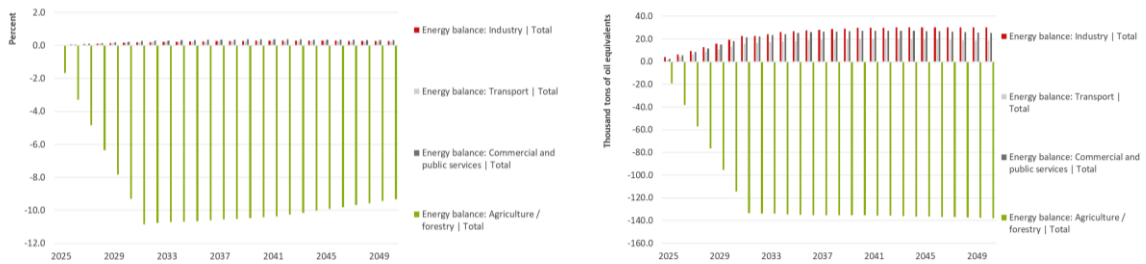


Figure 38: Effects of the "SSP5_8.5_CA" scenario on TFEC by sectors, 2025 - 2050, deviations from the "SSP5-8.5" scenario in ktoe (right figure) and percent (left figure)

Source: Own illustration based on e3.kz results

The CO_2 emissions follow the energy demand by sectors (Figure 39). All industries apart from agriculture – which is part of "other sectors" – and energy industries show at least a small increase in CO_2 emissions. Lower CO_2 emissions from energy industries result from the lower demand for oil products in agriculture which is not overcompensated by electricity, heat and oil product demand of other sectors.

Overall, CO_2 emissions are decelerating resulting in lower emissions of 0.4 Mt CO_2 emissions resp. 0.1% in 2050.

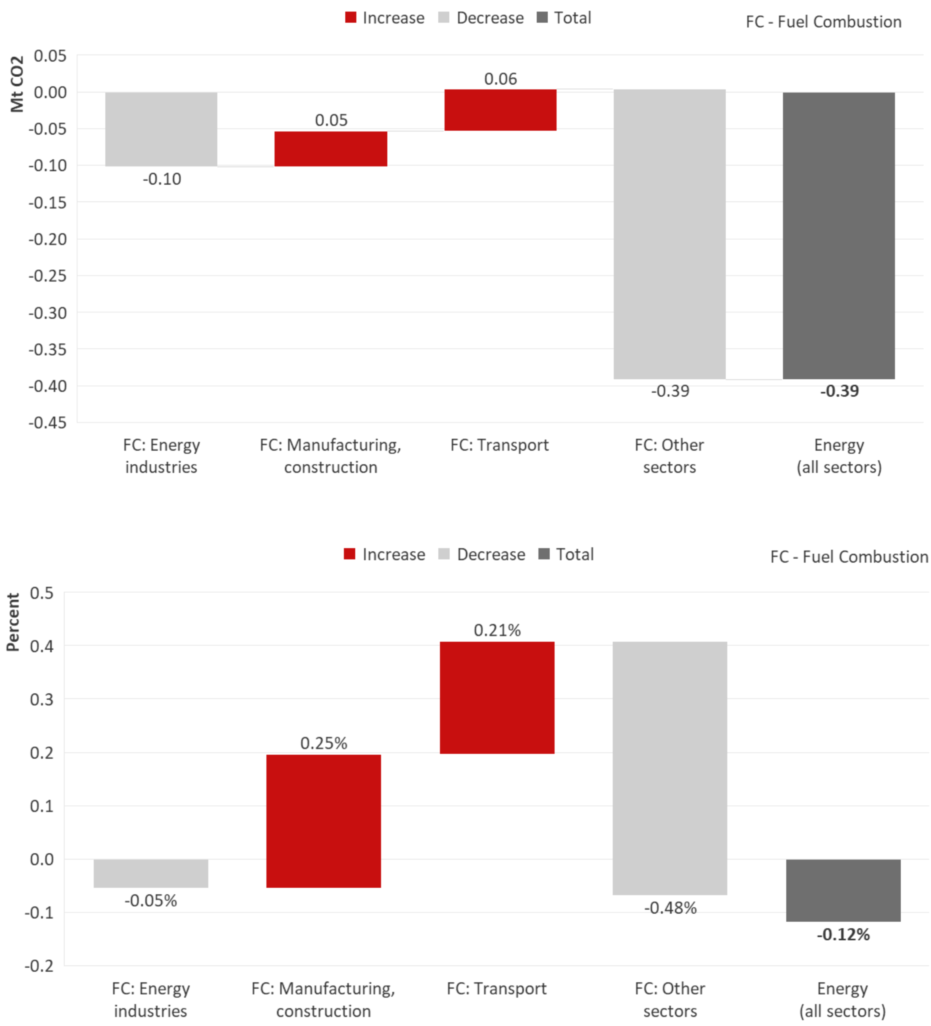


Figure 39: Effects of the "SSP5_8.5_CA" scenario on CO_2 emissions, 2025-2050, deviations from the "SSP5_8.5" scenario in kt CO_2 (top figure) and percent (bottom figure)

Source: Own illustration based on e3.kz results

5.3.3 Model results overview for SSP1-2.6, SSP2-4.5 and SSP5-8.5

The intensity and frequency of climate hazards and their resulting economic impacts differ with respect to the underlying climate scenario (c.f. chapter 4). The same holds true for the possible benefits of an adaptation measure. Figure 40 summarizes the results for real GDP by economic sectors for the all SSP_CA scenarios in comparison to the respective SSP scenarios.

The impact chains described in the previous section are the same. The main difference is that the benefit in agriculture as defined in the CBA under SSP5-8.5 is greater for the other SSP scenarios due to lower probability of occurrences for droughts and thus less negative impacts (c.f. Table 9). According to this, real GDP impacts are greatest for the SSP1-2.6_CA scenario (up to 0.55% in 2040), followed by the SSP2-4.5_CA scenario (up to 0.48% in 2040) and SSP5-8.5_CA scenario (up to 0.45% in 2040).

