MINISTERSTVO
ŽIVOTNÉHO PROSTREDIA
SLOVENSKEJ REPUBLIKY

Slovakia’s First Biennial Transparency Report

TO THE UNITED NATIONS FRAMEWORK CONVENTION ON CLIMATE CHANGE (UNFCCC) UNDER THE PARIS AGREEMENT

December 2024

PREFACE

Title of report	First Biennial Transparency Report of Slovakia
Compiled by:	*Miroslava Dančová, Anna Hinerová, Mário Gnida, Marek Sokolík* *Climate Change and Air Protection Division* *Ministry of Environment of the Slovak Republic* *Janka Szemesová, Ján Horváth, Jozef Orečný, Marcel Zemko, Roman Mach, Kristína Tonhauzer* *Department of Emissions and Biofuels* *Slovak Hydrometeorological Institute*
Approved by:	Jozef Škultéty Director General of the Climate Change and Air Protection Division Ministry of Environment of the Slovak Republic National Focal Point to the UNFCCC
Organisation:	Ministry of Environment of the Slovak Republic Slovak Hydrometeorological Institute
Address:	Nám. Ľ. Štúra 1, 812 35 Bratislava Jeséniova 17, 833 15 Bratislava
Email:	jozef.skultety@enviro.gov.sk
Version:	1.version – Final
Date of Submission:	December 2024

CONTENT

EXECUTIVE SUMMARY

ES.1. Introduction

This report represents the First Biennial Transparency Report (BTR) from the Slovak Republic.

By the decision 18/CMA.1 it was decided that the developed country Parties should enhance reporting in national communications and submit biennial transparency reports outlining their progress in achieving emission reductions and the provision of financial, technology and capacity-building support to non-Annex I Parties, building on existing reporting and review guidelines, processes and experiences, including Enhanced Transparency Framework. Parties shall submit BTR no later than 31 December 2024.

Chapter 1 provides a brief introduction of the BTR, **Chapter 2** summarizes the main trends in national greenhouse gas emissions and removals over the period 1990 – 2022, as described in the annual National Inventory Report of the Slovak Republic (submitted as a separate document). **Chapter 3** provides information about joint EU NDC, policies and measures (PAMs) of Slovakia per sector and the impact thereof, as well as the main projections results for GHG for the period 2022 – 2050. **Chapter 4** describes the main information about climate adaptation in the Slovak Republic. **Chapter 5** details the Slovakia´ support for climate action in developing countries and provides information on financial, technology transfer and capacity-building support provided and mobilized. **Chapter 6** identifies some areas of improvements in reporting compared to previously submitted reports.

ES.2. National Inventory Document

The National Inventory Document of the Slovak Republic for the 1990 – 2022 period is submitted to the UNFCC in as a separate report. The NID consist of the National Inventory Document (NID) and the Common Reporting Tables (CRT) including json file with data. These two parts together provide an overview of the Slovakia´s greenhouse gas inventory in quantitative and qualitative terms.

Slovakia´s total GHG emissions were 37 052.21 Gg of CO_2 eq. in 2022 (without LULUCF and with indirect emissions). This represents a reduction by 49.56% against the base year 1990. In comparison with 2021, the emissions decreased by 10%. The decrease in total emissions of 2022 compared to 2021 was due to decrease in the Energy and IPPU sectors.

ES.3. Information Necessary to Track Progress

In accordance with Article 13, Paragraph 5 and 6 of the Paris Agreement, the purpose of BTR is to provide clarity on Climate actions of Parties by tracking their progress towards their nationally determined contributions (NDC). There is a great importance in regular, transparent and precise reporting in order to sustainably progress.

The EU and its Member States, acting jointly, are committed to a legally binding target of a domestic reduction of net GHG emissions by at least 55% compared to 1990 by 2030. The European Climate

Law[1] sets the goal of climate neutrality by 2050 and the intermediate target of reducing net greenhouse gas emissions by at least 55% by 2030 compared to 1990 levels. This target for 2030 corresponds to the target of the EU NDC.

Under their updated NDC[2] the EU and its Member States, acting jointly, are committed to a legally binding target of a domestic reduction of net greenhouse gas emissions by at least 55% compared to 1990 by 2030. The term 'domestic' means without the use of international credits.

The NDC consists of a single-year target, and the target type is 'economy-wide absolute emission reduction'. The scope of the NDC covers the 27 Member States of the EU. Details on the EU NDC can be found in ***Table ES.1***.

Table ES.1: *Description of the NDC of the EU*

Information	**Description**
Target and description	Economy-wide net domestic reduction of at least 55% in greenhouse gas emissions by 2030 compared to 1990. The term 'domestic' means without the use of international credits.
Target type	Economy-wide absolute emission reduction.
Target year	2030 (single-year target)
Base year	1990
Base year value	Net greenhouse gas emissions level in 1990: 4 700 168 kt CO_2 eq..
Implementation period	2021 – 2030
Geographical scope	EU Member States (Belgium, Bulgaria, Czechia, Denmark, Germany, Estonia, Ireland, Greece, Spain, France, Croatia, Italy, Cyprus, Latvia, Lithuania, Luxembourg, Hungary, Malta, the Netherlands, Austria, Poland, Portugal, Romania, Slovenia, Slovakia, Finland, Sweden) including EU outermost regions (Guadeloupe, French Guiana, Martinique, Mayotte, Reunion, Saint Martin (France), Canary Islands (Spain), Azores and Madeira (Portugal)).
Sectors	Sectors as contained in Annex I to decision 5/CMA.3: Energy, Industrial processes and product use, Agriculture, Land Use, Land Use Change and Forestry (LULUCF), Waste. International Aviation: Emissions from civil aviation activities as set out for 2030 in Annex I to the EU ETS Directive are included only in respect of CO_2 emissions from flights subject to effective carbon pricing through the EU ETS. With respect to the geographical scope of the NDC these comprise emissions in 2024-26 from flights between the EU Member States and departing flights to Norway, Iceland, Switzerland and the United Kingdom.

---

[1] Regulation (EU) 2021/1119 establishing the framework for achieving climate neutrality and amending Regulations (EC) No 401/2009 and (EU) 2018/1999 ('European Climate Law'), http://data.europa.eu/eli/reg/2021/1119/oj.

[2] The update of the nationally determined contribution of the European Union and its Member States, https://unfccc.int/sites/default/files/NDC/2023-10/ES-2023-10-17%20EU%20submission%20NDC%20update.pdf.

Information	Description
	International Navigation: Waterborne navigation is included in respect of CO_2, methane (CH_4) and nitrous oxide (N_2O) emissions from maritime transport voyages between the EU Member States.
Gases	Carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), sulphur hexafluoride (SF_6), nitrogen trifluoride (NF_3)
LULUCF categories and pools	The included LULUCF categories and pools are as defined in decision 5/CMA.3.
Intention to use cooperative approaches	The EU's at least 55% net reduction target by 2030 is to be achieved through domestic measures only, without contribution from international credits. The EU will account and report for cooperation with other Parties in a manner consistent with the guidance adopted by CMA1 and any further guidance agreed by the CMA.
Any updates or clarifications of previously reported information, as applicable	The information on the NDC scope contains clarifications/further details compared to the information provided in the updated NDC of the EU.

Note: This table is identical to table 'Description of a Party's nationally determined contribution under Article 4 of the Paris Agreement, including updates,' which has been submitted electronically together with this BTR. This table is also annexed to this BTR.

Source: Updated NDC of the EU[3]

Policies and Measures

The overall policy framework for addressing climate change in the Slovak Republic consists of European climate strategies and policies, which are complemented by specific national policies and measures targeting the most critical areas. Given the very different challenges faced by different sectors, the Slovak Republic and its national authorities are opting for a wide range of instruments, relying on regulation, financing schemes, tax incentives, advice and various stakeholder support measures.

All relevant policies and measures at national level are strengthened to meet the 2030 targets of at least a 55% reduction in net greenhouse gas emissions by 2030 compared to 1990 levels. As can be seen from recent greenhouse gas emissions, the Slovak Republic is on track to meet its commitments and bring the Slovak Republic closer to achieving climate neutrality in 2050.

Projections

General methodology of the emission projections calculations was based on the same structure as in the national inventory of greenhouse gases. The data structure for activities, input data, emission factors and emission calculations are based on the Common Reporting Tables (CRT) of the UNFCCC.

---

[3] The update of the nationally determined contribution of the European Union and its Member States, https://unfccc.int/sites/default/files/NDC/2023-10/ES-2023-10-17%20EU%20submission%20NDC%20update.pdf.

The outputs are aggregated. Emission projections are generally calculated by similar methodology as in the case for the national GHG inventory.

Figures and tables of the GHG emission projections are describes in **Chapter 3.6** of this Report in overall trend of total aggregated emission projections. The WAM scenario achieves far greater reductions than WEM, with accelerated progress starting after 2025. Steady but moderate reduction in WEM scenario in emissions, reflecting limited measures. The steepest decline occurs between 2025 and 2035 in WAM scenario. LULUCF inclusion significantly amplifies the reduction in the WAM scenario, highlighting its critical role in achieving net-zero emissions. While WEM shows progress, it is insufficient to meet long-term climate targets, emphasizing the importance of additional measures in the WAM scenario.

ES.4. Information Related to Climate Change Impacts and Adaptation under Article 7 of the Paris Agreement

Impacts of climate change and global warming are also significantly manifested in Slovakia. The observed upward trend in the Earth's surface temperature is the most noticeable manifestation of ongoing climate change, especially since the second half of the 1980s, and in Slovakia especially since the early 1990s.

Slovakia has seen a significant increase in above-normal temperature years since 1991, with 2018 and 2019 being extremely warm. In the period 2001 – 2022, dry, rainfall-free periods have been shown to occur more frequently, which, combined with warmer average climatic conditions, leads to more frequent and more widespread soil drought. A major problem in Central Europe and Slovakia is the significant change in the temporal and spatial distribution of precipitation and snow cover. Precipitation in the warm part of the year occurs more often in the form of intense torrential downpours and in the cold part of the year more often in liquid form. The climate change scenarios described in this report assume comparable increases in monthly and annual temperatures of 1.5 to 4.7°C in Slovakia. While the temperature scenarios are very similar in all Slovak locations, the precipitation scenarios show some regional differences. Higher increases in annual precipitation totals are expected in the north of the country, with summer decreases in precipitation more significant in the southern lowlands. A comparable increase (decrease) is also projected for daily maximum precipitation totals.

The Slovak Republic defines adaptation to climate change as its priority in the strategic document Envirostrategy 2030. The main instrument for increasing the adaptive capacity of the Slovak Republic is the update of the Strategy for Adaptation of the Slovak Republic to the Adverse Impacts of Climate Change from 2014, called the Strategy for Adaptation of the Slovak Republic to Climate Change - Update (hereinafter referred to as the "NAS"), which was adopted in 2018. The Ministry of Environment of the Slovak Republic has also prepared an Action Plan for the implementation of the Strategy for Adaptation of the Slovak Republic to Climate Change (hereinafter referred to as the "NAP"), which is an implementation document of the NAS.

ES.5. Information on Financial, Technology Development and Transfer and Capacity-Building Support Provided and Mobilized under Articles 9-11 of the Paris Agreement

The chapter provides information on the provision of financial, technological and capacity-building support to developing countries. It embraces information on climate related financial support, which Slovakia provided to developing countries during the years 2021 and 2022.

Slovakia became a member of the community of donors providing assistance to developing countries with its accession to the OECD (2000), European Union (2004) and the OECD Development Assistance Committee – DAC (2013). Preparatory process and the Membership in these organizations have made a significant contribution to the creation of the mechanism for the Slovak Official Development Assistance (ODA).

The mechanism of providing development assistance ODA is based on the institutional, legal, and strategic framework for the Slovak development programming. The key national institutions involved in the bilateral ODA are: Ministry of Foreign and European Affairs of the Slovak Republic (MFEA) and the Slovak Agency for International Development Cooperation (SAIDC) - responsible for contracting and administering bilateral programmes and development projects in the recipient countries.

Multilateral development assistance includes development programmes and development projects, financed by Slovakia, performed by an international organization, whereas the contributions are paid by Slovakia to international organizations to finance their development activities. Slovak multilateral development aid is provided to the EU (EC and European Development Fund), the United Nations system (particularly FAO and WHO), the World Bank Group (particularly IDA), OSCE (Organization for Security and Co-operation in Europe), and other international organizations.

The summary of Slovakia´s public support, which amounted to 21,8 mil. € during 2021 and 2022, is as follows – the total amount of public financial support in 2021 was approximately 10,5 mil. € with approximately 8 mil. € through multilateral channels and approximately 2,53 mil. € through bilateral channels. The total amount of public financial support in 2022 was approximately 11.24 mil. € with approximately 8.9 mil. € through multilateral channels and approximately 2.3 mil. € through bilateral channels.

1. INTRODUCTION

This is the First Biennial Transparency Report (BTR) of the Slovak Republic, as a part of the Enhanced Transparency Framework, established by Article 13 of the Paris Agreement. The purpose of this BTR is to provide comprehensive information about climate change action in Slovakia, including tracking progress towards achieving Parties´ individual nationally determined contributions (NDCs), support provided to developing countries and information about adaptation to climate change.

The BTR consists of information requirements according to decision 18/CMA.1 respecting guiding principle of modalities, procedures and guidelines (MPGs).

The National Inventory Report is submitted as a separate report. A summary of the NIR has been provided in chapter 2 of the BTR.

2. NATIONAL INVENTORY DOCUMENT

The GHG emissions presented in the National Inventory Document 2024 were updated and recalculated using the last updated methods based on the IPCC 2019 Refinement to the IPCC 2006 Guidelines for National Greenhouse Gas Inventories, national conditions and data published by the Statistical Office of the Slovak Republic.

Slovakia was reviewed in the UNFCCC centralised review during the week from 17th – 22th October 2022. As a result of the 2022 submission' review of Slovakia, "Provisional Main Findings of the ERT" was received in the end of review week. The report included several recommendations and findings in tables 1 and 2, in accordance with paragraph 84 of the annex to decision 13/CP.20. There was no Saturday Paper, but the resubmission in LULUCF and KP LULUCF sectors was required during the review week. Re-submission has impact on GHG total: in the base year 1990 – 1.3% and in 2020 – 4.1%, but only for emissions with LULUCF). Slovakia received final of the Annual Review Report 2022 and several improvements were already included in the 2023 submission. More information can be found in Chapter 1.2 of the SVK NID 2024.

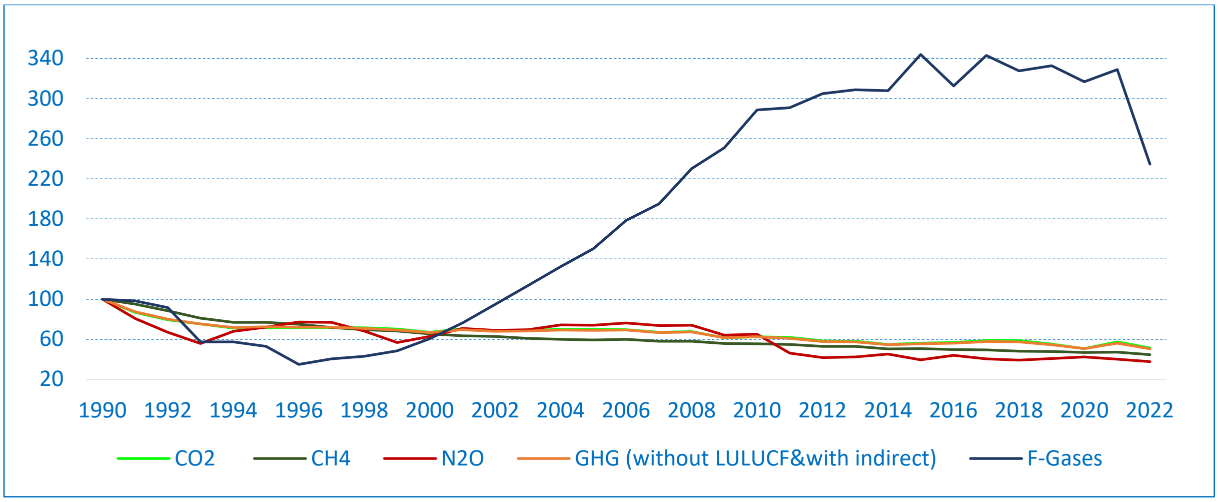
Total GHG emissions were 37 052.21 Gg of CO_2 eq. in 2022 (without LULUCF and with indirect emissions). This represents a reduction by 49.56% against the base year 1990. In comparison with 2021, the emissions decreased by 10%. The decrease in total emissions of 2022 compared to 2021 was due to decrease in the Energy and IPPU sectors.

The 2024 submission includes indirect CO_2 emissions in the solvents category (IPPU). This means, that indirect emissions were 39.50 Gg of CO_2 eq. in 2022. Indirect CO_2 emissions were estimated and reported for the time series 1990 – 2022.

The major changes in the 2024 national inventory of GHG emissions are caused by recalculations in the Fugitive Emissions, Agriculture, LULUCF and Waste sectors for the particular years or whole time series.

The emissions with LULUCF and with indirect emissions decreased in 2022 compared to 2021 by 12%. During period 1991 – 2022, the total greenhouse gas emissions in the Slovak Republic did not exceed the level of 1990. ***Tables ES.2*** and ***ES.3*** in the SVK NID 2024 (page 10) show the aggregated GHG emissions expressed in CO_2 equivalents and according to the gases in the period 1990 – 2022. ***Figure 2.1*** shows trend in the gases without LULUCF. The emissions of F-gases are the only emissions from consumption HFCs, PFCs and SF_6 in industry with the increasing trend since 1990 (despite decrease of PFCs gases from aluminium production).

Figure 2.1: *GHG emission trends compared with the base year (%) in the Slovak Republic*



GHG emissions in % to base years without LULUCF and indirect emissions; emissions are determined as of December 2024

Slovakia decreased its emissions by around 20% between 2010 and 2022. The latest available GHG emission projections have demonstrated emissions decrease as an evidence of the successful implementation of the policies and measures and their effect on the improvement in energy intensity and industrial production efficiency. These projections are in line with the Low-Carbon Strategy of Slovak Republic (approved in February 2020 by the Government). New drivers and parameters reflecting the actual pandemic situation were projected. Actually, during the year 2024, a new emissions projection among the National Energy and Climate Plan are preparing and will be published in the First Biennial Transparency Report.

Reduction of emissions in Slovakia in past years was conjunction of different impacts starting from impressive industrial and technological restructuring connected with the fuel switching of fossil fuels from coal and oil to the natural gas (air pollution legislation since 1991 was the main driving force), economy restructuring towards the less energy intensive production (mostly in recent years) and also by temporary changes in production intensity (driven by global and EU markets). Transport (mostly the road transport), with continuously increasing emissions is an important exception. The continuous pressure is being made in formulating the effective strategy and policy to achieve further reduction of emissions in this sector, too. For example, combination of regulatory and economic instruments (toll pay for freight vehicles based on their environmental characteristics in a combination with fuel and emission standards for new cars). The car tax system and the level of fuel taxation, which is close to the EU average, contribute to limit the increase of greenhouse gas emissions in the transport.

In Slovakia, the structural changes in the manufacturing industry towards less energy intensive industries, such as machinery and automotive industry, can explain why after 2009 the energy consumption did not pick up the same pace as prior to that year when led to a significant decrease in primary energy intensity (the GDP grew twice as fast as primary energy consumption). Therefore, the trend observed particularly in primary energy consumption is mainly due to other factors although some energy efficiency improvements did take place particularly during the period after the year 2012. The policy package still needs various improvements across the sectors including the sectoral mitigation targets particularly in transport, buildings, agriculture and waste. Preparation of the Act on Climate Change was in progress in Slovakia during 2022.

Although this optimistic trend recognised in previous years, it is visible since last 3 years, that the improvement of several indicators such as GHG per capita or GHG/GDP started slowed down and reached minimum level. GHG emissions level reached minimum in 2014 and trend is stabilised, fluctuated with increases in transport, households, waste and some industrial categories in the latest year, however, the year 2019 is the second lowest emissions' year since the base year. Covid-19 pandemic situation occurred in 2020 in conjunction with the industrial changes in iron and steel production, transformation of electricity and heat production sectors and changes in fuels combustion caused by increasing prices led to the dramatically high decrease of the total emissions in 2020. However, despite this optimistic development, the emission trend in 2021 increased back to the pre-pandemic level. Further reduction of emissions in 2022 was caused by the energy prices policy and due to economic reasons, several important industrial plants reduced or closed the operation. More information is in energy and IPPU sectoral chapters.

3. INFORMATION NECESSARY TO TRACK PROGRESS

3.1. National Circumstances and Institutional Arrangements

3.1.1. NATIONAL CIRCUMSTANCES RELEVANT TO GHG EMISSIONS AND REMOVALS TRENDS

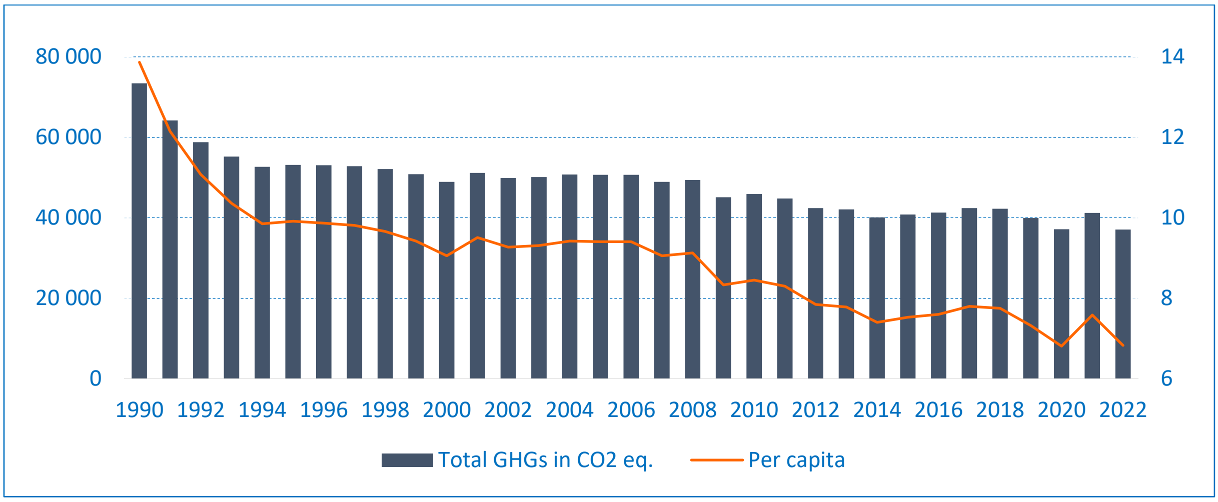
Beside the basic macroeconomic indicators as GDP, GDP per capita, foreign and domestic trade development, inflation, employment, there are also mentioned the data on the amount of investment in environmental protection and activities in the area of science and research, without specifying their orientation. The economic crisis that began in 2008 has brought a significant weakening of the external demand, causing a decreasing dynamic of the Slovak export, manufacturing, labour market and total domestic demand. The debt crisis in the Eurozone that broke out in 2012 again caused a decline in external demand. Emission situation in Slovakia can be considered and evaluated separately. While the EU ETS sources/sectors is going to further reduction of their emissions, the emissions in the non-EU ETS sources (ESR sectors/sources) is mostly stabilised or negative. Regulations included in the EU ETS push sources via economical instruments (Modernisation Fond) into larger investments and reduction of CO_2 emissions. In addition, the Slovak economy introduced changes in energy industry and steel production (phase-out of the furnace in the U.S. Steel company) what have positive effect on emissions in the EU ETS part of inventory. On the other hand, non-EU ETS sources representing agriculture, small industry, transport, waste and other small sources have not effective mitigation measures in place and the sectors policies are not targeting emissions reduction in a sufficient way. Therefore, the Ministry of Environment prepared the new Climate Change legislation, what introduces the sectoral targets with the shared responsibility among the ministries and the private sectors.

3.1.1.1. Demographic Profile

The indicators can assess the current economic and emission situation in Slovakia. While the indicator of carbon intensity can be changed much more rapidly in the situation of a high economic growth, GHG per capita is a different case where you can get very impressive results even without any measures, just by higher population growth rate. However, this is not the case of the Slovak Republic right now.

It will take much longer time to change numerator by the impact of new technologies implementation namely in combination with high dynamic of development in the energy intensive industries. However, the indicator reached the lowest level in 2020 (***Figure 3.1***). This was caused by combination of above-mentioned measures and special situation with COVID-19, Ukraine war and fuel prices policy in the last few years.

Figure 3.1: *Total GHG emissions in Gg of CO_2 eq. per capita in 1990 – 2022*



Aggregated GHG emissions without LULUCF and indirect emissions; emissions are determined as of December 2024

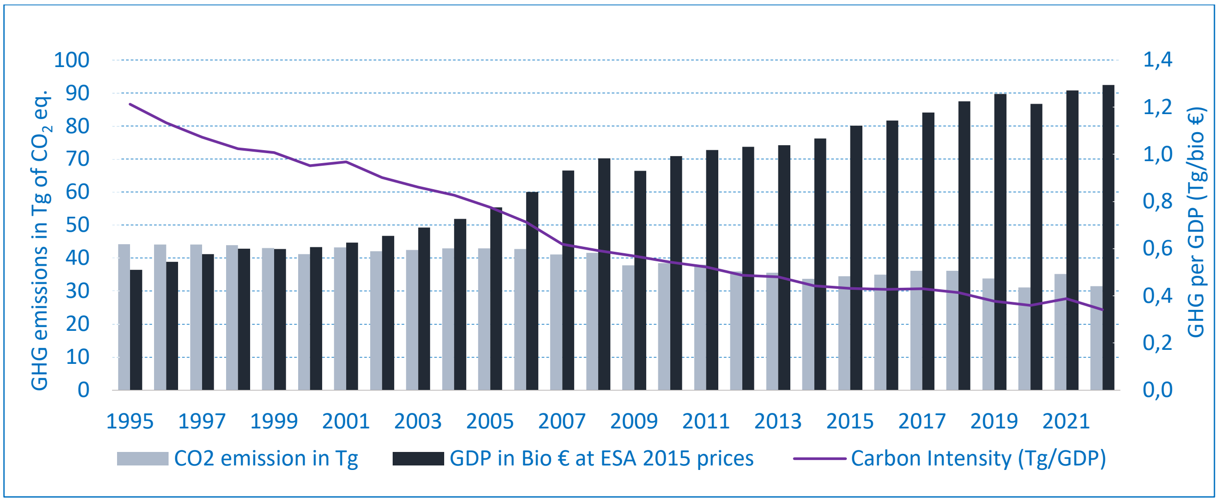
3.1.1.2. Energy Profile

Table 3.1 and ***Figure 3.2*** show the most significant trend indicator of GDP and GHG emissions decoupling which was achieved in Slovakia in past years. In addition, development in the last inventory year (2022) is an evidence of continuation of decoupling process started in the 1997 and continuing after economic crises in 2009. With the recovery of economy, carbon emissions did not follow GDP growth. This is a signal of total reconstruction of Slovak economy and industry. It is also expected, that similar trend will continue in the future, while there are planned investments in energy saving and efficiency and step by step building a carbon neutral economy.

Table 3.1: *Decrease of carbon intensity per GDP in the Slovak Republic in 2007 – 2022*

YEAR	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**
CO_2 emission *in Tg*	41.15	41.55	37.80	38.46	38.05	35.96	35.62	33.71
GDP *in Bio €* at ESA 2015 prices	66.53	70.24	66.41	70.87	72.76	73.72	74.19	76.19
Carbon Intensity *in Tg/GDP*	0.62	0.59	0.57	0.54	0.52	0.49	0.48	0.44
YEAR	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**	**2022**
CO_2 emission *in Tg*	34.53	34.96	36.17	36.16	33.83	31.15	35.22	31.55
GDP *in Bio €* at ESA 2015 prices	80.13	81.68	84.08	87.47	89.67	86.68	90.83	92.42
Carbon Intensity *in Tg/GDP*	0.43	0.43	0.43	0.41	0.38	0.36	0.39	0.34

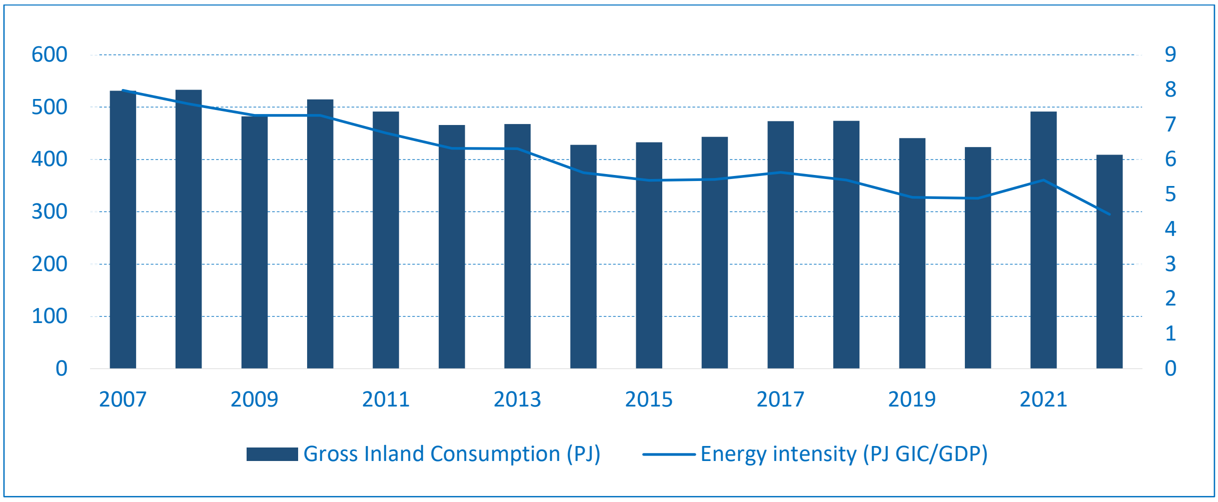
Figure 3.2: *Comparison of CO_2 emissions per GDP (carbon intensity) in 1995 – 2022*



The Slovak Statistical Office, Dpt. of National Accounts. Within the revision of annual national accounts (base year 2015)

According to the Joint Research Centre of the European Commission, the highest reduction in the energy intensity values during the 15-years period from 2000 to 2014 was found in the Slovak Republic, which has undergone a growth rate of 82.5%.[4] This positive development is the result of the successful restructuring of industry, the introduction of energy-efficient production processes in industry and effective energy-saving measures in household by superseding home appliances with more efficient variants (due to several support programmes focused on households). Energy intensity in 2022 decrease in comparison with the previous year, due to decrease of the GDP caused by the economic reasons and lower total inland energy consumption. The latest year development estimated the long-term trend in energy intensity per GDP and final decarbonisation of economy (***Figure 3.3***).

Figure 3.3: *The trend of energy intensity (right y axis) in the period 2007 – 2022 (estimated by the revised statistical approach NACErev.2)*



---

[4] Joint Research Centre: Energy Consumption and Energy Efficiency Trends in the EU-28 2000-2014 2016, p. 19.

3.1.1.3. Climate Profile

In terms of the global climatic classification, the territory of Slovakia belongs to the temperate climate zone with regular alternation of four seasons and variable weather with relatively even distribution of precipitation during the year. The climate of Slovakia is influenced by the prevailing westerly air flow in temperate latitudes between permanent pressure formations, the Azores pressure high and the Icelandic pressure low. The westerly flow from the Atlantic Ocean brings humid oceanic air of temperate latitudes, which moderates temperature amplitudes during the day and year and brings atmospheric precipitation to the territory of Slovakia. The influence of the Atlantic Ocean on the climatic conditions of Slovakia is gradually decreasing from west to east. Microclimatic factors, in particular the shape and orientation of the relief in relation to the cardinal directions, also influence the climate in different areas.

Between 1881 and 2021, Slovakia experienced a significant increase in annual mean air temperature of 0.15°C over 10 years. For annual atmospheric precipitation, we observed only a slight change of up to about 1%. However, there has been a change in the temporal distribution of atmospheric precipitation during the year, with an increase in the number of droughts, which are more intense and longer lasting, and an increase in the number of floods and flash floods. Up to an altitude of 800 m a.s.l. a decrease in snow cover was recorded, a slight increase is observed only in the top positions of mountains with an altitude above 1 000 m a.s.l. In the south-west of Slovakia, the relative humidity drops to about 6%. These conditions indicate a gradual desertification of the landscape, especially in the south of the country (increase in potential evapotranspiration and decrease in soil moisture). The characteristics of solar radiation have changed only insignificantly except for a transient decrease between 1965 and 1985.

Particular attention needs to be paid to climate change and variability, especially precipitation totals and the hydrological cycle. In the period 1991 – 2020, compared to the period 1961 – 1990, there have been relatively significant changes in the number of days with atmospheric precipitation up to 60 mm, especially in the distribution during the year. In spring and summer, the number of days with precipitation up to 60 mm decreases. Significantly, different changes compared to spring and summer were demonstrated in autumn and winter, where we registered a clear increase in these days, almost in our entire territory, with the exception of the northernmost regions. In winter, however, this increase is not as pronounced as in autumn. At the same time, the number of days with precipitation above 60 mm increases during the summer period. This trend results in a higher risk of localised flooding. On the other hand, local to regional moderate to extreme drought has occurred annually since 2017, caused by long periods of relatively warm weather and low rainfall. Based on indicators of air temperature, precipitation totals, evapotranspiration, snow cover and some other elements, the last two decades (2001-2010, but especially 2011 – 2020) are close to the conditions expected, given climate change scenarios, in 2030/2040.

3.1.2. 2030 ENERGY AND CLIMATE FRAMEWORK

Since the establishment of the Slovak Republic in 1993, the arrangement of state bodies has not changed. The president - the head of state - is directly elected for a five-year term, the highest legislative body is the National Council of the Slovak Republic with 150 members elected for a four-year term, and the Government of the Slovak Republic is headed by the prime minister. The

Government of the Slovak Republic consists of 4 deputy prime ministers and 11 ministers. The arrangement and responsibilities of central government bodies are governed by Act No. 134/2020 Coll. on the organisation of government activities and the organisation of central government.

The Slovak Republic joined the European Union (EU) on 1 May 2004, and a number of environmental legislative requirements were adopted, including climate change and air protection regulations. The EU considers climate change to be one of its four priorities. On 28 November 2018, the European Commission presented its long-term Clean Planet for All strategy to achieve a prosperous, modern, competitive and climate-neutral economy by 2050. This strategy encompasses almost all EU policies and is in line with the Paris Agreement targets to keep global temperature rise below 2°C.

The Ministry of Environment of the Slovak Republic is the main body to ensure conditions fulfilment and to monitor progress of the Slovak Republic for meeting all commitments and obligations of climate change and adaptation policy.

The Ministry of Environment of the Slovak Republic (MŽP SR) is responsible for the development of national environmental policy and measures related to climate change and adaptation.

The Ministry of Environment is responsible for the development of national environmental policy and measures related to climate change and adaptation. The international legal context for climate change policy is set by the United Nations Framework Convention on Climate Change (UNFCCC) adopted in New York on 9 May 1992. On behalf of the Slovak Republic, the UNFCCC was signed on 19 May 1993. The National Council of the Slovak Republic approved the Paris Agreement by Resolution No. 215 of September 2016. The Slovak Republic deposited its instrument of ratification jointly with the EU on 5 October 2016.

The Global Air Protection Climate Change and Adaptation Department of the MŽP SR serves as the National Focal Point for the UNFCCC. Together with the Climate Change Mitigation Department, they have coordinating roles to ensure that we meet our international commitments under the UNFCCC and the Kyoto Protocol.

The implementation of the measures will require the active involvement of the relevant sectors, the interconnection and consolidation of individual sectoral and cross-cutting policies, and society-wide engagement. Consistent horizontal implementation of measures that are in harmony with the objective of achieving climate neutrality by the middle of this century and in line with this strategy is to be ensured by the Council of the Government of the Slovak Republic for the European Green Deal adopted by the Government Resolution No. 699 of 4 November 2020.

The High-Level Committee was replaced in 2021 by the Council of the Government of the SR for the European Green Deal (CG EGD), which met for the first time on 20 April 2021. The CG EGD serves as an expert, advisory, coordinating and initiating body of the Government of the Slovak Republic on matters related to the European Green Deal as a vision for achieving the Sustainable Development Goals (i.e. national priorities for the implementation of the 2030 Agenda for Sustainable Development) and the transition to a carbon-neutral economy by 2050 and the related implementation of key policies and measures towards achieving the climate and environmental goals and the continued transformation of the economic, environmental, energy and social system of the Slovak Republic, including the transformation of industry, agriculture, transport, tourism, manufacturing, non-manufacturing, consumer and social sectors.

3.1.3. INFORMATION ON INSTITUTIONAL ARRANGEMENT

3.1.3.1. Information on Institutional Arrangement for GHG Emissions and Removals

Information according to the paragraphs 61 and 62 on institutional arrangement for GHG emissions of the Slovak Republic are providing in the Chapter 1.2. of the National Inventory Document of the Slovak Republic 2024 accompanied this Report.

3.1.3.2. Information on Institutional Arrangement for GHG Emission Projections and Relevant Policies and Measures

The Ministry of Environment of the Slovak Republic (MŽP SR) is responsible for the development and implementation of national environmental policy, including climate change and air protection objectives. The MŽP SR is responsible for the development of strategies and other implementation tools, such as laws, regulatory measures, economic and market instruments, in aim to meet cost-effectively the adopted objectives. Other ministries and relevant institutions are including in review process of concept papers as well as legislative proposals. After the commenting process, the proposed acts are discussed in the Legislative Council of the Government, approved by the Government and finally by the National Council of the Slovak Republic. The MŽP SR is the main body for ensuring the conditions and monitoring the progress of the Slovak Republic in fulfilling all commitments and obligations related to climate change and adaptation policy.

The National System for the Policies and Measures and Projections (NSPMP) of Anthropogenic GHG Emissions of the Slovak Republic is based on similar institutional and expert's framework as the National Inventory System of the Slovak Republic - roster of experts and technical organisations. This is to ensure using of harmonised input data and common understanding of sector categories for preparation of projections. Description of the timescale and arrangement is based on biennial basis (based on the legal requirements of the Governance Regulation and the UNFCCC reporting decisions), and is regularly evaluated and checked. Relevant ministries (Ministry of Environment, Ministry of Finance, Ministry of Transport and Construction, Ministry of Agriculture and Regional Development, Ministry of Economy) together with their relevant expert institutions are key actors of the National System for Policies and Measures and Projections. The Expert Group for Adaptation to Adverse Impacts of Climate Change and Expert Group for Low-Carbon Strategy were created under the Coordination Committee in 2012. These groups play important role in existing institutional structure for climate change policy in Slovakia. Ministry of Environment coordinates information and inputs from relevant ministries and institutions for reporting on policies and measures to reduce greenhouse gas emissions and for preparation and reporting on GHG emissions projections.

In the preparation of the policies, the policies and measures referred to in the national strategic documents of the different departments shall be collected. It shall be monitored whether the measures are quantified and to what extent they contribute to the reduction of greenhouse gas emissions. These are then provided by sectoral experts who apply them to the projections. Sectoral policies and measures were also discussed in the framework of the six working groups set up under the Government's Council for the European Green Agreement (Working Party on Energy, Transport, Waste, Circular Economy and Industry, Agriculture including LULUCF).

The compilation of the emission projections starts with the collection of activity data. A comprehensive description of the emission projections preparation is described in methodologies for individual sectors projections. The methodologies are updated regularly within the improvement plan and recommendation list and they are archived after formal approval. The most important source of activity data is the Statistical Office of the Slovak Republic and the sectoral statistics of the relevant ministries. Preparation of the GHG emission projections is closely connected with the GHG emissions inventory preparation. In addition, air pollutant emissions inventories and projections are a part of the national system, too.

The EU's Regulation (EU) 2018/1999 on the Governance of the Energy Union and Climate Action ('Governance Regulation') establishes a governance mechanism and specific arrangements to track the progress of the Union and its Member States towards the implementation and achievement of the EU's climate and energy targets and commitments under the UNFCCC and the Paris Agreement. These arrangements include the monitoring of GHG emissions and removals, the reporting of policies and measures, projections of GHG emissions and removals and progress on adaptation to climate change.

Under the Governance Regulation, the EU has established a Union Inventory System to ensure the timeliness, transparency, accuracy, consistency, comparability and completeness of the data reported by the EU and its Member States. This inventory system includes a quality assurance and quality control programme, procedures for setting emission estimates, and comprehensive reviews of national inventory data to enable the assessment of compliance towards climate goals.

