Economy-wide impacts of climate change and adaptation in Mongolia

Assessing the macroeconomic impacts of climate change and adaptation in Mongolia with the E3 prototype model

Executive summary

March 2023

Climate change seriously impacts Mongolia. This concerns not only the environment but also results in immense economic costs, affecting key industries and endangering jobs, wealth, and life of Mongolian people. Floods destroy infrastructures while dzuds cause crop and livestock losses in agriculture. Apart from theses direct impacts, further losses result from e.g., impaired production due to power outages.

Adaptation aims at limiting adverse effects of climate change and at the same time tries to maximize its benefits. For certain economic sectors and climate hazards, a number of single economic sector evaluations and different cost-benefit analyses for adaptation measures exist. However, macroeconomic impacts and intersectoral effects of climate change and adaptation are rarely considered.

For Mongolia's economy, knowledge about economy-wide effects of climate change and sectoral adaptation measures is essential, especially with regards to employment, GDP, and CO_2 emissions. Macroeconomic models such as the *e3.mn prototype model* combined with scenario analysis are valuable tools to raise awareness of the topic and to support policy makers to develop climate resilient strategies. The Excel-based *e3 (economy, energy, emission) prototype model* builds upon country-specific data from international datasets for capacity building purposes. Data on Mongolia was used to put the prototype model into practice, creating the *e3.mn prototype model.* The following report presents the exemplary macroeconomic assessments conducted for the impacts of dzuds and investments in irrigation systems to adapt against the impacts of dzuds.

Macroeconomic analyses with e3 models are based on specific expert knowledge and / or detailed sector models, which were only available to a limited extent for scenario analyses with the prototype. The results are thus only of limited use for policy advice and rather serve demonstration purposes.

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1. Introduction

Climate change adaptation and mitigation are key challenges for Mongolia. As a signatory to the Paris Agreement in 2016, Mongolia committed to reducing greenhouse gas emissions and helping to limit global warming (UNFCCC 2022). At the same time, Mongolia is confronted with extreme weather events (EWEs) such as dzuds and droughts as well as gradual long-term changes of the climate. Climate scientists expect even more frequent, more severe and recurring EWEs for Mongolia as well as increasing temperatures above global average (USAID 2017).

Climate change impacts lead to economic costs and affect key industries such as agriculture. Policymakers should be aware of potential impacts on the national economy, should know how to prepare for them, and need to develop adaptation strategies to reduce economic risks of climate change and thus initiating the transition to a climate resilient economy. E3 (economy-energy-emission) models in combination with scenario analysis support policymakers with these issues.

Under 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, Nuclear Safety and Consumer Protection (BMUV), such e3 models were developed for Georgia and Kazakhstan jointly with local partners combined with intensive capacity building. These models were then applied to better understand the economy-wide impacts of climate change and adaptation by evaluating the direct, indirect, and income-induced impacts.

First, climate change and adaptation scenarios were designed comprising data on the most relevant climate hazards, their sector-specific impacts as well as appropriate adaptation options. Second, these scenarios were analysed with the models. Results were then fed into stakeholder discussions and policy processes to support evidence-based policymaking and adaptation planning (GIZ 2022a).

The CRED approach briefly described above is ambitious in terms of data collection, modelling, coordination, and planning, as well as time-consuming for all partners involved. However, the highly participatory approach promotes exchange between field experts and line ministries. In addition, the use of modelling tools supports evidence-based policy making (GIZ 2021; GIZ 2022a; GIZ 2023a).

To enable also other countries to apply such modelling tools to climate change related issues without starting from scratch, a simplified *e3 model prototype* was developed for Mongolia based on international data sets (GIZ 2022a, 2023b).

A three-day training was conducted in Mongolia to explain the participants in a nutshell how to develop such a model in Microsoft Excel and how to apply this tool for climate adaptation policy questions. Feedback from training participants revealed ongoing interest to learn more about the *e3.mn model* and how it can be used to analyse the impacts of adaptation but also mitigation issues. Based on previous modelling and capacity building experiences, the authors are convinced that the CRED approach could also be successfully applied in other countries.

In this report, first an overview on climate change and its effects in Mongolia is given. Then, exemplary results from the macroeconomic analysis with the *e3.mn prototype model* are described by looking at the economy-wide impacts from dzuds and adaptation to it. Sector-specific expert knowledge for the climate change (dzud) and adaptation scenarios was only available to a limited extent. Thus, the results are of limited use for policy advice and rather serve demonstration purposes.

2. Climate change and its impacts in Mongolia

2.1 Country information

Mongolia is a land-locked East Asian country with a vast territory of 1.6 million square kilometres that borders Russia to the North and China to the South. It is surrounded by mountain ridges in the transition zone between the Siberian taiga and Central Asia's dry steppes and semi-deserts (USAID 2022). The land is predominantly characterized by semi-arid grass steppes and hardly arable (WBG 2015). With around 85%, most of the country lies more than 1,000 meters above sea level (WBG 2015). Less than one percent of the territory is classified as arable land (NSO 2021).

Total population is steadily increasing and reached 3.35 million in 2021 (Figure 1). However, Mongolia is one of the most sparsely populated countries with a population density of two inhabitants per square kilometre (NSO 2021). Nowadays, 70% of total population is living in urban areas with already 1.6 million people in the capital Ulaanbaatar (NSO 2021).

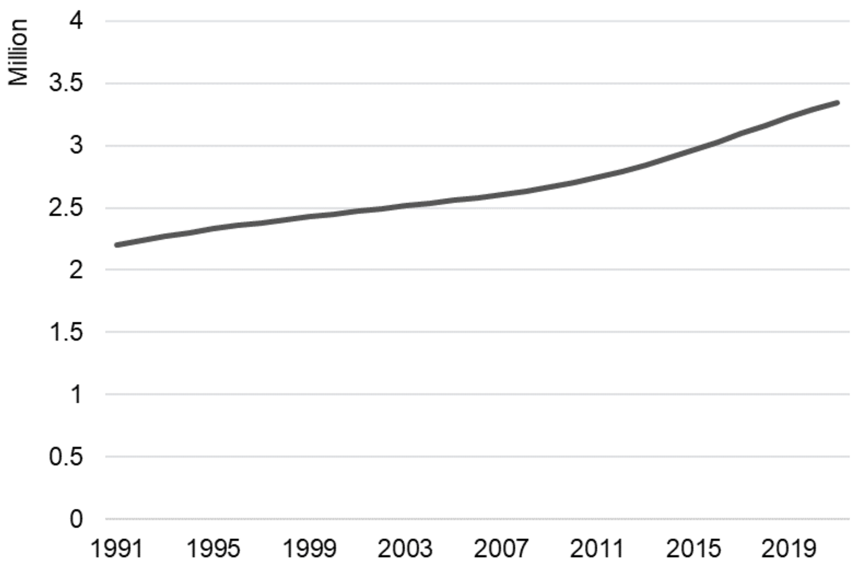

Figure 1: Development of Mongolia's Population 1991-2021

Source: own illustration based on UN (2022)

During the transition to a market economy, Mongolia experienced volatile economic growth (Figure 2) due to the dependency on the mining sector and the related exposure to external shocks (WBG and ADB 2021). Mongolia has rich deposits of e.g., gold, copper, iron, lead, zinc, coal and oil (see e.g. Muff et al. 2016). Mineral products are the main export commodities but agricultural products such as livestock, hides, and cashmere are exported was well (NSO 2021).

In the mid-1990s, economic recovery begun, interrupted by the Asian and Russian economic crises in 1997, 1998 and the global financial and economic crisis in 2009. After recovery, Mongolia entered an economic boom phase. In 2011, economic growth even reached 17.3%. This period was characterized by high investments in mining, rising export prices and expansionary monetary and fiscal policies (ADB 2021). With collapsing investments and falling commodity prices, economic growth also declined sharply with a GDP growth rate of 1.5% in 2016. Mongolia has implemented far-reaching fiscal and macroeconomic reforms to reduce the vulnerabilities associated to boom-bust cycles, and as of 2017 the economy began to recover, interrupted by the onset of the COVID-19 pandemic (ADB 2021).