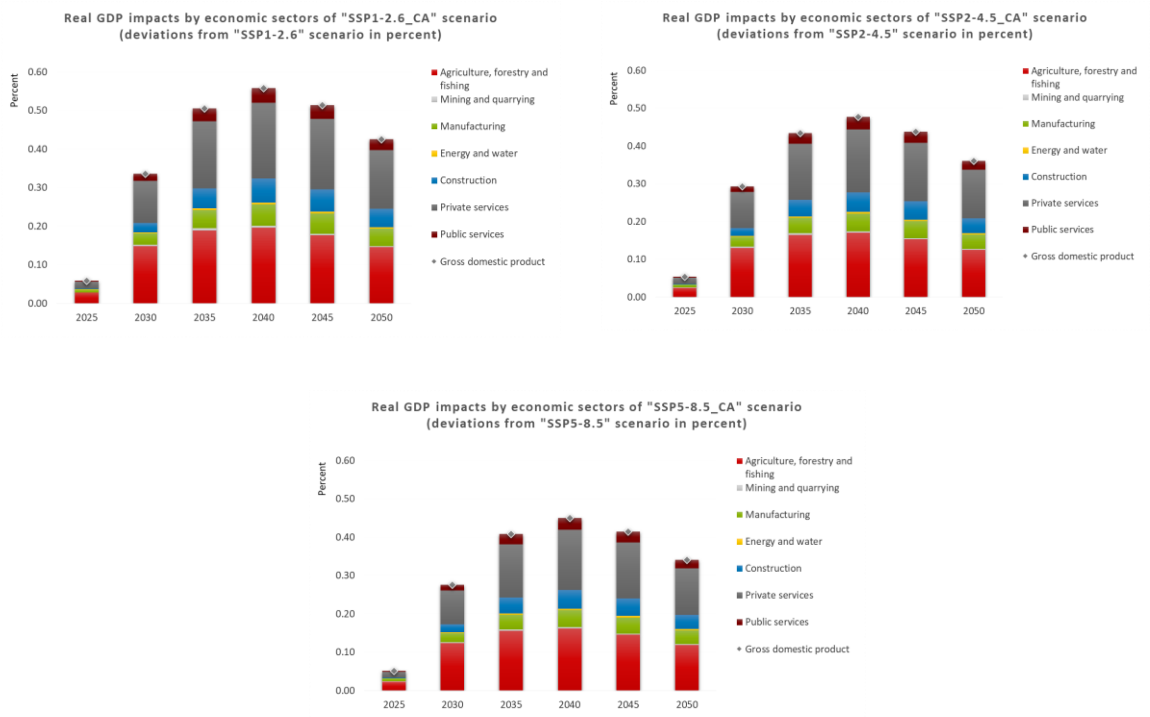


Figure 40: "SSP1-2.6_CA", "SSP2-4.5_CA" and "SSP5-8.5_CA" scenarios: Real GDP impacts by economic sectors, 2025-2050, deviations to the respective SSP scenario in percent*

Source: Own illustration based on e3.kz results
*Percentage deviation of sectoral gross output has been scaled to percentage deviation of GDP

Figure 41 shows key results for all SSP_CA scenarios in 2050 in comparison to the resp. SSP scenario. The stronger the effects on GDP and economic sectors, the greater the reactions for employment. From a gender perspective, male workers benefit slightly more from this adaptation measure than female workers. The impacts on energy consumption and CO_2 emissions are more or less on the level of the respective SSP scenario. The assumed savings on fuels for less soil tillage activities compensate the CO_2 emissions from higher economic activity.

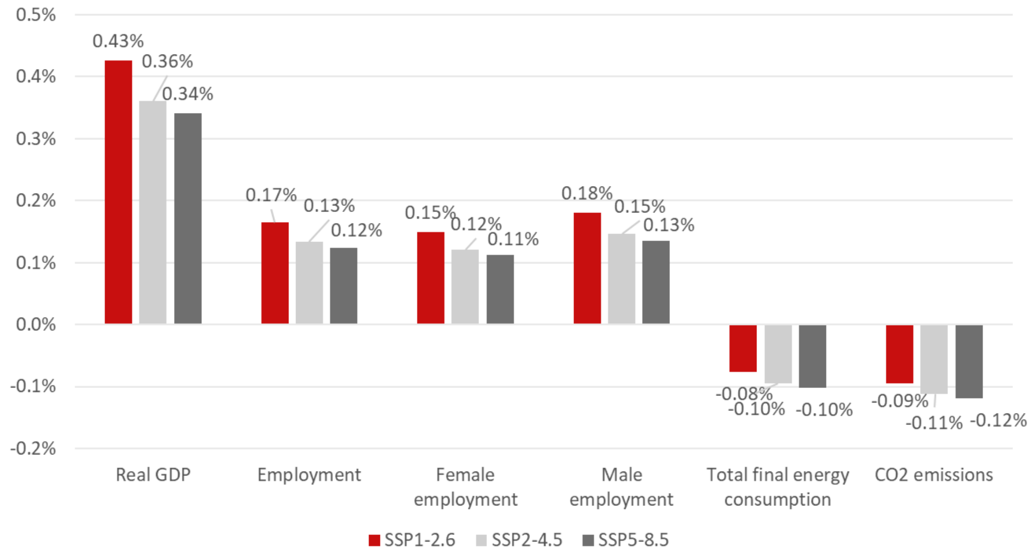


Figure 41: "SSP1-2.6_CA", "SSP2-4.5_CA" and "SSP5-8.5_CA" scenarios: Key impacts, year 2050, deviations to the respective SSP scenario in percent

Source: Own illustration based on e3.kz results

To summarize, CA technology has positive impacts on the economy and the environment. As intended, in particular agriculture profits in terms of higher production and jobs. In this regard, CA contributes to food security as the dependency from foreign countries decreases and export opportunities arise. The macroeconomic gains could be even higher if domestic production is promoted in particular in manufacturing.

The environmental impact of CA is also beneficial. Soil health and soil moisture is improved contributing to better agriculture conditions even under climate change. Additionally, the measure supports mitigation efforts by reducing CO_2 emissions in agriculture.

5.4 Incentives for sustainable pasture management

Increasing temperatures and lower water availability are pressing issues for pastures. Roughly 27 Mn. hectares resp. approx. 15% of total pastures are degraded by 2020 and will continue as long as no preventing measures are undertaken (World Bank, 2024b). Livestock productivity is expected to decline by 5 to 14% impacting food security (World Bank, 2024b; UNDP, 2020).

Various options exist to rehabilitate degraded pastures, for example integrated pasture management, pasture vegetation, rotational grazing, improved livestock breeds and health and investment in infrastructure rehabilitation (Polo et al, 2022).

This scenario sheds light on the economy-wide impacts of measures to improve degraded pastures in semi-arid and arid ecosystems with high livestock densities. This measure comprises, for example, to a limited extend soil tillage, the planting of varieties of perennial grasses, and crop protection measures (World Bank, 2024b).

5.4.1 Scenario settings

Roughly two to three million hectares out of 27 million hectares of degraded land are expected to be improved over the next five to ten years mainly in South-Eastern, Southern, Western and Desert zones where livestock density is the highest (World Bank, 2024b).

The estimated costs and benefits of sustainable pasture management (SPM) technologies as shown in Table 10 are specified for a farm with 10,000 ha. It is presumed that farmers have the necessary tillage and seeding machineries, thus, no capital investments are required. Considering the additional hectares on which SPM technologies are applied, the resulting costs and benefits are implemented into the e3.kz model to quantify the economy-wide impacts. It is presumed that the private sector can finance the necessary costs as the benefits are even higher.

Table 10: Assumptions for "Sustainable pasture management (SPM)" based on climate scenario SSP5-8.5

Costs (in USD per 10,000 ha)	Benefits (in USD per 10,000 ha)
• Fuel demand for tilling and seeding (52,000 USD) • Seeds (20,000 USD) • Fertilizer (20,000 USD) • Labor costs (49,200 USD) • Financially supported by the government	• Total value of hay harvested from new pastures over five years (5.4 Mn. USD)

Source: World Bank (2024b), p. 50

The costs and benefits of this adaptation option are supposed to be calculated under the assumption of the SSP5-8.5 scenario. The assumptions regarding the benefits assuming the same investments (costs) are adjusted for the SSP1-2.6 and SSP2-4.5 applying the same assumptions as for conservation agriculture (Table 11).

As there is no or little evidence, the following assumptions on the benefit-adjustments were made:

Table 11: Benefit adjustments under different climate scenarios

Adaptation benefit	SSP1-2.6	SSP2-4.5	SSP5-8.5 (basis for CBA)
Increased agricultural yields	116%	105%	100%

Source: Own assumptions

The next section describes the results of this adaptation measure under SSP5-8.5 because this was the basic assumption for the CBA. Afterwards, the results are presented in a nutshell for SSP1-2.6 and SSP2-4.5.