Each EU Member State compiles its GHG inventory in accordance with the requirements of the Paris Agreement and the relevant Intergovernmental Panel on Climate Change (IPCC) guidelines. Inventory data on GHG emissions and removals, including information on methods, are submitted electronically using a reporting system managed by the European Environment Agency (EEA). The submitted data are subject to quality control procedures and feed into the compilation of the GHG inventory of the EU. Net GHG emissions, calculated from emissions and removals reported in the GHG inventory of the EU, are the key information used for tracking progress towards the EU NDC target of a least -55% net emission reduction by 2030 compared to 1990.

Given the scope of the EU NDC related to international aviation and navigation, a specific share of international aviation and navigation emissions as reported in the GHG inventory data is calculated based on the Joint Research Centre's Integrated Database of the European Energy System (JRC-IDEES). Details on the methodology applied to identify GHG emissions from international aviation and navigation in the scope of the EU NDC, which are added to the national totals from the EU GHG inventory.

Under the Governance Regulation each Member State must report to the Commission biennially on the status of implementation of its integrated national energy and climate plans (NECPs). This process allows the Commission to ensure that the EU and the Member States remain on track to achieve the climate-neutrality objective and progress on adaptation. Under the Governance Regulation, Member States further operate national systems for policies and measures and projections and submit and report standardised information, which is subject to quality and completeness checks. Based on the submitted data, the EEA compiles projections of GHG emissions and removals for the EU. The EU-wide information is summarised annually in the Climate Action Progress Report by the European

Commission and in the ‘Trends and projections’ report by the EEA. Both the Union and the national systems are subject to continuous improvements.

The EU and its Member States have set up a comprehensive system for the implementation of the EU climate change mitigation targets. The European Climate Law[46] sets the goal of climate neutrality by 2050 and the intermediate target of reducing net greenhouse gas emissions by at least 55% by 2030 compared to 1990 levels. These targets cover emissions and removals that are regulated in the Union law.

To ensure that the EU and its Member States achieve their target, the 2030 Climate and Energy Framework was put in place. The main policies of this framework are the EU Emissions Trading System (EU ETS)[5], which caps GHG emissions in energy, industry, aviation and maritime transport; the LULUCF Regulation which includes national net removal targets for the LULUCF sector; and the Effort Sharing Regulation (ESR) which establishes national reduction targets for GHG emissions not covered by the EU ETS or the LULUCF Regulation i.e. domestic transport (excluding aviation), buildings, agriculture, small industry and waste. The implementation of the ESR is supported by additional sectoral policies and measures (details can be found in this BTR in the chapter on mitigation policies and measures). The legislative acts under the 2030 Climate and Energy Framework require the European Commission and the EU Member States to set up the institutional arrangements for implementing the specific policies and measures.

The revised EU ETS Directive increases the level of ambition in the existing system from 43% to 62% emissions reductions by 2030, compared to 2005 levels and extend the system to also apply to international maritime transport. A separate carbon pricing system will apply to fuel combustion in road transport and buildings and small-emitting sectors (ETS2) with a 42% emission reduction target compared to 2005 across the sectors covered. The amended Effort Sharing Regulation (ESR) increased, for the sectors that it covers, the EU-level GHG emission reduction target from 29% to 40% by 2030, compared to 2005, which translates in updated 2030 targets for each Member State. The new LULUCF Regulation sets an overall EU-level objective of 310 Mt CO_2 eq. of net removals in the LULUCF sector in 2030.

The ESR sets national targets for the reduction of GHG emissions in the Member States by 2030. Member States are also subject to gradually decreasing annual emission limits for each year from 2021 to 2030. The annual progress towards the national targets under the Effort Sharing Legislation is assessed by comparing GHG emission levels from the sectors covered by the ESR with the relevant annual emission allocations under the legislation (AEAs). To achieve compliance under the ESR, Member States are permitted to use flexibility options to a certain extent.

Progress in the implementation of these policies and measures is monitored under the Governance Regulation. Relevant information which is reported regularly and archived at the EEA include GHG inventories, approximated GHG inventories for the previous year, information on policies and

---

[5] This refers to the ETS1, i.e. the Emission Trading System for stationary sources (Chapter III of the ETS Directive) and for aviation and maritime transport (chapter II of the ETS Directive). Note that the ‘Emissions trading system for buildings, road transport and additional sectors’ (ETS2), added in 2023 as Chapter IVa of the ETS Directive, forms an instrument under the Effort Sharing Regulation (ESR).

measures, projections, and progress towards the implementation of integrated National Energy and Climate Plans (NECP). This information helps the EU and its Member States to correct their course if progress towards the targets of the 2030 Climate and Energy Framework is behind schedule. As an example, the European Commission assesses the drafts of new or updated NECPs and provides recommendations for improved planning and implementation. In addition, the reported information is subject to quality checks, and the GHG inventories reported by EU Member States are subject to comprehensive reviews in 2025, 2027 and 2032.[6]

All EU legislation, including the legislation under the 2030 Climate and Energy Framework, is subject to a stakeholder engagement process. So-called 'better regulation tools' ensure that policy is based on evidence and the best available practice. During the preparation of legislative proposals, the European Commission invites citizens, businesses and stakeholder organisations to provide their views on the subject of the new legislation. These comments are documented in a dedicated portal, and the European Commission reports on how it takes these comments into account in the development of the legislative proposals. Furthermore, the Governance Regulation sets requirements for Member States to ensure that the public is given early and effective opportunities to participate in the preparation of the NECPs.

3.1.3.3. Information on Institutional Arrangement for of the NDC in the Slovak Republic

The Ministry of Environment of the Slovak Republic (MŽP SR) is responsible for the development and implementation of national environmental policy, including climate change and air protection objectives. The MŽP SR is responsible for the development of strategies and other implementation tools, such as laws, regulatory measures, economic and market instruments, in aim to meet cost-effectively the adopted objectives. Other ministries and relevant institutions are including in review process of concept papers as well as legislative proposals. After the commenting process, the proposed acts are discussed in the Legislative Council of the Government, approved by the Government and finally by the National Council of the Slovak Republic. The MŽP SR is the main body for ensuring the conditions and monitoring the progress of the Slovak Republic in fulfilling all commitments and obligations related to climate change and adaptation policy.

The National System for the Policies and Measures and Projections (NSPMP) of Anthropogenic GHG Emissions of the Slovak Republic is based on similar institutional and expert's framework as the National Inventory System of the Slovak Republic - roster of experts and technical organisations. This is to ensure using of harmonised input data and common understanding of sector categories for preparation of projections. Description of the timescale and arrangement is based on biennial basis (based on the legal requirements of the Governance Regulation and the UNFCCC reporting decisions), and is regularly evaluated and checked. Relevant ministries (Ministry of Environment, Ministry of Finance, Ministry of Transport, Ministry of Agriculture and Regional Development, Ministry of Economy) together with their relevant expert institutions are key actors of the National System for Policies and Measures and Projections. The Expert Group for Adaptation to Adverse Impacts of Climate Change and Expert Group for Low-Carbon Strategy were created under the Coordination Committee

---

[6] Consolidated text (2023) of Regulation (EU) 2018/1999 on the Governance of the Energy Union and Climate Action, https://eur-lex.europa.eu/eli/reg/2018/1999/2023-11-20.

in 2012. These groups play important role in existing institutional structure for climate change policy in Slovakia. Ministry of Environment coordinates information and inputs from relevant ministries and institutions for reporting on policies and measures to reduce greenhouse gas emissions and for preparation and reporting on GHG emissions projections.

In the preparation of the policies, the policies and measures referred to in the national strategic documents of the different departments shall be collected. It shall be monitored whether the measures are quantified and to what extent they contribute to the reduction of greenhouse gas emissions. These are then provided by sectoral experts who apply them to the projections. Sectoral policies and measures were also discussed in the framework of the six working groups set up under the Government's Council for the European Green Agreement (Working Party on Energy, Transport, Waste, Circular Economy and Industry, Agriculture including LULUCF).

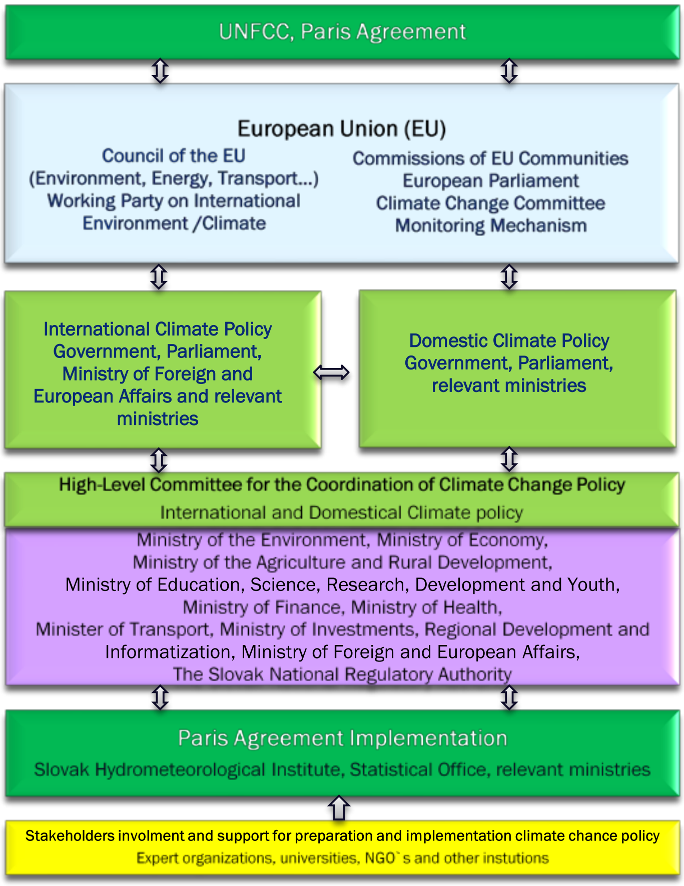
The compilation of the emission projections starts with the collection of activity data. A comprehensive description of the emission projections preparation is described in methodologies for individual sectors projections. The methodologies are updated regularly within the improvement plan and recommendation list and they are archived after formal approval. The most important source of activity data is the Statistical Office of the Slovak Republic and the sectoral statistics of the relevant ministries. Preparation of the GHG emission projections is closely connected with the GHG emissions inventory preparation. In addition, air pollutant emissions inventories and projections are a part of the national system, too.

Table 3.2: *Institutional arrangement of the NSPMS*

Institution	Roles and Responsibilities
Ministry of Environment	National Focal Point to the UNFCCC and KP Coordination and implementation of the commitments and obligations of policies, measures and projections of greenhouse gas emissions under the UNFCCC, KP and legislative requirements of the European Commission Coordination of information and inputs from relevant ministries and institutions for reporting on policies and measures to reduce greenhouse gas emissions and for preparation and reporting on GHG emissions projections
Slovak Hydrometeorological Institute – Emissions and Biofuels Department	Preparation of projections of greenhouse gas emissions based on requirements of the MŽP SR and UNFCCC, KP and the EC legislation frame Preparation of projections of emissions for basic air pollutants according to the Directive 81/2001/EC on National Emission Ceilings (NECD) and actual requirements of the Convention on Long-Range Trans boundary Air Pollution (CTRLTAP) Preparation of National Reports of the Slovak Republic on Climate Change and Biennial Report of the Slovak Republic under coordination of the MŽP SR and in accordance with the requirements of the UNFCCC and the European Commission legal instruments
Ministry of Finance	Forecasts of macroeconomic indicators for the preparation of GHG Emission projections, cooperation in the climate finance policy frame
Ministry of Economy	Strategies, policies and measures on energy efficiency, renewable energy, biofuels and innovation Objectives and choice of instruments for their implementation in the area of energy efficiency, renewable energy, biofuels and innovation
Slovak Innovation and Energy Agency	Analysis and modelling of potential measures to improve energy efficiency. Modelling the effect of a selection of measures for the household sector,

Institution	Roles and Responsibilities
	the sector of residential and public buildings Support programs and tools for achieving the objectives of increasing energy efficiency and renewable energy share on final energy consumption
Ministry of Transport	Strategies, policies and measures to reduce greenhouse gas emissions and basic pollutants from transport sector - road (passenger, freight), rail and water transport
Ministry of Transport - Construction Division	Strategies, policies and measures to reduce greenhouse gas emissions in building sector Modelling the effect of selection of mitigation measures for building sector
Ministry of Agriculture and Rural Development	Strategies, policies and measures for reducing greenhouse gas emissions from agriculture sector Strategies, policies and measures for reducing greenhouse gas emissions from, and enhancing sinks in, LULUCF (forest, cropland, grassland, wetlands, etc.)
National Forestry Centre	Cooperation in preparing projections of greenhouse gas emissions and sinks for forestry sector
National Agricultural and Food Centre	Cooperation in developing projections of greenhouse gas emissions and sinks for agriculture sector and LULUCF sector

Institutional arrangement for climate change policy and its implementation



3.2. Description of the Nationally Determined Contribution

Under their updated NDC the EU and its Member States, acting jointly, are committed to a legally binding target of a domestic reduction of net greenhouse gas emissions by at least 55% compared to 1990 by 2030. The term 'domestic' means without the use of international credits.

The NDC consists of a single-year target, and the target type is 'economy-wide absolute emission reduction'. The scope of the NDC covers the 27 Member States of the EU.

The 17 October 2023 updated NDC scope is supplemented by additional information to clarify the precise amount of international aviation and maritime emissions which are covered under the EU NDC. Details on the EU NDC can be found in ***Table 3.3*** and in the annex below.

Table 3.3: *Description of the NDC of the EU*

Information	**Description**
Target and description	Economy-wide net domestic reduction of at least 55% in greenhouse gas emissions by 2030 compared to 1990. The term 'domestic' means without the use of international credits.
Target type	Economy-wide absolute emission reduction.
Target year	2030 (single-year target)
Base year	1990
Base year value	Net greenhouse gas emissions level in 1990: 4 699 405 kt CO_2eq..
Implementation period	2021-2030
Geographical scope	EU Member States (Belgium, Bulgaria, Czechia, Denmark, Germany, Estonia, Ireland, Greece, Spain, France, Croatia, Italy, Cyprus, Latvia, Lithuania, Luxembourg, Hungary, Malta, the Netherlands, Austria, Poland, Portugal, Romania, Slovenia, Slovakia, Finland, Sweden) including EU outermost regions (Guadeloupe, French Guiana, Martinique, Mayotte, Reunion, Saint Martin (France), Canary Islands (Spain), Azores and Madeira (Portugal)).
Sectors	Sectors as contained in Annex I to decision 5/CMA.3: Energy, Industrial processes and product use, Agriculture, Land Use, Land Use Change and Forestry (LULUCF), Waste. ***International Aviation:*** Emissions from civil aviation activities as set out for 2030 in Annex I to the EU ETS Directive are included only in respect of CO_2 emissions from flights subject to effective carbon pricing through the EU ETS. With respect to the geographical scope of the NDC these comprise emissions in 2024-26 from flights between the EU Member States and departing flights to Norway, Iceland, Switzerland and the United Kingdom. ***International maritime Navigation:*** waterborne maritime navigation is included in respect of CO_2, methane (CH_4) and nitrous oxide (N_2O) emissions from maritime transport voyages between the EU Member States.
Gases	Carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), sulphur hexafluoride (SF_6), nitrogen trifluoride (NF_3)
LULUCF categories and pools	The included LULUCF categories and pools are as defined in decision 5/CMA.3.
Intention to use cooperative approaches	The EU's at least 55% net reduction target by 2030 is to be achieved through domestic measures only, without contribution from international credits. The EU will account and report for cooperation with other Parties in a manner consistent with the guidance adopted by CMA1 and any further guidance agreed by the CMA.

Information	Description
Any updates or clarifications of previously reported information, as applicable	The information on the NDC scope contains clarifications/further details compared to the information provided in the updated NDC of the EU.

Source: Updated NDC of the EU[7]

Note: This table is identical to table 'Description of a Party's nationally determined contribution under Article 4 of the Paris Agreement, including updates,' which has been submitted electronically together with this BTR. This table is also annexed to this BTR.

3.3. Indicator, Definitions, Methodologies and Progress

3.3.1. INDICATOR INCLUDING DEFINITIONS

For the tracking of progress towards implementing and achieving the NDC of the EU, an indicator issued which has the same unit and metric as the NDC base year and target values. The chosen indicators' annual total net GHG emissions consistent with the scope of the NDC in CO_2 eq. ***Table 3.4*** provides more information on this indicator.

Table 3.4: *Indicator for tracking progress*

Information	Description
Selected indicator	Annual total net GHG emissions consistent with the scope of the NDC in CO_2 eq.
Reference level and base year	The reference level is total net GHG emissions of the EU in the base year (1990). The reference level value for the EU is 4 699 405 kt CO_2 eq.
Updates	This is the first time the reference level is reported, hence there are no updates. The value of the reference level may be updated in the future due to methodological improvements to the EU GHG inventory and to the determination of international aviation and navigation emissions in the NDC scope.
Relation to the NDC	The indicator is defined in the same unit and metric as the target of the NDC. Hence it can be used directly for tracking progress in implementing and achieving the NDC target.
Definitions	Definition of the indicator 'annual total net GHG emissions in CO_2 eq.': Total net GHG emissions correspond to the annual total of emissions and removals reported in CO2 equivalents in the latest GHG inventory of the EU. The totals comprise all sectors and gases listed in the table entitled 'Reporting format for the description of a Party's nationally determined contribution under Article 4 of the Paris Agreement, including updates.' Indirect CO2 emissions are included from those Member States that report these emissions.

Source: The reference level is based on the Annual European Union GHG inventory 1990 – 2022.

Note: The information in this table is identical to the information in Common Tabular Format (CTF) tables 1 ('Description of selected indicators') and 2 ('Definitions needed to understand the NDC'), which were submitted electronically together with this BTR.

---

[7] The update of the nationally determined contribution of the European Union and its Member States, https://unfccc.int/sites/default/files/NDC/2023-10/ES-2023-10-17%20EU%20submission%20NDC%20update.pdf.

3.3.2. METHODOLOGIES AND ACCOUNTING APPROACH

The EU use the following accounting approach for tracking progress towards the joint EU NDC: annual GHG data from the national GHG inventory of the EU, complemented for international aviation and navigation with estimations from the Joint Research Centre's Integrated Database of the European Energy System[8]. The total net GHG emissions are provided in the scope of the EU NDC and are compared to the economy-wide absolute emission reduction target as defined in the NDC. The EU will account for its cooperation with other Parties in a manner consistent with guidance adopted by the CMA.

As far as emissions and removals from the LULUCF sector are concerned, net emissions are used for tracking progress towards the 2030 target of the NDC based on all reported emissions and removals.

Details on methodologies and accounting approaches consistent with the accounting guidance[9] under the Paris Agreement can be found in CTF table 3 ('Methodologies and accounting approaches'), which was submitted electronically together with this BTR.

3.3.3. STRUCTURED SUMMARY – STATUS OF PROGRESS

An important purpose of the BTR is to demonstrate where the EU and its Member States stand in implementing their NDC, and which progress they have made towards achieving it. The most recent information on GHG emissions and removals in the scope of the NDC constitutes the key information for tracking this progress. ***Table 3.5*** summarises the current status of progress.

Table 3.5: *Summary of progress towards implementing and achieving the NDC*

Indicator	Unit	Base year value	Values in the implementation period			Target level	Target year	Progress made towards the NDC
			2021	2022	2030			
Total net GHG emissions consistent with the scope of the EU NDC	kt CO_2eq.	4 699 405	3 272 650	3 205 223	NA	at least 55% below base year level	2030	The most recent level of the indicator is 31.8% below the base year level.

Source: The indicator values are based on the Annual European Union GHG inventory 1990 – 2022. NA: Not Applicable

Note that an annual emissions balance consistent with chapter III.B (Application of corresponding adjustment) will be provided in a subsequent BTR upon finalisation of relevant further guidance by the CMA, based on the annual information reported under Article 6.2.

Note: More detailed information can be found in CTF table 4 ('Structured summary: Tracking progress made in implementing and achieving the NDC under Article 4 of the Paris Agreement'), which has been submitted electronically together with this BTR.

Based on the GHG inventory data and data on international aviation and navigation for 2022, the EU and its Member States reduced net GHG emissions by 31.8% compared to 1990. The EU and its

---

[8] European Commission, Joint Research Centre, Rózsai, M., Jaxa-Rozen, M., Salvucci, R., Sikora, P., Tattini, J. and Neuwahl, F., JRC-IDEES-2021: the Integrated Database of the European Energy System – Data update and technical documentation, Publications Office of the European Union, Luxembourg, 2024, https://publications.jrc.ec.europa.eu/repository/handle/JRC137809.

[9] Decision 4/CMA.1, Further guidance in relation to the mitigation section of decision 1/CP21, https://unfccc.int/documents/193407.

Member States made progress towards implementing and achieving their NDC. The legal and institutional framework is in place to make further progress in the years ahead and to achieve the NDC target by 2030.

3.4. Mitigation Policies and Measures

The activities of the Slovak Republic on the development of policies and measures to mitigate GHG emissions have intensified since the publication of the Seventh National Climate Change Report of the Slovak Republic. Ministry of the Environment of the Slovak Republic (MŽP SR) and the Slovak Hydrometeorological Institute have taken all necessary steps to improve mechanisms for monitoring, evaluating and improving tools and measures to meet national reduction commitments under the UNFCCC. All relevant policies and measures at EU level shall be strengthened to meet the 2030 objectives of reducing net greenhouse gas emissions by at least 55% by 2030 compared to 1990 levels. Achieving these emissions reduction over the next decade is key to making Europe the world's first climate-neutral continent by 2050 and to making the European Green Deal a reality. With the proposals, the Commission is presenting the legislative tools to achieve the objectives agreed in the European climate legislation and the fundamental transformation of Slovak economy and society for a fair, green and prosperous future. As can be seen from recent GHG inventories, the Slovak Republic is on track to meet its commitments.

3.4.1. POLITICAL CONTEXT AT EU LEVEL

The European Union has committed to reducing its emissions by 55% between 1990 and 2030 (Fit for 55). Slovakia, as a member state of the European Union, is part of this commitment. Slovakia is playing its part in fulfilling the European contribution to climate change mitigation via the various mechanisms of the European Union and via substantial national arrangements, measures and targets. To achieve this target, Slovakia divides efforts between sector covered by EU ETS, LULUCF sector and sectors covered by ESR.

EU emissions trading system (ETS) sectors will have to cut emissions by 43% (compared to 2005) by 2030. This has been agreed under the Revised EU ETS Directive (2018/410).

Effort sharing sectors will need to cut emissions by 30% (compared to 2005) by 2030 – this has been translated into individual binding targets for Member States. The target for the Slovak Republic is 22.7% emissions reduction against 2005. This has been agreed under the Effort Sharing Regulation (2018/842). While the Effort Sharing Regulation does not cover the LULUCF sector as such, it does allow Member States to use up to 280 million credits from the land-use sector over the entire period 2021-2030 to comply with their national targets.

3.4.1.1. European Climate Law

The European Climate Act aims to achieve the goal set out in the European Green Deal to make Europe's economy and society climate neutral by 2050. The law also sets target to reduce net greenhouse gas emissions by at least 55% by 2030 compared to 1990. European Climate Law requires the EU and Member States to adopt adaptation strategies and sets out the rules for assessing progress towards the climate targets.

3.4.1.2. Emissions Trading System 2 (EU ETS 2)

In 2023, a new emissions trading system (ETS 2) was introduced, which also covers CO_2 emissions from road transport, buildings and small industries not covered by the existing EU ETS. The introduction of carbon pricing in those sectors will provide a market incentive for investments in building renovations and low-emission mobility. Like the existing EU ETS, ETS 2 is a ‘cap-and-trade’ emission mechanism, but it will address fuel suppliers rather than end consumers such as households or car users. Fuel suppliers will have to monitor and report emissions from fuels supplied by them and buy sufficient allowances at auctions to cover these emissions. The ETS 2 cap will be set in such a way as to bring emissions down by 42% by 2030 compared with 2005 levels. Part of the revenues will be earmarked for the Social Climate Fund (The allocation for Slovakia is expected to be € 1.5 billion).

3.4.2. POLICY CONTEXT AT NATIONAL LEVEL

The overall policy framework for addressing climate change in the Slovak Republic consists of European climate strategies and policies, which are complemented by specific national policies and measures targeting the most critical areas. Given the very different challenges faced by different sectors, the Slovak Republic and its national authorities are opting for a wide range of instruments, relying on regulation, financing schemes, tax incentives, advice and various stakeholder support measures.

3.4.2.1. National Reform Programme 2023[10]

National Reform Programme describes the reform efforts of the Government of the Slovak Republic in key structural areas. It aims to provide a comprehensive overview of the measures implemented and planned by the SR to respond to the Council of the EU's specific recommendations for Slovakia, regardless of whether these measures are implemented through EU cohesion policy, the Recovery and Resilience Plan of the Slovak Republic (RRP) or from the state budget. At EU level, the NRP is a key part of the European Semester cycle, in which it is presented to the Council of EU and the European Commission2 and plays a central role in facilitating collective monitoring and multilateral debate on policy challenges and how to address them. The NRP also serves as a tool to communicate the implementation of the 2030 Agenda for Sustainable Development and the European Pillar of Social Rights.

Affected greenhouse gases: CO_2, NO_X, SO_2, NMVOC, NH_3, $PM_{2,5}$ and CH_4
Type of measure: regulatory, economic instrument

3.4.2.2. Slovakia's Vision and Development Strategy 2030 (SLOVAKIA 2030)[11]

This long-term sustainable development strategy, approved by Government Resolution No. 41 of 20 January 2021, also fulfils the role of the National Strategy for Regional Development of the Slovak Republic. It thus integrates sectoral priorities and regional and territorial development priorities, thus linking the public administration (the Central Government Authorities) and the local government authorities (cities, municipalities, higher level territorial units). It is based on four principles: the

---

[10] https://www.mfsr.sk/files/en/finance/institute-financial-policy/strategic-documents/national-reform-program/national-reform-programme-2023.pdf

[11] https://rokovania.gov.sk/RVL/Material/25655/1

principle of sustainability, i.e. the balance between available resources and their use, the priority of quality of life over economic growth, efficiency based on synergies and the integration of policies and their instruments.

Its objectives in the field of air include:

- Reduce air emissions by 82%, NO_X by 50%, NMVOC by 32%, NH_3 by 30% and $PM_{2.5}$ by 49% by 2030 compared to 2005 by implementing adequate environmental measures across all sources of pollution (industry, energy, transport, agriculture, domestic heating) and ensuring adequate monitoring of air pollutants, supported by the establishment of new air quality monitoring stations.
- Reduce air pollution, especially from industry, energy, local heating and transport, and encourage the establishment of new air quality monitoring stations as part of the development and information of the population In terms of environmental objectives, Slovakia 2030 is to ensure the protection, restoration and enhancement of natural resources, including ensuring the stability and health of ecosystems and their services, and the reflection of adaptation and mitigation measures to the adverse effects of climate change in all departmental strategic documents and municipal and regional development documents as an overriding public interest (e.g. in transport planning, energy, spatial planning, spatial planning, water management, land management, forestry, sustainable tourism, overall care of the countryside, etc.).

Affected greenhouse gases: CO_2, NO_X, SO_2, NMVOC, NH_3, $PM_{2,5}$and CH_4
Type of measure: regulatory, economic instrument

3.4.2.3. Environmental Policy Strategy of the Slovak Republic until 2030 - Greener Slovakia (ENVIROSTRATEGY 2030)

This strategy was adopted in February 2019, defines a vision for 2030, taking into account possible, probable and desired future developments, identifies key systemic issues, sets targets for 2030, proposes framework measures to improve the current situation, and includes key outcome indicators to verify the results achieved. As part of climate change mitigation, Slovakia will reduce greenhouse gas emissions in emissions trading sectors by 43% and outside these sectors by at least 20% compared to 2005. An effective emissions trading system will continue. Adaptation measures in the regions will reflect their specificities and be sufficiently responsive to climate change.

Affected greenhouse gases: CO_2, NO_X, SO_2, NMVOC, NH_3, $PM_{2,5}$ and CH_4
Type of measure: regulatory

3.4.2.4. Low Carbon Development Strategy of the Slovak Republic until 2030 with a View to 2050 (NUS SR)[12]

This long-term strategy was approved by the Government of the Slovak Republic on 5 March 2020. The NUS SR responses to the commitments in the fight against climate change resulting from its membership in the European Union and the United Nations and the associated obligation to develop

---

[12] https://www.minzp.sk/files/oblasti/politika-zmeny-klimy/nus-sr-do-roku-2030-finalna-verzia.pdf

a long-term strategy with a scope of at least 30 years. The objective of the strategy is to identify existing and propose new additional measures within the SR to achieve climate neutrality by 2050. The primary objective of the NUS SR is to identify all measures, including additional ones that will lead to achieving climate neutrality in the Slovak Republic by 2050.

Affected greenhouse gases: CO_2, NO_X, SO_2, NMVOC, NH_3, $PM_{2,5}$and CH_4
Type of measure: regulatory

3.4.2.5. Update of the Integrated National Energy and Climate Plan National Energy and Climate Plan 2021 – 2023 (NECP) Update in Accordance with Regulation (EU) 2018/1999

The Integrated National Energy and Climate Plan and updating thereof is a broad conceptual material, which is based on existing or upcoming strategic materials of several ministries, sets the framework for the implementation of legislative and non-legislative measures aimed at climate protection and long-term sustainable energy. The main quantified targets of the NECP in the framework of the Slovak Republic by 2030 are the reduction of GHG emissions for non-ETS sectors by 222.7%. Taking into account the EC's recommendation to increase the ambition in renewable energy sources (RES), the current draft of the updated NECP foresees an objective of 25% RES in 2030. Ministry of Economy SR will take all available steps to accelerate the development of RES especially in heat production during 2021-2030 and to bring Slovakia closer to a higher share of RES in 2030. The industrial and buildings sectors will be key to achieving the objectives. Electricity interconnection is already above 50% and will remain so until 2030, so the objective of at least 50% interconnection will be met.

Affected greenhouse gases: CO_2, NO_X, SO_2, NMVOC, NH_3, $PM_{2,5}$, and CH_4
Type of measure: regulatory

3.4.2.6. National Emission Caps

The current Directive 2001/81/EC on national emission caps will be replaced from 1 July 2018 by the revised NEC Directive 2016/2284. Its main objective is to reduce the adverse health impacts of air pollution, including more than halving the number of premature deaths caused by air pollution each year. This revised Directive contains national emission reduction commitments for each Member State for the period up to 2030 (with interim objectives set for the period up to 2025) for six specific pollutants: NO_x, SO_2, NMVOC, NH_3, $PM_{2,5}$ and CH_4. The NES Directive is transposed into national legislation by Act No. 146/2023 Coll. on Air and supplemented by Act No. 190/2023 Coll. on Air Pollution Charges.

Affected greenhouse gases: CO_2, NO_X, SO_2, NMVOC, NH_3, $PM_{2,5}$, and CH_4
Type of measure: regulatory

3.4.2.7. National Emissions Reduction Programme

Directive (EU) 2016/2284 on the reduction of national emissions of certain air pollutants, amending Directive 2003/35/EC and repealing Directive 2001/81/EC sets emission reduction targets for sulphur oxides, nitrogen oxides, non-methane volatile organic compounds, ammonia and $PM_{2.5}$ by 2030. Government Resolution No. 103/2020 of 5 March 2020 approved the National Emission Reduction Programme, which proposes policies and measures to achieve the above-mentioned national commitments in two phases, for the period from 2020 to 2029 and for the period after 2030. The

National Emission Reduction Programme contributes to achieving the air quality objectives under Directive 2008/50/EC, as well as ensuring consistency with plans and programmes set out in other relevant policy areas, including climate, energy, agriculture, industry and transport. At the same time, it will encourage a shift of investment towards clean and efficient technologies.

Affected greenhouse gases: CO_2, NO_X, SO_2, NMVOC, NH_3, $PM_{2,5}$, and CH_4
Type of measure: regulatory

3.4.2.8. Biofuels Policy

Directive (EU) 2018/2001 of the European Parliament and of the Council on the promotion of the use of energy from renewable sources (recast) was adopted on 11 December 2018 and the authority responsible for its implementation is the Ministry of Economy of the Slovak Republic. The MŽP SR is responsible for the implementation of the sustainability criteria for biofuels and bioliquids, for calculations to determine the impact of biofuels and bioliquids on greenhouse gas emissions and for the calculation of greenhouse gas emissions released during the life cycle of fossil fuels pursuant to Article 7a of Directive 2009/30/EC and Council Directive (EU) 2015/652 of 20 April 2015 laying down calculation methodologies and reporting requirements pursuant to Directive 98/70/EC of the European Parliament and of the Council relating to the quality of petrol and diesel fuels.

In relation to the sustainability criteria, the Slovak Republic has implemented specific Articles of the Directive (EU) 2018/2001 and Articles 7a to 7d of Directive 2009/30/EC, Directive 2015/652 and the relevant articles of Directive 2015/1513 through Act No. 309/2009 Coll. on the Promotion of Renewable Energy Sources and High Efficiency Combined Generation, as amended, and Decree No. 271/2011 Coll. of the MŽP SR, establishing sustainability criteria and objectives for the reduction of greenhouse gas emissions from fuels, as amended.

This Act addresses, among other things, the basic roles and responsibilities of competent authorities and economic operators in a context that demonstrates the fulfilment of sustainability criteria for biofuels and bioliquids, which are prerequisites for meeting the national greenhouse gas emission reduction target as well as the objectives for renewable energy sources.

Decree of the MŽP SR No. 271/2011 Coll., as amended, has been in force since September 2011. This Decree contains the details of demonstrating compliance with the sustainability criteria for biofuels and bioliquids.

For assessing compliance with sustainability criteria along the biofuel production chain and bioliquids, voluntary schemes were established. These schemes are subject to the approval of the European Commission and are not therefore subject to national approval and national control, and each Member State must accept the results of these schemes unconditionally.

Decree of the Ministry of Agriculture and Rural Development No. 397/2023 Coll., which lays down a detailed declaration of the producer and supplier of biomass for the production of biofuels or bioliquids, has been in force since October 2023 and replaced the Decree No. 295/2011 Coll. The Slovak Republic has had a national system for demonstrating compliance with the sustainability criteria for biofuels and bioliquids in operation since 2011. This system is based on independent verifiers whose training is organised and who are subject to mandatory examination and registration by the MŽP SR.

Directive (EU) 2023/2413 of the European Parliament and of the Council of 18 October 2023 amending Directive (EU) 2018/2001, Regulation (EU) 2018/1999 and Directive 98/70/EC as regards the promotion of energy from renewable sources, and repealing Council Directive (EU) 2015/652 has a transposition deadline in 2025, therefore the Ministry of Economy of the Slovak Republic has recently started the process of its transposition. The MŽP SR will closely cooperate in field of the sustainability criteria. This will result in the amendment of the Act No. 309/2009 Coll., as well as the Decree of the MŽP SR No. 271/2011 Coll.

A priority for RES in the transport sector is the development of biofuels with high GHG savings. These are advanced biofuels (a term defined in the RES Promotion Act, also referred to as 2nd generation biofuels) from feedstock listed in Part A of Annex IX of the Directive (EU) 2018/2001 and renewable fuels of non-biological origin of the RES Directive. At the same time, given the existing capacity to produce biofuels from food and feed crops, this policy will maintain the maximum possible share of these biofuels that will count towards the transport targets.

Affected greenhouse gases: CO_2, CH_4 and N_2O
Type of measure: regulatory

3.4.2.9. Taxation of Energy Products and Electricity

The most significant in terms of tax revenue generation is the mineral oil tax. Revenues from electricity, coal and natural gas are relatively low. The Slovak Republic generates relatively little revenue from environmental taxes (excluding fuel tax) and the implicit tax rate on energy is low. There is considerable scope for environmental tax reforms. The largest share of total energy use and CO_2 emissions in the Slovak Republic is accounted for by heating and energy use in industrial processes.

As part of the Fit for 55 package, a draft directive on energy taxation has been published. Energy taxation can help realise the ambition of a net reduction in greenhouse gas emissions of at least 55% by 2030 compared to 1990, as well as the goal of zero pollution through the application of the 'polluter pays' principle, by ensuring that the taxation of motor fuels, heating fuels and electricity better reflects their environmental and health impacts. Such a taxation approach has a direct role to play in supporting the green transformation by sending the right price signals and providing the right incentives for sustainable consumption and production.

The Energy Taxation Directive can contribute to the more ambitious objective of reducing greenhouse gas emissions by at least 55% by 2030 by ensuring that the taxation of motor and heating fuels better reflects their environmental and health impacts. This can be achieved by removing disadvantages for clean technologies and introducing higher levels of taxation for inefficient and polluting fuels, together with carbon pricing through emissions trading.

Affected greenhouse gases: CO_2, CH_4 and N_2O
Type of measure: regulatory

3.4.3. SECTORAL POLICIES AND MEASURES: ENERGY AND IPPU SECTOR

Although the EU ETS Directive has been in force since 2005 and is now in its fourth phase (2021 – 2030), the ESR Regulation has been in force since 2013 – 2020, with a base year of 2005 (the year from which emission reductions under the ESR are calculated). Another difference between the two systems is the application of their obligations. While the EU ETS does not contain country-specific commitments, but annual trajectories of emission cap reductions, under the ESR the commitment is valid at the country level. Emissions under both schemes are subject to annual international verifications.

The change of the fuel mix based in the current combined heat and power plants (CHP), as main heat producers for the district heating system, is applied in the WEM and WAM scenarios. In some CHP facilities, the so-called fuel blend is available without new technology investments. This applies especially to producers with a fluid boiler, which is capable of co-combustion of biomass together with natural gas or solid fuels such as hard coal and lignite. Both scenarios also include fuel switch, where there is a complete change of the fuel mix to another. This applies to CHP facilities with combustion of solid fuels. These are the largest producers of district heat included in the EU-ETS. The most important facilities included in the emissions trading system have a planned fuel mix change in the cities of Košice, Martin, Zvolen, Žilina and Žiar nad Hronom. These cities are geographically situated differently and therefore the availability of biomass is also different. In some cases, it is currently not possible to phase out natural gas as the primary fuel for heat production for the district heating system of buildings. This mainly concerns the two largest cities in Slovakia, Bratislava and Košice and other regional cities where biomass is not available in the req.uired extent. Natural gas is also used for combustion stabilization. As a result of one of the measure in LULUCF category, the domestic availability of biomass is limited in both scenarios and that is the reason why the decline of natural gas consumption is not so significant. Use of alternative fuels (TAP) in heat production facilities are also expected to a greater extent. In the future, the implementation of a geothermal energy use in the city of Košice is planned. However, the current WAM scenario still provides insufficient technical data for modelling.

As a part of reducing dependence on fossil fuels, a project to use waste heat from a nearby municipal solid waste incinerator has begun to be prepared in the capital city. Example of Measure Selection in the Model are followed:

3.4.3.1. Decarbonisation Combined Heat and Power Plant Žilina

Coal replacement. The boiler for burning biomass and TAP will be connected to the existing distribution lines of the main production block of the MHTH plant Žilina. By building a boiler for burning TAP, the dependence of the heat source on fossil fuel will be reduced, the consumption of natural resources will be reduced, and the fuel base will be diversified.

Affected greenhouse gases: CH_4, N_2O, CO_2

Type of measure: regulatory and economic instrument

State: planned for 2025

Implemented in the scenario: WEM, WAM

Potential reduction of GHG: Average reduction for period 2025 – 2050 amount: 89 kt of CO_2.

3.4.3.2. Decarbonisation Combined Heat and Power Plant Zvolen

Substitution of coal combustion for natural gas and biomass. Changing the fuel base - excluding coal from the fuel mix. Construction of the basic source of heat production - wood chip steam boilers with an output of 2x20.0 MWt and an additional source of heat production - hot water gas boilers with an output of 3x12.5 MWt.

Affected greenhouse gases: CH_4, N_2O, CO_2

Type of measure: regulatory

State: planned for 2025

Implemented in the scenario: WEM, WAM

Potential reduction of GHG: Average reduction for period 2025 – 2050 amount: 40 kt of CO_2.

3.4.3.3. Decarbonisation Combined Heat and Power Plant Martin

Substitution of coal combustion for natural gas and other alternative fuels. Termination of coal operation in the power plant.