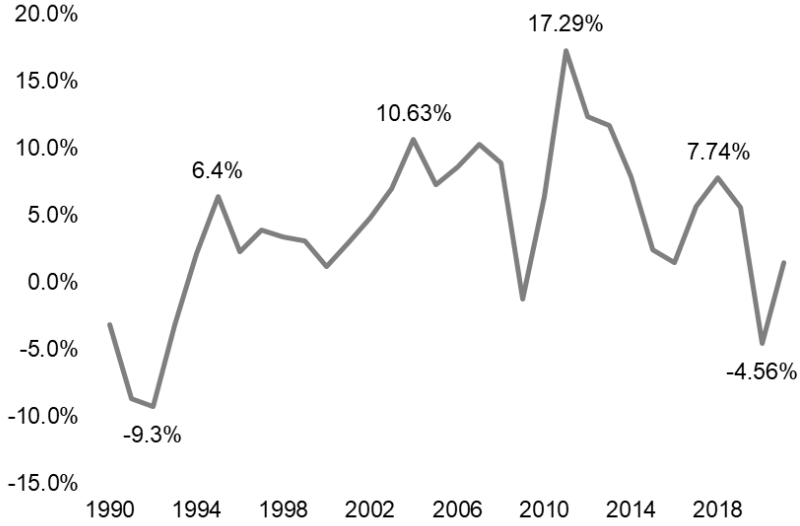

Figure 2: Mongolia’s Real GDP growth rate

Source: own illustration based on World Bank (2022)

Exports are the main driver of economic growth contributing to 58% of GDP. More than 50% of GDP is attributed to consumption of private households and non-profit institution serving households (NPISH, Figure 3). Gross capital formation has a GDP share of 35%. Mongolia’s high import dependency is reflected by an import share of 59% in GDP, including imported intermediate products as well as final goods.

Mongolia’s main trading partners are the People’s Republic of China (76% of exports and 37% of imports in 2021) and Russia (26% of imports in 2021), followed by Switzerland (19% of exports) and Japan (8% of imports).

Key economic sectors in Mongolia are mining and quarrying (24.3%), agriculture, forestry, and fishing (13.2%), trade (9.7%) and manufacturing (7.6%) as shown in Figure 4. Other services account for around 27%. The large majority of Mongolia’s agricultural outputs stem from livestock breeding (NSO 2021). Over time, Mongolia's economy has changed from herding and agriculture to one that is more focused on extractive industries (Helble et al. 2020).

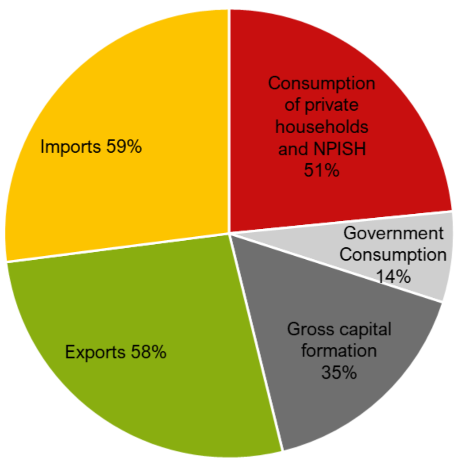

Figure 3: Mongolia’s GDP by expenditure approach, 2021

Source: own illustration based on ADB (2022)

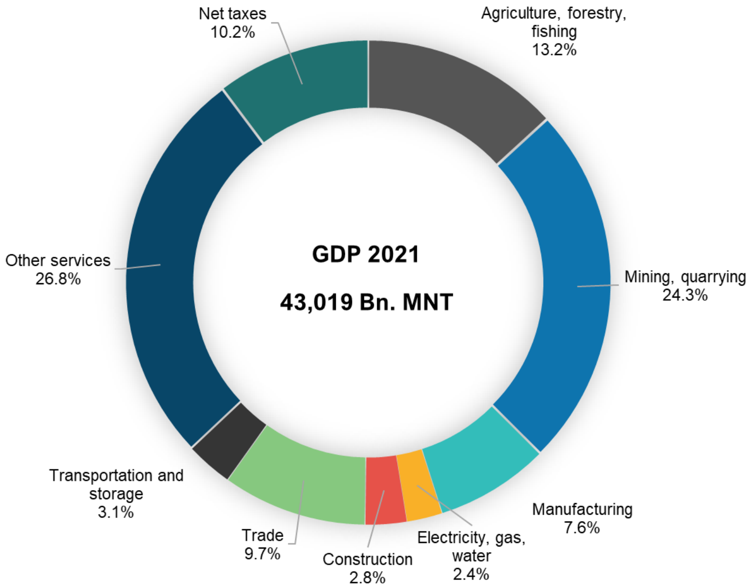

Figure 4: Mongolia's GDP by economic sectors, 2021

Source: own illustration based on ADB (2022)

Figure 5 shows the development by economic activity for the years 2000, 2010 and 2021. During this period, the total number of employed persons increased from 0.8 to 1.13 million. In 2021, the unemployment rate was 8.1% (ADB 2022). In 2000, nearly half of all employed persons worked in agriculture, but the share declined to 26% by 2021. A large part of the rural communities is engaged in nomadic livestock herding (FAO 2022), however, many people have moved to urban areas as herding was no longer sufficient to make their living. At the same time, the share of employed persons in the service sectors increased from 37% to 52% and in the construction sector from 3% to 7%. Although mining contributes to almost one quarter of the GDP, this sector only employs about 5% of the workforce in 2021.

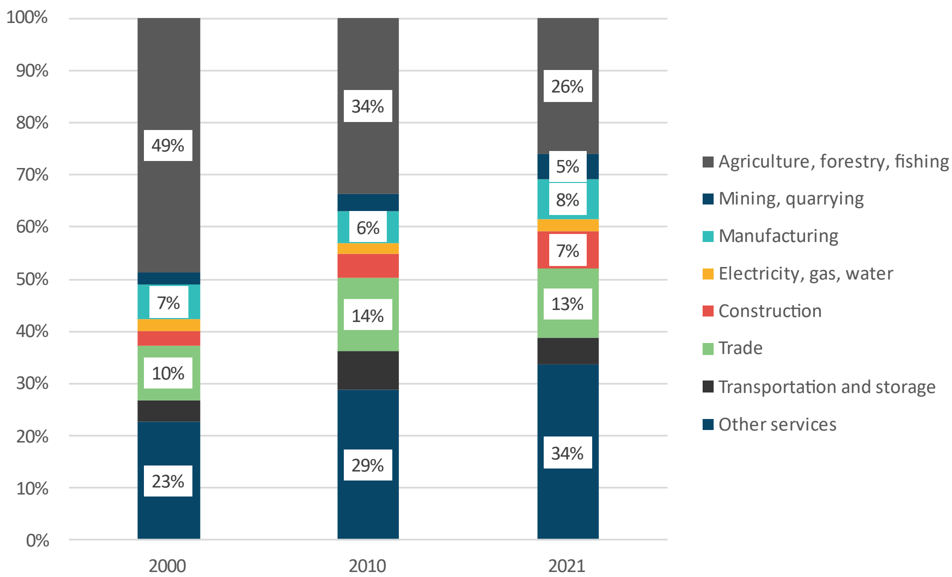

Figure 5: Mongolia's employment by economic activity, 2000,2010 and 2021

Source: own illustration based on ADB (2022))

2.2 Climatic conditions and threats

2.2.1 OVERVIEW AND PAST TRENDS

Mongolia is characterized by a dry subarctic continental climate with short hot summers, long cold winters and relatively low precipitation (USAID 2022; Batsukh et al. 2021; Yembuu 2021). Annual average temperatures range from -22°C to 17°C, but temperatures may reach -50°C during winters (MET 2018; UNDRR 2019). Annual precipitation is about 400 mm which is highest in the north and lowest in the south (WBG and ADB 2021).

The average annual air temperature increased by 2.24 °C between 1940 and 2015 (WBG and ADB 2021), (MET 2018). According to several studies and the observation of herders this increasing temperature trend is evident throughout the whole country and all seasons except for winter temperatures (USAID 2022). There has been an increase in hot days with daily mean air temperature above 26°C, especially in the central and north western regions (WBG and ADB 2021; MET 2018).

