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ADAPTATION IN CARBON-CONSTRAINED WORLD FOR MONGOLIA

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Abstract

In this study, we reviewed Mongolia's and major GHG emitting countries' experiences towards carbon reduction and their strategies in meeting their NDCs to achieve net-zero emissions. We also quantitatively assessed the long-term economic and environmental impact of a shock generated by the carbon-neutral policy in Mongolia. As for the quantitative assessment, we developed a Computable General Equilibrium (CGE) model based on the recursive dynamic CGE model for estimating the long-term economic impact of emission reduction policies in the coal sector. Using the model, we will project long-term economic development and CO_2 emissions under the four alternative scenarios. In addition, the environmental impact is measured by CO_2 emissions of sectors. Finally, we proposed policy recommendations and strategies to decrease the economic dependency on the coal sector and move towards a green technology-based economy.

JEL classification: C68, L71, O44, Q32, Q38, Q43, Q43, Q47, Q48, Q54

Key words: Carbon reduction strategies, Economic and Environmental impact, CGE, CO_2 emissions

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List of Abbreviations

BAU	Business as usual
CCS	Carbon capture and storage
CES	Constant elasticity of substitution
CET	Constant elasticity of transformation
CGE	Computable General Equilibrium
CHP	Combined heat and power
COP26	United Nations Climate Change Conference 2021
GDP	Gross domestic product
GHG	Green house gases
GoM	Government of Mongolia
HPP	Hydro power plant
MNT	Mongolian Togrog
Mt	Million ton
Mwt	Thermal megawatt
NDC	Nationally determined contribution
PEP	Partnership for Economic Policy
SAM	Social Accounting Matrix
SUT	Supply and Use Table
TFP	Total factor productivity
USD	United States Dollar

Introduction

In 2016, 196 countries, including Mongolia, joined the Paris Agreement – the international effort to limit the increase of global warming to below 2°C, preferably to 1.5°C, from the level in the pre-industrial period[1] and to reach climate neutral emissions before the end of the century. To achieve this long-term climate neutral goal, the largest greenhouse gas (GHG) emitting countries aim to reach the global peak of GHG emissions as soon as possible in order to be on the path towards carbon neutrality by 2050. If net-zero emissions are reached by 2050, global warming will be kept under 2°C by 2100.

The top 5 emitters of GHG since 1850 are the US, EU, China, Russia, and Germany. As of 2018, the top 5 annual emitters of GHG are China, US, EU, India, and Russia (Climate Watch , 2021). As G20 nations account for 75% of global GHG emissions, they have set ambitious emission reduction targets by 2030 in line with the 1.5°C limit on temperature increases and the goal to reach net-zero emissions by 2050 (Climate Analytics and WRI, 2021).

However, the implementation and enforcement of the Paris Agreement is lacking. Global emissions of GHG are still well above its target level. Between 2015 and 2019, the level of carbon dioxide in the atmosphere was more than 20% higher than in the previous five years (WMO, 2019). The global average temperature increased by 0.2°C between 2015 and 2019 and was 1.1°C higher than in the pre-industrial period. This suggests that global warming is accelerating and if the global average temperature increases more than 2°C, the climate consequence is likely to be dire. The Intergovernmental Panel on Climate Change report warned that even with full implementation of the Paris Agreement, global warming may raise the global temperature by 3°C.

Recently, during the 2021 United Nations Climate Change Conference (COP26) meeting, countries affirmed their commitment to the Paris Agreement. However, the policy measures and commitments mentioned were still not enough to significantly cut global emissions by 2030. If major GHG emitters renew their emission targets by the end of 2022, it will provide a clear idea of whether COP26 will keep emission targets compatible with the temperature increase limit of 1.5°C.

Within this worldwide effort to curb global warming, the Government of Mongolia (GoM) approved its nationally determined contribution (NDC) target in November 2019. According to Government Decree #407, Mongolia will reduce its national GHG emissions by 22.7% from its business-as-usual projected emissions level by 2030. During the COP26 meeting, Mongolia promised to further reduce GHG emissions to 27.2% of the business-as-usual scenario by developing its renewable energy resources, planting a billion trees by 2030, and allocating 1% of GDP annually to mitigate the adverse effects of climate change.

Mongolia not only needs to reduce its GHG emission, but it must also consider the economic and environmental impacts of carbon reduction policies in other countries. In particular, Chinese

[1] The pre-industrial period refers to the time period before the start of the Industrial Revolution in the mid-1700s.

policies aimed at fulfilling its NDC have crucial implications for Mongolia as China is the main consumer of Mongolian coal and other mineral commodities. Currently, Mongolia's actions towards reducing its GHG emissions are limited, and it hasn't yet adopted policy measures that reflect the external risks imposed on the coal and transport sectors.

For example, coal generates about 15 billion tons of CO_2 each year globally. However, China set a new goal to shift investment from coal to green technology in their new 5-year plan. Moreover, China is aiming to become the global leader in "low-carbon technology for a carbon-constrained world". In contrast, Mongolia declared the coal sector as a strategically important sector and is planning to expand the sector with massive investments in upcoming years. For instance, a coal washing plant will be built as part of the Tavan Tolgoi coal deposit infrastructure by 2024. The GoM also plans to build several coal-fired power plants in upcoming years to satisfy its growing demand for electricity.

Overall, although the GoM set a goal to reduce GHG emissions, it is reluctant to restrict coal production and consumption as the sector is one of the main pillars of the economy. The GoM is facing a challenge in managing a tradeoff between the "carbon neutral requirement from the world" and "revenue sustainability in the Mongolian energy sector".

In this study, we reviewed Mongolia's and major GHG emitting countries' experiences towards carbon reduction and their strategies in meeting their NDCs to achieve net-zero emissions. We also quantitatively assessed the long-term economic and environmental impact of a shock generated by the carbon-neutral policy in Mongolia.

As for the quantitative assessment, we developed a Computable General Equilibrium (CGE) model based on the PEP standard recursive dynamic CGE model[2] for estimating the long-term economic impact of emission reduction policies in the coal sector. Using the model, we will project long-term economic development and CO_2 emissions under the following alternative scenarios:

- Coal production, use and exports are restricted
- Use of renewable energy increases
- Use of improved coal briquettes increases
- The above three conditions are met simultaneously

We assessed emission reduction policies' impact on macroeconomic variables such as GDP, employment, investment, household consumption, exports and imports, and current account balance and sectoral impacts. The environmental impact is measured by CO_2 emissions of sectors.

[2] The Modeling and Policy Impact Analysis program of Partnership for Economic Policy assists developing country researchers in constructing models of their national economy to simulate the impact of macroeconomic shocks/policies on various dimensions of poverty and welfare. The program has proposed a series of new standard CGE models that can respond to needs for reference models that were more elaborate and closer to real-life conditions than the ones that had been used so far. The research team of ERI used this type of model before in studies titled "The Economic and Environmental Impact of Foreign Direct Investment on the Mongolian Coal-Export Sector" (ERI, 2018a) and "Basic Macroeconomic Data Analyses for the Project to Formulate the National Comprehensive Development Plan of Mongolia" (ERI, 2018b)

Finally, we proposed policy recommendations and strategies to decrease the economic dependency on the coal sector and move towards a green technology-based economy.

1. Country cases

As mentioned above, the Paris Agreement, if fully implemented, is believed to be effective in curbing global warming and keeping it under 2°C. However, current trends suggest that without significant emission reduction this modest target may not be achieved. Significant global reduction in emissions is only possible if major emitters such as the US, China and Russia will carry our deep reductions in emissions.

For instance, the US, one of the largest emitters of GHG, recently announced a new target to achieve a 50-52% reduction from 2005 levels in economy wide net GHG pollution in 2030 (The White House, 2021). In December 2020, the EU submitted an updated version of its determined contributions to the United Nations Climate Change Secretariat (UNFCCC, 2020a). Its new target is that “economy-wide net domestic reduction of at least 55% in GHG emissions by 2030 compared to 1990”.

As for China, another large GHG emitter, President Xi Jinping declared at the United Nations General Assembly that China would scale up its NDCs by adopting more vigorous policies and measures and aims to have CO_2 emissions peak before 2030 and achieve carbon neutrality before 2060 (UNFCCC, 2021). According to this commitment, by 2030, China will lower its CO_2 emissions per unit of GDP by over 65% from its 2005 level, increase the share of non-fossil fuels in primary energy consumption to around 25%, increase the forest stock volume by 6 billion m^3 from its 2005 level, and bring its total installed capacity of wind and solar power to over 1.2 billion kW.

In this section, we will discuss the emission reduction strategies and compliance with the Paris Agreement of major emitters such as China and Russia, coal exporting countries such as Indonesia and Australia as well as major consumers of coal-based energy such as South Korea. As we will see, experiences, challenges, and strategies to be compliant with the Paris Agreement are diverse among these countries. Moreover, we will see that there is no “one size fits all” strategy to the significant reduction in emissions. Rather, we will see that countries are devising their own strategies based on unique characteristics of the country and diverse sources of the emissions in the country.

China

China is one of the biggest emitters of CO_2 in the world. The country accounts for 29% of the world’s total CO_2 emissions and is the second biggest contributor. On per capital basis, China’s emission is 7.06 tCO_2, which is lower than the US’s 14.4tCO_2 as of 2019.

China’s rapid economic growth strongly correlates with growing CO_2 emissions. Since the 1990s, China’s economy grew 14-fold whereas its emissions of CO_2 increased 4-fold. This correlation is commonly observed as the country experienced high economic growth through rapid industrialization. Indeed, today's highly industrialized countries experienced this increasing correlation between emissions and economic growth in their early stages of development (Eckardt, Martin, & Huang, 2020)

It is also evident from the experiences of industrialized countries that emissions on a per capita basis decrease, suggesting that a decoupling takes place between emissions and economic growth as a country utilizes more advanced technology with less of an ecological footprint.

In its 12th Five-Year Plan which ran between 2011 and 2015, China put forth policies promoting lower carbon growth through reduction of energy intensity and advancements in renewable energy. These policies yielded a significant drop in the annual growth of CO_2 emissions for the period between 2000 and 2010, from 9.4% prior to the 2000s, to 1.1%. It is estimated that this sustainable reduction in the growth of CO_2 emissions will result in China meeting its 2030 NDCs in accordance with the Paris Agreement (Eckardt, Martin, & Huang, 2020).

The key to meeting the emissions target is to shift towards renewable energy. Although China's energy sector remains highly reliant on coal, by far the largest contributor to CO_2 emissions and produces 64.7% of the country's total energy, the share of renewable energy sources increased and reached 13.2% of total energy (Eckardt, Martin, & Huang, 2020). This trend of replacing coal is set to continue.

Moreover, China will reduce the energy intensity by over 65% and increase forest stock volume by 6 billion m^3 by 2030 from its 2005 levels respectively. However, it should be noticed that the carbon neutrality of China will greatly depend on the economic growth and its energy needs for the foreseeable future.

Russia

Russia is one of the largest emitters of greenhouse gases in the world. The country's total emissions stood at 1,585 $MtCO_2$ as of 2019, which ranked the country as the fourth largest in the world. It should be noted that Russia possesses one of the largest deposits of energy resources in the world and is highly reliant on the exports of fossil fuels.

Russia's commitment with regards to the emissions in accordance with the Paris Agreement is to contain it at 25% - 30% lower levels that its 1990 levels by 2030, which is higher than the current levels by 36%. It is expected that the country's emission will reach its peak in 2030. This modest commitment indicates the fact that the country will continue to be reliant on the export of fossil fuels and energy intensive goods. Russia recently announced its target to reach carbon neutrality by no later than 2060, though it has not been officially ratified yet.

