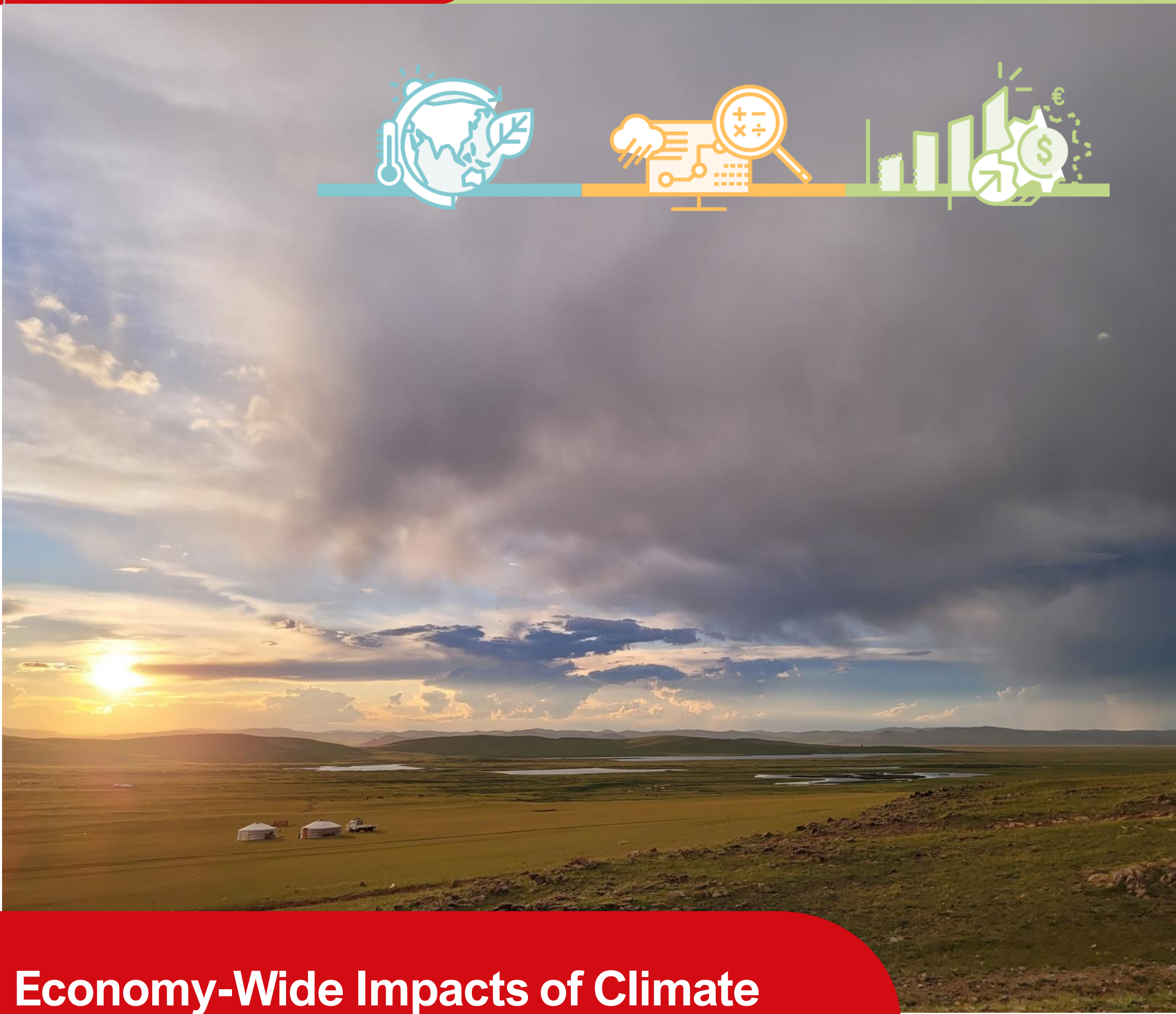

Economy-Wide Impacts of Climate Change and Adaptation in Mongolia

Assessing the Macroeconomic Impacts of Climate Change and Adaptation in Mongolia with the e3.mn Model

Updated Country Report

March 2025

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

based on a decision of the German Bundestag

IKI INTERNATIONAL CLIMATE INITIATIVE

giz Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH

EXECUTIVE SUMMARY

Mongolia is seriously impacted by climate change affecting not only the environment but also inducing immense economic costs, affecting key industries and endangering jobs, wealth, and life of the Mongolian population.

Floods destroy infrastructures while dzuds and droughts cause crop and livestock losses. Apart from these direct impacts, further losses result from e.g. impaired production due to destroyed infrastructure and power outages.

Climate change will accelerate and amplify, which calls for appropriate, swift adaptation actions to curb from the negative impacts on the economy, environment and the people. In 2019, Mongolia launched its National Adaptation Plan (NAP) aiming at integrating climate change adaptation into existing policies and strategies across the most vulnerable sectors.

Raising the awareness about the impacts of climate change on key sectors and finding suitable adaptation options are the starting point. While assessments of costs and benefits for single adaptation projects exist, the economy-wide and intersectoral effects of climate change and adaptation are rarely considered.

Environmentally extended economic models such as the e3.mn model in combination with scenario analyses provide insights into the economy-wide effects of climate change and adaptation policies, especially with regards to employment, GDP, and GHG emissions and thus support policy makers to identify those adaptation options that are highly effective and are beneficial for the economy, the people and the environment (win-win options).

This report presents the economy-wide impacts of climate change and adaptation conducted for the main climate hazards and for four adaptation measures targeting at agriculture and water management to limit the negative climate change impacts on the Mongolian economy and people.

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ADB	Asian Development Bank
BAU	Business as Usual
bbl	Barrel
BMU	Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (Germany)
BMUV	Federal Ministry for the Environment, Nature Conservation, Nuclear Safety and Consumer Protection (Germany)
Bn.	Billion
CAREC	Central Asia Regional Economic Cooperation Program
CBA	Cost-Benefit Analysis
CDCPIII	Capacity Development for Climate Policy in the Countries of Southeastern and Eastern Europe, Southern Caucasus and Central Asia
cf.	Confer
CHP	Combined Heat and Power
CMIP	Coupled Model Intercomparison Project
CO_2	Carbon Dioxide
CO_2e	Carbon Dioxide Equivalent
CRED	Policy Advice for Climate Resilient Economic Development
DI	Drip Irrigation
DIAPOL-CE	Policy Dialogue and Knowledge Management on Climate Protection Strategies
DIOM-X	Dynamic Input-Output Model in Microsoft Excel
EWE	Extreme Weather Events
E3	Economy, Energy, Emission
FEC	Final Energy Consumption
GDP	Gross Domestic Product
GCF	Green Climate Fund
Gg	Gigagram
GHG	Greenhouse Gas
GIZ	Deutsche Gesellschaft für Internationale Zusammenarbeit
GWS	Institute of Economic Structures Research (Gesellschaft für wirtschaftliche Strukturforschung)
ha	Hectare
HP	Herding Points
ICT	Information and Communications Technology
IFRC	International Federation of Red Cross and Red Crescent Societies
IEA	International Energy Agency
IMF	International Monetary Fund
ILO	International Labor Organization

IO	Input-Output
IOT	Input-Output Table
IPCC	Intergovernmental Panel on Climate Change
MET / MECC	Ministry of Environment and Climate Change (Mongolia) – former Ministry of Environment and Tourism
MNT	Mongolian Tugrik (Currency)
MW	Megawatt
Mn.	Million
Mt	Megaton
NAMEM	National Agency for Meteorology and Environmental Monitoring (Mongolia)
NAP	National Adaptation Plan
NCC	National Climate Committee (Mongolia)
NDCAP	Nationally Determined Contributions Action Plan
n.d.	No date
n.e.c.	Not elsewhere classified
NEMA	National Emergency Management Agency
NPISH	Non-Profit Institution Serving Households
p.a.	Per annum
PJ	Petajoule
PV	Photovoltaic
RE	Renewable Energy
SSP	Shared Socioeconomic Pathways
t	Ton
TFEC	Total Final Energy Consumption
TJ	Terajoule
Tn.	Trillion
TWC	Tuul Water Complex
UN	United Nations
UNDRR	United Nations Office for Disaster Risk Reduction
UNEP	United Nations Environment Programme
UNFCCC	United Nations Framework Convention on Climate Change
UNStats	United Nations Statistics Division
USAID	United States Agency for International Development
USD	US Dollar
WR	Water Reservoirs

1. Introduction

Climate change is a major threat to Mongolia's economy and people, particularly through dzuds and floods impacting, for example, the agriculture and water sector as well as infrastructure. At the same time, greenhouse gas (GHG) emissions have risen sharply in recent decades due to the high dependence on fossil fuels. Thus, adaptation and mitigation of climate change are key priorities for Mongolia. As a participant in the Paris Agreement since 2016, the country has pledged to reduce GHG emissions and contribute to global efforts to curb warming (UNFCCC 2022). Simultaneously, Mongolia faces extreme weather events (EWEs) alongside slow onset climate change. Climate experts predict an increase in the frequency, intensity, and recurrence of climate hazards for Mongolia, as well as temperature rises exceeding the global average (MET 2024, WBG & ADB 2021, USAID 2017).

These climate impacts impose economic costs, particularly on key sectors such as agriculture. Policymakers must understand the potential effects on the national economy, prepare for them, and develop adaptation strategies to mitigate economic risks, thereby fostering a transition to a climate-resilient economy. E3 (economy-energy-emission) models, combined with scenario analysis, provide valuable tools for addressing these challenges.

Building on experiences[1] within the global program “Policy Advice for Climate Resilient Economic Development” (CRED) implemented by Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) on behalf of the Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (BMU), the E3 (Economy-Energy-Emission) model prototype e3.mn for Mongolia was developed based on the model prototype described in GIZ (2022a).

Such an E3 model enhances the single sector analysis of climate change impacts and adaptation measures by incorporating indirect and induced impacts. Supply chain and income-induced impacts are covered and shed light on the sectoral interdependencies as well as income and demand relationships. The ability to consider long-term, economic developments (until 2050) in Mongolia supports policy makers to detect possible climate change impacts on key economic sectors and to plan adaptation measures foresightedly.

The cooperation between the projects “Policy Dialogue and Knowledge Management on Climate Protection Strategies (DIAPOL-CE)”, “Policy Advice for Climate Resilient Economic Development” (CRED) and “Capacity Development for Climate Policy in the countries of Southeastern and Eastern Europe, Southern Caucasus and Central Asia (CDCPIII)” enables the continuation of the modelling and capacity building activities in Mongolia. The e3.mn model was updated and extended to also simulate economy-wide carbon pricing impacts (GIZ 2024) and additional climate change and adaptation scenarios. The data collection processes, and climate modelling were supported by national and international experts, e.g. National Emergency Management Agency (NEMA), National Agency for Meteorology and Environmental Monitoring (NAMEM) and Earthyield Advisories.

The process involved designing climate change and adaptation scenarios, incorporating data on key climate hazards, their sector-specific impacts, and suitable adaptation measures. These scenarios were then analysed using the e3.mn model, with results integrated into stakeholder discussions and policy processes to inform evidence-based adaptation planning (GIZ 2025b).

[1] See for example, GIZ (2022b)

The CRED approach, while ambitious in terms of data collection, modelling, coordination, and planning, is also time-intensive for all involved partners. Nevertheless, its highly participatory nature fosters collabouration between field experts and government ministries supporting evidence-based policymaking (GIZ 2023c, d).

This report is organized as follows:

Chapter 2 provides an overview of the methodology – the e3.mn model and scenario analysis – used for modelling the economy-wide impacts from climate change and adaptation in a nutshell. Chapter 3 briefly describes the assumptions and results of the baseline scenario, which serves as a basis for the climate change and adaptation scenarios. Chapter 4 addresses past and future climate trends and the observed sectoral impacts of climate change. Chapter 5 illustrates the results for the 3 Es (economy, energy and emissions) of three Shared Socioeconomic Pathways (SSP) scenarios. Chapter 6 presents four adaptation measures aiming to reduce or even avoid negative impacts in the key sectors agriculture and water. 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 7 concludes and provides an outlook.

2. Modelling the economy-wide impacts of climate change and adaptation in Mongolia

2.1 The e3.mn model

Environmentally extended macroeconomic models have become more and more important to evaluate climate change policies[2]. In combination with scenario analysis, these models are applied to analyse the economy-wide impacts of climate change adaptation measures and mitigation policies (GIZ 2021, GIZ 2023e, GIZ 2024). The e3.mn is such a model. It covers the structure of the Mongolian economy and depicts the main connections to the environment, i.e. usage of energy resources and combustion-related GHG emissions. The model details are presented in the model handbook which has been updated in 2024 (GIZ 2023b). The e3.mn model has been developed as part of a series of similar country models (see GIZ 2023b).

The three Es in the model name refer to the underlying integrated modelling approach covering economy, energy and emissions in one model. This approach allows for calculating impacts for the whole economy (e.g. gross domestic products (GDP)) as well as impacts on single economic sectors (e.g., employment in agriculture) to furthermore draw conclusions on social balance and to detect environmental benefits.

The three model parts and their interrelations are depicted in Figure 1. Number 1 indicates the economic core of the E3 model, number 2 shows the energy module, which separates different energy carriers including renewables and number 3 indicates the emission module.

The foundation of each of the three parts is a rich and up-to-date, country-specific dataset composed of annual time series from 2008 until 2022 for most the important economic data and from 1990 to 2021 for energy and emission data. The core of the economic model part is built upon an input-output table (IOT) and the system of national accounts (macroeconomic data) plus population and labour market data such as employment. At the centre of the energy model part, energy balances including energy supply, energy transformation and final energy demand can be found. The data is given in physical units, thus combustion-related GHG emissions can be directly calculated by using fixed emission factors.

[2] See https://web.jrc.ec.europa.eu/policy-model-inventory/ for a comprehensive model overview applied for energy and climate policy questions at EU level.

The observed and theoretical relationships of the Mongolian economy are formulated in a simplified way as a set of mathematical equations within e3.mn. Some calculations can be computed by definition, such as GDP, which is the sum of consumption, investment and foreign trade. Furthermore, econometric methods and expert knowledge are used to derive future developments from historical data.

Possible future pathways of Mongolia's economy depend on some exogenous inputs (e.g., population, world market prices) and the modelled (inter)relationships within the three model parts.

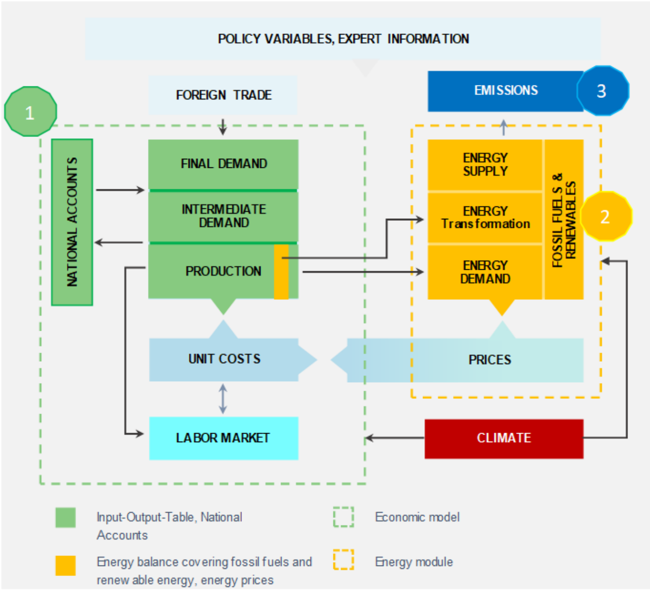


Figure 1: E3.mn model at a glance

Source: Own illustration, based on GWS (2022)

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

2.2.1 OVERVIEW

Scenario analysis refers to a technique that tries to depict different possible future pathways by analyzing consistent sets of quantified assumptions. The pathways can reveal what and/or who is affected in which way, but they should not be considered exact forecasts.

At the beginning, a baseline scenario must be defined, which is a description of future developments based on continued, already observed past behaviour and some exogenous factors. In the baseline scenario, climate change impacts and adaptation policies are excluded to provide the basis against which alternative scenarios including such policies are evaluated.

Three climate scenarios based on SSP[3]1-2.6, SSP2-4.5 and SSP5-8.5 have been simulated with the e3.mn model to reveal the possible economy-wide impacts. These climate scenarios consider the probability of occurrences for the main climate hazards and their observed sectoral impacts on the Mongolian economy that are not part of the baseline scenario. In the next step, climate change adaptation scenarios have been designed considering both the sector-specific costs and benefits of adaptation measures resulting from project or sector-specific cost-

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

benefit analyses (CBAs). Necessary settings and data have been jointly collected with national, sector and climate experts.

During simulations, the respective scenario settings of the climate change and adaptation scenarios cause chain reactions in the e3.mn model with "alternative" futures. The impacts of a climate change scenario can be revealed by evaluating the values of relevant model variables (such as employment, GDP or production) against their values in the baseline scenario (Figure 2). An adaptation scenario must be compared to the respective climate change scenario including climate change impacts but excluding adaptation policies.

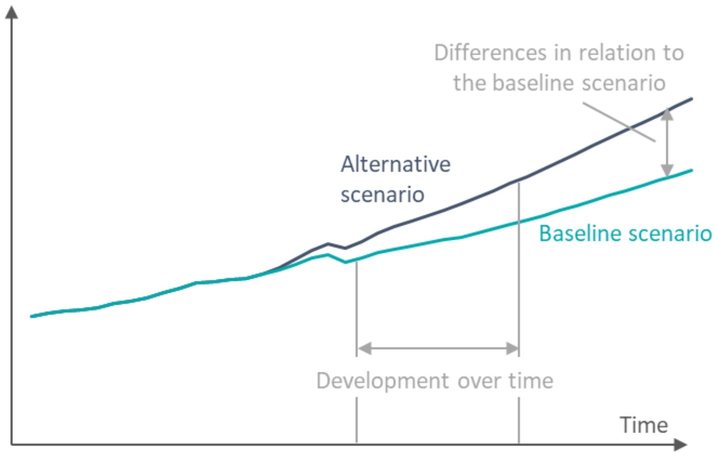


Figure 2: Scenario comparison

Source: Own representation by GWS.

The e3.mn model helps to reveal direct, but also indirect and feedback effects of alternative scenarios, both on a sectoral basis and for the macroeconomy. Furthermore, the model enables users to identify those adaptation options that are highly effective and have positive effects on the economy, employment, and the environment. This is made possible by the aforementioned integrated e3 modelling approach which describes the causal relationships between and within the three Es.

2.2.2 PROCEDURE TO IMPLEMENT CLIMATE CHANGE AND ADAPTATION INTO THE E3.MN MODEL

The analysis of climate change and its impacts on Mongolia begins with the selection of SSP scenarios, which depict various global climate policy decisions influencing GHG emissions. Within this project, the focus is on the SSP1-2.6, SSP2-4.5, and SSP5-8.5 scenarios, spanning from low to high emission trajectories. Higher numerical suffixes in SSPs indicate more pronounced climate warming effects.

Climate models play a crucial role in understanding how future GHG emissions and land-use changes drive responses in the climate system, manifesting in slow-onset events and extreme weather phenomena. These projections, particularly regarding the intensity and frequency of dzuds, droughts, heatwaves, and floods, serve as vital inputs for the climate change scenarios simulated with the e3.mn model.

Given the differing temporal and spatial scales, as well as the distinct indicators of climate and economic models, a 4-step process (Figure 3) was implemented to (1) incorporate climate change impacts and (2) the project or sector-specific costs and benefits of selected adaptation measures to finally evaluate the economy-wide impacts (for further details, refer to GIZ 2022b):

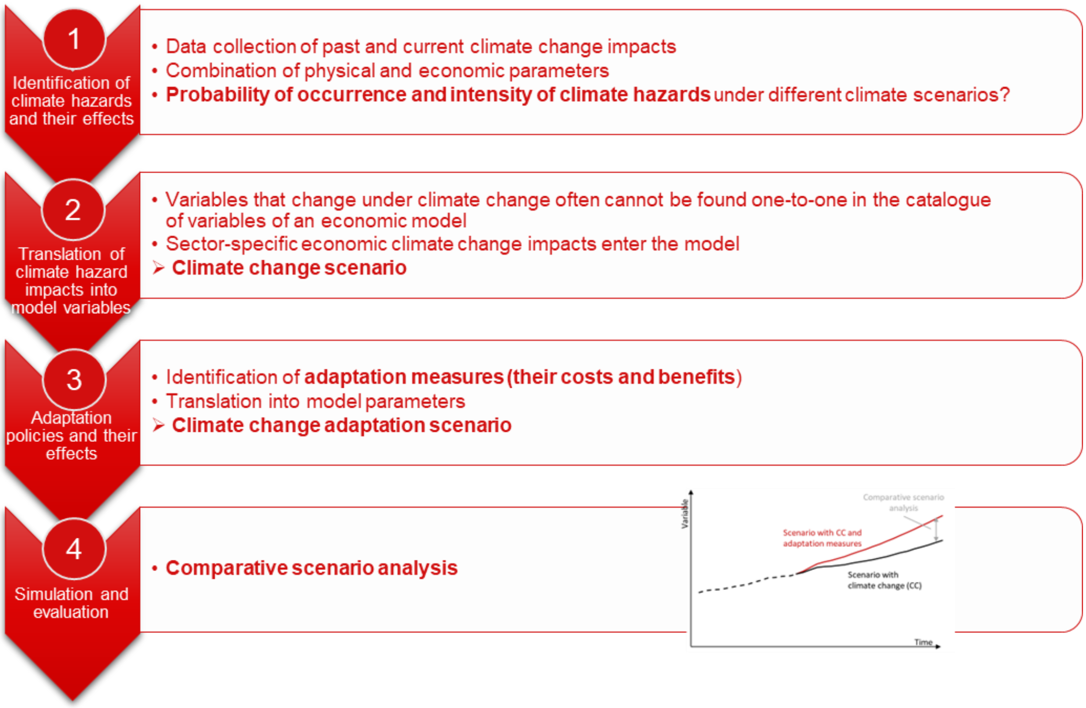


Figure 3: Four-step approach to implement climate change impacts and adaptation measures in an economic model

Source: Adapted from GIZ (2022b)

Data from field experts serves as input for step 1 “Identification of climate hazards and their effects” and step 3 ”Adaptation policies and their effects”:

Step 1: The **probability of occurrence and the intensity of country-specific climate hazards** (dzuds, droughts, heatwaves and floods) are provided for **three SSP**[4] (SSP1-2.6, SSP2-4.5 and SSP5-8.5) **scenarios** by Earth Yield Advisories (GIZ 2025a) to enable the analysis of the economic impacts of climate change in greater detail. The frequencies of climate hazards differ by intensity (low, medium, high) and for the SSP scenarios.

Historical and current sectoral damage resp. impact data related to climate hazards – when available, categorized into low, medium, and high intensity levels – are gathered and used as a benchmark for projecting future climate hazard impacts (so-called "bottom-up" approach). The collection of past and current climate change impacts was supported by national partners such as NEMA and NAMEM (Appendix 1).

Adjustments to the benchmarks are applied by assuming, for instance, that doubling the annual probability of occurrence will also double the benchmark impacts (Figure 4).

[4] 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. cli-mateknowledgeportal.worldbank.org/overview)

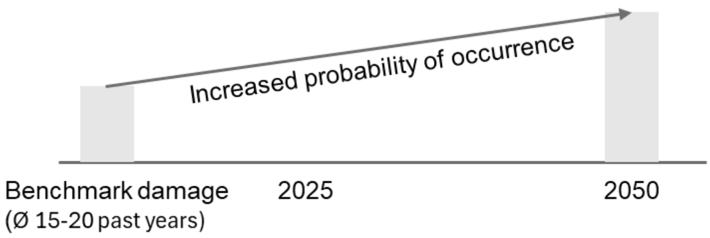


Figure 4: Exemplary projection of benchmark impacts into the future by applying the climate hazard probability of occurrence by hazard intensity

Source: Own illustration

By combining the projected future trends of climate hazards by intensity levels with their observed benchmark impacts categorized by intensity, a time series of expected future impacts for each climate hazard is generated. Using probabilities of occurrence, the damages resp. impacts from irregularly occurring climate hazards are transformed into a continuous curve (Figure 5). For example, damage from a climate hazard that occurs once every ten years is evenly distributed across that decade.

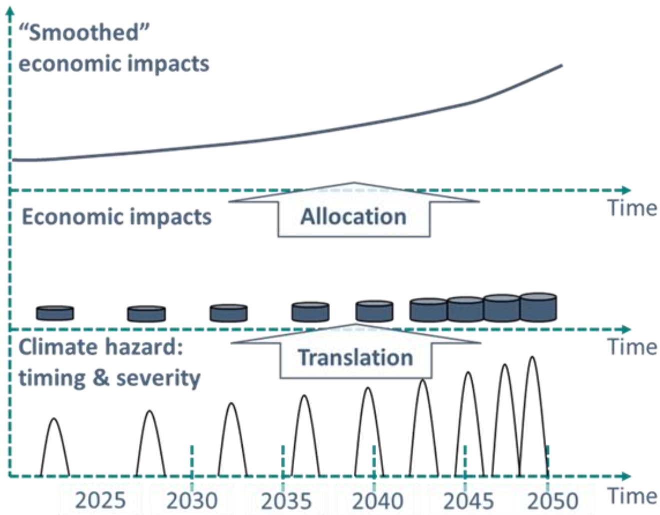


Figure 5: Conversion of irregularly occurring climate hazards into a smooth curve

Source: Own illustration based on Wolter et al. (2023)

To supplement the "bottom-up" approach, which lacks a comprehensive and systematic data collection, other studies examining the macroeconomic impacts of climate hazards in Mongolia are reviewed ("top-down" approach). This method offers (1) additional data on climate impacts in Mongolia from a "birds-eye" perspective (e.g., projections of labour productivity losses during heatwaves from Climate Analytics), (2) helps to scale up "bottom-up" data when it is insufficient, and (3) allows for comparison with own scenario results. For instance, studies by Kahn et al. (2019) and Waidelich et al. (2024) provide GDP per capita losses for various SSP scenarios.

Alternative options include relying on country-specific forecasts from "bottom-up" sector models (e.g., agricultural yield forecasts under different climate scenarios, as seen in Mendelsohn 2014).

In step 3, sector-specific **costs and benefits of adaptation measures** are implemented into the e3.mn model to analyse the macroeconomic impacts. Ideally, results from CBAs are utilized to better understand specific costs and benefits.

All data (from steps 1 and 3) are integrated into e3.mn by identifying appropriate model variables (step 2). Initial impacts of climate hazards can be modelled as effects on human behaviour (e.g., increased demand for cooling and healthcare), investments (e.g., needed for reconstruction or needed to realize adaptation plans), reduced labour productivity, or changes in foreign trade (indicated by ● in Figure 6), triggering chain reactions within the e3.mn model. The economy-wide impacts of three SSP scenarios are detailed in chapter 5.

The costs of adaptation measures are typically modelled as investments, while benefits are represented as the reversal of climate change impacts. The results of four adaptation measures are discussed in chapter 6.