Average annual precipitation declined by 7% between 1940 and 2015 but the observations are of low significance. Despite the overall decrease in precipitation, winter snowfall has increased and more precipitation occurs on days with precipitation (MET 2018; WBG and ADB 2021).

Mongolia is particularly vulnerable to dzuds, droughts and fires, but also to extreme precipitation and wind (UNDRR 2019). Dzuds are EWEs and a national phenomenon characterized by preceding droughts in summer, followed by severe cold and/or heavy snow and severe storms in winter causing massive livestock losses (UNDRR 2019). In the last decades, it has already been observed that dzuds and droughts have occurred more frequently with an increasing intensity. Further, the number of consecutive drought years has also increased (Nandintsetseg and Shinoda 2013; MET 2018).

2.2.2 CLIMATE PROJECTIONS

Projections of future average daily temperatures range from an increase of 1.5°C (RCP2.6[1]) to 5.5°C (RCP8.5) by the end of this century, which is well above the global average (WBG and ADB 2021). Changes in minimum and maximum temperatures are projected to be more rapid and to be spread unevenly throughout the year (WBG and ADB 2021). The trends with increasing summer days and reduction in frost days as well as the melting of permafrost are projected to continue throughout the century (MET 2018).

Projections of average annual precipitation for Mongolia range from an increase of 8% to 14% by 2100 (WBG and ADB 2021). Snow fall is projected to increase throughout the century by 50-75% (MET 2018).

Mongolia is facing a potentially significant change in its hydrological system, including a shift in the seasonality of runoff (USAID 2022). Since 2000, river flow has remained far below the long-term average, resulting in the reduction of the national lake area by about 7% and the drying up of about 600 lakes (USAID 2022). Despite projected slight increases in precipitation, an increase in evaporation and a decline in lake water levels is expected (USAID 2022).

The magnitude and frequency of EWEs are supposed to further increase. Heatwaves are projected to increase under all RCP climate scenarios as well as the probability of experiencing severe droughts and dzud events (WBG and ADB 2021). The increase in drought conditions is accompanied by an increase in consecutive

[1] The Representative Concentration Pathways (RCP) 8.5 (2.6) is the most pessimistic (optimistic) scenario assuming a global temperature increase of +4.8°C (+2°C) compared to the preindustrial level.

drought years (MET 2018). The frequency of dzuds is expected to increase by up to 40% under the high emission scenario by the end of the century (MET 2018).

2.2.3 SECTOR IMPACTS

Climate change affects the economy and the life of people in many ways. As outlined in the previous section, as climate change proceeds, more frequent and intense EWEs will occur. Particularly the vulnerability to dzuds remains high in Mongolia (WBG and ADB 2021). Almost 40% of the economic losses in the period of 1996-2013 were caused by dzuds causing losses in agriculture. The dzud event in 2009/2010 alone reached 4% loss of yearly GDP(UNDRR 2019).

Sectors that are highly vulnerable to climate change are agriculture, mining, water, energy, infrastructure and human health (WBG and ADB 2021; USAID 2022). The economic impacts in each of the sectors differ and are caused by different EWEs and slow-onset events.

Infrastructure (transport, building, energy, water) is in particular affected by extreme wind and precipitation events which cause damages to buildings, gers, transmission lines and lighting poles, bridges and roads (USAID 2022; UNESCAP 2020).

The energy sector is also affected by heatwaves, droughts and increasing temperatures which limits the power generation capacity and results in impaired efficiencies. At the same time, demand for cooling in summer may increase (WBG and ADB 2021).

Agriculture, mining, energy, and human health are facing challenges regarding water availability and water quality (USAID 2022; Fan 2020). Mines are located in rather dry areas, but the production process is water intensive. However, the mining industry also faces risks from floods (USAID 2022).

Human health is, amongst others, negatively affected by increasing risks of malnutrition, polluted and insufficient drinking water as well as heat-related mortality (WBG and ADB 2021; Fan 2020; IFRC 2021). Demand for health care services and expenditures in the health care system may accelerate also due to the risk of tropical diseases.

In the following, the impacts of climate change and options for adaptation in agriculture are presented in more detail.

Current situation in agriculture

Agriculture, and especially animal husbandry with more than 80% of the agricultural outputs, is still an important sector of the Mongolian economy. Herding is the source of subsistence in particular for rural population that rely largely on natural pastures as harsh environmental conditions hinder traditional farming (FAO 2022; WBG and ADB 2021; UNDRR 2019).

Two thirds of the rural population is engaged in nomadic or semi-nomadic livestock herding (FAO 2022). Increasing numbers of livestock (e.g., sheep, goats, cows, and horses) per hectare continuously exceeded the country's pasture capacity in the last decades (MET 2018). Mongolia is characterized by a short vegetation period and limited scope for crop production (FAO 2022). Due to the rather low crop productivity and the small area under cultivation, the country is dependent on imports of food (FAO 2022). Certain crops are planted in rain-fed areas (over 90% of grain crops, 60% of potatoes and 70% of cultivated fodders) and thus are mainly dependent on the climatic conditions of the growing seasons (MET 2018).

The increasing number of EWEs has already threatened the traditional lifestyle and destroyed the livelihood of the poorest and most vulnerable herders. Thus, more and more are migrating from rural to urban areas trying to find jobs e.g., in the service sector (UNDRR 2019; IFRC 2021). The rapid urbanization creates new challenges. For instance, unplanned settlement has taken place in areas particularly prone to flash floods (USAID 2022; IFRC 2021).

Impacts of climate change on agriculture

The agricultural sector is highly vulnerable to various EWEs such as droughts, dzuds, extreme wind, and precipitation. Climate change has had already various impacts on agriculture and food production – both on arable farming and on animal husbandry – and it will continue to intensify in the future (MET 2018). While there might be positive impacts on agricultural production through increasing temperatures, it is expected that overall impacts are likely to be negative due to reduced water availability, decreasing soil fertility, reduced pasture productivity and increasing desertification (Fan 2020).

EWEs like dzuds, droughts and heatwaves lead to crop and livestock losses. Four severe dzud events occurred in Mongolia since 1999 resulting in huge losses of livestock (Rao et al. 2015). In the Third National Communication, MET (2018) reports an expected increase in livestock mortality rates of more than 50% by mid-century and 100% by the end of the century due to increased frequencies and intensities of droughts and dzuds. Further declines in wheat yields might be significant. MET (2018) discloses a range of 20%–50% by 2080.

Options for building climate resilience in agriculture

MET (2018) identifies several adaptation options for arable and livestock farming. Adaptation options in the field of arable farming include reducing evaporation, effective irrigation systems, increasing moisture availability, cultivating drought-resistant, high-yielding varieties, and improving soil fertility. Adaptation options in the field of livestock farming include strengthening animal survival quality, breeding high productive animals, pasture management, increasing livestock forage, irrigated hay feeding, decreasing animal diseases and early warning system against drought-dzud risks (MET 2018).

Already earlier, MEGD (2013) conducted a technology needs assessment for several adaptation measures of which an excerpt is shown in Table 1. Not all adaptation options are quantified with respect to their costs and benefits. In particular, quantified benefits of such measures in terms of damage reduction are very rare. More recent data on adaptation options are also available; one of them is used in the illustrative example in the section on adaptation which can be found below.

Table 1: Overview of selected climate change adaptation measures for Mongolia

Adaptation Measures	Adaptation Benefits	Investment (million USD)
Seasonal to inter-annual prediction and livestock early warning system	Based on the technology, animal loss in winter can be reduced by 20-50 % especially during dzuds.	800
Planting of forage perennials resistant to drought and cold winter for fodder production	Increased biomass, reduced pasture degradation and mitigation of greenhouse gases	1.3
Sustainable pasture management	Increased resilience of livestock which is vulnerable to climate change	15.8
Crop growing under plastic mulches	Water use for irrigation will be halved to 10.4 Mn. m^3; yields might increase by 35%	3.3

Vegetable production system using drip irrigation and water saving methods	Drip irrigation systems can save water and increase crop and vegetable production.	100

Source: own illustration based on MEGD (2013)

3. Macroeconomic analysis of climate change and adaptation measures

Cost-benefit analyses show suitable solutions for the respective sectoral climate change related issue. A macroeconomic analysis goes a step further and evaluates the economy-wide impacts in terms of e.g., changes in GDP, employment, and production of sectoral adaptation options.