It is widely understood that decarbonization can be achieved via multipronged approach. However, one of the major contributions towards decarbonization would be through a reduction in energy intensity. To achieve lower energy intensity or higher energy efficiency, the country is expected to improve and implement energy efficiency standards in buildings, change tariffs to incentivize energy efficiency and commercialize heat supply systems.

Moreover, Russia can increase the utilization of renewable energy sources, which include hydro, solar, wind, biomass and geothermal. The country possesses one of the richest sources of renewable energy and fully utilized, it can replace both domestic supply and export. Currently, renewables provide around 3.6% of the total energy mix. According to the International Renewable Energy Agency (IRENA), this share will increase to 4.6% by 2030.

Russia sees hydrogen production as a way to decarbonize its economy. The advantage for Russia is that it can transport hydrogen using its existing network of gas pipelines. However, since hydrogen production requires energy, its net carbon impact is dependent on what energy it uses in production. Therefore, this strategy's impact is dependent on whether the country generates sufficient renewable energy to take full advantage of hydrogen production.

Indonesia

Indonesia is one of the largest emitters of GHG. In 2018, the country produced 542 Mt of greenhouse gases and is responsible for 1.7% of global carbon emissions making the country the tenth largest emitter in the world. However, it should be noticed that the emissions vary greatly as peatland "megafires" occur frequently. Peatlands are large areas composed of layers of partly decomposed material that store CO_2 and are highly flammable when drained. They are under risk of drainage and cleared for agriculture, forestry, peat extraction, palm oil production and infrastructure development (UNEP, 2019). Excluding peatland fires, Indonesia's main source of emissions are from energy production and forestry and other land use.

Indonesia is home to 10% of the world's tropical rainforest and 36% of tropical peatlands, which contains 28 billion tons of CO_2. Moreover, Indonesia is a large exporter of crude palm-oil, which is the third largest export after coal and petroleum. Palm oil production causes significant deforestation as forest area is cleared by practicing "slash and burn" techniques. This leads to the release of vast CO_2 into the atmosphere. Moreover, in order to free up land to grow timber and palm trees, peatlands are drained which makes them susceptible to wildfires. In 2015, for example, peatland, forest and land-use accounted for 79% of total GHG emissions.

Indonesia is also the fifth largest exporter of coal and almost 60% of its electricity is produced using coal. As was mentioned before, a country's carbon emissions are correlated with economic growth and a rising population. Indonesia is likely to face ever more increased demand for coal power plants as it is a cheaper source of electricity.

Indonesia ratified the Paris Agreement in 2016 and committed to reducing GHG emissions 29% below baseline emissions by 2030, which could potentially reach up to 41% under different conditions.

Although this commitment is perceived to be less than ambitious, Indonesia is aiming to reach this NDC target by reducing fossil energy sources and increasing renewable sources. In particular, the country aims to increase new and renewable energy source up to 31% of total supply energy mix, reduce oil sources below 20% and coal sources below 24% by 2050.

The country is expected to face challenges in financing this shift towards renewable sources and away from fossil fuels. Moreover, in terms of reducing emissions from land use and forestry, the country aims to enforce its policies to manage land forest resources. Namely, the management capacity needs to be strengthened in the fight against illegal activities, which is the culprit for deforestation and forest degradation.

Australia

Australia emitted 499 Mt of emissions and is the fourteenth largest emitter of GHG. This accounts for 1% of global emissions. The largest emitter is the energy sector contributing around a third of the emissions. The energy sector produces electricity using fossil fuels, in particular by burning coal.

Notably, Australia has emerged as the highest coal power emitter in the world on a per capita basis. The country produced 5.34 tCO_2 per person per year from coal power stations, which is 40% higher than the next largest emitter from coal. The stationary energy sector such as mining, manufacturing and residential and commercial fuel use is the second largest emitter of CO_2, followed by the transportation sector.

Australia committed to reduce its emissions by 26-28% below its 2005 levels by 2030, in accordance with the Paris Agreement. At the COP26 conference, the country announced it will achieve net-zero emissions by 2050. As of 2021, the government officially declared that its emissions is 20.8% below its 2005 levels and is on the path to reach its 2030 target.

Currently, the country is still not phasing out coal powered stations. The decline in emissions resulted from the usage of land, investments in renewable energy and reductions in emissions in the transportation sector.

To reach net-zero emissions by 2050, Australia will undertake a multipronged approach to develop and invest in new technology. As electricity generation is the largest emitter of GHG in the country, accounting for 33.6% of total emissions, Australia plans to invest in and develop low emission electricity technology, alternative fuels, and energy storage.

The electrification of commercial and residential buildings, the development and investment in alternative fuels as well as improvements in energy efficiency will be important in decarbonizing the economy. Electrification and the development of alternative fuels is also key as the transportation sector makes up 17.6% of total emissions. Moreover, Australia's plan for decarbonization in the industrial sector will involve developing carbon capture and storage.

South Korea

Although South Korea only accounts for 1.38% of the world's total emissions, at the COP26 conference in Glasgow, it declared that the country would reduce emissions by 30% compared to 2018 levels by 2030. Moreover, the country pledged to reach carbon neutrality by 2050.

The structure of the South Korean economy is such that the country will face significant headwinds in decarbonizing its economy. The economy is reliant on energy intensive heavy industry that consumed 54% of its total electricity production in 2019 (US EIA , 2021). Furthermore, it should be noted that the country is heavily reliant on energy generated using fossil fuels. According to the Korea Energy Economics Institute, 82.5% of the country's primary energy supply (energy production + energy imports – energy exports) in 2021 was made up of fossil fuels. The majority of its energy supply is imported (94% in 2017) and about 40% of its power generation is produced using coal power plants (D'Ambrogio, 2021).

The Korean government's strategy to achieve carbon neutrality includes the development of clean power and hydrogen, improved energy efficiency, carbon removal, increased industrial sustainability and the enhancement of carbon sinks.

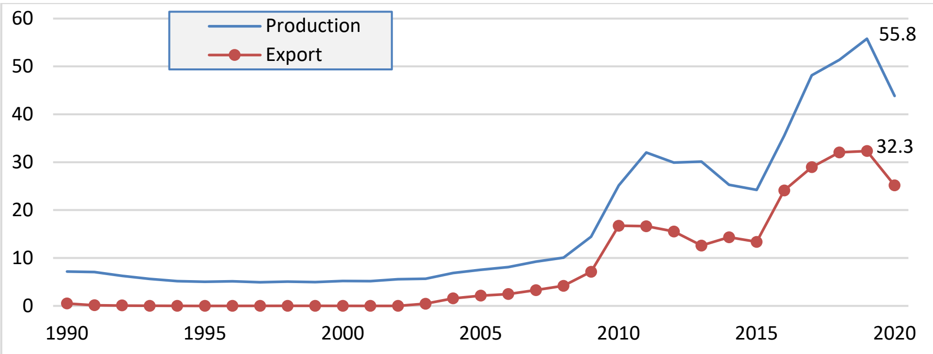
In particular, South Korea will replace 35% of total energy production with renewable energy by 2040 and aims to make it the major source of energy by 2050. Moreover, the country is closing down and reducing the number of coal-fired power stations as well stopping the financing of building new power stations.

2. GHG emissions and related policy in Mongolia

2.1. Carbon sector development and CO_2 emissions

The Mongolian coal sector has expanded rapidly in the recent decade as operations of large-scale mines such as Tavan Tolgoi began. In particular, total coal production reached a historical peak of 55.8 Mt in 2019 (Figure 1). The export volume reached 32.6 Mt, worth about USD 3 billion which is 40.4% of Mongolian total exports. Currently, Mongolia is the second largest coal supplier for China after Australia.

Figure 1. *Mongolian coal production and export, Mt*



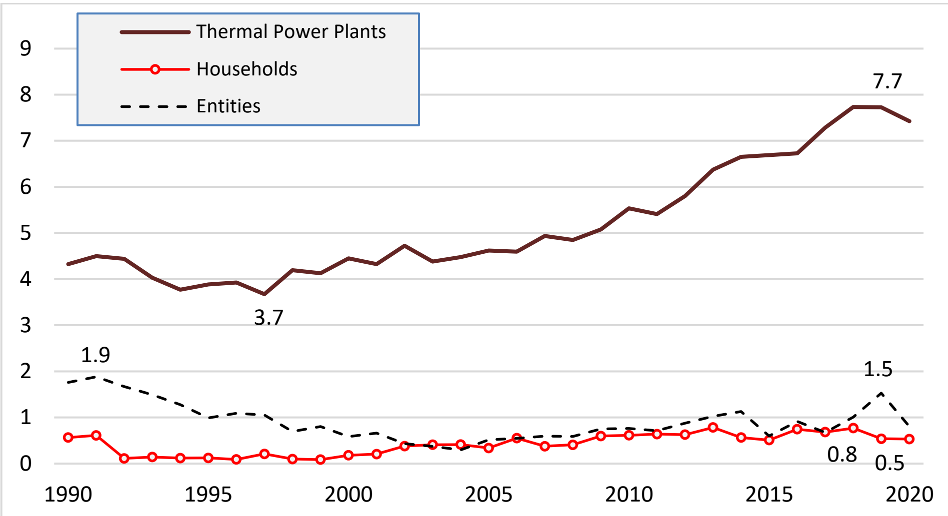
Source: Balance of Coal, National Statistics Office (www.1212.mn)

As the sector expands more, the sectoral contribution to the economy increases as well. The coal sector contribution to the state budget and exports revenue exceeded the copper sector's contribution since 2017. As of 2019, the coal sector constituted 10.1% of the total state budget revenue alone. However, the coal sectors' production and export were negatively affected during the COVID-19 pandemic due to the restrictions in transportation and cross-border issues. The sector's contraction became one of the significant driving forces behind the economic slowdown (5.3% year-on-year decrease) in 2020. Mongolia's coal production and export decreased by more than 20% due to COVID-19 related border restrictions. However, the GoM plans to promote coal exports and sectoral production to revive the economy after COVID-19 with policy directed to remove transportation and cross-border bottlenecks. For instance, according to the medium-term fiscal framework approved by the GoM, coal export volumes are expected to reach a historical record of 43 Mt by 2024.

Although the economic contribution of the coal sector is significant, the paved and gravel road transportation of coal creates massive environmental problems. According to transport statistics of NSO, total carried freight reached its historic peak at 69.0 Mt in 2019 and of which 40.8 Mt (~32.0 Mt was export coal transport) was transported by auto road. Between 2000 and 2019, total carried freight increased 6.5-fold while carried freight by auto road increased 27.6-fold. Most of the increase of auto transport comes from the coal sector. High utilization of road transport has a major environmental impact – dust, air and soil pollution.

In addition, coal is used extensively as a fuel in the domestic market. The main domestic consumption is electricity production at thermal power plants. Since the mid-1990s, power plant consumption has doubled as shown in Figure 2. As the population grows, distributed coal to households for fuel purposes increased from 0.1 Mt in 1990s to its peak of 0.8 Mt in 2018, but it has dramatically decreased in 2019 and 2020 as the government banned burning raw coal and distributed subsidized improved coal briquettes for fuel purposes to households in Ulaanbaatar where almost half of the population resides. As a result, the coal consumption of households decreased by 30% and reached 0.5 Mt in 2019 and 2020.