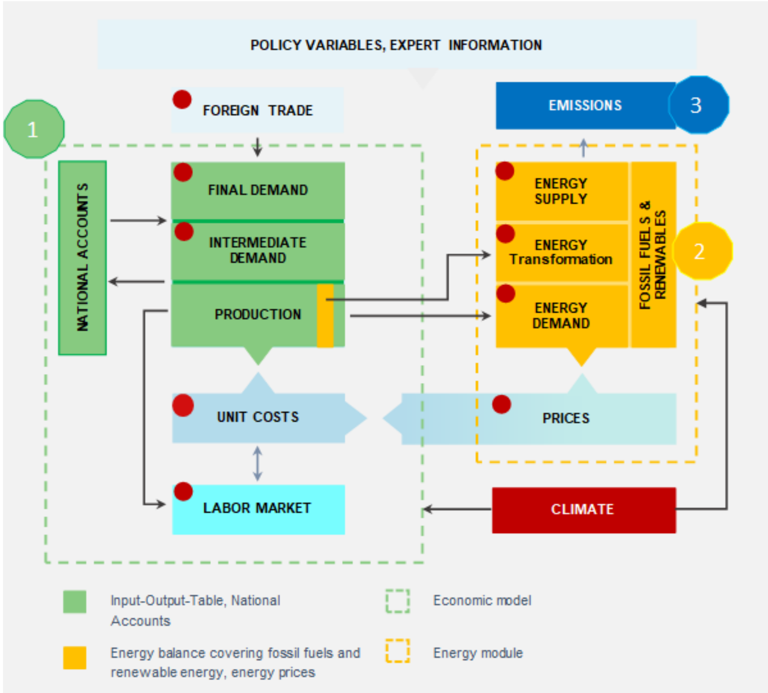


Figure 6: Implementing the impacts of climate change and adaptation measures into e3.mn

Source: GIZ (2022b)

3. Baseline scenario

3.1 Assumptions

The baseline scenario extrapolates the economic relationships observed in the past into the future. Model variables, parameters and assumptions are carefully selected to provide a reliable projection until 2050 and to provide a solid basis for scenario analyses. The economic development is mainly driven by exogenous population projections and expectations about world market indicators such as world market prices and exports as well as endogenous growth as it has evolved in the past.

Nonetheless, the baseline scenario is not to be interpreted as a pathway in terms of the most realistic development. It serves as a benchmark to compare model results of other scenario analyses, i.e. climate change and adaptation scenarios.

Population projections

According to the UN World Population Prospects 2024 (UN 2024), Mongolia's population development continues to grow until 2050 reaching 4.5 Mn. people. However, growth rates have been declining since 2019 from 2.2% to 0.7% in 2050 (Figure 7). Population by age groups show opposing developments. While the population aged older than 64 years is increasing the most, the population younger than 16 years shows only a small increase and partly a decline. Population at working age is expected to show continuously decelerated growth until 2050.

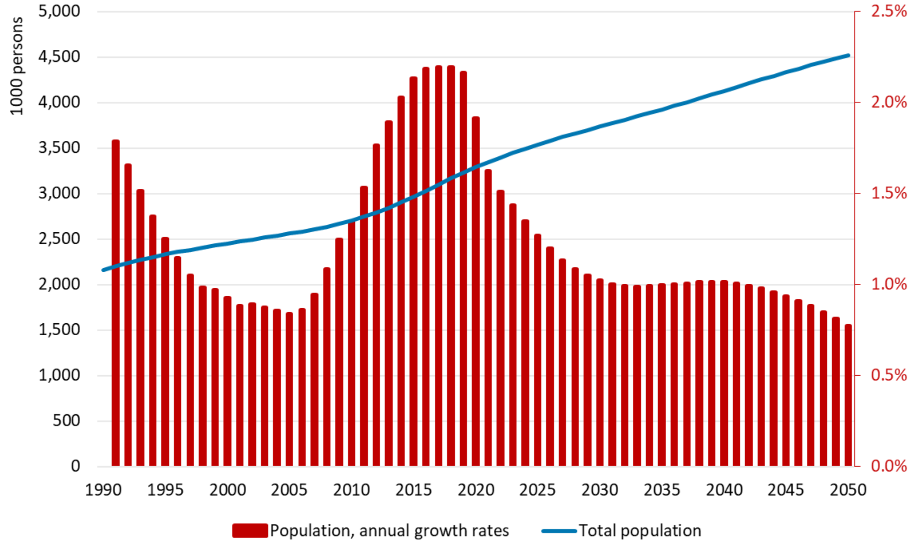


Figure 7: Baseline scenario: population development in 1 000 persons and average annual growth rates in % (1990–2050)

Source: UN (2024).

World market indicators

Exports in goods and services follow the International Monetary Fund (IMF 2024a) projections for Mongolia from 2024 to 2029. According to this projection, growth rates are 13.7% at the beginning of the projection period and then decelerate to 4.3% in 2029. Afterwards, export growth is expected to be 5% p.a. (2030–2050). The exchange rate is assumed to grow by one percent p.a. until 2050.

World market price indices for traded commodities such as agriculture and mining products follow the projections of the World Bank until 2025 and the IMF until 2027. Afterwards, the price indices follow their historical trend. The crude oil and coal projections are taken from the IEA World Energy Outlook (IEA 2023, p. 96) "Stated Policies Scenario" until 2050 (Table 1).

Table 1: World market price indices for selected commodities, average annual 10-year growth rates in % (2000–2050)

	2000–2010	**2010–2020**	**2020–2030**	**2030–2040**	**2040–2050**
Agriculture price index (2015=100, nominal USD)	7.4%	-1.4%	3.0%	2.2%	2.2%
Commodity Metals Price Index (2015=100)	14.5%	-2.8%	2.8%	2.3%	2.3%
Commodity Wool Index includes Coarse & Fine Wool Price Indices (2015=100)	6.3%	0.1%	0.8%	1.0%	1.0%
Crude oil, Brent (USD / bbl)	10.8%	-6.2%	5.0%	1.0%	0.9%
Coal (USD / t)	14.8%	-5.1%	7.5%	-2.0%	-2.6%

Source: Calculations based on World Bank (2024a) and IEA (2023).

Energy indicators

In the baseline scenario, a carbon price and consequently the changes in energy prices and energy demand are not introduced. Such an analysis has been conducted and reported in the carbon tax policy brief (GIZ 2024).

Furthermore, the total renewable energy (RE) capacity remains at its level of the year 2022 resulting in a total RE capacity of 280 MW of which wind is 156 MW, solar PV 95 MW and hydro 29 MW.

3.2 Results

Economic development

In the baseline scenario, the Mongolian economy continues to grow after the coronavirus pandemic until 2050 but at a slower rate compared to the historical development. The average annual 10-years growth rate is 4.9% p.a. between 2020 to 2030, followed by 3.8% p.a. between 2030 to 2040 and 4.1% p.a. in the next decade (2040–2050, Table 2). Until 2050, GDP in constant prices will almost increase fourfold compared to 2020 resulting in 94 Tn. MNT. The economic projections of the baseline scenario are largely in line with GDP estimates from other institutions such as IMF (2024b), World Bank (2024b) and ADB (2024b) projecting growth rates of approx. 6% p.a. until 2027 or 2029.

Table 2: Baseline scenario: GDP and components in constant prices, average annual 10-years growth rates in % (2010–2050)

	2010–2020	2020–2030	2030–2040	2040–2050
GDP	6.6%	4.9%	3.8%	4.1%
Final consumption of the households and NPISH	8.3%	4.7%	3.6%	4.0%
Final consumption of general government	9.4%	4.4%	2.7%	2.5%
Gross capital formation	1.6%	9.6%	3.1%	3.3%
Exports	11.6%	8.5%	2.8%	2.6%
Imports	10.9%	9,4%	2.3%	2.2%

Source: Until 2022 historical data based on ADB, e3.mn results (2023–2050)

The economic development is mainly driven by exports as in the past. Domestic demand such as investments and household consumption are influenced by overall economic development. Government consumption follows population growth and thus decelerates in the projection period.

Due to the high import dependency, in particular in the manufacturing sector, imports are expected to further increase. Final and intermediate products are imported either to be consumed directly, e.g. as clothing, or to be processed into final products in the production process, e.g. cotton fabric to produce a cardigan.

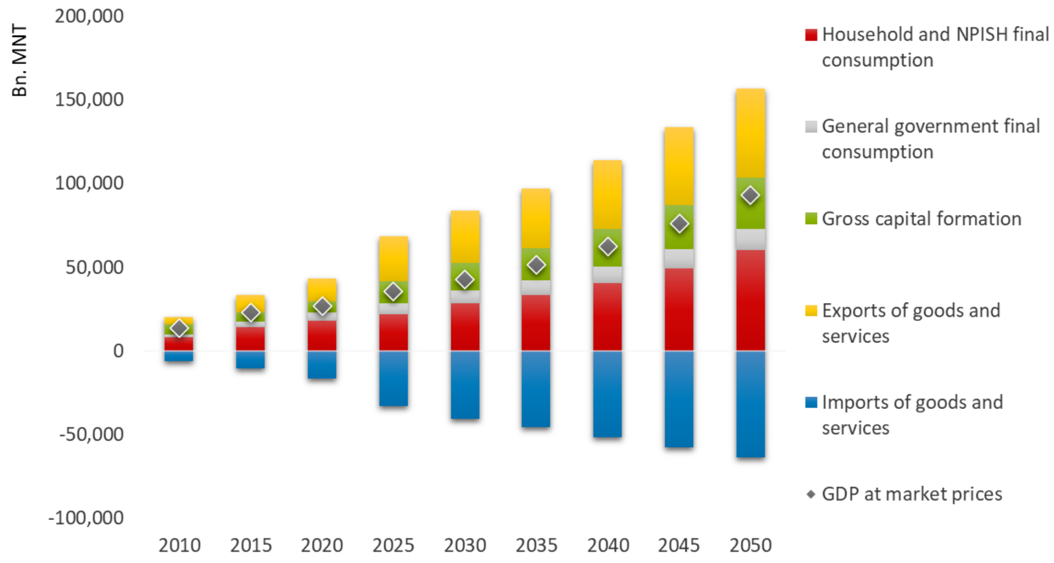


Figure 8: Baseline scenario: GDP and its components in constant prices in Bn. MNT (2010–2050)

Source: Until 2022 historical data based on ADB, e3.mn results (2023–2050)

The import deflator – which measures the import price development – is expected to grow at max. with 4% p.a. following the import price assumptions mentioned in the previous section.

The average wage rate is further increasing reflecting the labour scarcity, labour productivity and inflation. During the decade 2020 to 2030, the average wage rate is accelerating following the high inflation resulting in 12.9% p.a. in this period (see Table 3). Afterwards, the average wage rate is between 7.6% p.a. (2030–2040) and 6.8% p.a. (2040–2050).

The GDP deflator growth rate is expected to decline from 9.1% p.a. (2020–2030) to 3.9% (2030–2040) and 3.8% (2040–2050) reflecting the import price and wage rate developments.

Table 3: Baseline scenario: Wage and price developments, average annual 10-year growth rate in % (2010–2050)

Average annual growth rates of	2010–2020	2020–2030	2030–2040	2040–2050
GDP deflator	7.4%	9.1%	3.9%	3.8%
Average wage per employee (nominal)	13.6%	12.9%	7.6%	6.8%
Imports of goods and services deflator	2.9%	5.5%	3.9%	3.4%

Source: Until 2022/2023 historical data based on ADB, e3.mn results (2023/2024–2050)

Sectoral production follows macroeconomic development considering inter-industry relationships. Export growth impacts in particular export-oriented sectors such as "Mining and quarrying" and "Agriculture, hunting, forestry" as stated in the Mongolian IOT from 2022 (ADB 2023). Consumption-oriented sectors are more dependent on domestic demand. For the projection period, no structural changes or economic diversification of the economy are assumed. Figure 9 depicts the projections for gross production by economic sectors at constant prices.

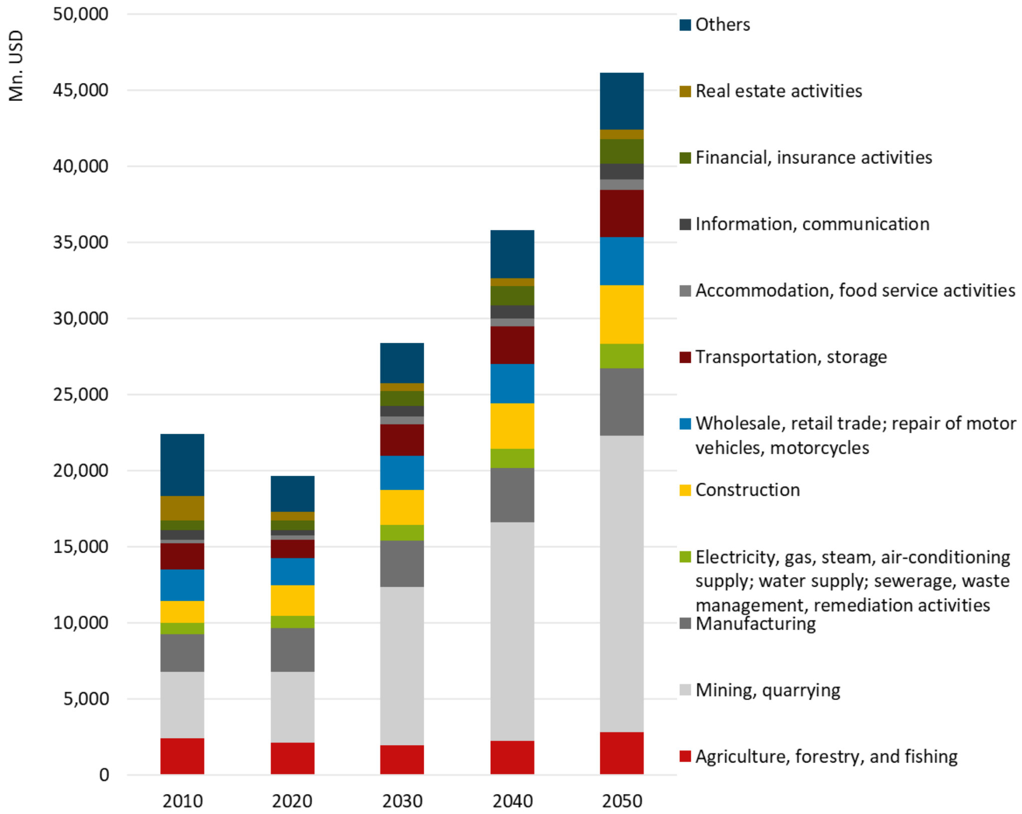


Figure 9: Baseline scenario: Gross production by economic sectors in constant prices in Mn. USD (2010, 2020, 2030, 2040, 2025)

Source: Until 2022 historical data based on ADB, e3.mn results (2023–2050)

After the coronavirus pandemic, gross production recovers and increases steadily. Gross production in constant prices almost doubles from 23 Bn. USD in 2010 to 45 Bn. USD in 2050. The "Mining and quarrying" sectors contribute the most to gross output in constant prices, followed by service sectors, "Manufacturing" and "Construction".

Employment by economic activities follows sectoral production considering labour intensities. Most persons are employed in “Other” sectors (432 000 persons) which includes, for example, the public administration, defense, compulsory social security and education (225 000 persons), followed by trade (230 000 persons) and “Agriculture, forestry and fishing” (211 000 persons, Figure 10). In total, 1.65 Mn. people are employed in 2050 which is 1.4-fold more than in 2020.

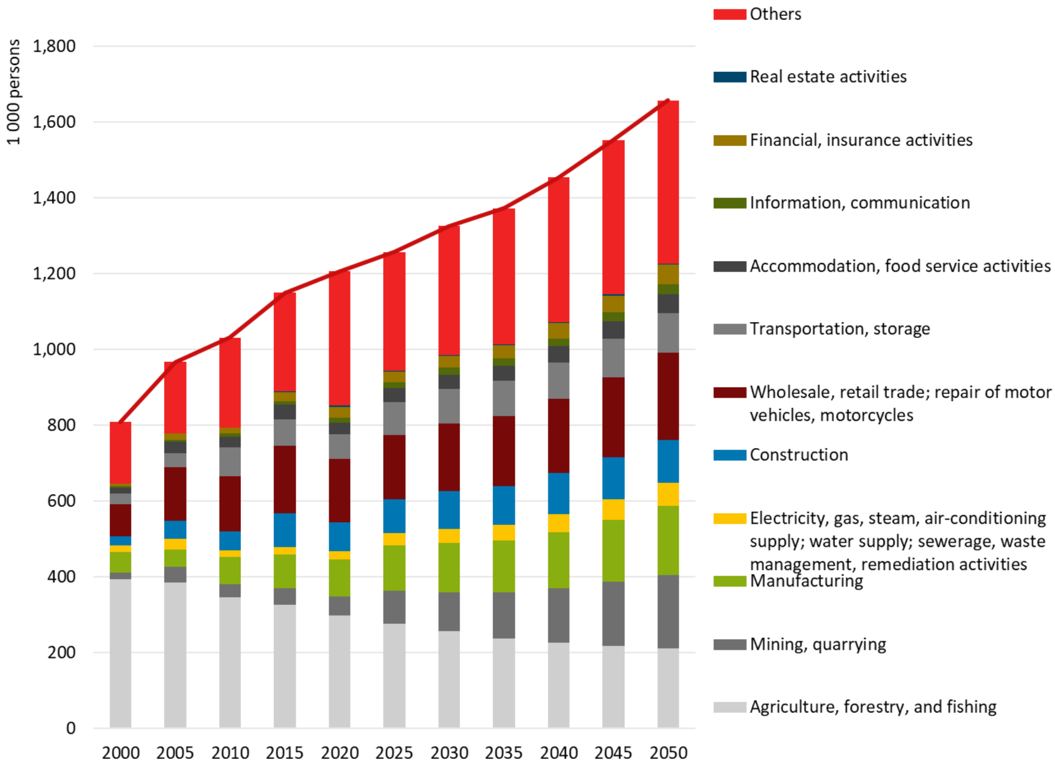


Figure 10: Baseline scenario: Employment by economic activities in 1 000 persons (2000–2050)

Source: Until 2022 historical data based on ILO, e3.mn results (2023–2050)

Considering employment by gender, the distribution of male and female workers across economic activities is quite similar (Figure 11). In 2020, most employed persons of both genders work in the private service sector (34% each), and a similar proportion of women and men work in agriculture (24% and 26% respectively), manufacturing (8% each) and energy and water supply (2% each). However, there are also differences. While 29% of female persons work in the public sector, only 14% of male persons do so. In contrast, 10% and 7% of male persons work in construction and mining and quarrying respectively, where in both cases only 2% of all female persons work.

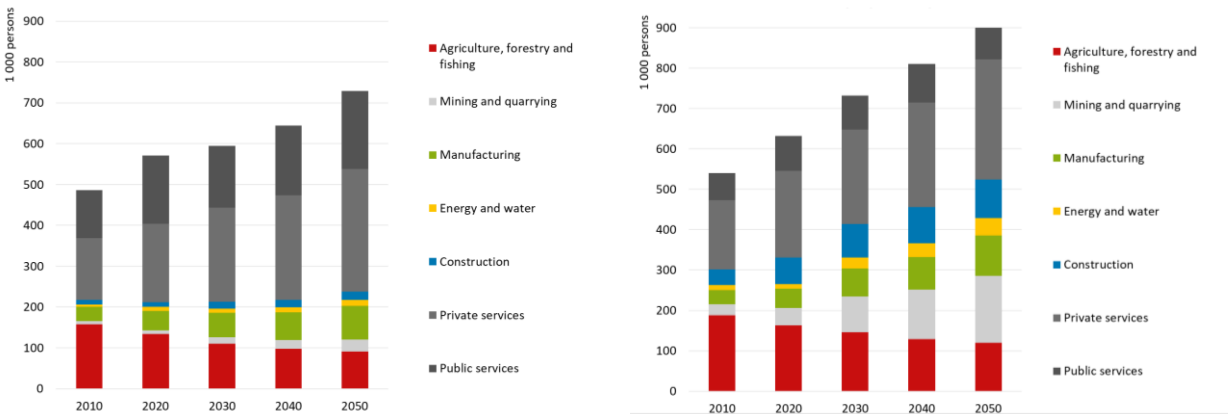
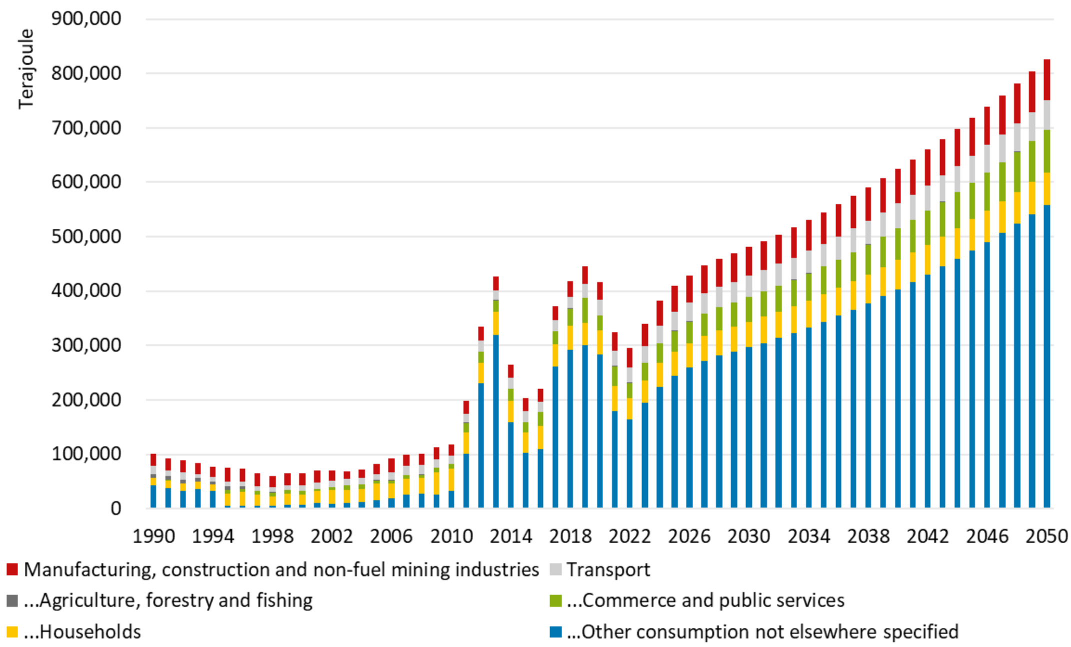


Figure 11: Baseline scenario: Employed persons by economic activities and gender (female: left figure, male: right figure) in 1 000 persons (2010–2050)

Source: Until 2022 historical data based on ILO, e3.mn results (2023–2050)

Energy and emissions

The main drivers of future final energy demand by sectors are the expected economic growth in the respective economic sectors, energy price developments and population growth for the residential sector. While greater economic activity and increased population leads to a higher final energy demand, energy price increases have an opposing impact. Energy efficiency developments as observed in the past are expected to continue (Figure 12).



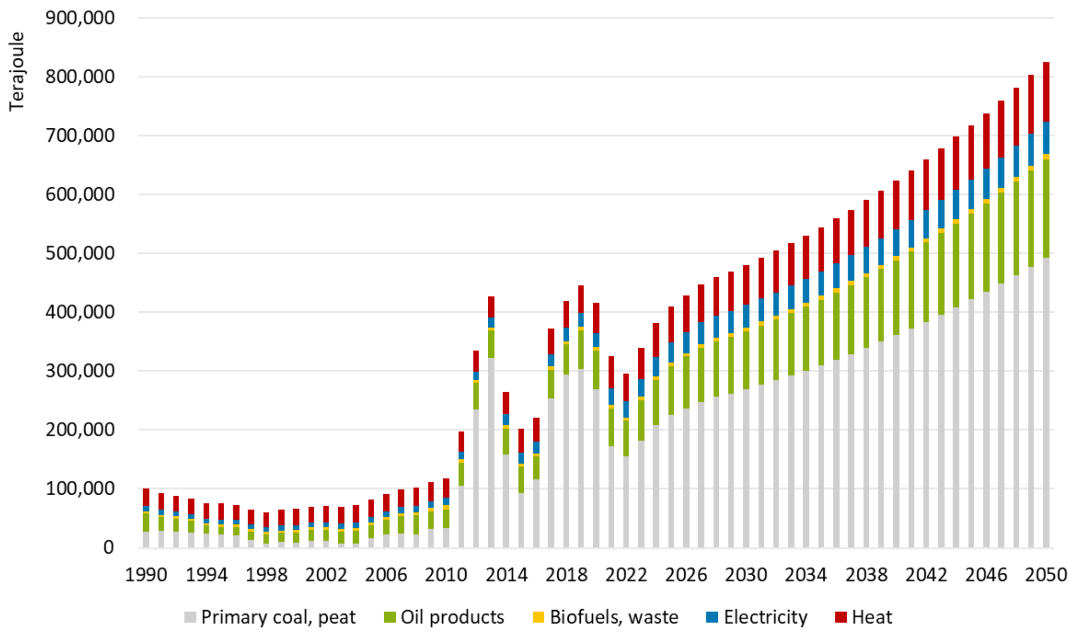


Figure 12: Baseline scenario: Final energy demand by sectors (top figure) and energy carriers (bottom figure) in Terajoule (1990–2050)

Source: Until 2021 historical data based on UNStats, e3.mn results (2022–2050)

In 2021, the biggest energy consumers are "other consumption not elsewhere specified" (55%), the residential sector (14%), commerce and public services (11%), the manufacturing, construction and non-fuel mining industries (11%), and the transport sector (8%, Figure 12 top figure). Coal and peat are mostly consumed (53%), followed by oil products (19%) used mainly for transportation and heat (17%) demanded for by residential sector, commerce and public services and manufacturing sectors (Figure 12 bottom figure).

A stronger use of RE is not presumed – neither in final energy demand nor in the energy transformation sectors. Heat and electricity production heavily depend on fossil fuels, in particular coal. The dominant use of fossil fuels increases GHG emissions resulting in 45 Mt CO_2e by 2050 and thus doubles compared to 2020 (Figure 13).