Affected greenhouse gases: CH_4, N_2O, CO_2

Type of measure: regulatory

State: planned for 2025

Implemented in the scenario: WEM, WAM

Potential reduction of GHG: Average reduction for period 2025 – 2050 amount: 90 kt of CO_2.

3.4.3.4. Decarbonisation Combined Heat and Power Plant Strážske

Energy recovery of biomass by highly efficient production of heat and electricity. The subject of the investment - construction "Energy utilization of biomass through highly efficient production of heat and electricity" in Strážské is the modernization of the existing heating plant TP 2 in Strážské, which burns fossil fuels, for energy equipment - biomass heating plant - Bioenergy. For highly efficient combined production of heat and electricity in heat and power production.

Affected greenhouse gases: CH_4, N_2O, CO_2

Type of measure: regulatory

State: planned for 2025

Implemented in the scenario: WEM, WAM

Potential reduction of GHG: Average reduction for period 2025 – 2050 amount: 4.6 kt of CO_2.

3.4.3.5. Decarbonisation Combined Heat and Power Plant Košice

Substitution of coal combustion for natural gas and biomass. Denitrification of the PK4n boiler, modification of the black coal boiler so that it can operate 100% on natural gas and the possibility of a higher % utilization of the incinerator and biomass.

Affected greenhouse gases: CH_4, N_2O, CO_2

Type of measure: regulatory

State: planned for 2025

Implemented in the scenario: WEM, WAM

Potential reduction of GHG: Average reduction for period 2025 – 2050 amount: 157 kt of CO_2.

3.4.3.6. Decarbonisation Combined Heat and Power Plant Žiar nad Hronom

Construction of a device for cleaning bio-gas from gasifiers and subsequent combustion in a new source with the possibility of gasification of sorted waste (TAP). Greening of resources - construction of new gasifiers, alternatively reconstruction of gasifiers for burning bio-gas.

Affected greenhouse gases: CH_4, N_2O, CO_2

Type of measure: regulatory

State: planned for 2025

Implemented in the scenario: WEM, WAM

Potential reduction of GHG: Average reduction for period 2025 – 2050 amount: 134 kt of CO_2.

3.4.3.7. Decommissioning - Vojany Thermal Power Plant

Decommissioning of the Vojany coal-fired power plant. Termination of electricity production.

Affected greenhouse gases: CH_4, N_2O, CO_2

Type of measure: economic instrument, fiscal

State: implemented in 2024

Implemented in the scenario: WEM, WAM

Potential reduction of GHG: Average reduction for period 2025 – 2050 amount: 600 kt of CO_2.

3.4.3.8. Decommissioning - Nováky Thermal Power Plant

Decommissioning of the Nováky coal-fired power plant. Termination of electricity and heat production.

Affected greenhouse gases: CH_4, N_2O, CO_2

Type of measure: regulatory

State: adopted in 2023

Implemented in the scenario: WEM, WAM

Potential reduction of GHG: Average reduction for period 2025 – 2050 amount: 850 kt of CO_2.

3.4.3.9. Decarbonizing - Lime Rotary Furnace

Decarbonisation of lime production in a rotary lime kiln. Decarbonisation of lime production in a rotary lime kiln. Replacement of fossil fuel - natural gas - with biogas produced by biomass gasification.

Affected greenhouse gases: CH_4, N_2O, CO_2

Type of measure: fiscal

State: planned for 2025

Implemented in the scenario: WEM, WAM

Potential reduction of GHG: Average reduction for period 2025 – 2050 amount: 850 kt of CO_2.

3.4.3.10. Decarbonizing - Effort Sharing Regulation – Energy Savings

Change of fuel base in manufacture energy industry combustion. Energy Savings - GWh saved over GWh consumed (%) taken from PRIMES model. Transition from solid fossil fuels to natural gas, biomass and hydrogen:

Energy Savings - GWh saved over GWh consumed (%) from 2.1 to 11 – Food processing.

Energy Savings - GWh saved over GWh consumed (%) from 2.5 to 20 – Iron and steel.

Energy Savings - GWh saved over GWh consumed (%) from 0.9 to 4.7 – Non-Ferrous.

Energy Savings - GWh saved over GWh consumed (%) from 1.6 to 13 – Chemicals.

Energy Savings - GWh saved over GWh consumed (%) from 3.17 to 23 – Mineral production.

Energy Savings - GWh saved over GWh consumed (%) from 2.1 to 12 – Pulp paper print.

Affected greenhouse gases: CH_4, N_2O, CO_2

Type of measure: regulatory, economic instrument

State: planned for 2025

Implemented in the scenario: WEM, WAM

Potential reduction of GHG: Average reduction in (WAM) 2025 – 2050 amount: 533 kt of CO_2. Average reduction in (WEM) 2025 – 2050 amount: 430 kt of CO_2.

3.4.3.11. Decarbonizing - Cement Production

Change of fuel base in manufacture industries combustion. Substitute Petrol coke, Refinery waste, Old tires and natural gas by alternative fuels (gas) to increase TSR from 10% to 75%. New technology will allow to co-incinerate alternative fuels (gas) and thus reduce fossil fuel consumption (coal and natural gas). The objective of the proposed investment is to procure a technological line for sorting and crushing waste - production of solid alternative fuels (SRF). The aim is to sort the energy-valuable fraction that will be used as a substitute for fossil fuels (in the form of alternative fuels) in the cement plant.

Affected greenhouse gases: CH_4, N_2O, CO_2

Type of measure: regulatory, economic instrument

State: planned for 2025

Implemented in the scenario: WEM, WAM

Potential reduction of GHG: Average reduction for period 2025 – 2050 amount: 700 kt of CO_2.

3.4.3.12. Decarbonizing - Households – Building Insulation

Improving of energy efficiency in building sector – Effort sharing regulation. Reducing energy demand of existing buildings to nearly zero energy levels by significantly improving their energy performance and decarbonising fuel supplies. Increasing of hydrogen consumption in (WAM) and Biomass (WEM and WAM).

Affected greenhouse gases: CH_4, N_2O, CO_2

Type of measure: economic instrument

State: planned for 2025

Implemented in the scenario: WEM, WAM

Potential reduction of GHG: Average reduction for (WEM) 2025 – 2050 amount: 121 kt of CO_2. Average reduction for (WAM) 2025 – 2050 amount: 310 kt of CO_2.

3.4.3.13. Decommissioning the Coking Battery

The shutdown of coke production by processing coking coal is planned as part of decarbonisation for 2026.

Affected greenhouse gases: CO_2

Type of measure: economic instrument

State: planned for 2026

Implemented in the scenario: WAM

Potential reduction of GHG: Average reduction for 2026 – 2050 amount: 1 880 kt of CO_2.

3.4.3.14. Decarbonizing – Agglomerate Production

The production of agglomerate, which is used to convert iron into steel and is a key component in the process of iron and steel production after 2026, will be replaced by other materials and partially replaced by imports from outside the Slovak Republic

Affected greenhouse gases: CO_2

Type of measure: economic instrument

State: planned for 2026

Implemented in the scenario: WAM

Potential reduction of GHG: Average reduction for 2026 – 2050 amount: 442 kt of CO_2.

3.4.3.15. Decarbonizing - Electric Arc Furnace

USSK is currently an integrated metallurgical plant producing steel using coal, agglomerate, blast furnaces and a steel mill. Current technology no longer allows substantial reductions in CO_2 emissions. In order to meet the reduction targets of the EU by 2050, new steel production technology is needed. The European steel industry is oriented towards the production of steel using electricity in melting furnaces. The electric arc furnace is currently a green technology capable of radically reducing CO_2 emissions. The electric arc furnace will enable the achievement of the set reduction goals.

Information on how this measure modifies longer-term trends in GHG emissions and removals Decommissioning of VKB 1, sintering belts 1.2, blast furnaces 1.2 - reduced CO_2 calculated from the production of these aggregates for 2022. The calculation also includes the increase of CO_2 at VP3 and CO_2 from EAF.

Affected greenhouse gases: CO_2

Type of measure: economic instrument

State: planned for 2027

Implemented in the scenario: WAM

Potential reduction of GHG: Average reduction for 2026 – 2050 amount: 1 300 kt of CO_2.

3.4.3.16. Decarbonizing - Finalization Process

A project focused on minimizing CO_2 emissions through more efficient processes and reducing fuel consumption. By reducing the consumption of metallurgical gases after the modernization of HF 1,2 and transferring the saved gases to other operations, the production of CO_2 with Natural gas and coal will be reduced as a result.

Affected greenhouse gases: CO_2, $CH_{4,}$ N_2O

Type of measure: economic instrument

State: planned for 2026

Implemented in the scenario: WAM

Potential reduction of GHG: Average reduction for 2026 – 2050 amount: 67 kt of CO_2.

3.4.3.17. Decarbonizing - ESP

The endless belt production technology is a breakthrough technology in modern steelmaking. The project eliminates the entire Hot Rolling Mill with associated operation (note: liquid steel is poured directly into the strips without the need for the production of gates, their heating rolling).

Information on how this measure modifies longer-term trends in GHG emissions and removals Shutdown of two NP, CO_2 calculated from natural gas consumption - relatively individual gases: BFG: Blast furnace gas, COG: Coke oven gas and NG- Natural gas.

Affected greenhouse gases: CO_2

Type of measure: regulatory, economic instrument

State: planned for 2027

Implemented in the scenario: WAM

Potential reduction of GHG: Average reduction for period 2026 – 2050 amount: 240 kt of CO_2.

3.4.3.18. Decarbonizing - Natural Gas Injection

The project is aimed at installing technology for injecting natural gas into blast furnaces through blowing melds and thereby reducing CO_2 emissions. Injection of natural gas at a rate of 25 kg per ton of liquid iron replaces 30 kg of coke per ton of liquid iron. Natural gas and its use in combination with pulverized coal blowing will increase the efficiency of blast furnace melting technology.

Affected greenhouse gases: CO_2

Type of measure: regulatory

State: planned for 2027

Implemented in the scenario: WAM

Potential reduction of GHG: Average reduction for period 2026 – 2050 amount: 138 kt of CO_2.

3.4.3.19. Decarbonizing - Electricity and Heat Production

Current energy production technology emits a significant amount of emissions during the production of electricity and steam. The purpose of the project is the installation of a high-efficiency combined cycle (cogeneration) technology using metallurgical gases for the production of electricity and steam, thereby reducing CO_2 emissions (compensation for burning thermal coal).

Affected greenhouse gases: CO_2

Type of measure: regulatory

State: planned for 2027

Implemented in the scenario: WAM

Potential reduction of GHG: Average reduction for 2026 – 2050 amount: 750 kt of CO_2.

3.4.3.20. Decarbonizing - Non-Metallic Minerals

Substitution of traditional raw materials (limestone, clay sand) as alternative sources. These are materials with a higher calcium oxide (CaO) content as a potential substitute for limestone; a higher content of Al-Fe-Si oxides as a substitute for the clay; materials containing SiO2 - substitution of sand. Raw material mixture with the share of alternative materials is characterized by lower burn ability - lower energy intensity for firing, at the same time saving natural resources of traditional materials and reducing the production of emissions, including CO_2 emissions, which in the cement industry are the result of thermal decomposition of limestone:

CaCO3 (s) = CaO (s) + CO_2 (g). Reducing the consumption of the raw material mixture represents a saving of about 300 000 t of limestone per year by replacing it with about 700 000 t of alternative materials.

Affected greenhouse gases: CO_2

Type of measure: economic instrument

State: planned for 2025

Implemented in the scenario: WAM

Potential reduction of GHG: Average reduction for period 2025 – 2050 amount: 140 kt of CO_2.

3.4.4. SECTORAL POLICIES AND MEASURES: TRANSPORT

The “Fit for 55” package represents the European Commission's legislative action to achieve the economy-wide target of reducing greenhouse gas emissions by at least 55% below 1990 levels by 2030. One measure to contribute to this target should be the implementation by individual Member States of Regulation (EU) 2023/839 which revises Regulation (EU) 2018/841.

3.4.4.1. Setting Stricter Requirements for Regular Technical Inspections

Stricter technical controls combined with new taxes on internal combustion engine vehicles may encourage drivers to buy low-emission vehicles. Roadside checks to measure emissions are a complementary measure to technical vehicle checks to ensure that vehicles are in a safe and environmentally friendly condition. To carry out more frequent checks, vehicle testing equipment needs to be purchased. Roadside technical inspections should focus in particular on detecting vehicles on which diesel particulate filters (DPFs) have been removed or rendered inoperable. The analysis of the measure assumes that DPFs will be removed mainly in EURO 5 and 6 vehicles with a share of 15-20% of vehicles. The measure could have a significant preventive effect and the non-compliance rate could decrease by up to 20%. This measure may help to control of tampered control module in heavy-duty vehicles.

Affected greenhouse gases: CO_2, CH_4, N_2O

Type of measure: regulatory

State: planned for 2024

Implemented in the scenario: WAM

3.4.4.2. Support for the Use of Low-Emission Vehicles

The aim of the increased representation of electric vehicles in the transport system is the transition to low-emission forms of transport, which is a trend strategically defined at the level of the European Commission and it is part of low carbon economy. Road transport is currently dominant polluter, especially in urban areas. For the development of electromobility, it is necessary to ensure the continuity of direct support for purchasing electric vehicles by creating a new support project. The measure proposes to build on previous support projects and consider expanding the range of supports. New support projects, prepared by the Ministry of Economy, has the opportunity to capture a new generation of vehicles and use its potential. Foreign experience shows the success of the implementation of similar measures, support from the state is the key process in market creation for alternative fuel vehicles.

Affected greenhouse gases: CO_2

Type of measure: economic instrument

State: planned for 2024

Implemented in the scenario: WAM

3.4.4.3. Promotion of Biofuels

Continued increase in the share of biofuels and renewable gases (especially advanced) in transport in accordance with RED III as well as Act 309/2009 Coll. on the Promotion of Renewable Energy Sources and High Efficiency Combined Heat and Power Generation as amended

Affected greenhouse gases: CO_2

Type of measure: economic instrument

State: implemented in 2007

Implemented in the scenario: WEM

3.4.4.4. Low Emission Zones in Cities

Low emission zones are one of the partial solutions for improving air quality in Slovakia. These are geographically defined areas. There is limited entry of cars to this area based on the emission standards, i.e. emissions directly emitted by cars. Their goal is to improve air quality in cities. Low emission zones and their creation in agglomerations in Slovakia will contribute to the improvement of poor air quality, and at the same time the reduction of traffic in cities will have a positive impact on the quality of life of the inhabitants.

Affected greenhouse gases: CO_2

Type of measure: regulatory

State: planned for 2024

Implemented in the scenario: WAM

3.4.4.5. Impact of European Legislation - EURO 7

Euro 7 (Regulation (EU) 2024/1257 of the European Parliament and of the Council of 24 April 2024) replaces and unifies the previously separate emission rules for cars and vans (Euro 6) and trucks and buses (Euro VI). However, the rules under the new standard will already apply to all these vehicles (cars, vans and trucks and buses) sold in the EU.

In addition, the new rules are fuel and technology neutral. This means that the same emission limits apply to all vehicles within the same category, regardless of the technology (e.g. conventional combustion engine, hybrid or plug-in hybrid) or the fuel used (petrol, diesel, etc.). They also apply to vehicles with zero CO_2 emissions (electric or fuel cell cars).

Affected greenhouse gases: CO_2, CO, NOx, $PM_{2.5}$, PM_{10}

Type of measure: regulatory

State: planned for 2025

Implemented in the scenario: WAM

3.4.4.6. Passenger Modal Shift

Modal shift in passenger transport implies a shift of passengers from passenger vehicle transport to public passenger transport (PPT). As a result, the occupancy rate of passenger vehicles is expected to increase by 50% compared to 2020, reducing in particular the number of kilometres travelled by passenger vehicles up to 33% by 2050. The transfer of passengers to the PPT will go in two directions at the same time: road PPT and rail PPT. In the case of the rail PPT, it is expected that there will be an improvement in the quality of transport as well as the restoration of a number of railway connections. The prerequisite for this is the approved new Transport Service Plan for railways passenger transport. In the case of bus services, it is expected that there will be a slight increase in kilometres travelled. This effect on public bus services was reflected in a 10% increase in average annual mileage.

Affected greenhouse gases: CO_2

Type of measure: economic instrument

State: planned for 2024

Implemented in the scenario: WAM

3.4.4.7. Freight Modal Shift

According to the Strategic Transport Development Plan of the Slovak Republic up to 2030, the road freight transport performance has recorded marked growth since 2000, while the significance of transport modes suitable for the transport of large freight volumes without excessively burdening the infrastructure and the environment is decreasing. The aim of this measure is to support for the development and use of rail transport.

Affected greenhouse gases: CO_2

Type of measure: regulatory, economic instrument

State: planned for 2024

Implemented in the scenario: WAM

3.4.4.8. Impact of European Legislation - Regulation (EU) 2019/631 of the European Parliament and of the Council of 17 April 2019 Setting CO_2 Emission Performance Standards for New Passenger Cars and Light Commercial Vehicles

Increase cars efficiency and to decrease the GHG emissions production from cars, vans. Effect of European legislative - regulation (EU) 2019/631 of the European Parliament and of the Council which sets CO_2 emission performance standards for new passenger cars and for new light commercial vehicles. The regulation set a fleet-wide target of 95 g CO_2/km from the 1st of January 2020 for new passenger cars, and 147 g CO_2/km for the average emissions of new light commercial vehicles.

Affected greenhouse gases: CO_2

Type of measure: regulatory

State: implemented in 2021

Implemented in the scenario: WEM, WAM

3.4.4.9. Impact of European Legislation - Regulation (EU) 2023/851 of the European Parliament and of the Council of 19 April 2023 Amending Regulation (EU) 2019/631 as Regards Strengthening the CO_2 Emission Performance Standards for New Passenger Cars and New Light Commercial Vehicles

Increase cars efficiency and to decrease the GHG emissions production from cars, vans. Effect of European legislative - regulation (EU) 2023/831 of the European Parliament and of the Council which sets strengthening CO_2 emission performance standards for new passenger cars and for new light commercial vehicles. It also schedules the following targets:

- 2025: -15% reduction of the target in 2021
- 2030: -55% reduction of the target in 2021 (target for LCV: -50%)
- 2035: -100% reduction of the target in 2021

Affected greenhouse gases: CO_2

Type of measure: regulatory

State: planned for 2025

Implemented in the scenario: WAM

3.4.4.10. Impact of European Legislation - Regulation (EU) 2024/1610 of the European Parliament and of the Council of 14 May 2024 Amending Regulation (EU) 2019/1242 as Regards Strengthening the CO_2 Emission Performance Standards for New Heavy-Duty Vehicles and Integrating Reporting Obligations, Amending Regulation (EU) 2018/858 and Repealing Regulation (EU) 2018/956

Increase cars efficiency and to decrease the GHG emissions production from heavy-duty vehicles. Effect of European legislative - regulation (EU) 2024/1610 of the European Parliament and of the Council which sets strengthening CO_2 emission performance standards for new heavy-duty vehicles. It also schedules the following targets:

-43% for all vehicle sub-groups for the reporting periods of the years 2030 to 2034;

-64% for all vehicle sub-groups for the reporting periods of the years 2035 to 2039;

-90% for all vehicle sub-groups for the reporting periods of the year 2040 onwards; -100% for urban buses for reporting periods of the year 2040 onwards.

Affected greenhouse gases: CO_2

Type of measure: regulatory

State: planned for 2025

Implemented in the scenario: WAM

3.4.5. SECTORAL POLICIES AND MEASURES: AGRICULTURE

The comprehensive list of measures in the agricultural sector was designed on the basis of the available literature and included measures applicable to both crop and livestock production. In the livestock sector production, the measures were further subdivided by animal species into categories: dairy cattle, non-dairy cattle, sheep, poultry and pigs.

3.4.5.1. Detailed Description of Measure - Improved Animal Longevity

Lengthening the life of cattle and sheep can be achieved by decreasing animal mortality and delaying culling date. Decreasing mortality can be achieved via health- and well-being related measures such as ensuring sufficient bunk space, stalls and bed quality, heat abatement strategies, hygiene, etc. Doing so can lead to higher productivity by increasing the number of calves/lambs (and associated higher production of milk in the case of dairy cows and sheep), hence increasing profitability per animal.

Affected greenhouse gases: CH_4, N_2O

Type of measure: regulatory

State: planned for 2035

Implemented in the scenario: WAM

Potential reduction of GHG:

Dairy cattle:

- Average reduction per animal: 178.29 kg CO_2 eq./year
- Total: 22.44 kt CO_2 eq./year

Non-dairy cattle:

- Average reduction per animal: 42.60 kg CO_2 eq./year
- Total: 13.05 kt CO_2 eq./year

Sheep:

- Average reduction per animal: 0.65 kg CO_2 eq./year
- Total: 0.21 kt CO_2 eq./year

Costs/revenues (-): Dairy cattle: -755.20 € per animal, per year, Non-dairy cattle: -113.28 € per animal, per year, Sheep: -0.96 € per animal, per year.

Cost effectiveness: Dairy cattle: -3 388.66 per tonne of CO_2 eq. per year; Non-dairy cattle: -2 127.55 € per tonne of CO_2 eq. per year; Sheep: -892.43 € per tonne of CO_2 eq. per year.

3.4.5.2. Detailed Description of Measure - Daily Removal of Manure from Animal Housing Systems

This measure focuses on removing manure from animal housing systems daily, and is applicable to cattle, poultry and swine. Daily removal of manure decreases GHG emissions as it reduces its exposure to aerobic conditions. Subsequently, manure can be used in anaerobic digestion or can be stored and later applied to soil as organic fertiliser.

Affected greenhouse gases: CH_4, N_2O

Type of measure: regulatory

State: implemented in 2024

Implemented in the scenario: WEM, WAM

Potential reduction of GHG:

Cattle:

- Average reduction (estimate from SK expert): 89.14 kg CO_2 eq./animal/year
- Per dairy cattle (estimate from literature): 210.67 kg CO_2 eq./year
- Per non-dairy cattle (estimate from literature): 66.92 kg CO_2 eq./year
- Total: 11.22 kt CO_2 eq./year

Poultry:

- Average reduction (estimate from SK expert): 0.03 kg CO_2 eq./animal/year

- Per animal (estimate from literature): 0.13 kg CO_2 eq./year
- Total: 0.31 kt CO_2 eq./year

Swine:

- Average reduction (estimate from SK expert): 3.63 kg CO_2 eq./animal/year
- Per animal (estimate from literature): 44.94 kg CO_2 eq./year
- Total: 1.95 kt CO_2 eq./year

Costs/revenues (-): Cattle: 10.64 € per animal per year; Poultry: 0.0002 € per animal per year; Swine: 0.27 € per animal per year.

Cost effectiveness: Cattle: 95.51 € per tonne of CO_2 eq. per year; Poultry: 7.62€ per tonne of CO_2 eq. per year; Swine: 58.64 € per tonne of CO_2 eq. per year.

3.4.5.3. Detailed Description of Measure - Anaerobic Digestion

This measure entails the anaerobic digestion of manure from cattle, poultry and swine. Anaerobic digestion consists in the biochemical conversion of organic matter in the absence of molecular oxygen that involves microorganisms. Biogas is produced when this process occurs in a sealed tank, which can be used for electricity generation, heat and/or vehicle fuel. Another by-product of this process is digestate, a nutrient-rich substance that can substitute inorganic fertilisers. Anaerobic digestion considerably reduces CH_4 emissions from stored manure, and also reduces N_2O emissions from livestock slurries.

Feed-in tariffs (FIT) are an example of a successful policy tool to incentivise anaerobic digestion. FITs require electric utilities to purchase – and in some cases pay a premium price for - electricity generated via anaerobic digestion that is supplied to the grid, therefore ensuring revenue generation to the producers. FIT programs.

Affected greenhouse gases: CH_4, N_2O

Type of measure: regulatory

State: implemented in 2024

Implemented in the scenario: WEM, WAM

Potential reduction of GHG:

Dairy cattle:

- Average reduction (estimate from SK expert): 27.86 kg CO_2 eq./animal/year
- Per animal (estimate from literature): 114.32 kg CO_2 eq./year
- Total: 3.51 kt CO_2 eq./year

Non-dairy cattle:

- Average reduction (estimate from SK expert): 8.87 kg CO_2 eq./animal/year
- Per animal (estimate from literature): 36.44 kg CO_2 eq./year

- Total: 2.72 kt CO_2 eq./year

Poultry:

- Average reduction per animal: 0.04 kg CO_2 eq./year
- Total: 0.51 kt CO_2 eq./year

Swine:

- Average reduction (estimate from SK expert): 3.63 kg CO_2 eq./animal/year
- Per animal (estimate from literature): 9.67 kg CO_2 eq./year
- Total: 1.95 kt CO_2 eq./year

Costs/revenues (-): Dairy cattle: 10.61 € per animal, per year; Non-dairy cattle: 5.07 € per animal per year; Poultry: 0.003 € per animal per year; Swine: 0.26 € per animal per year.

Cost effectiveness: All: 57.13 € per tonne of CO_2 eq. per year.

3.4.5.4. Detailed Description of Measure - Improved Beef Live Weight Gains

This measure aims to increase productivity via genetic improvements, with a specific focus on improving beef live weight gains.

Affected greenhouse gases: N_2O

Type of measure: regulatory

State: implemented in 2024

Implemented in the scenario: WEM, WAM

Potential reduction of GHG:

- Average reduction per animal: 70.99 kg CO_2 eq./year
- Total: 21.75 kt CO_2 eq./year

Costs/revenues (-): -18.40 € per animal per year.

Cost effectiveness: -207.37 € per tonne of CO_2 eq. per year.

3.4.5.5. Detailed Description of Measure - Low Protein Diet for Poultry

Amending poultry diets by switching to feed with a lower protein content (e.g., reducing soybean content while increasing maize content) reduces the N_2O emissions from poultry manure.

Affected greenhouse gases: N_2O

Type of measure: regulatory

State: implemented in 2024

Implemented in the scenario: WEM, WAM

Potential reduction of GHG:

- Average reduction per animal: 70.99 kg CO_2 eq./year

- Total: 21.75 kt CO_2 eq./year

Costs/revenues (-): 0.03 € per animal, per year.

Cost effectiveness: -2 406.25 € per tonne of CO_2eq. per year.

3.4.5.6. Sexed Semen and Crossbreeding

This measure entails the use of sexed-semen and an increased reliance on crossbreeding in dairy cattle and sheep rearing. Using sexed-semen leads to higher ratio of female calves and sheep, leading to an increase in productivity. Crossbreeding also increases productivity, to a smaller extent.

Affected greenhouse gases: N_2O

Type of measure: regulatory

State: implemented in 2024

Implemented in the scenario: WEM, WAM

Potential reduction of GHG:

Dairy cattle:

- Average reduction (estimate from SK expert): 148.57 kg CO_2 eq./animal/year
- Per animal (estimate from literature): 307.73 kg CO_2 eq./year[13]
- Total: 18.70 kt CO_2 eq./year

Sheep:

- Average reduction per animal: 0.83 kg CO_2 eq./year

Total: 2.36 kt CO_2 eq./year. Costs/revenues (-): Dairy cattle: -75.62 € per animal per year; Sheep: -7.64 € per animal per year.

Cost effectiveness: Dairy cattle: -407.15 € per tonne of CO_2 eq. per year; Sheep: -3 234.45 € per tonne of CO_2 eq. per year.

3.4.5.7. Forage Quality and Management

This measure entails modifying forage feed practices (quality and management) and applies to cattle and sheep. Improving forage quality and management translates into improvements in the digestibility of ruminant diets, leading to a reduction in emissions from enteric fermentation. main barriers identified in an EIP-AGRI Focus group study to the implementation of this measure are farmers' awareness and training, reluctance to change traditional practices, and the commercial availability of appropriate genetic varieties for a given environment. Policies to implement this measure should therefore focus on removing these barriers, for instance via awareness raising and provision of training.

---

[13] JRC (2019) Impact of animal breeding on GHG emissions and farm economics. Available here: https://publications.jrc.ec.europa.eu/repository/bitstream/JRC117897/jrc_report_29844.pdf

Affected greenhouse gases: CH_4, N_2O

Type of measure: regulatory

State: implemented in 2024

Implemented in the scenario: WEM, WAM

Potential reduction of GHG:

Dairy cattle:

- Average reduction (estimate from SK expert): 252.58 kg CO_2 eq./animal/year
- Per animal (estimate from literature): 305.42 kg CO_2 eq./year
- Total: 31.79 kt CO_2 eq./year

Non-dairy cattle:

- Average reduction (estimate from SK expert): 99.39 kg CO_2 eq./animal/year
- Per animal (estimate from literature): 169.17 kg CO_2 eq./year
- Total: 30.45 kt CO_2 eq./year

Sheep:

- Average reduction per animal: 1.44 kg CO_2 eq./year
- Total: 0.46 kt CO_2 eq./year

Costs/revenues (-): Dairy cattle: -89.40 € per animal per year; Non-dairy cattle: -24.77 € per animal per year; Sheep: -11.25 € per animal per year.

Cost effectiveness: Dairy cattle: -355.45 € per tonne of CO_2 eq. per year; Non-dairy cattle: -174.43 € per tonne of CO_2 eq. per year; Sheep: -3 911.30 € per tonne of CO_2 eq. per year.

3.4.5.8. Low Emission Housing

This measure focuses on removing manure from animal housing systems daily, and is applicable to cattle, poultry and swine. Daily removal of manure decreases GHG emissions as it reduces its exposure to aerobic conditions. Subsequently, manure can be used in anaerobic digestion or can be stored and later applied to soil as organic fertiliser.

Affected greenhouse gases: CH_4, N_2O

Type of measure: regulatory, economic instrument

State: planned for 2030

Implemented in the scenario: WAM

Potential reduction of GHG:

Average reduction per animal: 334.29 kg CO_2 eq./year; Total: 42.07 kt CO_2 eq./year

Costs/revenues (-): 72.14 € per animal, per year.

Cost effectiveness: -215.79 € per tonne of CO_2 eq., per year.

3.4.5.9. Zero Emissions Livestock Project (ZELP) Cattle Wearable Technology

This measure entails fitting cattle with the ZELP cattle wearable technology, which is a device fitted on the cow which neutralises methane emissions from exhalation.

ZELP is a wearable device that reduces methane production from enteric fermentation by neutralising methane from exhalation. Its development was supported by an EU-funded project in 2019. The technology has not been yet deployed but should be commercially available in the near future.

Affected greenhouse gases: CH_4

Type of measure: regulatory, economic instrument

State: planned for 2030

Implemented in the scenario: WAM

Potential reduction of GHG:

Dairy cattle:

- Average reduction (estimate from SK expert): 984.30 kg CO_2 eq./animal/year
- Per animal (estimate from literature): 809.37 kg CO_2 eq./year[14]
- Total: 123.87 kt CO_2 eq./year

Non-dairy cattle:

- Average reduction (estimate from SK expert): 470.33 kg CO_2 eq./animal/year
- Per animal (estimate from literature): 448.29 kg CO_2 eq./year[15]

Total: 144.11 kt CO_2 eq./year

Costs/revenues (-): Dairy and non-dairy cattle: 13.61 € per animal per year.

Cost effectiveness: Dairy cattle: 13.83 € per tonne of CO_2 eq. per year; Non-dairy cattle: 28.94 € per tonne of CO_2 eq. per year.

3.4.5.10. Feed Additive: Nitrate

Low emission housing includes equipment that contribute to mitigating emissions of air pollutant, odours and/or GHG. The main ways in which NH3 and GHG emissions can be mitigated is by installing flooring that dries manure and urine fast as well as drainage systems for more efficient manure removal and management

Affected greenhouse gases: CH_4

Type of measure: regulatory

---

[14] European Commission (n.d.) Zero emission livestock project. Available here: https://cordis.europa.eu/article/id/418257-wearable-livestock-device-reduces-methane-emissions

[15] European Commission (n.d.) Zero emission livestock project. Available here: https://cordis.europa.eu/article/id/418257-wearable-livestock-device-reduces-methane-emissions

State: planned for 2030

Implemented in the scenario: WAM

Potential reduction of GHG:

Dairy cattle:

- Average reduction (estimate from SK expert): 133.72 kg CO_2 eq./animal/year
- Per animal (estimate from literature): 173 kg CO_2 eq./year[16]
- Total: 16.83 kt CO_2 eq./year

Non-dairy cattle:

- Average reduction (estimate from SK expert): 5.32 kg CO_2 eq./animal/year
- Per animal (estimate from literature): 173 kg CO_2 eq./year[17]

Total: 1.63 kt CO_2 eq./year

Costs/revenues (-): Dairy cattle: 9.25 € per animal per year; Non-dairy cattle: 6.09 € per animal per year.

Cost effectiveness: Dairy cattle: 20.75 € per tonne of CO_2 eq. per year; Non-dairy cattle: 228.75 € per tonne of CO_2 eq. per year.

3.4.5.11. Feed Additive: Plant Bioactive Compounds (Tannins)

This measure entails complementing the diet of cattle with tannins as a feed additive. Using tannins as feed additive reduces methane production from enteric fermentation due to their inhibitory effect on methanogens, protozoa and other hydrogen-producing microbes.

Affected greenhouse gases: CH_4

Type of measure: regulatory

State: planned for 2040

Implemented in the scenario: WAM

Potential reduction of GHG:

Dairy cattle:

- Average reduction (estimate from SK expert): 742.87 kg CO_2 eq./animal/year
- Per animal (estimate from literature): 610.85 kg CO_2 eq./year[18]

---

[16] Pellerin et al. (2017) Identifying cost-competitive greenhouse gas mitigation potential of French agriculture. Available here: https://www.sciencedirect.com/science/article/abs/pii/S1462901117304288

[17] Pellerin et al. (2017) Identifying cost-competitive greenhouse gas mitigation potential of French agriculture. Available here: https://www.sciencedirect.com/science/article/abs/pii/S1462901117304288

[18] Ouatahar et al. (2021) Modelling the effect of feeding management on greenhouse gas and nitrogen emissions in cattle farming systems. Citing Gerber et al., 2013; Kumar et al., 2014. Available here:

- Total: 93.49 kt CO_2 eq./year

Non-dairy cattle:

- Average reduction (estimate from SK expert): 354.96 kg CO_2 eq./animal/year
- Per animal (estimate from literature): 338.33 kg CO_2 eq./year[19]

Total: 108.76 kt CO_2 eq./year

Costs/revenues (-): Dairy cattle: 814.67 € per animal per year; Non-dairy cattle: 484.76 € per animal per year.

Cost effectiveness: Dairy cattle: 1 096.65 € per tonne of CO_2 eq. per year; Non-dairy cattle: 1 365.67 € per tonne of CO_2 eq. per year.

3.4.5.12. Detailed Description of Measure - Feed Additive: Adding Lipids/Fatty Acids to Diet

Low emission housing includes equipment that contribute to mitigating emissions of air pollutant, odours and/or GHG. The main ways in which NH3 and GHG emissions can be mitigated is by installing flooring that dries manure and urine fast as well as drainage systems for more efficient manure removal and management

Affected greenhouse gases: CH_4, N_2O

Type of measure: regulatory

State: planned for 2030

Implemented in the scenario: WAM

Potential reduction of GHG:

Dairy cattle:

- Average reduction (estimate from SK expert): 32.69 kg CO_2 eq./animal/year
- Per animal (estimate from literature): 314.59 kg CO_2 eq./year[20]
- Total: 4.11 kt CO_2 eq./year

Non-dairy cattle:

- Average reduction (estimate from SK expert): 17.30 kg CO_2 eq./animal/year

---

https://www.sciencedirect.com/science/article/pii/S0048969721009992#s0050Available here: https://www.sciencedirect.com/science/article/pii/S0048969721009992#s0050

[19] Ouatahar et al. (2021) Modelling the effect of feeding management on greenhouse gas and nitrogen emissions in cattle farming systems. Citing Gerber et al., 2013; Kumar et al., 2014. Available here: https://www.sciencedirect.com/science/article/pii/S0048969721009992#s0050Available here: https://www.sciencedirect.com/science/article/pii/S0048969721009992#s0050

[20] Ouatahar et al. (2021) Modelling the effect of feeding management on greenhouse gas and nitrogen emissions in cattle farming systems. Citing Lanigan et al., 2018. Available here: https://www.sciencedirect.com/science/article/pii/S0048969721009992#s0050https://www.sciencedirect.com/science/article/pii/S0048969721009992#s0050

- Per animal (estimate from literature): 287 kg CO_2 eq./year[21]

Total: 5.30 kt CO_2 eq./year

Costs/revenues (-): Dairy cattle: 19.50€ per animal per year; Non-dairy cattle: 6.99€ per animal per year.

Cost effectiveness: Dairy cattle: 19.50 € per animal per year; Non-dairy cattle: 6.99 € per animal per year; Dairy cattle: 262.47 € per tonne of CO_2 eq. per year; Non-dairy cattle: 262.47 € per tonne of CO_2 eq. per year.

3.4.5.13. Concentrate Inclusion in Ration

Low emission housing includes equipment that contribute to mitigating emissions of air pollutant, odours and/or GHG. The main ways in which NH3 and GHG emissions can be mitigated is by installing flooring that dries manure and urine fast as well as drainage systems for more efficient manure removal and management.

Affected greenhouse gases: CH_4

Type of measure: regulatory

State: planned for 2030

Implemented in the scenario: WAM

Potential reduction of GHG:

Dairy cattle:

- Average reduction (estimate from SK expert): 260 kg CO_2 eq./animal/year
- Per animal (estimate from literature): 610.85 kg CO_2 eq./year
- Total: 32.72 kt CO_2 eq./year

Non-dairy cattle:

- Average reduction (estimate from SK expert): 46.15 kg CO_2 eq./animal/year
- Per animal (estimate from literature): 338.33 kg CO_2 eq./year
- Total: 14.14 kt CO_2 eq./year

Sheep:

- Average reduction per animal: 0.50 kg CO_2 eq./year
- Total: 0.16 kt CO_2 eq./year

Costs/revenues (-): Dairy cattle: 55.84 € per animal per year; Non-dairy cattle: 33.27 € per animal per year; Sheep: 5.95 € per animal per year.

---

[21] Pellerin et al. (2017) Identifying cost-competitive greenhouse gas mitigation potential of French agriculture. Available here: https://www.sciencedirect.com/science/article/abs/pii/S1462901117304288

Cost effectiveness: Dairy cattle: 150.33 € per tonne of CO_2eq. per year; Non-dairy cattle: 468.68 € per tonne of CO_2 eq. per year; Sheep: 4 135.41 € per tonne of CO_2 eq. per year.

3.4.5.14. Feed Additives: 3-Nitrooxypropanol

This measure entails complementing the diet of cattle and sheep with 3-Nitrooxypropanol as a feed additive. The use of 3-nitrooxypropanol (3-NOP) as feed additive reduces methane emissions from enteric fermentation by inhibiting methyl-coenzyme M reductase (MCR), the enzyme responsible for methane formation.

Affected greenhouse gases: CH_4

Type of measure: regulatory

State: planned for 2035

Implemented in the scenario: WAM

Potential reduction of GHG:

Dairy cattle:

- Average reduction (estimate from SK expert): 668.58 kg CO_2 eq./animal/year
- Per animal (estimate from literature): 916.27 kg CO_2 eq./year
- Total: 742.87 kt CO_2 eq./year

Non-dairy cattle:

- Average reduction (estimate from SK expert): 354.96 kg CO_2 eq./animal/year
- Per animal (estimate from literature): 507.50 kg CO_2 eq./year
- Total: 354.96 kt CO_2 eq./year

Sheep:

- Average reduction per animal: 5.75 kg CO_2 eq./year
- Total: 7.19 kt CO_2 eq./year

Costs/revenues (-): Dairy cattle: 91.49 € per animal per year; Non-dairy cattle: 91.49 € per animal per year; Sheep: 10.44 € per animal per year.

Cost effectiveness: Dairy cattle: 123.15 € per tonne of CO_2 eq. per year; Non-dairy cattle: 257.74 € per tonne of CO_2 eq. per year; Sheep: 1 452.41 € per tonne of CO_2eq. per year.

3.4.5.15. Feed Additive: Amino-Acids

Animals do not actually require protein, but rather the specific amino acids (AA) that are the building blocks that make up proteins. By selecting proper protein sources and AA in a balanced diet, AA needs of cattle are ensured while reducing crude protein intake. Conversely, a diet imbalanced in AA supply can result in poor feed N use efficiency because one or more amino acids can limit protein synthesis and thus the productive use of the other amino acids and increase GHG emissions.