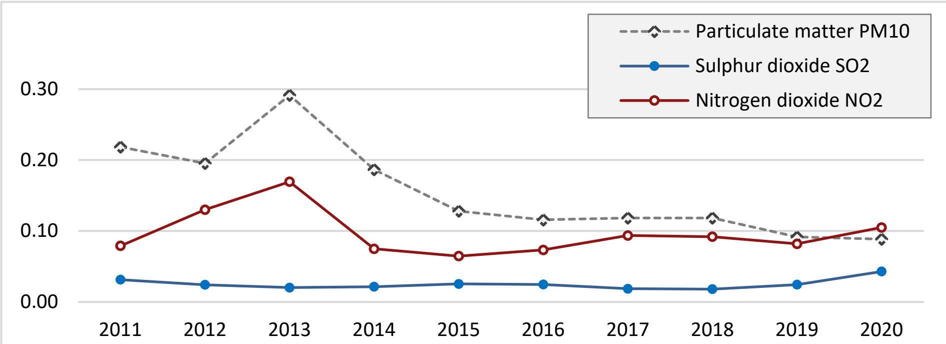
***Figure 2.** Mongolian domestic coal consumption, Mt*



Source: Balance of Coal, National Statistics Office (www.1212.mn)

Despite the implementation of the improved coal briquette distribution program in 2019, improvements in air quality in Ulaanbaatar are mixed. Specifically, while the particulate matters (PM10, or PM2.5) in the air dropped by more than 20%, sulphur dioxide (SO_2) increased sharply, and nitrogen dioxide (NO_2) also increase as shown in Figure 3.

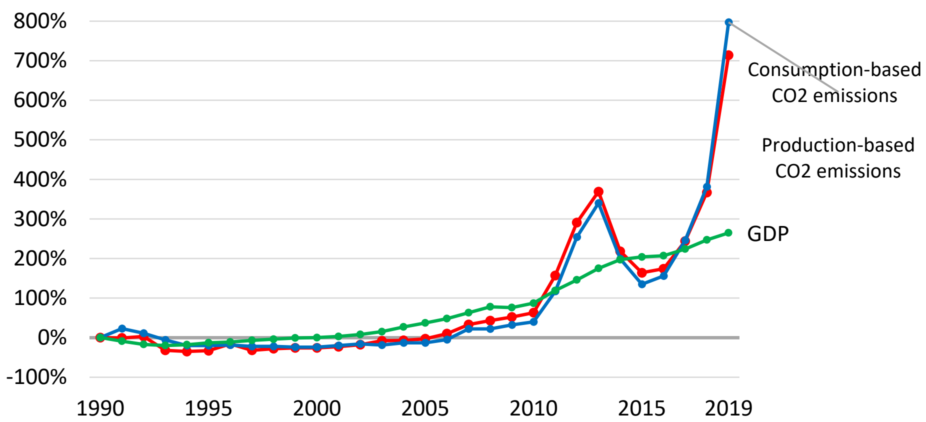
Figure 3. *Concentration of air pollution in Ulaanbaatar[3], mg/m³*



Source: Concentration of air pollution, NSO (www.1212.mn)

According to the World Bank, in 2019, Mongolia's CO_2 emissions reached a historical peak of 88.7 Mt from 9.9 Mt in 1990. Generally, the growth of CO_2 emissions and GDP are positively correlated and in Mongolia CO_2 emissions grew at a slower rate than GDP until 2010. Since then, however, coal production and exports increased significantly and both production-based and consumption-based CO_2 emissions exceeded GDP sharply (Figure 4). We can see that the CO_2 emissions trend closely follow the coal production and export trends in Figure 1.

Figure 4. *Change in CO_2 emissions and GDP, Mongolia*



Source: Global Carbon Project; World Bank; OurWorldInData.org/co2-and-other-greenhouse-gas-emissions

Note: Gross Domestic Product (GDP) figures are adjusted for inflation (PPP, constant 2017 international $)

[3] When measuring air pollution, we selected the West crossroad station, one of the nearest stations to the city center. General trends in the concentration of air pollution measured at other stations are comparable and similar.

In Figure 4, consumption-based emissions are domestic emissions which have been adjusted for trade. It is calculated by subtracting emissions embedded in exports from production-based emissions and emissions embedded in imports.

Conversely, for the last three decades, world GDP grew by 155% while CO_2 emissions has increased by 61%. Most OECD countries have managed to grow their economies while reducing CO_2 emissions. For these countries, it's not just about offshoring emissions overseas, consumption-based CO_2 also fell.

2.2. Decarbonization policies in Mongolia

Following the international trend of increased green economy requirements, the GoM set goals to reduce carbon emissions in strategic and policy documents. In the Mongolian Vision 2050[4] - long term development policy paper, the GoM proposed to develop a low-carbon, productive and inclusive green economy and contribute to international efforts to mitigate climate change. To achieve this goal, the government will support renewable energy, reduce GHG emissions in sectors such as energy, agriculture, construction, transportation, heavy and light industries, and waste, and will encourage carbon capture activities. By 2050, the country will be carbon neutral. In order to reach that goal, the government is planning to reduce GHG emission by 12.3% from the baseline scenario in 2025 and by 22% in 2030.

Mongolia ratified the Paris Agreement of the UN Framework Convention on Climate Change in 2016. The GoM approved the NDC target for the implementation of the Paris Agreement[5]. As estimated in the policy document, in 2010 the total annual emission of GHG was 25.8 $MtCO_2$ equivalent emission and if no climate policy actions are taken, it is projected to reached 74.2 $MtCO_2$ equivalent emission by 2030. As the reference level is 74.2 $MtCO_2$ equivalent emission in the commitment, the targeted CO_2 equivalent emission in 2030 is 57.3 $MtCO_2$. This is not very ambitious and is 122% more than the emissions levels observed in 2010.

Nevertheless, to achieve the policy target, the following activities will be carried out:

- Improve energy supply efficiency and use of renewable energy
- Limit growth and improve quality and productivity of livestock
- In the manufacturing sector, save industrial energy, extract methane from coal mines to generate electricity, and use powdered ash in cement production
- In the transportation sector, switch to Euro-5 standard fuel and export coal via railway
- In the construction sector, use improved coal briquettes in Ulaanbaatar and improve heating of outdated apartments
- In the waste sector, support the waste recycling industry

[4] Parliament Resolution, No.52, May 13, 2020.
[5] Government Resolution No 407, November 19, 2019

In its Action Program for 2020-2024[6], the GoM proposed the development of renewable energy production for domestic use. However, it is not clear how the government will manage it in terms of financing and technology. Moreover, the GoM also plans to expand and promote coal mining operations for export. For instance, a coal washing plant will be built as part of the Tavan Tolgoi coal deposit infrastructure along with the establishment of an industrial and technology park. The GoM also plans to build several coal-fired power plants in upcoming years.

Based on an analysis of Mongolia's current policy documents, the research team offers the following policy recommendations:

- The GoM should have explicit targets at reducing mining sector production as the sector is likely to be affected by international carbon reduction policies from other countries such as China. Mongolia's current carbon reduction policies and its economic development policies which highlight the importance of the mining sector seem disjointed. According to Mongolia's current NDC target, the GoM plans to reduce its CO_2 emissions by 27.2% from its business-as-usual projected emission level through the implementation of mitigation and adaption actions. The mitigation actions are focused on increasing the energy production of the renewable energy sector, decreasing the CO_2 emissions of the conventional energy sector (transportation, construction, and industry), and decreasing the CO_2 emissions of non-energy sectors (agriculture, industrial processes and product use, and waste). While a target to shift coal export transportation from auto transport to railway was included in the target for the transportation sector, there is no other mention of the mining sector. There are no targets at reducing mining sector production or how the mining sector may be affected by international carbon reduction policies from other countries such as China.

- The GoM needs to reconcile conflicted energy sector targets. While the GoM has a target to increase renewable energy production, it also plans to construct several coal-fired power plants in the near future. These two policies seem counter productive and question the GoM's commitment to reducing its CO_2 emissions. Attempts at increasing renewable energy production are likely to be ineffective in reducing CO_2 emissions if Mongolia continues to be reliant on the coal sector for energy.

- Mongolia should research the possibility of utilizing new technologies such as carbon capture and storage (CCS) in its carbon reduction policies as new technologies promise to mitigate the effects of global warming, In its NDC submission, the GoM stated that "if conditional mitigation measures such as carbon capture and storage and waste-to-energy technology are implemented, then Mongolia could achieve a 27.2% reduction in total national GHG emissions" (Government of Mongolia, 2020). Despite the mention of CCS technology, no targets or actions were mentioned on the topic. This was also mentioned in the support needs section of the NDC submission which included technology transfer and the need to conduct a technology needs assessment in determining the most suitable, efficient, and effective

[6] Parliament Resolution No 24, August 28, 2020

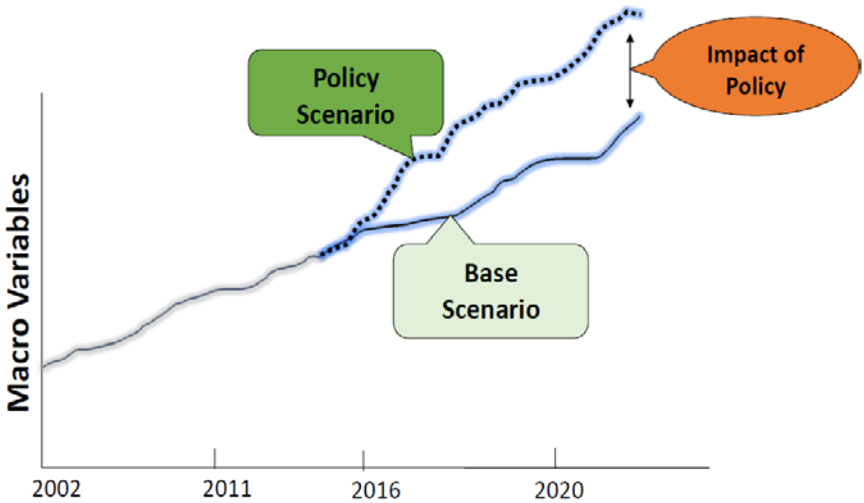
technologies needed to reach Mongolia’s NDC target. Moreover, as CCS technology is very new, Mongolia should look into obtaining technical support from other countries that are engaged in the development and research of new technologies such as Japan.

Overall, although the GoM set a goal to reduce GHG emissions in the long-term, it is reluctant to directly restrict coal production and consumption due to the sector’s economic importance. Thus, the GoM is facing a challenge in managing a tradeoff between the “carbon neutral requirement from the world” and “revenue sustainability in the Mongolian energy sector”. In Section 3, we will discuss this further and assess the impact of coal sector related external shocks and other alternative policy scenarios.

3. Methodology and data

To evaluate the long-term economic and environmental impact of implementing a carbon neutral policy, we used an in-house dynamic CGE model[7]. The model is an extension of the dynamic CGE model used in Galindev et al., (2019). This model is quite different from the model used in the "Revenue management update-II" study in that we developed a long-term baseline economic projection for the upcoming 10 years. We then introduced alternative scenarios. Comparing the results of the alternative scenarios with the baseline scenario will allow us to assess the economic and environmental impact of implementing carbon neutral policies. In particular, the impacts are implied as a difference between the results of the baseline scenario and the alternative scenarios as shown in the figure below.

Figure 5. *Policy Impacts Analysis*



Source: ERI, 2017

3.1. Dynamic CGE model

The dynamic CGE model is a general equilibrium model where a change in one part of the system affects all other parts of the system.

The model has the following basic features:

- The production side of the model is divided into different activities/industries. Each activity has a nested structure, and each level uses a production function with constant

[7] This model is an extension of the PEP-1-t model which is described fully in Decaluwé et al. (2013).

returns to scale. Specifically, the first level of production is a Leontief function of value added and intermediate consumption.

At the next level, value added ($VA_{j,t}$) function in activity j at period t is a constant elasticity of substitution (CES) function of labor ($L_{j,t}$) augmented with technical change ($A_{j,t}$) and capital ($K_{j,t}$) as follows.

$$VA_{j,t} = B_j(\beta_j(A_{j,t}L_{j,t})^{-\rho_j} + (1-\beta_j)K_{j,t}^{-\rho_j})^{-\frac{1}{\rho_j}} \quad (1)$$

where is B_j a scale parameter, β_j is a parameter relating to labor income share and ρ_j is the elasticity of substitution.