5.4.2 Model results under SSP5-8.5

With sustainable pasture management, real GDP is expected to increase by up to 0.3% resp. 195 Bn. KZT p.a. (Figure 42). Agricultural exports such as dairy and other livestock products will accelerate, and agricultural imports will decelerate. The benefits will increase over time and are expected to be fully utilized as soon as the measure is fully implemented.

With the expansion of the economic activity, more jobs and income, also investment (up to 0.26% p.a.) and household expenditure (up to 0.23% p.a.) will increase compared to a situation without adaptation and climate change (SSP5-8.5).

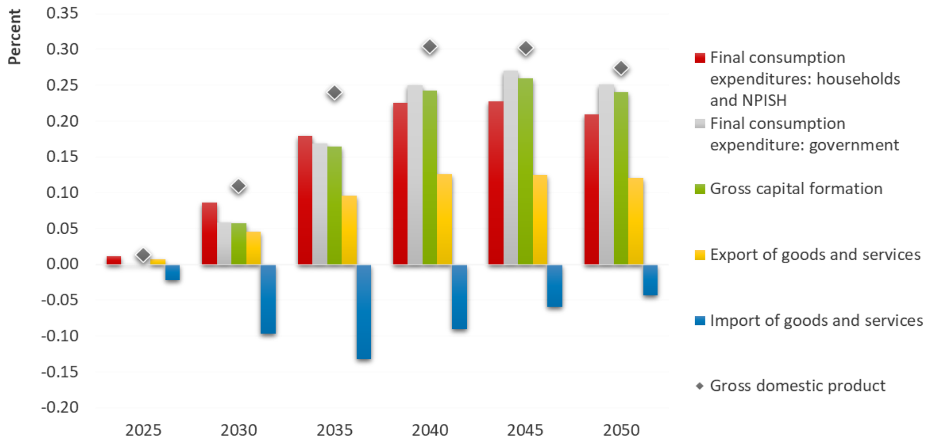


Figure 42: Macroeconomic effects of the "SSP5-8.5_SPM" scenario, 2022-2050, deviations from the " SSP5-8.5" scenario in percent

Source: Own illustration based on e3.kz scenario results

Livestock as part of the agriculture sector is expected to benefit the most through increased milk and meat production. Due to intersectoral linkages other sectors benefit as well. During the implementation period (until 2035), additional demand can be observed for the chemical industry (fertilizers), manufacturing (oil products) and agriculture (seed demand).

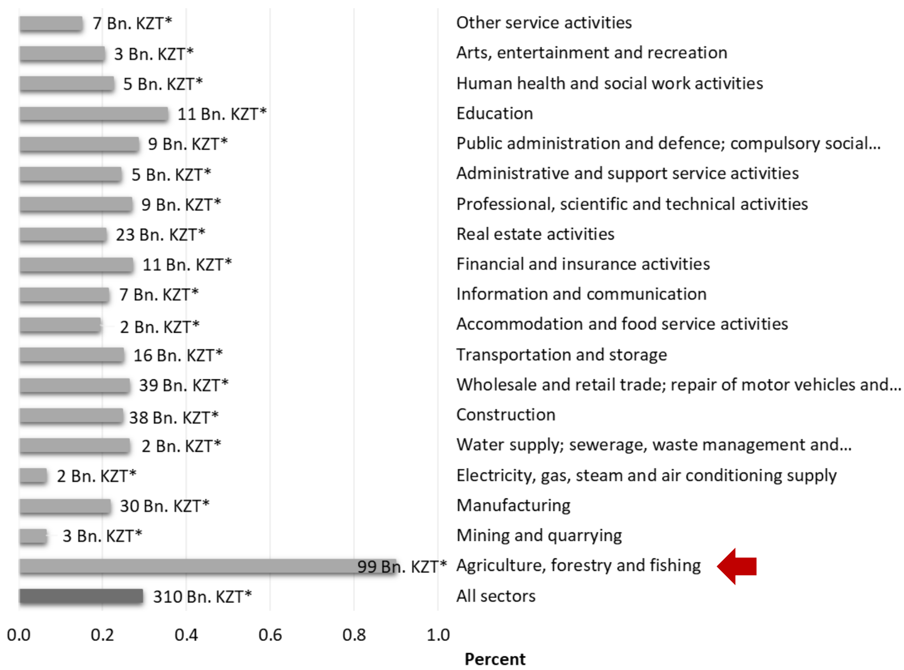


Figure 43: Effects of the "SSP5-8.5_SPM" scenario on real production by economic sectors, in 2050, deviations from the "SSP5-8.5 " scenario in Bn. KZT (x-axis) and percent (*)

Source: Own illustration based on e3.kz scenario results

According to the CBA labor demand in agriculture is increasing during the implementation period but also afterwards. Up to 8 thousand more persons are employed in agriculture compared to a situation without this measure and climate change. Depending on the sectoral economic activity and the respective labor intensities, additional jobs are also created in private service sectors and to a limited extent in public services and construction. In total, up to 15 thousand more people (+0.16%) are employed (Figure 44).

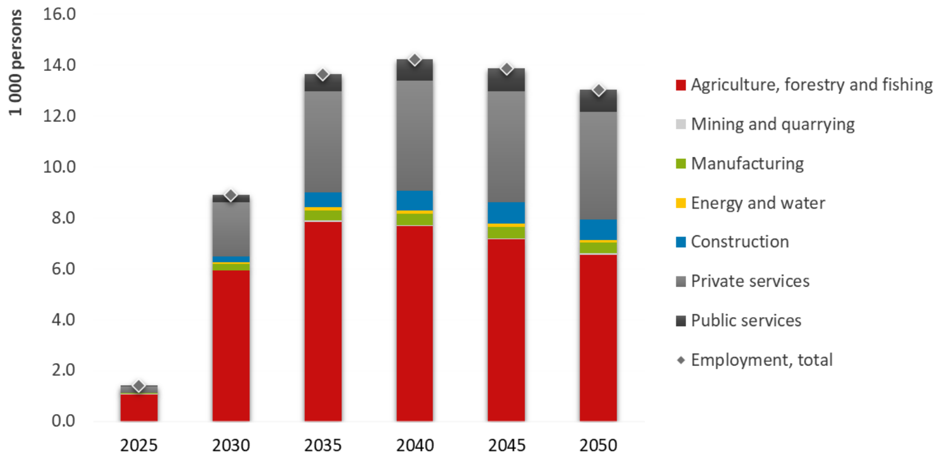


Figure 44: Employment effects of the " SSP5_8.5_SPM" scenario, 2025-2050, deviations from the "SSP5_8.5" scenario in 1,000 persons

Source: Own illustration based on e3.kz results

Most of the additional jobs are for male workers (0.18% resp. 8.5 thousand, Figure 45). Additional jobs for female workers amount to up to 0.14% resp. 6.5 thousand persons. For both genders, most jobs are created in agriculture, followed by private services.