Affected greenhouse gases: N_2O

Type of measure: regulatory, economic instrument

State: implemented in 2024

Implemented in the scenario: WEM, WAM

Potential reduction of GHG:

Dairy cattle:

- Average reduction per animal: 27.86 kg CO_2 eq./year
- Total: 3.51 kt CO_2 eq./year

Non-dairy cattle:

- Average reduction per animal: 5.32 kg CO_2 eq./year
- Total: 1.63 kt CO_2 eq./year

Costs/revenues (-): Dairy cattle: 5.86 € per animal per year; Non-dairy cattle: 5.06 € per animal per year.

Cost effectiveness: Dairy cattle: 105.21 € per tonne of CO_2 eq. per year; Non-dairy cattle: 190.04 € per tonne of CO_2 eq. per year.

3.4.5.16. Optimally – Balanced Ration

This measure entails balancing the diet of beef cattle in the most optimal way. Ensuring that cattle is fed an optimally reduced ration contributes to increased digestibility, which reduces methane emissions from enteric fermentation, as and also leads to reduction in N_2O emissions from manure as feed tends to be too rich in nitrogen.

Affected greenhouse gases: CH_4, N_2O

Type of measure: regulatory, economic instrument

State: implemented in 2022

Implemented in the scenario: WEM, WAM

Potential reduction of GHG:

Average reduction (estimate from SK expert): 35.50 kg CO_2 eq./animal/year

Per animal (estimate from literature): 525.94 CO_2 eq./year[22]

Total: 10.88 kt CO_2 eq./year

Costs/revenues (-): 32.04 € per animal per year

Cost effectiveness: 90.25b€ per tonne of CO_2 eq. per year.

---

[22] Marques et al. (2022) Evaluating environmental and economic trade-offs in cattle feed strategies using multiobjective optimization. Available here: https://www.sciencedirect.com/science/article/abs/pii/S0308521X21002614?via%3Dihub

3.4.5.17. Improved Beef Maternal Traits

This measure focuses on improving the maternal traits of beef cattle in order to enhance efficiency. Trait alteration can influence feed production, methane production via enteric fermentation, and the number of animals needed to reach similar productivity levels.

Affected greenhouse gases: CH_4, N_2O

Type of measure: economic instrument

State: planned for 2035

Implemented in the scenario: WAM

Potential reduction of GHG:

Average reduction (estimate from SK expert): 141.99 kg CO_2 eq./animal/year

Per animal (estimate from literature): 0.81 CO_2 eq./year[23]

Total: 43.50 kt CO_2 eq./year

Costs/revenues (-): -103.05 € per animal per year

Cost effectiveness: -580.63 € per tonne of CO_2 eq. per year.

3.4.5.18. Storage and Covering of Manure and Slurry

The storage of manure with gas-tight covers reduces volatilisation of nitrogen compounds (in turn reducing indirect N_2O emissions) and can also reduce methane emissions.[24]

As reported in a recent EEA assessment of EU MS policies and measures to mitigate agricultural GHG emissions, several MS (e.g., the Netherlands, Denmark and Poland) have mandatory and well-enforced requirements for new slurry stores to be covered, resulting in high uptake. The lack of financial resources and space on smaller farms were however identified by the respondents consulted for that study as limiting factors for upgrading manure management systems. Availability of funding and communication about funding available is important to ensure requirements on storage and coverage are implemented on smaller farms. Moreover, to address the second limitation, one good practice from Romania has been to setup communal manure storage areas with impermeable bases to prevent leaching.[25]

Affected greenhouse gases: CH_4, N_2O

---

[23] Lanigan et al. (2019) An Analysis of Abatement Potential of Greenhouse Gas Emissions in Irish Agriculture 2021-2030. Available here: https://www.teagasc.ie/media/website/publications/2018/An-Analysis-of-Abatement-Potential-of-Greenhouse-Gas-Emissions-in-Irish-Agriculture-2021-2030.pdf

[24] EEA (2021) Agricultural climate mitigation policies and measures Good practice, challenges, and future perspectives. ETC/CME Eionet Report | 6/2021. Available at: https://www.eionet.europa.eu/etcs/etc-cme/products/etc-cme-reports/etc-cme-report-6-2021-agricultural-climate-mitigation-policies-and-measures-good-practice-challenges-and-future-perspectives/@@download/file/ETC_CME_Eionet%20report%202021_Agriculture_PaMs%20analysis%2020220510.pdf

[25] EEA (2021) Agricultural climate mitigation policies and measures Good practice, challenges, and future perspectives. ETC/CME Eionet Report | 6/2021. Available at: https://www.eionet.europa.eu/etcs/etc-cme/products/etc-cme-reports/etc-cme-report-6-2021-agricultural-climate-mitigation-policies-and-measures-good-practice-challenges-and-future-perspectives/@@download/file/ETC_CME_Eionet%20report%202021_Agriculture_PaMs%20analysis%2020220510.pdf

Type of measure: economic instrument

State: implemented in 2024

Implemented in the scenario: WEM, WAM

Potential reduction of GHG:

Dairy cattle:

- Average reduction (estimate from SK expert: 27.86 kg CO_2 eq./animal/year
- Per farm (estimate from literature): 170 CO_2 eq./year[26]
- Total: 3.51 kt CO_2 eq./year

Non-dairy cattle:

- Average reduction (estimate from SK expert): 5.32 kg CO_2 eq./animal/year
- Per farm (estimate from literature): 170 CO_2 eq./year[27]
- Total: 1.63 kt CO_2 eq./year

Sheep:

- Average reduction per animal: 0.86 kg CO_2 eq./year

Total: 0.28 kt CO_2 eq./year

Costs/revenues (-): Dairy cattle: 34.39 € per animal per year; Non-dairy cattle: 19.91 € per animal per year; Sheep: 2.89 € per animal per year.

Cost effectiveness: Dairy cattle: 308.62 € per tonne of CO_2 eq. per year; Non-dairy cattle: 373.93 € per tonne of CO_2 eq. per year; Sheep: 2 675.18 € per tonne of CO_2 eq. per year.

3.4.5.19. Precision Agriculture Techniques

Precision agriculture (PA) is a management strategy based on observing, measuring and responding to temporal and spatial variability to improve agricultural production sustainability. Includes techniques such as integrated nutrient management, integrated pest and disease management, and automated targeting. It can also involve the use of technologies such as Variable Rate Technology, machine guidance, etc. PA leads to reduced input use (fertilisers, pesticides, water) and increased efficiency, therefore also reducing GHG emissions and pollution (reduced pollution of terrestrial and water ecosystems, with benefits for biodiversity).

PA is plan to publicly financed via Common Agricultural Policy (CAP) instruments, including rural development investments (e.g., machinery), farm advisory services and trainings, or eco-scheme payments Cost information 9.48 € per hectare, per year.

---

[26] Pellerin et al. (2017) Identifying cost-competitive greenhouse gas mitigation potential of French agriculture. Available here: https://www.sciencedirect.com/science/article/abs/pii/S1462901117304288

[27] Pellerin et al. (2017) Identifying cost-competitive greenhouse gas mitigation potential of French agriculture. Available here: https://www.sciencedirect.com/science/article/abs/pii/S1462901117304288

Affected greenhouse gases: N_2O

Type of measure: regulatory, economic instrument

State: planned for 2030

Implemented in the scenario: WAM

Potential reduction of GHG:

Per hectare: 161.27 kg CO_2 eq./year

Total: 135.50kt CO_2 eq./year

Costs/revenues (-): 9.48 € per hectare per year

Cost effectiveness: 58.79 € per tonne of CO_2 eq. per year

3.4.5.20. Use of Nitrification Inhibitors

Use of nitrification inhibitors. This measure entails switching from inorganic N fertiliser to N fertiliser containing nitrification inhibitors, which slow the microbial conversion of ammonium-N to nitrate-N (nitrification). Nitrification inhibitors can be applied to slow down the transformation of ammonium into other forms that result in nitrogen losses and have adverse effects on the environment. This leads to a decrease in GHG emissions as with less nitrogen losses, and hence also to a reduction in fertiliser use.

Affected greenhouse gases: N_2O

Type of measure: regulatory, economic instrument

State: planned for 2025

Implemented in the scenario: WAM

Potential reduction of GHG:

Per hectare: 130.55 kg CO_2 eq./year

Total: 132.54 kt CO_2 eq./year

Costs/revenues (-): 4.27 € per hectare

Cost effectiveness: 32.74 € per tonne of CO_2 eq. per year

3.4.5.21. Use of Urease Inhibitor

This measure entails the application of urease inhibitor alongside urea. When applied to soil, urea dissolves rapidly. It reacts to form ammonia (NH_3) and carbon dioxide (CO_2), and then is nitrified to NO_3-. The release of N_2O can also occur, mainly through nitrification and denitrification. Urease inhibitors contribute to the reduction of GHG emissions from these processes.

Affected greenhouse gases: N_2O, CO_2

Type of measure: regulatory

State: planned 2025

Implemented in the scenario: WAM

Potential reduction of GHG:

Per hectare: 44.59 kg CO_2 eq./year

Total: 63.54 kt CO_2 eq./year

Costs/revenues (-): 6.98 € per hectare per year

Cost effectiveness: 156.50 € per tonne of CO_2 eq. per year

3.4.5.22. Switch to Organic Fertilisers

This measure focuses on switching from inorganic to organic fertilisers (compost, manure, sewage sludge). Compost, manure and sewage sludge, when properly incorporated into the soil, lead to less emissions than the application of inorganic fertilisers. In addition, organic fertilisers improve soil health and biodiversity (in soil and on land), improve nutrient cycling, and decrease emissions from other stages of the value chain (removes emissions associated with the production of inorganic fertilisers).

Affected greenhouse gases: N_2O

Type of measure: regulatory, economic instrument

State: implemented 2024

Implemented in the scenario: WEM, WAM

Potential reduction of GHG:

Compost:

- Per ha: 106.21 kg CO_2 eq./year
- Total: 37.18 kt CO_2 eq./year

Manure (sheep, poultry & goat):

- Per ha: 141.61 kg CO_2 eq./year
- Total: 49.58 kt CO_2 eq./year

Manure (cattle):

- Per ha: 141.61 kg CO_2eq./year
- Total: 49.58 kt CO_2eq./year

Sewage sludge:

- Per ha: 141.61 kg CO_2 eq./year

Total: 49.58 kt CO_2 eq./year

Costs/revenues (-): Compost: -97.62 € per hectare, per year; Manure (sheep, poultry & goat): -117.84 € per hectare, per year; Manure (cattle): 13.95 € per hectare, per year; Sewage sludge: 1 238.65 € per hectare, per year

Cost-efficiency: Compost: -919.11 € per tonne of CO_2 eq. per year; Manure (sheep, poultry & goat): -832.12 € per tonne of CO_2 eq. per year; Manure (cattle): 98.48 € per tonne of CO_2 eq. per year; Sewage sludge: 9 064.73 € per tonne of CO_2 eq. per year.

3.4.6. SECTORAL POLICIES AND MEASURES: WASTE

In general, the more waste we produce, the more we have to get rid of. Some waste disposal methods release both pollutants and greenhouse gases into the air. Recycling is one method of reducing the impact of waste disposal on the air and climate. However, there are also ways of dealing with waste that are more environmentally friendly. The waste management sector consists of the following categories:

- 5.A Landfilling of solid waste
- 5.B Biological treatment of solid waste
- 5.C Incineration and uncontrolled burning of waste
- 5.D Wastewater treatment

The most common disposal methods are landfill and, to a lesser extent, incineration. As waste from landfills decomposes, non-methane volatile organic compounds (NMVOCs) and methane are released into the air, and particulate matter (PM) emissions are released when the waste is handled.

Incineration is the second most common method of waste disposal in the Slovak Republic. In the past, this energy was not often used and waste was only disposed of. Modern plants now use waste as a fuel in the production of energy or heat, and waste is recovered in this way. In this case, the emissions from combustion are classified in the energy sector. In our country, waste incineration contributes significantly to the number of dioxins and furans (PCDDs/PCDFs) that are emitted into the air. Since dioxins are virtually undegradable in nature and can persist for hundreds of years, they are deposited in animal tissues and thus enter the human food chain. Dietary intake, especially of meat, fish, eggs, milk and fats, is the most important route of entry of dioxins into the human body. Incineration of waste also releases high levels of heavy metal emissions into the air. Modern waste incinerators capture these substances efficiently, but this was not common practice in the past. Heavy metals are deposited in the soil and subsequently in organisms, from which they are difficult to break down. Thanks to the food chain, the contamination of organisms is gradually increasing. Animals at the end of the food chain, and therefore humans, are particularly at risk from heavy metals. The risk is particularly higher in coastal areas where seafood consumption is generally higher.

Recycling is not the only sustainable way to recover waste. Composting any organic waste, such as food and garden waste, is one of them. The organic waste decomposes into mulch within a few weeks, which can be used as a fertiliser for the soil. Many households practise small-scale composting and large-scale composting systems are being developed with the collection of organic waste from parks and urban amenities. Similar types of organic waste can also be treated in biogas plants. Unlike composting, here the waste is decomposed anaerobically (without access to air) and biogas is produced, which can be further burned to generate energy that can be used for heating.

Also included in this sector are cremations of human and animal remains, which are also a source of air pollution through emissions of heavy metals and POPs.

Wastewater treatment also releases pollutants and greenhouse gases (both CH_4 and N_2O). In general, emissions of POPs as well as NMVOCs, CO and NH_3 occur in wastewater treatment plants, but in most cases, these are negligible.

3.4.6.1. Act No. 79/2015 Coll. on Waste and on Amendments and Additions to Certain Acts, as Amended

This act emphasises the sorting of packaging and recyclable materials. It also changes the funding scheme for separate collection from the State Recycling Fund to the Producer Responsibility Organisation. Disposal of waste is only allowed at permitted controlled landfills). This Act prohibits the disposal of garden waste, biodegradable waste by landfill and incineration, and requires the separate collection of kitchen waste. In particular, the Act aims to reduce the amount of waste that is disposed of by landfilling, to adjust and focus on waste prevention, to minimize the negative impacts of waste generation and management on the environment and human health, to introduce and apply extended producer and importer responsibility in a standard way common in other EU Member States and to translate it to the municipal level.

Affected greenhouse gases: CO_2, CH_4, N_2O

Type of measure: regulatory, economic instrument

State: implemented in 2015

Implemented in the scenario: WEM, WAM

3.4.6.2. Waste Management Programme of the Slovak Republic for 2021 – 2025

The main objective of the waste management of the Slovak Republic for the period 2021 – 2025 is the diversion of waste from landfill disposal, especially for municipal waste, increasing recycling together with improving sorted collection and introducing and increasing reuse. It includes a number of key climate change mitigation objectives: Increase the rate of separate collection of municipal waste to 60% by 2025 and the rate of preparation for re-use and recycling of municipal waste to 55%; reduce the share of biodegradable municipal waste in mixed municipal waste to 25% by 2025, divert municipal waste from landfill to 10% by 2035. In the area of textile collection, the main objective is to create a functional system for textiles in the Waste Act with effect from 1 January 2025.

Affected greenhouse gases: CO_2, CH_4, N_2O

Type of measure: regulatory, economic instrument

State: implemented in 2021

Implemented in the scenario: WEM, WAM

3.4.6.3. Concept of Water Policy of the Slovak Republic Until 2030 with a View to 2050

The main objective of the concept is to ensure the gradual restoration of damaged water bodies, to halt water pollution and the decline in groundwater quantity, as well as to ensure the availability of drinking water in the regions. It defines ten priorities, interlinked areas, one of the main objectives being to increase the proportion of the population connected to sewerage systems, with the aim of achieving 85% coverage by 2050.

Affected greenhouse gases: CH_4, N_2O

Type of measure: regulatory

State: adopted in 2022

Implemented in the scenario: WEM, WAM

3.4.6.4. Act No. 302/2019 on the Backup of Disposable Beverage Packaging and on Amending and Supplementing Certain Acts

This Act emphasises the sorting of packaging and recyclable materials. It also changes the funding scheme for separate collection from the State Recycling Fund to the Producer Responsibility Organisation. Disposal of waste is only allowed at permitted controlled landfills). This Act prohibits the disposal of garden waste, biodegradable waste by landfill and incineration, and requires the separate collection of kitchen waste. In particular, the Act aims to reduce the amount of waste that is disposed of by landfilling, to adjust and focus on waste prevention, to minimize the negative impacts of waste generation and management on the environment and human health, to introduce and apply extended producer and importer responsibility in a standard way common in other EU Member States and to translate it to the municipal level.

Affected greenhouse gases: CH_4

Type of measure: regulatory, economic instrument

State: implemented in 2019

Implemented in the scenario: WEM, WAM

3.4.6.5. Financial Support for Increasing the Number of Inhabitants Connected to Public Sewerage

The measure is implemented under funding from municipalities or water companies as operators of wastewater treatment plants. Significant assistance is provided by the Slovak Government through the Environment Fund, and this assistance has grown significantly, especially in recent years

Cost information Approximately EUR 11.6 million will be made available in 2021, with a total of EUR 96 million expected to be earmarked for wastewater and water infrastructure projects. (Approximately EUR 160 million will be earmarked for the financing of measures to address the country's urgent infrastructure needs (2021 – 2027)

Affected greenhouse gases: CH_4, N_2O

Type of measure: economic instrument

State: implemented in 2021

Implemented in the scenario: WEM, WAM

3.4.7. SECTORAL POLICIES AND MEASURES: LAND USE, LAND-USE CHANGE AND FORESTRY SECTOR (LULUCF)

The “Fit for 55” package represents the European Commission's legislative action to achieve the economy-wide target of reducing greenhouse gas emissions by at least 55% below 1990 levels by 2030. One measure to contribute to this target should be the implementation by individual Member States of Regulation (EU) 2023/839 which revises Regulation (EU) 2018/841. Therefore, the policy and consequently the modelling of GHG emission/absorption projections for the LULUCF sector also include a condition in Regulation (EU) 2023/839 and Regulation (EU) 2018/841 that each Member State ensures that emissions do not exceed removals (zero emissions) in the periods 2021 to 2025 and 2026 to 2030, taking into account the flexibility instruments set out in Articles 12 and 13. The policies used in the projections are set out below.

3.4.7.1. Slovak Rural Development Programme for the Period 2023 – 2027

A substantial part of the support of the Slovak Republic Rural Development Plan for the period 2023 – 2027 is focused on adaptation to climate change. The planned measures are intended to contribute to the specific objective of CAP S04: SO4 "Contribute to climate change mitigation and adaptation, including the reduction of greenhouse gas emissions and improved carbon storage as well as the promotion of sustainable energies".

In particular, these are the following measures:

- protection and maintenance within the established agroforestry system,
- setting up an agroforestry system,
- afforestation of agricultural land,
- investment in increasing the water retention function of forests,
- integrated projects for good management practice in forests (part - non-productive investments)

Affected greenhouse gases: CO_2

Type of measure: economic instrument

State: implemented in 2022

Implemented in the scenario: WEM, WAM

3.4.7.2. Afforestation of Non-Utilised Agricultural Land

Afforestation of agricultural land has a high carbon sequestration potential; this measure was implemented within Rural Development Programmes. Afforestation of non-utilised agricultural land was supported by 15 projects with a total afforestation area of 100 ha in the first Rural Development Programme from 2004 to 2006. According to the Rural Development Programme 2007 - 2013, afforestation continued by 28 projects with a total area of 133.35 ha and according to the Rural Development Programme 2014 - 2020, forest trees were planted on an agricultural land fund with a total area of 332 ha in Slovakia during the both seven years programming periods. There was also a project implemented to plant fast-growing trees on 35 ha of non-utilised agricultural land.

Affected greenhouse gases: CO_2

Type of measure: economic instrument

State: implemented in 2004

Implemented in the scenario: WEM, WAM

3.4.7.3. National Forestry Programme of the Slovak Republic 2022 – 2030

The National Forestry Programme of the Slovak Republic is the basic document of the state forestry policy and a strategic and political instrument of the state for the direction of sustainable forest management at the national level, including prevention of deforestation (as an integrated part of sustainable forest management). Its preparation represents efforts to streamline inter-ministerial cooperation and the implementation of international commitments related to forests and forestry.

Affected greenhouse gases: CO_2

Type of measure: economic instrument

State: adopted in 2023

Implemented in the scenario: WAM

3.4.7.4. Implementation of Measures to Increase Carbon Sequestration in Agricultural Soils

Farm soils rich in carbon is key to soil productivity. Carbon-rich soils contribute to yield and long-term sustainability which can have good impacts on profit. The measure results from the Low Carbon Development Strategy of the Slovak Republic.

Affected greenhouse gases: CO_2

Type of measure: economic instrument

State: adopted in 2023

Implemented in the scenario: WAM

3.4.7.5. Increasing the Share of Long-Life Wood Products (HWP), Including for Construction Purposes

The measure results from the Low Carbon Development Strategy of the Slovak Republic. More efficient use of products based on the principles of circular bioeconomy is also part of the upcoming National Forestry Programme of the Slovak Republic 2022.

Affected greenhouse gases: CO_2

Type of measure: regulatory

State: adopted in 2023

Implemented in the scenario: WAM

3.4.7.6. Motivating Forest Managers to Start the Process of Conversion to Nature-Friendly Forms of Forest Management

The measures stem from another strategic objective of the National Forestry Programme, such as the introduction of nature-friendly forms of forest management (Strategic Objective II), which can also be expected to result in a higher stock of biomass, and hence carbon sequestered in forests. The measure is intended to motivate forest managers to start a relatively complex and long-term process of transition of forests to nature-friendly forests, at least on ¼ of the area of forests in Slovakia, where especially at the beginning, temporarily increased operational and overhead costs are expected.

Affected greenhouse gases: CO_2

Type of measure: regulatory

State: adopted in 2023

Implemented in the scenario: WAM

3.4.7.7. Grassland Maintenance and Restoration

The aim of this measure is to maintain and restore permanent grasslands. Maintenance of arable land and grassland with a high natural value, introduction of extensive grazing practices and conversion of arable land to grassland are included in Agri-environment-climate measures (article 28) in Rural Development Programme 2014 – 2020. The trend shows that the gradual reduction of the area of permanent grasslands will most likely continue, mainly due to the transfer of unused and abandoned pastures and meadows to the forests, ecological and water protection restrictions, introduction of forest-pastoral systems (agroforestry), transfer of land under nature conservation management. In the case of introduction and application of appropriate socio-economic and ecosystem measures and PES schemes (payments for ecosystem services), the acreage in this category could be stabilized and its use improved.

Affected greenhouse gases: CO_2

Type of measure: regulatory

State: adopted in 2023

Implemented in the scenario: WAM

3.4.7.8. Climate Change Adaptation Strategy - Update

The Adaptation Strategy Update also includes supporting measures to increase carbon sinks as part of sustainable forest management. Modify tree species composition to increase the resilience of stands to drought and reduce vulnerability to biotic and abiotic factors.

Affected greenhouse gases: CO_2

Type of measure: regulatory

State: adopted in 2023

Implemented in the scenario: WAM

3.5. Summary of Greenhouse Gas Emissions and Removals

Slovakia is providing information on GHG emissions and removals in the BTR **Chapter 3.5** and in a separate National Inventory Document 2024 of the Slovak Republic accompanied this First Biennial Transparency Report 2024; and in the CRT Tables 1990 – 2022.

Information on GHG emissions and removals of the Slovak Republic are providing in Executive Summary and in the Chapter 2. of the National Inventory Document of the Slovak Republic 2024 accompanied this Report.

3.6. Projections of Greenhouse Gas Emissions and Removals

General methodology of the emission projections calculations was based on the same structure as in the national inventory of greenhouse gases. The data structure for activities, input data, emission factors and emission calculations are based on the Common Reporting Tables (CRT) of the UNFCCC. The outputs are aggregated. Emission projections are generally calculated by similar methodology as in the case for the national GHG inventory.

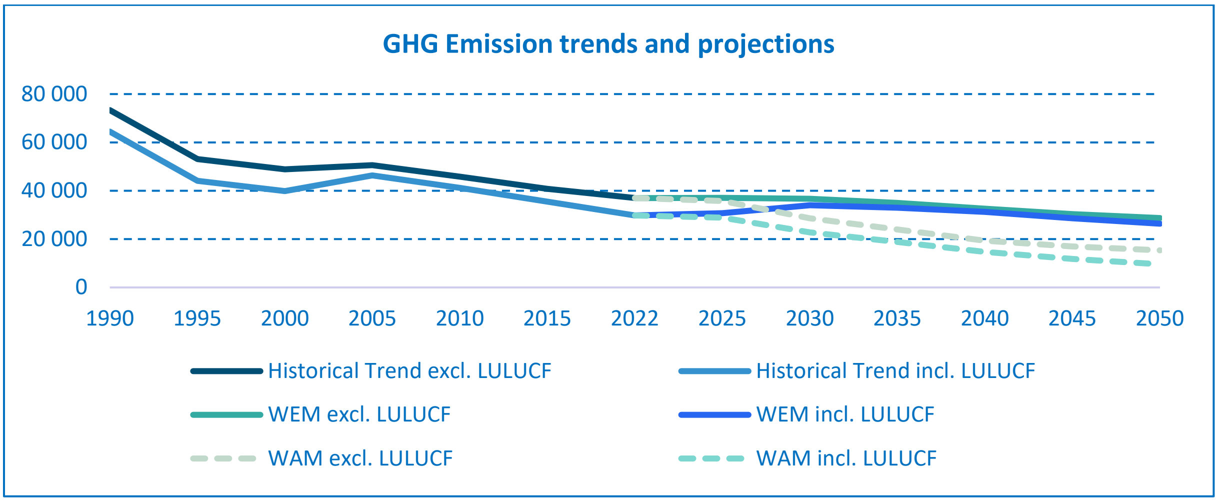
Table 3.6: *Total aggregated GHG emission projections in Gg of CO_2 eq.*

WEM	**2022***	**2025**	**2030**	**2035**	**2040**	**2045**	**2050**
Total excluding LULUCF	37 013	37 069	36 726	34 930	32 524	30 386	28 709
Total including LULUCF	29 787	30 786	34 005	32 962	31 278	28 654	26 367
WAM	**2022***	**2025**	**2030**	**2035**	**2040**	**2045**	**2050**
Total excluding LULUCF	37 013	35 807	28 556	24 018	19 357	16 928	15 361
Total including LULUCF	29 787	28 816	22 756	18 874	14 686	11 726	9 592

* Base year 2022; based on the GHG inventory submission 15. 3. 2024

Figures and tables in this chapter describes overall trend of total aggregated emission projections. The WAM scenario achieves far greater reductions than WEM, with accelerated progress starting after 2025. Steady but moderate reduction in WEM scenario in emissions, reflecting limited measures. The steepest decline occurs between 2025 and 2035 in WAM scenario. LULUCF inclusion significantly amplifies the reduction in the WAM scenario, highlighting its critical role in achieving net-zero emissions. While WEM shows progress, it is insufficient to meet long-term climate targets, emphasizing the importance of additional measures in the WAM scenario.

Figure 3.4: *GHG emission trends and emission projections in Gg of CO_2 eq.*



3.6.1. AGGREGATED GHG EMISSION PROJECTIONS BY SECTORS AND BY GASES

This chapter describes in figures and tables the projections of total aggregate GHG emissions for all monitored sectors of the Slovak economy.

ENERGY (EXCLUDING TRANSPORT)

In 2022, this sector accounted for approximately 51.4% of total emissions and by 2050, its share decreases to about 45.5% in WEM scenario and to 37.7% in WAM scenario. WEM scenario reflecting a gradual reduction over time. Trend is steady decline, with emissions dropping by around 30% between 2022 and 2050. WAM scenario reflecting a faster and more substantial reduction. Trend is stronger declining, with emissions decreasing by more than 67% from 2022 to 2050.

TRANSPORT

Transport emissions make up 22.4% of the total in 2022 and in WEM they initially rise to a peak of 25.3% in 2025 but drop significantly to 19.7% by 2050 and more significantly in WAM scenario – to 13.2% of total emissions. Trend shows a short-term increase followed by a steady decline, reducing emissions by approximately 30% between 2022 and 2050 in WEM and sharp decline by 74% in WAM scenario.

IPPU (INDUSTRIAL PROCESSES AND PRODUCT USE)

This sector contributes 21.7% in 2022 and remains relatively stable at 27.0% in 2050 – WEM scenario, and 33% in WAM scenario, which shows slower decrease in trend compare to previous sectors.

AGRICULTURE

Agriculture emissions represent the share of 5.6% in 2022 and maintain a similar proportion, ending at 6.7% in 2050 in WEM scenario and 8.5% in WAM. Emissions trend in WEM remain almost flat, with minor changes across the years. In WAM scenario emissions decline by approximately 33% but maintain a relatively stable share of the total.

LULUCF (LAND USE, LAND-USE CHANGE, AND FORESTRY)

In 2022, LULUCF acts as a carbon sink, offsetting about -20.8% of total emissions. By 2050, its offset capacity decreases slightly to -8.5% in WEM, and -32.6% in WAM scenario. Reduced carbon sequestration over time in WEM scenario, indicating potential challenges in land-use management. And improved carbon sequestration capacity in WAM scenario, highlighting the effectiveness of land-use measures.

WASTE

The share of Waste emissions on national totals are 5.6% in 2022 and in WEM scenario is stable on almost same 5.6% by 2050 in WEM scenario and declining to 8.2% in WAM scenario. Trend shows gradual reduction, with emissions decreasing by about 20% in WEM, resp. 35% in WAM scenario.

Table 3.7: *Sectoral GHG emission trends and emission projections in Gg of CO_2 eq.*

WEM	2022*	2025	2030	2035	2040	2045	2050
Energy (excluding transport)	17 833.28	16 432.81	15 555.23	14 744.77	13 724.26	13 117.64	12 496.17
Transport	7 778.85	9 118.71	9 903.88	9 282.92	7 973.86	6 447.16	5 421.12
IPPU	7 536.24	7 733.90	7 627.36	7 444.46	7 422.17	7 403.30	7 422.24
Agriculture	1 934.43	1 956.11	1 935.36	1 816.59	1 836.69	1 843.13	1 841.10
LULUCF	-7 225.74	-6 283.51	-2 721.47	-1 967.62	-1 246.26	-1 732.14	-2 341.62
Waste	1 929.92	1 827.68	1 704.41	1 641.37	1 567.32	1 574.55	1 528.04
WAM	**2022***	**2025**	**2030**	**2035**	**2040**	**2045**	**2050**
Energy (excluding transport)	17 833.28	16 417.05	11 827.37	10 306.46	7 692.03	6 604.18	5 735.59
Transport	7 778.85	8 309.62	7 880.07	5 583.91	3 800.69	2 625.51	2 007.38
IPPU	7 536.24	7 363.04	5 453.83	5 276.95	5 131.44	5 076.97	5 073.26
Agriculture	1 934.43	1 932.89	1 803.84	1 404.42	1 390.64	1 334.53	1 294.36
LULUCF	-7 225.74	-6 990.42	-5 800.22	-5 144.73	-4 671.18	-5 202.41	-5 769.61
Waste	1 929.92	1 783.95	1 590.79	1 446.58	1 342.05	1 287.03	1 250.70

***** Base year 2022; based on the GHG inventory submission 15. 3. 2024

Figure 3.5: *Sectoral GHG emission trends and emission projections in Gg of CO_2 eq. in WEM scenario*

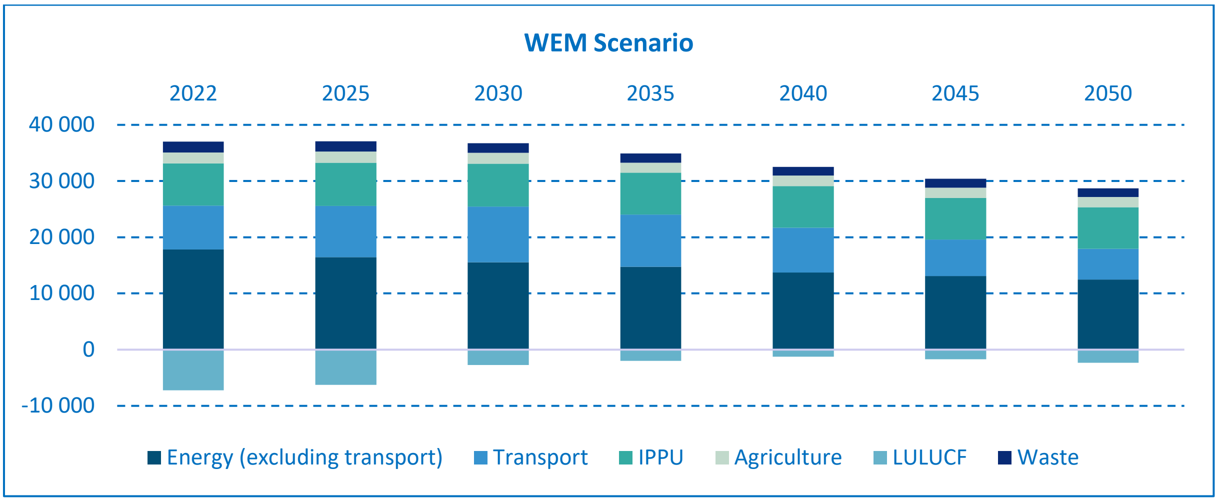
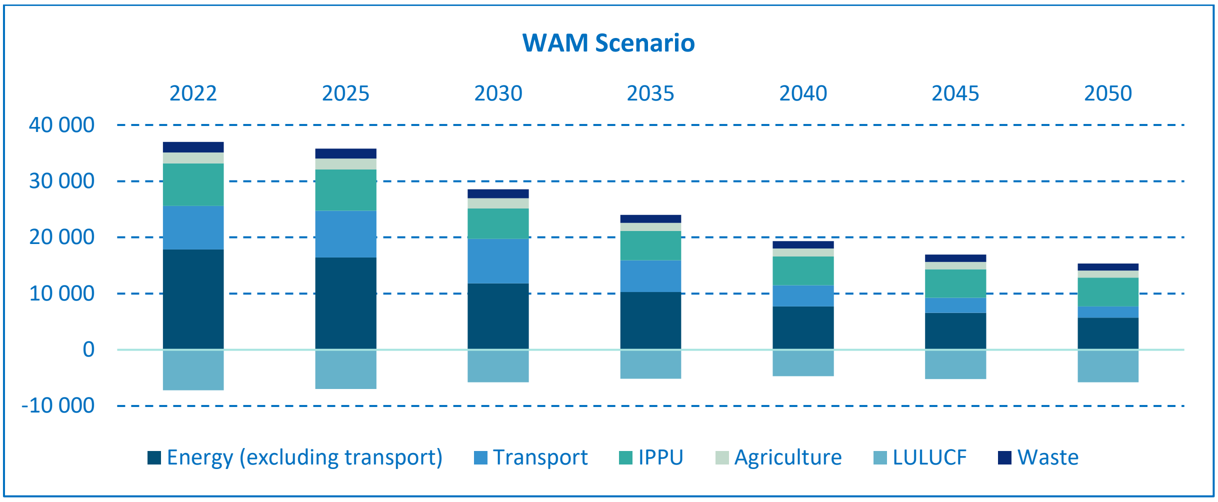


Figure 3.6: *Sectoral GHG emission trends and emission projections in Gg of CO_2 eq. in WAM scenario*



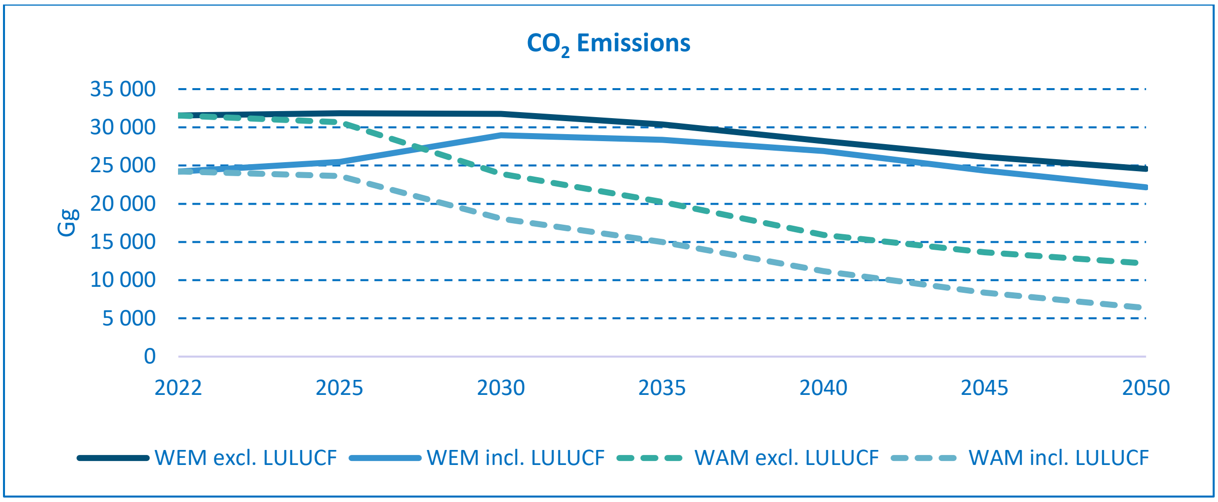
CO_2 emissions accounted for 85% of total GHG emissions in 2022 (excluding CO_2 from LULUCF). CO_2 emissions excluding LULUCF in WEM scenario are expected to decrease by 26% in 2030 compared to 2005 and by 48% compared to 1990. In 2050, a 43% decrease is expected compared to 2005 and 60% decrease compared to 1990. In WAM scenario emissions are expected to decrease by 44% in 2030 compared to 2005 and by 61% compared to 1990. In 2050, 72% decrease is expected compared to 2005 and 80% decrease compared to 1990. CO_2 emissions including LULUCF in WEM scenario are expected to decrease by 25% in 2030 compared to 2005 and by 45% compared to 1990. In 2050, a 43% decrease is expected compared to 2005 and 58% decrease compared to 1990. In WAM scenario emissions are expected to decrease by 53% in 2030 compared to 2005 and by 66% compared to 1990. In 2050, 84% decrease is expected compared to 2005 and 88% decrease compared to 1990. Projections of CO_2 emissions according to WEM and WAM scenarios are presented in ***Figure 3.7*** and ***Table 3.8***.

Table 3.8: *Emission projections of CO_2 in Gg sector in WEM and WAM scenarios up to 2050*

WEM	**2022***	**2025**	**2030**	**2035**	**2040**	**2045**	**2050**
CO_2 emissions excl. LULUCF	31 550.24	31 842.89	31 750.79	30 386.54	28 219.73	26 137.96	24 563.52
CO_2 emissions incl. LULUCF	24 233.52	25 491.80	28 963.17	28 355.20	26 907.31	24 337.80	22 153.21
WAM	**2022***	**2025**	**2030**	**2035**	**2040**	**2045**	**2050**
CO_2 emissions excl. LULUCF	31 550.24	30 665.47	23 907.10	20 215.71	15 903.24	13 644.19	12 188.21
CO_2 emissions incl. LULUCF	24 233.52	23 612.55	18 046.27	15 013.68	11 173.52	8 382.19	6 358.70

* Base year 2022; based on the GHG inventory submission 15. 3. 2024

Figure 3.7: *Emission projections of CO_2 in Gg sector in WEM and WAM scenarios up to 2050*



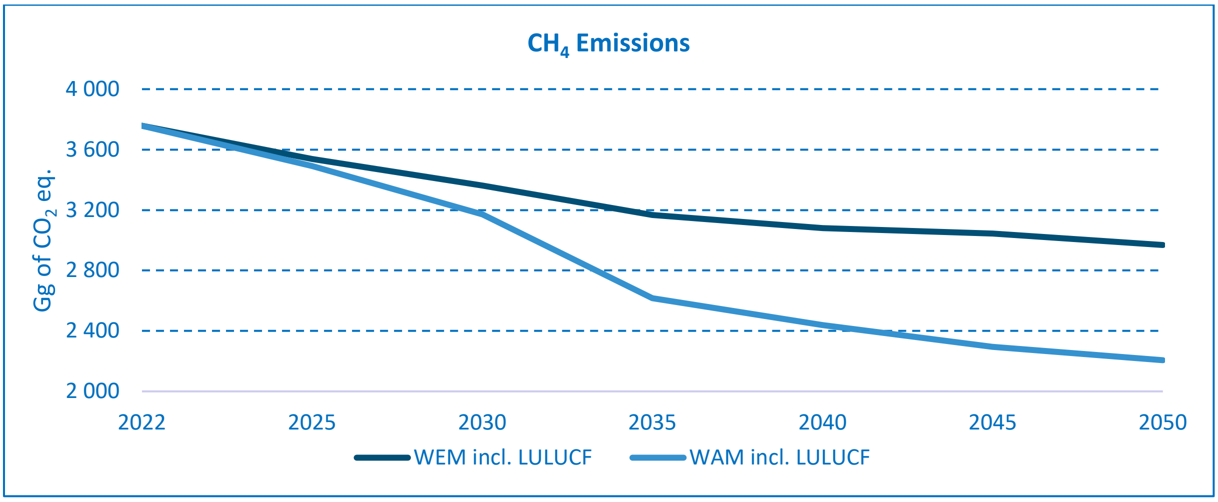
CH_4 emissions accounted for approximately 10% of total GHG emissions in 2022 (excluding CO_2 from LULUCF). CH_4 emissions including LULUCF in WEM scenario are expected to decrease by 32% in 2030 compared to 2005 and by 60% compared to 1990. In 2050, 40% decrease is expected compared to 2005 and 64% decrease compared to 1990. In WAM scenario emissions are expected to decrease by 36% in 2030 compared to 2005 and by 62% compared to 1990. In 2050, 55% decrease is expected compared to 2005 and 74% decrease compared to 1990.Projections of CH_4 emissions according to WEM and WAM scenarios are presented in ***Figure 3.8*** and ***Table 3.9***.