$A_{j,t}$ is also considered as total factor productivity (TFP) for sector j and we estimated it using the conventional growth accounting method as a Solow residual. We consider the growth rate of the estimated TFP for the projections.

The stock of capital in each sector increases by investment but decreases by depreciation as in growth models such as Solow (1956). Investment in public services, mining activities and livestock sectors are exogenous while investment in other industries is endogenous depending on the return (ratio between the rental rate and user cost of capital - the depreciation and interest rate).

Total labor supply grows at an exogenous rate in line with population growth. In each period, labor is mobile between activities.

- Intermediate consumption of each commodity, on the other hand, is proportional to production by sector. Each sector may produce multiple commodities, which are aggregated by a constant elasticity of transformation (CET) function. Finally, quantities to sell domestically or to export are governed by a CET function and relative prices.
- On the demand side, the consumption of a commodity is a CES function of domestic and imported quantities. A representative household allocates its disposable income from capital, labor, and transfers between consumption and savings. Its demand for commodities is governed by a linear-expenditure system. Demand for commodities for investment and government spending purposes are proportional to respective total expenditures. Investment demand distinguishes between gross fixed-capital formation and changes in inventories. Export demand for domestic commodities is an iso-elastic function of relative prices (foreign price expressed in domestic currency divided by domestic price).
- Government revenue from income taxes and indirect taxes (production, commodities, and foreign trade) and transfers from other agents are divided between savings, current expenditures and transfers to other agents, and wealth funds according to the Fiscal Stability Law and Law on Future Heritage Fund. Here, government spending and transfers to other agents are exogenous.
- The model specifications also include public debt dynamics, which changes by budget deficit.

- The model is a savings-driven-investment model – i.e., total investment is the sum of savings of all agents and net changes of wealth funds.
- Current account balance in the balance of payments is determined by the amount of exogenous foreign savings. Private savings and government savings are endogenous.

We made the following extensions:

- As the goal of the study is to compute the change of CO_2 emissions during the implementation of carbon neutral policies, we added CO_2 emission in the model.

CO_2 emission is specified as a linear function of output:

$$\mathrm{EMIS}_{\mathrm{i,j,t}} = \mathrm{em\_rate}_{\mathrm{i,j}} \cdot DI_{\mathrm{i,j,t}} \quad (2)$$

$$\mathrm{EMISH}_{\mathrm{i},h,\mathrm{t}} = \mathrm{em\_rateh}_{i.h} \cdot C_{\mathrm{i,h,t}} \quad (3)$$

where $\mathrm{EMIS}_{\mathrm{i,j}}$ is volume of CO2 emission by sector j from usage of intermediate consumption, $\mathrm{EMISH}_{\mathrm{i},h,\mathrm{t}}$ is the volume of CO2 emission by households, $\mathrm{em\_rate}_{\mathrm{i,j}}$ is the emission rate of sector j from usage of commodity i and $\mathrm{em\_rateh}_{i.h}$ is the emission rate of households from usage of commodity i. $DI_{\mathrm{i,j,t}}$ is intermediate consumption of sector j. $C_{\mathrm{i,h,t}}$ is household consumption. The volume of emission is endogenous while we set the emission rates as exogenous.

- As an alternative scenario, the use of improved coal briquettes will be increased. To reflect this, we assume that there is a substitution between coal and improved coal briquettes. We added a few equations to illustrate this substitution in the model.

3.2. Main database – Social Accounting Matrix (SAM) 2018

We constructed the 2018 SAM data using the Supply and Use Table (SUT), the balance of payments, and the government budget data. Table 1 shows the macro SAM as a share of nominal GDP, which was MNT 32.4 trillion in 2018. Household consumption, government current expenditure, investment, exports, and imports were 54.3%, 11.7%, 39.6%, 58.0% and 63.6% of GDP respectively. The economy is relatively more intensive in capital (50.0%) than in labor (38.7%). The sum of value added in GDP is 88.7%, and the remaining 11.3% is from import taxes – TM (2.1%), commodity taxes – TI (8.8%) and net taxes on production (0.4%).

Table 1. *Mongolia Macro SAM 2018 (% of GDP)*

		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	**Labor**								1.4	38.7						40.1
2	**Capital**								0.3	50.0						50.3
3	**Households**	39.2	40.7		9.7				2.4							91.9
4	**Government**			5.3		14.1	2.1	8.8	0.7	0.4						31.4
5	**TD**			14.1												14.1
6	**TM**										2.1					2.1
7	**TI**										8.8					8.8
8	**ROW**	0.8	9.3	0.8	2.2						63.6					77.1
9	**Sectors**										134.6	53.4			185.8	118.0
10	**Dom/com**			54.3	11.7					98.9	15.7	4.5	23.3	6.1	10.2	224.7
11	**Ex/com**								58.0							58.0
12	**INV/PRI**			17.4					14.0							31.4
13	**INV/PUB**			0.0	7.8				0.4							8.2
14	**VSTK**												8.1	2.1		10.2
15	**TOTAL**	40.1	50.3	91.9	31.4	14.1	2.1	8.8	66.4	185.8	224.7	58.0	31.4	8.2	10.2	

The micro SAM is a square matrix with 85 columns and rows. The accounts of the SAM consist of 23 sectors and 24 commodities, two production factors (capital and labor), three types of institutions (households, government, and the rest of the world), three types of taxes (income tax, import duties and taxes on commodities) and savings (investment) accounts divided into public investment, private investment, and changes in inventories (Table 2). In the SAM, firms and households are combined into one agent named ‘Households’. In that sense ‘Households’ refer to the private sector.

Table 2. Accounts in the SAM

	Sectors (23)	Commodities (24)	Institutions (3)
1	Agriculture	Agriculture	Households (H)
2	Coal	Coal	Government (GVT)
3	Export coal	Export coal	Rest of the world (ROW)
4	Oil	Oil	
5	Metal ores	Metal ores	**Taxes (3)**
6	Other mining	Other mining	Income taxes (TD)
7	Renewable energy	Electricity	Import duties (TM)
8	Coke and chemicals	Manufacturing	Taxes on commodities (TI)
9	Manufacturing	Improved coal briquettes	
10	Improved coal briquettes	Fuel	**Factors (2)**
11	Water	Construction	Labor (Lab)
12	Construction	Trade	Capital (Cap)
13	Trade	Accommodation	
14	Accommodation	Transportation	**Savings-Investment (3)**
15	Transportation	Postal and courier service	Public investment (INV_PUB)
16	Information	Energy supply services	Private investment (INV_PRI)
17	Energy	Financial activities	Changes in inventories (VSTK)
18	Financial activities	Real estate	
19	Real estate	Rent service	
20	Administration and support	Professional activities	
21	Professional activities	Support services	
22	Public administration	Public administration	
23	Other activities	Waste	
24		Other service	

We have created 3 new sectors (export coal, renewable energy, and improved coal briquettes) and 2 new commodities (export coal[8] and improved coal briquettes) for the purpose of this study: a) Export coal commodity/sector represents only the exported part of the coal commodity/sector. The remaining coal is sold domestically (domestic coal[9]), b) Renewable energy sector represents hydropower, wind, and solar energy. We have included the renewable energy sector in our model using share of total renewable energy production in total energy production c) Improved coal briquette commodity/sector represents coal briquette that is burned by households in Ulaanbaatar for heating. To reduce Ulaanbaatar's air pollution, the GoM implemented a ban on the consumption of raw coal in Ulaanbaatar from 15 May 2019 and introduced new coal briquettes. The new coal briquettes began being sold on 15 June 2019.

[8] This is mainly made up of raw coking coal and some washed coking coal.
[9] This is made up of thermal coal used by households and power plants.

Production structure: Agriculture and trade sectors contribute most to total labor income while the metal ores and coal export sectors contribute most to capital income. Water and agriculture sectors are highly intensive in labor while crude oil and coal (domestic and export) sectors are highly intensive in capital. The economy as a whole is relatively more intensive in capital (Table 3).

***Table 3.** Production structure (%)*

Sector	Labor	Capital	Value added	Value added/ total output	Factor intensity	
					Labor	Capital
Agriculture	20.0	6.0	12.2	66.3	72.0	28.0
Domestic Coal	0.4	3.3	2.0	51.7	8.3	91.7
Export coal	1.4	12.2	7.5	51.7	8.3	91.7
Crude oil	0.2	2.1	1.3	38.5	8.3	91.7
Metals ores	9.1	18.5	14.4	52.2	27.6	72.4
Other mining	1.1	1.7	1.5	35.7	32.6	67.4
Manufacturing	6.4	10.0	8.4	33.2	33.1	66.9
Coke and chemicals	0.7	3.3	2.1	46.5	14.2	85.8
Improved coal briquettes	0.0	0.0	0.0	46.5	14.2	85.8
Renewable energy	0.1	0.0	0.0	24.8	56.1	43.9
Energy	2.4	1.4	1.8	24.8	56.1	43.9
Water	0.8	0.1	0.4	34.9	81.1	18.9
Construction	5.6	3.0	4.1	24.4	59.2	40.8
Trade	13.7	8.1	10.6	54.7	56.6	43.4
Transportation	7.4	3.6	5.3	38.4	61.7	38.3
Accommodation	1.6	0.7	1.1	33.0	64.1	35.9
Information	1.6	2.2	1.9	38.3	36.4	63.6
Financial activities	3.7	6.7	5.4	72.6	29.7	70.3
Real estate	0.5	10.9	6.3	78.7	3.2	96.8
Professional activities	2.1	1.0	1.5	36.6	63.0	37.0
Administrative and support	1.1	0.7	0.9	31.1	54.4	45.6
Other activities	1.7	0.3	0.9	47.4	80.7	19.3
Total	100.0	100.0	100.0		43.6	56.4

Trade structure: Table 4 shows the trade structure of the economy. Metal ore and coal exports account for more than half of total exports (59.5%), while imports of manufacturing and fuel make up the majority of total imports (74.2%).

Table 4. *Trade structure (%)*

Commodities	Export shares	Import shares	Export intensity[10]	Import penetration
Agriculture	3.9	1.6	13.1	6.9
Domestic coal	-	0.0	0.0	0.1
Export coal	24.3	-	100.0	0.0
Crude oil	5.4	0.0	98.4	1.6
Metal ore	35.2	0.0	100.0	100.0
Other mining	2.3	0.0	95.5	59.0
Electricity	0.0	1.7	0.2	31.7
Manufacturing	9.5	59.9	18.0	62.3
Improved coal briquettes	0.0	-	83.0	0.0
Fuel	6.3	14.3	83.0	93.0
Construction	0.6	2.5	2.0	9.1
Trade	-	-	0.0	0.0
Accommodation	1.7	1.9	33.2	39.8
Transportation	5.3	5.0	23.6	25.7
Postal and courier service	0.0	0.0	0.0	0.1
Energy supply services	0.0	0.1	0.5	0.8
Financial activities	0.3	1.9	2.2	15.5
Real estate	0.5	0.7	3.6	5.8
Rent service	0.0	0.2	1.0	10.3
Professional service	3.7	6.4	26.6	42.8
Support services	0.1	0.1	0.7	1.2
Public administration	0.7	3.5	2.7	13.5
Waste	0.0	0.0	0.5	0.9
Other service	0.1	0.1	2.6	4.2
Total	100.0	100.0		

Demand structure: Table 5 shows the demand structure for each commodity. Most of accommodation and real estate services are consumed by households. In contrast, more than half of the public administration products are consumed by government. Electricity, manufacturing, and mining commodities are mainly used as intermediate inputs for production. Trade is 100% a margin commodity while 4.7% of transportation is used as a margin. Whereas construction services are mainly used for investment purposes.