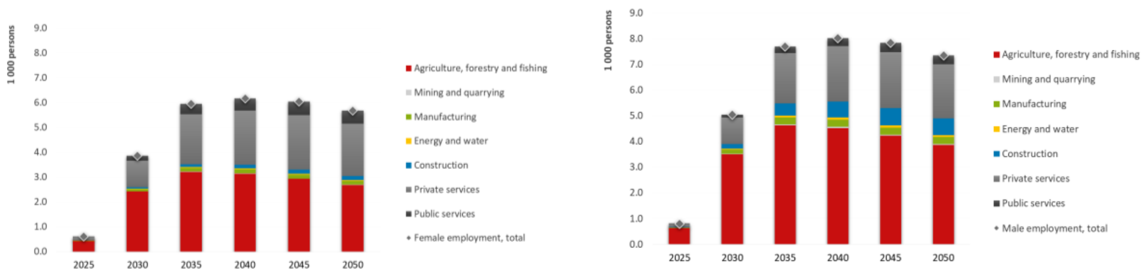


Figure 45: Employment effects of the "SSP5-8.5_SPM" scenario: employment by gender and economic activity (female: left figure, male: right figure), 2025-2050, deviations from the "SSP5_8.5" scenario in 1,000 persons

Source: Own illustration based on e3.kz results

As there are no additional mitigation measures – neither energy efficiency improvements nor renewable energy deployment – compared to the SSP5-8.5 scenario, energy demand follows the sectoral economic activity and energy intensities. Total final energy consumption increases by up to 0.15%. CO_2 emissions increase in line with the use of fossil fuels resulting in up to 0.14% compared to a situation without adaptation and climate change (Figure 46).

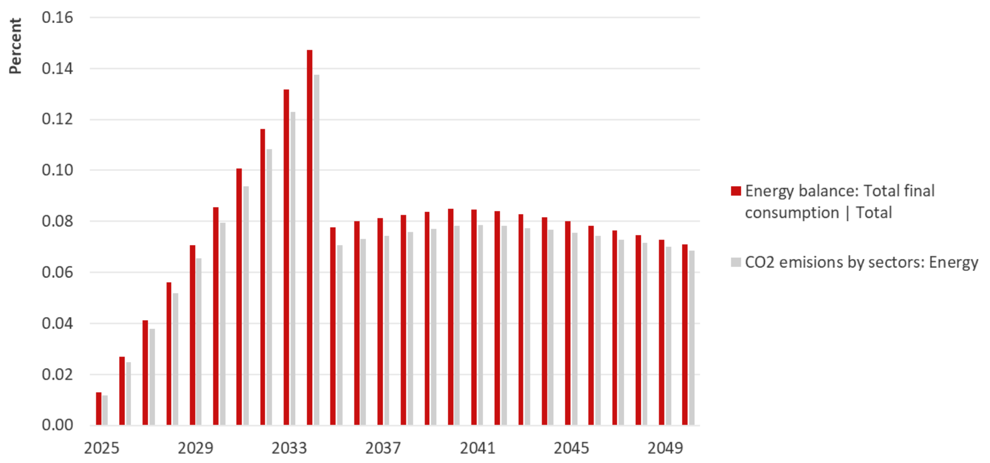


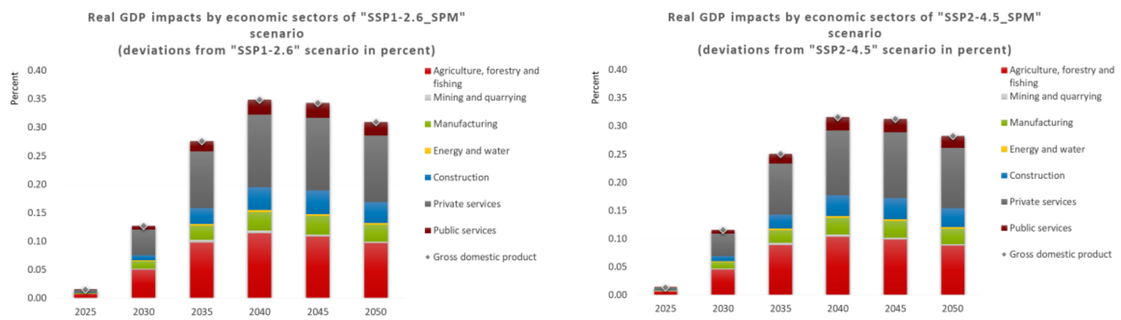
Figure 46: Effects of the "SSP5-8.5_SPM" scenario on TFEC and CO_2 emissions, 2025 - 2050, deviations from the "SSP5-8.5" scenario in percent

Source: Own illustration based on e3.kz results

5.4.3 Model results overview for SSP1-2.6, SSP2-4.5 and SSP5-8.5

The intensity and frequency of climate hazards and their resulting economic impacts differ with respect to the underlying climate scenario (c.f. chapter 4). The same holds true for the possible benefits of an adaptation measure. Figure 47 shows the GDP impact by economic sectors for all SSP_SPM scenarios.

The impact chains described in the previous section are the same. The main difference is that the specified benefit defined in the CBA under SSP5-8.5 is greater for the other SSP scenarios (c.f. Table 11). For SSP1-2.6 the benefits are highest resulting in increased GDP of up to 0.35%, followed by SSP2-4.5 with an increase of 0.32% and SSP5-8.5 with an increase up to 0.3%. The impacts of the economic sectors follow the macroeconomic development.



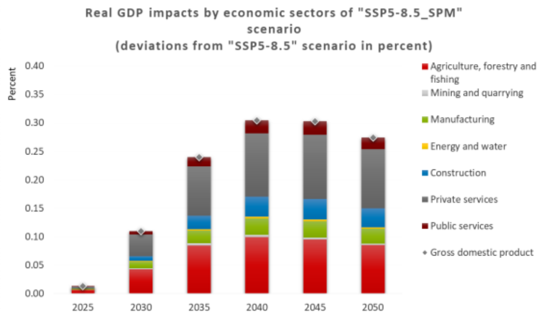


Figure 47: "SSP1-2.6_ SPM", "SSP2-4.5_SPM" and "SSP5-8.5_SPM" scenarios: Real GDP impacts by economic sectors, 2025-2050, deviations to the respective SSP scenario in percent*

Source: Own illustration based on e3.kz results
*Percentage deviation of sectoral gross output has been scaled to percentage deviation of GDP

Figure 48 shows key results for all SSP_SPM scenarios in 2050 in comparison to the resp. SSP scenarios. Due to small differences in benefits, the results do not differ much. However, it can be observed that higher GDP growth is more beneficial for employment but less positive for the environment.

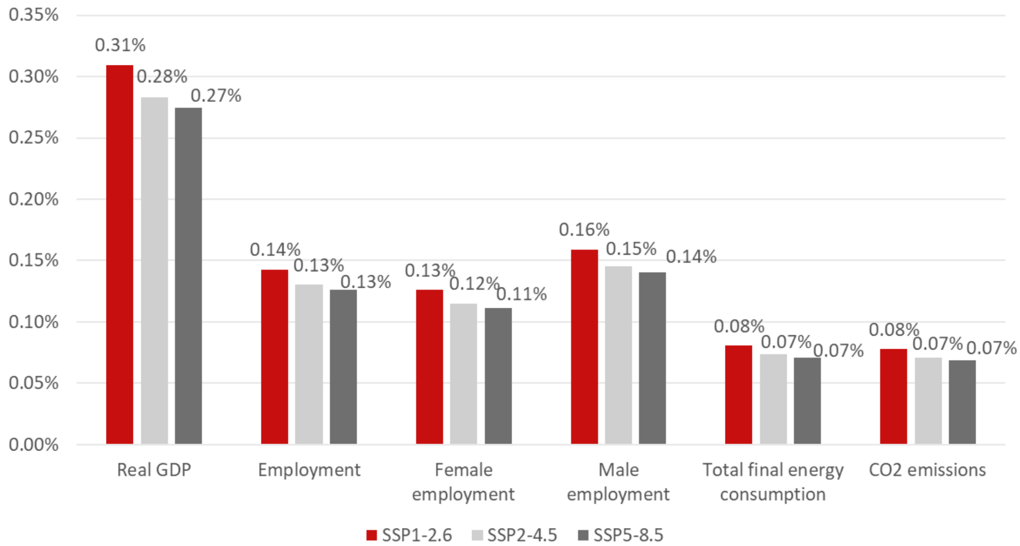


Figure 48: "SSP1-2.6_SPM", "SSP2-4.5_SPM" and "SSP5-8.5_SPM" scenarios: Key impacts, year 2050, deviations to the respective SSP scenario in percent

Source: Own illustration based on e3.kz results

To conclude, pasture management has positive impacts on the economy and the environment without high investment. That might be attractive for farmers with smaller financial resources. Following the World Bank (2024b), the benefits are higher than the costs. However, it takes time to improve degraded pastures which is a hurdle as farmers benefit from increased income later.