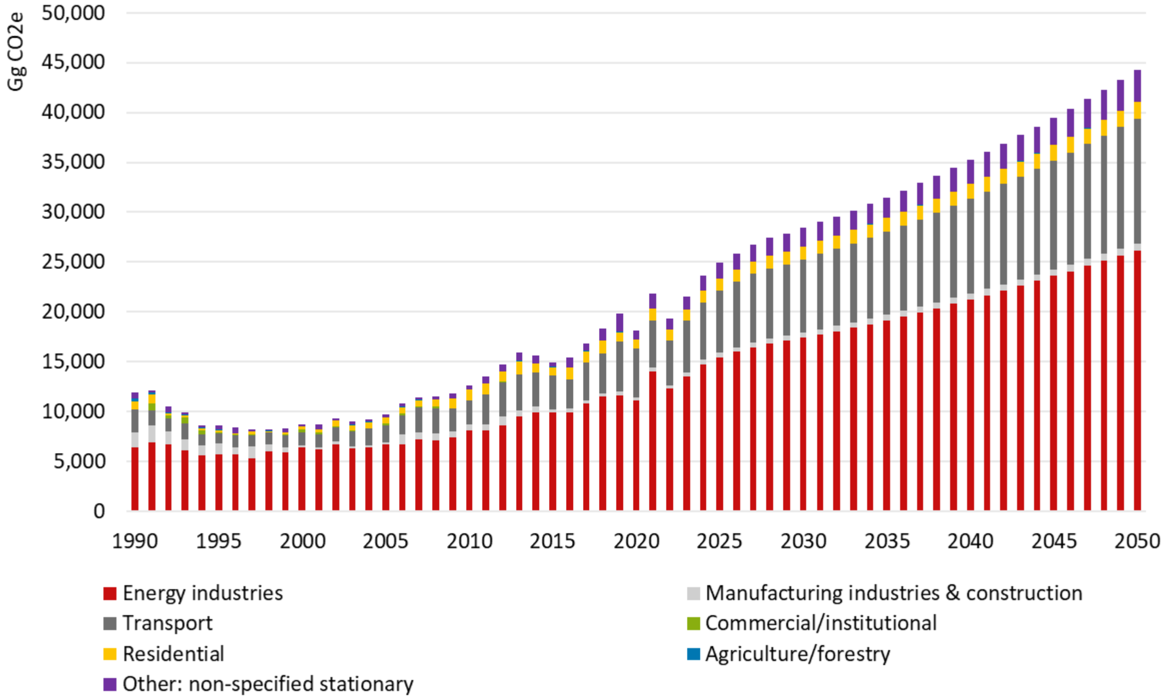


Figure 13: Baseline scenario: GHG emissions by sectors in Gg CO_2e (1990–2050)

Source: Until 2020 historical data based on MET (2023), e3.mn results (2021–2050)

4. Climate change and its impacts in Mongolia

4.1 Current climate and projections

Current climate

Due to its heterogenous geographical incidences with the Gobi Desert located at the south to west of the country, mountain areas in the middle and west and lower-level areas in the middle to the east, Mongolia is characterized by multiple climate zones with differences in precipitation and high amplitude of temperature across the country (MET 2024).

The climate is characterized as a dry subarctic continental climate with short summers, long cold winters and relatively low precipitation (USAID 2022; Batsukh et al. 2021; Yembuu 2021). Average temperatures range from -32°C to 29°C over the year but can reach -50°C during winter seasons (MET 2024; UNDRR 2019). Average annual precipitation is about 400 mm and is much higher in the north, where most of the country's pastureland and forest areas are located. In the Gobi Desert, annual rainfall is only 5-10 mm (MET 2024).

From 1940 to 2022, the annual average air temperature increased by 2.46°C which is evident throughout the country and all seasons except for winter. Also, the number of hot days with daily mean air temperature above 30°C has been growing, too, especially in the central and northwestern regions whereas frost days declined (MET 2024).

During the same period, annual precipitation has fluctuated around the average rainfall level depending on the region. However, the length of dry periods tends to increase and also the frequencies of intense rain, which implies high water runoffs, flash floods and inadequate water absorption by the soil (MET 2024, USAID 2022).

Climate extremes and disastrous weather events become more frequent and more severe. Mongolia is particularly vulnerable to dzuds, droughts, heat and cold waves, but also to extreme precipitation as well as wind and sandstorms (MET 2024, UNDRR 2019, USAID 2022, Han et al. 2021). Dzuds are a national phenomenon characterized by a drought in summer, followed by a severe cold and/or a heavy snow and severe storms in winter causing massive livestock losses.

Figure 14 shows the historical occurrences of EWEs based on data collections of the National Emergency Management Agency (NEMA) and the National Agency for Meteorology and Environmental Monitoring (NAMEM). The total number of EWEs shows an increasing trend. In particular precipitation-related EWEs (grey bar) increased, followed by wind related EWEs (red bar). Other events occurred less frequently such as dzuds (e.g. in 2001/2002, 2009/2010 and 2023/2024) but have very severe impacts.

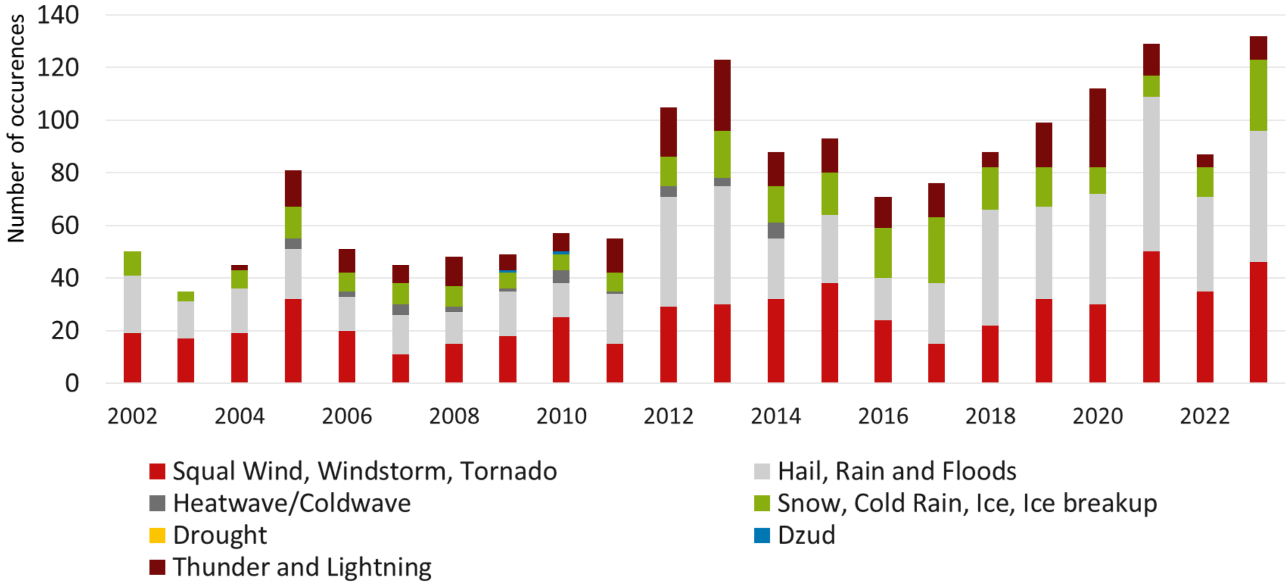


Figure 14: Occurrences of extreme and hazardous weather events in Mongolia (2002–2023)

Source: Own illustration based on data collected by NEMA and NAMEM

Climate projections

The future climate is highly dependent on the global GHG emission trajectories. Coupled Model Intercomparison Projects (CMIPs) are applied to improve the understanding of the interactions between the natural and social systems[5]. SSPs are defined to represent different climate policy choices at global scale impacting GHG emissions pathways. They are used in climate models to translate them into responses of the climate system globally, at national and subnational level.

In course of this project, GIZ (2025a) derived the probabilities of occurrences by intensity of the main climate hazards in Mongolia for SSP1-2.6, SSP2-4.5 and SSP5-8.5 scenarios. In general, climate hazards will occur more

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

frequently and more severely in the future. However, the frequency will not grow steadily which can be in particular observed for dzuds (Figure 15).

On average (2025-2050), floods will occur every two (low hazard intensity), three (medium hazard intensity) to 12 to 18 years (high hazard intensity). Dzuds are expected every four (low hazard intensity), six (medium hazard intensity), and 14 to 26 years (high hazard intensity). However, specifically dzuds the frequency is highly volatile over the coming decades while for droughts the frequency is broadly stable.

The frequency for the climate hazards between the SSP scenarios is similar for droughts but different for floods, heatwaves and dzuds. There is a tendency that the probability of occurrence of climate hazards is greater in SSP scenarios with higher warming potential due to higher emission pathways, e.g. SSP5-8.5 compared to SSP1-2.6 (GIZ 2025a). In contrast, the probability of dzuds is greater under SSP1-2.6 compared to SSP5-8.5 (Figure 15).

Overall, in all SSPs, the climate hazards under consideration will occur more often in the future compared to the baseline period of 1981 to 2010, which highlights the importance of taking adaptation actions in Mongolia.


Drought SSP1-2.6
Drought SSP2-4.5
Drought SSP5-8.5
0.0
0.1
0.2
0.3
Dzud SSP1-2.6
Dzud SSP2-4.5
Dzud SSP5-8.5
0.0
0.1
0.2
0.3
0.4
0.5
0.6
Flood SSP1-2.6
Flood SSP2-4.5
Flood SSP5-8.5
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
Baseline (1981-2010)
2026
2029
2032
2035
2038
2041
2044
2047
2050
Low
Medium
High

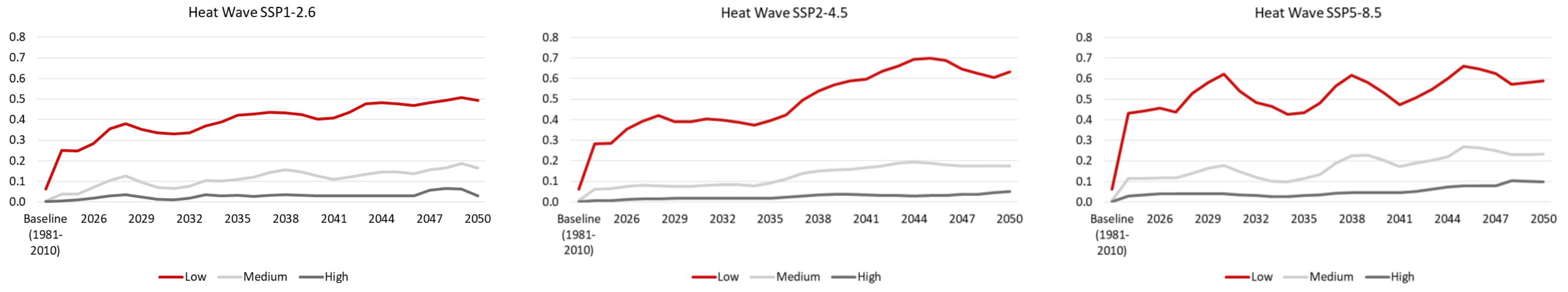


Figure 15: Probability of occurrence by intensity (low, medium, high) for dzuds, droughts, heatwaves and floods under SSP1-2.6, SSP2-4.5 and SSP5-8.5 scenario

Source: GIZ (2025a)

4.2 Sector impacts

As outlined in the previous section, Mongolia is heavily impacted by climate change in the past which is expected to continue in the future. Thus, climate change impacts are likely to amplify and hamper economic growth and people's life.

To better understand possible future impacts, the impacts of the past and as of today are explored. The damage resp. impact data collection of climate hazards and exchanges with local experts reveals that agriculture, forestry, energy and water sectors as well as human health are mostly and directly affected from key climate hazards in Mongolia (WBG & ADB 2021; USAID, 2017, 2022, Chepelianskaia & Sarkar-Swaisgood 2022). However, also other sectors are either directly and / or indirectly affected such as industrial sectors as well as building and transport infrastructure.

Table 4 summarizes exemplary impacts from key climate hazards on the economic sectors which are manifold and differ with respect to the kind of impact, e.g. infrastructure damages, labour productivity losses or price effects. Some economic sectors are affected by more than one climate hazard such as agriculture.

The vulnerability of a sector depends on the intensity of a hazard and the preparedness of the sector. Additionally, the regional occurrence of a climate hazard determines the size of the impact: while drought, heatwaves and dzuds often affect a large area, heavy rain occurs more locally. In economically strong and / or populous regions, the damage of e.g. floods is expected to be greater than in regions with less people and infrastructure. With the highest population density, offering homes for around half of the Mongolian population, Ulaanbaatar is especially exposed to floods destroying houses, cars, roads and other infrastructure (CAREC 2022; Narangerel & Suzuki 2024).

The livelihood of people is also affected by climate change which threatens the quality of drinking water, food security and implies heat stress especially in urban areas, the so-called heat island effect (USAID 2022). Moreover, jobs are at risk, for example in traditional pastoralism. Consequently, people migrate to the cities to find new jobs, but new challenges arise, for example, unplanned settlements around Ulaanbaatar (IFRC 2021).

To better understand the magnitude of climate change affects, quantified information on the different impacts is essential. So far, there is no systematic and harmonized data collection on the sectoral impacts of climate hazards publicly available. With the support of NEMA and NAMEM, available data was collected and compiled in one Excel database ("MNG_ClimateDamageImpactDatabase.xlsx") which records the following information, if available, to get a better overview:

- Date,
- Subnational region,
- Kind and intensity of climate hazard,
- Physical description of impact / damage (e.g. damaged buildings, yield loss, died animals),
- Quantification of sectoral damage,
- Number of affected people

The subsequent paragraphs summarise the reported, quantified and monetized impacts associated with past climate hazards on key economic sectors.

Table 4: Exemplary climate impacts by economic sectors from relevant climate hazards in Mongolia

Impacted economic sector	Dzuds	Heat waves	Floods	Droughts
Agriculture	Reduced pasture productivity Killed animals	Increased water demand Reduced pasture productivity Harvest losses	Killed animals Soil erosion	Reduced pasture productivity Harvest losses Increased water demand
Mining		Increased water demand	Flooded underground mines reducing production potential	Increased water demand
Energy		Decreased hydropower generation Lower power generation capacity from thermal power plants Increased cooling demand	Damaged infrastructure (poles, coal storage facilities, transmission lines)	Decreased hydropower generation Lower power generation capacity from thermal power plants
Road transport		Deterioration of road surface asphalt Expansion of bridge joints and railway tracks	Wash out of road surfaces Damage to the railway network Blocked roads and tunnels	
Water		Reduced water quality Bacterial water pollution	Contamination of underground water	Water shortages
ICT		Reduced efficiency of wireless transmission	Damaged infrastructure	
Tourism	Biodiversity loss	Biodiversity loss		Biodiversity loss
Health	Micronutrient deficiencies	Increased health expenditures Risk of zoonotic, mosquito-borne or tick-borne diseases Malnutrition	Injured persons Increased mortality Water-borne diseases	Micronutrient deficiencies
Cross-sectoral		Labor productivity losses	Impaired production due to power outages	

Sources: e.g., Chepelianskaia & Sarkar-Swaisgood (2022), IFRC (2021), Fan (2020)

Agriculture is a key sector of Mongolia although the share in GDP is steadily declining to 7% in 2024 but increasingly contributing to exports (8% in 2022, NSO 2025, ADB 2023). This sector covers 26% of total employment, mainly population living in rural areas (MET 2024, ADB 2024a).

Climate change is heavily impacting agriculture through water scarcity, extreme heat and extreme cold. Desertification and declining pasture productivity affect livestock herding. Additionally, the overuse of the pasture through an increased number of goats and sheep, for example, accelerates degradation of pastureland. While dzuds cause immense losses to livestock, droughts and heatwaves reduce crop production potential because only 7% of agricultural land is irrigated (FAO 2024a). Based on the data collection, the recorded monetized crop losses range from one to nine Mn. MNT per event. Compared to the monetized livestock losses (see below), the impact is smaller due to the limited suitability of arable land in Mongolia. Crops production is mainly in northern central Mongolia (MET 2024).

Dzuds have a severe impact on livestock mortality which reaches 16% in 2000/2001, 23% in 2009/2010 and 11% in 2023/2024 (FAO 2024b, c). The dzud events of 2000–2002, 2009/2010 and 2023/2024 together caused more than 27 Mn. dead animals (Rao et al. 2015, MET 2024) which has a severe impact on the agricultural sector as 83% of agricultural production stems from herding activities, while vegetable and crop production only make up 17% (MET 2024). Meat and other animal products are important export goods, while crops and vegetables are imported to ensure food security (MET 2024). As a consequence of the dzud in 2009/2010, the GDP declined by 4% (ADRC 2022, UNDRR 2019, Chepelianskaia & Sarkar-Swaisgood 2022). Moreover, many nomadic families lost their income, leading to growing poverty and migration (MET 2024).

Mining is another major sector contributing to 27% of GDP in 2024 (NSO 2025), accounting for 60% of all exported goods and employing almost 6% of all employed persons (ADB 2023, 2024a).

The mining sector is affected by climate change due to its high-water intensity (MET 2024). Mines are often located in regions with low water availability such as the Gobi Desert relying on groundwater or located close to rivers such as the Tuul river (WBG 2024). Their risk of being flooded increases due to melting glaciers in the Altai Mountains or due to river floods (Serdyanjiv et al., 2024).

Energy and water sector account for less than one percent of GDP but the availability of energy and water is of high importance as they supply households and companies. Droughts and heatwaves imbalance supply and demand of energy and water. On the one hand, they constrain energy production due to insufficient (cooling) water for CHP and to a limited extent hydro power plants. Until 2059, the IEA (2021) expects a mean hydro power capacity factor[6] in South and Southeast Asia that is up to 5.2% lower compared to the past. Similar results are reported in van Vliet et al. (2016) for hydropower and thermoelectric power in Europe.

On the other hand, during those events, demand for water and energy is high. The water demand in agriculture, mining and of the people increases (Chepelianskaia & Sarkar-Swaisgood 2022). The same is true for the cooling needs of the people and for technical equipment. According to WBG & ADB (2021), an increase of one percent in ambient temperature can result in 0.5% to 8.5% higher cooling demand in the residential and service sectors. The imbalance of supply and demand may also increase prices.

Moreover, floods can damage energy and water infrastructure, causing blackouts and lack of water which interrupts production processes and thus leading to additional losses. In the past, the average annual loss from floods was estimated at 24 Mn. USD (CAREC 2022) which is approx. 0.15% of nominal GDP.

Similar impacts could happen if the **transport** infrastructure and buildings are damaged either by floods, melting permafrost or from extreme heat (Chepelianskaia & Sarkar-Swaisgood 2022). Damage to infrastructure such as roads, bridges, and buildings is mainly observed from floods and accounts for up to 33 Bn. MNT resp. 9.5 Mn. USD such as the river flood in 2023 (Narangerel & Suzuki 2024, p. 697). A minor share of the total damage is attributed to the agricultural sector, damaged cars, gers and household equipment. Additional losses may arise

[6] The capacity factor is the ratio of the actual electricity generation p.a. over the maximum possible electricity generation per year.

due to higher costs from using other transport modes, delivery delays, or due to the lower capacity utilization (Schattenberg 2023).

Human health is mainly indirectly affected by climate change. Water scarcity can lead to a decline of drinking water and water quality, potentially causing waterborne diseases (MET 2024, USAID 2022). Increased food scarcity may lead to malnutrition. Rising temperatures may also facilitate the spread of infectious diseases (World Bank 2024c). Extreme cold, extreme heat and floods have a direct impact on the people causing heat strokes, frostbite, and injuring people.

Many sectors of the economy are vulnerable to heat-related labour productivity losses which are assumed to decline due to heat stress between -0.2% (RCP2.6) and -0.4%(RCP8.5) until 2050 (Climate Analytics n.d.). In especially outdoor workers in agriculture and construction are affected.

5. Macroeconomic analysis of key climate hazards

This chapter analyses three climate change scenarios (SSP1-2.6, SSP2-4.5, and SSP5-8.5) and their economy-wide effects on economic growth, employment, and environmental indicators. Building on the introduction in section 2.2.2, the future developments of the main climate hazards under different climate change scenarios (cf. section 4.1) and their observed benchmark impacts on various economic sectors (section 4.2) – based on past observations – are combined to evaluate the impacts on the three Es (economy, energy system and emissions).

According to exchanges with national climate experts and additional desk research, the most relevant climate hazards that impact Mongolian people and the key economic sectors either directly or indirectly are dzuds, floods, heatwaves and droughts (MET 2024; CAREC 2022; Han et al. 2021; WBG & ADB 2021). The impacts of these climate hazards are jointly examined with the e3.mn model to detect nation-wide impacts.

5.1 Scenario settings

This section provides a summary of the assumptions underlying the three climate scenarios. The benchmark impacts outlined in Table 5 serve as the foundation for all scenarios. The probability of climate hazards occurring at varying intensities differs across the three SSP scenarios, as illustrated in Figure 15. Most climate hazards will occur even more frequently and more severely. In general, less severe or intense climate hazards are expected to happen more often than those with high intensity (GIZ 2025a). It must be noted that the probability of occurrence for the climate hazards for all intensities does not increase steadily but is highly volatile during the simulation period except for droughts.

The sectoral benchmark damages applied in the scenarios are derived through two primary methods: a "bottom-up" approach, which involves gathering data from media, websites, and other sources, or through macroeconomic analyses conducted under various climate scenarios (e.g., Climate Analytics). Based on this data and information (as detailed in section 4.2), the key climate hazards primarily affect agriculture, energy, water and infrastructure (see Table 5). However, the impacts of these climate hazards vary significantly across different economic sectors:

Dzud events mainly impact livestock which has a share of 83% of total agriculture production (MET 2024). The benchmark damage from severe dzud events is set to 191 Mn. USD which is lower than the most severe dzud in 2009 / 2010 equalling 390 Mn. USD but greater than the dzud impact in 2000/2001 with 145 Mn. USD and the dzud in 2017 with 40 Mn. USD (ADRC 2022, p. 9, 22). Additionally, during dzuds an increased fodder demand can be observed (and approximated from the intermediate demand in IO tables) which increases costs and prices for livestock products.

Major damage occurs also during **flooding,** especially in densely populated areas such as Ulaanbaatar. Less severe events occur more often than the very severe events, but the reported damage is lower. On average, the benchmark damage from high intensity flood events is estimated at 5.4 Mn. USD and the benchmark damage from medium intensity flood events is estimated to be 0.4 Mn. USD. Damages from low intensity events are not reported. Based on the "bottom-up" damage data collection, the reported damages vary highly depending on the region they occur.

The damage to the infrastructure impairs production, which leads to increased imports and lower exports, depending on the industry affected. The average annual loss from floods was estimated to be approx. 0.15% of nominal GDP. This benchmark is used for medium intensity flood events and reduced to 0.08% resp. increased to 0.3% for low resp. high intensity events.

Drought impacts are visible in crop losses but also in deterioration of pasture conditions preventing livestock from gaining weight. Recorded economic losses in agriculture range from one to nine Mn. MNT per event all attributed to high intensity droughts according to the "bottom-up" damage data collection. The benchmark damage was set to 5 Mn. USD. Due to insufficient precipitation, water demand increases in those agricultural areas which have irrigation systems installed. The changes in water demand of agriculture during drought events can be approximated from the IO tables.

The energy sector is also affected by lower water levels. Energy generation capacity from hydro power is set to 5.2% less compared to the past for high intensity events. For low (medium) intensity heatwaves, the generation potential was reduced to -3.9% (-4.6%). Energy supply from CHP plants during droughts is assumed to be -3.8% (-4.7%) lower for low (medium and high) intensity events as of today.

Heat waves have consequences for many sectors: The energy sector is simultaneously affected through limited energy generation from hydro power and CHP (see above) and increased electricity demand. It is assumed that the cooling demand in the residential and service sectors increases by 0.5% during low intensity events up to 8.5% for high intensity events.

The agriculture sector, in particular crop production, is expected to show an increase in water demand during heatwaves (similar to drought impacts). Moreover, the temperature increase will lead to a decline in crop production estimated at 3 Mn. to 12 Mn. USD with a temperature increase of 1.5°C resp. 3°C (Mendelsohn 2014). Thus, for the three SSP scenarios the following crop losses are associated with 8 Mn. USD under SSP1-2.6, 12 Mn. USD under SSP2-4.5, and 48 Mn. USD under SSP5-8.5.

Average labour productivity declines due to heat stress between -0.2% (RCP2.6) and -0.4% (RCP8.5) until 2050 (Climate Analytics n.d.). The more physically intensive (less intensive) the work in a sector is the greater (lower) the loss in labour productivity compared to the average. The productivity losses mean lower sectoral production without heat-related layoffs.

Not all impacts of climate hazards are captured, neither in monetary terms nor in physical measurements. As a result, the macroeconomic assessment of climate change is confined to those impacts that have been quantified. Furthermore, the benchmark impacts are approximations and should be further evaluated against evidence.

Table 5: Quantifiable benchmark impacts from main climate hazards in Mongolia

	Agriculture	Energy	Infrastructure	Water	Cross-sectoral
Droughts	• Average crop losses per event in agriculture (5 Mn. USD)	• Lower capacity factor for hydro power (-3.9% to -5.2%) • Limited energy supply from CHP plants due to insufficient cooling (-3.8% to 4.7%)	• -	• Increased water demand in agriculture	• -
Sources	• MNG_ClimateDamageImpactDatabase.xlsx	• IEA (2021) • van Vliet et al. (2016)	• -	• IOT 2007-2022 from ADB	-
Dzuds	• Average livestock losses per event 191 Mn. USD • Increased fodder demand	• -	• -	• -	• -
Sources	• MNG_ClimateDamageImpactDatabase.xlsx • IOT 2007-2022 from ADB	• -	• -	• -	• -
Heatwaves	• Average crop losses (8 to 48 Mn. USD)	• Lower capacity factor for hydro power (-3.9% to -5.2%) • Limited energy supply from CHP plants due to insufficient cooling (-3.8% to 4.7%) • Additional cooling demand: 0.5% to 8.5% per	• -	• Increased water demand from agriculture	• Average labour productivity losses due to heat stress (-0.2 to -0.4 by 2050)

		1°C change in ambient temperature			
Sources	Adopted from Mendelsohn (2014)	• IEA (2021) • van Vliet et al. (2016) • WBG & ADB (2021)	• -	• IOT 2007-2022 from ADB	• Climate Analytics (n.d.)
Floods	• -	• -		• -	• Average damage to infrastructure per event 0.4 Mn. to 5.4 Mn. USD • Average annual losses of 0.08% to 0.3% of GDP
Sources	• -	• -		• -	• CAREC 2022

Source: Based on data collection during CRED I (GIZ 2023a) and data updates during this project (MNG_ClimateDamageImpactDatabase.xlsm)

5.2 Results for SSP5-8.5

In this scenario, all key climate hazards (dzuds, droughts, floods and heat waves) with their respective probabilities of occurrences and intensities under the SSP5-8.5 scenario as well as the benchmark damages are combined and implemented into the e3.mn model and causes reactions in the E3 modelling system.

The combined effects of those climate hazards result in a real GDP growth path which is up to 4% lower compared to the baseline scenario (Figure 16). The volatility over the simulation period is subject to the frequency of climate hazards. The greater the probability of occurrence, the greater the impact per year.

Exports decelerate and are up to 4.3% lower compared to a hypothetical scenario without climate change (baseline scenario) due to the negative impacts on agriculture and mining in particular. Export losses in trade and transport sectors occur due to damaged and destroyed infrastructure (mainly roads and buildings).

Imports are affected by countervailing effects: on the one hand, imports accelerate if production capacities are constrained, for example due to labour productivity losses during heat waves, damaged infrastructure from flooding and died animals during dzuds. In this sense, imports compensate for the production losses during the year to satisfy the demand, depending on the duration of the production interruption, but this was not considered in this scenario. On the other hand, due to the high import dependency in many sectors, imports are offset by decelerating GDP resulting in up to 3.6% less imports compared to the baseline scenario.