[10] Export excluding taxes and margins – i.e., at base prices.

Table 5. Demand structure (%)

Commodities	Household consumptio	Governme nt	Intermedia te	Margi n	GFC F	Stock variatio	Total Deman
Agriculture	23.8	-	47.8	-	19.2	9.3	100.0
Coal	1.1	-	62.2	-	-	36.7	100.0
Export coal	-	-	-	-	-	100.0	100.0
Crude oil	-	-	-	-	-	100.0	100.0
Metal ore	-	-	6611.4	-	-	-6511.4	100.0
Other mining	2.4	-	536.3	-	-	-438.7	100.0
Electricity	0.7	-	99.3	-	-	-	100.0
Manufacturing	34.1	0.1	42.2	-	14.9	8.8	100.0
Improved coal	14.3	-	81.7	-	-	4.0	100.0
Fuel	14.3	-	81.7	-	-	4.0	100.0
Construction	0.4	0.0	26.3	-	73.4	-	100.0
Trade	-	-	-	100.0	-	-	100.0
Accommodation	63.0	0.1	36.9	-	-	-	100.0
Transportation	18.0	0.1	77.2	4.7	-	-	100.0
Postal and courier	0.9	-	99.1	-	-	-	100.0
Energy supply	10.8	0.0	89.2	-	-	-	100.0
Financial activities	24.7	-	75.3	-	-	-	100.0
Real estate	78.5	-	21.5	-	-	-	100.0
Rent service	1.1	-	40.5	-	58.4	-	100.0
Professional services	18.0	5.3	76.1	-	0.6	-	100.0
Support services	15.9	0.2	74.9	-	9.0	-	100.0
Public administration	28.1	65.0	6.8	-	-	-	100.0
Waste	12.4	38.6	49.0	-	-	-	100.0
Other service	58.1	16.0	25.9	-	-	-	100.0

Structure of government income and expenditure: The main sources of government revenue are direct taxes (personal income taxes and corporate taxes) (44.9%) and taxes on products (16.8%). On the other hand, half of the budget was spent on purchasing goods and services while 30.8% of the budget was received by households as transfers. The remaining government revenue is recorded as savings in the SAM and is used to cover its capital expenditure (Table 6).

Table 6. *Government budget (%)*

-Government revenue		Government expenditure	
Transfers from- households	16.8	Transfers to households	30.8
Direct taxes /TD/	44.9	Transfers to ROW	7.1
Import duties /TM/	6.7	Public consumption	37.2
Export taxes	-	Savings	24.9
Net taxes on products /TI/	27.9		
Transfers from ROW	2.3		
Net taxes on production	1.4		
Total	**100.0**	**Total**	100.0

Structure of household (private sector) income and expenditure: Labor and capital are the main sources of household income, and they jointly constitute 86.9% of total household income (Table 7). Households spend 59.1% of their income on consumption and pay 15.3% as direct taxes. Savings make up 19% of total income while transfers to the government and ROW are relatively small (6.6%).

Table 7. *Household Income and Expenditure (%)*

Household income		Household expenditure	
Wages	42.7	Consumption	59.1
Capital income	44.2	Direct taxes	15.3
Transfers from government	10.5	Transfers to the government	5.7
Transfers from ROW	2.6	Transfers to ROW	0.9
		Savings	19.0
Total	100.0	**Total**	**100.0**

Investment/savings structure: The majority of total investment is financed by household[11] savings while rest of the world contributes 36.2% of total investment (Table 8). 58.9% and 15.3% of the total investment budget is dedicated to financing private and public investments (gross fixed capital formation).

[11] Note that the SAM does not have firms, implying that household savings cover all the saving of the private sector.

***Table 8**. Investment/Savings Structure (%)*

Source		Allocation	
Household	44.0	Private investment	58.9
Government	19.7	Public investment	15.3
Rest of the world	36.2	Change in inventories	25.8
Total	**100.0**	**Total**	**100.0**

3.3. CO_2 emissions

Besides the SAM, we introduce the value of carbon dioxide emission (CO_2) rates by sectors as additional data (Table 10).

There are five alternative databases of Mongolian CO2 emissions including emission data from NSO, Our World in Data, Climate Watch Data, Mongolia's National Inventory Report 2017, and the GTAP-7 Data Base. The CO2 emission data from NSO, Our World in Data, Climate Watch Data and Mongolia's National Inventory Report 2017 were disaggregated into 6-18 activities. The data from the GTAP-7 Data Base, on the other hand, had emission data from 65 activities and 4 commodities, making it more suitable for the SAM and the CGE model. In other words, the model contained data on CO2 emissions from 65 sectors using four types of commodities in production. We reduced the 65 sectors into 23 sectors (Table2) and 4 commodities into 3 commodities (coal, oil, fuel). However, the last available data for GTAP was in 2007. Thus, we assumed the sector's share of total emissions remained stable.

The data from the GTAP-7 Data Base was then used to calculate CO2 emissions generated by sectoral intermediate consumption and households. In terms of sectoral CO2 emissions, 71.3% of total CO2 emissions come from the electricity sector alone, 11% from the transportation sector, 4.6% from the manufacturing sector, 4.1% from the public administration sector, 3.6% from the metal ore sector, and 5.3% from other sectors.

Table 9. *CO_2 emission of sectors, thousand tons*

	CO_2 emission, thousand tons	% in total CO_2
Energy	11646.0	71.3
Transportation	1803.0	11.0
Manufacturing	743.0	4.6
Public administration	670.0	4.1
Metal ore	592.5	3.6
Trade	219.0	1.3
Agriculture	205.0	1.3
Construction	153.0	0.9
Other mining	87.5	0.5
Accommodation	87.0	0.5
Coke	42.0	0.3
Other service	26.0	0.2
Water	20.0	0.1
Administration	17.0	0.1
Financial activities	10.0	0.1
Real estate	4.0	0.0
Information	2.0	0.0
Improved coal briquettes	0.006	0.0
Total	16327.0	

Source: GTAP-7 Data Base

Household CO_2 emissions are derived from the consumption of four products (Table 10). In particular, 68.5% of total household emissions come from coal consumption while 31.3% came from fuel usage.

Table 10. *CO_2 emissions of household consumption, thousand tons*

	CO_2 emission, thousand tons	% in total CO_2
Coal usage	1494	68.5
Fuel usage	683	31.3
Electricity usage	3	0.1
Improved coal briquette usage	0.03	0.001
Total	2180	

Source: GTAP-7 Data Base

4. Scenarios and simulation results

In order to assess the economic and environmental impact of carbon reduction policies, we simulated the model for 10 years (2021-2030) under the following four scenarios:

- Baseline scenario: No carbon reduction policies.
- Scenario 1: Increase the capacity of the renewable energy sector to 30% of the total capacity of the energy sector by 2030.
- Scenario 2: Provide improved fuel to all coal-consuming households in Ulaanbaatar and 20% of rural coal-consuming households by 2030.
- Scenario 3: No new investments into the export coal sector after 2025, a 75% reduction in investments into the coke and chemicals sector after 2025.

The following subsections detail the main assumptions imposed in the four scenarios as well as the simulation results.

4.1. Alternative scenarios

Baseline scenario

In this scenario, we assume that the government does not implement any policies targeted at reducing carbon emissions.

Scenario 1: To increase the capacity of renewable energy sector

As of 2020, the Mongolian energy sector's total installed capacity was 1485.3Mwt with an installed capacity utilization of 60.8%. Installed capacity utilization increases to 80-90% in winter and falls in the warmer summer season. Additionally, the transmission and distribution losses of combined heat and power (CHP) averaged 13.6% in 2020. These findings highlight the inefficiencies of Mongolia's energy sector.

While the installed capacity of renewable energy accounts for 18.3% of the total capacity of the energy sector, it only produced 7.1% of the total domestic energy supply. The Government of Mongolia is currently pursuing a policy to increase its renewable energy capacity. According to the "Vision 2050" long-term policy document, Mongolia plans to increase the renewable energy sector's capacity to 30% of the total capacity of the energy sector by 2030. The "Vision 2050" document details a number of projects aimed at increasing the production of conventional and renewable energy by 2030. For instance, the following projects are planned to boost conventional energy production: the construction of new power plants in Shivee-Ovoo (5280Mwt), Baganuur (400Mwt), Buuruljuut (300Mwt) and Tavan Tolgoi (450Mwt) as well as the expansion of existing power plants (611Mwt). The following projects are planned to boost renewable energy production: Shuren hydro power plant (HPP) (100Mwt), Erdeneburen HPP (90Mwt), Egiin Gol HPP (315Mwt), Khusghiin Khundii solar power plant (35Mwt), battery storage (100Mwt), and wind farm (30Mwt). As large projects require substantial funding and are under political pressures, we did not include the Shivee-Ovoo, Baganuur, Buuruljuut, Tavan Tolgoi, Shuren HPP, and Egiin Gol HPP projects in the simulations as they are unlikely to be completed within 2021-2030. The following table shows the installed capacity of conventional and renewable energy for 2020 as well as the forecast for 2030.

Table 11. *Energy sector installed capacity and its forecast, Mwt*

	2020	2030*	Growth %
Conventional energy	1211.8	1822.8	50%
Renewable energy	271.2	782.2	188%
Diesel power	2.3	2.3	0%
Total	**1485.3**	**2607.3**	**76%**
Share of renewable energy in total installed capacity %	18.3%	30.0%	

**researchers' calculations* *Source: Vision 2050 policy document*

As shown in Table 11, the installed capacity of the conventional energy sector will increase by 611Mwt while the installed capacity of the renewable energy sector will increase by 5110Mwt by 2030. This entails investments of MNT 2.5 trillion into the conventional energy sector and MNT 1.5 trillion into the renewable energy sector.

In this scenario, we assessed the impact of an MNT 1.5 trillion investment into the renewable energy sector from 2021 to 2030 that increased renewable energy production 1.8-fold.

Scenario 2: To increase improved coal use and production

In order to reduce air pollution in Ulaanbaatar, the Government of Mongolia banned the burning of raw coal in 2019. Instead, improved coal briquettes were produced and supplied to households in Ulaanbaatar. Plans to continue this and supply improved coal briquettes to all households were included in the "Vision 2050" long-term policy document. According to our estimates, 77% of households that burn coal in Ulaanbaatar used improved coal briquettes while only 28% of all Mongolian households that burn coal used improved coal briquettes in 2020. We forecast that 60% of all Mongolian households will use improved coal briquettes by 2030. Within this, all households in Ulaanbaatar that burn coal and 40% of rural households that burn coal will use improved coal briquettes.

In this scenario, we simulated the increase in improved coal briquette production and investments needed to make the aforementioned forecast possible.

Scenario 3: To decrease investment of the export coal and coke and chemicals sectors

Raw coking coal accounts for most of Mongolia's coal exports, and its demand is entirely dependent on Chinese steel production. According to the China Metallurgical Industry Planning and Research Institute, China plans to hit peak carbon emissions before 2030 and achieve carbon neutrality before 2060. Relating to this goal, the country initially plans to achieve peak carbon emissions and output from the steel sector in 2025. The steel sector's emissions are then expected to fall by 30% from their peak by 2030. In light of this, we assume that Mongolia's raw coking coal exports may fall up to 30% between 2025 and 2030.

We forecast that there will be no additional investments made into the export coal sector after 2025 and that by 2030 coal exports will fall 25% compared to 2025. Additionally, we estimate that investments made into the coke and chemicals sector will fall 75% after 2025 with washed coking coal production decreasing 10% in 2030 compared to 2025. Moreover, we assume that foreign direct investment will fall by the total decrease in investments into export coal and coke and chemicals sectors. This scenario will detail the economic impact of the assumptions above.