6 CONCLUSIONS AND OUTLOOK

Kazakhstan is very vulnerable to climate change and policy-makers should be aware of how climate change is impacting the economy, the people and the environment to formulate suitable adaptation strategies. The combination of comprehensive cost-benefit analyses and macroeconomic analyses with the model e3.kz supports the design of the National Adaptation Plan (NAP) by providing indicators, such as necessary investment, GDP, employment and CO_2 emissions, relevant for different line ministries. Not only financial and economic impacts are relevant for policy-makers to decide which adaptation measure is "most effective": To get a more comprehensive evaluation, other criteria must be considered as well, such as health aspects, ecosystem services (e.g., biodiversity), distributional effects, other GHG emissions as well as international / political implications.

The four adaptation options (EE, CRR, CA and SPM) analyzed in more detail show that they are not only beneficial when looking at costs and benefits of single adaptation projects but also from an economy-wide perspective as the results from applying the e3.kz model show:

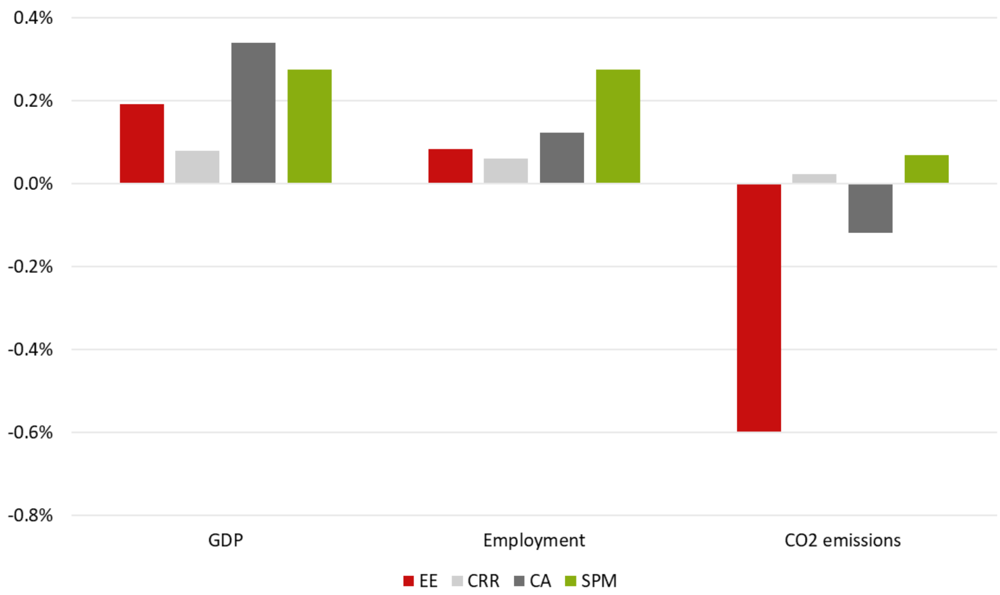


Figure 49: Key impacts of all adaptation scenario under SSP5-8.5, in 2050

Source: e3.kz model results

Depending on the specific adaptation measures, the magnitude of effects differs and in some cases also the direction of impact. The greater the required investment and / or the benefit for the target sector, the better the economic effect, in particular if the measure primarily supports domestic production and thus, creates jobs.

The results presented above assume that either the government, households or international donor pay for the adaptation measures. Financial support from international donors has even bigger economic impacts as there is no additional burden to Kazakh people and economy compared to the other financing options , as long as all other conditions are the same. As long as either the government or consumer pays for the additional investment, less money can be spent for other purposes. However, the savings in energy costs, for example, at least partially offset the overall financial burden. In addition, any damage avoided reduces the costs of damage control.

Figure 49 reveals the biggest GDP impacts for conservation agriculture (CA), sustainable pasture management (SPM) and energy efficiency (EE) in buildings. While investments are higher for EE, CA and SPM is beneficial for agriculture, a key sector in Kazakhstan. The most jobs are created when sectors with high labor intensity profit the most such as agriculture (CA and SPM) or service sectors. The latter are mostly effected from so-called income-induced effects meaning due to more jobs and income, more money is spent for food, other essential products and various services.

The environmental benefits are highest, if adaptation and mitigation measures are combined. Improving the energy efficiency– either in buildings (EE measure) or in agriculture (CA) – helps to reduce the energy demand and thus, CO_2 emissions. However, without a decoupling of economic growth and energy demand or the shift to renewable energy, CO_2 emissions will increase in the sectors affected. This negative side effect should be taken into account by policy-makers when designing adaptation strategies.

A single adaptation measure usually focusses on benefits for a single sector and climate hazard. While EE is focusing on energy security, the other adaptation analyzed options are concentrating on food security and water regulation. Thus, measures should be combined to combat climate change more broadly and to support the regions that are impacted from climate change differently.

Due to uncertainties regarding future developments of climate change as well as the current limited knowledge on adaptation costs and benefits, the results presented in this report are subject to several uncertainties. However, the results provide valuable insights in possible effects which help to prepare climate-sensitive development strategies for the long term.

7 References

Astana Times (2024). Kazakhstan Provides Financial support to 20,600 Flood-Affected Families. Astana Times. https://astanatimes.com/2024/05/kazakhstan-provides-financial-support-to-20600-flood-affected-families/ (last accessed March 3, 2025).

AvantGarde (2025). Interim report in the project "Policy Recommendations for Climate-Resilient Economic Development". Section: "Comprehensive analysis of efficiency through cost-benefit assessment (CBA) of improving energy efficiency of residential buildings in Kazakhstan". Astana.

Broka, S., Giertz, Å., Christensen, G., Rasmussen, D., Morgounov, A., Fileccia, T., Rubaiza, R. (2016). Kazakhstan – Agricultural sector risk assessment. World Bank Group Report Number 103076-KZ. February 2016. https://documents1.worldbank.org/curated/en/422491467991944802/pdf/103076-WP-KZ-P154004-Box394863B-PUBLIC-ASRA.pdf (last accessed March 3, 2025).

Caspian News. (2024). Kazakhstan reaffirms commitment to global climate goals at COP29. Caspian News. https://caspiannews.com/news-detail/kazakhstan-reaffirms-commitment-to-global-climate-goals-at-cop29-2024-11-12-14/ (last accessed March 3, 2025).

Deutsches Institut für Wirtschaftsforschung (DIW) Econ (2021). Kazakhstan: Towards Net Zero by 2060. Opportunities and challenges. Project: Long-term Low Greenhouse Gas Emission Development Strategy (LEDS) of Kazakhstan. Second draft. Implemented by GIZ on behalf of Federal Ministry for the Environment, Nature Conversation and Nuclear Safety, Germany.