With lower employment and income compared to the baseline scenario, household and NPISH consumption is limited, and investments decelerate following GDP.

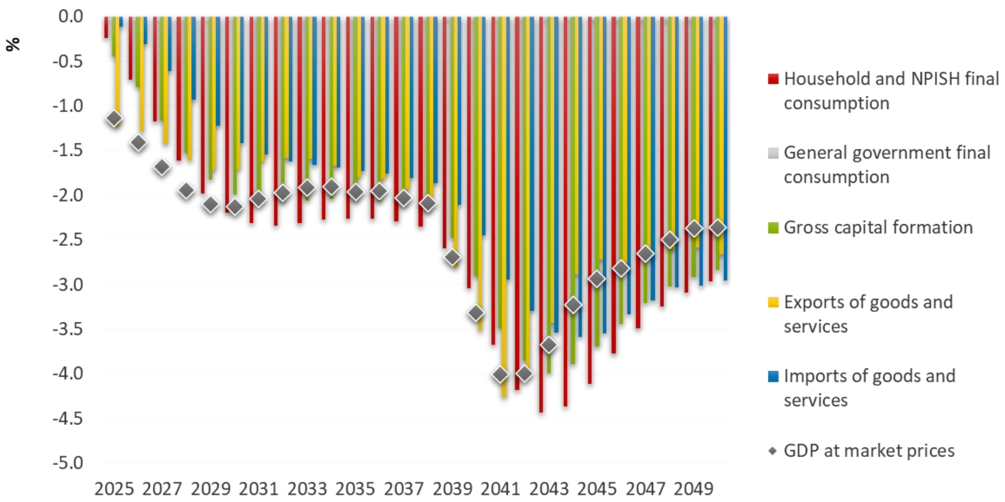


Figure 16: SSP5-8.5 scenario: Macroeconomic effects, 2025–2050, deviations from a hypothetical "No climate change" (baseline) scenario in percent

Source: Own illustration based on e3.mn results

Sectoral production follows macroeconomic development resulting in 2% resp. close to one billion USD less in 2050 (Figure 17). The magnitude of the impacts varies for the economic sectors and during the simulation period until 2050. The latter depends on the probability of the occurrence of climate hazards. Overall sectoral output is at max. 3% lower compared to the baseline scenario.

Production in agriculture is highly impacted (-3.7% resp. 104 Mn. USD in 2050), followed by construction (3% resp. 114 Mn. USD) and private services (2.7% resp. 308 Mn. USD). While agriculture is directly affected by climate hazards, the other sectors mentioned previously are not only impacted directly, even more indirectly and due to income-induced effects. Although reduced labour productivity has an impact on many sectors, especially those with outdoor activities, this effect is limited according to Climate Analytics (n.d., max. -0.5%). Less household consumption and investments have an impact on service demand and construction activities. The greater demand for fodder, water and cooling needs are overcompensated by the less strong economic development.

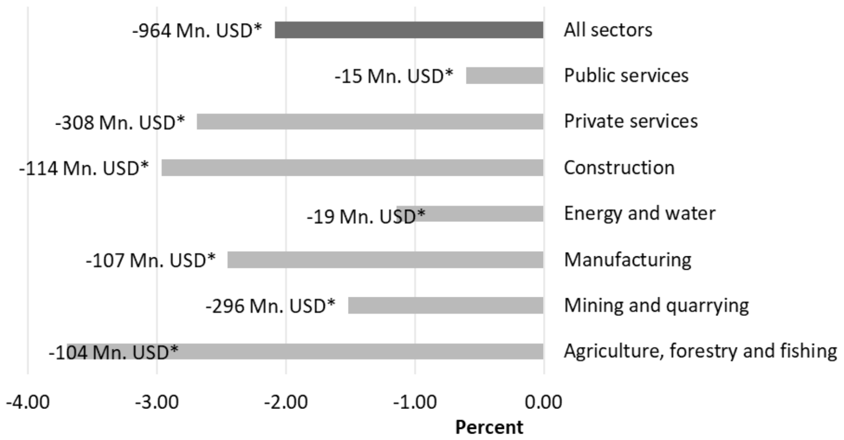


Figure 17: SSP5-8.5 scenario: Gross production by economic sectors in constant prices, 2050, deviations from a hypothetical "No climate change" (baseline) scenario in percent (x-axis) and Mn. USD(*)

Source: Own illustration based on e3.mn results

Sectoral employment follows the sectoral economic activity and their respective labour productivity. Although no heat-related suspension of staff is assumed, the aforementioned negative production effects have an impact on employment as well. As shown in Figure 18, the private service sector (incl. trade and transport) is impacted the most (up to 3.8% resp. 20 thousand persons), followed by agriculture (up to 4.5% resp. 10 thousand persons). Total employment decelerates and is up to 3% resp. 45 thousand persons lower compared to the baseline scenario.

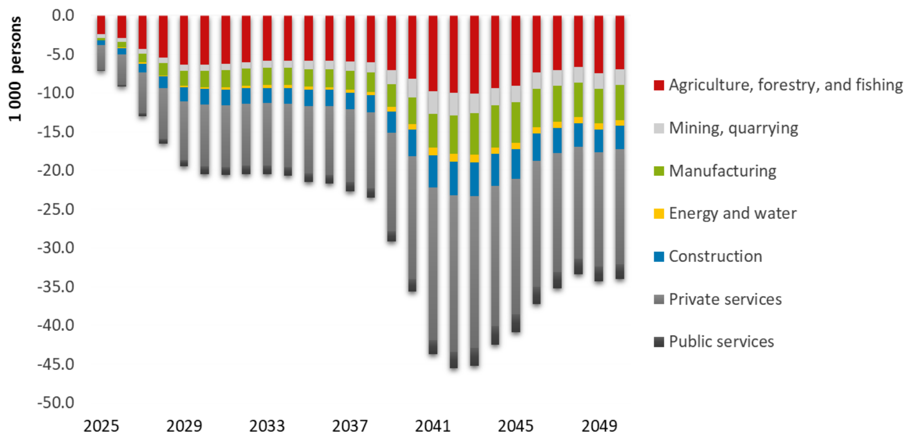
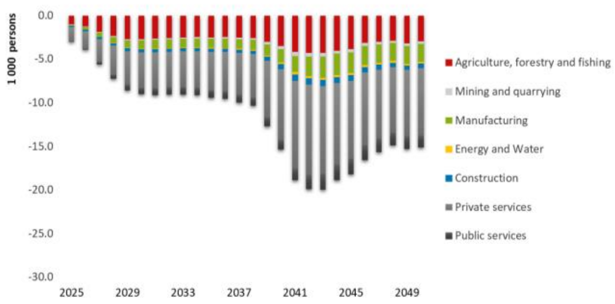


Figure 18: SSP5-8.5 scenario: Employment by economic activities, 2025–2050, deviations from a hypothetical “No climate change" (baseline) scenario in 1 000 persons

Source: Own illustration based on e3.mn results

Looking at female and male employment separately reveals that male workers (26 thousand resp. 3.1%) are more affected than female workers (20 thousand resp. 3%) under this scenario (Figure 19). Male workers dominate in construction and “Mining and quarrying”. They also have a greater share in “Agriculture, forestry and fishing” and manufacturing. Contrary, females dominate in private and public service sectors.



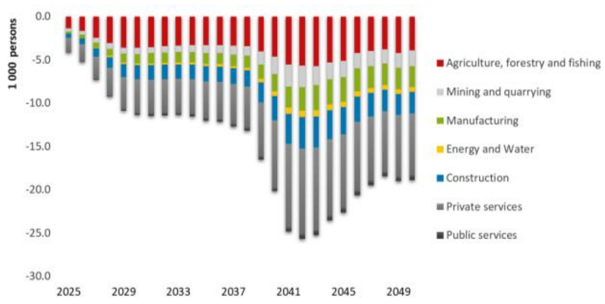


Figure 19: SSP5-8.5 scenario: Employment by economic activities and gender (female: left figure, male: right figure), 2025–2050, deviations from a hypothetical “No climate change" (baseline) scenario in 1 000 persons

Source: Own illustration based on e3.mn results

The limited economic growth results in lower final energy demands which in total is 2.9% resp. 19 PJ. Depending on the sectoral economic activity and sectoral energy intensity, final energy demand by sectors decelerates (Figure 20). “Other consumption n.e.c”, “Agriculture, forestry and fishing” and “Commerce and public services” are up to 3.3% to 3.5% lower. All other sectors show a smaller decline. Households increase their energy demand slightly due to additional cooling needs. In absolute terms, final energy demand decelerates the most in “Other consumption n.e.c” resulting in up to 14 PJ less energy use. All other sectors reduce energy use by less than 2 PJ per year.

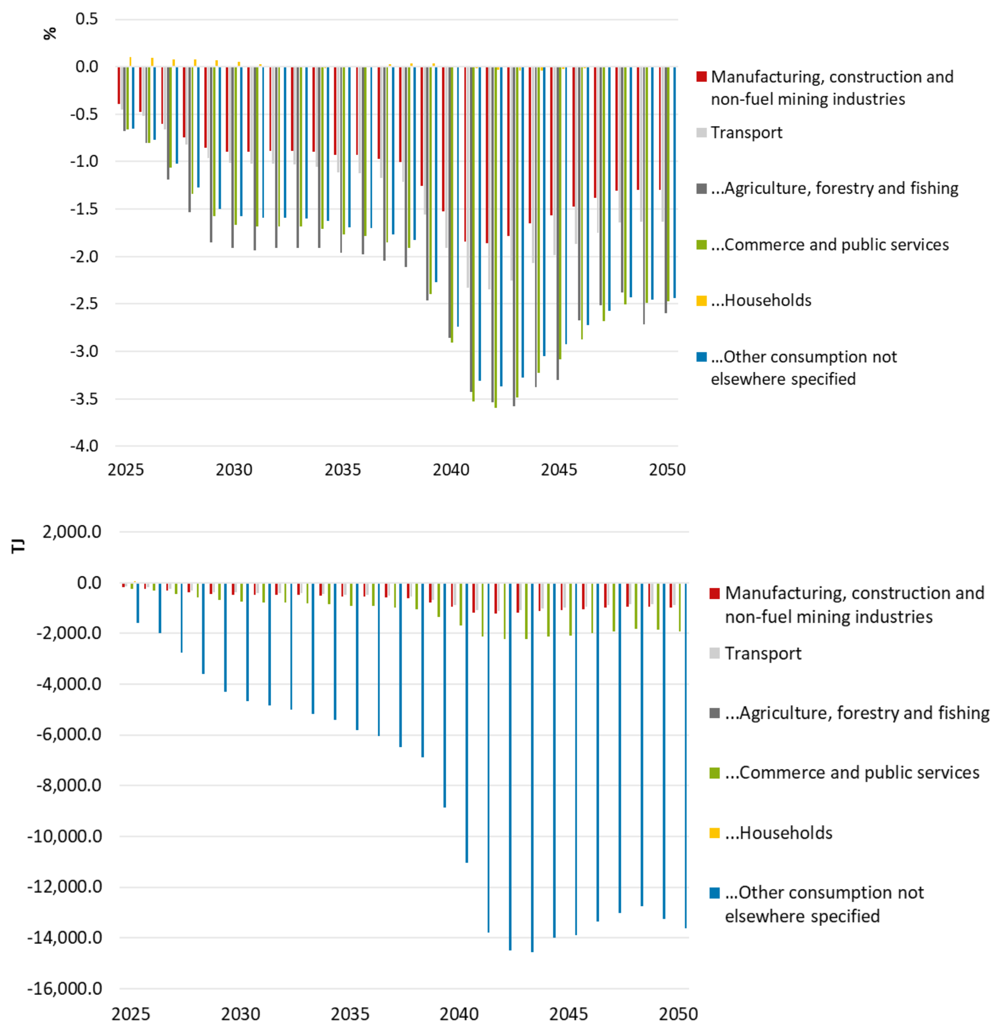


Figure 20: SSP5-8.5 scenario: Final energy demand by sectors, 2025–2050, deviations from a hypothetical "No climate change" (baseline) scenario in percent (top figure) and TJ (bottom figure)

Source: Own illustration based on e3.mn results

Due to less final energy demand, less fuels are needed for energy production such as heat and electricity. The slightly increased electricity demand during heatwaves is offset by lower energy demand needed during production processes.

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 increased electricity generation in electricity plants using oil products as long as capacity is sufficient. Otherwise, electricity must be imported to satisfy the demand which is not presumed in this scenario. However, oil products needed for electricity generation are imported.

All sectors decelerate fuel combustion-related GHG emissions due to limited economic growth and energy demand resulting in lower GHG emissions (-4.2% resp. 1.5 Mt CO_2e, Figure 21).

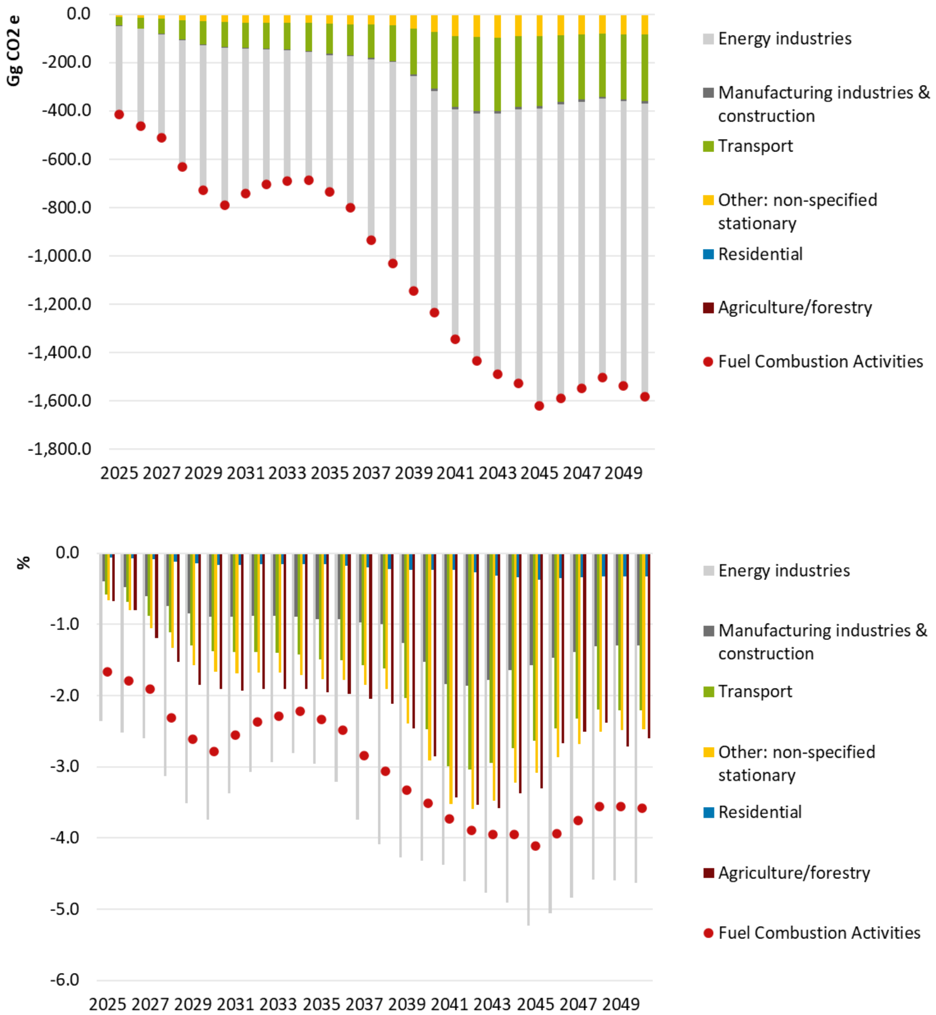


Figure 21: SSP8-8.5 scenario: GHG emissions, 2025- 2050, deviations from a hypothetical "No climate change" (baseline) scenario in Gg CO_2e (top figure) and percent (bottom figure)

Source: Own illustration based on e3.mn results

5.3 Comparative analysis of the macroeconomic effects for SSP1-2.6, SSP2-4.5 and SSP5-8.5

The comparative representation of the three SSP scenarios and their economy-wide impacts show differences driven by the frequencies and intensities of dzuds, floods, droughts and heatwaves (Figure 22). As shown in Figure 15, droughts at all three intensity categories (low, medium and high) are expected to occur more or less with the same frequency and intensity. For all other climate hazards, they differ in particular when comparing the three decades or single years between the SSPs.

In general, heatwaves show an increased probability of occurrence with global temperature increase (SSP1-2.6 to SSP5-8.5). The volatility of the frequency is quite high over the simulation period under SSP5-8.5. SSP1-2.6 and SSP2-4.5 show a steadier increase over time but accelerating under SSP2-4.5 starting from 2035.

For floods, the frequency under SSP1-2.6 is broadly stable over time but in contrast to the other SSPs higher at the beginning of the simulation period. Under less global climate protection ambitions (SSP5-8.5), the frequency increases starting in 2035 but decelerating again in the last decade. Under SSP2-4.5 flood frequency accelerates starting in 2030.

For dzuds, the frequency is extremely volatile esp. under SSP1-2.6. This scenario shows also the highest probabilities. Overall, the probability of dzuds (max. 0.59 p.a.) is greater than for droughts (max. 0.22 p.a.), but smaller than for heatwaves (max. 0.7 p.a.) and floods (max. 0.82 p.a.).

The implications for the macroeconomy and the economic sectors are greatest for the SSP5-8.5 which show a worsening impact on GDP until 2040 reaching -4% in real GDP compared to a hypothetical situation without climate change (Figure 22 upper left). Floods in particular cause direct damage to infrastructure and, as a result, economic losses in various other sectors, leading to even worse macroeconomic impacts. Due to the higher frequency of dzuds and floods under SSP1-2.6 compared to SSP2-4.5, the effects are higher under SSP1-2.6 (Figure 22 bottom left).

The direct impacts from climate change can be seen in particular for agriculture and mining. Other sectors such as private services (including trade and transport) and construction suffer from indirect and income-induced effects.

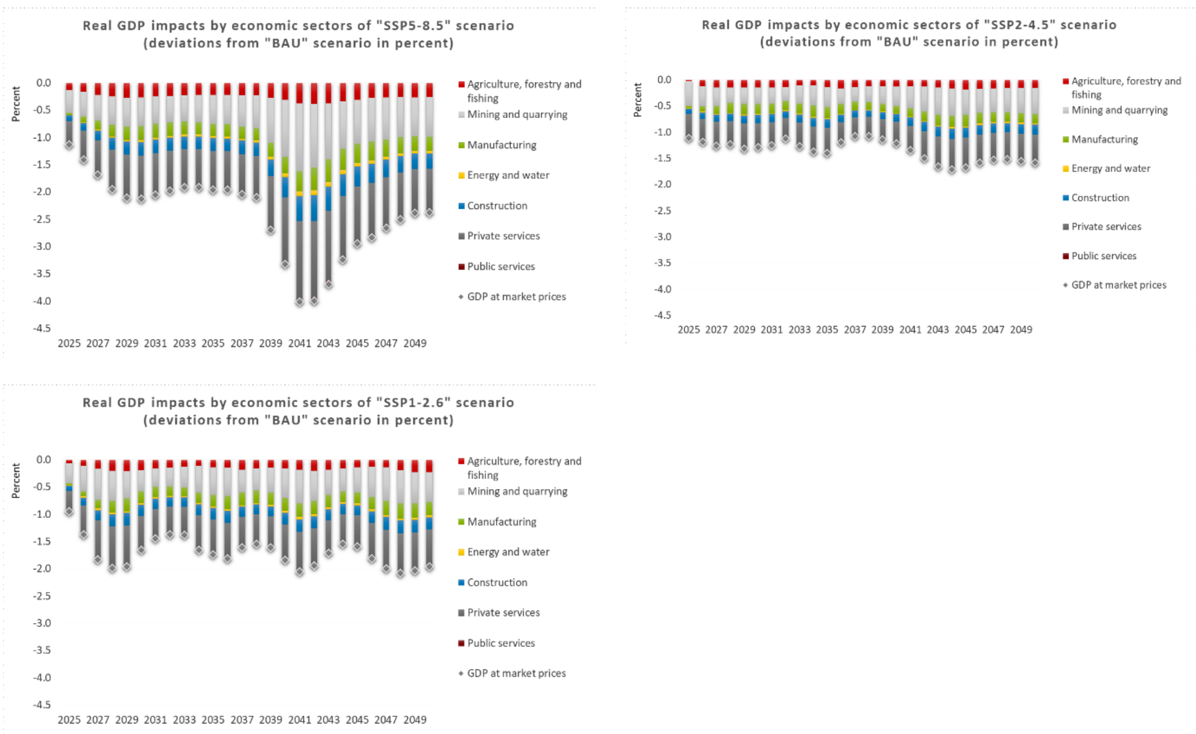


Figure 22: *SSP1-2.6, SSP2-4.5 and SSP5-8.5 scenarios: Real GDP impacts by economic sectors, 2025–2050, deviations from a hypothetical "No climate change" (baseline) scenario in percent*

Source: Own illustration based on e3.mn results

In summary, climate change significantly affects key economic sectors, threatening food, water and energy security. Exports are restricted, and disrupted production processes in Mongolia lead to higher imports, increasing reliance on other nations. Beyond economic challenges, the population suffers. To safeguard both the Mongolian people and the economy, the government should take proactive measures to mitigate recurring climate hazards, thereby reducing the need for repeated spending on damage control.

Under the given probability of occurrences for dzuds, floods, heatwaves and droughts, the lowest economic impact is expected for scenario SSP2-4.5, followed by SSP1-2.6 which assumes global climate protection activities and thus lower GHG emission concentrations in the atmosphere. Both scenarios show lower economic activity which fluctuates at around -1.5% (SSP2-4.5) resp 2% p.a. (SSP1-2.6, Figure 22 top right and bottom left). The macroeconomic results for the SSP5-8.5 scenario are even more negative.

Regarding the GDP impacts, the results for SSP 5-8.5 are within the range of other studies analysing the economic effects of climate change (Table 6). For SSP2-4.5 (SSP1-2.6), the GDP impacts are smaller (greater) which is mainly driven by the fact, that the frequency of dzuds and floods is less in SSP2-4.5 compared to SSP1-2.6.

Table 6: GDP per capita losses in % in 2050

Source	SSP1-2.6	SSP2-4.5	SSP5-8.5
Kahn et al. (2019)	-0.35%	-	-2.1% to -4.2%
Waidelich et al. (2024)	-	-2.6%	-4.6% to -5.4%

Source: Kahn et al. (2019), Waidelich et al. (2024)

Key results of comparing all SSP scenarios with the baseline scenario for 2050 are shown in Figure 23. The more pronounced the impacts on GDP and economic sectors, the more significant the consequences for employment, total final energy demand, and GHG emissions. From a gender perspective, climate change impacts male and female employment broadly equally.

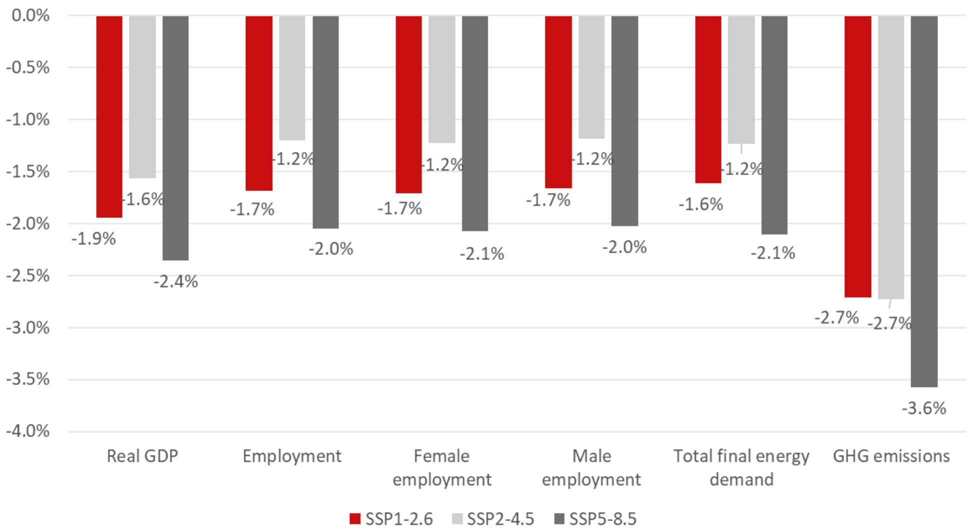


Figure 23: SSP1-2.6, SSP2-4.5 and SSP5-8.5 scenarios: Key impacts, year 2050, deviations from a hypothetical "No climate change" (baseline) scenario in percent

Source: Own illustration based on e3.mn results

6. Macroeconomic analysis of climate change adaptation

Mongolia faces significant vulnerability to climate change, particularly from dzuds, droughts, floods, and heatwaves, which affect key sectors, as mentioned in the previous section.

As climate change intensifies and becomes even more frequent, it is important for Mongolia to take appropriate adaptation actions. In collabouration with Mongolian experts, relevant options have been identified and evaluated by first conducting sector-specific CBAs.

The CBA results were then fed into the e3.mn model to examine the economy-wide impacts of the underlying adaptation option (see sections 6.1 to 6.4). The great advantage of such macroeconomic analyses is that both the direct and indirect, sometimes unwanted feedback effects can be revealed for the macroeconomy and specific economic sectors. Decision makers are then enabled to focus on measures that are highly effective and show positive impacts on the economy, employment and the environment (win-win-options).

6.1 Investing in drip irrigation to increase resilience of crops

In Mongolia, approximately one percent resp. 1.1 Mn. ha of total agricultural land (112 Mn. ha) is used as cropland mainly for temporary crops (FAO 2024a). In total, arable farming accounts for 17% of agricultural output and approx. 70% of food products are imported into Mongolia (MET 2024). To reduce the import dependency on various non-animal food products policy measures are aiming at increasing local arable farming.

At the same time, droughts and heat waves cause crop yield losses due to water scarcity, increase harvest instability and overall limit the growing season. Irrigation of agriculture accounts for 30% of water consumption (WBG 2024) although only seven percent of cropland area is currently irrigated (FAO 2024a). Thus, most of the cropland is rain-fed which indicates that crops are highly dependent on climate and weather conditions (IFRC 2021, MET 2024). With increased frequency and intensity, climate hazards will cause higher economic losses in agriculture, affecting jobs and food security.

Adaptation measures reduce vulnerability to climate change and safeguard farmers from crop losses. There are various options such as drought-resistant crops, drip irrigation, minimal resp. no tillage to improve soil fertility and moisture as well as to reduce degradation and erosion of agricultural land (GIZb 2025, MEGD 2013, MET 2024).

This scenario analyses the economy-wide impacts of the expansion of drip irrigation measures including eco-synthetic film coverage to prevent water scarcity and to improve agricultural productivity under climate change scenarios.