Scenario 4: To implement all carbon reduction policies

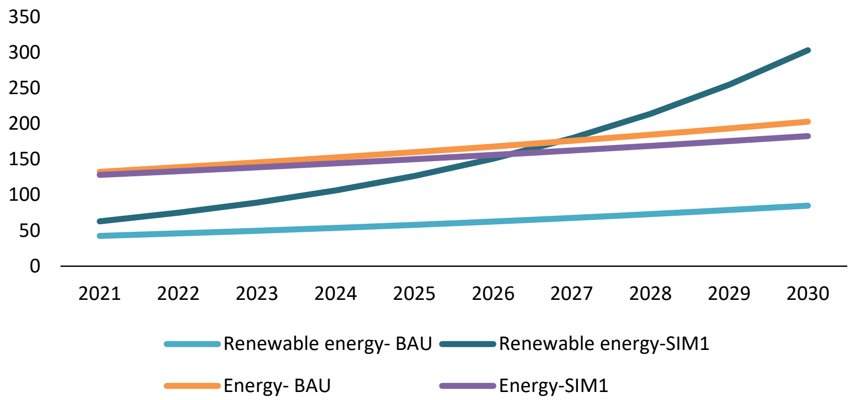
This scenario is designed to show the impact of various carbon reduction policies simultaneously. Thus, we develop this scenario as a combination of Scenario 1, 2 and 3.

4.2. Simulation results

Scenario 1: To increase the capacity of renewable energy sector (SIM1)

Under Scenario 1, investment in the renewable energy sector is estimated to increase by 142.5% from the 2020 level, and 2.6-fold from the baseline scenario (BAU) in 2030. In 2021-2030, a total of MNT 1.5 trillion will be invested in the renewable energy sector (Figure 6). Investment in the conventional energy sector is estimated to increase from its 2021 level in 2030, but less than the baseline scenario. By 2030, investment in the conventional energy sector is expected to decline by 10% compared to the baseline scenario.

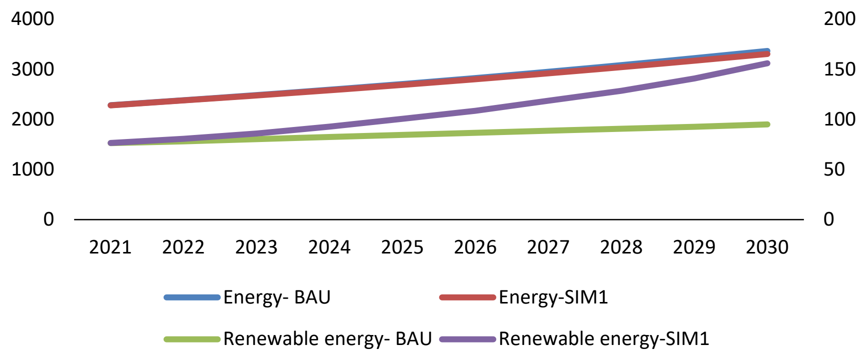
Figure 6. Investment in renewable energy and energy sector, billion MNT



In terms of production growth in both sectors, the renewable energy sector grew faster than in the baseline scenario, while the conventional energy sector was almost identical to the baseline scenario (

Figure 7). However, renewable energy production still accounts for a very small percentage of the total energy sector. In 2020, renewable energy accounted for only 2.2% of the total energy sector's production. According to the simulation, this will increase to 4.5% of the total energy sector's production by 2030.

Figure 7. *Production of renewable energy (right-hand) and energy sectors (left-hand), billion MNT*



Investment in the renewable energy sector increased significantly between 2021 and 2030 but did not have a significant impact on macroeconomic indicators (Table 11). For example, in 2021-2030, real economic growth in the baseline scenario averages 4.7%, while in Scenario 1 it is expected to reach 4.71%. Other macroeconomic variables have hardly changed. Furthermore, total CO_2 emissions growth is expected to be only 0.13 percentage points lower than the baseline in 2030.

Table 12. *Macroeconomic indicators: Scenario 1*

	Average growth %: 2021 to 2030		
	Baseline scenario	Scenario 1	Change %
GDP growth	4.76	4.71	-0.05
Government income	4.46	4.46	0.00
Household income/consumption	4.40	4.40	0.00
Wage rate	2.33	2.32	-0.01
Total investment	4.70	4.69	-0.01
Export	4.33	4.32	-0.01
Import	4.43	4.42	-0.01
CO_2 emission of households	5.15	4.86	-0.29
CO_2 emission of sectors	4.42	4.28	-0.14
Total CO_2 emission	4.49	4.36	-0.13

Although renewable energy investments are expected to increase 2.6-fold and output 1.8-fold in 2030, sectoral CO_2 emissions are only 1.4% lower than in the baseline scenario. Despite significant investments into the renewable energy sector, it accounts for a small share of total energy production due to low installed capacity utilization. Furthermore, as the conventional energy sector, the largest emitter of CO_2, still makes up the majority of total energy production, CO_2 emissions have not declined in any meaningful way.

Scenario 2: To increase improved coal use and production (SIM2)

Household consumption of raw coal declined due to an increase in the household consumption of improved coal briquettes (table 13). In 2020, improved coal briquettes and raw coal accounted for 28.9% and 71.1% of total coal consumption, respectively. In 2030, this changed significantly, and the consumption of improved coal briquettes and raw coal is 60% and 40%, respectively.

Table 13. Percentage of improved coal and raw coal in total coal consumption by households, %

	Improved coal briquettes	Raw coal
2020	28.9	71.1
2021	27.5	72.5
2022	26.5	73.5
2023	25.9	74.1
2024	26.1	73.9
2025	27.2	72.8
2026	29.6	70.4
2027	33.6	66.4
2028	39.8	60.2
2029	48.6	51.4
2030	60.0	40.0

The production of improved coal briquettes is expected to increase significantly, supported by investments (Figure 9). By 2030, the production of improved coal briquettes will be 2.3-fold higher that in the baseline scenario.

***Figure 8**. Improved coal investment, billion MNT*

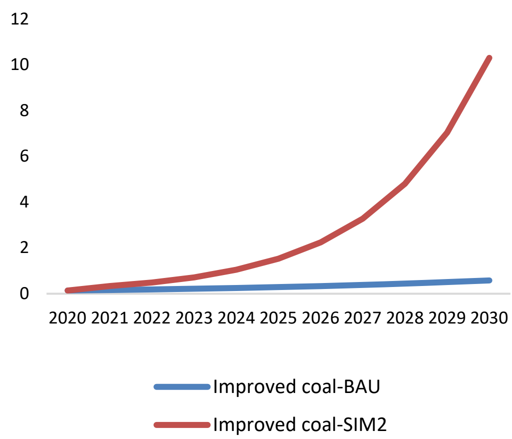
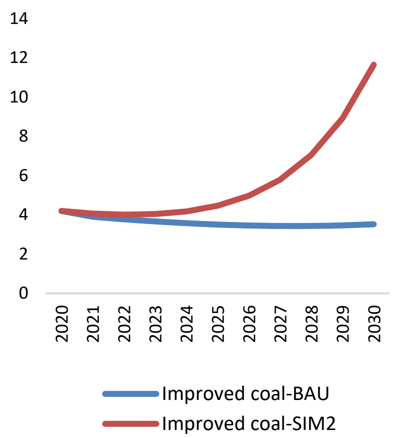


***Figure 9.** Improved coal production, billion MNT*



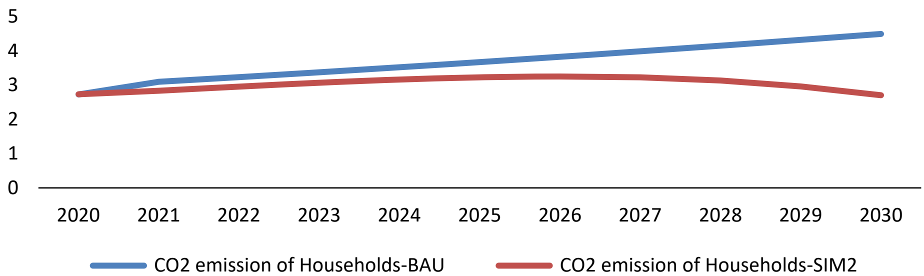
In this scenario, as the improved coal briquette sector is relatively small, investments into it do not have a significant impact on macroeconomic indicators. However, the amount of CO_2 emitted by households was significantly reduced (Table 14). This was due to the fact that as households increase their consumption of low emission improved coal briquettes, they substitute their use of high emission raw coal. However, it is worth noting that household emissions account for a very small percentage of total emissions, with most emissions coming from economic sectors. Therefore, total CO_2 emissions are estimated to be slightly lower than the baseline in 2030.

Table 14. Macroeconomic indicators: Scenario 2

	Average growth %: 2021 to 2030		
	Baseline scenario	Scenario 2	Change %
GDP growth	4.76	4.76	0.00
Government income	4.46	4.46	0.00
Household income/consumption	4.40	4.40	0.00
Wage rate	2.33	2.34	0.00
Total investment	4.70	4.70	0.00
Export	4.33	4.33	0.00
Import	4.43	4.43	0.00
CO_2 emission of households	5.15	0.00	-5.15
CO_2 emission of sectors	4.42	4.44	0.02
Total CO_2 emission	4.49	4.06	-0.43

As shown in Figure 10, household CO_2 emissions in 2030 are 39.8% lower than in the baseline scenario due to declining raw coal consumption.

Figure 10. CO2 emission of households, Scenario 2, Mt, 2020-2030



Scenario 3: To decrease investment of the export coal and coke and chemicals sectors (SIM3)

In Scenario 3, we assessed the impact of a decrease in production and investment in the export coal and coke and chemicals sectors.

The following figure details investments into the aforementioned sectors. According to our assumptions, there will be no new investments into the export coal sector after 2025 as well as a 75% decrease in investments into the coke and chemicals sector after 2025, compared to the baseline scenario.

***Figure 11**. Investment of export coal and coke and chemical sectors, billion MNT*

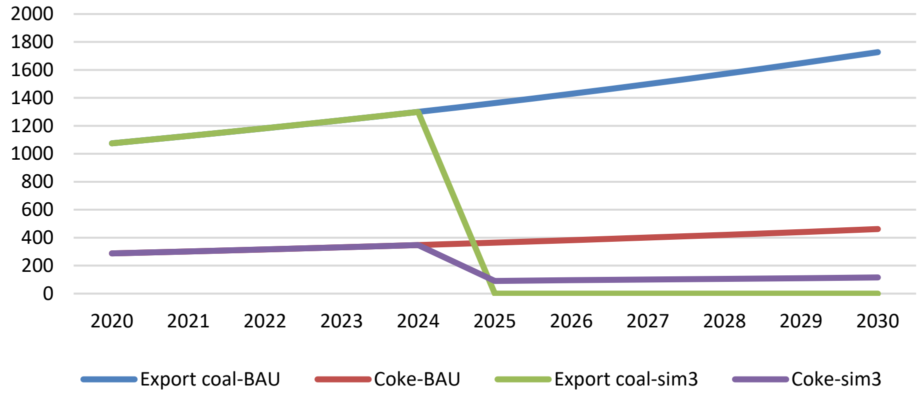
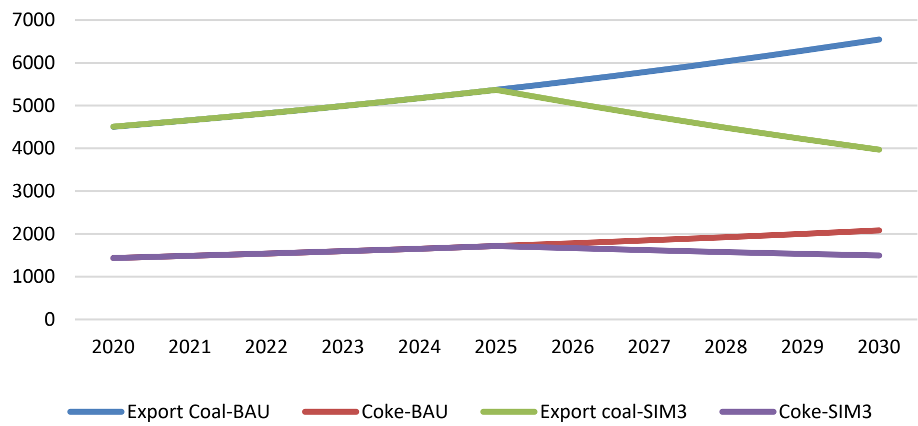


Figure 12 shows the production of the export coal and coke and chemicals sectors. As a result of the decrease in investment, the production of the export coal sector will decrease by 39% in 2030 compared to 2025 while the production of the coke and chemicals sector decreases by 12.2%.