Gesellschaft für Wirtschaftliche Strukturforschung (GWS) (2022). Modell PANTHA RHEI. https://gws-os.com/fileadmin/Redaktion/Files/Modelle/Energie-und-Klima/modell-panta-rhei-en.png (last accessed March 3, 2025).

Großmann, A., Hohmann, F. (2019). Static and Dynamic Input-Output Modelling with Microsoft Excel. SHAIO Conference Paper 2019, Osnabrück.

GIZ (2023). Economic Impacts of Climate Change Adaption. A Subnational View for Kazakhstan: Subnational Extension of e3.kz – a Simplified Approach [Großmann, A., Hohmann, F.]. Published by Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ), Berlin.

GIZ (2022). Supporting Climate Resilient Economic Development in Kazakhstan. Application of the e3.kz Model to Analyze the Economy-Wide Impacts of Climate Change Adaption [Großmann, A., Hohmann, F., Lutz, C., Reuschel, S.]. Published by Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ), Bonn and Eschborn. https://www.giz.de/en/downloads/giz2022-en-supporting-climate-resilient-economic-development-in-kazakhstan.pdf (last accessed March 3, 2025).

GIZ (2025a): Country concept note: Water-related hazards and adaptation measures in Kazakhstan - Data and literature analysis [Brundell, F., Lüttringhaus, S.] GIZ, Berlin.

GIZ (2025b): Strategies for a Climate-Resilient Economy: Kazakhstan Policy Handbook [Pavlenishvili, L., Salopiata, M.] GIZ, Berlin.

Hallegatte, S., Ranger, N., Mestre, O., Dumas, P., Corfee-Morlot, J., Herweijer, C., Muir Wood, R. (2011). Assessing climate change impacts, sea level rise and storm surge risk in port cities: a case study on Copenhagen. In: Climatic Change 104, no. 1: pp. 113–137.

Intergovernmental Panel on Climate Change (IPCC) (2012). Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation. A Special Report of Working Groups I and II of the Intergovernmental Panel on Climate Change [Field, C.B., V. Barros, T.F.

Stocker, D. Qin, D.J. Dokken, K.L. Ebi, M.D. Mastrandrea, K.J. Mach, G.-K. Plattner, S.K. Allen, M. Tignor, and P.M. Midgley (eds.)]. Cambridge University Press, Cambridge, UK, and New York, NY, USA, 582 pp. https://www.ipcc.ch/site/assets/uploads/2018/03/SREX_Full_Report-1.pdf (last accessed March 3, 2025).

Intergovernmental Panel on Climate Change (IPCC) (2014). Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part A: Global and Sectoral Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. Field, C. B., Barros, V. R., Dokken, D. J., Mach, K. J., Mastrandrea, M. D., Bilir, T. E., Chatterjee, M., Ebi, K. L., Estrada, Y. O., Genova, R. C., Girma, B., Kissel, E. S., Levy, A. N., MacCracken, S., Mastrandrea, P. R., White, L. L. (ed.). Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, 1132 pp. https://www.ipcc.ch/site/assets/uploads/2018/02/WGIIAR5-PartA_FINAL.pdf (last accessed March 3, 2025).

Kahn, M. E., Mohaddes, K., Ng, R. N. C., Pesaran, M. H., Raissi, M., Yang, J.-C. (2019). Long-Term Macroeconomic Effects of Climate Change: A Cross-Country Analysis. IMF Working Paper No. 2019/215. International Monetary Fund (IMF), Fiscal Affairs Department, Washington, DC.

Ministry of Ecology, Geology and Natural Resources of the Republic of Kazakhstan, United Nations Development Programme (UNDP) in Kazakhstan, Global Environmental Facility (GEF) (2022). Eighth National Communication and Fifth Biennial Report of the Republic of Kazakhstan to the UN Framework Convention on Climate Change. Astana. https://unfccc.int/documents/626607 (last accessed February 28, 2025)

Mirasgedis, S., Georgopoulou, E., Sarafidis, Y., Papagiannaki, K., Lalas, D. P. (2013). The Impact of Climate Change on the Pattern of Demand for Bottled Water and Non-Alcoholic Beverages. Business Strategy and the Environment, Volume 23, Issue 4. DOI: 10.1002/bse.1782. https://www.researchgate.net/publication/256667603_The_Impact_of_Climate_Change_on_the_Pattern_of_Demand_for_Bottled_Water_and_Non-Alcoholic_Beverages (last accessed March 3, 2025).

Organisation for Economic Co-operation and Development (OECD) (2018). Climate-resilient Infrastructure. OECD Environment policy paper No. 14. https://www.oecd.org/en/publications/climate-resilient-infrastructure_4fdf9eaf-en.html (last accessed March 3, 2025).

Polo, M. d. M., Santos, N., Syzdykov, Y. (2022). Adoption of climate technologies in the agrifood system: Investment opportunities in Kazakhstan. Food and Agriculture Organization of the United Nations (FAO), Rome. https://openknowledge.fao.org/server/api/core/bitstreams/af1bbd2d-0b6c-4021-82c6-70cd179d9b74/content (last accessed March 3, 2025).

QAZSTAT (2024). Fuel and energy balance of the Republic of Kazakhstan 2023. 5th series energy statistics. Agency for Strategic Planning and reforms of the Republic of Kazakhstan. Bureau of National statistics.

Schattenberg, M. (2023). Current water level of the Rhine brings back memories of the year 2022. Deutsche Bank Research. https://www.dbresearch.com/PROD/RPS_EN-PROD/PROD0000000000528728/Current_water_level_of_the_Rhine_brings_back_memor.xhtml?rwnode=RPS_EN-PROD$PROD0000000000435632 (last accessed February 28, 2025).

Tengrinews (2025). Workforce shortage: who will Kazakhstan need by 2031. Tengrinews.kz English. https://en.tengrinews.kz/kazakhstan_news/workforce-shortage-who-will-kazakhstan-need-by-2031-267033/ (last accessed March 3, 2025).

United Nations Economic and Social Commission for Asia and the Pacific (UNESCAP) (2021). Infrastructure Financing in Kazakhstan. A study commissioned by the United Nations Economic and Social Commission for Asia and the Pacific (UNESCAP).

United Nations Economic and Social Commission for Asia and the Pacific (UNESCAP) (2022). Kazakhstan – Climate Change and Disaster Risk Profile. UNESCAP, Information and Communications Technology and Development Section (ICT) and Disaster Risk Reduction Division, Bangkok. https://www.unescap.org/kp/2022/kazakhstan-climate-change-and-disaster-risk-profile (last accessed February 28, 2025).

United Nations Development Programme (UNDP) (2020). Summary analytical report on the assessment of economic losses in the agricultural sectors. UNDP project "Development of the Eighth National Communication of the Republic of Kazakhstan under the UNFCCC and preparation of two (fourth and fifth) biennial reports".

United Nations Framework Convention on Climate Change (UNFCCC) (1992). https://unfccc.int/files/essential_background/background_publications_htmlpdf/application/pdf/conveng.pdf (last accessed March 3, 2025).

United Nations Framework Convention on Climate Change (UNFCCC) (2013). Glossary of climate change acronyms. http://unfccc.int/essential_background/glossary/items/3666.php#A (last accessed October 4, 2021).

Van Vliet, M. T. H., Sheffiled, J., Wiberg, D., Wood, E. F. (2016). Impacts of recent drought and warm years on water resources and electricity supply worldwide. Environmental Research Letters 11. 124021. DOI: 10.1088/1748-9326/11/12/124021.