The *e3.mn prototype model* for Mongolia was developed to showcase the economy-wide impacts of climate change and sector-specific adaptation measures. It helps to identify adaptation measures that are highly effective and have positive effects on the economy, employment, and the environment. This can only be achieved if the socio-economic relationships are captured, as well as the relationships between economic activity, energy, and the environment, as carried out with the so-called e3 (economy, energy, emission) models.

In a climate change scenario, assumptions are made about the frequency and intensity of a single EWE and combined with sector- and country-specific climate damages. In a climate change adaptation scenario, costs and benefits of adaptation measures are covered which are borrowed from expert studies. If no specific data is available, own assumptions are made which can later be adapted if better data becomes available. The initial impacts in each of these scenarios trigger chain reactions in the e3.mn model.

The model results do not only show the direct effects but also the indirect and induced macroeconomic consequences (GDP, jobs, imports, sector-specific output) for Mongolia due to economic interrelationships. On the one hand, model results show what could happen under climate change scenarios (awareness raising). On the other hand, policymakers can identify those adaptation measures that are highly effective and have positive effects on the economy, employment, and the environment (win-win options). Thus, they are better prepared to make meaningful decisions.

3.1 Macroeconomic analysis of dzuds in agriculture

In this subsection, the macroeconomic effects of dzuds are illustrated exemplarily. To do so, the first two steps of a four-step approach to implement climate change and adaptation in an economic model (described in detail in GIZ 2022b) are taken (see also Figure 6). The main prerequisites for this analysis are the future evolution of dzuds (expected frequency and intensity) and the quantified economic damages from the past. This information is then translated into e3.mn model variables as described in GIZ (2023b). The economy-wide impacts of dzud events are then revealed by comparing this climate change scenario with the hypothetical “no climate change” scenario which is laid out as business-as-usual (BAU) scenario.

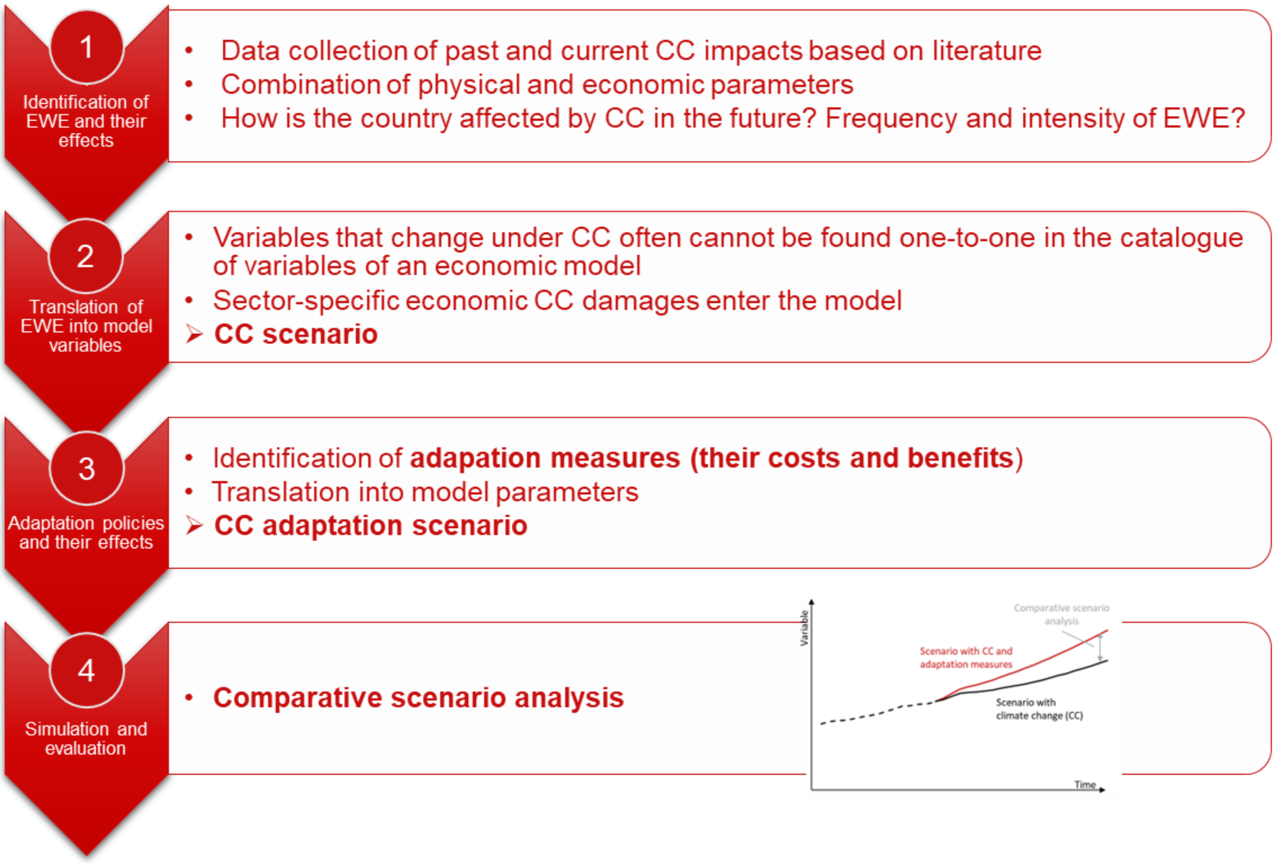

Figure 6: Four-step approach to implement climate change and adaptation in an economic model

Source: GIZ 2022b

3.1.1 SCENARIO SETTINGS

In line with CFE-DM (2022), in the "dzud" scenario it is assumed that dzuds will occur every 5 years, and thus twice as often as in the past. Livestock losses may increase by 50% by 2050 (MET 2018). The average benchmark damage for livestock losses from past events amounts to 373 Bn. MNT which is adjusted by the expected value of livestock losses (GIZ 2023b; Ailtgui 2022). This assures that an increasing intensity of dzuds is reflected in future climate change damages. Overall, livestock losses are expected to double by 2050 compared to the average benchmark damage.

3.1.2 MODEL RESULTS

Based on the assumption that dzuds occur every five years, six of these events occur in the simulation period until 2050.

Dzuds are negatively impacting the economy. Mongolia's GDP is up to 0.9% resp. 846 Bn. MNT p.a. lower compared to a situation without a dzud (Figure 7). Livestock exports cannot be realized and are up to 1.4% resp. 432 Bn. MNT p.a. lower. Agricultural imports are increasing to satisfy the domestic demand. Other imports are decreasing due to lower economic activity and import dependency. Furthermore, lower employment and income levels reduce the spending opportunities of private households.

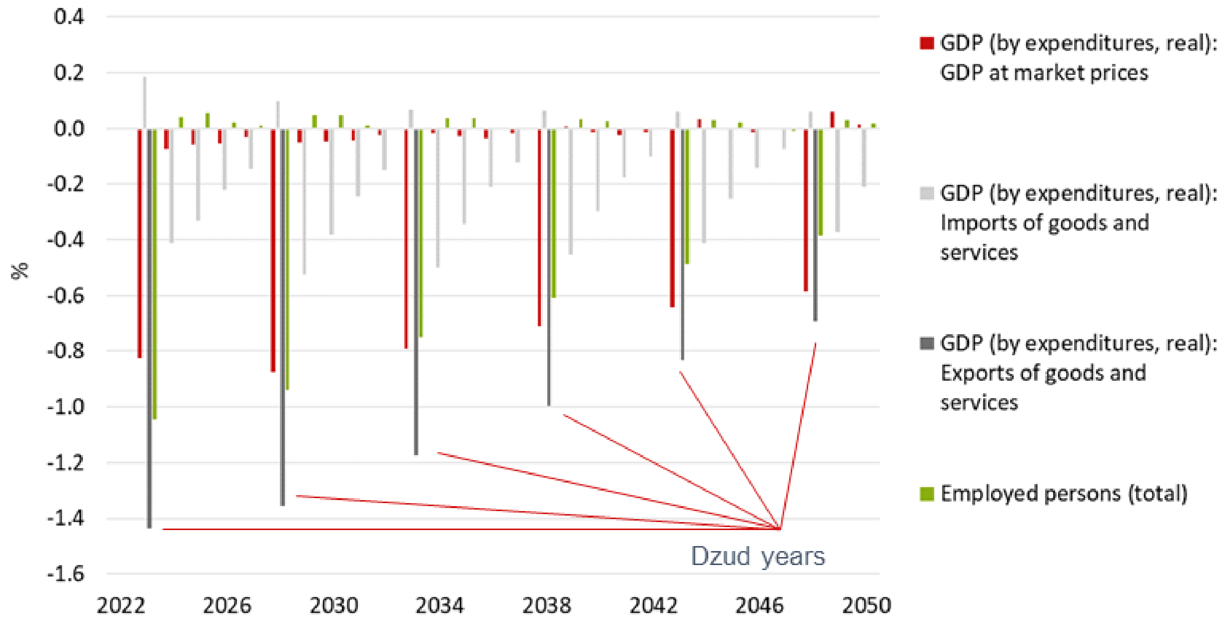

Figure 7: „Dzud“ scenario: Macroeconomic effects, 2022-2050, deviations from a hypothetical "No dzud" (BAU) scenario in percent