***Figure 12.** Production of export coal and coke and chemical sectors, billion MNT*



The following figure shows the export volumes of the sectors. The volume of export coal will fall 25.5% in 2030 as compared to 2025, a 38.8% decrease compared to the baseline scenario. The export of the coke and chemicals sector will also fall 12.9% in 2030 compared to the baseline scenario.

***Figure 13.** Export volume of export coal and coking coal, billion MNT*

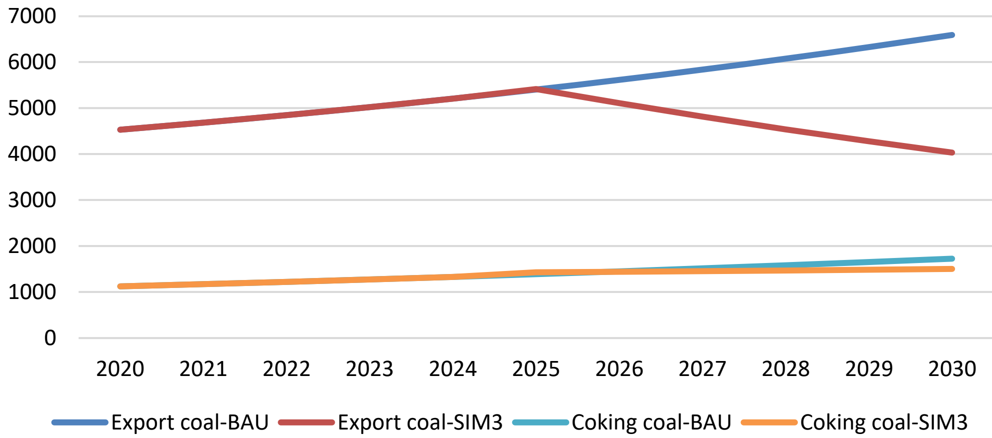


Figure 14 shows the average growth of production in all sectors. As the production of the export coal and coke and chemicals sectors declined, the sectors that are dependent on them and that supply their intermediate consumption experienced contractions in their average production growth. For instance, the average production growth of the domestic coal, construction, transportation, energy, administration and support, financial activities and real estate sectors decreased by up to 1.9 percentage points. As the production growth of these sectors slowed, labor and investment shifted to other sectors with the production growth of the oil, metal ore, manufacturing, renewable energy, water, accommodation, professional activities, and public administration sectors increasing marginally.

***Figure 14.** Average growth of production in all sectors, Scenario 3, %, 2021-2030*

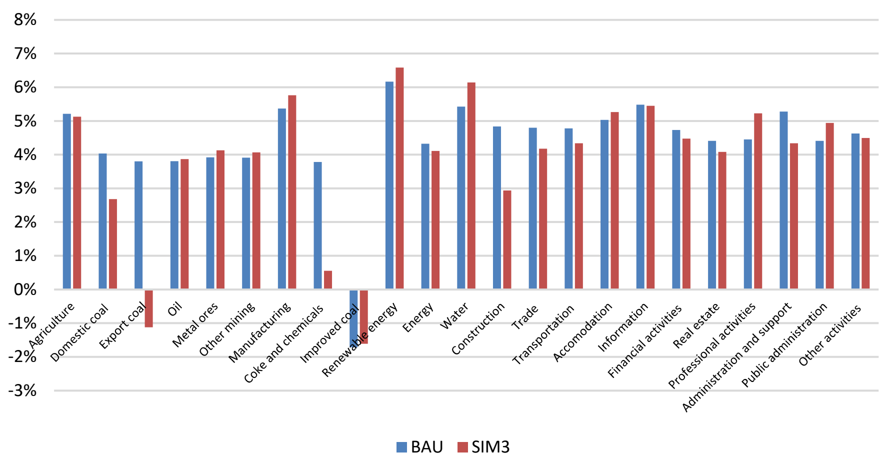


Table 15 shows the macroeconomic impact of Scenario 3. As the growth of the export coal, coke and chemicals, and related coal-dependent sectors contracted, average GDP growth declined 0.03 percentage points compared to the baseline scenario. The fall in investments into the target sectors also led to a 2.36 percentage point decrease in the average growth of total investment compared to the baseline scenario. Additionally, the labor force shifted from relatively high-wage sectors to other low-wage sectors. As a result, the average growth of the wage rate decreased by 1.15 percentage points with the average growth of household income and consumption decreasing by 0.98 percentage points. Average government income growth also decreased by 1.01 percentage points due to a decline in the average growth of government tax income. The average growth of total imports fell 1.27 percentage points due to a decline in the incomes of all agents. Meanwhile, as coal production and exports decreased, the average growth of total exports also fell 0.71 percentage points.

Table 15. Macroeconomic indicators: Scenario 3

	Average growth %: 2021 to 2030		
	Baseline scenario	Scenario 3	Change percentage point
GDP growth	4.76	4.73	-0.03
Government income	4.46	3.45	-1.01
Household income/consumption	4.40	3.42	-0.98
Wage rate	2.33	1.18	-1.15
Total investment	4.70	2.34	-2.36
Export	4.33	3.62	-0.71
Import	4.43	3.16	-1.27
CO_2 emission of households	5.15	4.17	-0.97
CO_2 emission of sectors	4.42	4.24	-0.18
Total CO_2 emission	4.49	4.23	-0.26

In terms of environmental impact, the average growth of household CO_2 emissions decreased by 0.97 percentage points owing to decreased household consumption growth. As the production growth of the energy sector, the sector responsible for emitting the most CO_2, declined, the average growth of total sectoral CO_2 emissions fell slightly. As a result, by 2030, total CO_2 emissions will decline compared to the baseline scenario with the average growth of total CO_2 emissions falling by 0.26 percentage points. 89% of this decrease can be attributed to declining emissions from the energy sector.

The following figures show detail the CO_2 emission trends of sectors and households. In 2030, sectoral and household CO2 emissions will decline 1.7% and 9.1% compared to the baseline scenario, respectively.

Figure 15. *CO_2 emission of the sectors, Scenario 3, Mt, 2020-2030*

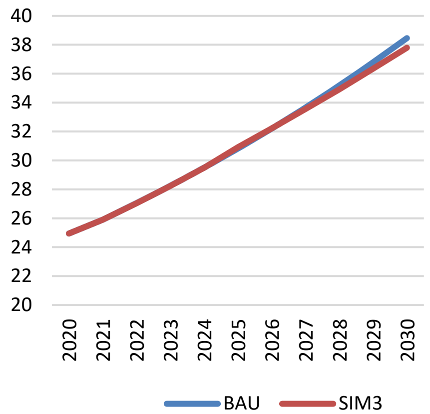
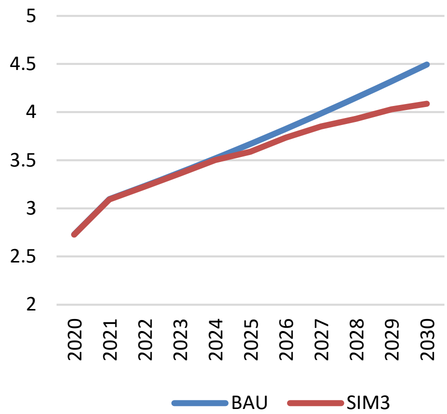


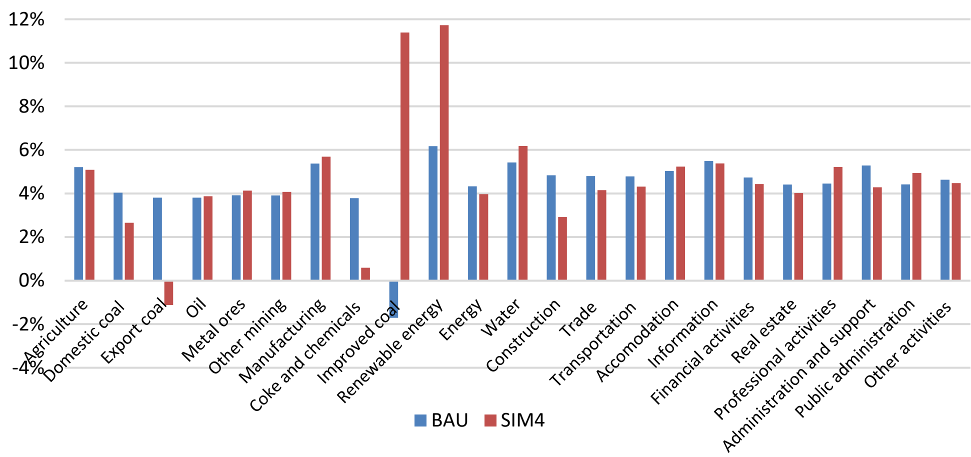
Figure 16. *CO_2 emission of households, Scenario 3, Mt, 2020-2030*



Scenario 4: To implement all carbon reduction policies

In this scenario, the average production growth rates of the improved coal and renewable energy sectors increased moderately due to an increase in investments (Figure 17). Conversely, average production growth rates of the export coal and coke and chemicals sectors fell owing to a fall in investments. The average production growth rates of the domestic coal, construction, transportation, energy, administration and support, financial activities and real estate sectors decreased for the same reasons as in Simulation 3. The production growth of the oil, metal ore, manufacturing, water, accommodation, professional activities, and public administration sectors accelerated slightly.

Figure 17. *Average growth of production in all sectors, Scenario 4, %, 2021-2030*



In this scenario, the macroeconomic indicators are the same as in Scenario 3. As for the environmental impact, the average household CO_2 emission growth decreased 6.16 percentage points largely due to the increased usage of improved coal briquettes. Similarly, the average sectoral CO_2 emission growth also fell slightly as the energy sector's production growth declined. Overall, the average growth of total CO_2 emissions decreased by 0.59 percentage points.

Table 16. *Macroeconomic indicators: Scenario 4*

	Average growth %: 2021 to 2030		
	Baseline scenario	Scenario 4	Change percentage point
GDP growth	4.76	4.69	-0.07
Government income	4.46	3.44	-1.02
Household income/consumption	4.40	3.41	-0.99
Wage rate	2.33	1.17	-1.16
Total investment	4.70	2.33	-2.37
Export	4.33	3.61	-0.72
Import	4.43	3.15	-1.28
CO_2 emission of households	5.15	-1.02	-6.16
CO_2 emission of sectors	4.42	4.13	-0.30
Total CO_2 emission	4.49	3.71	-0.79

In 2030, household CO_2 emissions were 45.9% lower than in the baseline scenario due to the usage of improved coal briquettes (Figure 19). The CO_2 emissions of sectors were 2.8% lower than in the baseline scenario as production growth in the energy sector declined slightly. This resulted in a 7.35% decrease in total CO_2 emissions compared to the baseline scenario.