Table 3.9: *Emission projections of CH_4 in Gg of CO_2 eq. in WEM and WAM scenarios up to 2050*

WEM	**2022***	**2025**	**2030**	**2035**	**2040**	**2045**	**2050**
CH_4 emissions excl. LULUCF	3 712.00	3 506.66	3 330.98	3 138.02	3 051.72	3 015.70	2 940.00
CH_4 emissions incl. LULUCF	3 757.85	3 537.13	3 361.30	3 168.07	3 081.48	3 044.89	2 968.65
WAM	**2022***	**2025**	**2030**	**2035**	**2040**	**2045**	**2050**
CH_4 emissions excl. LULUCF	3 712.00	3 462.85	3 143.40	2 588.99	2 411.06	2 266.58	2 179.07
CH_4 emissions incl. LULUCF	3 757.85	3 490.53	3 171.28	2 616.89	2 438.93	2 294.12	2 206.23

***** Base year 2022; based on the GHG inventory submission 15. 3. 2024

Figure 3.8: *Emission projections of CH_4 in Gg of CO_2 eq. in WEM and WAM scenarios up to 2050*



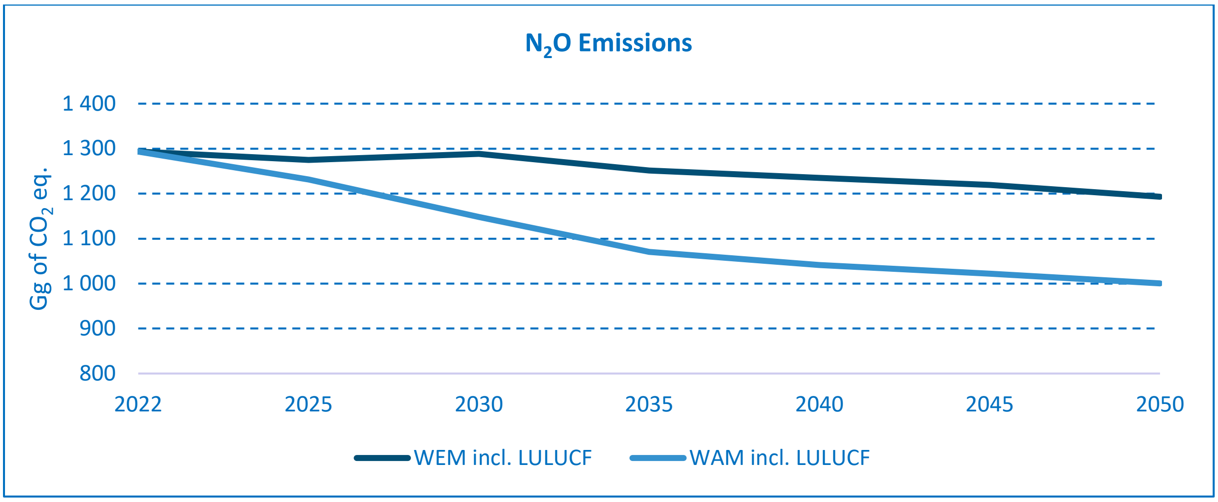
N_2O emissions accounted for less than 4% of total GHG emissions in 2022 (excluding CO_2 from LULUCF). N_2O emissions including LULUCF in WEM scenario are expected to decrease by 48% in 2030 compared to 2005 and by 63% compared to 1990. In 2050, a 52% decrease is expected compared to 2005 and 65% decrease compared to 1990. In WAM scenario emissions are expected to decrease by 54% in 2030 compared to 2005 and by 67% compared to 1990. In 2050, 60% decrease is expected compared to 2005 and 71% decrease compared to 1990. Projections of N_2O emissions according to WEM and WAM scenarios are presented in ***Figure 3.9*** and ***Table 3.10***.

Table 3.10: *Emission projections of N_2O in Gg of CO_2 eq. in WEM and WAM scenarios up to 2050*

WEM	**2022***	**2025**	**2030**	**2035**	**2040**	**2045**	**2050**
N_2O emissions excl. LULUCF	1 248.32	1 237.83	1 252.34	1 217.84	1 198.63	1 180.20	1 153.04
N_2O emissions incl. LULUCF	1 293.45	1 274.95	1 288.17	1 251.52	1 235.02	1 219.01	1 193.08
WAM	**2022***	**2025**	**2030**	**2035**	**2040**	**2045**	**2050**
N_2O emissions excl. LULUCF	1 248.32	1 196.63	1 115.45	1 041.40	1 010.39	989.70	967.71
N_2O emissions incl. LULUCF	1 293.45	1 231.45	1 148.17	1 070.80	1 041.06	1 021.75	1 000.45

* Base year 2022; based on the GHG inventory submission 15. 3. 2024

Figure 3.9: *Emission projections of N_2O in Gg of CO_2 eq. in WEM and WAM scenarios up to 2050*



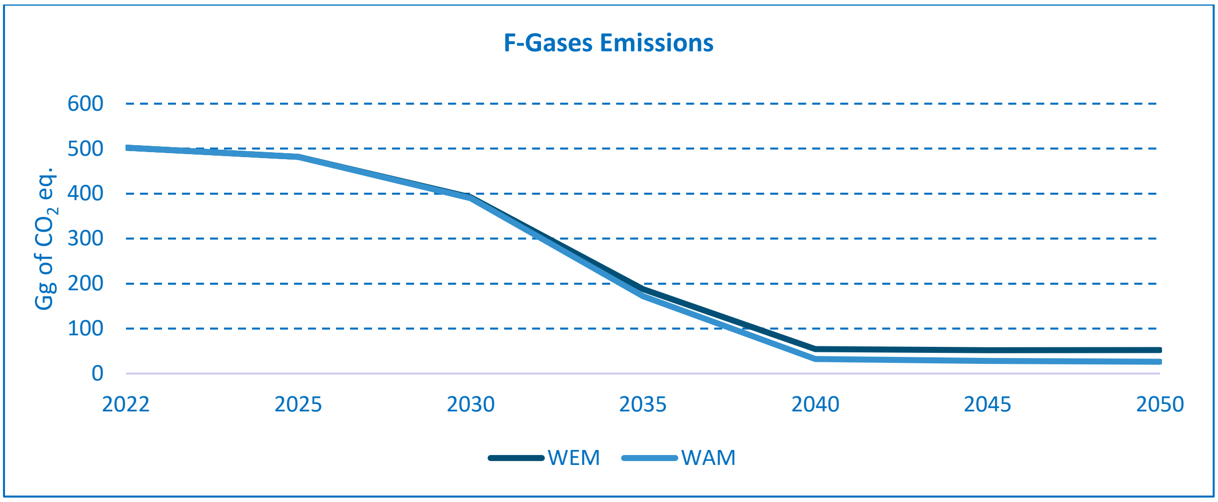
Emissions of F-gases accounted for over 1% of total GHG emissions in 2022 (excluding CO_2 from LULUCF). The most produced gases are HFCs with a share of almost 96%, followed by SF_6 with a share of 3% in 2022. Emissions of F-gases in WEM scenario are expected to increase by 22% in 2030 compared to 2005 and by 83% compared to 1990. In 2050, 84% decrease is expected compared to 2005 and 76% decrease compared to 1990. In WAM scenario emissions are expected to increase by 21% in 2030 compared to 2005 and by 82% compared to 1990. In 2050, 92% decrease is expected compared to 2005 and 88% decrease compared to 1990. Projections of F-gases emissions according to WEM and WAM scenarios are presented in ***Figure 3.10*** and ***Table 3.11***.

Table 3.11: *Emission projections of F-gases in Gg of CO_2 eq. in WEM and WAM scenarios up to 2050*

WEM	**2022***	**2025**	**2030**	**2035**	**2040**	**2045**	**2050**
HFCs emissions	480.86	466.67	377.92	175.14	42.03	39.73	39.90
PFCs emissions	5.91	0.00	0.00	0.00	0.00	0.00	0.00
SF_6 emissions	15.38	15.16	14.20	12.57	12.20	12.20	12.20
NF_3 emissions	0.00	0.00	0.00	0.00	0.00	0.00	0.00
WAM	**2022***	**2025**	**2030**	**2035**	**2040**	**2045**	**2050**
HFCs emissions	480.86	466.62	376.23	160.44	21.02	16.74	15.28
PFCs emissions	5.91	0.00	0.00	0.00	0.00	0.00	0.00
SF_6 emissions	15.38	14.98	13.73	11.79	11.14	11.02	11.02
NF_3 emissions	0.00	0.00	0.00	0.00	0.00	0.00	0.00

***** Base year 2022; based on the GHG inventory submission 15. 3. 2024

Figure 3.10: *Emission projections of F-gases in Gg of CO_2 eq. in WEM and WAM scenarios up to 2050*



3.6.2. OVERVIEW, SCENARIO DEFINITION, BASE YEAR

General methodology of the emission projections calculations was based on the same structure as In the national inventory of greenhouse gases. The data structure for activities, input data, emission factors and emission calculations is based on the Common Reporting Format (CRF) of the UNFCCC. The outputs are aggregated. Emission projections are generally calculated by similar methodology as in the case for the national GHG inventory. Base year 2022 was selected for the emission projection. GWP from AR5 were used. In this report are presented results from WEM and WAM scenarios.

With Existing Measures scenario (WEM) – includes policies and measures (PAMs) adopted and implemented at the EU and national levels by the end of 2022 (base year) and the measures being in place to achieve the national renewables (RES) and energy efficiency targets.

With Additional Measures scenario (WAM) – is similar to the scenario decarbonisation scenario of CPS-PRIMES model and available draft of National Energy and Climate Plan. This is consistent with the results presented in the available draft of National Energy and Climate Plan of Slovakia, however scenario was updated based on the latest input data from operators and other parameters.

3.6.3. EU ETS/ESR SPLIT

An important indicator of emission trends is their development in individual sectors. European Commission legislation categorizes greenhouse gas emissions into two main groups based on the regulatory instrument governing them: emissions included in the EU ETS (Emissions Trading System) and those included in the EU ESR (Effort Sharing Regulation). The obligation to report greenhouse gas emissions separately for the EU ETS and EU ESR is also enshrined in the Regulation on the Governance of the Energy Union. This data is prepared by the Slovak Hydrometeorological Institute - Department of Emissions and Biofuels.

Although the EU ETS directive has been in force since 2005 and is currently in its fourth phase (2021 – 2030), the EU ESR decision is divided into the period from 2013 to 2020 (originally the EU ESD decision) and the period from 2021 to 2030 with a base year of 2005 (the year from which the reduction of emissions under the EU ESR is calculated). Another difference between the two systems is the application of their obligations. While the EU ETS does not contain specific obligations for the state (only rules for individual economic operators in the scheme) but annual trajectories for reducing the emission cap, under the EU ESR, the obligation is valid at the state level. Emissions under both systems undergo annual international verifications.

Table 3.12, ***Table 3.13***, ***Figure 3.11*** and ***Figure 3.12*** show detailed split of EU ETS and ESR GHG emission projections in WEM and WAM scenarios.

Table 3.12: *GHG emission projections split in EU ETS and ESR by sectors in Gg of CO_2 eq.*

WEM								
EU ETS	**2005***	**2022***	**2025**	**2030**	**2035**	**2040**	**2045**	**2050**
Total excluding LULUCF	25 231.77	17 418.25	16 981.80	16 707.93	16 376.58	16 023.11	15 804.40	15 613.14
1. Energy	16 092.23	10 534.09	9 873.16	9 614.22	9 249.36	8 777.70	8 572.21	8 359.94
2. Industrial processes	9 139.53	6 884.16	7 108.64	7 093.72	7 127.22	7 245.42	7 232.19	7 253.20
ESR	**2005***	**2022***	**2025**	**2030**	**2035**	**2040**	**2045**	**2050**
Total excluding LULUCF	25 383.78	19 594.46	19 939.23	19 864.27	18 403.29	16 362.07	14 451.92	12 972.42
1. Energy	20 793.45	15 078.03	15 529.59	15 690.24	14 627.52	12 780.76	10 862.60	9 433.71
2. Industrial processes	445.54	652.08	625.85	534.26	317.80	177.30	171.64	169.58
3. Agriculture	2 534.66	1 934.43	1 956.11	1 935.36	1 816.59	1 836.69	1 843.13	1 841.10
5. Waste	1 610.14	1 929.92	1 827.68	1 704.41	1 641.37	1 567.32	1 574.55	1 528.04

A significant trend observed in recent years is a shift in the proportion of emissions regulated under the EU ETS, which no longer account for a majority (declining from 50% in 2005 to 47% in 2022). This outflow of emissions from the EU ETS is due to several factors, including changes in the scope of the directive's application to individual installations (inclusion of aviation from 2012, expansion of the scope of activities from 2013), rising emission allowance prices, a decrease in free allowances, and, last but not least, the deliberate division of larger companies into smaller ones to avoid falling under the EU ETS.

Table 3.13: *GHG emission projections split in EU ETS and ESD/ESR by sectors in Gg of CO_2 eq.*

WAM								
EU ETS	**2005***	**2022***	**2025**	**2030**	**2035**	**2040**	**2045**	**2050**
Total excluding LULUCF	25 231.77	17 418.25	16 571.62	11 298.29	10 845.66	9 314.14	8 902.11	8 686.76
1. Energy	16 092.23	10 534.09	9 833.62	6 371.47	5 861.49	4 323.88	3 954.03	3 734.14
2. Industrial processes	9 139.53	6 884.16	6 738.00	4 926.82	4 984.17	4 990.26	4 948.08	4 952.62
ESR	**2005***	**2022***	**2025**	**2030**	**2035**	**2040**	**2045**	**2050**
Total excluding LULUCF	25 383.78	19 594.46	19 132.96	17 166.59	13 096.77	9 976.09	7 962.03	6 612.63
1. Energy	20 793.45	15 078.03	14 790.49	13 244.33	9 952.42	7 101.67	5 211.05	3 946.41
2. Industrial processes	445.54	652.08	625.63	527.62	293.35	141.73	129.42	121.16
3. Agriculture	2 534.66	1 934.43	1 932.89	1 803.84	1 404.42	1 390.64	1 334.53	1 294.36
5. Waste	1 610.14	1 929.92	1 783.95	1 590.79	1 446.58	1 342.05	1 287.03	1 250.7

* Base year 2022; based on the GHG inventory submission 15. 3. 2024

Figure 3.11: *GHG emission projections split in EU ETS and ESR in Gg of CO_2 eq. in WEM scenario*

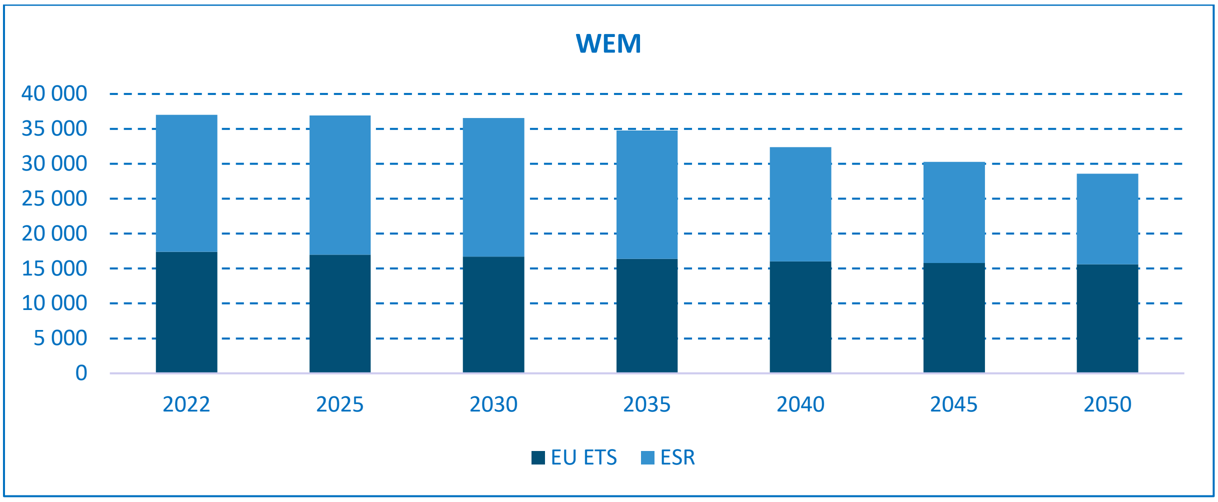
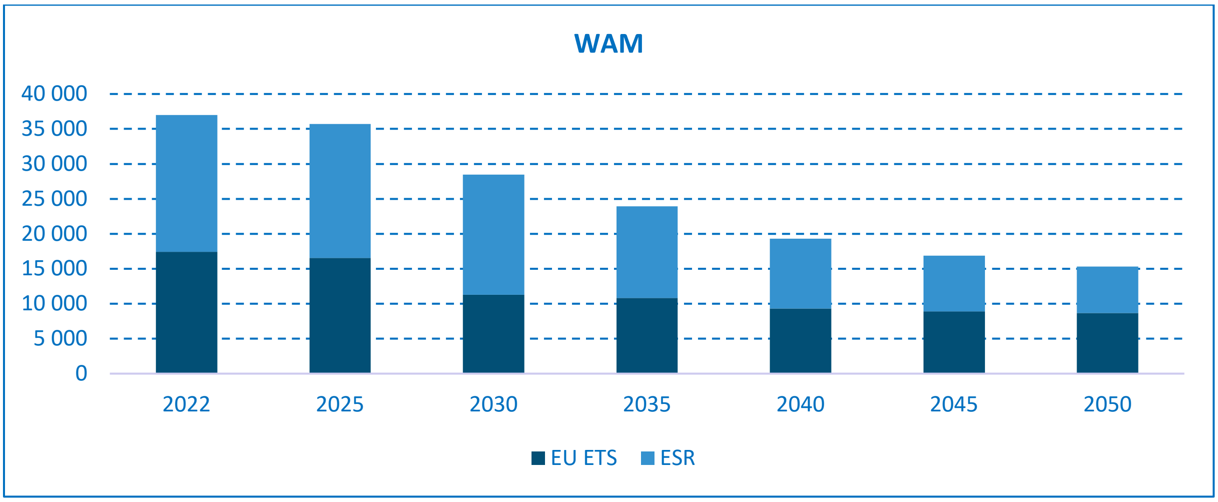


Figure 3.12: *GHG emission projections split in EU ETS and ESR in Gg of CO_2 eq. in WAM scenario*



3.6.4. INDIRECT EMISSION PROJECTIONS OF PRECURSORS

Emissions of precursors of greenhouse gases (GHGs) are detailed along with other air pollutants in the Report on Air Pollutants Emission Projections 2023 of the Slovak Republic[28]. Notably, carbon monoxide (CO) is excluded from this report, and no updated projections have been calculated up to date. Nevertheless, LULUCF sectoral precursor are not estimated as this sector is not part of the air pollutants report.

The emission projections for precursors under the WEM and WAM scenarios indicate significant reductions across key pollutants:

- Nitrogen oxides (NO_X): Projections show a decrease of 32.5% under the WEM scenario and 54.1% under the WAM scenario.
- Non-methane volatile organic compounds (NMVOC): Emissions are expected to decrease by 24.6% under WEM and 29.8% under WAM.
- Sulphur oxides (SO_X): Reductions of 25.9% in WEM and 56.5% in WAM are anticipated.
- Ammonia (NH_3): Emissions are projected to decrease by 14.6% under WEM and 32.6% under WAM.

The projected reductions are derived from detailed modelling of sectoral activities, incorporating existing and planned policies. Emission trends reflect technological advancements, shifts in energy sources, and the implementation of stricter air quality regulations. A breakdown of projected emissions by year and sector is provided in the tables below.

Table 3.14: *Emission projections of NO_X in kt*

Sector	2019	2020	2025	2030	2040	2050
	WEM					
Energy	45.33	43.10	42.74	36.16	28.19	25.21
IPPU	6.13	5.75	7.08	6.61	6.53	6.11
Agriculture	7.33	7.12	7.61	7.77	7.99	8.33
Waste	0.03	0.03	0.03	0.03	0.03	0.03
TOTAL	58.82	56.00	57.46	50.57	42.74	39.68
Sector	**2019**	**2020**	**2025**	**2030**	**2040**	**2050**
	WAM					
Energy	45.33	43.10	37.55	29.26	21.66	17.24
IPPU	6.13	5.75	6.86	4.42	4.30	3.87
Agriculture	7.33	7.12	6.28	6.30	6.19	5.85
Waste	0.03	0.03	0.03	0.03	0.02	0.02
TOTAL	58.82	56.00	50.72	40.01	32.18	26.99

Table 3.15: *Emission projections of SO_X in kt*

Sector	2019	2020	2025	2030	2040	2050
	WEM					
Energy	7.98	6.65	6.22	5.67	5.28	5.00
IPPU	7.72	6.65	8.05	7.25	7.12	6.63
Agriculture	NA	NA	NA	NA	NA	NA
Waste	0.006	0.006	0.005	0.005	0.005	0.004
TOTAL	15.71	13.30	14.28	12.92	12.41	11.63

---

[28] Report is available here: https://oeab.shmu.sk/app/cmsSiteBoxAttachment.php?ID=201&cmsDataID=0

Sector	2019	2020	2025	2030	2040	2050
	WAM					
Energy	7.98	6.65	5.82	3.89	3.28	2.54
IPPU	7.72	6.65	7.74	4.91	4.76	4.28
Agriculture	NA	NA	NA	NA	NA	NA
Waste	0.006	0.006	0.005	0.005	0.004	0.004
TOTAL	15.71	13.30	13.56	8.81	8.05	6.83

***Table 3.16:** Emission projections of NMVOC in kt*

Sector	2019	2020	2025	2030	2040	2050
	WEM					
Energy	57.06	53.56	59.39	52.65	45.88	38.49
IPPU	26.41	26.77	26.97	25.25	24.75	23.98
Agriculture	14.81	13.88	13.70	13.57	12.77	12.65
Waste	1.03	1.01	0.91	0.81	0.58	0.45
TOTAL	91.98	88.37	94.20	85.57	77.66	69.31
Sector	**2019**	**2020**	**2025**	**2030**	**2040**	**2050**
	WAM					
Energy	57.06	53.56	62.37	54.37	45.29	37.29
IPPU	26.41	26.77	26.65	22.78	22.10	21.22
Agriculture	7.49	7.02	6.33	6.24	5.88	5.80
Waste	1.03	1.01	0.81	0.61	0.37	0.27
TOTAL	91.98	88.37	96.15	84.01	73.64	64.59

***Table 3.17:** Emission projections of NH_3 in kt*

Sector	2019	2020	2025	2030	2040	2050
	WEM					
Energy	1.99	1.96	1.92	1.75	1.53	1.23
IPPU	0.21	0.27	0.28	0.28	0.27	0.26
Agriculture	34.32	30.06	29.63	29.49	29.19	29.30
Waste	0.37	0.45	0.43	0.44	0.47	0.49
TOTAL	30.20	26.77	26.28	26.12	25.80	25.78
Sector	**2019**	**2020**	**2025**	**2030**	**2040**	**2050**
	WAM					
Energy	1.99	1.96	1.92	1.71	1.35	1.04
IPPU	0.21	0.27	0.28	0.27	0.27	0.25
Agriculture	27.63	24.10	19.18	19.15	18.75	18.58
Waste	0.37	0.45	0.43	0.43	0.45	0.48
TOTAL	30.20	26.77	21.80	21.57	20.81	20.35

3.6.5. SENSITIVITY ANALYSIS

The current methodologies for the projections of emissions and removals have been used since the NC8 and BR5, however, sensitivity analysis for the projections is not performed. This is because the appropriate methodology for sensitivity analysis has not been considered. Sensitivity analysis can be implemented in the model TIMES for energy and IPPU emission projections, but more capacity is necessary. Further effort is needed in other sectors. This work will be implemented in future reporting.

Sensitivity analysis for LULUCF sector is provided in **Chapter 3.6.9.4**.

3.6.6. GHG EMISSION PROJECTIONS IN ENERGY SECTOR

Dynamic changes in global politics as well as economic developments in recent years and months have also significant impact and they were complications for the preparation of GHG emission projections, especially in view of the constant changes in the estimated development of macroeconomic indicators for the near future. The long-term development of greenhouse gas emissions also depends on other parameters, such as energy market developments, technological developments and the trading of CO_2 emission allowances. The EU ETS is one of the measures that was implemented before the projected base year, but the new trading period will continue to have an impact in the future. Nevertheless, the additional impact of this measure is limited due to the technical and economic potential. Despite the existing constraints resulting from dynamic changes in critical parameters, it is possible to reach a state of actual compliance with the emission reduction targets, as well as to create the conditions for further emission reductions after 2023.

Emission projections for first Biennial Transparency Report, were modelled separately for large and medium-sized energy sources, households, transport, fugitive emission categories.

3.6.6.1. GHG Emission Projections in Stationary Fuel Combustion

Input Parameters for Emission Projections

Input data for the calculation of GHG projections in model TIMES-Slovakia for energy are provided by CPS and Macro Economical Model (IEP), which was developed for the needs of the Low Carbon Strategy (NUS SK). Additional input data was available from the EU ETS Reports, National Energy Statistical yearbook, National Emission Information System (NEIS), NIMs (National Implementation Measures).

Fuels data provided by (ÚRSO) - prices of tradable fuels, if possible also separately for sectors such as industry, households and others: natural gas in EUR/GJ, heating oils, brown coal, black coal, coke, fuel wood, waste wood, wood chips in EUR/ton or EUR/GJ. Input data for the calculation of GHG projections in model TIMES from industry and energy are provided by model Compact PRIMES for Slovakia (CPS) and Macro Economical Model Envisage, which was developed for the needs of the Low Carbon Development Study of the Slovak Republic (LCDS). Additional input data was available from the EU ETS Reports, National Energy Statistical yearbook, NEIS, NIMs templates for benchmarking emissions of participating installations.

RES technologies provided by Ministry of Economy of the Slovak Republic - or with the association of operators of renewable sources accompanied with structure and time development. For individual types of resources, the following data are taken from: The JRC European TIMES Energy System Model.[29]

- Photovoltaics - estimated potential of electricity production in MWh/year in topographic distribution, i.e. by districts or regions
- Annual distribution of production - when it can be divided into hours, days, weeks and months, as the case may be, in a different arrangement than this production is balanced
- Investment costs EUR/kW
- Wind power plants - similar to photovoltaics
- Investment costs EUR/kW

---

[29] https://data.jrc.ec.europa.eu/collection/id-00287

- Annual power distribution as in the case of photovoltaics, (CPS-Slovakia)
- Biomass - biomass potential in TJ/year according to its type - wood, wood chips, etc., (CPS-Slovakia)
- Geothermal - Potential TJ/year in geographical distribution, investment costs EUR/GW, (CPS-Slovakia)

As a first step for the input parameters for projections in the TIMES-Slovakia model, energy and industrial sources included in the EU-ETS were analysed. The reasons for this approach are as follows:

- Sources included in this group are the most significant stationary sources of GHG emissions, primarily CO_2. These inputs parameters are crucial for correct aggregation of total CO_2, CH_4 and N_2O emissions.
- The new sets of NIMs (submitted in 2024) tentatively show decreasing trend of EU-ETS enterprises,
- The analysis is based on the data of 2022, for which there are data from files processed for the preparation of NIMs after 2022. These files contain data not only on fuel consumption and CO_2 emissions, but also on the production of electricity, heat, and benchmark commodities necessary for setting free emission allowances.
- Recommended parameters for reporting on GHG projections in ***Table 3.18*** shows the trajectory of the carbon price for sectors under the existing ETS in its current scope (power, industry, centralized heat, aviation sectors, and maritime industry) up to 2030, corresponding to the legally binding -55% climate target context. For long-term values beyond 2030, Table 3 shows two trajectories: a trajectory based on the EU Reference Scenario 2020 for the carbon value in “WEM” scenarios, and an indicative carbon value trajectory across the economy to reaching the EU climate neutrality for national (“WAM”) scenario.

Table 3.18: *Harmonized trajectory for the carbon price based on EC recommendations*

Scenario	Carbon price	2025	2030	2035	2040	2045	2050
WEM	ETS	95*	95*	100	100	160	190
	ETS 2	-	-	-	-	-	-
WAM	ETS	95*	95*	140	290	430	490
	ETS 2	-	45	70	100	130	160

* The corresponding carbon prices expressed in nominal values are about 100 and 102 EUR / t CO_2 for 2025 and 2030, assuming an index of 126.38 in 2023, 132 in 2025 and 145.74 in 2030, compared to 100 in 2015.[30]

- In addition to carbon prices, the model also offers other options for how measures can be achieved - it is possible to prohibit the purchase of new equipment with a certain fuel, to discard equipment that does not meet the technical parameters (such as older coal-fired

---

[30] Combining ESTAT HICP index for data until 2023 (data extracted in February 2024) and ECB HICP Survey of Professional Forecasters (Q1 2024) for data in 2024-2028:
https://www.ecb.europa.eu/stats/ecb_surveys/survey_of_professional_forecasters/html/ecb.spf2022q1~082bc1deaa.en.html

boilers) or, depending on the scenario, to enable the use of new technologies such as artificial carbon capture, hydrogen fuel based on regional availability in JRC-EU TIMES.[31]

- ***Table 3.19*** shows the proposed central harmonized trajectories for oil, gas, and coal fuel international prices recommended by European Commission.
- Final energy consumption figures are integrated, and primary energy consumption and the energy used in other energy conversion sectors are determined, using data provided by CPS-Slovakia.[32]

Table 3.19: *Proposed harmonized central trajectories for international fuel prices*

EUR2023	**Oil**			**Gas (NCV)**		**Coal**	
	€/GJ	**€/toe**	**€/boe**	**€/GJ**	**€/toe**	**€/GJ**	**€/toe**
2022*	16.7	701	102	35.1	1 469	10.9	457
2023*	12.5	523	76	10.9	455	4.4	183
2024	13.1	547	80	8.3	349	4.1	172
2025	12.4	520	76	9.4	394	4.1	172
2030	13.9	582	85	9.0	377	4.0	169
2035	15.4	645	94	8.2	344	3.8	161
2040	15.8	663	97	10.1	422	3.8	160
2045	17.2	718	105	9.9	412	4.0	166
2050	19.7	825	121	9.6	403	4.0	166
2055	23.8	996	146	9.6	403	4.1	170

Note: * 2018-2023 data are yearly average of daily value expressed in current EUR of dated Brent for oil, TTF day ahead for gas, steam coal CIF ARA 6000k for coal. The conversion from current EUR to EUR2023 uses the ESTAT HICP index (data extracted in March 2024).

Methodologies and Key Assumptions/Trends

The 2024 Projection Report, which forms the basis for this report, shows how greenhouse gas emissions might develop up to 2050, assuming the framework data in place and the parametrization of the instruments.

The projection report is based on models calculations by the Emissions and Biofuels Department (OEaB) with cooperation of Institute of Environmental Policy (IEP), Ministry of Environment of the Slovak Republic (MŽP SR) and with individual companies and their technological management-experts.

The results are presented with the sectors as defined in the Integrated National Energy and Climate Plan (NECP): energy, industry, buildings, (transport, agriculture, LULUCF and waste/other – sectors covered by other models). The results of the sectoral models are integrated with the assistance of an overarching model. Framework data, instruments to be included, and major assumptions for their parametrization were coordinated with the relevant ministries in the year 2023 – 2024.

The methodological model represents individual agents' energy demand and supply decisions and balances their supply and demand decisions using cost minimization. This approach, according to economic theory, leads in conditions of perfect competition to a solution with minimal energy costs

---

[31] https://web.jrc.ec.europa.eu/policy-model-inventory/explore/models/model-jrc-eu-times/

[32] https://www.minzp.sk/files/iep/2019_01_low-carbon-study.pdf

(Objective function) for end users. The output of the model are projections of key energy indicators in individual sectors:

- Energy demand (from the point of view of energy efficiency)
- Use of individual fuels
- Consumption and use of electricity
- Share of renewable energy sources
- CO_2, CH_4, N_2O emissions
- Amount of investments, fuel and other costs
- Fuel and electricity prices for the end user

Key assumption:

Hydropower

Looking ahead to the year 2030, it can be concluded that the construction of additional hydropower plants will be significantly limited, both for the sake of maximum use of the effective potential of water flows, as well as from the point of view of the effects of these waterworks on the environment. Further increase of installed capacity and production from hydro will take place mainly in the form of their reconstruction or modernization.

Geothermal

Support for the search and exploration of geothermal energy sources in order to make them available for energy purposes is also included in the Slovakia Program. The aim of this measure is mainly to support exploratory wells, which are the riskiest part of the investment in the use of geothermal resources. The most important project is the national project "Use of geothermal energy in the Košice basin".

Photovoltaic

Currently, support mechanisms for the installation of photovoltaic panels are operating in Slovakia, such as Green Homes and partially the Renovate the House program, which can be used by residents and households. In addition, the planned Green program is an enterprise that small and medium-sized enterprises will be able to use for the installation of photovoltaic panels. The basic prerequisite for the maximum use of photovoltaics in Slovakia is the ability to effectively integrate them into the electricity system, which is combined with the need to adapt and strengthen the electricity system so that it can provide capacity for these energy sources. In addition, the speed of development of commercial sources that supply power directly to the grid will depend mainly on the ability to increase the flexibility of the electricity system using battery storage, consumption management and intelligent grid management.

Wind

In December 2023, Slovakia joined the European Wind Charter, which includes, among other things, the acceleration of permitting processes or the commitment of member states to build new capacities. Based on this situation, it can be assumed that by 2030 it will be possible to build and put into operation wind power plants with a total installed capacity of 750 MW.

Biogas

Several projects are currently being prepared, including new biogas stations in Leopoldov and Žiar nad Hronom, and an increase in the installed capacity of the already existing biomethane production facility in Jelšava. Conversion of currently active biogas stations to biomethane stations is also planned. The produced biomethane will be used mainly as a fuel in heating plants in the highly efficient combined production of electricity and heat, and to a lesser extent in transport.

Preparation of data into model for projections

Structure of the model, TIMES-Slovakia, needs to process the conversion chain from primary sources to final energy consumption. This chain is compatible with the structure of the energy balance, which includes the levels of final consumption according to economic sectors, the area of energy transformation, i.e. production of electricity, heat, use of fuels in technologies, etc. and primary energy sources. The system applied in modelling is expressed by the following simplified diagram, where a virtual fuel mix level is created - where the fuel input to individual conversion technologies is simulated and the emission factors of the emissions are assigned at plant – specific level.

In the previous projections, for the increase in consumption - demand, we were based on the assumptions of economic growth expressed by the growth of sectoral value added (VA) for individual economic sectors. The final consumption of energy in the form of electricity, heat or direct consumption of fuels was aggregated for individual sectors, and its further increase was then controlled by the growth of VA. Due to the uncertainty of the economic development, we have decided where it is possible to tie the final consumption to a selected commodity for sources within the ETS, such as e.g. cement, glass, steel products, plastics, etc. However, where no representative commodity can be used, the output flows were aggregated according to the NACE category.

For non-EU ETS sources, we used a modelling approach that recalculates sectoral value added from the CPS Primes Slovakia model. These values are tied to sectoral fuel consumption and a pre-determined 'Demand projection' input." EU ETS-2 extension to transport and residential & commercial sectors is not included. Currently, there is not enough information about the implementation of this extension to reliably model its effects.

Emission projections in households

Emission from households combustion was modelled separately in MS Excel sheet model, where was taken into account improving of efficiency, equipment status and structure and good practise.

The projection calculation is based on inputs from CPS model calculations by Institute of environmental policy (IEP) and in line with the prepared National Energy and Climate Plan.

Information were obtained from the questionnaire surveys in households, new implemented and planned measures were taken into account. Based on this information datasets were improved together with estimations of natural improvement in the structure of households and heating equipment was implemented.

Main characteristic:

- Based on emission inventory methodology – excel model,
- Estimation of total energy demand per m^2 of living space in the household sector,

- Number of flats - living area of flats, flats under DH, age and renewal of flats,
- Structure of heating equipment, method of heating,
- Climatic conditions.

Model Description

TIMES (an acronym for *The Integrated MARKAL-EFOM System*) is an economic model generator for local, national, multi-regional, or global energy systems, which provides a technology-rich basis for representing energy dynamics over a multi-period time horizon. It is usually applied to the analysis of the entire energy sector, but may also be applied to study single sectors such as the electricity and district heat sector. Estimates of end-use energy service demands (e.g., car road travel; residential lighting; steam heat requirements in the paper industry; etc.) are provided by the user for each region to drive the reference scenario. In addition, the user provides estimates of the existing stocks of energy related equipment in all sectors, and the characteristics of available future technologies, as well as present and future sources of primary energy supply and their potentials.

All VEDA-TIMES model input data is organized in Excel workbooks (or files). VEDA2.0 then integrates information from all of these workbooks into internal databases to facilitate management of the model data and to prepare and submit a TIMES model, generated and solved with the GAMS sub-system.

The main goal of the model TIMES (***Table 3.20***) is to find energy system, that meets all demands over the entire time period at least costs. The scenarios are used specifically for region needed based on the possibilities of energy supplies, energy trade and technology availability. The configuration of production and consumption of commodities and their prices is performed.

The optimization is done across all sectors as well as across time periods. The result is optimal mix of technologies and fuels for the specific time period including emissions produced.

Once all the inputs, constraints and scenarios have been put in place, the model will attempt to solve and determine the energy system that meets the energy service demands over the entire time horizon at least cost. It does this by simultaneously making equipment investment decisions and operating, primary energy supply, and energy trade decisions, by region. TIMES assumes perfect foresight, which is to say that all investment decisions are made in each period with full knowledge of future events. It optimizes horizontally (across all sectors) and vertically (across all time periods for which the limit is imposed). The results will be the optimal mix of technologies and fuels at each period, together with the associated emissions to meet the demand. The model configures the production and consumption of commodities (i.e. fuels, materials, and energy services) and their prices; when the model matches supply with demand, i.e. energy producers with energy consumers, it is said to be in equilibrium. The model itself operates with several sectors:

- Energy Industry Combustion – (Public electricity and heat)
- Manufacturing Industries Combustion – (Food processing, Pulp and paper, Other)
- Iron and Steel - IPPU
- Chemicals - IPPU
- Non - Metallic Mineral - IPPU

- Non - Ferrous Metal - IPPU
- Refinery and Petrochemicals - IPPU

Initial work and prerequisites for the implementation of the TIMES model.

As a first step for the preparation of projections in the TIMES model were analysed energy and industrial resources included in the EU-ETS. The reasons for this procedure are as follows:

- Sources included in this group are the most significant stationary sources of greenhouse gas emissions, primarily CO_2.
- There is a need for price economic pressure to reduce CO_2 emissions caused by those CO_2 quotas and thus also the assumption of an increased price of CO_2 on the market with emission quotas. The new NIMs tentatively indicate this trend, especially for sources that will be reclassified from "carbon leakage" (CL) to nonCL.
- The analysis is based on the data of the year 2022, for which there are data from the files processed for the preparation of NIM after 2023. These files only contain data on fuel consumption and CO_2 emissions, but also on the production of electricity, heat, and commodities necessary for setting the benchmark (this serves for set quotas for the period after 2023). However, some files also contain data on the production of other commodities, even if these are not used to set quotas.
- In the case of changed projects, the growth of consumption - demand is based on the assumptions of the growth of the economy expressed by the growth of the added value "VA" for individual economic sectors. The final consumption of energy in the form of electricity, heat or direct consumption of fuels was aggregated for individual sectors and the further increase was then controlled by the growth of VA. With the uncertainty of the economic development (pandemic), we decided that where it is possible to link the final consumption to the selected commodity such as the production of cement, glass, steel products, plastics, etc. within the EU ETS. Where no representative commodity could be used, output streams were aggregated according to NACE rev.2 category - first two digits.
- TIMES model is used in the EU and outside it. It is very flexible, allows data processing individually for important sources or groups of sources, and the scope is not limited.