6.1.1 SCENARIO SETTINGS

The scenario settings rely on a CBA conducted within the framework of the Mongolian Nationally Determined Contribution Action Plan (NDCAP, see NCC 2021). According to this, drip and permeable irrigation systems are planned to be introduced for a total of additional 290 000 ha. The implementation period is set for 2026 to 2030 (Table 7). Total investment adds up to 235 Bn. MNT. After the implementation period, costs for operation and maintenance amount to 98 Bn. MNT per year. The investment costs are presumed to be paid by international donors. Once the adaptation measure is fully realized, agricultural production is expected to increase by 502 Mn. USD per year.

Table 7: Assumptions on costs and benefits for "Drip irrigation (DI)"

Costs and benefits	2026	2027	2028	2029	2030
Cumulation of additional irrigated area (1 000 hectares)	58	116	174	232	290
Investment in drip irrigation, eco-synthetic film coverage etc. (Mn. MNT per 100 hectare)	81	81	81	81	81
Operation and maintenance costs p.a. (Bn. MNT)	20	39	59	79	98
Increased agricultural production p.a. (Bn. MNT)	100	201	301	402	502

Source: CBA conducted for the Green Climate Fund (GCF) funded UNEP/MET implemented project "Building Capacity to Advance National Adaptation Plan Process in Mongolia", see also NCC (2021)

Regarding the costs and benefits of this adaptation option, it is presumed that they have been specified under the assumption of a SSP5-8.5 scenario being more severe with respect to GHG emission concentration and temperature increase. Assumptions regarding benefits given the same investments (costs) must therefore be adjusted for the SSP1-2.6 and SSP2-4.5 scenario.

The benefits are adjusted by reflecting the frequency of droughts under the three SSP scenarios. According to this, droughts are less frequent (-4% resp. -17%) in SSP2-4.5 resp. SSP1-2.6 compared to SSP5-8.5 (Table 8) which is interpreted as being beneficial for crop production.

Table 8: Benefit adjustments for "DI" under different climate scenarios

Adaptation benefit	SSP1-2.6	SSP2-4.5	SSP5-8.5 (basis for CBA)
Increased agricultural production	117%	104%	100%

Source: Own assumptions

6.1.2 MODEL RESULTS UNDER SSP5-8.5

The expansion of drip irrigation systems and eco-synthetic film coverage has positive impacts on the economy as shown in Figure 24. Real GDP is accelerating and is up to 0.6%, resp. 270 Bn. MNT higher compared to a situation without this adaptation action and climate change (SSP5-8.5). During the implementation period of drip irrigation systems, economic growth is supported by the necessary investments (up to +0.6% p.a.) and the steadily increasing additional yields in agriculture (cf. Table 7). After the full expansion of additional drip irrigation systems (until 2030), the full benefits can be achieved, which provide additional export chances (up to +0.4% p.a.) and lower agricultural imports. Operation and maintenance activities occur also after the implementation period with positive impacts on economic growth.

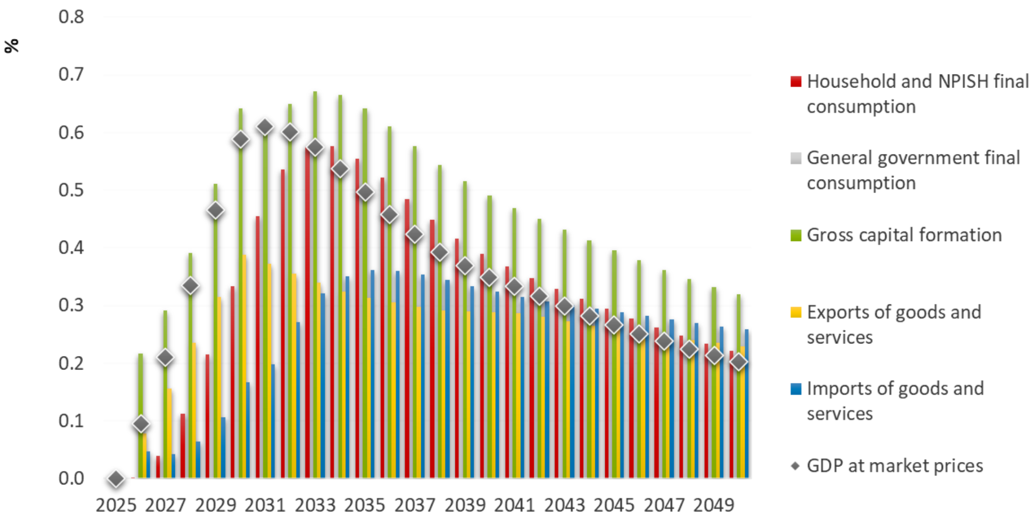


Figure 24: Macroeconomic effects of the "SSP5-8.5_DI" scenario, 2025–2050, deviations from a SSP5-8.5 scenario in percent

Source: Own illustration based on e3.mn results

GDP growth is limited by the high import dependency of Mongolia specifically in manufacturing. Drip irrigation systems, machinery and other equipment necessary for irrigation and the management for additional agricultural land are mainly imported. Overall, imports are increasing to 0.36% p.a. compared to a situation without adaptation and climate change (SSP5-8.5).

With more jobs and higher income, spending opportunities arise for households (up to 0.6% p.a.). Furthermore, higher economic activity results in additional (expansion) investments (beyond investment in irrigation) to satisfy higher consumer and intermediate demand.

Initially, sectoral economic output is mainly triggered in the sectors producing the products and offering services that are needed for expansion of irrigation systems and in agriculture which is the targeted sector under the adaptation measure. Agricultural production is impacted the most and increases by up to 1.7% resp. 32 Mn. USD (Figure 25). Manufacturing (+13.5 Mn. USD resp. 0.45% p.a.) and construction (+10 Mn. USD resp. 0.4% p.a.) show also positive impacts due to activities related to additional irrigated agricultural land.

Other sectors such as private service sectors (including trade and transport) benefit from indirect and income-induced effects which are related to higher demand for sectors along the value chain and additional consumer demand. In total, real production is up to 84 Mn. USD resp. +0.3% higher. After the implementation period, the positive impact on real production weakens but remains higher compared to a situation without adaptation and climate change.

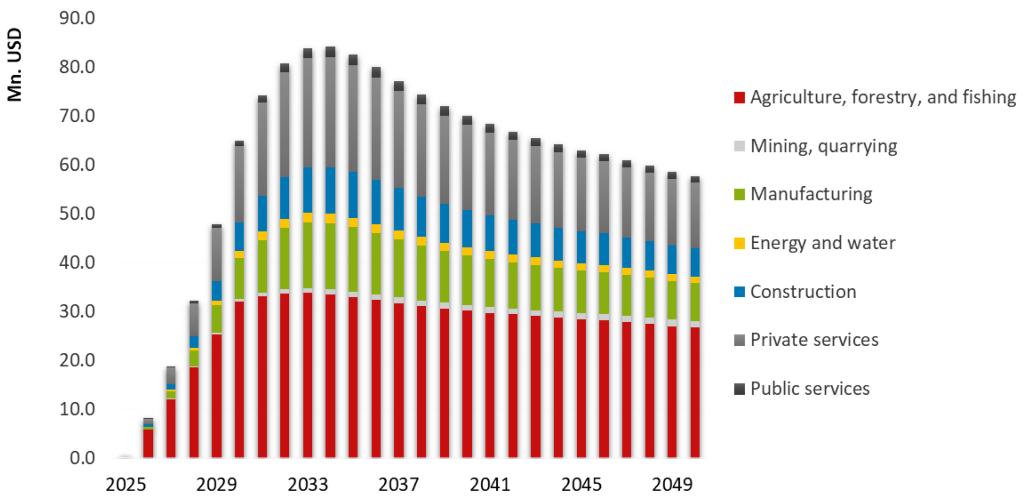


Figure 25: Effects of the "SSP5-8.5_DI" scenario on gross production by economic sectors in constant prices, 2025–2050, deviations from the SSP5-8.5 scenario in Mn. USD

Source: Own illustration based on e3.mn results

Employment effects by economic activities follow the sectoral economic growth and the respective labour productivities. Thus, most jobs are created in agriculture (up to 4 000 persons resp. 1.7% p.a.), followed by private services with additional 1 400 persons resp. 0.3% p.a. (Figure 26). Construction (400 resp. 0.4% p.a.) and the manufacturing sector (600 persons resp. 0.4% p.a.) show a smaller increase due to a smaller initial trigger resp. lower labour intensity. Total employment increases by up to 7 000 persons resp. 0.5% per year.

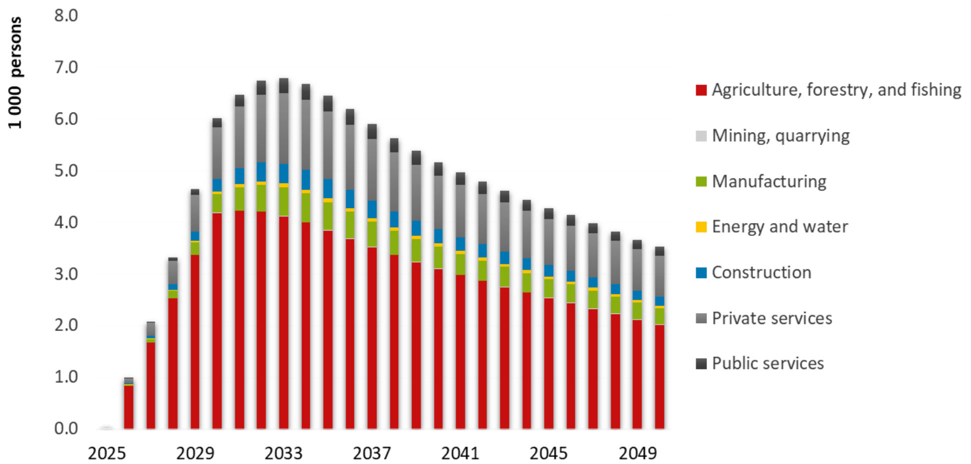


Figure 26: Effects of the "SSP5-8.5_DI" scenario on employment by economic activities, 2025–2050, deviations from the SSP5-8.5" scenario in 1 000 persons

Source: Own illustration based on e3.mn results

Impacts on employment by gender and economic activities are illustrated in Figure 27. Female and male workers are overall broadly equally affected but it differs for the economic activities. Total female employment increases by up to three thousand persons and male employment by up to 3 700 persons. Males are more prominent in construction and agriculture while females have a higher share in the private and public services sector.

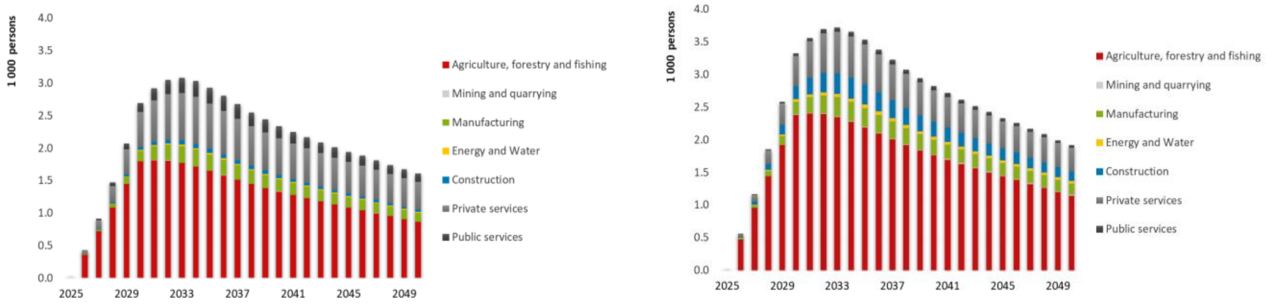


Figure 27: Effects of the "SSP5-8.5_DI" scenario: employment by economic activities and gender (female: left figure, male: right figure), 2025–2050, deviations from the SSP5-8.5 scenario in 1 000 persons

Source: Own illustration based on e3.mn results

Economic growth increases final energy demand according to the respective sectoral energy intensities if no additional energy efficiency measures are implemented. Thus, the final energy demand increases in all sectors resulting in an additional up to 0.26% resp. 1.4 PJ. The impact for the sectors differs and is highest for "Other consumption n.e.c." which is expected to be related to activities in agriculture and services not mentioned in the corresponding sectors (up to 1.1 PJ resp. 0.3% p.a.) followed by service sectors (up to 140 TJ resp. 0.3% p.a.), manufacturing sectors and transport (each up to approx. 70 TJ resp. 0.1% p.a., Figure 28). Agriculture shows a smaller increase in absolute terms (up to 8 TJ p.a.) but the greatest in relative terms (1.3% p.a.).

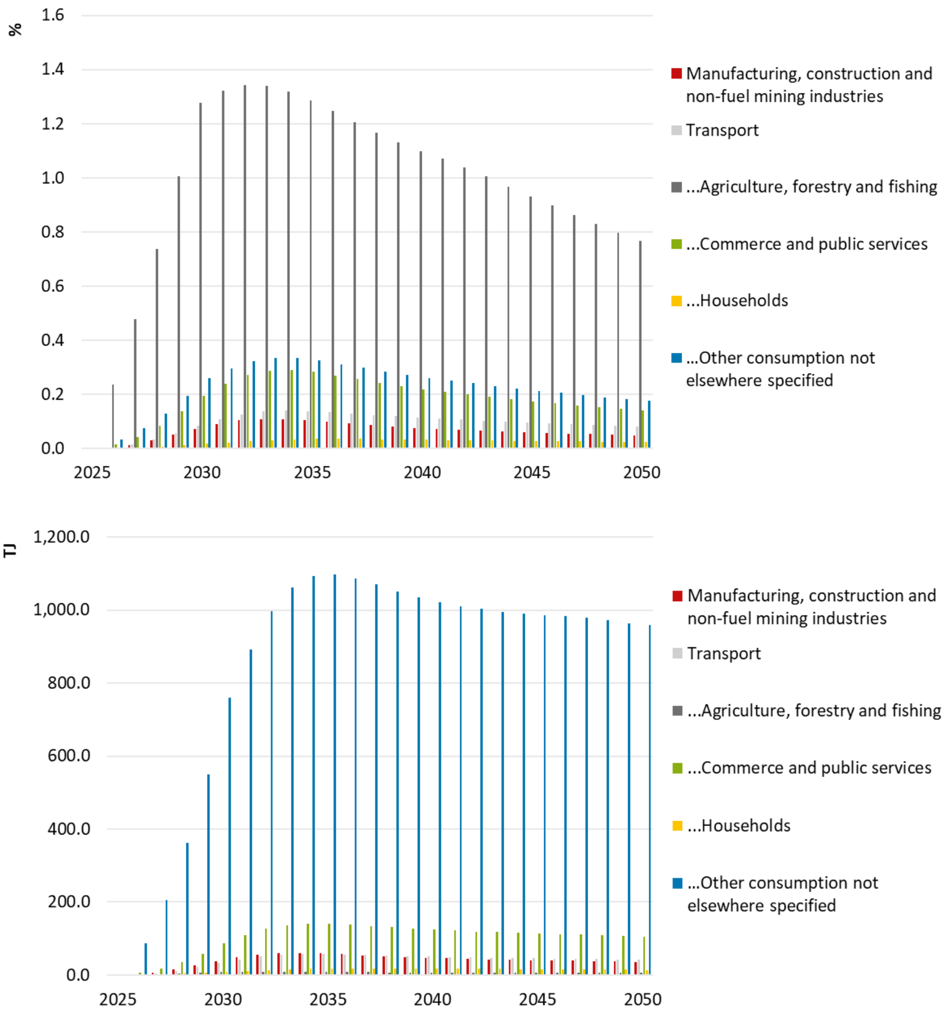


Figure 28: Effects of the "SSP5-8.5_DI" scenario on FEC by sectors, 2025–2050, deviations from the SSP5-8.5 scenario in percent (top figure) and TJ (bottom figure)

Source: Own illustration based on e3.mn results

Fuel combustion-related GHG emissions are strongly connected with the final energy demand as long as no fuel switch to RE is presumed. GHG emissions accelerate the most for energy industries (up to 30 Gg CO_2e resp. 0.16% p.a.) and transport (up to 21 Gg CO_2e resp. 0.26% p.a.) due to their high reliance on fossil fuels, mainly coal and oil products (Figure 29). GHG emissions caused by private and public service sectors are part of "Other: non-specified stationary". Overall, GHG emissions rise by up to 0.2%, resp. 58 Gg CO_2e.

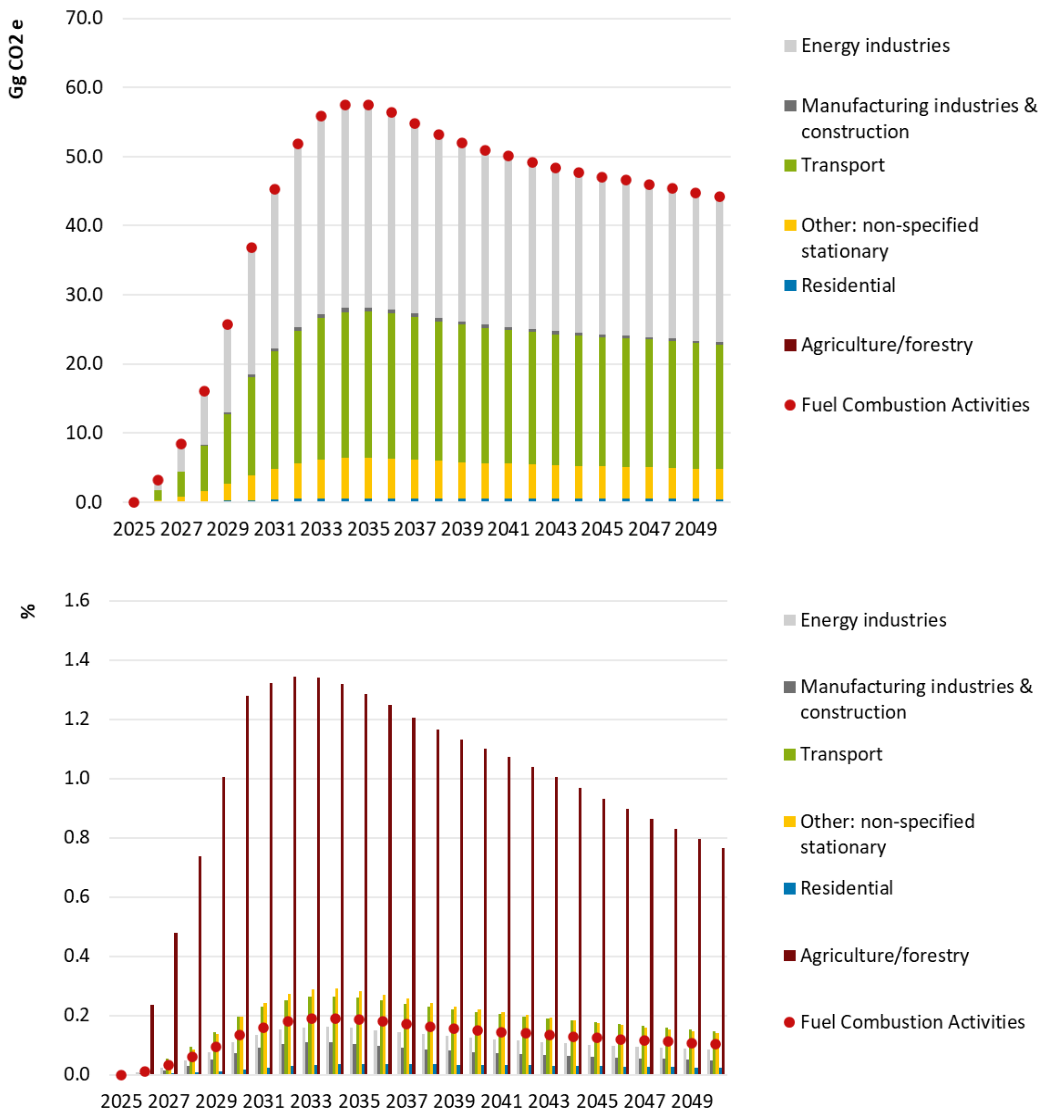


Figure 29: Effects of the "SSP5-8.5_DI" scenario on GHG emissions by sector, 2025-2050, deviations from the SS5-8.5 scenario in Gg CO_2e (top figure) and percent (bottom figure)

Source: Own illustration based on e3.mn results

6.1.3 MODEL RESULTS OVERVIEW FOR SSP1-2.6, SSP2-4.5 AND SSP5-8.5

The intensity and frequency of climate hazards differ depending on the respective climate scenario, and consequently the economic impacts (cf. section 5). The benefits of an adaptation measure differ as well, depending on the underlying climate scenario but given the same investments.

Apart from the same impact chains as described in the previous section, the distinction is that the macroeconomic effects are driven by adjusted benefits for agriculture which are 17% resp. 4% greater in SSP1-2.6 resp. SSP-4.5 compared to SSP5-8.5 (cf. Table 8).

The key results for all "SSP_DI" scenarios in comparison to the resp. SSP scenario in 2050 are shown in Figure 30. The GDP effects are greatest for the SSP1-2.6 scenario due to the improved benefits, followed by SSP2-4.5. With accelerating economic activity more jobs are created. The same is true for energy demand and GHG emissions if no additional mitigation measures are taken. From a gender perspective, male and female workers are more or less equally affected from this adaptation measure (cf. Figure 27).

To summarize, the economic impacts of a drip irrigation measure are limited due to the high import dependency in manufacturing, but it is beneficial for agriculture and food security under intensifying climate change and water scarcity.

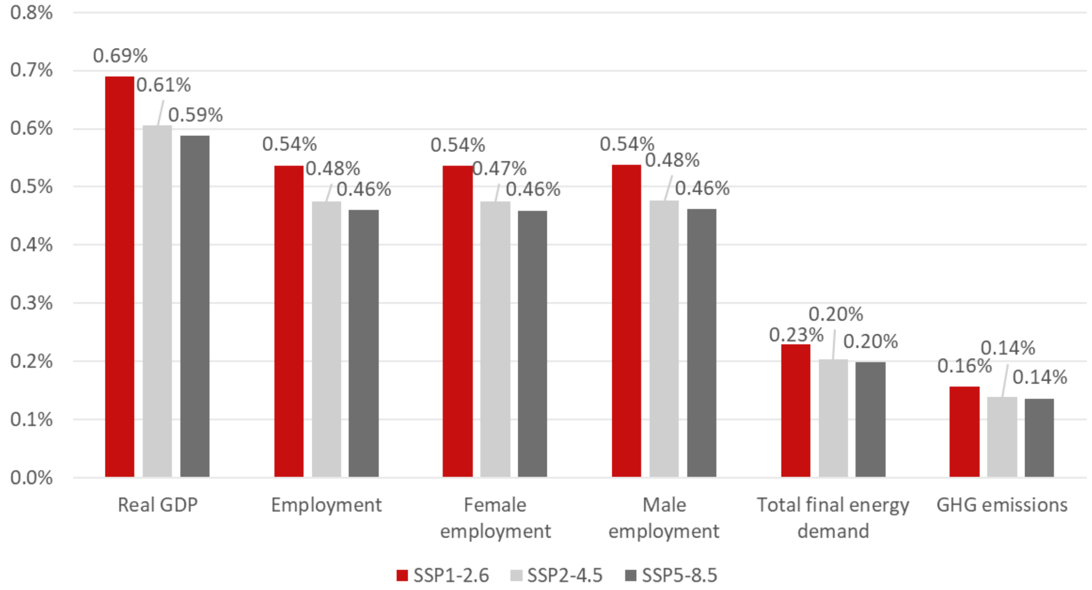


Figure 30: “SSP1-2.6_DI”, “SSP2-4.5_DI” and “SSP5-8.5_DI” scenarios: Key impacts, year 2030, deviations to the respective SSP scenario in percent

Source: Own illustration based on e3.mn results

6.2 Investing in herding points for resilient livestock

The Mongolian agricultural sector is dominated by livestock and herding which accounts for 83% of agricultural output and employs 30% of total employment (MET 2024). Over the last decades, the number of livestock increased significantly leading to overgrazing and degradation of pastures (MET 2024). Increasing temperatures and EWEs such as droughts and heatwaves exacerbate these issues.

A major threat to the Mongolian agricultural sector are dzuds which cause dramatic livestock losses because animals cannot gain weight in summer to be better prepared for wintertime. With deep snow (white dzud), iced surfaces (iron dzud)[7] and others in winter the situation becomes worse as the animals do not have access to sufficient gras. Livestock losses often reach more than 10% of total livestock, and during very severe dzud in 2009/2010 even 20% (Altansukh et al. 2024).

The vulnerability to climate change can be improved by better pasture and livestock management. Options include reducing the number of livestock to more sustainable levels and reducing overgrazing, improving pastures by rotational grazing, implementing soil management practices and increasing the number of herding and water points to enlarge the effective grazing area (GIZb 2025).

[7] https://www.undrr.org/understanding-disaster-risk/terminology/hips/mh0041

The latter adaptation option is the basis for the subsequent macroeconomic analysis. This measure aims at increasing the number of herding points resulting in less animals per herding point, which improves the sustainable use of pastures and reduces overgrazing.

6.2.1 SCENARIO SETTINGS

Following the NDCAP, 800 new herding points are expected to be constructed within five years – each year additional 160. Each herding point consists of engineered wells, stables, fences, open yards, and herder's houses. According to the CBA results (Table 9), the investment amounts to 261 Bn. MNT which is – according to the NDCAP – fully paid by the government. In this scenario, it is further presumed that the government will reduce expenditures for public administration over the next ten years. Operation and maintenance for the additional 800 herding points are 29 Bn. MNT per year. The expected benefits from increased livestock production amount to 169 Bn. MNT per year.

Table 9: Assumptions on costs and benefits for "Herding points (HP)"

Costs and benefits	2026	2027	2028	2029	2030
Cumulated number of additional herding points	160	320	480	640	800
Investment in herding points (Mn. MNT per herding point)	326	326	326	326	326
Operation and maintenance costs p.a. (Bn. MNT)	6	11	17	23	29
Increased agricultural production p.a. (Bn. MNT)	34	68	101	135	169

Source: CBA conducted for the GCF funded UNEP/MET implemented project "Building Capacity to Advance National Adaptation Plan Process in Mongolia", see also NCC (2021)

The cost-benefit analysis for this adaptation option was assumed to be initially conducted under the SSP5-8.5 scenario. Given the same investments (costs), assumptions regarding the benefits must therefore be adjusted for SSP1-2.6 and SSP2-4.5.

The benefits are adjusted by reflecting the frequency of dzuds under the three SSP scenarios. According to this, surprisingly at a first, dzuds are more frequent (46% resp. 38%) in SSP1-2.6 resp. SSP2-4.5 compared to SSP5-8.5 which means lower benefits for SSP1-2.6 and SSP2-4.5 (Table 10).

Table 10: Benefit adjustments for "HP" under different climate scenarios

Adaptation benefit	SSP1-2.6	SSP2-4.5	SSP5-8.5 (basis for CBA)
Increased agricultural production	54%	62%	100%

Source: Own assumptions

6.2.2 MODEL RESULTS UNDER SSP5-8.5

The construction of new herding points is beneficial for the Mongolian economy. Compared to a situation without this adaptation measure and climate change (SSP5-8.5), real GDP increases by up to 0.24%, resp. 120 Bn. MNT p.a. (Figure 31). During the implementation period (until 2030), additional investment (up to 0.3%) supports economic growth, afterwards the contribution to growth is smaller and is based on expansion investment due to accelerated overall economic activity.