Waidelich, P., Batibeniz, F., Rising, J., Kikstra, J. S., Seneviratne, S, I. (2024). Climate damage projections beyond annual temperature. Nature Climate Change 14, 592-599. https://doi.org/10.1038/s41558-024-01990-8 .

Wolter, M. I., Bernardt, F., Daßler, J., Reuschel, S., Stöver, B. (2023). Klimafolgen und Anpassung – 2023: Aus den Arbeiten zur Basisprojektion des INFORGE-Modells, GWS Research Report, No. 2023/06. Published by Gesellschaft für Wirtschaftliche Strukturforschung (GWS), Osnabrück. https://papers.gws-os.com/gws-researchreport23-6.pdf (last accessed February 28, 2025).

World Bank (2011). Climate Impacts on Energy Systems. Key issues for energy sector adaptation. https://www.esmap.org/sites/esmap.org/files/E-Book_Climate%20Impacts%20on%20Energy%20Systems_BOOK_resized.pdf (last accessed March 3, 2025).

World Bank (2012). East-West Roads Project (Almaty-Korgos Section): Western Europe - Western China International Transit Corridor (CAREC - 1b) (P128050).

World Bank (2015). Kazakhstan: Nationwide assessment of climate-change related risks and formulation of mitigation strategy. Policy and Institutional Directions for Bolstering Climate Resilience in the Agriculture, Forestry and Energy Sectors. Joint Economic Research Program (JERP). https://openknowledge.worldbank.org/bitstream/handle/10986/22488/Kazakhstan000N0mitigation0strategy.pdf?sequence=1 (last accessed March 3, 2025).

World Bank (2018a). Kazakhstan: The Quest for a New Growth Model: The Urgency of Economic Transformation. Country Economic Update. Spring 2018. Washington, D.C.

World Bank (2018b). Green Economy: Realities & Prospects in Kazakhstan. August 2018. https://sk.kz/upload/iblock/8d9/8d97878e7ec2466e04ab62e5d8f4c3a3.pdf (last accessed March 3, 2025).

World Bank (2011). Climate Impacts on Energy Systems – Key Issues for Energy Sector Adaptation. Washington. https://www.esmap.org/sites/esmap.org/files/E-

Book_Climate%20Impacts%20on%20Energy%20Systems_BOOK_resized.pdf (last accessed October 4, 2021)

World Bank (2019). Enterprise Surveys. www.enterprisesurveys.org (last accessed March 3, 2025).

World Bank (2020a). South Caucasus and Central Asia Belt and Road Initiative – Kazakhstan Country Case Study. June 2020.

World Bank (2020b): Adaptation Principles: A Guide for Designing Strategies for Climate Change Adaptation and Resilience. World Bank, Washington, DC. https://openknowledge.worldbank.org/bitstream/handle/10986/34780/AdaptationPrinciples.pdf?sequence=1&isAllowed=y (last accessed November 21, 2021).

World Bank (2022). Kazakhstan. Country climate and development report. World Bank, Washington, DC. https://openknowledge.worldbank.org/server/api/core/bitstreams/e91f4c4e-a61b-507d-bb91-a39c5ad2f499/content (last accessed March 3, 2025)

World Bank (2024a). The Cost of Inaction: Quantifying the Impact of Climate Change on Health in Low- and Middle-Income Countries. World Bank, Washington, DC. https://openknowledge.worldbank.org/server/api/core/bitstreams/bc51aeec-288e-4cbc-b4ca-b5a942057044/content (last accessed March 3, 2025)

World Bank (2024b). Republic of Kazakhstan: Climate Adaptation Options and Opportunities in the Agriculture Sector. World Bank, Washington, DC. https://documents1.worldbank.org/curated/en/099060424004022607/pdf/P50211216a88d304191601df346d0b1713.pdf (last accessed March 3, 2025)

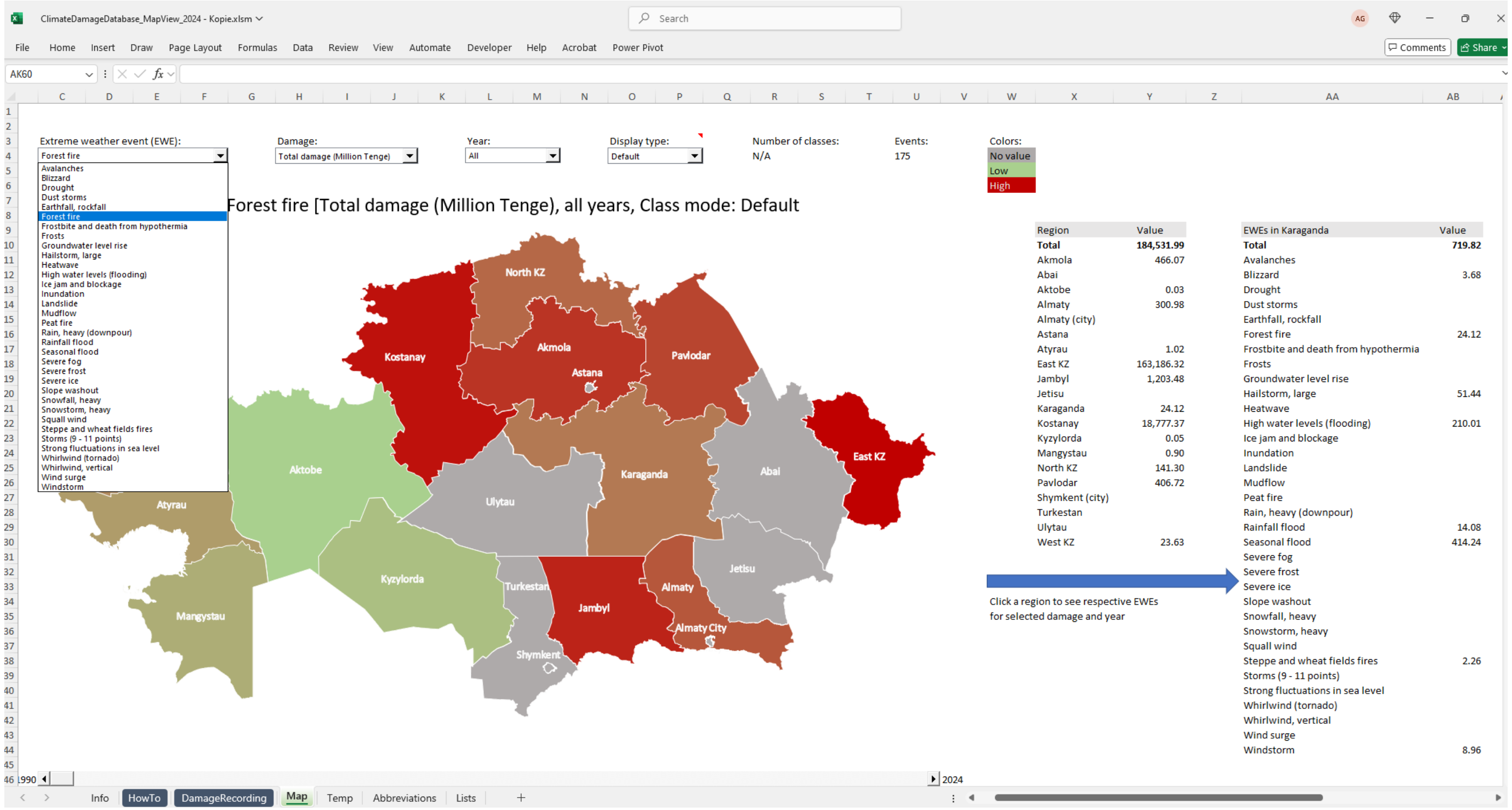
World Bank, Asian Development Bank (ADB) (2021). Climate Risk Country Profile: Kazakhstan. https://www.adb.org/sites/default/files/publication/722246/climate-risk-country-profile-kazakhstan.pdf (last accessed March 3, 2025).