Before preparing input data for the model, it is necessary to prepare a balance sheet, i.e. so. Called the spider, which represents the network of progress and processing of incoming commodities - fuels and materials in the process of processing, energy production, distribution and final consumption of products and energy. In the entire scheme ***(Figure 3.13)*** there are several levels that more or less coincide with the energy statistics data processing system for the Statistical Office of the Slovak Republic:

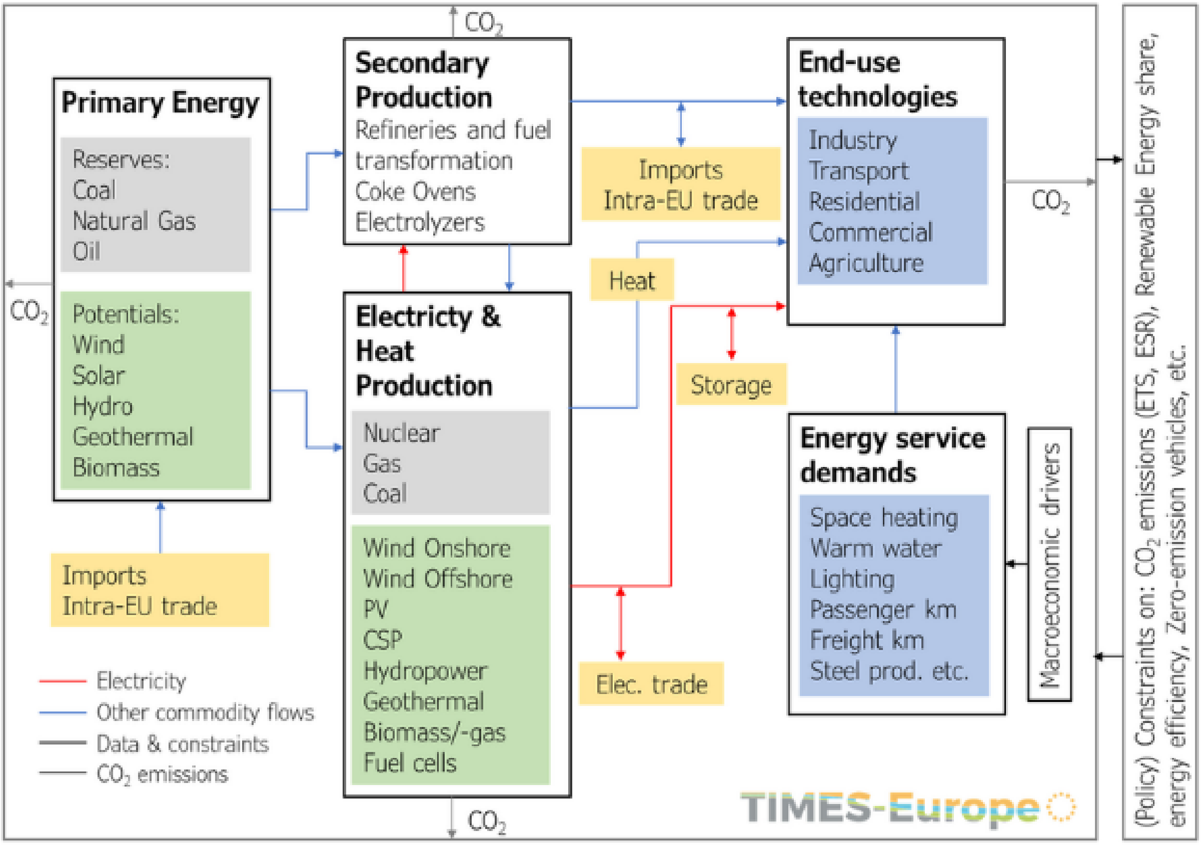
- Primary fuels – simulation**s** of their import or extraction.
- Material inputs. This represents for individual sources a summary of material inputs that participate in the formation of CO_2, for example by the decomposition of carbonates contained in them - inputs to lime plants, cement plants, ceramic production, glass plants, etc.

- Secondary fuels. In the specific conditions of the Slovak Republic, these are petroleum products, i.e. their production in the Slovnaft refinery together with the refinery gas that is burned in this complex. Furthermore, there are technical gases such as blast furnace gas, coke oven gas and converter gas, all produced and consumed within metallurgy.
- Fuelmix represents the simulation of the entry of fuels into energy or production processes. At this level, based on the composition of the fuel mixture, the aggregated GHG emission factor is defined for individual appliances and, if necessary, also the other AP.
- Production of energy carriers - electricity and heat. A mixture of fuels enters each such set, and electricity and heat leave in heating and power plants, and only heat in heating plants. Within the framework of the scheme, the distribution of the produced heat is used directly by the source or enters the remote supply system - DH.
- Integration of energy and material flows for the enterprise. This applies to enterprises with their own consumption of electricity and heat, which produce it themselves. Here, the flow of heat and electricity from own consumption is integrated with the material flow as well as the external supply of electricity and heat. In the latter case, the balance of import and export of electricity or heat is calculated.
- Simulation of the public electricity and heat distribution network.
- Simulation of final consumption - Demand according to macroeconomic and/or production indicators = assumption of product volumes, value added (VA) sectors, etc.
- Data processing from ETS reports and National implementation measures (NIMs) for modelling CO_2 and other GHG emissions.

Table 3.20: *SWOT analysis of the TIMES – Veda model*

Strengths	**Opportunities**
-Compatibility with emission model for emission inventories -Detailed data break down -Database used is compatible with EU data and national data -Detailed sectoral break down -Available Emission trading system -Finding Objective function (optimal solution) -Stochastic modelling -Seasonal availability -User constraint options (environmental, energy, monetary, supply, production, subsidies)	-Incorporate to the model new technologies (CHP, HP, ELE) -Attach transport (all transport categories) -Versatile use on different geographical level (Regional break down of energy demand) -Versatile use of time series (Day, Night and Peak availability) -Modelling of air pollutants (PM, NOx, SOx, CO, TOC) -Stochastic modelling of RES -Trading between regions
Treats	**Weakness**
-Maintenance fee -Infeasibility due to lack of macro economical and technology data -GAMS solvers need to be paid separately	-Disconnected from macroeconomic models -Too much pre-calculations needed -Lack of economic data -Lack of technology data (Investment cost for new technology) -Whole structure needed to be built up from scratch

Figure 3.13: *Different elements and structure of the TIMES model*



The projections should provide the decision-making authorities with answers to the following questions:

- Will it really be economically and technically possible to achieve carbon neutrality in 2050?
- What political, economic and technical measures will have to be applied?
- Will the technical measures considered so far be sufficient, such as changes in the fuel base, the use of biomass and other renewable energy sources, and measures on the side of consumption and reduction of energy intensity?
- Is it realistic to apply the CCS system in conditions of Slovakia?
- What preliminary costs would the considered measures represent?

Attributes for TIMES – Times contains so called „sets „which describes structural information of the energy system or qualitative characteristics of its entities (e.g. processes or commodities), parameters contain numerical information. Examples of parameters are the import price of an energy carrier or the investment cost of a technology. Most parameters are time-series where a value is provided (or interpolated) for each year (data year). The TIMES model generator distinguishes between user input parameters and internal parameters. The former is provided by the modeler (usually by way of a data handling system or "shell" such a VEDA-FE or ANSWER-TIMES), while the latter are internally derived from the user input parameters, in combination with information given by sets, in order to calculate for example, the cost coefficients in the objective function.

Basic modelling assumptions - TIMES model is particularly suited to the exploration of possible energy futures based on contrasted scenarios. Given the long horizons that are usually simulated with TIMES, the scenario approach is really the only choice (whereas for the shorter term, econometric methods may provide useful projections). Scenarios, unlike forecasts, do not pre-suppose knowledge of the main drivers of the energy system. Instead, a scenario consists of a set of coherent assumptions about the future trajectories of these drivers, leading to a coherent organization of the system under study. A scenario builder must therefore carefully test the scenario assumptions for internal coherence, via a credible storyline.

Policy 1: Carbon tax
A tax is levied on emissions of CO_2 at point of source. This policy is easily represented in TIMES making sure that all technologies that emit CO_2 have an emission coefficient, and then defining a tax on these emissions. The policy may indicate that the tax be levied upstream for some end-use sectors (e.g. automobiles), in which case the emission coefficient is defined at the oil refinery level rather than at the level of individual car types.

Policy 2: Cap-and-trade on CO_2
An upper limit on CO_2 emissions is imposed at the national level (alternatively, separate upper limits are imposed at the sector level). If the model is multi-country, trade of emission permits is allowed between countries (and/or between sectors). The trade may also be upper bounded by a maximum percentage of the actual emissions, thus representing a form of the subsidiarity principle.

Policy 3: Portfolio standard A sector is submitted to a lower limit on its efficiency
A sector is submitted to a lower limit on its efficiency. For instance, the electricity subsector using fossil fuels must have an overall efficiency of 50%. A similar example is an overall lower limit on the efficiency of light road vehicles.

This type of policy requires the definition of a new constraint that expresses that the ratio of electricity produced (via fossil fuelled plants) over the amount of fuel used be more than 0.5. TIMES allows the modeler to define such new constraints via the user constraints.

Policy 4: Subsidies for some classes of technologies
A more elaborate form of the subsidy might be to first levy an emission tax, and then use the proceeds of the tax to subsidize low-emitting and non-emitting technologies. Such a compound policy requires several sequential runs of TIMES, the first run establishing the proceeds of the carbon tax, followed by subsequent runs that distribute the proceeds among the targeted technologies. Several passes of these two runs may well be required in order to balance exactly the proceeds of the tax and the use of them as subsidies.

Scenarios, Parameters and PAMs
The base (reference) year for modelling the GHG emissions projection was the latest revised inventory year 2022 in all scenarios.

The policies and measures used were taken from the Low Carbon Strategy of the Slovak Republic[33], the National Program for the Reduction of Pollutant Emissions[34] and the Recovery Plan of the Slovak Republic.[35]

WEM scenario includes the following policies and measures at EU level and related national measures.

- Eco-design Framework Directive (Directive 2005/32/EC)
- Energy Labelling Directive (Directive 2010/30/EÚ)
- Energy Performance of Buildings Directive (2010/31/EU), Energy Efficiency Directive (Directive 2012/27/EU)
- Completion of the internal energy market, including the provisions of the 3rd package (Directive 2009/73/EC, Directive 2009/72/EC), Regulation (EC) 715/2009, Regulation (EC) 714/2009
- Directive on the Promotion of the Use of Energy from Renewable Sources - Renewable Energy Directive - including the amendment on ILUC (Directive 2009/28 EC as amended by Directive (EU) 2015/1513)
- Implementation of the Commission's proposed EU objective for a 25% share of renewable energy sources (RES) in total consumption by 2030, which was based on the proposal for a "Clean Energy for All Europeans" package presented by the European Commission in November 2016. The modelling did not take into account the fact that a considerably more ambitious EU objective (32%) was eventually adopted in December 2018
- National Renewable Energy Action Plan, in force since 2011
- EU ETS Directive 2003/87/EC with the latest amendment in 2015 (Decision (EU) 2015/1814 - Market Stabilization Reserve). The EU ETS is an economic and regulatory measure with a high positive impact on the reduction of greenhouse gas emissions and stimulates the use of biomass in the fuel mix and forces technological innovation
- Act No. 137/2010 Coll. on Air Protection as amended. This Act is supplemented by Act No. 401/1998 Coll. on air pollution charges, which serves to control and regulate emission limits for basic air pollutants
- Increasing energy efficiency with a number of measures in force since 2014 on the energy consumption side, according to which energy savings are reflected as a reduction in final energy consumption. These measures are broken down by sector (buildings, industry, public sector, transport and appliances). In the buildings sector, it is mainly about improving the thermal-technical performance of buildings by carrying out cost-effective deep renovation.

---

[33] Ministry of Environment of the Slovak Republic, "Low Carbon Strategy of the Slovak Republic," Ministry of Environment, 2020. [Online]: https://www.minzp.sk/klima/nizkouhlikova-strategia/

[34] Ministry of the Environment of the Slovak Republic, "National Emission Reduction Program" Ministry of the Environment, 2020. [Online]: https://www.minzp.sk/ovzdusie/ochrana-ovzdusia/narodne-zavazky-znizovania-emisii/narodny-program-znizovania-emisii/

[35] European Commission, "Recovery Plan", Office of the Government of the Slovak Republic, 2021. [Online]: https://www.planobnovy.sk/kompletny-plan-obnovy/zelena-ekonomika/

Legislation and changes to national technical standards since 2012 have introduced conditions for progressively stricter energy performance requirements for new and substantially renovated buildings, which are regularly reviewed. Measures in the buildings sector represent the most important source of potential energy savings by 2030.

- Optimization of district heating systems - switching from fossil fuels to biomass and natural gas and installation of combined heat and power (CHP) units in district heating systems. Industrial cogeneration plants produce industrial steam, which can also be used for district heating or is a secondary use of industrial steam. Other measures are also taken into account (e.g. improving the efficiency of central heat supply (CHS) systems, installing innovative district heating technologies, improving the supply of heat from combined heat and power plants).
- Earlier decommissioning of solid fuel power plants. The decommissioning of the Vojany and Nováky plants is foreseen in 2024 and 2023, in that order.

The specification of the WAM scenario according to the Low Carbon Development Strategy of the Slovak Republic depends on the logic of the draft EU scenarios and in particular on the EUCO3030 scenario[36], which sets the EU target for energy efficiency for 2030 at 30%.

The WAM scenario includes all measures from the WEM scenario named in the Low Carbon Development Strategy of the Slovak Republic, while additionally includes measures and more ambitious targets for RES and EE, ambitious plans of the new EC under the Green Deal.[37]

- The national target for the ESR is -22.7%
- Increasing the EU ETS carbon price after 2022 - The EU ETS carbon price affects the energy sector as well as energy-intensive industries and is a major driver of emissions reductions. Electricity generators will need to respond to the pressure of rising allowance prices to facilitate their own transition from coal to other low- to zero-emission sources.
- Decarbonizing electricity generation after 2022 through RES and nuclear development.
- RES support scheme in electricity generation with envisaged RES technologies such as solar PV, onshore wind turbines, biogas/biomethane and biomass. The scenarios assume support of 50 MW in the period 2030-2050, followed by support of a further 500 MW on the basis of auctions.
- Increasing the share of nuclear energy in the energy mix of the Slovak Republic. This increase in the medium term (2022-2027) will be mainly due to the commissioning of two new nuclear reactors at the Mochovce Nuclear Power Plant.
- Continuing to reduce final energy consumption in all sectors after 2022. The measure puts emphasis on policies supporting the acceleration of the renewal of the building stock

---

[36] European Commission, „EUCO scenarios," 2016. [Online]: http://www.e3mlab.eu/e3mlab/index.php?option=com_content&view=article&id=532%3Aeuco-scenarios&catid=1%3Alatest-news&Itemid=82&lang=en

[37] European Commission, „EU Green Deal," 2019. [Online]: https://ec.europa.eu/info/strategy/priorities-2019-2024/european-green-deal#documents

(residential and non-residential, public and private), with a focus on carrying out cost-effective in-depth renovations and applying minimum energy performance requirements for near-zero energy buildings after 2025 for new buildings.

Most of the above measures were applied at the level of the Compact Primes for Slovakia (CPS-PRIMES[1])[38] model, from which trends in energy consumption or other parameters were taken for modelling emissions in the TIMES model.[39]

In addition to the measures mentioned above, the WAM scenario also took into account:

- Assessment of the future structure of appliances used for domestic heating based on survey data.
- Support for the replacement of old solid fuel boilers in households with low-emission systems.
- Support for insulation of family houses - Program Slovakia, Green renovation.
- Awareness campaign and education on good coal and biomass combustion practices.

Emission levels in the coming years are determined only by the final energy growth rate.

The long-term development of greenhouse gas emissions also depends on other parameters, such as energy market developments, technological developments and the trading of CO_2 emission allowances. The EU ETS is one of the measures that was implemented before the projected base year, but the new trading period will continue to have an impact in the future. Nevertheless, the additional impact of this measure is limited due to the technical and economic potential. Despite the existing constraints resulting from dynamic changes in critical parameters, it is possible to reach a state of actual compliance with the emission reduction targets, as well as to create the conditions for further emission reductions after 2025.

This chapter exclude emissions from the fuel consumption in transport and fugitive emissions. Emissions from small households not connected to district heating system (DHS) were modelled separately and a description of the procedure is given at the chapter “Methodologies and key assumption”.

GHG Emission Projections by Categories and Gases

Emission projections in the Energy sector were modelled separately for large and medium-sized energy appliances, households’ categories. The calculations of the scenarios in the projection report are based on the national Greenhouse Gas Inventory. The current Greenhouse Gas Inventory available at the time this scenario was calculated is the provisional Greenhouse Gas Inventory from the 2024 reporting year. It was prepared in accordance with the 2006 IPCC Guidelines for National Greenhouse Gas Inventories. The greenhouse gas potentials used for the 2024 projections correspond to those of the 5th Assessment Report of the IPCC (AR5).

---

[38] European Commission, „Integrated National Energy and Climate plan for 2021 to 2030 for Slovakia,“ 2019. [Online]: https://ec.europa.eu/energy/sites/ener/files/sk_final_necp_main_en.pdf

[39] ETSAP, „The TIMES model,“ The Energy Technology Systems Analysis Program, 2005. [Online]: https://iea-etsap.org/index.php/etsap-tools/model-generators/times

Figure 3.14 shows trend of the GHG emission projections in the energy sector in stationary fuels combustion categories. The decrease in emissions is visible especially in the category of electricity and heat production and in households (1.A.4). The largest share of the decrease in emissions in the WAM scenario is visible in category 1.A.1 (***Figure 3.15***). A shorter decrease in emissions is expected in industrial energy.

Figure 3.14: *Total GHG emission projections in Gg of CO_2 eq. in the Energy sector in WEM scenarios*

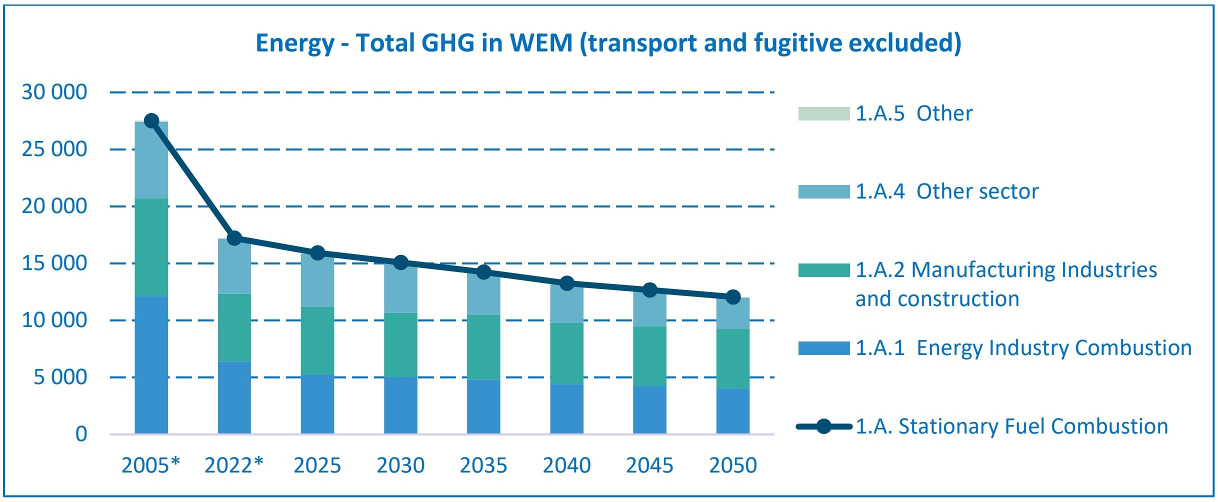


Figure 3.15: *Total GHG emission projections in Gg of CO_2 eq. in the Energy sector in WAM scenarios*

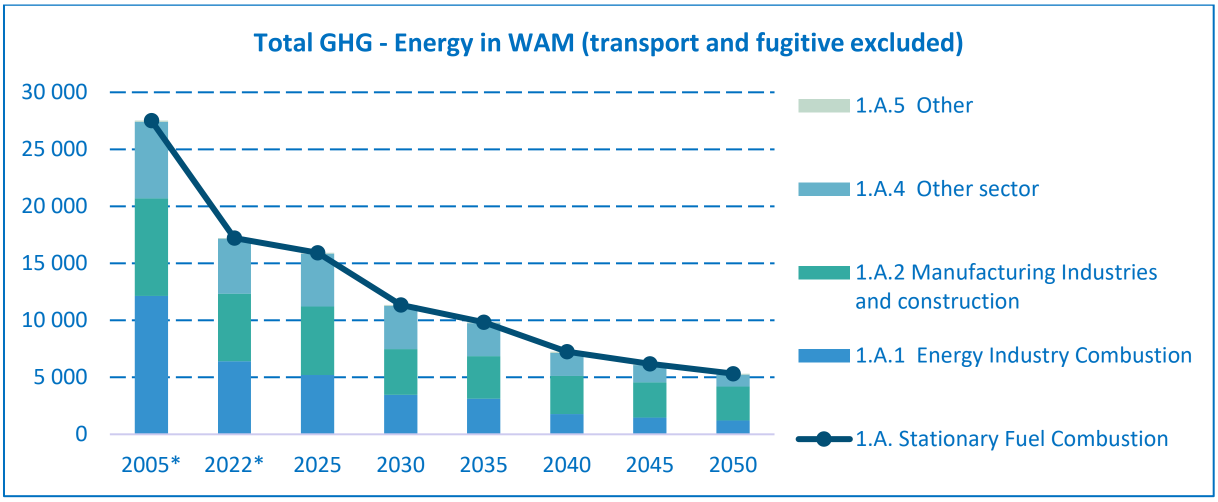


Table 3.21: *GHG emission projections in Gg of CO_2 eq. in Energy sector in WEM and WAM scenarios*

WEM	**2022***	**2025**	**2030**	**2035**	**2040**	**2045**	**2050**
1.A. Stationary Fuel Combustion	17 221.17	15 927.51	15 070.00	14 250.79	13 244.38	12 661.96	12 060.63
1.A.1 Energy Industry Combustion	6 407.46	5 251.81	5 023.25	4 836.86	4 424.12	4 242.35	4 024.53
1.A.2 Manufacturing Industries and construction	5 922.85	5 941.10	5 641.26	5 633.23	5 353.29	5 264.02	5 220.06
1.A.4 Other sector	4 828.48	4 645.80	4 314.78	3 689.66	3 376.91	3 067.34	2 729.60
1.A.5 Other	62.38	88.80	90.71	91.03	90.06	88.24	86.43

WAM	2022*	2025	2030	2035	2040	2045	2050
1.A. Stationary Fuel Combustion	17 221.17	15 927.49	11 357.81	9 835.15	7 237.44	6 173.51	5 326.45
1.A.1 Energy Industry Combustion	6 407.46	5 200.48	3 468.38	3 124.04	1 782.18	1 463.09	1 213.50
1.A.2 Manufacturing Industries and construction	5 922.85	6 005.65	3 997.01	3 735.62	3 336.52	3 091.44	2 971.82
1.A.4 Other sector	4 828.48	4 632.56	3 801.72	2 884.45	2 028.68	1 530.73	1 054.70
1.A.5 Other	62.38	88.80	90.71	91.03	90.06	88.24	86.43

***** Base year 2022; 2022 based on the GHG inventory submission 15. 3. 2024

Projections of CO_2 emissions in the Energy sector

CO_2 emissions in the Energy sector decreased between 2005 and 2022 from 27 Gg CO_2 to 16,8 Gg CO_2. The mentioned decrease represents a value of 37%. Emissions in the energy sector - fuel combustion come mainly from the energy industry (production of electricity and heat), processing industry and construction, fuel pipeline transport and other energy industries. The most important sources of emissions are emissions from electricity and heat production, oil refineries and iron and steel production. Emissions from road, rail, air and ship transport are listed separately in the subsection below. The breakdown of emissions within the EU ETS into individual parts is shown in ***Figures 3.16***. and ***3.17***. In the ***Table 3.22*** are projection in energy sector for both WEM and WAM scenarios. As it is visible, both scenarios contain decarbonisation measure, known as phase-out of solid fossil fuel in Slovakia’s biggest thermal power plant in Vojany and Nováky.

Figure 3.16: *Emission projections of CO_2 in Gg in the Energy sector in WEM scenarios*

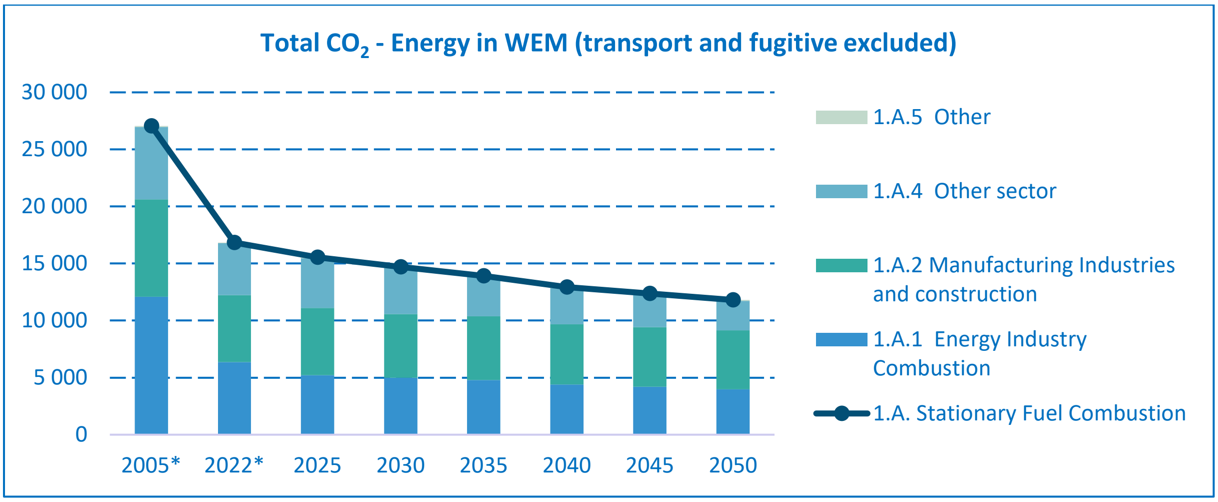


Figure 3.17: *Emission projections of CO_2 in Gg in the Energy sector in WAM scenarios*

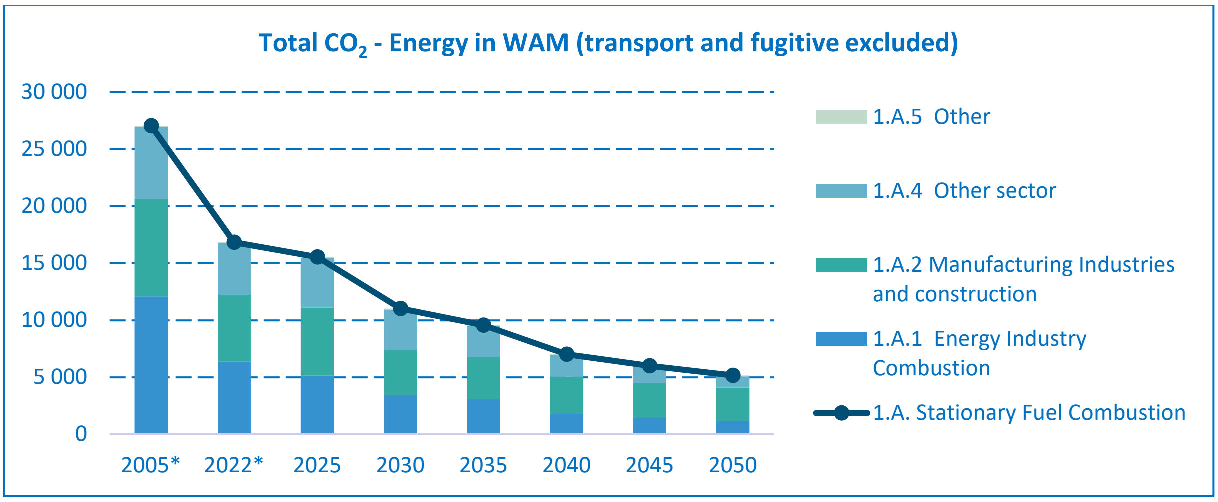


Table 3.22: *Emission projections of CO_2 in Gg in the Energy sector in WEM and WAM scenario*

WEM	**2022***	**2025**	**2030**	**2035**	**2040**	**2045**	**2050**
1.A. Stationary Fuel Combustion	16 832.08	15 555.71	14 699.12	13 919.59	12 930.71	12 380.38	11 806.34
1.A.1 Energy Industry Combustion	6 366.07	5 217.18	4 986.82	4 800.10	4 387.02	4 205.66	3 987.24
1.A.2 Manufacturing Industries and construction	5 873.92	5 897.97	5 588.66	5 583.05	5 294.44	5 204.98	5 162.09
1.A.4 Other sector	4 530.23	4 352.30	4 033.47	3 445.95	3 159.74	2 882.04	2 571.12
1.A.5 Other	61.85	88.26	90.17	90.49	89.52	87.71	85.89
WAM	**2022***	**2025**	**2030**	**2035**	**2040**	**2045**	**2050**
1.A. Stationary Fuel Combustion	16 832.08	15 553.27	11 032.83	9 567.92	7 022.44	5 990.95	5 163.48
1.A.1 Energy Industry Combustion	6 366.07	5 165.94	3 443.71	3 098.89	1 757.42	1 438.32	1 186.80
1.A.2 Manufacturing Industries and construction	5 873.92	5 959.45	3 949.49	3 685.41	3 280.57	3 035.99	2 915.73
1.A.4 Other sector	4 530.23	4 339.62	3 549.46	2 693.13	1 894.93	1 428.93	975.06
1.A.5 Other	61.85	88.26	90.17	90.49	89.52	87.71	85.89

***** Base year 2022; 2022 based on the GHG inventory submission 15. 3. 2024

Projections of CH_4 Emissions in the Energy Sector

CH_4 emission projections in the Energy sector ***Figures 3.18*** and ***3.19*** and ***Table 3.23***.

Figure 3.18: *Emission projections of CH_4 in Gg in the Energy sector in WEM scenario up to 2050*

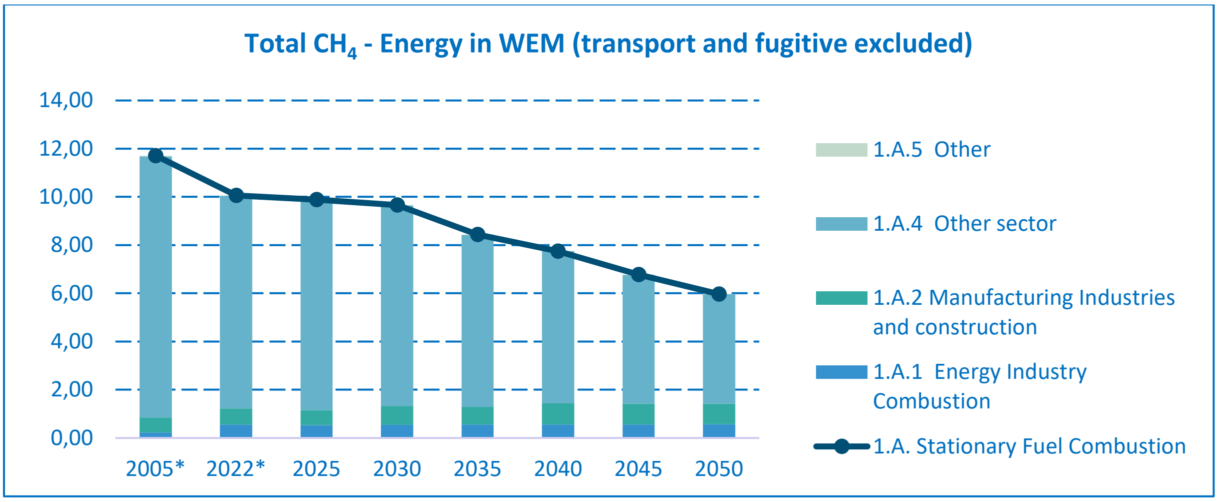
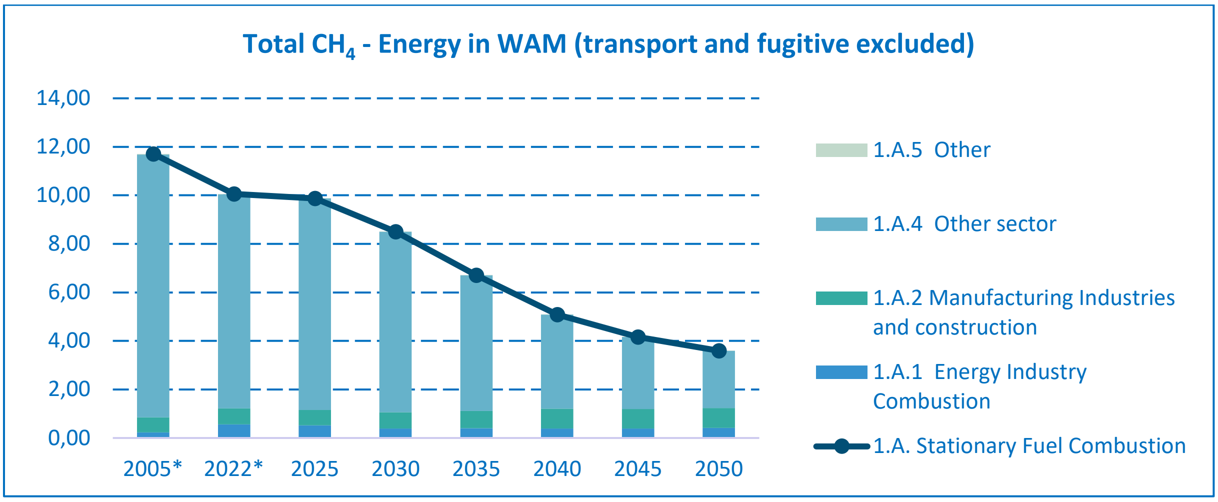


Figure 3.19: *Emission projections of CH_4 in Gg in the Energy sector in WAM scenario up to 2050*



The following ***Table 3.23*** shows result of projections for both scenario WEM and WAM for CH_4.

Table 3.23: *Emission projections of CH_4 in Gg in the Energy sector in WEM and WAM scenarios*

WEM	**2022***	**2025**	**2030**	**2035**	**2040**	**2045**	**2050**
1.A. Stationary Fuel Combustion	10.06	9.89	9.66	8.43	7.75	6.77	5.97
1.A.1 Energy Industry Combustion	0.56	0.53	0.55	0.56	0.56	0.56	0.56
1.A.2 Manufacturing Industries and construction	0.66	0.63	0.78	0.74	0.87	0.87	0.85
1.A.4 Other sector	8.83	8.73	8.33	7.13	6.31	5.34	4.54
1.A.5 Other	0.011	0.01	0.01	0.01	0.01	0.01	0.01
WAM	**2022***	**2025**	**2030**	**2035**	**2040**	**2045**	**2050**
1.A. Stationary Fuel Combustion	10.06	9.875	8.508	6.711	5.088	4.161	3.596
1.A.1 Energy Industry Combustion	0.56	0.525	0.387	0.396	0.389	0.390	0.421
1.A.2 Manufacturing Industries and construction	0.66	0.630	0.678	0.725	0.814	0.807	0.816
1.A.4 Other sector	8.83	8.71	7.44	5.58	3.88	2.96	2.35
1.A.5 Other	0.011	0.01	0.01	0.01	0.01	0.01	0.01

***** Base year 2022; 2022 based on the GHG inventory submission 15. 3. 2024

Less than 1.6% of emissions average comes from methane (CH_4), which is associated with processing and combusting fossil fuels. Emissions from the electricity sector are almost entirely covered by the European Emission Trading System. In WEM scenario, category (Public electricity and heat production) and Manufacturing Industries and construction we are expecting to slight increase of methane emission due to biomass consumption increase and shortage of natural gas.

Energy-related CH_4 emissions arise from the combustion and conversion of fossil fuels. Fugitive methane emissions arise from the extraction, transport and processing of fuels. Projections of CH_4 emissions from the combustion and conversion of fossil fuels were modelled using the fuel consumption in each scenario according to the IPCC method and the IPCC recommended aggregated emission factors.

The modelling used the same scenarios as for CO_2 emissions from combustion and fuel switching. This approach makes it possible to determine the impact of CO_2 reduction measures on the level of CH_4 emissions. Annual fugitive CH_4 emissions were calculated separately in chapter "Fugitive emission".

Projections of N_2O Emissions in the Energy Sector

N_2O emissions in the Energy sector are described in the following ***Figures 3.20*** and ***3.21*** for WEM and in the ***Table 3.24*** for WAM scenario. Energy-related N_2O emissions arise from the combustion and conversion of fossil fuels. N_2O emissions from transport have been calculated within this sector. Projections of methane N_2O emissions were similarly calculated using the IPCC method, which uses recommended emission factors. The scenarios for calculating emissions from combustion and fuel conversion are the same as those for CO_2 and CH_4 emissions, making it possible to analyse the impact of measures to reduce CO_2 emissions and N_2O production.