The benefits of herding points become more and more visible over time and are fully exploited after the implementation period (cf. Table 9). As a result, livestock exports increase, and agricultural imports can be reduced. However, overall imports are accelerating due to the high import dependency and result in up to 0.13% per year. Total export increases by up to 0.23% p.a. so that the trade balance is positive for Mongolia.

To support farmers, the government fully finances the investment in herding points at the expense of expenditures for public administration over ten years. Thus, government consumption is decelerating resulting in up to 0.15% less compared to a situation without adaptation and climate change.

The expansion of the economy and the creation of jobs and income is beneficial for private households who can spend more money for consumption purposes. Overall, household and NPISH consumption increase by up to 0.23% which is beneficial for both domestic production and imports.

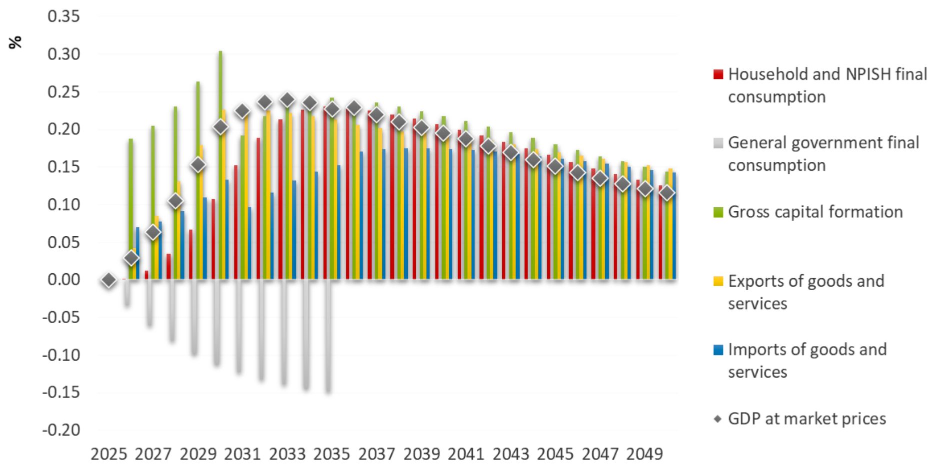


Figure 31: Macroeconomic effects of the "SSP5-8.5_HP" scenario, 2025–2050, deviations from a SSP5-8.5 scenario in percent

Source: Own illustration based on e3.mn results

Due to the adaptation measure, agriculture profits the most in terms of real production (17 Mn. USD resp. 0.9% p.a., Figure 32). Manufacturing and construction benefit from the activity taken to implement the herding points, i.e. costs associated with machinery and equipment and building wells, stables and fences. However, production in both sectors accelerates only to a limited extent (each sector up to 5 Mn. USD resp. 0.2% p.a.) due to import dependency of manufacturing and limited scope of the measure and implementation period.

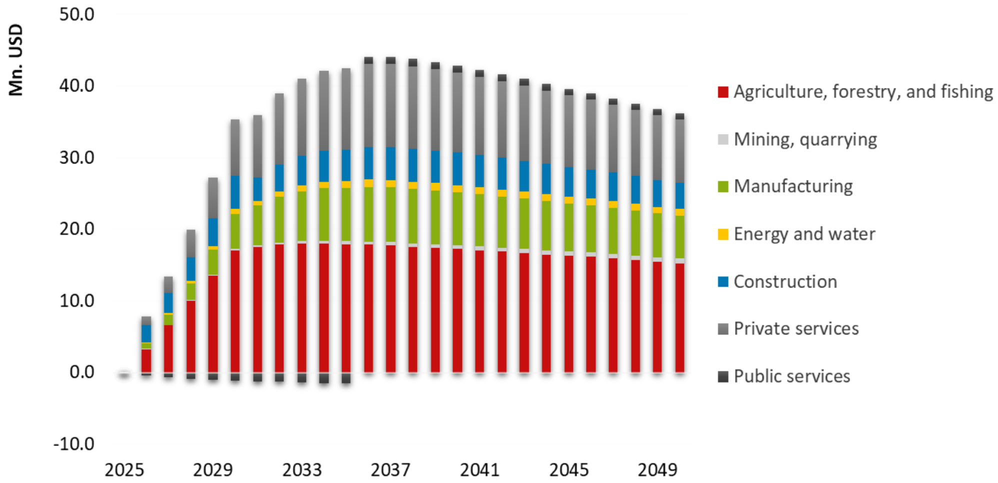


Figure 32: Effects of the "SSP5-8.5_HP" scenario on gross production by economic sectors in constant prices, 2025–2050, deviations from the SSP5-8.5 scenario in Mn. USD

Source: Own illustration based on e3.mn results

While real production in the public services sector slows down in the first decade and then accelerates, the private services sector has consistently positive effects. The impact on public services is a result of the presumed lower expenditures in public administration which is part of the public service sector to finance the government expenditures for the adaptation measure. The private service sector profits from indirect and income-induced effects due to overall positive economic development (up to 12 Mn. USD resp. 0.14%).

Overall, real production increases by up to 45 Mn. USD resp. 0.14% per year. After the implementation period, the positive impact on real production declines but remains higher compared to a situation without the adaptation measure due to its benefits.

The employment impacts are similar to the production effects. If sectoral economic activity is expanding or contracting, the same is true for employment. The magnitude differs depending on the sectoral labour productivity which is high in agriculture and service sectors. Most jobs are created in agriculture (2 200 persons resp. 0.9% p.a.), followed by private services sectors (700 persons resp. 0.14% p.a., Figure 33). Overall, employment increases by up to 3 400 persons resp. 0.25% per year.

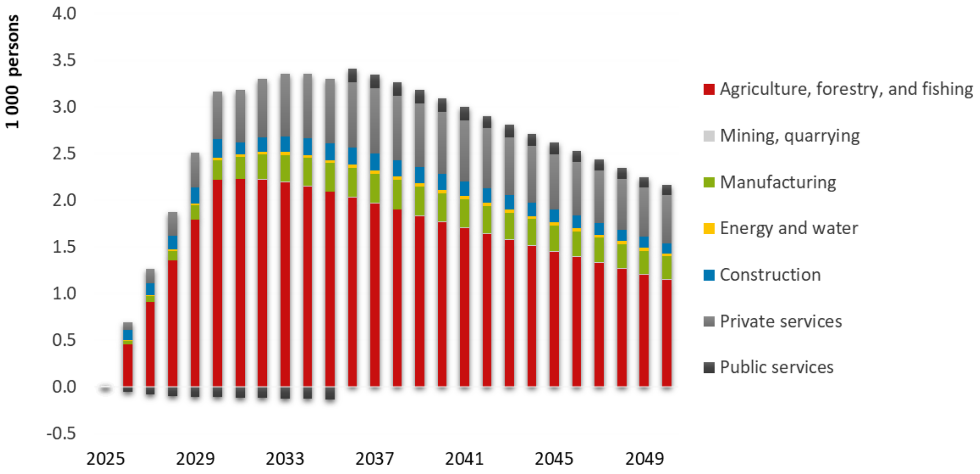


Figure 33: Effects of the "SSP5-8.5_HP" scenario on employment by economic activities, 2025–2050, deviations from the SSP5-8.5" scenario in 1 000 persons

Source: Own illustration based on e3.mn results

The impacts on total employment by gender are broadly similar but differ for the economic activities (Figure 34). In total, female employment increases by up 1 600 (0.24% p.a.) and male employment by up to 1 800 persons (0.25%) p.a. (Figure 33). Due to the gender structure, the impact for female workers is greater in the private and public services sector than for male workers and vice versa in construction and agriculture.

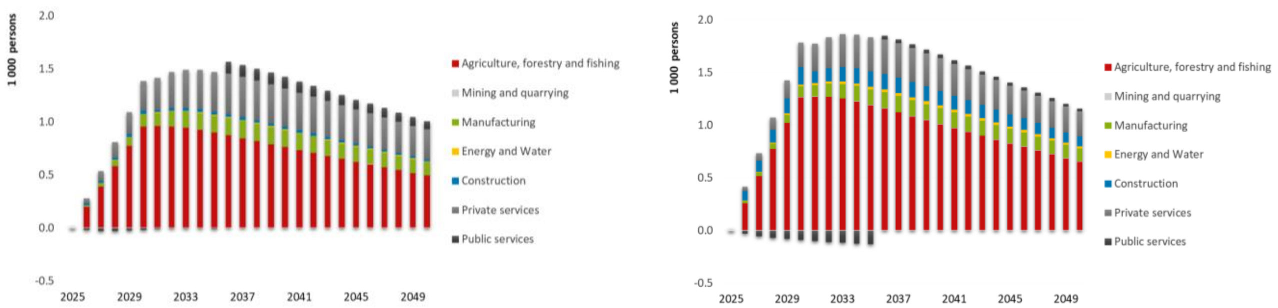


Figure 34: Effects of the "SSP5-8.5_HP" scenario: employment by economic activities and gender (female: left figure, male: right figure), 2025–2050, deviations from the SSP5-8.5 scenario in 1 000 persons

Source: Own illustration based on e3.mn results

With accelerated economic growth, total final energy consumption increases as well resulting in 0.1% resp. 700 TJ (Figure 35). "Other consumption n.e.c" contributes the most (up to 560 TJ resp. 0.15% p.a.) to this development, followed by public and private services final energy consumption increases the most (70 TJ resp. 0.12% p.a.) due to the higher production levels.

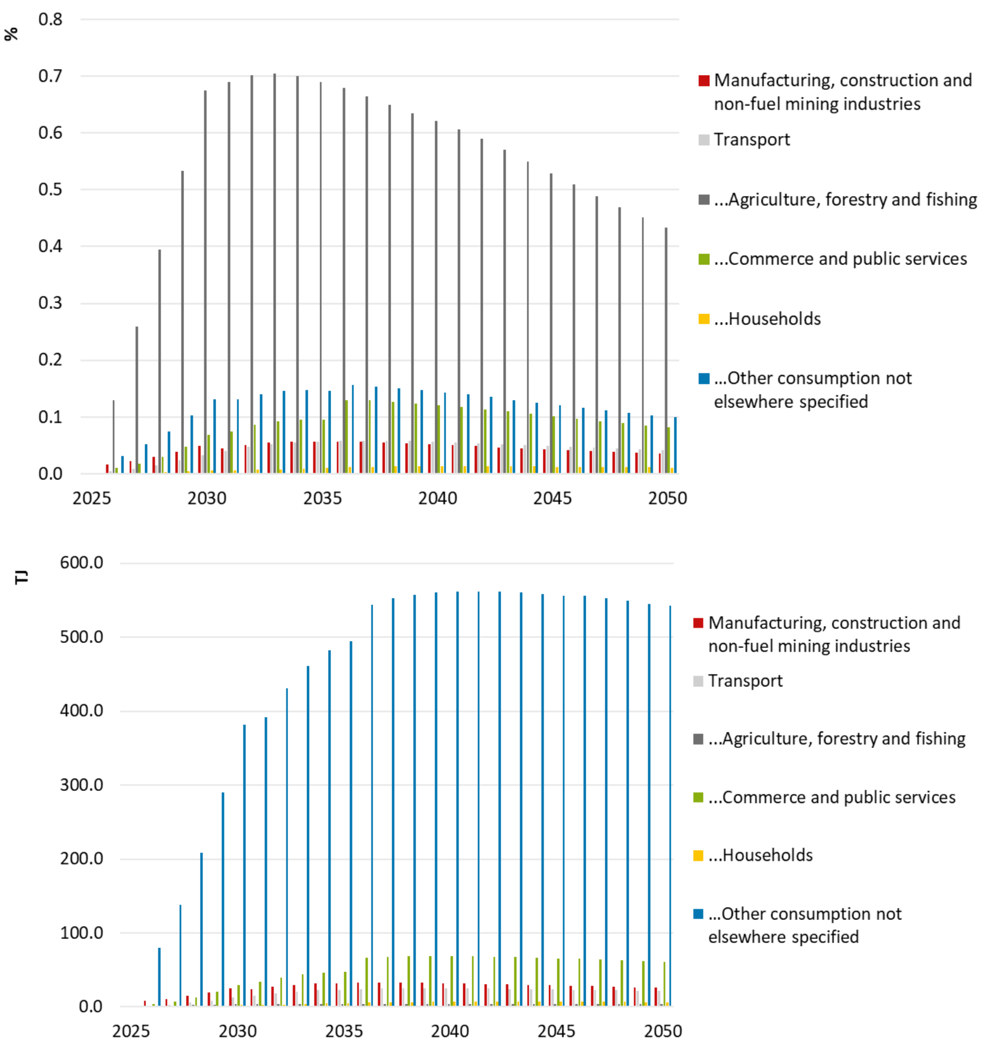


Figure 35: Effects of the "SSP5-8.5_HP" scenario on FEC by sectors, 2025–2050, deviations from the SSP5-8.5 scenario in percent (top figure) and TJ (bottom figure)

Source: Own illustration based on e3.mn results

Fuel combustion-related GHG emissions are closely connected with energy consumption and the energy carriers used mainly. GHG emissions in the energy industries increase the most (up to 15 Gg CO_2e resp. 0.1% p.a.) due to greater demand for electricity and heat, followed by transport which causes additional GHG emissions of up to 11 Gg resp. 0.12% per year, and GHG emissions from commerce and public services (3 Gg resp. 0.13% p.a., Figure 36). Overall, GHG emissions increase by almost 30 TJ resp. 0.1% per year.

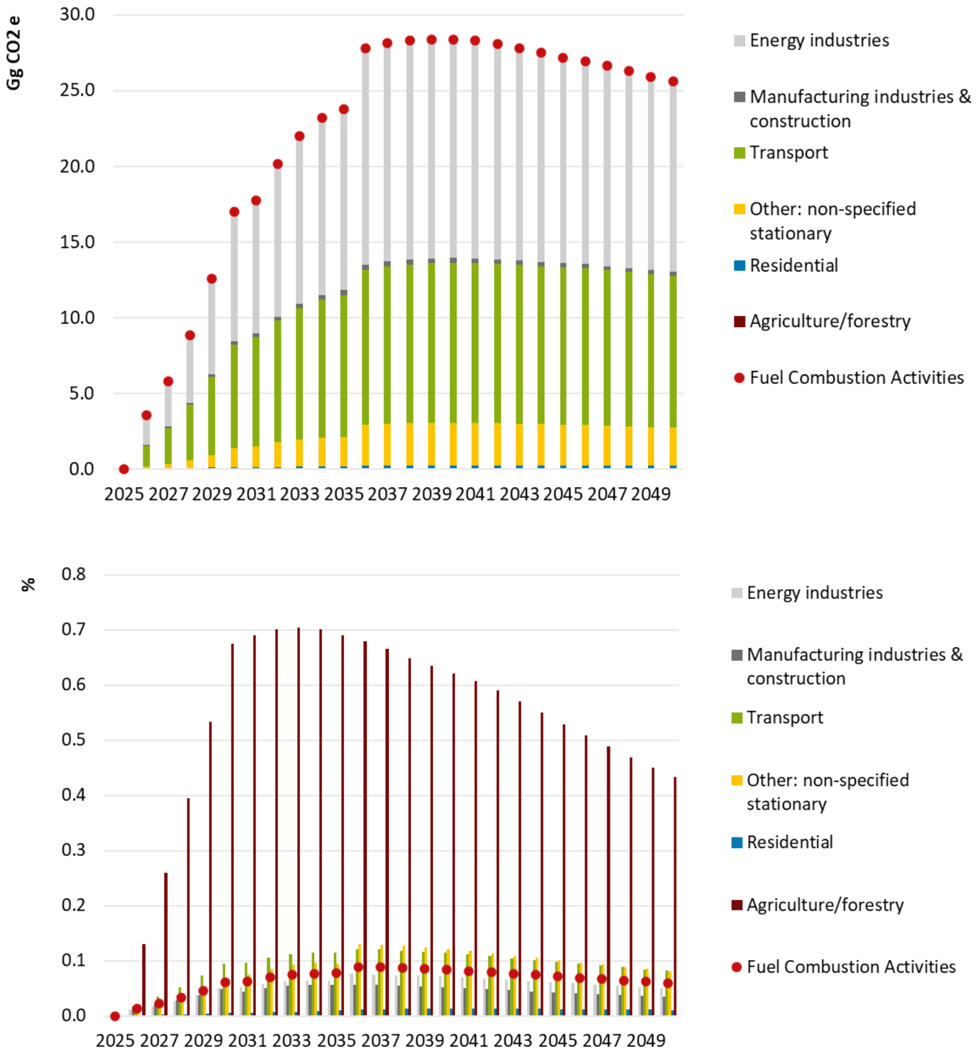


Figure 36: Effects of the "SSP5-8.5_HP" scenario on GHG emissions by sectors, 2025-2050, deviations from the SSP5-8.5 scenario in Gg CO_2e (top figure) and percent (bottom figure)

Source: Own illustration based on e3.mn results

6.2.3 MODEL RESULTS OVERVIEW FOR SSP1-2.6, SSP2-4.5 AND SSP5-8.5

The intensity and frequency of climate hazards differ depending on the respective climate scenario, and consequently the economic impacts (cf. section 5). The benefits of an adaptation option differ as well, depending on the underlying climate scenario assuming the same investments in adaptation.

The results for GDP by economic sectors for all "SSP_HP" scenarios are shown in Figure 28. The impact chains remain the same as described in section 6.2.2. Macroeconomic effects vary in their magnitude depending on the benefit specified for SSP1-2.6 and SSP2-4.5 (cf. Table 10).

Surprisingly, on first view, the macroeconomic effects are greatest under the SSP5-8.5 scenario. The reason is that dzuds are more frequent overall under SSP1-2.6, followed by SSP2-4.5 and thus the expected benefit is lower. Therefore, additional output in agriculture is constrained the most in SSP1-2.6. Following this, the overall macroeconomic effects are not as beneficial as under SSP5-8.5.

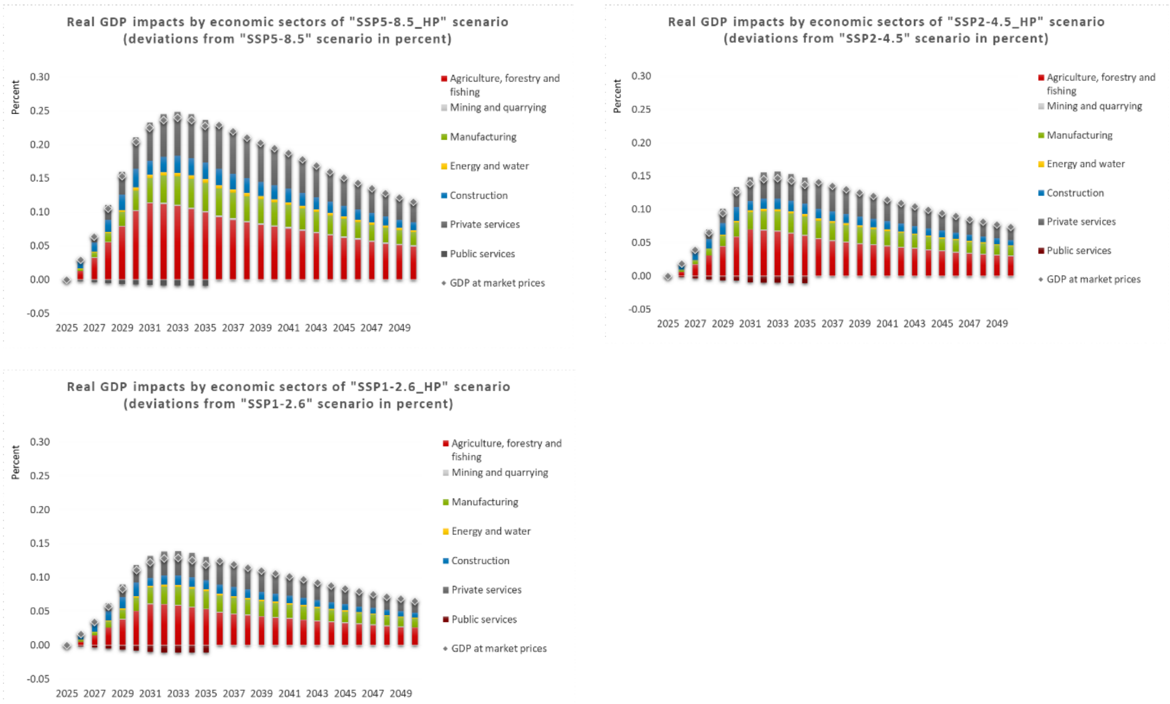


Figure 37: "SSP1-2.6_HP", "SSP2-4.5_HP" and "SSP5-8.5_HP" scenarios: Real GDP impacts by economic sectors, 2025–2050, deviations to the respective SSP scenario in percent*

Source: Own illustration based on e3.mn results

*Percentage deviation of sectoral gross output has been scaled to percentage deviation of GDP

Figure 30 shows key results for all "SSP_HP" scenarios in 2030 and 2050 in comparison to the resp. SSP scenarios. The effect on employment depends on the strength of the effect on GDP and economic sectors. Female workers benefit slightly more from this adaptation measure than male workers because activities with a greater share of females are affected. Energy consumption and GHG emissions increase follow economic growth considering the energy intensities of the sectors and anergy carriers used.

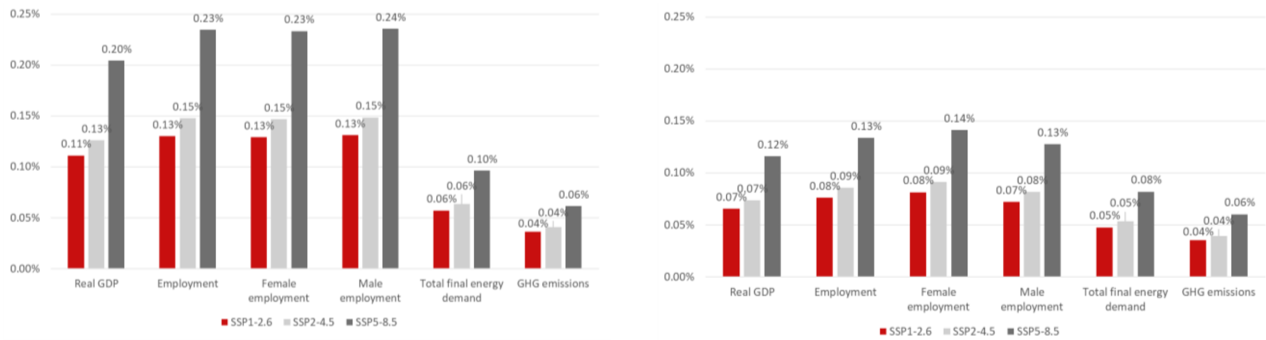


Figure 38: "SSP1-2.6_HP", "SSP2-4.5_HP" and "SSP5-8.5_HP" scenarios: Key impacts, year 2030 (left figure) and 2050 (right figure), deviations to the respective SSP scenario in percent

Source: Own illustration based on e3.mn results

Overall, this measure supports pasture improvement and thus the livelihood of people in rural areas. It also contributes to food and income security.

6.3 Investing in water reservoirs in high mountain area for additional water supply

Mongolia is confronted with changing rainfall patterns and extremes – droughts and floods – impacting water availability (MET 2024, USAID 2022, GIZ 2025a). Droughts and heatwaves exacerbate water scarcity, reduce soil moisture and dry out rivers, accelerating desertification. During extreme precipitation events, the reduced water absorption potential of the soil leads to flooding, which damages assets and worsens soil erosion.

Improved water management helps to prevent flooding and to increase water availability during dry periods. For example, water reservoirs capture excess water which can be used for multiple purposes, e.g. to irrigate agricultural land. Other adaptation measures such as retention basins and floodplains also help to reduce flood damage (GIZ 2025b, ADB 2020).

One of Mongolia's political goals is the establishment of water harvesting points to retain rainwater, snow and ice melt to reduce water scarcity and to improve pasture quality during dry periods which is analysed subsequently. Improved water availability is assumed to be beneficial for agriculture and mining.

6.3.1 SCENARIO SETTINGS

Following the NDCAP, twelve water reservoirs are planned to be constructed within four years with costs and benefits as specified in the NCC (2021). The CBA results serve as input for the e3.mn model to evaluate also the economy-wide impacts.

Building a water reservoir to collect water is expected to cost 4 Bn. MNT per dam (Table 11). Additional investments are needed to use the water in agriculture. The costs for irrigation systems, machinery for grain production, and other agricultural machineries amounts to 2 Bn. MNT for additional agricultural land that can be supplied by one dam. The CBA results further show that one dam can supply water for an area of 900 hectares. The investments needed for this adaptation measure are fully financed by the government over a period of eight years, i.e. twice the implementation period, at the expense of other government expenditures.

With more agricultural land, the output in agriculture is expected to increase by up to 9 Bn. MNT per year. Additionally, the value of additional water resources is valued at 3 Bn. MNT per dam and year. Agriculture, mining and the energy sector (hydro power) could benefit from an increased water supply. In this scenario, it is presumed that apart from agriculture, also mining increases its production due to the improved water availability.

Table 11: Assumptions on costs and benefits for "Water reservoirs (WR)"

Costs and benefits	2026	2027	2028	2029
Cumulated number of dams	3	6	9	12
Construction costs for dam (Bn. MNT per dam)	4	4	4	4
Investment in machinery for grain production, irrigation systems etc. (Bn. MNT per dam, i.e. 900 hectares)	2	2	2	2
Increased agricultural production p.a. (Bn. MNT)	2	5	7	9
Improved water supply benefits mining production p.a. (Bn. MNT)	9	18	27	36

Source: CBA conducted for the GCF funded UNEP/MET implemented project "Building Capacity to Advance National Adaptation Plan Process in Mongolia", see also NCC (2021)

Again, it is presumed that the costs and benefits of this adaptation option have been calculated under the SSP5-8.5 scenario. Assumptions regarding benefits given the same investments (costs) must therefore be adjusted for the SSP1-2.6 and SSP2-4.5 scenario.

The benefits for agriculture are assumed to be climate-independent and thus the same in all three SSP scenarios, assuming that during heatwaves and droughts, the water reservoirs provide sufficient water to be used in agriculture. In particular, during hot summers, glacier melts are accelerated and even more water is available (Table 10). If no additional investment is undertaken to enlarge the irrigated land, the benefits cannot be increased.

Benefits in the mining sector are assumed to be higher under SSP1-2.6 and SSP2-4.5, assuming that the mining sector has the capacities to increase production if sufficient water is available. Benefits are adjusted following the average drought and heatwave intensities under the respective scenarios which are lowest for SSP2-4.5, followed by SSP1-2.6.