World Bank, Food and Agriculture Organization (FAO) (2019). Understanding the drought impact in the grain production areas in Eastern Europe and Central Asia (ECA): Russia, Ukraine, and Kazakhstan (RUK). https://reliefweb.int/sites/reliefweb.int/files/resources/ca3758en.pdf (last accessed October 4, 2021).

Zhaosong F., Nan L., Baizhan L., Guozhi L., Yanqi H. (2014). The effect of building envelope insulation on cooling energy consumption in summer, Energy and Buildings, Volume 77, 2014, Pages 197-205, ISSN 0378-7788, https://doi.org/10.1016/j.enbuild.2014.03.030 (last accessed February 10, 2025)

8 APPENDIX

Appendix 1: Data collection in Kazakhstan on climate change effect damages (excerpt) – interactive map view



Region	Value
Total	**184,531.99**
Akmola	466.07
Abai	
Aktobe	0.03
Almaty	300.98
Almaty (city)	
Astana	
Atyrau	1.02
East KZ	163,186.32
Jambyl	1,203.48
Jetisu	
Karaganda	24.12
Kostanay	18,777.37
Kyzylorda	0.05
Mangystau	0.90
North KZ	141.30
Pavlodar	406.72
Shymkent (city)	
Turkestan	
Ulytau	
West KZ	23.63

EWEs in Karaganda	Value
Total	**719.82**
Avalanches	
Blizzard	3.68
Drought	
Dust storms	
Earthfall, rockfall	
Forest fire	24.12
Frostbite and death from hypothermia	
Frosts	
Groundwater level rise	
Hailstorm, large	51.44
Heatwave	
High water levels (flooding)	210.01
Ice jam and blockage	
Inundation	
Landslide	
Mudflow	
Peat fire	
Rain, heavy (downpour)	
Rainfall flood	14.08
Seasonal flood	414.24
Severe fog	
Severe frost	
Severe ice	
Slope washout	
Snowfall, heavy	
Snowstorm, heavy	
Squall wind	
Steppe and wheat fields fires	2.26
Storms (9 - 11 points)	
Strong fluctuations in sea level	
Whirlwind (tornado)	
Whirlwind, vertical	
Wind surge	
Windstorm	8.96

Source: ClimateDamageDatabase_MapView_2024.xlsm (interactive mapview created by GWS using simplemaps.com)

Appendix 2: Data collection in Kazakhstan on climate change effect damages (excerpt) – table view

ClimateDamageDatabase_MapView_2024 - Kopie.xlsm

G3135: A storm wind with gusts of over 20 meters per second raised a mass of sand and dust into the air, covering almost all microdistricts of the city of Atyrau.

	A	B	C	D	E	F	G	H	AO	AP	AQ	AR
1	Date of EWE (mm/yyyy or dd/mm/yyyy)	Region (select from list)	EWE (e.g. drought, flood) (select from list)	Source (e.g., institution, website)	Author	Date of registry	(Physical) damage description	Description of quantified damage or persons affected (see next columns) (select from list)	2022	2023	2024	2025
3075	22.08.2023	Jambyl	Drought	xa-i-deficit-vody-v-kazaxstane-tolko-	Svetlana	02.11.2024	Drought and water shortage in Kazakhstan:					
3076	08.06.2023	East KZ	Forest fire	ews/opublikovanyi-foto-14-	Svetlana	02.11.2024	On June 8, 2023, a large forest fire broke	Persons died (number)		14		
3077	08.06.2023	East KZ	Forest fire	oblasti-abay-proishodit-meste-	Svetlana	02.11.2024	14 dead employees of Semey Ormany. 63	Total damage (Million Tenge)		161000		
3078	06.08.2024	Astana	(downpour)	ews/ulitsyi-astanyi-zatopilo-posle-	Svetlana	01.11.2024	Astana streets flooded after rain					
3079	30.04.2024	West KZ	Inundation	449708-kakoy-ushcherb-pavodki-	Svetlana	02.11.2024	The Akimat of the West Kazakhstan Region	Transport (Million Tenge)			1000	
3080	30.04.2024	West KZ	Inundation	https://primeminister.kz/ru/news/	Svetlana	02.11.2024	12 social institutions, 53 transport	Buildings (Million Tenge)			3700	
3081	30.04.2024	West KZ	Inundation	https://primeminister.kz/ru/news/	Svetlana	02.11.2024	In the West Kazakhstan region	Buildings (Million Tenge)			3700	
3082	30.04.2024	West KZ	Inundation	https://primeminister.kz/ru/news/	Svetlana	02.11.2024	In the West Kazakhstan region	Agriculture (Million Tenge)			151	
3083	30.04.2024	Aktobe	Inundation	https://primeminister.kz/ru/news/	Svetlana	02.11.2024	In the Aktobe region, 4,087 real estate	Buildings (Million Tenge)			9000	
3084	30.04.2024	Aktobe	Inundation	https://primeminister.kz/ru/news/	Svetlana	02.11.2024	In Aktobe region as a result of floods...	Buildings (Million Tenge)			8000	
3085	30.04.2024	Aktobe	Inundation	https://primeminister.kz/ru/news/	Svetlana	02.11.2024	In the Aktobe region, as a result of	Agriculture (Million Tenge)			1098	
3086	30.04.2024	Aktobe	Inundation	https://primeminister.kz/ru/news/	Svetlana	02.11.2024	In Aktobe region, 7 schools and 6	Buildings (Million Tenge)			6200	
3087	30.04.2024	Aktobe	Inundation	https://primeminister.kz/ru/news/s	Svetlana	02.11.2024	in Aktobe region... Compensation for	Buildings (Million Tenge)			1400	
3088	30.04.2024	Atyrau	Inundation	https://primeminister.kz/ru/news/	Svetlana	02.11.2024	... during a working visit to the Atyrau	Buildings (Million Tenge)			1300	
3089	30.04.2024	Atyrau	Inundation	https://primeminister.kz/ru/news/	Svetlana	02.11.2024	... as part of a working visit to the Atyrau	Transport (Million Tenge)			5900	
3090	30.04.2024	Kostanay	Inundation	https://primeminister.kz/ru/news/	Svetlana	02.11.2024	In Kostanay region, 1 school and 1	Buildings (Million Tenge)			897	
3091	06.10.2024	Karaganda	Forest fire	451553-krupnyy-pozhar-v-	Svetlana	02.11.2024	Situations reported that while	Persons died (number)			1	
3092	06.10.2024	Karaganda	Forest fire	451553-krupnyy-pozhar-v-	Svetlana	02.11.2024	Situations reported that while	Persons injured (number)			4	
3093	09.04.2020	Almaty City	Avalanches	ews/lavina-soshla-v-gorah-almatyi-	Svetlana	02.11.2024	spontaneously descended in the basin of					
3094	17.02.2020	Almaty City	Avalanches	ews/7-lavin-soshlo-v-gorah-almatyi-	Svetlana	02.11.2024	period of February 16-17, seven snow					

Info | HowTo | DamageRecording | Map | Temp | Abbreviations | Lists

Source: ClimateDamageDatabase_MapView_2024.xlsm