Source: own illustration based on e3.mn results

Between the dzud years, the economy recovers over time but not fully due to lagged reactions in investment and household consumption expenditures.

In dzud years, production in agriculture is constrained resulting in -2.3% resp. 143 Mn. USD (Figure 8). Other sectors that are not directly affected by the dzud are also influenced via sectoral interlinkages. Demand for intermediate products, for example pesticides, is decreasing. Lower consumption expenditures of private households on food and beverages, among other things, cause further production adjustments.

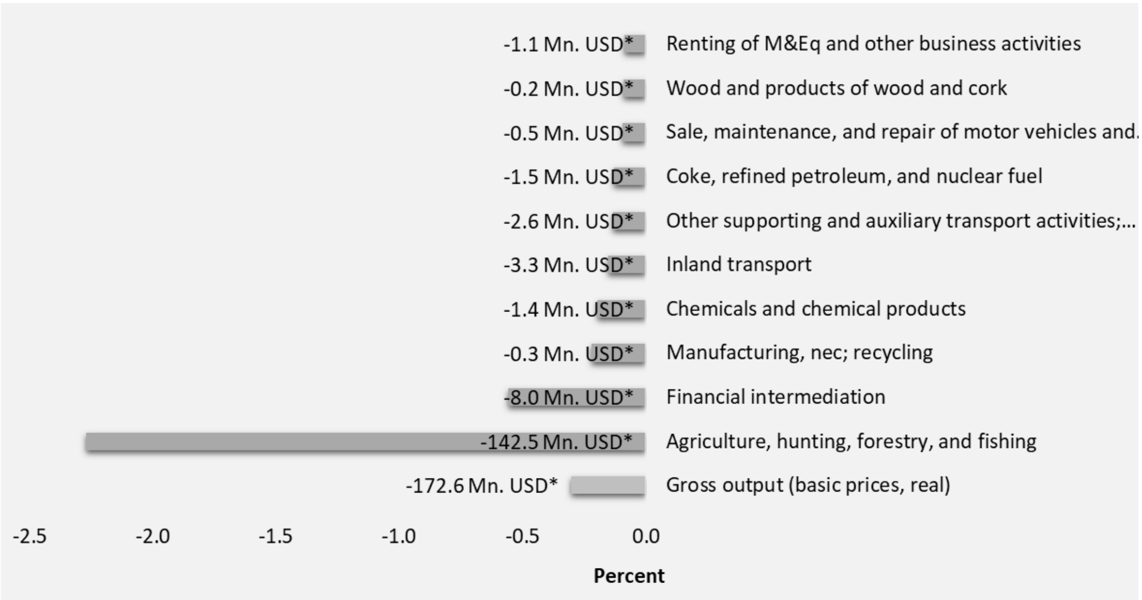

Figure 8: „Dzud“ scenario: impacts on real production by economic sectors, drought year 2048, deviations from a hypothetical "No dzud" (BAU) scenario in percent (x-axis) and Mn. USD (*)

Source: own illustration based on e3.mn results

Employment reacts depending on production and sectoral labour productivity. Employed persons in agriculture suffer the most (-3.8% resp. -10,800 persons in 2022) and intensify migration to the capital. The overall employment is at max. 1% resp. 11,600 persons lower compared to the BAU scenario (Figure 9).

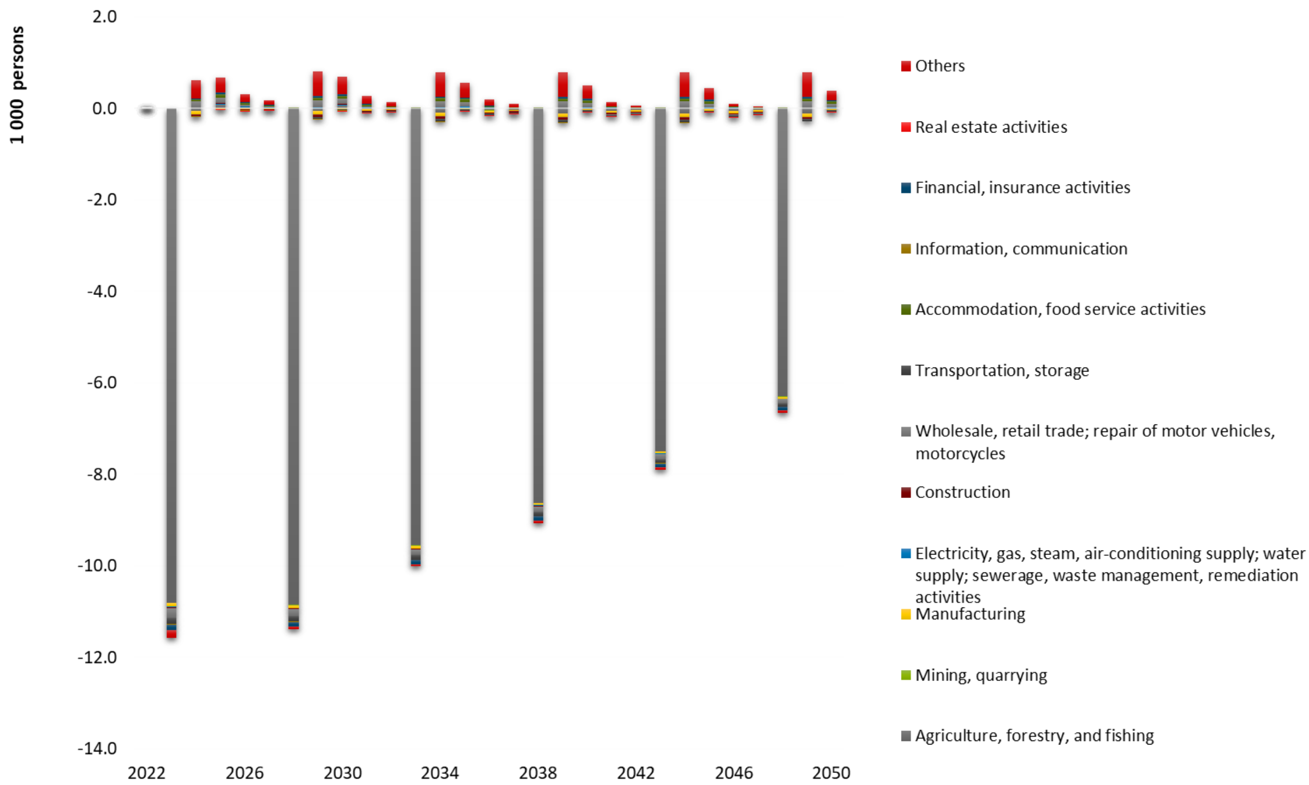

Figure 9: „Dzud“ scenario: impacts on employment by economic activities, 2022-2050, deviations from a hypothetical “No dzud” (BAU) scenario in 1,000 persons

Source: own illustration based on e3.mn results

The impacts on the environment are positive. Lower economic activity results in less final energy demand and thus lower emissions (Figure 10 and Figure 11). Final energy demand is at max. 0.6% resp. 3,111 TJ p.a. lower compared to the BAU scenario. The economy is heavily dependent on coal and oil products, less on electricity. Thus, fossil fuels are reduced more than electricity.