Table 12: Benefit adjustments for "WR" under different climate scenarios

Adaptation benefit	SSP1-2.6	SSP2-4.5	SSP5-8.5 (basis for CBA)
Increased agricultural production	100%	100%	100%
Increased mining production	125%	132%	100%

Source: Own assumptions

6.3.2 MODEL RESULTS UNDER SSP5-8.5

The investments needed to build the twelve water reservoirs are comparatively low compared to other adaptation measures. Thus, the macroeconomic impact is small. Real GDP is up to 0.03% higher compared to a situation without adaptation and climate change (Figure 39). During the implementation period 2026-2030, investment increases by 0.06% per year. Simultaneously, the expected benefits from the measure can be achieved. According to this, export chances arise for agricultural and mining products resulting in slightly higher total exports (up to 0.05% p.a.).

Household consumption accelerates within a limited scope due to minor positive effects on jobs and income. Dampening impacts on GDP growth have accelerating imports and decelerating government consumption expenditures. The measure triggers, apart from construction activity which is primarily domestic, even more demand for machinery and irrigation systems which are mainly imported. The reduced government consumption (up to 0.06% p.a.) during the first years of the simulation period is related to the assumption that government cuts other expenditures to financially support the building of water reservoirs.

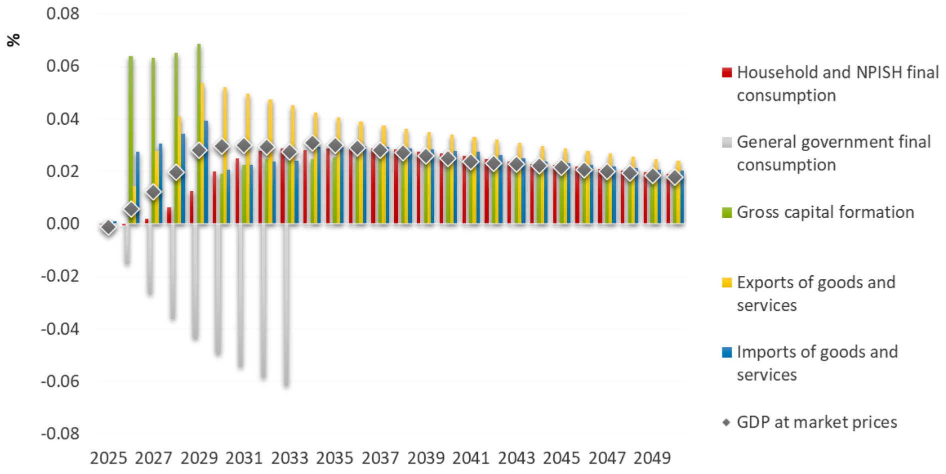


Figure 39: Macroeconomic effects of the "SSP5-8.5_WR" scenario, 2025–2050, deviations from a SSP5-8.5 scenario in percent

Source: Own illustration based on e3.mn results

Due to improved water availability in the agricultural and mining sectors, real production in those sectors can be increased following the expected benefits (Figure 40). Other sectors such as manufacturing and construction show minor increases, too, which is related to the investment stimulus. Overall, real output increases by up to 10 Mn. USD (+0.04%) per year.

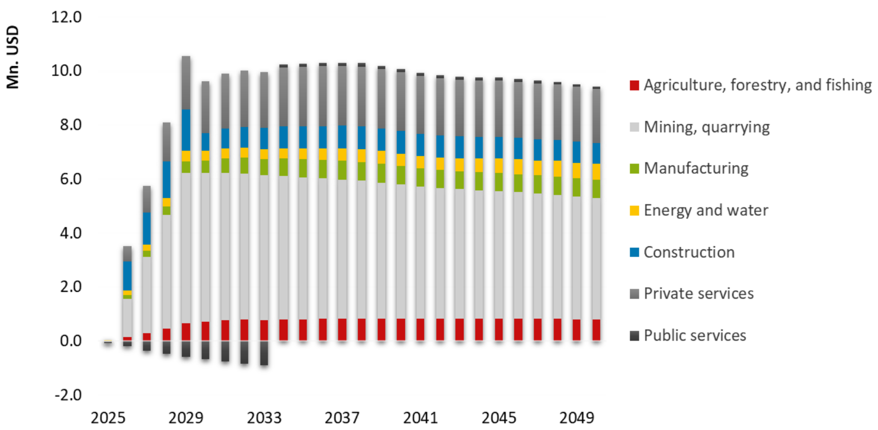


Figure 40: Effects of the "SSP5-8.5_WR" scenario on gross production by economic sectors in constant prices, 2050, deviations from the SSP5-8.5 scenario in percent (x-axis) and respective Mn. USD (*)

Source: Own illustration based on e3.mn results

Due to higher labour intensity, the agriculture and private service sectors including also trade and transport receive most of the additional employment, contrary to the mining sector, which is less labour intense. Total employment increases to a limited extent resulting in up to additional 400 employed persons p.a. (0.03% p.a., Figure 41).

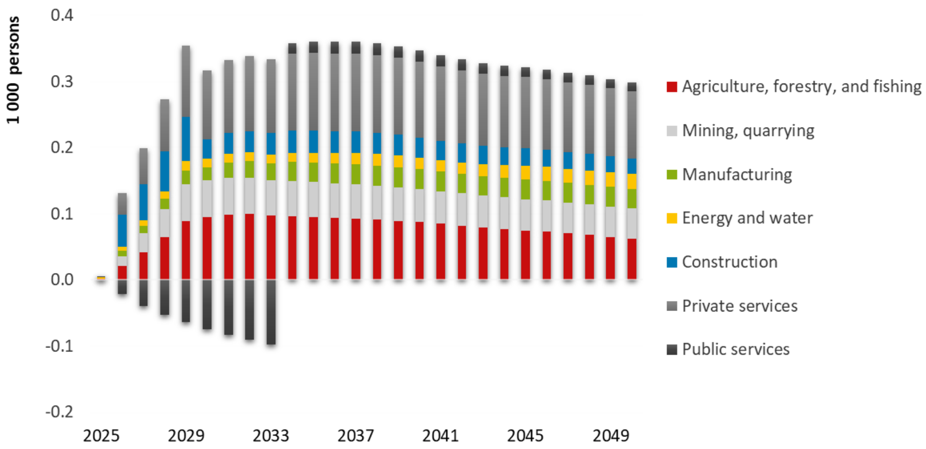


Figure 41: Effects of the "SSP5-8.5_WR" scenario on employment by economic activities, 2025–2050, deviations from the SSP5-8.5" scenario in 1 000 persons

Source: Own illustration based on e3.mn results

The measure is more beneficial for male workers (up to 220 persons p.a.) than for female workers (up to 140 persons p.a.) because in particular those economic activities are impacted that are more common for males such as construction, mining and quarrying (Figure 42).

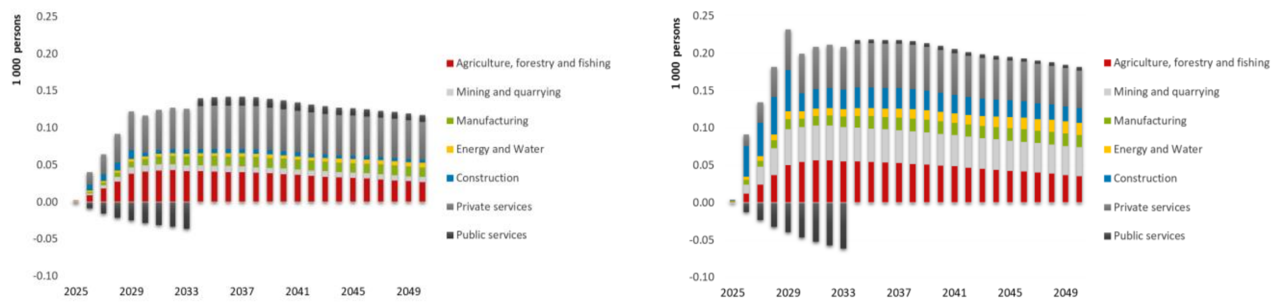


Figure 42: Effects of the "SSP5-8.5_WR" scenario: employment by economic activities and gender (female: left figure, male: right figure), 2025–2050, deviations from the SSP5-8.5 scenario in 1 000 persons

Source: Own illustration based on e3.mn results

The impact on final energy demand and GHG emissions is rather limited. TFEC increases by up to 0.03% and GHG emissions even less (Figure 43).

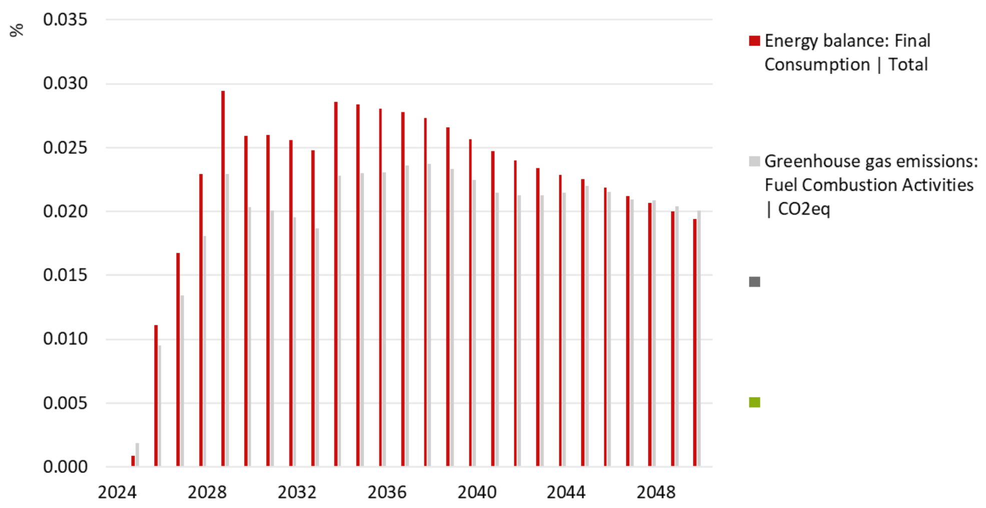


Figure 43: Effects of the "SSP5-8.5_WR" scenario on TFEC and GHG emissions, 2025-2050, deviations from the SSP5-8.5 scenario in percent

Source: Own illustration based on e3.mn results

6.3.3 MODEL RESULTS OVERVIEW FOR SSP1-2.6, SSP2-4.5 AND SSP5-8.5

The intensity and frequency of climate hazards differ depending on the respective climate scenario, and therefore the economic impacts (cf. section 5). Similarly, an adaptation measure yields different benefits (cf. Table 12) given an investment under different climate scenarios.

Figure 30 shows key results for all "SSP_WR" scenarios in 2050 in comparison to the resp. SSP scenario. The impacts on the national economy are rather small but greater for SSP2-4.5 and SSP1-2.6 due to the expected greater benefits for agriculture under less severe climate change scenarios.

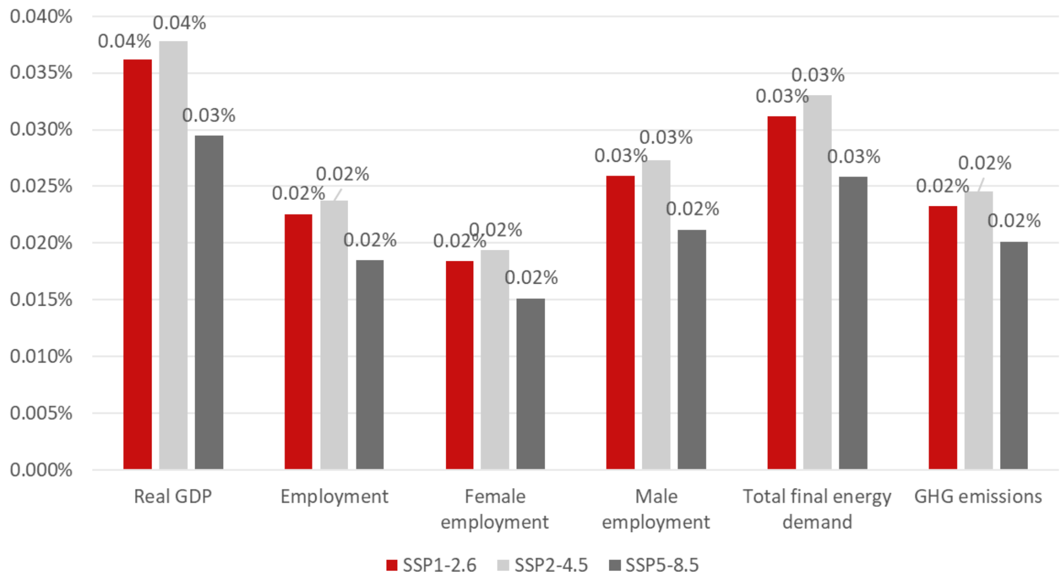


Figure 44: "SSP1-2.6_WR", "SSP2-4.5_WR" and "SSP5-8.5_WR" scenarios: Key impacts, year 2050, deviations to the respective SSP scenario in percent

Source: Own illustration based on e3.mn results

Overall, water reservoirs need no high investment, but their benefit for the economy and the people is rather limited. Increased exploitation of the benefits of additional water supply, if possible, and a less import dependent economy would improve the macroeconomic effects. The same is true if international donors financially support this adaptation measure.

6.4 Regulating water flows to improve water supply

As introduced in section 6.3, changing rainfall patterns in particular extremes increased the flooding risk in Mongolia which is expected to continue (see Figure 14). Ulaanbaatar being located at the Tuul River and its tributary Selbe River is densely populated and therefore vulnerable to flooding and river overflows after heavy rainfall (CAREC 2022). Major historical floods in Ulaanbaatar city cause damages ranging from 136 Mn. MNT in 1982 to 33 Bn. MNT in 2023 (Narangerel & Suzuki 2024). With the migration of the population from the countryside to the city and the establishment of businesses, the damage to people and infrastructure also increases which underlines the need for adaptation actions.

Flood countermeasures are underway, amongst others relocation of people from flood-prone areas and developing the Tuul River Basin Integrated Water Management Plan (MEGD 2012) aiming at collecting excess water to prevent flooding as well as storing and treating the water for multi-purpose use (Prestige Engineering n.d., MEGD 2012). The need for additional purified water supply is immanent due to rapid urbanization and environmental pressures.

This scenario analyses the macroeconomic impacts of the Tuul water complex project including the construction of the dam, reservoirs, water treatment facilities and pipeline systems.

6.4.1 SCENARIO SETTINGS

Costs and benefits are quantified by the Prestige Engineering company and serve as input for the e3.mn model.

The implementation period is expected to be from 2026 to 2040. During this period, the dam will be constructed, water supply facilities, water pipelines and water pumps etc. will be installed. The total investment costs amount to 333 Mn. USD and will be equally allocated over the project period. Costs for operation and maintenance amount to 9 Mn. USD p.a., including amongst others, costs for sludge processing as well as power and heat expenses (Table 13). It is presumed that the government fully finances the investment at the expense of other government consumption expenditures allocated over 25 years.

The expected benefits from this adaptation measure are the avoided damage from flooding and an improved water supply to households. The benefits can be partly achieved starting in 2030 and can be fully exploited in 2035.

The CBA authors calculate with a benchmark damage of 12 Mn. USD per flood event. Under the given probability of occurrences of such a flood (between 5 to 14 years, cf. Figure 15), the avoided damage p.a. – meaning the benefit of the measure – is lower. Furthermore, it is estimated that not all, but only 50% of flood damage can be avoided. In addition to the damage avoided, particularly to infrastructure, losses due to production interruptions in various sectors can also be reduced by 50% (not part of Table 13). The benefits of improved water supply to households are quantified with at maximum 50 Mn. USD starting in 2035. Before the benefits are smaller and increase steadily starting in 2030.

Table 13: Assumptions on costs and benefits for "Tuul Water Complex (TWC)"

Costs and benefits	2025 - 2029	2030 - 2040	2041 - 2050
Annual investments for the Tuul river complex project (Mn. USD per year)	22	22	-
Operation and maintenance costs (Mn. USD per year)	-	1-9	9
Annual benefits from flood prevention (Mn. USD per year)	-	Up to 1	0.6-1.4
Annual benefits from improved water supply (Mn. USD per year)	-	Up to 50	50

Source: based on GIZ calculations

Regarding the costs and benefits of this adaptation option, it is presumed that they have been calculated under the SSP5-8.5 scenario. Assumptions regarding benefits given the same investments (costs) must therefore be adjusted for the SSP1-2.6 and SSP2-4.5 scenario.

As of now with no better information available, the probability of occurrences of floods under the three SSP scenarios is used to adjust the benefits. On average, under SSP1-2.6 (SSP2-4.5) scenario, flood events occur 16% (28%) less often than under SSP5-8.5. Therefore, the benefit from flood prevention is set to 128% (116%) for SSP1-2.6 (SSP2-4.5), assuming that with less severe flooding events damage can be prevented to a greater extent. The benefit from improved water supply is assumed to be climate independent and thus the same for all SSP scenarios.

Table 14: Benefit adjustments for "TWC" under different climate scenarios

Adaptation benefits	SSP1-2.6	SSP2-4.5	SSP5-8.5 (basis for CBA)
Flood prevention benefit	116%	128%	100%
Improved water supply benefit	100%	100%	100%

Source: Own assumptions

6.4.2 MODEL RESULTS UNDER SSP5-8.5

From a macroeconomic point of view, the Tuul river complex project is beneficial. Economic growth accelerates once the benefits can be exploited, and GDP increases by up to 1.8% p.a. compared to a situation without adaptation and climate change (Figure 45).

The investment has a minor positive impact compared to the expected benefits because particularly machinery and equipment for the water supply facilities are mainly imported. Construction activities to build the dam support domestic production. Government consumption decelerates due to less public administration expenditures to finance the adaptation investments.

The benefits of the Tuul water complex have opposing effects for the macroeconomy: the lower damage from flooded infrastructure (e.g. buildings, roads, bridges, operating facilities) means less (involuntary) spending for reconstruction. Conversely, lower losses due to undisrupted production processes lead to either fewer imports or more exports (up to 1.8% p.a.), depending on the economic sector affected. A positive impact on household consumption has greater water demand due to the improved water supply which is assumed to be realized without replacing other consumption purposes due to scarce household income.

With the expansion of the economy, more income for households and companies results in more investment (up to 1.8% p.a.) in capital stock expansion and household consumption (up to 2.4% p.a.). The high import dependency of the economy increases the overall imports by up to 1.8% per year.

The high volatility in economic growth is related to the reduced flood damages and losses which depend on the probability of flood occurrences over time. After 2040, only operation and maintenance costs of the Tuul river complex project and the benefits play a role.

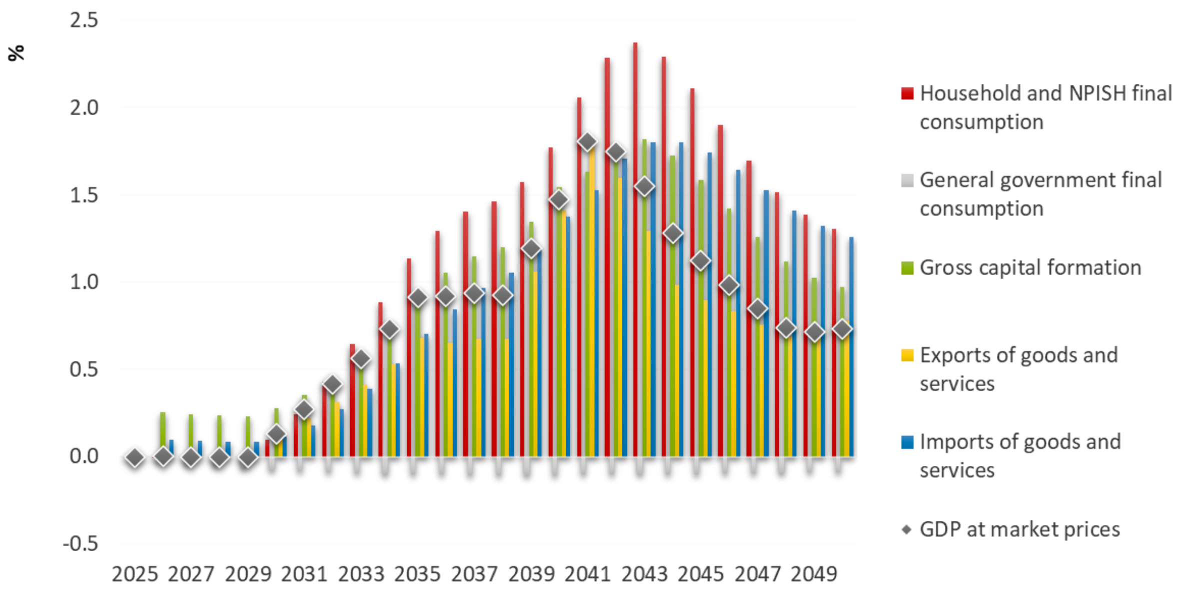


Figure 45: Macroeconomic effects of the "SSP5-8.5_TWC" scenario, 2025–2050, deviations from a SSP5-8.5 scenario in percent

Source: Own illustration based on e3.mn results

The positive macroeconomic impacts can be observed for real production by economic activities as well. Overall real production is up to 500 Mn. USD resp. 1.4% p.a. higher compared to a situation without adaptation and climate change (SSP5-8.5). The magnitude of impacts is different for the economic sector. During the implementation period, construction (up to 60 Mn. USD resp. 2% p.a.) and to a limited extent the manufacturing sector (up to 53 Mn. USD resp. 1.5% p.a.) also expand. Other sectors such as "Mining and quarrying" are indirectly affected due to the higher demand for concrete to build the dam and directly from improved water demand which increases mining production. Additionally, due to less losses from prevented flooding, many sectors show accelerated production. The private services sector including trade and transport benefits (up to 186 Mn. USD resp. 2% p.a.) during implementation from additional business activities such as planning and administrative activities and afterwards from income-induced effects.

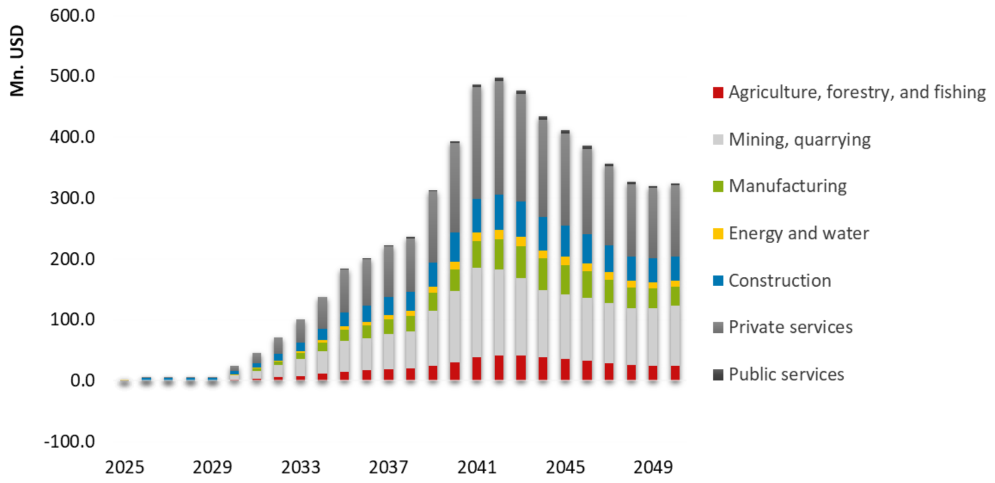


Figure 46: Effects of the "SSP5-8.5_TWC" scenario on gross production by economic sectors in constant prices, 2025–2050, deviations from the SSP5-8.5 scenario in Mn. USD

Source: Own illustration based on e3.mn results

Depending on the sectoral economic activity and the respective labour intensity, additional employment can be observed. The most jobs are created in the private services sector which results in up to 9 000 persons resp. 1.8% p.a., followed by "Agriculture, forestry and fishing" (up to 4 000 persons resp. 1.9% p.a.) which is related to additional household expenditures mainly for essential goods such as food and beverages. To a limited extent, in construction and manufacturing new jobs can be created – both during project implementation and also permanent jobs related to operation and maintenance. In total, employment increases by up to 20 thousand persons resp. 1.4% p.a. (Figure 47).

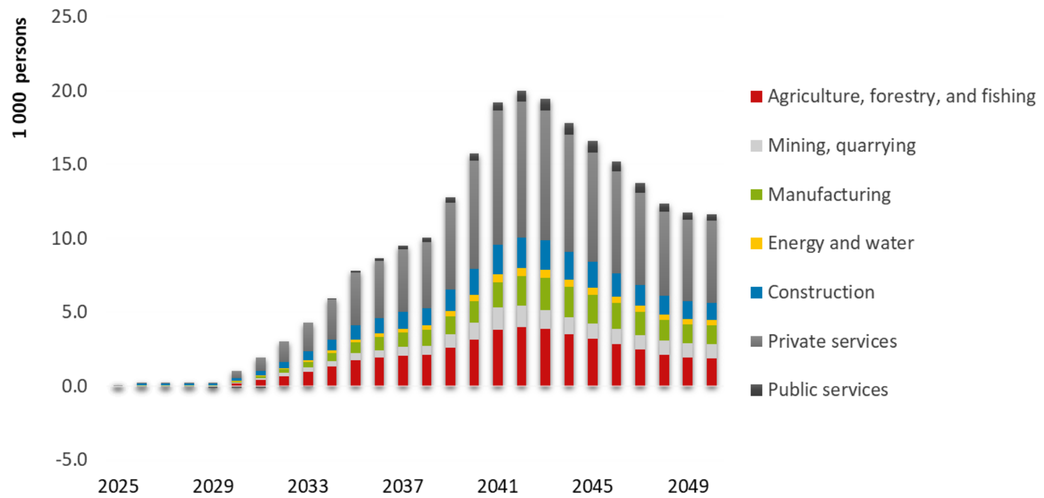


Figure 47: Effects of the "SSP5-8.5_TWC" scenario on employment by economic activities, 2025–2050, deviations from the SSP5-8.5" scenario in 1 000 persons

Source: Own illustration based on e3.mn results

From a gender perspective, more jobs are created for male workers (11.4 thousand resp. 1.4% p.a.) than for females (up 8.6 thousand resp. 1.4% p.a., Figure 48) due to the gender structure by economic sectors and the triggered economic activities. Male workers benefit from additional jobs in construction as well as “Mining and quarrying”, female workers more in private services sector.