Figure 18. *CO_2 emission of sectors, Scenario 4, Mt, 2020-2030*

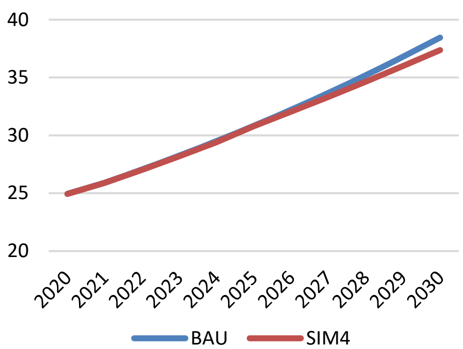
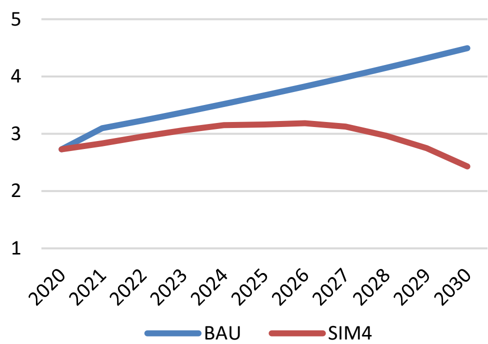


Figure 19. *CO_2 emission of households, Scenario 4, Mt, 2020-2030*



5. Conclusion

The Paris Agreement, an international effort to limit the increase of global warming to below 2°C, preferably to 1.5°C, from the pre-industrial level and reach climate neutral emissions by the end of the century, came into effect in 2016. 196 countries, including Mongolia, joined the Paris Agreement and the largest carbon emitting countries aim to reach peak global GHG emissions as soon as possible in order to be on the path towards carbon neutrality by 2050. If net-zero emissions are achieved by 2050, global warming could be kept under 2°C by 2100.

The top 5 GHG emitters since 1850 include the US, EU, China, Russia, and Germany while the top 5 annual GHG emitters as of 2018 are China, the US, EU, India, and Russia (Climate Watch , 2021). G20 nations account for 75% of global GHG emissions and have set ambitious emission reduction targets that are in line with the Paris Agreement goals of a 1.5°C limit on global warming and net-zero emissions by 2050 (Climate Analytics and WRI, 2021).

However, the implementation and enforcement of the Paris Agreement remains lacking. Global GHG emissions are still above target levels and from 2015-2019, the level of CO_2 in the atmosphere was more than 20% higher than in the previous five years (WMO, 2019). The global average temperature increased by 0.2°C from 2015-2019 and was 1.1°C higher than the pre-industrial level. This points to accelerating global warming and according to the Intergovernmental Panel on Climate Change, even full implementation of the Paris Agreement may result in global warming reaching 3°C.

At the 2021 COP26 meeting, countries reaffirmed their commitment to the Paris Agreement. However, current policy measures and commitments are still not enough to significantly cut global emissions by 2030. Major emitting countries are expected to renew their emission targets by the end of 2022 which will clarify if COP26 targets are compatible with the 1.5°C temperature limit.

Amidst this international effort to combat global warming, the GoM approved its NDC target in November 2019. Accordingly, Mongolia will reduce its GHG emissions by 22.7% by 2030 from its business-as-usual projected emission level. Mongolia also announced plans to further reduce this target to 27.2% of the business-as-usual projected emission level during the COP26 meeting. To reach this target, Mongolia plans to focus on developing renewable energy resources, plant a billion trees by 2030 and allocate 1% of GDP annually to mitigating the adverse effects of climate change.

However, in addition to reducing its own emissions, Mongolia must also consider the carbon reduction policies of other countries. China's policies related to reaching its NDC target is particularly important for Mongolia as China is its main market for coal and other mineral commodities. Mongolia's current carbon reduction policies are limited and do not yet reflect possible external risks in the coal and transport sectors.

Globally, burning coal generates about 15 billion tons of CO_2 annually. In light of this, China set a new goal to shift investments from coal to low-emission green technology in their new 5-year plan. In contrast, Mongolia declared the coal sector as a strategically important sector and plans to make sizable investments into the coal sector in upcoming years. These plans include the construction of a coal washing plant and several coal-fired power plants.

In general, while the GoM has set a goal to reduce GHG emissions, it is reluctant to restrict coal production and consumption due to its economic importance. Thus, Mongolia faces the ongoing challenge of managing a tradeoff between the "carbon neutral requirement from the world" and "the revenue sustainability of the Mongolian energy sector."

To explore this tradeoff, we reviewed the country experiences of Mongolia and major GHG emitters in carbon reduction and the strategies they employ to meet their NDC targets to achieve net-zero emissions. We then assessed the long-term economic and environmental impact of implementing various carbon-neutral policies in Mongolia. To do so, we developed a CGE model based on the PEP standard CGE model to project long-term economic development and changes in CO_2 emissions under the following alternative scenarios:

- Coal production, use and exports are restricted
- Use of renewable energy increases
- Use of improved coal briquettes increases
- The above three conditions are met simultaneously

Based on these assessments and analysis, the research team has put forth the following conclusions and recommendations:

- As the Mongolian economy is highly dependent on the mining sector, a decline in the investment into and production of the coal sector resulted in the slowdown of several dependent sectors. This reflects aspects of Dutch disease and has a negative impact on macroeconomic indicators. For instance, GDP growth, investment growth, government and household income growth and foreign trade growth all decelerated in Simulation 3 and 4 where investments into the coal sector fell. The worldwide shift toward reducing CO_2 emissions and eventually eliminating coal consumption had a considerable negative impact on the Mongolian economy and emphasizes the need to diversify and develop its non-mining sectors.

- In Mongolia, 68.5% of household CO_2 emissions are due to the burning of high emission raw coal. Thus, increasing the production of improved coal briquettes and providing more households with it is an effective method of reducing household CO_2 emissions. However, as household CO2 emissions account for a very small percentage of total CO2 emissions, reducing household CO2 emissions alone is not enough to make a considerable dent in emissions.

- This study examined how increasing the installed capacity of the renewable energy sector may lead to reductions in CO2 emissions. However, a detailed look into the renewable energy sector found it unable to significantly reduce emissions due to its low utilization and inefficiency. For instance, the renewable energy sector's production accounted for only 2.2% of the energy sector's total production in 2020. As such, even if the installed capacity of the renewable energy sector improved, its share of the energy sector's total production is likely to remain low. Moreover, the Vision 2050 long-term policy document includes provisions to make significant investments into Mongolia's energy sector, the sector that contributes most to CO_2 emissions. The implementation of these provisions will weaken the effect of policies aimed at improving the installed capacity of the renewable energy sector and reducing CO_2 emissions. To make meaningful improvements in reducing CO_2 emissions, there is a need to improve the installed capacity of the renewable energy sector, limit investments into the conventional energy sector, and improve the overall efficiency of the entire energy sector.

Bibliography

Climate Analytics and WRI. (2021). *Closing the Gap: The Impact of G20 Climate Commitments on Limiting Global Temperature rise to 1.5°C.* Climate Analytics and World Resources Institute .

Climate Watch . (2021). *Historical GHG Emissions*. Retrieved from Climate Watch : https://www.climatewatchdata.org/ghg-emissions?end_year=2018&start_year=1990

Climate Watch. (2021). Retrieved from https://www.climatewatchdata.org/data-explorer/historical-emissions?historical-emissions-data-sources=cait&historical-emissions-gases=all-ghg&historical-emissions-regions=All%20Selected%2CMNG&historical-emissions-sectors=All%20Selected&page=1&sort_col=sec

D'Ambrogio, E. (2021, June 28). *Briefing: South Korea's pledge to achieve carbon neutrality by 2050 .* Retrieved from Think Tank European Parliament : https://www.europarl.europa.eu/RegData/etudes/BRIE/2021/690693/EPRS_BRI(2021)690693_EN.pdf

Eckardt, S., Martin, R., & Huang, D. (2020, February 4). *The decoupling the world is waiting for: China's green growth breakthrough*. Retrieved from Brookings: https://www.brookings.edu/blog/future-development/2020/02/04/the-decoupling-the-world-is-waiting-for-chinas-green-growth-breakthrough/

Energy Regulatory Commission. (2018-2020). *Energy statistics.* Energy Regulatory Commission.

Global times. (2021, Mar 30). Retrieved from https://www.globaltimes.cn/page/202103/1219867.shtml

Global Trade Analysis Project. (2007). *CTAP-7 Data Base.* Retrieved from https://www.gtap.agecon.purdue.edu/databases/v7/

Government of Mongolia. (2020). *MONGOLIA'S NATIONALLY DETERMINED CONTRIBUTION TO THE UNITED NATIONS FRAMEWORK CONVENTION ON CLIMATE CHANGE.* Retrieved from UNFCCC: https://www4.unfccc.int/sites/ndcstaging/PublishedDocuments/Mongolia%20First/First%20Submission%20of%20Mongolia%27s%20NDC.pdf

International Renewable Energy Agency. (2020). *Renewable Power Generation cost in 2020.* IRENA.

Mineral Resources and Pertoleum Authority . (2018, 2020). *Mineral statistics.* MPRAM.

Ministry of Energy. (2018-2020). Retrieved from https://energy.gov.mn/content?t=3

National Statistical Office. (2019). Retrieved from https://1212.mn/BookLibraryDownload.ashx?url=Ub_health_2019.pdf&ln=Mn

National Statistical Office. (2021). *1212.mn*.

Our World in Data. (2021). Retrieved from https://ourworldindata.org/co2-and-other-greenhouse-gas-emissions

Ragchaasuren.G, o. (2018). *Road versus rail transport of coal: implications for CO2 .* Parthnership for economic policy.

The Government of Mongolia. (August 28, 2020). *Parliament Resolution No 24.*

The Government of Mongolia. (2018). *The Medium-Term Energy Plan 2018-2023.*

The Government of Mongolia. (2020). *The Vision-2050.* The Government of Mongolia.

The Ministry of Energy. (2020, 10 05). Retrieved from The Ministry of Energy: http://energy.gov.mn/c/1163

The Ministry of Energy. (2020, 10 05). Retrieved from The Ministry of Energy: https://energy.gov.mn/c/1157

The Ministry of Energy. (2021, 11 01). Retrieved from The Ministry of Energy: https://energy.gov.mn/c/1278

The White House. (2021, April 22). *The White House.* Retrieved from whitehouse.gov: https://www.whitehouse.gov/briefing-room/statements-releases/2021/04/22/fact-sheet-president-biden-sets-2030-greenhouse-gas-pollution-reduction-target-aimed-at-creating-good-paying-union-jobs-and-securing-u-s-leadership-on-clean-energy-technologies/

UNEP. (2019, October 23). *Why peatlands matter*. Retrieved from United Nations Environment Program: https://www.unep.org/news-and-stories/story/why-peatlands-matter

UNFCCC. (2020a, December 17). *www4.unfccc.int.* Retrieved from The update of the nationally determined contribution of the European Union and its Member States: https://www4.unfccc.int/sites/ndcstaging/PublishedDocuments/Germany%20First/EU_NDC_Submission_December%202020.pdf

UNFCCC. (2021). *China's Achievements, New Goals and New Measures for Nationally Determined Contributions.* Retrieved from www4.unfccc.int: https://www4.unfccc.int/sites/ndcstaging/PublishedDocuments/China%20First/China%E2%80%99s%20Achievements,%20New%20Goals%20and%20New%20Measures%20for%20Nationally%20Determined%20Contributions.pdf

US EIA . (2021, July 26). *In 2020, the United States produced the least CO2 emissions from energy in nearly 40 years*. Retrieved from US Energy Information Administration: https://www.eia.gov/todayinenergy/detail.php?id=48856

WMO. (2019). *WMO Statement on the State of the Global Climate in 2019.* Geneva: World Meteorological Organization.