As the energy mix remains as in the past and no further expansion of renewable energy is assumed in this scenario, emissions are at a lower level during the dzud years. Percentage deviation is highest in agriculture because production decelerates the most (Figure 11). Overall, GHG emissions can be reduced by up to 48 Gg CO_2e with energy industries and transport contributing the most.

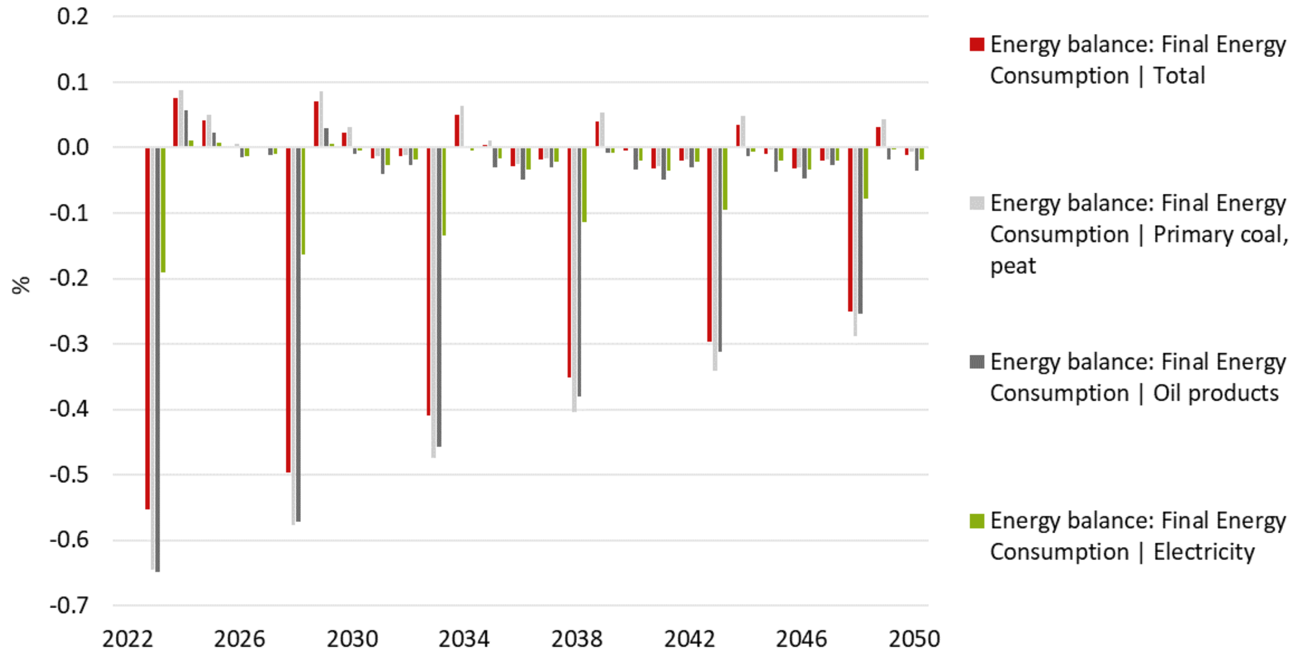

Figure 10: „Dzud“ scenario: impacts on final energy consumption by energy carriers, 2022-2050, deviations from a hypothetical "No dzud" (BAU) scenario in percent

Source: own illustration based on e3.mn results

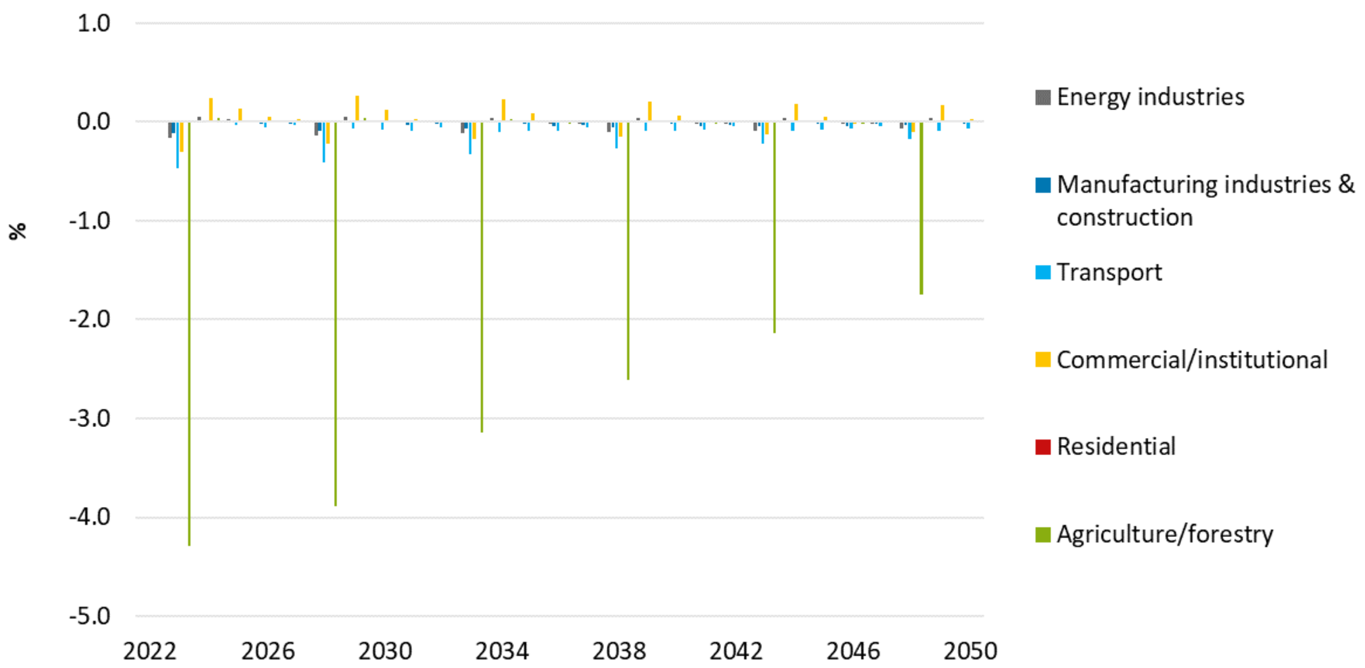

Figure 11: „Dzud“ scenario: impacts on GHG emissions by sectors, 2022-2050, deviations from a hypothetical "No dzud" (BAU) scenario in percent

Source: Own illustration based on e3.mn results

3.2 Macroeconomic analysis of adaptation to dzuds in agriculture

In this subsection, the macroeconomic effects of the adaptation measure "Construction and restoration of irrigation systems" is presented as an example of how to reduce the impacts from dzuds. Irrigation systems help to prevent from water scarcity in particular during droughts preceding dzuds and to improve pasture productivity under climate change. As shown in the previous section, dzuds are expected to occur more frequently and more severely causing increasingly higher economic losses in agriculture, affecting jobs and food security.

Therefore, climate change adaptation is critical for Mongolia to reduce vulnerability to climate change impacts. Adaptation means anticipating the adverse effect of climate change and taking appropriate action to prevent or minimize the damage or taking advantage of opportunities that may arise.

The remaining two steps of the four-step approach (cf. Figure 6) are taken which comprise the identification of suitable adaptation measures as well as their costs and benefits. The costs are typically investments, and the benefits are the reverse impacts of climate change. Again, this information must be translated into e3.mn model variables. The economy-wide impacts of the adaptation measure are then evaluated by comparing the climate change adaptation scenario with the respective climate change scenario. Several adaptation options can be evaluated against each other to identify favourable solutions.

3.2.1 SCENARIO SETTINGS

Investments in construction and restoration of irrigation systems allow for irrigated hay feeding. According to the brief research of Ailtgui (2022), related costs amount to 321 Bn. MNT[2]. To maintain the irrigation systems also in the future, ongoing replacement investments are assumed. It is expected that the government finances the investment at the expense of other government consumption expenditures.