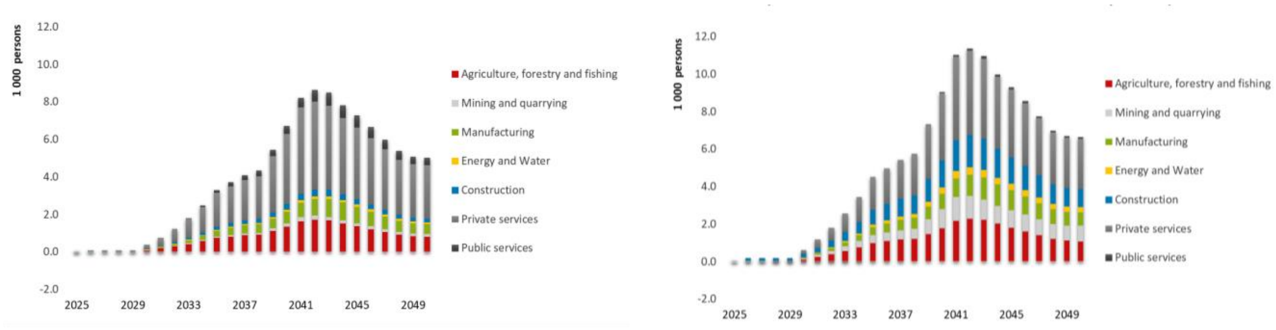
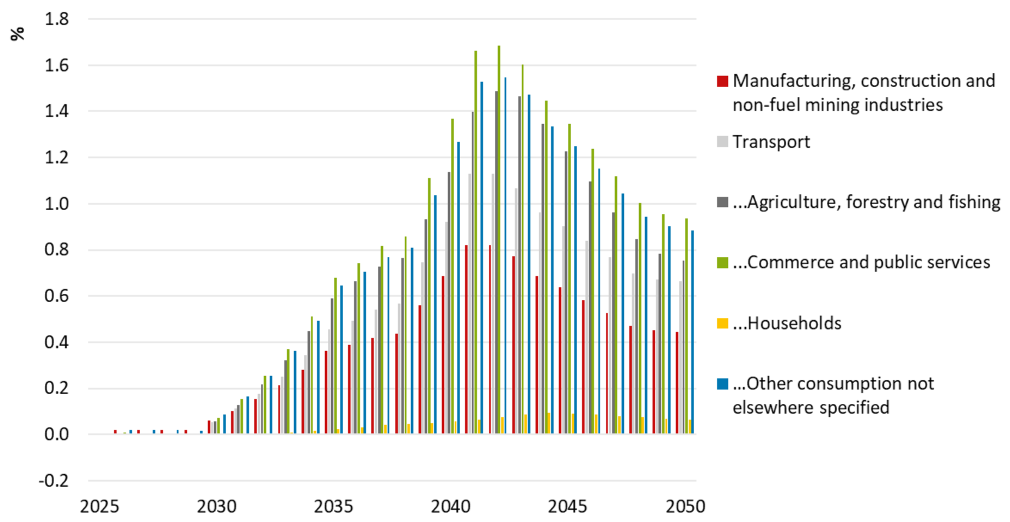


Figure 48: Effects of the “SSP5-8.5_TWC” scenario: employment by economic activities and gender (female: left figure, male: right figure), 2025–2050, deviations from the SSP5-8.5 scenario in 1 000 persons

Source: Own illustration based on e3.mn results

As visible in Figure 49, all economic sectors show an increase in final energy consumption. The magnitude depends on the sectoral production and energy intensity and ranges from a maximum of 1.1% in “manufacturing, construction and non-fuel mining industries” to 1.7% for “Commerce and public services”. In total energy demand increases by up to 1.3% resp. 8.5 PJ per year.



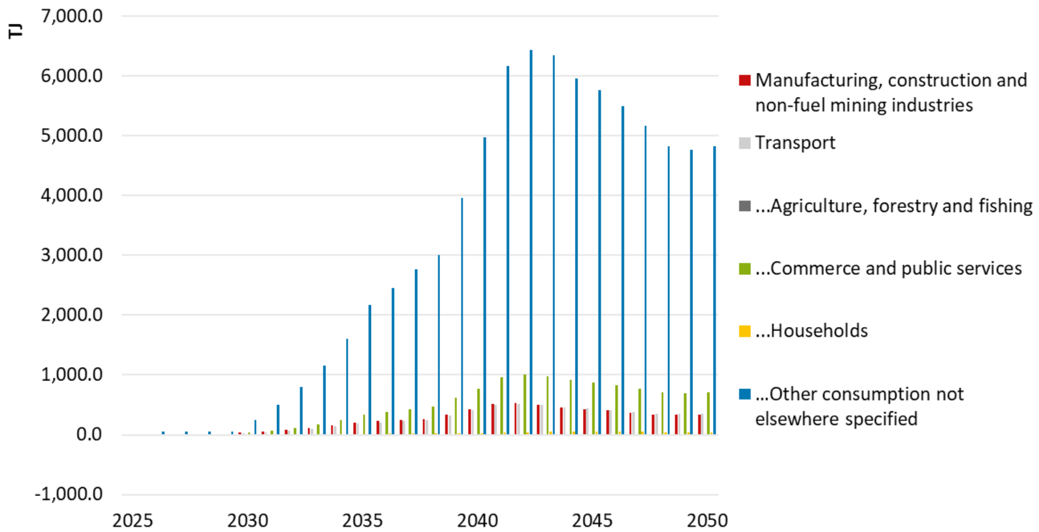


Figure 49: Effects of the "SSP5-8.5_TWC" scenario on FEC by sectors, 2025–2050, deviations from the SSP5-8.5 scenario in percent (top figure) and TJ (bottom figure)

Source: Own illustration based on e3.mn results

Depending on the fuels used, GHG emissions increase in those economic sectors. GHG emissions from heat and electricity are attributed to "Energy industries". Overall combustion-related GHG emissions increase up to 1.1% resp 390 Gg CO_2e p.a. (Figure 50) to which emissions from heat and electricity generation contribute the most, followed by transport and "Other non-specified stationary" related to activity in service sectors.

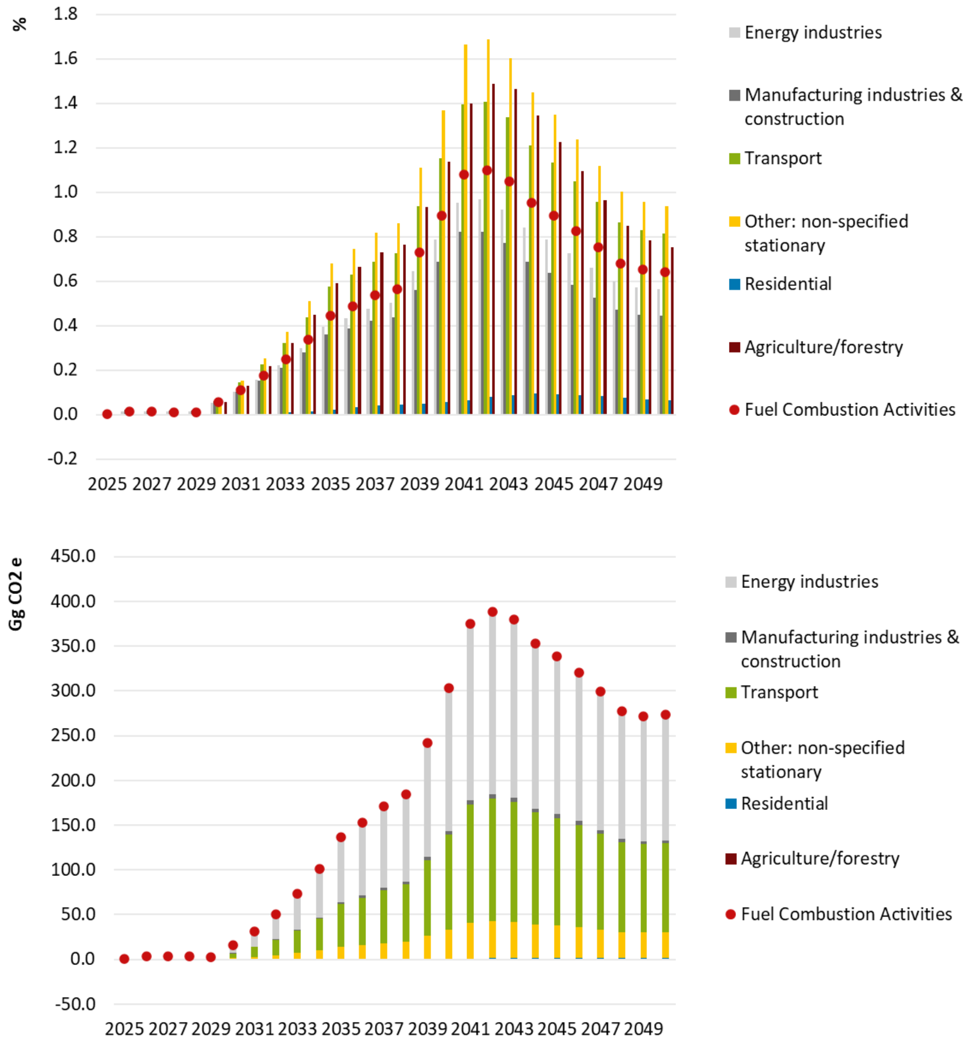


Figure 50: Effects of the "SSP5-8.5_TWC" scenario on GHG emissions by sectors, 2025-2050, deviations from the SSP5-8.5 scenario in percent (top figure) and Gg CO_2e (bottom figure)

Source: Own illustration based on e3.mn results

6.4.3 MODEL RESULTS OVERVIEW FOR SSP1-2.6, SSP2-4.5 AND SSP5-8.5

The intensity and frequency of climate hazards differ depending on the respective climate scenario, and as a result the economic impacts (cf. section 5). The benefits of an adaptation option differ as well, depending on the climate scenario assuming the same adaptation investments. Figure 51 summarizes the results for GDP by economic sectors for all "SSP_TWC" scenarios.

The impact chains of the previous section remain unchanged. The main difference is that the specified benefits defined in the CBA under SSP5-8.5 are greater (cf. Table 14) resulting in better macroeconomic effects. The capacity of the water reservoir is the same for all scenarios but the probability of occurrences of floods and thus, the expected damage and loss from flooding differs. The benefit from flood prevention cannot, of course, be greater than the damage and losses without adaptation. While the triggered economic sectors from the adaptation measure are the same for all SSP scenarios, the magnitude of sectoral effects related to the benefits from flood prevention are smaller under SSP1-2.6 and SSP2-4.5.

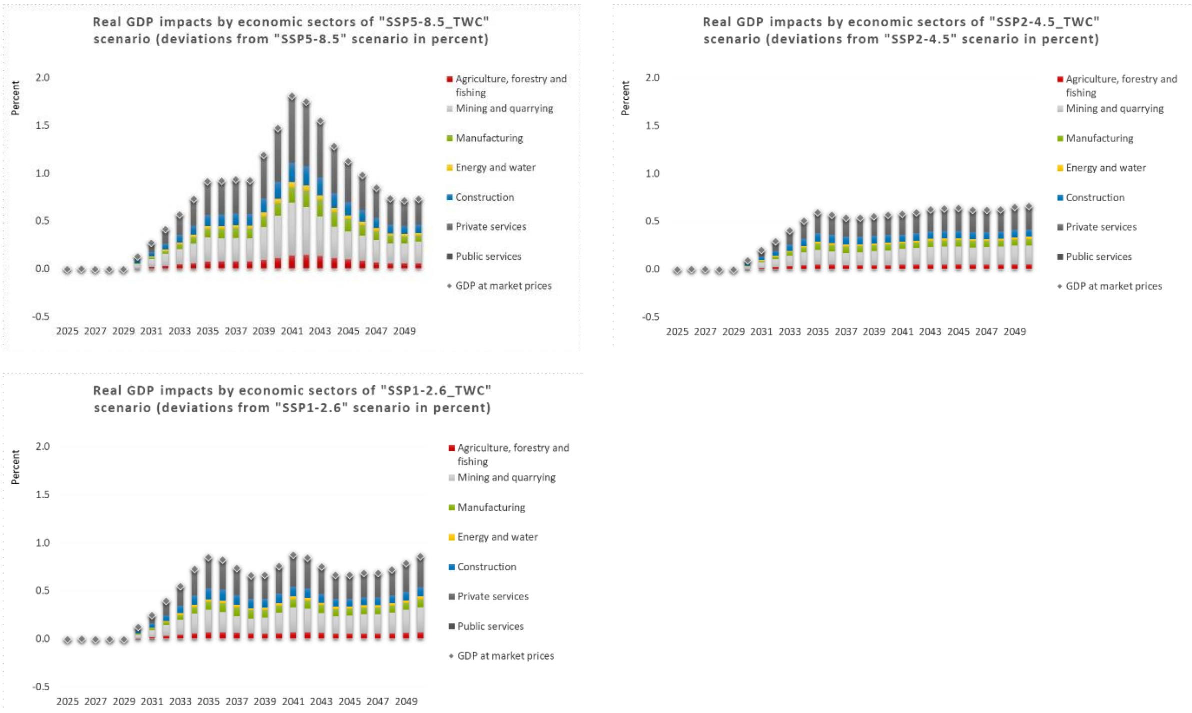


Figure 51: "SSP1-2.6_TWC", "SSP2-4.5_TWC" and "SSP5-8.5_TWC" scenarios: Real GDP impacts by economic sectors, 2025–2050, deviations to the respective SSP scenario in percent*

Source: Own illustration based on e3.mn results

*Percentage deviation of sectoral gross production has been scaled to percentage deviation of GDP

The key results for all "SSP_TWC" scenarios in comparison to the resp. SSP scenario in 2050 are shown in Figure 52. The effect on employment depends on the strength of the effect on GDP and economic sectors. Male workers are better off from this adaptation measure than female workers. The environmental impacts are less positive with economic growth if no additional energy efficiency measures and the replacement of fossil fuels by RE are introduced.

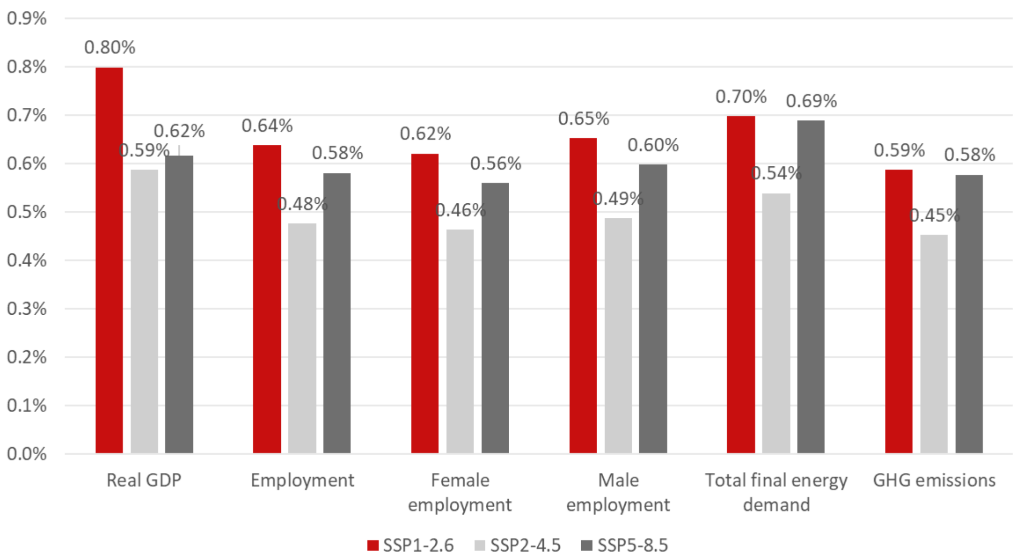


Figure 52: "SSP1-2.6_TWC", "SSP2-4.5_TWC" and "SSP5-8.5_TWC" scenarios: Key impacts, year 2050, deviations to the respective SSP scenario in percent

Source: Own illustration based on e3.mn results

To conclude, water management is beneficial for the people and the economy. Involuntary (defensive) spendings of the affected people and businesses and the government can be limited due to damage and loss reduction. In addition, the improved water supply helps to avoid water shortages. More and "better" purified water is available for household consumption in Ulaanbaatar which is important as migration to the capital intensifies. Specifically, residents in ger areas have restricted access to water and consume much less than those living in urban apartments.

Additional water may also be beneficial for agriculture, mining, the energy sector and other industries such as food processing and textile industry. Other business opportunities may arise from the establishment of artificial lakes (Prestige Engineering n.d.). However, this was not part of this scenario.

7. Conclusions and outlook

Mongolia faces significant vulnerability to climate change forcing policymakers to develop adaptation strategies which minimize negative impacts to the economy, the people and the environment. Pairing comprehensive CBAs and macroeconomic analyses with the e3.mn model effectively supports the design of a NAP by providing suitable indicators including investment, GDP, employment and combustion-related GHG emissions, which are relevant for different line ministries.

Effectiveness is not limited to financial or economic impacts: Policymakers must also consider other aspects, such as health, ecosystem issues (e.g., biodiversity), distributional effects, other GHG emissions as well as international / political implications.

The e3.mn model results show that certain adaptation options prove to be beneficial not only for single adaptation projects, but also from an economy-wide point of view:

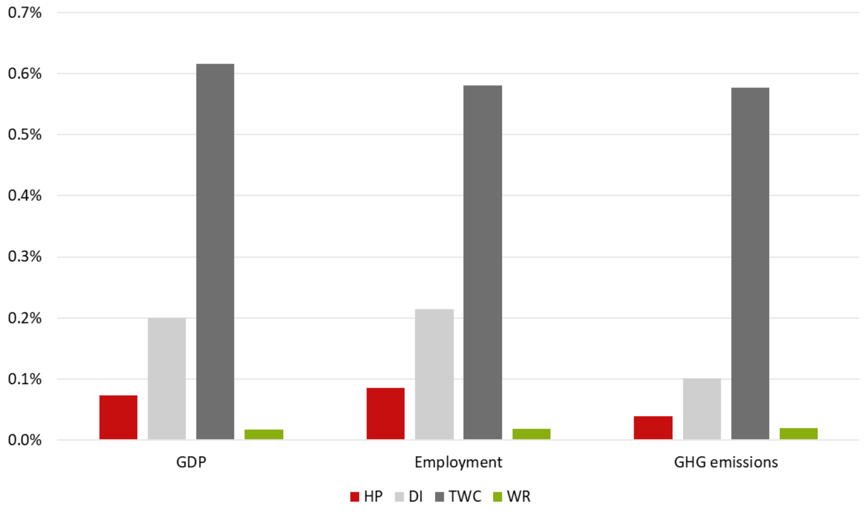


Figure 53: Key impacts of all adaptation scenario under SSP5-8.5, in 2050

Source: e3.mn model results

The magnitude of effects differs depending on the specific adaptation measure. The economic effect becomes better with higher required investments and / or benefit(s) for the target sector(s), even more importantly, if the measure supports domestic production and as an outcome creates jobs.

The Mongolian people and economy profit even more from a measure if financial support comes from international donors, because government and consumers can spend the saved money on other purposes. Additionally, the costs for damage control decrease with any damage that can be avoided with the measure.

Figure 53 reveals the largest GDP impacts for the Tuul water complex project (TWC), investment in drip irrigation systems (DI) and additional herding points (HP) in 2050. It must be noted that the impacts differ over the simulation period, depending on the implementation period of the measure.

The investment needs range from 78 Bn. MNT for “WR” to 1.2 Tn. MNT for “TWC” which means a different stimulus for the economy. Additionally, if investment goods and services must be imported, which is mainly the case for manufactured goods such as drip irrigation systems and water supply facilities, the benefits for Mongolia are limited.

“DI” and “HP” are expected to be favorable especially for agriculture which is also true to a limited extent for “WR”. After the implementation period, operation and maintenance activities support other industries as well. Due to income-induced effects caused by the increasing number of jobs and higher incomes, service sectors and other consumption-related economic sectors such as food processing industry will experience higher demand. Compared to “TWC”, the magnitude of GDP growth and job creation is smaller but also the adaptation costs.

The “TWC” project is beneficial for the people and many economic sectors. On the one hand, the water supply for the people can be improved. On the other hand, expectations for flood prevention are also considerable, which means less damage to infrastructure and production losses for affected businesses.

Quantifiable environmental effects are limited as no additional mitigation measures are introduced. With higher economic activity, GHG emissions will increase in the affected sectors if economic growth is not decoupled from energy demand or the shift to RE does not take place. In the design of adaptation strategies this negative side effect has to be considered.

Single adaptation measures usually focus on benefits only for a single sector. The adaptation options analysed give attention to food and water security which is related to two of the priority sectors in the NAP. Agriculture is both a key sector of Mongolia and at the same time highly vulnerable to climate change. Water is relevant for many sectors and the people and should be better regulated regarding excess water and water scarcity. Both aspects will become more frequent and severe according to climate projections.

The combination of more than one adaptation measure helps to address climate change impacts more broadly and provides better solutions for regions that experience different climate change impacts. Mitigation and adaptation options should be considered jointly. Energy efficiency standards in buildings are low and heat loss in wintertime significant. Retrofitting buildings has huge mitigation potential and would reduce heating demand during harsh winters and cooling demand during heatwaves.

The results in this report are accompanied by several uncertainties stemming from currently limited knowledge on adaptation costs and benefits, and on future developments of climate change in general. Nevertheless, the results give valuable insights helping to better understand the possible effects of long-term climate-sensitive strategies.

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Appendix

Appendix 1: Data collection in Mongolia on climate change effect damages (excerpt)

MNG_ClimateDamageImpactDatabase_241121 - Kopie.xlsm

1	Date (day/month/year)	Provinces/capital city	Climate hazard category (select from list)	Climate hazard severity	Climate hazard severity by measure	Physical damage/impact description	Description of quantified SECTORAL damage / impact or persons affected (see next columns)	2020	2021	2022	2023	2024
2306	01-12.2023	Hövsgöl	Зуд /Zud	ГУ (High)			Хорогдсон малын тоо/Livestock mortality				383,700	
2307	01-12.2023	Hentiy	Зуд /Zud	ГУ (High)			Хохирол (төг) Total damage (thous.MNT)				77,439,570	
2308	01-12.2023	Hentiy	Зуд /Zud	ГУ (High)			Хорогдсон малын тоо/Livestock mortality				421,923	
2309	01-09.2024	Bayan-Ölgiy	Халуун хуурай салхи/hot dry w	Low (alarm)								
2310	01-09.2024	Hovd	Халуун хуурай салхи/hot dry w	Low (alarm)								
2311	12-01.2024	Hovd	Халуун хуурай салхи/hot dry w	Low (alarm)								
2312	19-01.2024	Övörhangay	цасан шуурга/snowstorm	АУ (Medium)	average wind speed 10 m/s, snowstorm, distance 2000 m or more, 3 hours more							
2313	19-01.2024	Dundgovĭ	цасан шуурга/snowstorm	АУ (Medium)	average wind speed 10 m/s, snowstorm, distance 2000 m or more, 3 hours more							
2314	19-01.2024	Dornogovĭ	цасан шуурга/snowstorm	АУ (Medium)	average wind speed 10 m/s, snowstorm, distance 2000 m or more, 3 hours more							
2315	19-01.2024	Sühbaatar	цасан шуурга/snowstorm	АУ (Medium)	average wind speed 10 m/s, snowstorm, distance 2000 m or more, 3 hours more							
2316	19-01.2024	Hovd	цасан шуурга/snowstorm	АУ (Medium)	average wind speed 10 m/s, snowstorm, distance 2000 m or more, 3 hours more							
2317	19-01.2024	Hovd	цасан шуурга/snowstorm	АУ (Medium)	average wind speed 10 m/s, snowstorm, distan		Хорогдсон малын тоо/Livestock mortality				4,434	
2318	12-13-04.2024	Uvs	цасан шуурга/snowstorm	АУ (Medium)	average wind speed 10 m/s, snowstorm, distance 2000 m or more, 3 hours more							
2319	12-13-04.2024	Dzavhan	цасан шуурга/snowstorm	АУ (Medium)	average wind speed 10 m/s, snowstorm, distance 2000 m or more, 3 hours more							
2320	12-13-04.2024	Hovd	цасан шуурга/snowstorm	АУ (Medium)	average wind speed 10 m/s, snowstorm, distance 2000 m or more, 3 hours more							
2321	13-04.2024	Bayanhongor	салхи шуурга / Windstorm	АУ (Medium)	The average wind speed is 18 m/s, more than 2		нурсан гэр/Ger destroyed/					22
2322	13-04.2024	Övörhangay	салхи шуурга / Windstorm	АУ (Medium)	The average wind speed is 18 m/s, more than 2		Айлын хашаа /household fence destroyed					52
2323	13-04.2024	Bulgan	салхи шуурга / Windstorm	АУ (Medium)	The average wind speed is 18 m/s, more than 2		Хорогдсон малын тоо/Livestock mortality					4,437
2324	13-04.2024	Dundgovĭ	салхи шуурга / Windstorm	АУ (Medium)	The average wind speed is 18 m/s, more than 24 m/s							
2325	13-04.2024	Dornogovĭ	салхи шуурга / Windstorm	АУ (Medium)	The average wind speed is 18 m/s, more than 24 m/s							
2326	13-04.2024	Töv	салхи шуурга / Windstorm	АУ (Medium)	The average wind speed is 18 m/s, more than 24 m/s							
2327	10-06.2024	Selenge	нөөлөг салхи / Squal wind	Low (alarm)	Wind speed will exceed 15 m/s		Хохирол (төг) Total damage (thous.MNT)					1,964
2328	10-06.2024	Selenge	нөөлөг салхи / Squal wind	Low (alarm)	Wind speed will exceed 15 m/s		Айлын хашаа /household fence destroyed					151
2329	10-06.2024	Selenge	нөөлөг салхи / Squal wind	Low (alarm)	Wind speed will exceed 15 m/s		нурсан гэр/Ger destroyed/					1
2330	10-06.2024	Selenge	нөөлөг салхи / Squal wind	Low (alarm)	Wind speed will exceed 15 m/s		цахилгааны тулгуур багана тоо/number o					7
2331	27-08.2024	Hövsgöl	аянга цахилгаан /Thunder and l	Low (alarm)			Нас барсан хүний тоо/Persons died (numb					1
2332	12-08.2024	Hövsgöl	аадар бороо, уруйн үер /Heavy	АУ (Medium)	30 mm or more, less than 3 hour		Хорогдсон малын тоо/Livestock mortality					210
2333	12-13-09.2024	Ömnögovĭ	Их бороо/Heavy rain	АУ (Medium)	30 mm or more, 12 hours or less		family house flooded number					3
2334	12-13-09.2024	Dundgovĭ	Их бороо/Heavy rain	АУ (Medium)	30 mm or more, 12 hours or less		барилгын дээвэр/roof of buildings peeled					4
2335	12-13-09.2024	Dornogovĭ	Их бороо/Heavy rain	АУ (Medium)	30 mm or more, 12 hours or less							
2336	01-10.2001		Зуд /Zud	ГУ (High)			Хохирол (төг) Total damage (thous.MNT)					

Source: MNG_ClimateDamageImpactDatabase_241121.xlsm

Published by:
Deutsche Gesellschaft für
Internationale Zusammenarbeit (GIZ) GmbH

Registered offices:
Bonn and Eschborn, Germany

Dag-Hammarskjöld-Weg 1-5
65760 Eschborn, Germany
T +49 61 96 79-0
F +49 61 96 79-11 15
E info@giz.de
I www.giz.de

Project:
Policy dialogue and knowledge management on climate protection strategies (DIAPOL-CE)

Anita Richter, Project lead
Köthener Straße 3
10963 Berlin, Germany
E anita.richter@giz.de

This programme is part of the International Climate Initiative (IKI). The Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (BMUV) supports this initiative on the basis of a decision adopted by the German Bundestag.

Prepared by:
Dr. Anett Großmann, GWS
Frank Hohmann, GWS
Peter Dreuw, GWS

Concept & Design:
Atelier Löwentor GmbH, Darmstadt