Figure 3.20: *Emission projections of N_2O in Gg in the Energy sector in WEM scenario up to 2050*

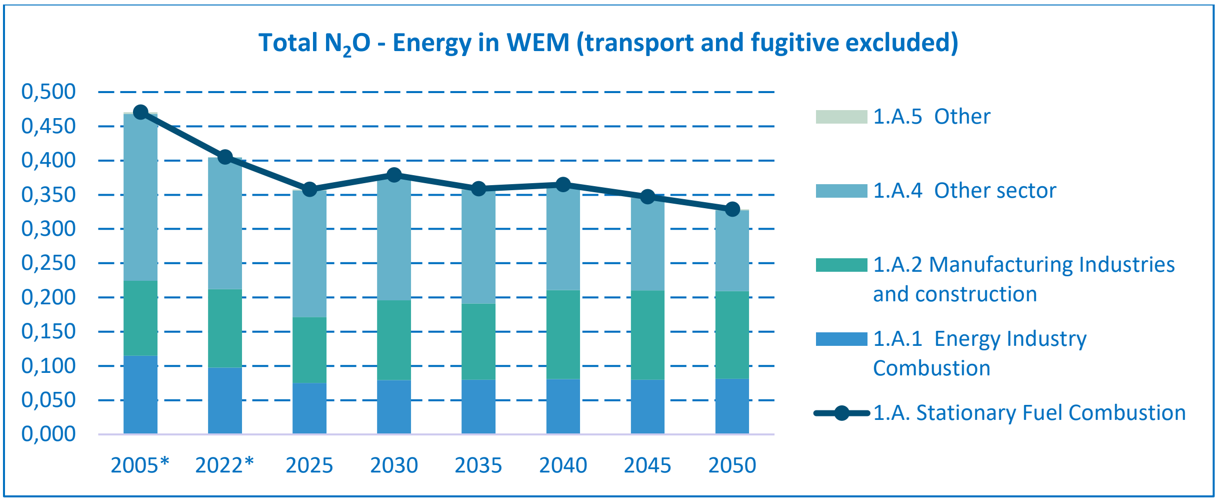


Figure 3.21: *Emission projections of N_2O in Gg in the Energy sector in WAM scenario up to 2050*

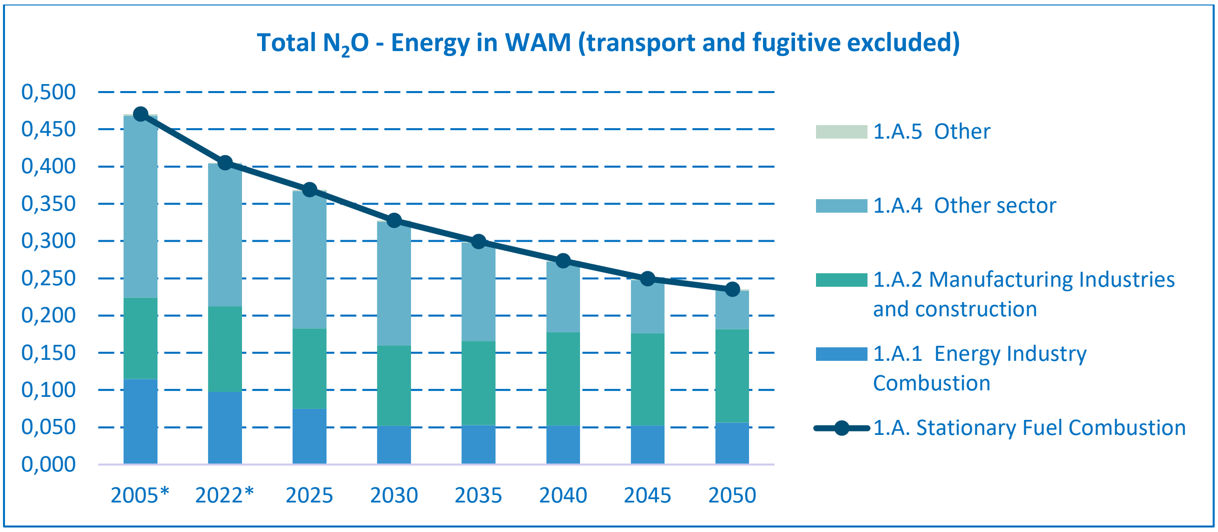


Table 3.24: *Emission projections of N_2O in Gg in the Energy sector in WEM and WAM scenarios*

WEM	**2022***	**2025**	**2030**	**2035**	**2040**	**2045**	**2050**
1.A. Stationary Fuel Combustion	0.405	0.358	0.379	0.359	0.365	0.347	0.329
1.A.1 Energy Industry Combustion	0.098	0.075	0.079	0.080	0.081	0.080	0.081
1.A.2 Manufacturing Industries and construction	0.115	0.096	0.116	0.111	0.130	0.131	0.129
1.A.4 Other sector	0.192	0.185	0.182	0.166	0.152	0.135	0.118
1.A.5 Other	0.001	0.001	0.001	0.001	0.001	0.001	0.001
WAM	**2022***	**2025**	**2030**	**2035**	**2040**	**2045**	**2050**
1.A. Stationary Fuel Combustion	0.405	0.369	0.327	0.299	0.274	0.249	0.235
1.A.1 Energy Industry Combustion	0.098	0.075	0.052	0.053	0.052	0.052	0.056
1.A.2 Manufacturing Industries and construction	0.115	0.108	0.108	0.113	0.125	0.124	0.125
1.A.4 Other sector	0.192	0.185	0.166	0.132	0.095	0.072	0.052
1.A.5 Other	0.001	0.001	0.001	0.001	0.001	0.001	0.001

* Base year 2022; 2022 based on the GHG inventory submission 15. 3. 2024

General Summary

Emissions in WAM scenario will continue to decline across all sectors between 2025 and 2035, with the largest declines, both absolute and relative, expected in the electricity and heat sector. Electricity and heat emissions will decrease because the capacity of solar and wind energy will increase further towards 2035, while electricity demand will increase in WAM scenario mainly due to higher consumption in households and services. In WEM scenario we used a less ambitious electrification scenario provided by Slovak electricity transmission system (SEPS). Additionally, we are assuming the start-up of the fourth nuclear reactor (Mochovce IV) in both scenarios.

Overall, this would result in emissions by 2030 that would be 52% below 1990 levels respectively 60% in WAM scenario. In both variants, the national target to reduce greenhouse gas emissions with 55% by 2030 compared to 1990 levels is achieved only in WAM. Looking towards 2040, greenhouse gas emissions are expected to decline further in almost all sectors after 2035. However, as described in the Climate and Energy Outlook, there are currently limited policies which detail further major emission reductions by 2040. In February 2024, the European Commission proposed a European climate target for 2040 of a net 90 percent greenhouse gas emission reduction compared to 1990 European decision-making on the 2040 target still has to take place, however.

Achieving the short-term binding target of a 55% emission reduction by 2030 would be possible primarily through the electrification of the Kosice steelworks. Other important measures include the adoption of electric vehicles (described in Transport category), building insulation, and electrification across various sectors. The closure of coal-fired power plants in Nováky and Vojany, along with the launch of an additional unit at the Mochovce nuclear power plant (Block IV), has already contributed to a cleaner energy mix. A crucial step is the introduction of an Emissions Trading System (ETS) for the building and transport sectors (ETS 2) starting in 2027, with an anticipated price of around €59 per ton in 2030.[40]

Electricity production

The Slovak government approved a plan in 2018 to phase out coal-based electricity generation at the Nováky power plant by the end of 2023. This decision has raised concerns about the future of heat supply in the region of Horná Nitra, which heavily relies on the plant for heating. The Nováky power plant provides heat to several cities and towns, including Prievidza, Nováky, and Zemianske Kostoľany, as well as various industrial facilities. The current system of heat supply is centred around a centralized heat source that combust brown coal.

With the imminent closure of the coal-fired plant, there is an urgent need to find a sustainable alternative to ensure uninterrupted heat supply for the region. The Slovak government has identified the development of a sustainable heating system as a priority, focusing on solutions that are both environmentally friendly and economically viable.

Key points:

- Phase-out of coal: The Nováky power plant, a major source of heat for the Horná Nitra region, is set to close in 2023.
- Need for a sustainable alternative: A new heating system must be developed to replace the coal-fired plant and ensure continued heat supply.
- Government involvement: The Slovak government is actively involved in finding a solution and has organized discussions with stakeholders.
- Challenges: The transition to a new heating system presents challenges, including the need to balance environmental concerns with economic viability.

In essence, need to find a sustainable solution for heating the Horná Nitra region following the closure of the coal-fired power plant. The government is actively seeking a solution that will meet the region's energy needs while also protecting the environment. One of the options in (WEM and WAM) is the installation of a new solid biomass heat source, a heat pump and a natural gas backup source.

The Vojany power plant in Slovakia has experienced a significant decline in its operations due to the phasing out of coal-fired power generation.

---

[40] The implementation of ETS 2 measures was hindered by the incomplete sectoral representation within the TIMES-Slovakia model.

Key points:

- Gradual shutdown: Several units at Vojany were taken out of service starting in 2014 due to factors such as technical obsolescence, environmental regulations, and market conditions.
- Reduced capacity: The total capacity of the units that were decommissioned amounted to 1210 MW.
- Operational units: Before its complete closure, Vojany consisted of two operational units with a combined capacity of 220 MW.
- Flexible operation: These units were typically operated based on the demand for electricity and prevailing market prices.
- Final closure: The coal-fired operations at Vojany were fully terminated in March 2024, marking a significant milestone in Slovakia's transition away from coal-based power generation.

Fuel production

Slovakia has one large refinery, situated in capital city of Bratislava. This refinery has a total capacity of about 5.5 million tonnes of crude oil. The degree of utilisation is high, in some years reaching 100%. It is the biggest seller in the domestic market. In the petrochemical segment, main activities include the production and sale of polyethylene and polypropylene. The refinery in Slovakia produce many relatively light oil products (LPG, naphtha, petroleum, diesel) from heavier crude oil with a sulphur content of 1.5%. During 2023, refinery processed the most alternative oil in history, namely 815 thousand tons, which is almost 4 times the volume compared to the year 2022. In the coming period, refinery will focus on the implementation of transformation projects in connection with the expansion of the processing of non-Russian oil. Given the constraints of the available technological measures, we do not foresee a substantial decrease in emissions within this scenario. The reduction is predominantly attributed to a decline in the proportion of fossil fuels in the transport sector, as projected by the COPERT model (see section Transport). Both scenarios within this category are contingent upon projected developments in transportation. Notably, the WAM scenario exhibits a more pronounced reduction in GHG emissions from fuel production (Slovnaft) owing to synergistic effects stemming from the proliferation of electric mobility and the advent of hydrogen technologies.

Steel production (industrial combustion)

"U.S. Steel Košice experienced a slight recovery after the COVID-19 pandemic, with increased production. However, the steel industry is facing a financially and technologically challenging period, especially considering the potential disruption to decarbonisation plans due to a potential change in ownership. The company had planned to install electric arc furnaces to significantly reduce greenhouse gas emissions, a crucial step for both the company and Slovakia in meeting its -55% emissions reduction target by 2030. Other planned measures in Energy sector included the decommissioning of the coking battery (category 1.A.2) and replacing the combustion of energy-grade coal used for generating process steam and electricity with natural gas. Further decarbonisation efforts involved additional shutdowns and efficiency improvements in various divisional plants. However, the future of these plans hinges on the new owner's commitment to decarbonisation. There is a possibility that the company may pursue a different path, such as hydrogen-based iron ore reduction. The full picture regarding these uncertainties is expected to become clearer after 2025." As a result, we have chosen to keep these scenarios unchanged and to proceed with the planned technological shift from two conventional blast furnaces to two electric arc furnaces, as envisaged in the WAM scenario.

Fertilizer production

The biggest ammonia producer in Slovakia consumes, natural gas as basic raw material for ammonia production, where, in addition to energy use, it serves as a raw material for the production of hydrogen by steam reforming. Today, nitrogen is almost exclusively produced by low-temperature rectification of liquefied air, and rather forms surpluses during the production of more desirable oxygen. The energy source here is electrical energy for liquefaction. It is the production of hydrogen that is responsible for the consumption of natural gas, and by replacing it with electrolysis we obtain the so-called green hydrogen in the event that electricity from renewable energy sources is used as a source - photovoltaics, wind power plants and/or electricity from nuclear power plants. The proposed measure aims to transition the existing ammonia production process from using grey hydrogen produced by steam methane reforming to a hybrid system that incorporates green hydrogen produced via electrolysis powered by renewable energy. Under current EU rules for non-ETS installations, the resulting ammonia will be a blend of grey and green ammonia, with the composition directly related to the proportion of each hydrogen feedstock. This measure was excluded from all scenarios due to the unavailability of the required technical data within the timeframe of our projections. Additionally, an external study commissioned by the manufacturer revealed a negligible reduction in GHG emissions within the Energy section.

Heat production

The Slovak government is aiming to decarbonize the heating sector by promoting the use of renewable energy sources, improving energy efficiency, and supporting flexible operation of heat plants. This transition is aligned with the EU's broader climate goals

The key points include:

- Promotion of renewable energy sources: The government will prioritize the use of renewable energy sources (RES) such as biomass, biogas, and waste for heat production. This includes supporting district heating systems (DHS) that utilize RES and waste heat from industrial processes.
- Encouraging heat pumps: Heat pumps, which are considered a form of RES, will also be promoted due to their significant cost savings in heat production.
- Phased transition from coal to natural gas: While the transition from coal to natural gas will be supported, investments in natural gas-fired heat generation facilities must align with the EU's climate goals for 2030 and 2050.
- Promoting flexible operation of heat plants: The government plans to stimulate flexible operation of heat plants for regulatory purposes, such as providing capacity payments.
- Prioritizing combined heat and power (CHP): CHP plants will be preferred over traditional fossil fuel-based power generation, as they offer greater efficiency and can contribute to grid stability.

- Integrating renewable energy into existing infrastructure: The existing infrastructure of heat plants will be utilized to integrate RES, such as biogas and biomethane, into the CHP process.
- Promoting circular economy: The text also emphasizes the importance of promoting the circular economy by utilizing waste for energy generation.

Households

The WEM scenario projects a significant reduction in solid fossil fuel consumption and balanced trend in gas consumption these two trends will stabilise greenhouse gas emissions by 2030, keeping them at slightly lower level as in the 2022. In the WAM scenario, a significant reduction in emissions by 2030 (-23.6%). This reduction will be mainly due to significant savings in heating. Due to investments in insulation and more efficient equipment. There will be a decrease in the consumption of natural gas (-19.7%) and solid fuels (-76.1%).

After 2030, the share of heat pumps in heating will increase the use of heat pumps will lead to partial savings in final energy consumption. These will be significantly supported, especially in the WAM scenario, by investments in improving the thermal insulation properties of buildings. The final energy consumption of fuels for heating and hot water (excluding electricity consumption) in households sector between 2030 and 2050 will decrease by 45% in WEM scenario and by 70% in WAM scenario.

Due to decarbonisation in the WAM scenario will also see a significant shift away from natural gas, which will be gradually replaced by biogas and hydrogen and with mix of synthetic gases. In the WEM scenario, the share of natural gas will also be significantly reduced, mainly in favour of electricity. Due to the significant electrification of heating (especially through the use of heat pumps), the use of biomass will decrease between 2030 and 2050 in both scenarios.

Energy efficiency

Slovakia has made significant strides in reducing its energy intensity over the past few decades, particularly between 2000 and 2015 when it achieved a 50.8% reduction. This progress is attributed to industrial restructuring, adoption of low-energy production processes, improvements in building insulation, and a shift towards more energy-efficient appliances. Despite these achievements, Slovakia still ranks seventh among EU countries in terms of energy intensity. This is largely due to the structure of its industry, with a significant portion consisting of energy-intensive sectors. To address this, Slovakia plans to focus more on industrial energy efficiency and related services, including energy production. The country aims to further reduce its energy intensity and align with the European average. Slovakia has fully integrated the EU's energy efficiency framework into its national policies and regulations.

Renewable energy sources

Slovakia has a substantial hydropower capacity, but further expansion is limited due to geographical constraints and environmental considerations. The focus is now on optimizing the performance of existing plants and exploring smaller-scale hydropower projects. While there is potential for modest growth in the coming years, the overall hydropower capacity is expected to stabilize.

Key points:

- Slovakia has a long history of hydropower generation.
- Most of the hydropower potential has already been exploited.

- Future growth will focus on modernizing existing plants and smaller-scale projects.
- Environmental concerns will limit the construction of new large hydropower plants.
- Hydropower plays a crucial role in meeting peak demand and providing ancillary services.

Slovakia's geothermal energy potential is substantial, with estimated reserves of 48 500 GWh. However, uneven distribution, high exploration costs, and complex permitting processes have hindered widespread development. Geothermal waters, found at depths of 200-5 000 meters, are the primary resource. While there are numerous geothermal wells, current utilization remains relatively low. The Košice project, aiming to use geothermal heat for district heating, demonstrates the potential for large-scale applications. The TIMES model, a tool for energy system analysis, could provide more detailed insights but lacks necessary data for the Košice project. Government support and technological advancements are expected to drive future growth in geothermal energy utilization in Slovakia.

3.6.6.2. GHG Emission Projections in Transport

The transport sector consists of five subcategories:

- 1.A.3.a Air transport (0.02%)
- 1.A.3.b Road transport (98.53%)
- 1.A.3.c Rail transport (1.17%)
- 1.A.3.d Water transport (0.07%)
- 1.A.3.e Other mode of transport (e.g. pipeline transport) (0.21%)

The largest contributor to transport emissions is road transport, in particular the use of diesel heavy-duty vehicles (HDV), but also passenger cars. The transport sector includes emissions from road transport (passenger cars, light-commercial vehicles, heavy-duty vehicles and buses, mopeds and motorcycles) as well as emissions from petrol evaporation, tyre and brake wear abrasion and road abrasion. In addition to road transport, this includes air, rail, maritime and pipeline transport (e.g. of natural gas). However, almost 99% of all emissions in 2022 came from road transport, including pipeline transport. If pipeline transport, which is included in the EU ETS emissions trading system. For this reason, Slovakia focuses on and analyses in detail only the potential reduction of emissions from road transport and for other transport categories the ARIMA model is used.

The starting point for gaining control over emissions is a thorough understanding of the current situation and an understanding of how emission trends have changed both quantitatively and compositionally. Based on official sources a detailed, complete and consistent set of data on vehicles and their activity can be prepared. This dataset is the basis for calculating the most accurate emissions at the national level using highly advanced emissions modelling tools.

Both the WEM and WAM scenarios for transport show an increase in emissions (***Figure 3.22, Table 3.25***), with the WAM scenario peaking as early as 2025, followed by a slow and gradual decline in GHG emissions, which are only 2% higher in 2030 compared to 2005 and 74% lower in 2050 compared to 2005. In the WEM scenario, emissions will continue to rise until 2030 before declining thereafter and are still expected to be 20% lower in 2050 compared to 1990 levels. The high emissions from road transport are mainly due to the fact that the development of transport as the main carrier system took place only at the beginning of the 21st century, in particular with the development of the light-commercial vehicle (LCV) segment, which will continue to play an important role in the future. In terms of climate change, road transport will be a key sector for reducing GHG emissions.

Figure 3.22: *Historical, WEM and WAM scenario GHG emissions from transport in CO_2 eq. (Gg)*

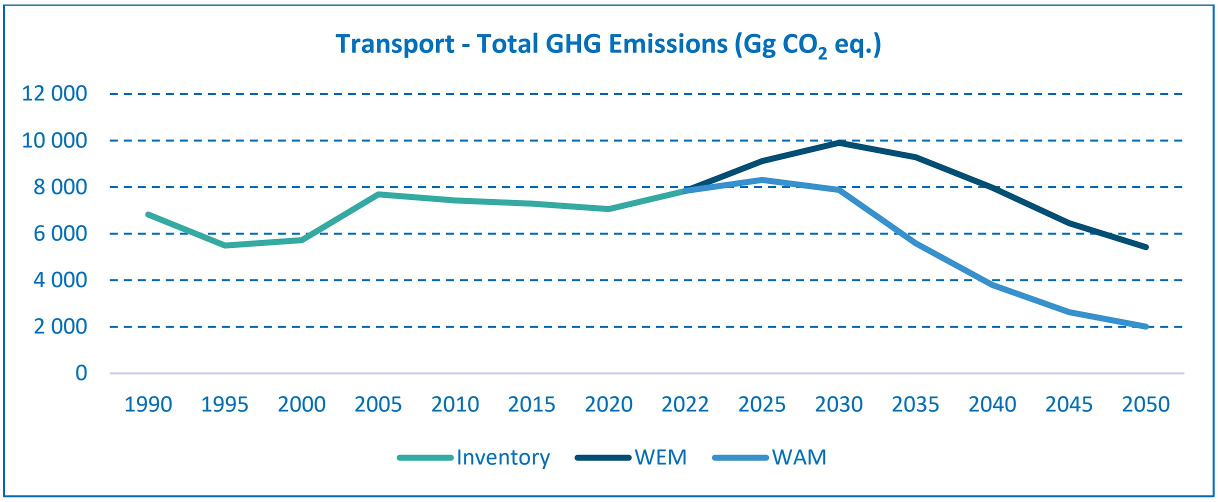


Table 3.25: *GHG emission projections from transport*

YEAR	WEM	WAM
	Gg CO_2 equivalents	
1990	6 816.32	6 823.77
1995	5 490.92	5 495.29
2000	5 721.59	5 725.61
2005	7 693.08	7 697.61
2010	7 421.48	7 425.74
2015	7 293.40	7 301.70
2020	7 061.50	7 069.21
2022	7 778.85	7 778.85
2025	9 118.71	8 309.62
2030	9 903.88	7 880.07
Comparison with 1990	45.30%	15.48%
Comparison with 2005	28.74%	2.37%
2035	9 282.92	5 583.91
2040	7 973.86	3 800.69
2045	6 447.16	2 625.51
2050	5 421.12	2 007.38
Comparison with 1990	-20.47%	-70.58%
Comparison with 2005	-29.53%	-73.92%

Methodologies, Key Assumptions/Trends and Input Parameters in Road Transport

Input (historical) data for the calculation of GHG emission projections from road transport are the IS EVO (Vehicle Registration Information System) database provided by the Ministry of Interior of the Slovak Republic – Police department (DI PPZ), the database of the Slovak Technical Control (STK) of the

Ministry of Transport and Construction of the Slovak Republic (MDV SR) and the transport indicators from the CPS+ model (Compact PRIMES model) provided by the Institute of Environmental Policy (IEP). The Sybil database is also an important input source of information in the preparation of emission projections and input parameters. This database is being prepared by EMISIA[41] on the basis of:

- EUROSTAT statistical data (national statistics)
- Project outputs (FLEETS, TRAACS, NMP project) for all EU countries
- EC Statistical Pocketbooks
- ACEA (The European Automobile Manufacturers' Association)
- ACEM (The Motorcycle Industry in Europe)
- CO_2 monitoring database (operated by the EEA)
- EAFO
- NGVA EUROPE/NGV GLOBAL
- UNFCCC reports
- Weibull´s distribution for preparing the age structure until 2050

The data in this database are based on the same input parameters as the EU Reference Scenario for Slovakia, which was discussed and presented in 2018 – 2019. The EU Reference Scenario for Slovakia was modelled using the PRIMES model and its transport module TREMOVE. The fleet development trends are therefore based on the same parameters and complex calculations, taking into account changes in the market as well as dynamic developments in the sector. This model is not directly applicable to Slovak conditions, as it requires a lot of detailed data, which Slovakia does not have.

Using trends from the Sybil database, an estimate of fleet development was prepared based on real data for the years 2013 – 2022. The data for this time period were obtained from IS EVO as a by product of a project[42]. Data and emissions prior to 2013, i.e. the period 1990 – 2012, were compiled according to official DI PPZ statistics and historical emission inventories.

Another important factor for calculating emissions and energy demand is the average value of annual mileage in each vehicle category and the average value of total vehicle kilometres travelled in each category. These data for the historical years 1990 – 2012 were taken from emission inventories. Subsequently, for the years 2013 – 2019, these figures were calculated using the information contained in the Slovak Technical Control database. Specifically, it is the information from the odometer about the kilometres driven. Using the VIN number, the data is matched with the data from IS EVO. A detailed description of the methodology was published in the first phase of the project "Improving the allocation of road transport emissions in the AEA module”.

---

[41] Spin-off of the Applied Thermodynamics Laboratory of the Aristotle University of Thessaloniki: https://www.emisia.com/

[42] Project: Improving the allocation of road transport emissions in AEA module and coherence between AEA and PEFA modules, Grant agreement no. 101022801 — 2020-SK-ENVACC: https://oeab.shmu.sk/app/cmsSiteBoxAttachment.php?ID=124&cmsDataID=0

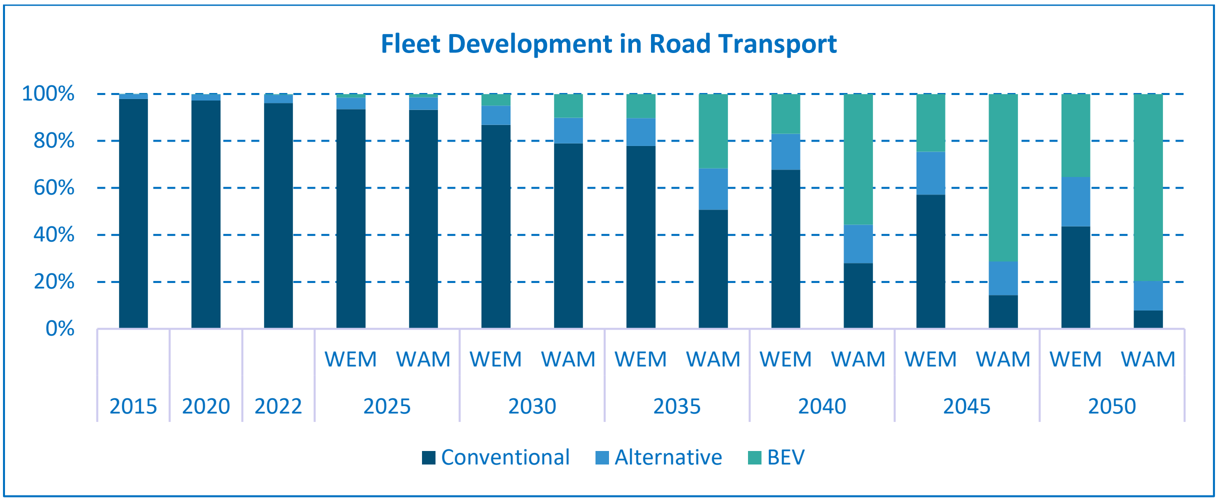
The COPERT model itself operates with 5 vehicle categories:

- Passenger cars (M1)
- Light-commercial vehicles (N1)
- Heavy-duty vehicles- trucks (N2 and N3)
- Buses (M2 and M3)
- L-category (L1 to L7)

Estimates for the period 2020 – 2050 were taken directly from the Sybil database and then broken down into individual fuel bases, segments (by engine capacity or vehicle weight) and emission standards. The model works with up to 620 separate data streams in total. The numbers of vehicles in each data stream each year are determined by an age composition matrix and a "survival rate" calculated from the data of the above-mentioned projects and the Weibull distribution and EUROSTAT data.

Vehicle engines (fuel types) are subdivided and described in detail in the model, but for the purpose of this report, the different types of engines are divided into three groups: conventional, alternative, and zero emission (BEV). Conventional engines are diesel and gasoline with their bio-component. CNG, LPG, LNG, hybrid (both diesel and petrol) and plug-in hybrid (both diesel and petrol) are being considered as alternative engines. BEV is currently represented by electric and hydrogen engine. The overall evolution of the fleet can be seen in ***Figure 3.23***.

Figure 3.23: *Fleet development by fuel types in WEM and WAM scenarios*

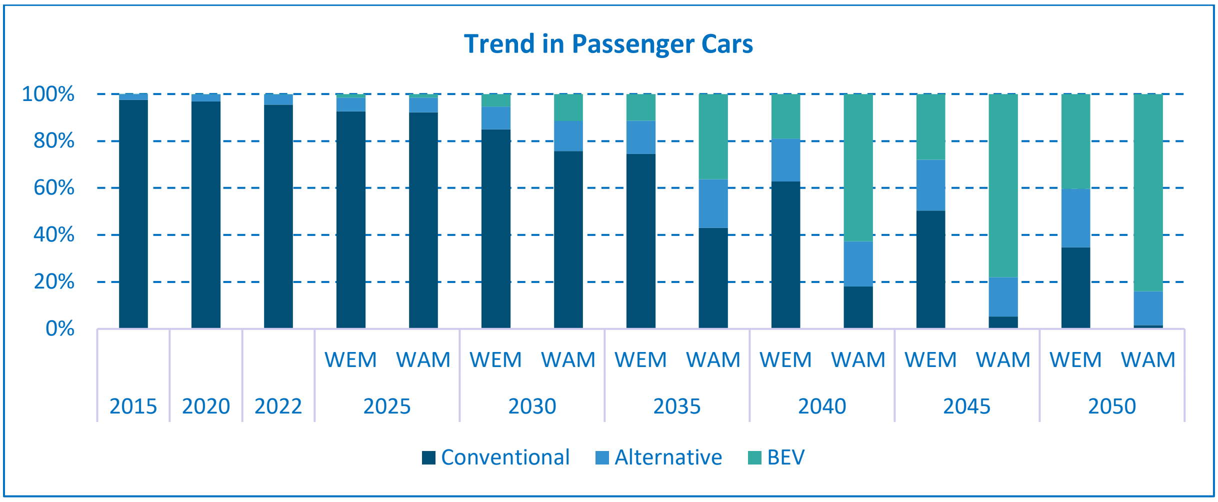


Passenger cars (M1)

Passenger cars account for the largest share of the fleet. In recent years, there has been a significant increase in their number. The main assumption for the projections is that the number of passenger cars in the fleet has still not at its peak. It is expected to peak around 2040, followed by a gradual and slow decline in the number of passenger cars, also driven by a declining demographic curve.

WEM scenario expects conventional passenger car sales will peak in 2030 (***Figure 3.24***). In the case of the WAM scenario, this peak could happen earlier, sometime around the year 2026. For alternative engines, there is a slightly lower increase in the WAM and this is due to the greater weight given to BEV in the fleet development for this scenario, which have exponential growth up to 2050.

Figure 3.24: *Development of passenger cars in WEM and WAM scenarios*



Light-commercial vehicles (LCV or N1)

The light-commercial vehicle category (category N1 - up to 3.5 tonnes) has undergone a significant change, moving from a category of no major importance in the 1990s to one of the key categories for future decarbonisation. The reason for its significant growth and the assumption of further growth is mainly due to the development of courier services and the "last mile" transport of goods. If the Slovak Republic does not try to decarbonise this part of road transport, the number of these conventionally fuelled vehicles (petrol and diesel) could reach up to 350 000 vehicles in 2050 (***Figure 3.25***). For LCVs, there is little expectation of a turnover to alternative fuels as there would be a reduction in transport space and hence the WAM scenario will not affect this category. For the overall decarbonisation of road transport, it will be necessary to decarbonise in particular the 'last mile' in the form of zero-emission vehicles.

Heavy-duty vehicles – trucks (HDV or N2 and N3)

The heavy-duty vehicles category (traditional freight transport) is also extremely specific within road transport, mainly because of the possibilities of replacing conventional fuels with alternative fuels. This often leads to greenwashing campaigns about emission-free transport in the form of LNG/CNG. Decarbonisation is challenging due to the need for extremely high range and engine power.

In the WEM scenario, there is a steady increase in the number of HDVs (***Figure 3.26***) as the production of goods that will needed to be transported over medium and long distances are projected to increase by the CPS+ model. Alternative fuels can contribute to reducing GHG emissions but cannot be the ultimate solution in this category. The WAM scenario assumes a significant change and an exponential increase and shift away from conventional fuels towards BEV. This is limited, as for the other categories, only by the production capacities of the car manufacturers.

Figure 3.25: *Development of light-commercial vehicles in WEM and WAM scenarios*

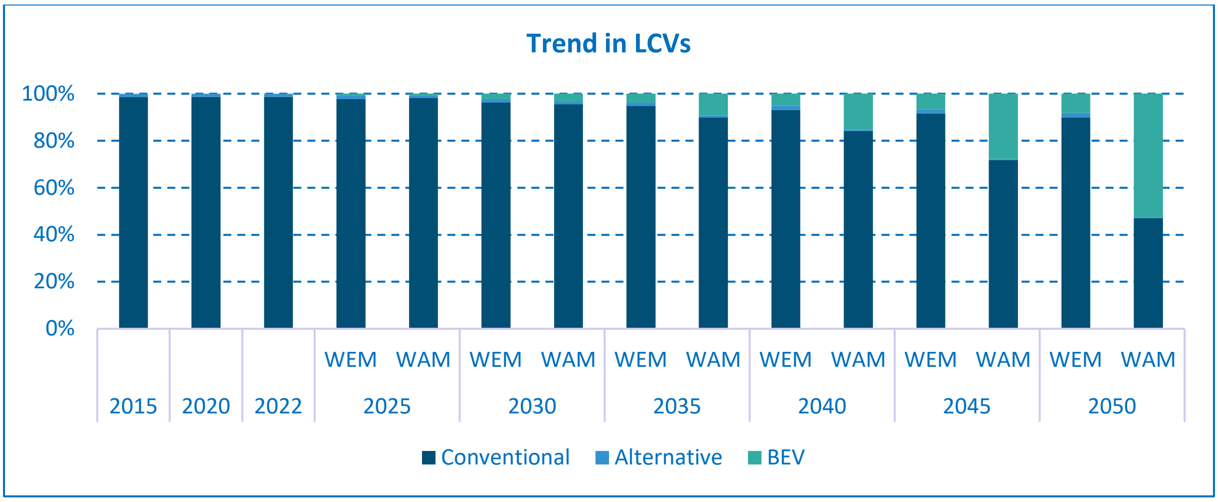
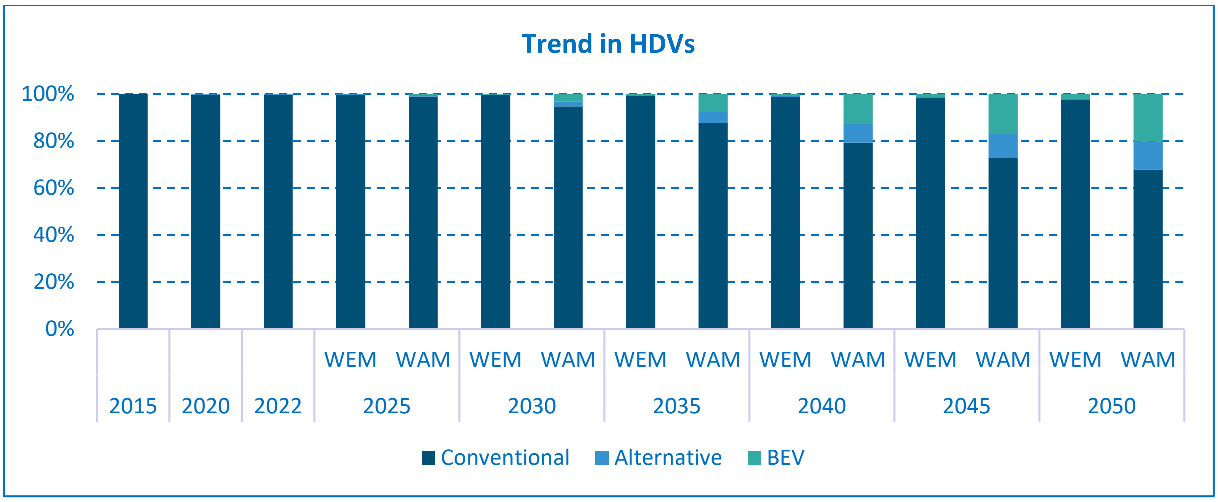


Figure 3.26: *Development of HDV fleet in WEM and WAM scenarios*

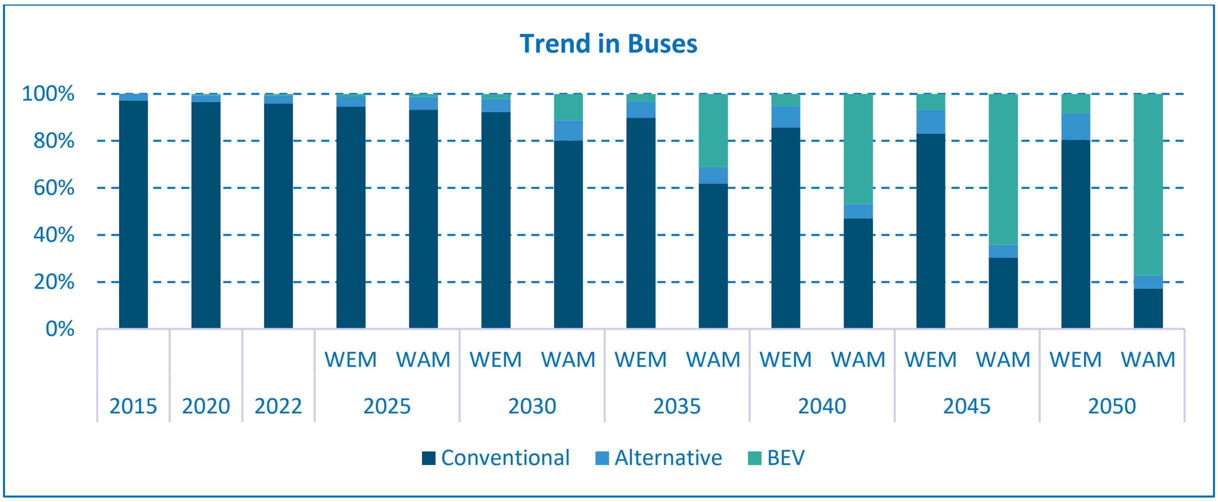


Buses (M2 and M3)

In the case of public passenger transport (PPT), there is no difference between the development in the WEM and WAM fleet scenario in total number of vehicles, but there is a turnover of the fleet (***Figure 3.27***). The WAM scenario assumes a shift of passengers to rail and a densification of PPT intervals, which is reflected in higher annual bus mileage. This assumption was subsequently reflected in the model. Given the small share in road transport, no major interventions in the form of measures to support the fleet turnover have been necessary.

The decline in alternative fuel buses between 2015 and 2020 is mainly due to the phasing out of CNG buses. This trend is changing with the gradual introduction of hybrid buses and their gradual growth, replacing not only conventional buses but also older CNG-powered buses.

***Figure 3.27**: Development of buses fleet in WEM and WAM scenario*



L-category (L1 to L7)

This category includes all two- and three-wheel vehicles. In addition to these, quadricycles (ATVs) and micro-cars are included. The term micro-car is used in the model to unite all vehicles of category L (1-7) that use diesel as a source of energy. Overall, this category consists of:

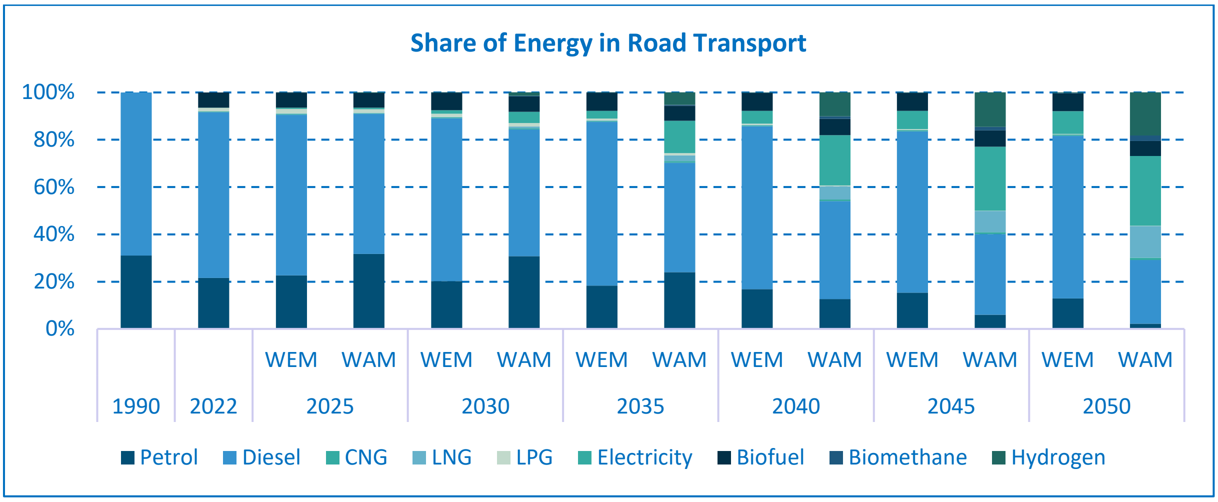
- Mopeds
- Motorbikes
- ATVs
- Buggies
- Micro-cars

This is the smallest and least important vehicle category in terms of emissions. These vehicles account for around 0.3% of greenhouse gas emissions and projections show that this trend should not change, with the massive decarbonisation of the passenger car category seeing the share rise to around 1% in 2050.

Energy consumption

In terms of energy, according to the WEM scenario, in Slovakia will dominate consumption of diesel oil until 2050. Its consumption will slowly decrease in this scenario but will still account for up to 69% of the total energy consumption of road transport in 2050. From other alternative fuels will be the most dominant electricity consumption, rising gradually from a share of 2% (2 178 TJ or 605 GWh) in 2030 to around 10% (7 710 TJ or 2 140 GWh) in 2050 (***Figure 3.28***).

Figure 3.28: *Historical evolution of the energy demand for road transport for the years 1990 – 2022 and WEM and WAM scenarios development assumptions*



In the WAM scenario, significant diversification and an overall decline in fuel and energy consumption is expected in 2050. In this case, electricity will be the most used source of fuel, accounting for 1% (856 TJ or 240 GWh) in 2030 and up to 30% (15 400 TJ or 4 300 GWh) of the total energy demand in 2050. Diesel oil will still have a similarly important but significantly smaller share, with a share of 54% in 2030, falling to half (27%) in 2050. This significant share, despite strong decarbonisation, is mainly due to the heavy-duty vehicles' category, which is extremely difficult to decarbonise while maintaining the parameters required of them.

Model Description

Input data for the calculation of GHG projections from road transport are databases provided by the Traffic Inspectorate of the Presidium of the Police Force of the Slovak Republic (IS EVO - Information System of Vehicle Registration) and the Ministry of Transport and Construction of the Slovak Republic (STK=PTI – Periodical Technical Inspection), transport indicators from the CPS+ model (IEP MŽP SR), which was developed for the needs of the Low Carbon Strategy.