It is assumed that construction and restoration of irrigation systems mainly involves local construction works.

The benefits of this measure are stabilized moisture supply, increased yields and reduced losses during droughts. Thus, herders can produce hay in sufficient quantities to feed livestock adequately during droughts and stocks can be built up for the winter. Quantified benefits are not available. Thus, it is assumed that 50% of the damage during dzuds can be avoided once the irrigation systems are fully implemented after 5 years.

3.2.2 MODEL RESULTS

The additional investments in irrigation infrastructure have positive impacts on the economy as Figure 12 shows. GDP is at max 0.4% resp. 200 Bn. MNT p.a. higher compared to a situation with dzuds and no adaptation. Agricultural exports are increasing (+0.7% resp. 216 Bn. MNT) while agricultural imports can be avoided due to less livestock losses. Overall imports are increasing by 0.6% resp. 332 Bn. MNT due to import dependency in particular for manufactured goods.

As the government subsidizes the adaptation measure, government consumption expenditures in other areas are assumed to be cut.

[2] https://www.mongolbank.mn/documents/press_conference/20210906_05.pdf; https://mofa.gov.mn/branch/gazar_tarialan/616f9ffd73bc4a5fc70f2211

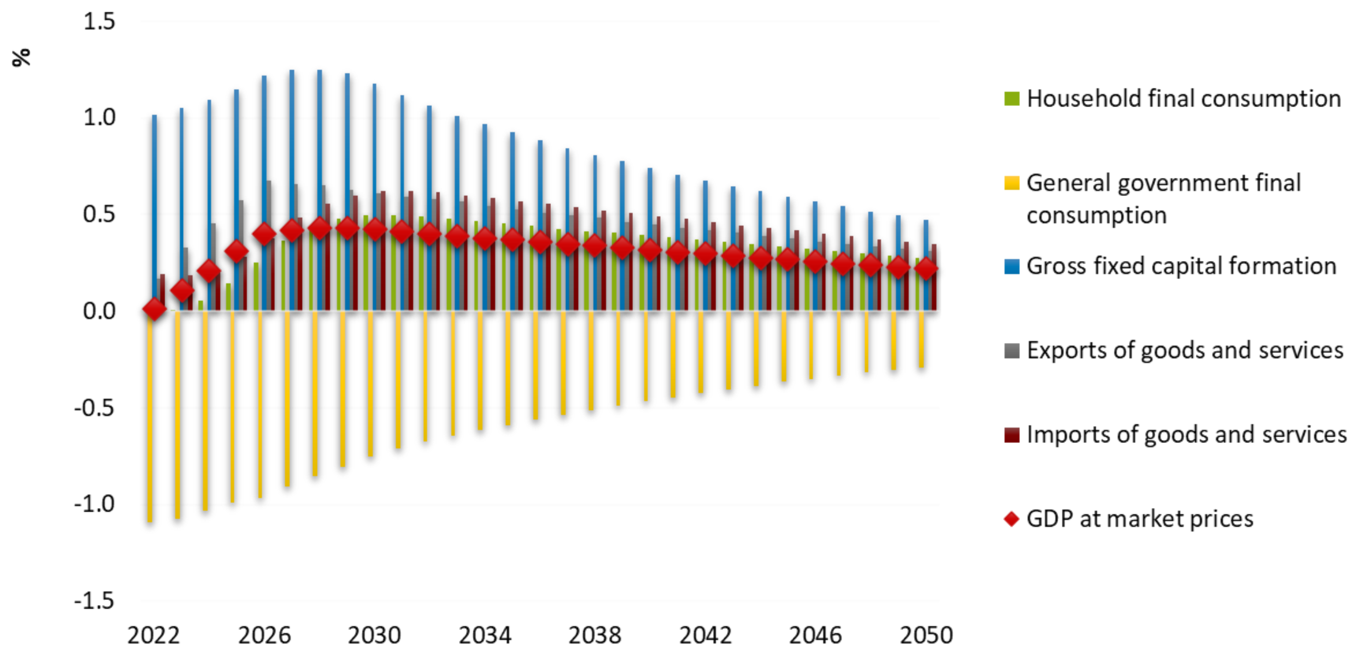

Figure 12: Macroeconomic effects of the „Irrigation" scenario, 2022-2050, deviations from "Dzud" scenario in percent

Source: Own illustration based on e3.mn results

Irrigated hay feeding helps to increase the agricultural production during dzud years (Figure 13) but also in years without dzuds. Furthermore, investments in irrigation systems stimulate construction activity with positive impacts for several other industries (e.g., concrete which is shown in "other non-metallic minerals"). Indirect and income-induced effects also show positive impacts especially for the food processing industry.

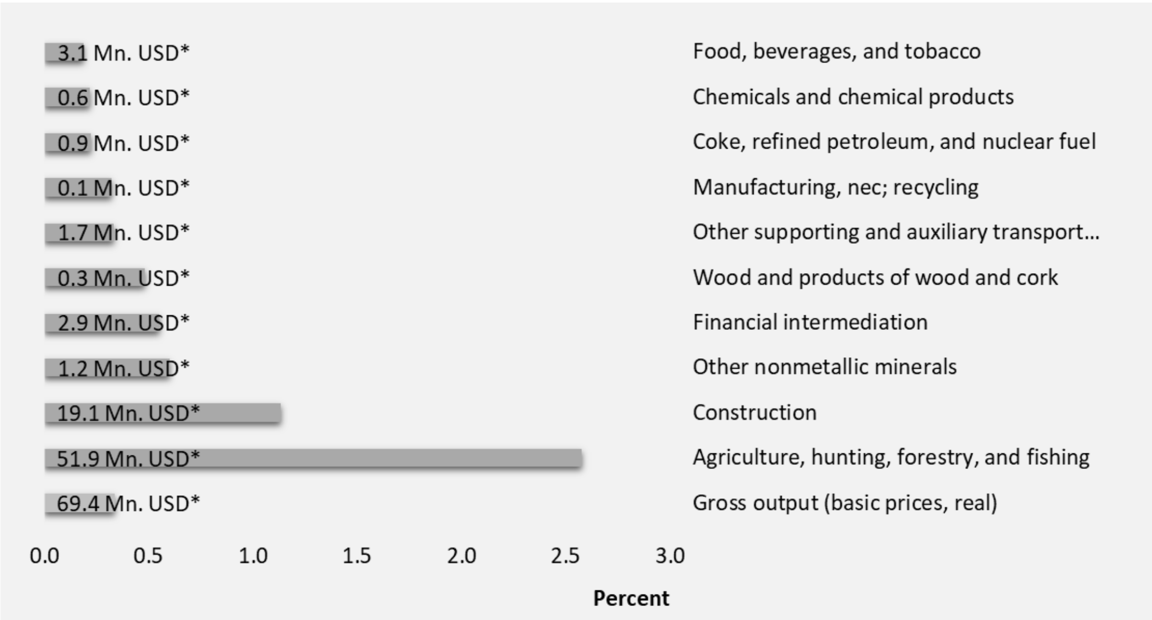

Figure 13: Effects of the „Irrigation" scenario on real production by economic sectors, 2026, deviations from a "Dzud" scenario in percent (x-axis) and Mn. USD (*)

Source: Own illustration based on e3.mn results

Overall employment increases by up to 0.4% (4,700 persons) compared to the dzud scenario without adaptation (Figure 14). Employeesin agriculture, manufacturing, and construction profit the most whereas employees in public administration ("others") suffer due to the assumption that the government financially supports adaptation at the expense of other government consumption expenditures.

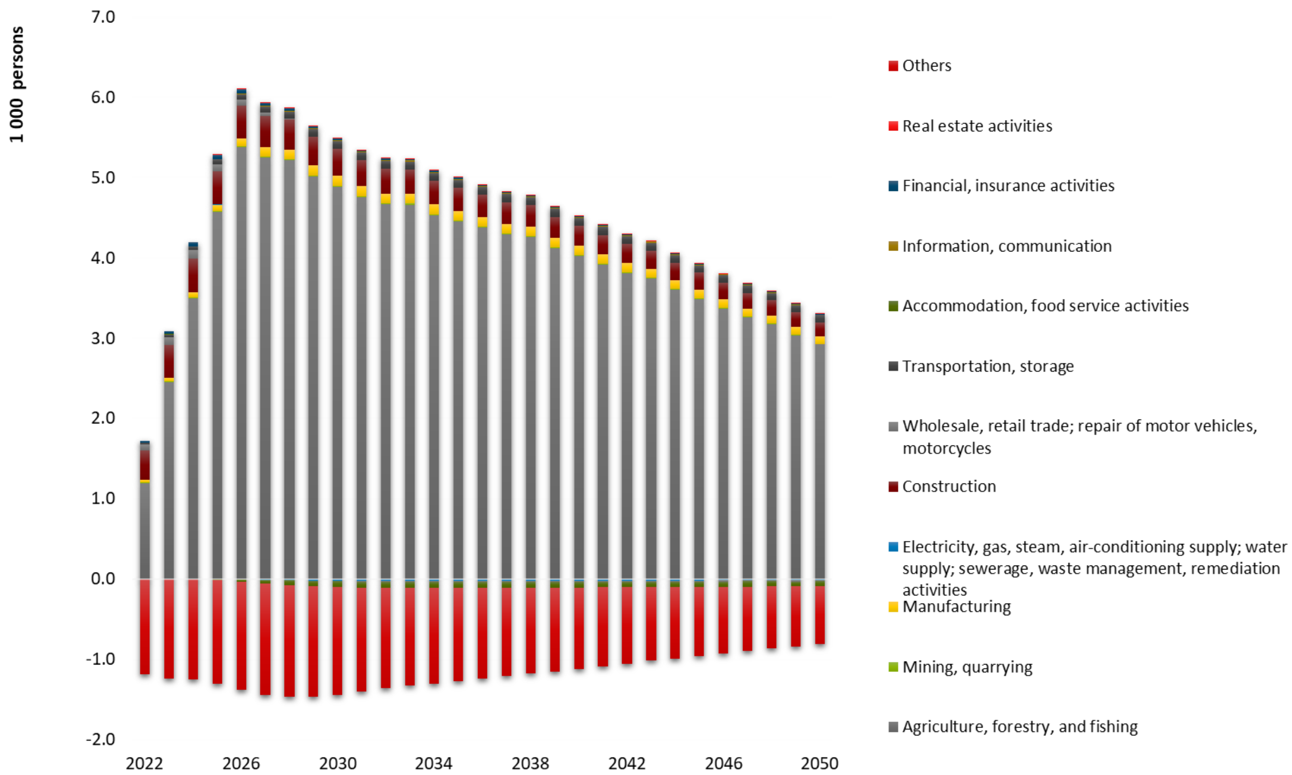

Figure 14: Effects of the „Irrigation" scenario on employment by economic activities, 2022-2050, deviations from a "Dzud" scenario in 1,000 persons

Source: Own illustration based on e3.mn results

The higher economic activity shows on the one hand positive impacts on jobs, income and thus spending opportunities for households and investment plans for companies. On the other hand, energy demand and GHG emissions accelerate as long as no mitigation options are considered.

Final energy consumption is up to 0.26% resp. 1,840 TJ p.a. higher compared to the "dzud" scenario with coal and oil products increasing the most (Figure 15).

GHG emissions develop in line with the use of fossil fuels in the respective economic sectors. Overall, the GHG emissions increase by up to 46 Gg CO_2e. Agriculture and construction as well as up- and downstream industries (such as transport and energy) are mainly benefitting from this adaptation measure and thus emit more GHG (Figure 16). GHG emissions from the commercial / institutional sector are lower compared to a "dzud" scenario because government consumption and related activity is expected to be lower.

Figure 15: Effects of the „Irrigation" scenario on final energy consumption by energy carriers, 2022-2050, deviations from a "Dzud" scenario in percent

Source: Own illustration based on e3.mn results

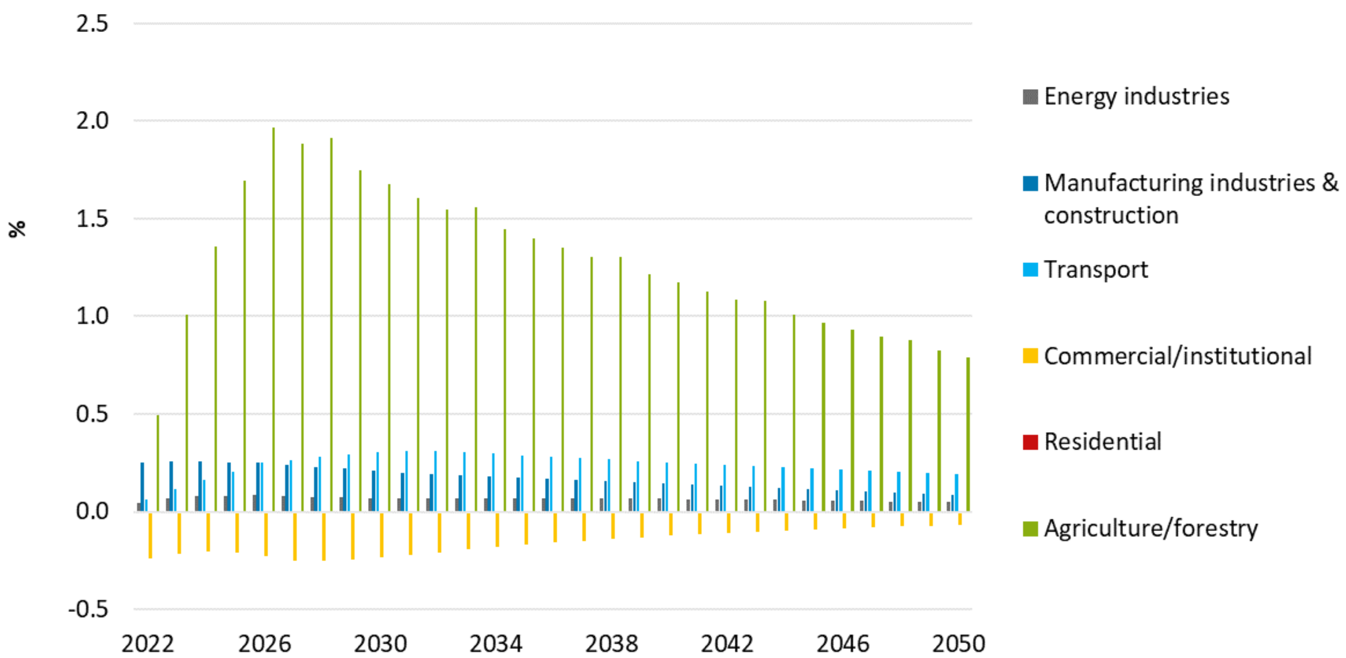

Figure 16: Effects of the „Irrigation" scenario on GHG emissions by sectors, 2022-2050, deviations from a "Dzud" scenario in percent

Source: Own illustration based on e3.mn results

4. Conclusions and outlook

Climate change results in challenges for Mongolia. EWEs cause economic costs, affect key industries such as agriculture and endanger jobs, wealth, and life of Mongolian people.

The first exemplary scenario results calculated with the e3.mn prototype model show that not only directly impacted economic sectors are affected but also further industries along the value chain. Climate change and adaptation can therefore have far-reaching economic effects.

Investment in adaptation provides co-benefits: it reduces economic losses in agriculture as well as in up- and downstream industries and creates and secures jobs. Well-designed adaptation measures may support domestic production (i.e., construction) but high import-dependency of manufactured and refined products curtails the advantages.

Results for the environment show that climate change requires a holistic approach including both mitigation and adaptation to avoid rebound effects. GHG emissions could be curtailed through efficiency improvements and the expansion of renewable energies.

The *prototype e3.mn model* is based on a simplified e3 model which utilizes international data for Mongolia. The necessary information from detailed sector models and expert knowledge for the scenario analyses was limited. Thus, the scenario results are of limited use for policy advice and rather serve demonstration purposes. However, the model as well as the CRED approach received a lot of interest and further collaboration would be appreciated. On the one hand, local partners would like to learn more about the development and application of e3 models to analyse the impacts of climate change and adaptation. On the other hand, the use of national datasets for e3 modelling is desired to improve the quality of the analyses.

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