An important aspect in the preparation is the Sybil database. This database is being prepared by EMISIA on the basis of:

- EUROSTAT statistics (national statistics),
- Project outputs (FLEETS, TRAACS, NMP project) for all EU countries,
- EC Statistical Pocketbooks
- ACEA (The European Automobile Manufacturers' Association)
- ACEM (The Motorcycle Industry in Europe)
- CO_2 monitoring database (operated by the EEA)
- EAFO (European Alternative Fuels Observatory)
- NGVA EUROPE/NGV GLOBAL (The Natural & bio Gas Vehicle Association)
- UNFCCC reports
- Proprietary algorithms for the preparation of the age structure up to 2050

The data in this database are based on the same input parameters as the EU reference scenario for Slovakia. The EU reference scenario for Slovakia was modelled using PRIMES and its transport module TREMOVE. However, for the conditions of Slovakia, as a small country, this model is directly inapplicable, as it requires many detailed data, which Slovakia does not have.

Using trends from the Sybil database, an estimate of fleet development was prepared based on real data for the years 2013 – 2022. The data for this time were obtained from IS EVO. Data and emissions prior to 2013, i.e. the period 1990 – 2012, were compiled from official Traffic Inspectorate of Police statistics and historical emission inventories.

Another important factor for calculating emissions and energy demand is the average value of annual mileage in each vehicle category and the average value of total vehicle kilometres travelled in each category. These data for the historical years 1990 – 2012 were taken from emission inventories. Subsequently, for the years 2013 – 2023, these data were calculated using the information contained in the Vehicle Technical Inspection (VTI) database.

The model itself operates with 5 vehicle categories:

Passenger vehicles (M1)

Light-commercial vehicles (N1)

Heavy-duty vehicles - trucks (N2 and N3)

Buses (M2 and M3)

L-category (L1 to L7)

Table 3.26: *SWOT analysis of the COPERT CLI model*

Strengths	Opportunities
Compatibility with emission model for emission inventories Detailed data break down Database used is compatible with EU data and national data	Incorporate to the model new technologies Versatile use on different geographical level Versatile use of time series
Treats	**Weakness**
Easy data entry Basic software is free	Disconnected from macroeconomic models Disconnected from national energy models (needs to feed outcomes to energy models) Too much pre-calculations needed

Estimates for the period 2023 – 2050 were taken directly from the Sybil database. These estimates are based on European statistics and qualified estimates by transport experts. Subsequently divided into individual fuel bases, segments (by engine capacity or vehicle weight) and emission standards, the model works with up to 866 separate data streams in total. The numbers of vehicles in each data stream each year are determined by an age composition matrix and a "survival rate" calculated based on data from the above-mentioned projects and EUROSTAT data.

The COPERT model is used for the actual calculation using the CLI module, which allows new technologies that are not directly defined by the model to be brought into the model. This includes emissions-intensive technologies such as LNG, flexi-fuel, e-fuel or hydrogen engines.

The COPERT model always reflects and incorporates the latest developments and scientific knowledge into emissions calculations. The emission calculation methodology is described in the EMEP/CORINAIR Atmospheric Emissions Inventory Guidebook (EMEP GB) on tailpipe emissions from road transport. The model has roughly 50 predefined (and modifiable) parameters, ranging from environmental conditions (air temperature and humidity) to parameters detailing the generation of emissions in individual vehicle types. When using the CLI module, many of these parameters are unavailable and set to the default value.

Basic emission factors are integrated in the model, which are adjusted based on user-supplied input parameters. Emission factors are defined for each greenhouse gas separately. Carbon dioxide emissions are specific as they are calculated based on the ratio of hydrogen to carbon in fuels and thus the amount of CO_2 depends on the total amount of fuel burned. Actual values for 2022 were used for the model, except for new technologies where it was necessary to supply emission factors directly.

In terms of technology and the use of different technologies within a single vehicle (plug-in hybrids, CNG, LPG), basic settings were used. In the case of CNG and LPG, it is assumed that 100% of these fuels are used at the expense of petrol, and in the case of plug-in hybrids, the split is 75% in favour of petrol and diesel and 25% in favour of electricity (electric motor). The low share of electric motor use is based on several studies summarised by the ICCT (International council on clean transportation).

Minimum and maximum temperatures have also been introduced into the model, which affect emissions to some extent. The regional climate model KNMI-RACMO22E and its optimistic scenario RCP2.6 were used.

Scenarios, Parameters and PAMs

Slovakia prepared two scenarios for road transport: WEM and WAM scenario. The WEM scenario describes the development of vehicle fleet and GHG emissions using only existing measures in force until end of 2022. In contrast, the WAM scenario foresees a number of additional measures and policies that will need to be put in place both nationally and locally. The policies and measures used are based directly on legislation or on national and EU strategies and action plans. The reference year to compare to the WAM scenario was 2005. The reason for choosing this year as a reference year for comparison is that in 1990 road transport in Slovakia was not yet developed in all areas and did not reflect the current situation. In 1990, the light-commercial vehicle segment, which plays an important role today and especially in the future, was almost non-existent. At the same time, the last validated year with real values was determined to be 2022.

The policies affecting emissions from road transport can be split to three types: energy policies, transport policies and environmental policies. Energy policies and measures focus mainly on energy efficiency and renewable energy sources in transport. Transport policies and measures focus on transport infrastructure and intensity, and environmental policies and measures focus directly on reducing emissions of greenhouse gases and pollutants. The policies and measures taken into account in each scenario are based on a number of national documents:

- Low-Carbon Development Strategy of the Slovak Republic until 2030 with a view to 2050 (NUS SR)
- Action plan for the development of electromobility in Slovakia
- National Air Pollution Control Program (NAPCP)
- Strategic plan for the development of transport in Slovakia up to 2030
- Integrated National Energy and Climate Plan of Slovakia (NECP)
- Review and update of the National Policy Framework for the Development of the Alternative Fuels Market
- EU hydrogen strategy

In addition to these documents, separate acts and European directives also intervene in the preparation of individual scenarios:

- Act No. 277/2020 amending Act No. 309/2009 Coll. on the Promotion of Renewable Energy Sources and High Efficiency Combined Heat and Power Generation
- Regulation (EU) 2018/1999 of the European Parliament and of the Council on the Governance of the Energy Union and Climate Action
- Regulation (EU) 2021/1119 of the European Parliament and of the Council establishing the framework for achieving climate neutrality

WEM Scenario

The baseline scenario is the WEM (With Existing Measures) scenario, which includes only policies and measures in place by the end of 2022. The WEM scenario contains only five known measures that affect the energy mix and the vehicle fleet. They are:

- Act No. 277/2020, which is a partial national transposition of consolidated Directive (EU) 2018/2001 of the European Parliament and of the Council (RED III) on the promotion of the use of energy from renewable sources
- Sale of low-emission vehicles (electric hybrids or plug-in hybrids) or directly zero-emission vehicles (battery electric cars and fuel-cell electric cars)
- Energy efficiency
- Regulation (EU) 2019/631 of the European Parliament and of the Council of 17 April 2019 setting CO_2 emission performance standards for new passenger cars and light-commercial vehicles
- Regulation (EU) 2019/1242 of the European Parliament and of the Council of 20 June 2019 setting CO_2 emission performance standards for new heavy-duty vehicles

The RED III Directive on the promotion and use of energy from renewable sources is currently still not fully transposed into national legislation. Its validity and inclusion in the WEM scenario was necessary and mandatory based on the scenario preparation framework. The RED III Directive sets new targets for the blending of renewable fuels (biofuels) into fossil fuels.

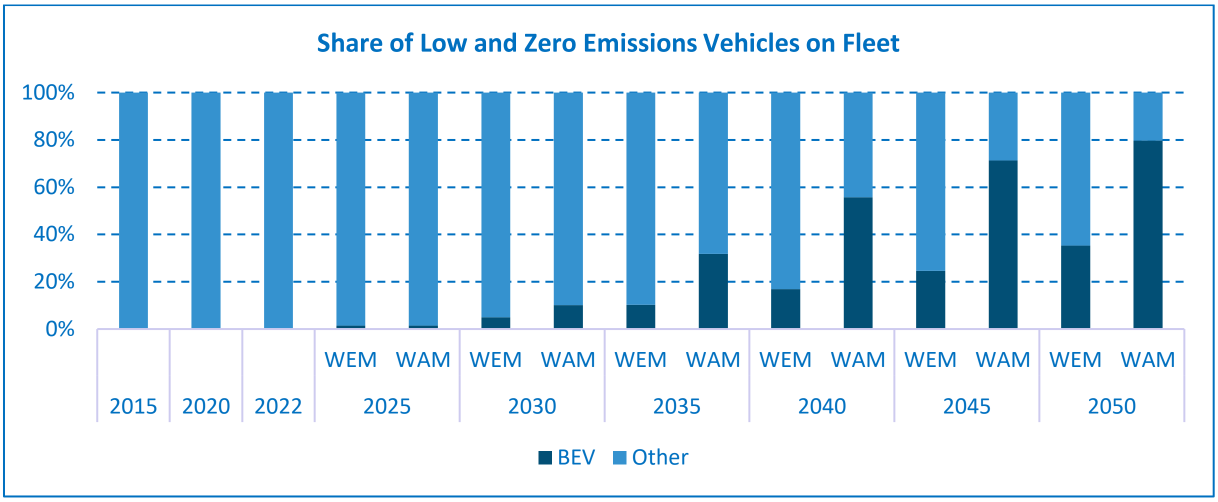
The new, increased targets are:

2023	2024	2025	2026	2027	2028	2029	2030
8.6%	8.8%	9.2%	9.5%	10.0%	10.4%	10.8%	11.4%

At the same time as this increased target, the possibility of double counting of the energy share of advanced biofuels has also been introduced. However, the double counting of advanced biofuels has no impact on the production of greenhouse gas emissions.

The historical and projected promotion of zero-emission vehicles (BEV) can be seen in ***Figure 3.29***. Total BEV accounts for 4.9% of the vehicle fleet in 2030, 35% in 2050 according to the WEM scenario and 9.2% in 2030 and 44% in 2050 according to the WAM scenario. Passenger cars account for the largest share of eBEV, accounting for 75% in 2022, 86% in 2025 and up to 93% of all BEV on the road in 2030 and up to 96% in 2050 in the WAM scenario.

Figure 3.29: *Share of low- and zero-emission vehicles in the total vehicle fleet of the Slovak Republic - historical development and projections to 2050*



Energy efficiency is converted into the model identically to the real options. The potential for improving combustion and engine efficiency to the level of "ultra-efficiency" was estimated at 15% in the ERTRAC report for passenger cars with spark-ignition engines. For diesel engines for passenger cars, this estimate was a 12% improvement by 2050, but for light and heavy duty vehicles there is only a 10% level by making the engine more efficient. In the model it is represented by coefficient directly reducing the outputs of energy demand and CO2 emissions. Both EU regulations (2019/631 and 2019/1242) are also incorporated into the model this way.

WAM Scenario

WAM (With Additional Measures) scenario is built on policies and measures, strategies and action plans that have not been put into force before 2022. The list of policies and measures used is summarised in ***Table 3.27***.

Table 3.27: *List of policies and measures used in WAM scenario*

Name of the measure	Scenarios	Short description for WAM
Regulation for CO_2 emission standards for new passenger cars & light commercial vehicles	WEM, WAM	WEM: 2021 Targets WAM: 2025, 2030, 2035 targets (Fit for 55) achieved
Regulation for CO_2 emission standards for new heavy-duty vehicles	WAM	2030, 2035, 2040 targets partially achieved
Freight Modal Shift	WEM, WAM	WEM: Low Modal Shift - e.g. Trucks to Rail WAM: High Modal Shift - e.g. Trucks to Rail
Passenger Modal Shift	WAM	High Modal Shift - e.g. cars to cycling or public transport
Euro 7: Council adopts new rules on emission limits for cars, vans and trucks	WAM	In compliance
Support for the use of low-emission vehicles	WEM, WAM	WEM: Moderate transition to low-emission forms of transport WAM: High transition to low-emission forms of transport
Promotion of biofuels	WEM, WAM	WEM: In compliance WAM: High increase of biofuels share
Low-emission zones in cities	WAM	UVAR for conventional vehicles
Setting stricter requirements for regular technical inspections	WEM, WAM	Stricter technical control to prevent tampering

The measure to support the continuation of direct support for the use of low-emission vehicles is mentioned in the Action Plan for the Development of Electromobility in the Slovak Republic and is also referred to in the National Air Pollution Control Program. In this measure, the penetration of electric vehicles in the passenger car segment is assumed to be more efficient, up to twice as strong, than in the WEM scenario.

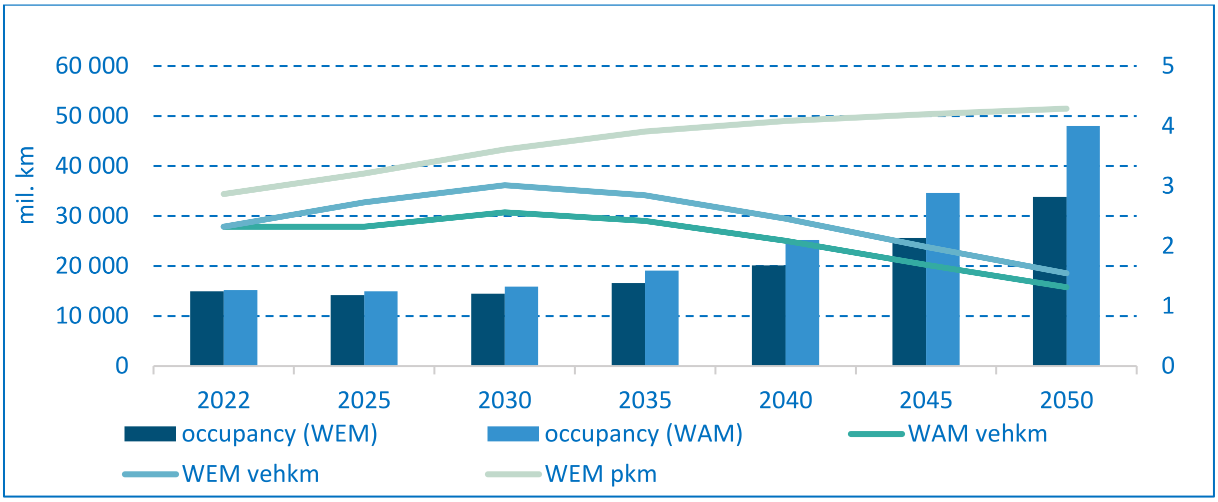
Stricter technical and emission inspections should result in the capture and removal of the oldest and non-compliant vehicles from transport. Strict rules are now in place for technical and emission inspection stations, but despite these measures, there is still circumvention of the rules. According to some research there can be up to 60% of tampered heavy-duty vehicles. This measure is expected to have a gradually diminishing effect under the influence of positive changes in the behaviour of vehicle owners. In the model, this measure manifests itself as a change in the age structure of the passenger car fleet.

Modal shift in passenger transport implies a shift of passengers from passenger vehicle transport to public passenger transport (PPT) or cycling in cities. As a result, the occupancy rate of passenger vehicles is expected to increase by 50% compared to 2022, reducing in particular the number of kilometres travelled by passenger vehicles up to 33% by 2050. The transfer of passengers to the PPT will go in two directions at the same time: road PPT and rail PPT. In the case of the rail PPT, it is expected that there will be an improvement in the quality of transport as well as the restoration of a number of railway connections. The prerequisite for this is the approved new Transport Service Plan for railways passenger transport. In the case of bus services, it is expected that there will be a slight increase in kilometres travelled. This effect on public bus services was reflected in a 10% increase in average annual mileage.

For shorter distances and in the city, it is also possible to use bicycle transport in addition to PPT. This possibility should also results from the National Strategy for the Development of Cycling Transport and Cycling Tourism in the Slovak Republic. It is estimated that it could reduce the share of road passenger transport in cities up to 10% by 2030. For the purposes of the projections, more conservative estimates of 6% have been used (3% for traffic peak and 3% for off-peak traffic).

The input data are pkm (person-km), which is a macroeconomic indicator from the CPS+ model for the Low Carbon Development Strategy of the Slovak Republic. From this data, the vehicle occupancy was then calculated, to which the increased occupancy was applied. It was then possible to calculate the new mileage with increased vehicle occupancy while maintaining passenger kilometres (***Figure 3.30***).

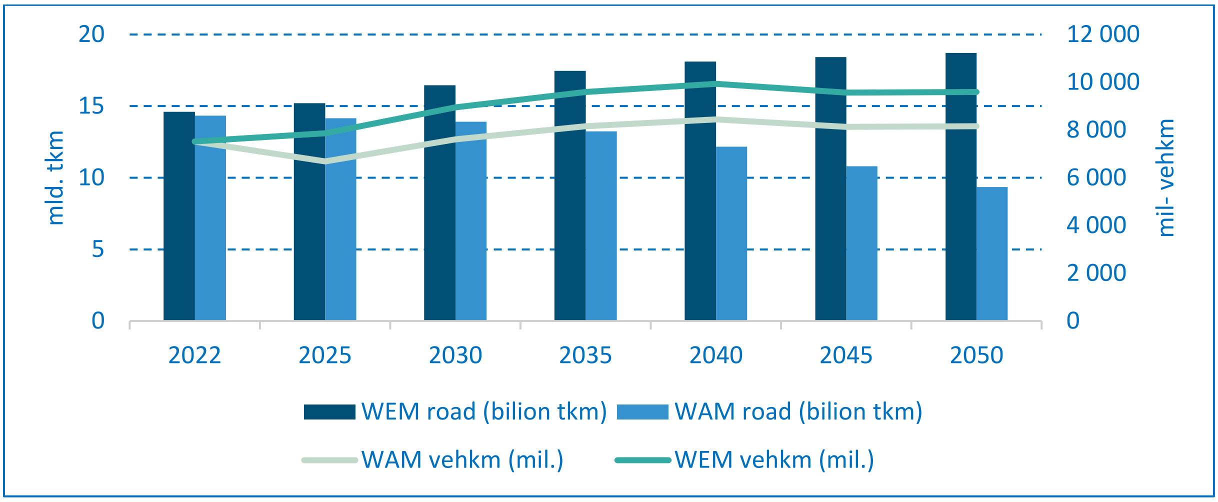
Figure 3.30: *Changes in passenger vehicle occupancy, annual passenger vehicle miles travelled, and passenger vehicle miles travelled by CPS+ model*



Modal shift in freight transport or the movement of goods in Slovakia is currently mainly carried out by freight road transport. From this point of view, modal shift in freight transport is more than necessary. According to the freight modal shift policy, the volume of goods transported by trucks is expected to decrease by 50% by 2050. This goal is foreseen in the Low Carbon Development Strategy of the Slovak Republic. As a consequence of shifting some of the goods to the railways, the annual vehicle mileage will be reduced and ultimately the number of trucks will also be reduced. A possible reduction in the number of trucks has not been estimated, as the WAM scenario currently only assumes a reduction in annual mileage.

The calculation procedure is analogous to the modal shift in passenger transport. In this case, tonne-kilometres (tkm) play a role, which were also obtained from the CPS+ model for the Low Carbon Development Strategy of the Slovak Republic as a macroeconomic indicator (***Figure 3.31***).

Figure 3.31: *Changes in freight transport, annual boarding and goods transported by road and rail (billion tkm)*



The most effective measure in this scenario appears to be the phasing out of fossil fuelled cars and light-commercial vehicles and their replacement by electric and hydrogen vehicles, especially for last mile goods movements. A complete ban on the sale of these pure fossil fuel vehicles (diesel and petrol) is due to take place in 2035. This measure will result in an exponential growth of BEVs in the light-commercial vehicle category. This measure will be also facilitated by the introduction of low emission zones in cities.

The introduction of hydrogen passenger vehicles, similar to trucks, was estimated in the European Hydrogen Strategy report to reach a maximum possible implementation rate of 20% of the vehicle fleet by 2050. In Slovakia, this level is reduced to 10% in the WAM scenario following a consensus of experts in the field.

The addition of bio-based methane (bio-methane) to vehicle fuels is now common practice in other EU countries. In Slovakia, this obligation will be introduced by the amendment of Act No. 309/2009 on the Promotion of Renewable Energy Sources and High Efficiency Combined Production. This amendment introduces an obligation to add a bio-component to compressed natural gas (CNG) and liquefied natural gas (LNG) from 2023. The minimum energy content of this bio-ingredient is determined as follows:

2023	2024	2025	2026	2027	2028	2029	2030
2.0%	3.0%	4.0%	6.0%	8.0%	10.0%	12.0%	14.0%

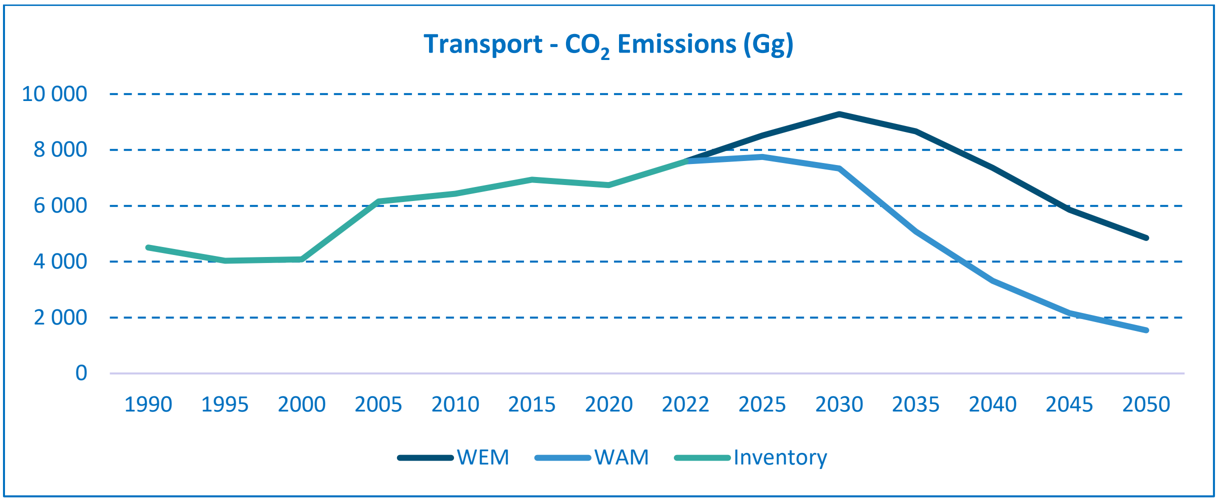
Even at the highest achievable share in 2030 (14% of the bio-based component), this does not have a significant reduction impact on emissions and traffic intensity in the scenario.

GHG Emission Projections by Categories and Gases

CO_2 Emission Projections

CO_2 emissions are the most significant GHG emissions for road transport. All measures are primarily aimed directly at reducing these emissions. Therefore, the CO_2 emission scenarios (***Figure 3.32***) also follow the trend of GHG emissions expressed in CO_2 eq.

Figure 3.32: *Historical trends of CO_2 emissions in Gg from road transport for the years 1990 – 2022 and emission projections in the WEM and WAM scenarios*



CH_4 and N_2O Emission Projections

CH_4 and N_2O emissions (***Figure 3.33*** and ***3.34***) are insignificant in terms of the amount produced by road transport and the impact on total GHG emissions in Slovakia, as they account for only 1% of total GHG emissions from road transport. Methane emissions decline in the WAM scenario, but at a significantly slower rate than the other two GHGs. This is mainly due to the introduction of compressed or liquefied natural gas vehicles as an alternative to petrol and diesel vehicles. On the one hand, these fuels reduce overall CO_2 emissions, but on the other hand they reduce the effect of other measures that also reduce methane emissions.

Figure 3.33: *Historical trends of CH_4 emissions in Gg of CO_2 eq. from road transport for the years 1990 – 2022 and emission projections in WEM and WAM scenarios*

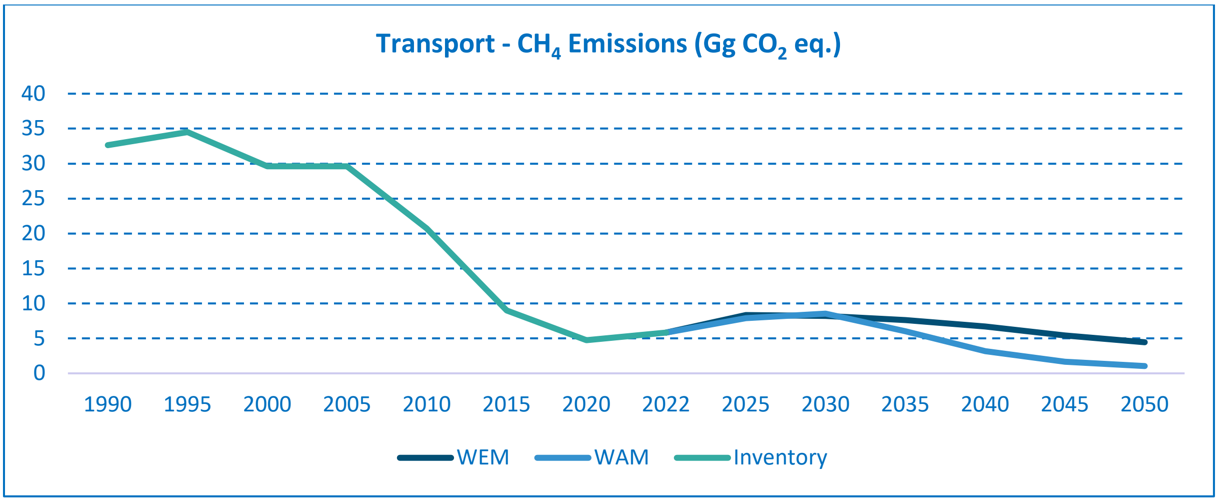
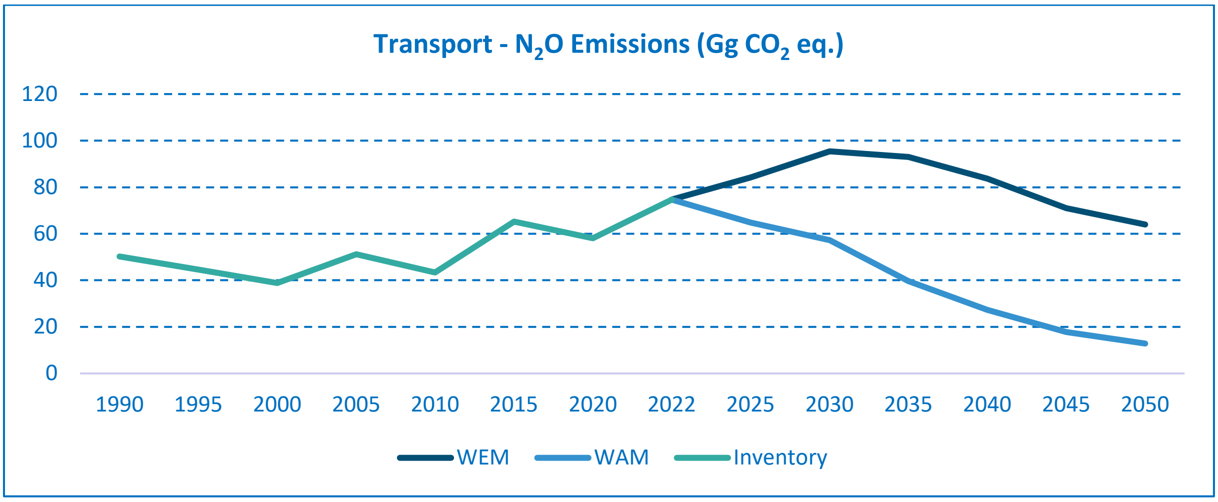


Figure 3.34: *Historical trends of N_2O emissions in Gg of CO_2 eq. from road transport for the years 1990 – 2022 and emission projections in WEM and WAM scenarios*



3.6.6.3. Emission Projections in Energy Sector – Non-Road Transportation (1.A.3.a, c, d, e)

In addition, projections of GHG emissions from non-road transport in the Slovak Republic have been prepared, but their relevance to overall GHG emissions projections is negligible, so only the WEM scenario has been prepared. Projections of non-road emissions were calculated using ARIMA (AutoRegressive Integrated Moving Average) modelling. Emissions from pipeline transport have been prepared based on information about projections of long-distance transmission of natural gas through the pipelines system (***Table 3.28***).

Table 3.28: *GHG emission projections by gases in non-road transport for the WEM scenario*

Gases	Transport Sector	Unit	2022	2025	2030	2035	2040	2045	2050
CO_2	Air transport	kt	1.48	1.25	1.34	1.34	1.34	1.34	1.38
	Rail transport		82.29	108.02	111.46	115.28	119.31	131.71	139.60
	Navigation transport		5.29	2.66	2.27	2.08	1.89	1.04	0.53
	Pipeline transport		16.12	290.91	287.28	283.28	294.08	280.53	274.13
CH_4	Air transport	t	0.03	0.031	0.031	0.031	0.031	0.031	0.032
	Rail transport		4.95	5.50	5.70	5.90	6.10	6.34	6.57
	Navigation transport		0.50	0.30	0.30	0.30	0.30	0.25	0.23
	Pipeline transport		0.29	0.01	0.01	0.01	0.01	0.01	0.00
N_2O	Air transport		0.04	0.019	0.019	0.019	0.019	0.019	0.02
	Rail transport		34.14	37.80	39.00	40.40	41.80	61.61	71.38
	Navigation transport		0.14	0.06	0.06	0.06	0.06	0.04	0.03
	Pipeline transport		0.0288	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005

3.6.6.4. GHG Emission Projections in Fugitive Emissions

Fugitive emissions from the mining and post-mining activities of brown coal, solid fuels transformation and production, transmission and distribution of crude oil and natural gas (NG) were projected. Total share of emissions represented in CO_2 eq.., in the Slovak Republic has decreasing trend and is almost negligible in comparison with the emissions from combustion of fuels (around 1%).

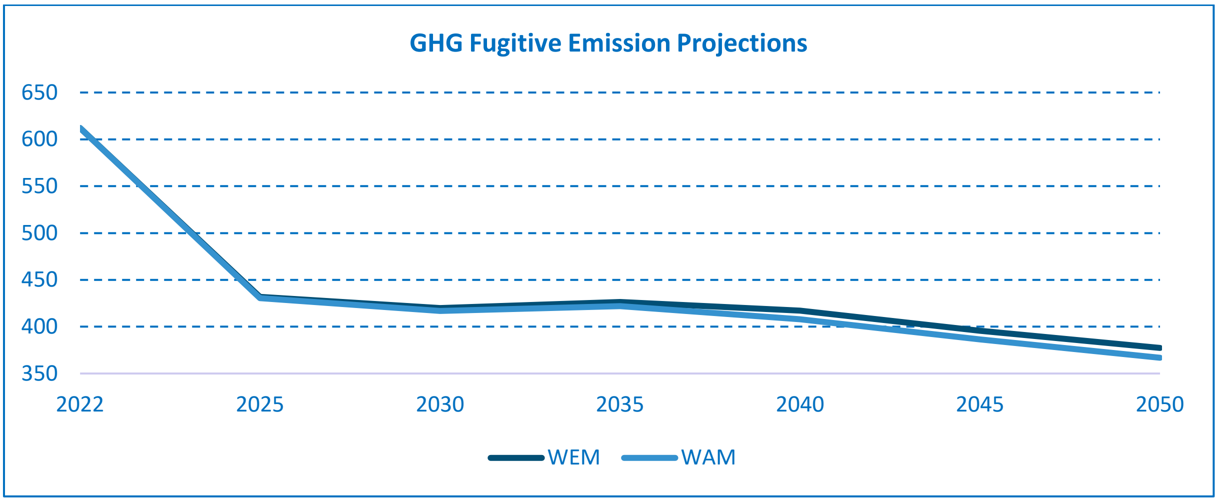
Based on the information on trends in the solid fuels mining and handling activity, as well as fuel transformation, and the information on trends in the oil and NG activity in Slovakia, the following emissions projections based on the WEM and WAM scenario were calculated and are presented in ***Table 3.29*** and ***Figure 3.35***.

Table 3.29: *Projections of GHG emissions in Gg of CO_2 eq. in WEM and WAM scenarios up to 2050*

WEM	2022*	2025	2030	2035	2040	2045	2050
1.B Fugitive emissions from fuels	612.11	431.70	419.77	426.46	417.29	395.52	377.31
1.B.1 Solid fuels	200.66	39.67	34.82	31.19	28.36	26.07	24.18
1.B.2 Oil and natural gas	411.45	392.03	384.95	395.26	388.93	369.45	353.13
WAM	**2022***	**2025**	**2030**	**2035**	**2040**	**2045**	**2050**
1.B Fugitive emissions from fuels	612.10	430.39	416.86	421.88	407.91	386.28	366.83
1.B.1 Solid fuels	200.66	39.67	34.82	31.19	28.36	26.07	24.18
1.B.2 Oil and natural gas	411.45	390.73	382.04	390.69	379.55	360.21	342.64

*Base year 2022; 2022 based on the GHG inventory submission 15. 3. 2024

Figure 3.35: *Projections of GHG emissions in Gg of CO_2 eq. in WEM and WAM scenarios up to 2050*



Methodologies, Key Assumptions/Trends and Model Description

Projections of emissions were prepared in accordance with the methodology of IPCC 2006 Guidelines and its 2019 IPCC Refinements. The methodology is consistent with the methodology of estimating emissions under Article 26 par. 3 of Regulation (EU) 2018/1999. The calculation analysis tool is based on the MS Excel platform and the calculation includes various policies and measures (in numerical formulation) defined according to the WEM and WAM scenarios.

Data for the calculation of fugitive emissions for 2025 – 2050 were obtained from sources:

- EU Reference Scenario for Slovakia for 2020 – 2050 (EU REF 2020);

- Integrated National Energy and Climate Plan 2022 – 2050 (NECP);
- Data provided by EUSTREAM, a. s. on the projected outlook for fugitive methane emissions from natural gas transit pipelines (Long-distance transport of natural gas; 20°C, 101 325 kPa).

For the calculation of fugitive methane emissions, emission factors from the following sources were used:

- 2006 IPCC Guidelines for National GHG Inventories - Chapter 4: Fugitive emissions;
- 2019 Refinement to the 2006 IPCC Guidelines for National GHG Inventories – Vol. 2, Chapter 4: Fugitive emissions
- IPCC Guidelines on best practices and management of unpredictability in national GHG inventories - Fugitive emissions from oil and gas operations;
- Results on crude oil processing, NG consumption and coke production from model TIMES;
- Results on residential appliances based on national model for sector 1.A.4.b.

Scenarios, Parameters and PAMs

Reference year for the preparation of emission projections was the year 2022, projections were prepared until 2050. In the sector 1.B.1 Solid fuels were prepared two scenarios based on the two scenarios for Energy sector:

- WEM scenario – with measures already in place (adopted) by the end of 2023;
- WAM scenario – with additional measures (optimistic).

For the period from 2023 onwards, all mines are categorised as "closed mines" (WEM and WAM scenarios). The emission factor for fugitive methane emissions from abandoned mines was estimated based on emission factors from 2019 Refinements to the 2006 IPCC Guidelines.

In the sector 1.B.2 Oil and Natural gas were prepared two scenarios:

- WEM scenario based on the starting average level of the years 2015 – 2022. The intensity and mitigation of fugitive emissions are at the same level as it is average of the years 2015 – 2022. Replacement or investments into technological equipment only in limited range. Installed capacity at compressor stations and the capacity of the transmission network would remain at the same level until 2050. The scenario also calculates with the SK-PL (Slovak-Poland) gas pipeline with a new metering station put into operation in 2022.
- CH_4 Action scenario (WAM) – this scenario is based on the assumption of further optimization and reduction of the installed capacity at some compressor stations after 2022. This scenario calculates with lower transmission and distribution of NG and crude oil procession. These data are based on projections for the Energy sector from the TIMES model.

Oil and NG

EUSTREAM, a. s. – the transmission company for NG. The capacity of the transmission network of the EUSTREAM, a. s. company is about 80-90 billion m^3 of the natural gas (NG) per year. The construction of the Poland-Slovakia gas pipeline (Veľké Kapušany) with a capacity of approx. 6 billion m^3/year, together with the current reverse flow of the NG from Veľké Kapušany to Ukraine, as well as the considered strengthening of capacity from Hungary to the Slovak Republic will change the transport characteristics. A massive redirection of the NG flows will take place, but the total transported volume of the NG will maintain unchanged. The increasing transport capacity of the NG through the Slovak Republic from the Czech Republic will also contribute to these circumstances.

SPP Distribution, a. s. – company provides distribution of the natural gas in the Slovak Republic. Leakages of GHGs from distribution pipelines (approximately 30 million m^3 annually) significantly contribute to fugitive CH_4 emissions.

Nafta, a. s. – carries out oil and gas extraction in the Slovak Republic. It operates underground storage tanks with a capacity of more than 3 billion storage tanks. Oil production after 2023 will be stopped, while the extraction of gas will continue until 2045 without significant changes.

Ministry of Economy – Integrated National Energy and Climate Plan 2022 – 2030 (NECP SK), Energy Policy and Energy Security Strategy. Fugitive CH_4 emissions from transport and distribution of natural gas and oil in the Slovak Republic were calculated from the data listed below. Data on natural gas and oil were obtained from sources:

- Statistical Office of the Slovak Republic
- EUSTREAM, a. s.
- SPP Distribúcia, a. s.
- Nafta, a. s.
- TIMES model

GHG Emission Projections by Categories and Gases

The most important gas in fugitive emissions is methane accounting for over 90% of total GHG emissions in 2022. Projections of emissions by gas according to WEM and WAM scenarios are presented in ***Tables 3.30*** and ***3.31, Figures 3.36*** and ***3.37***.

Table 3.30: *Projections of fugitive GHG emissions by gas in Gg in WEM scenario up to 2050*

Year	CO_2 emissions	CH_4 emissions	N_2O emissions
2022*	57.1824	19.8111	0.0005
2025	49.1555	16.2864	0.0005
2030	49.2672	15.5653	0.0005
2035	48.0088	15.9231	0.0005
2040	45.5817	15.5066	0.0004
2045	42.0411	14.7690	0.0004
2050	38.7478	14.1675	0.0004

*Base year 2022; 2022 based on the GHG inventory submission 15. 3. 2024

Table 3.31: *Projections of fugitive GHG emissions by gas in Gg in WAM scenario up to 2050*

Year	CO_2 emissions	CH_4 emissions	N_2O emissions
2022*	57.1824	19.8111	0.0005
2025	28.0805	16.2638	0.0005
2030	26.7116	15.5985	0.0005
2035	26.3446	15.6752	0.0004
2040	25.6781	15.1026	0.0003
2045	24.1033	14.3053	0.0002
2050	21.1706	13.6415	0.0002

*Base year 2022; 2022 based on the GHG inventory submission 15. 3. 2024

Figure 3.36: *Projections of GHG emissions by gas in WEM scenario up to 2050*

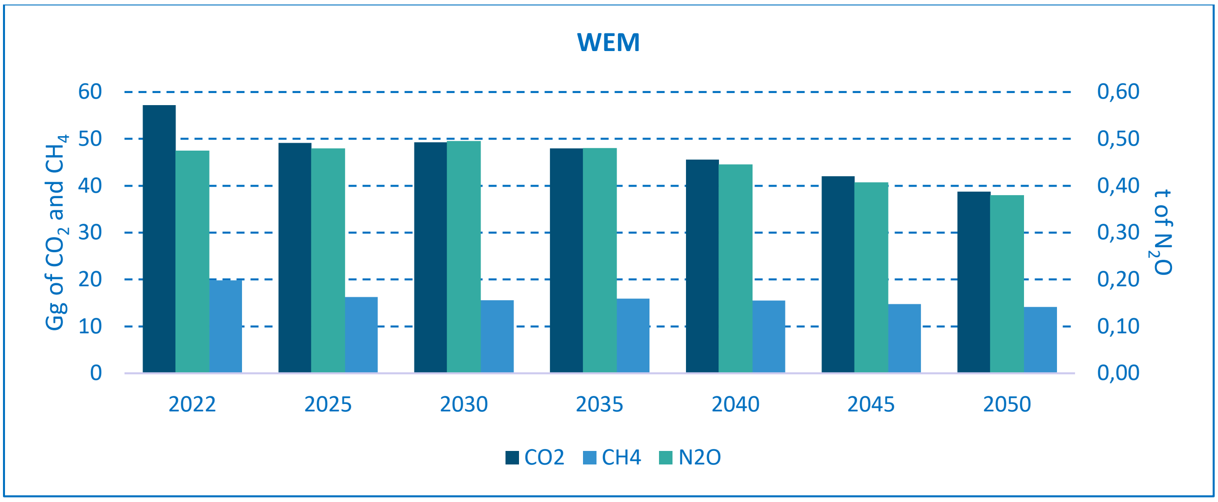
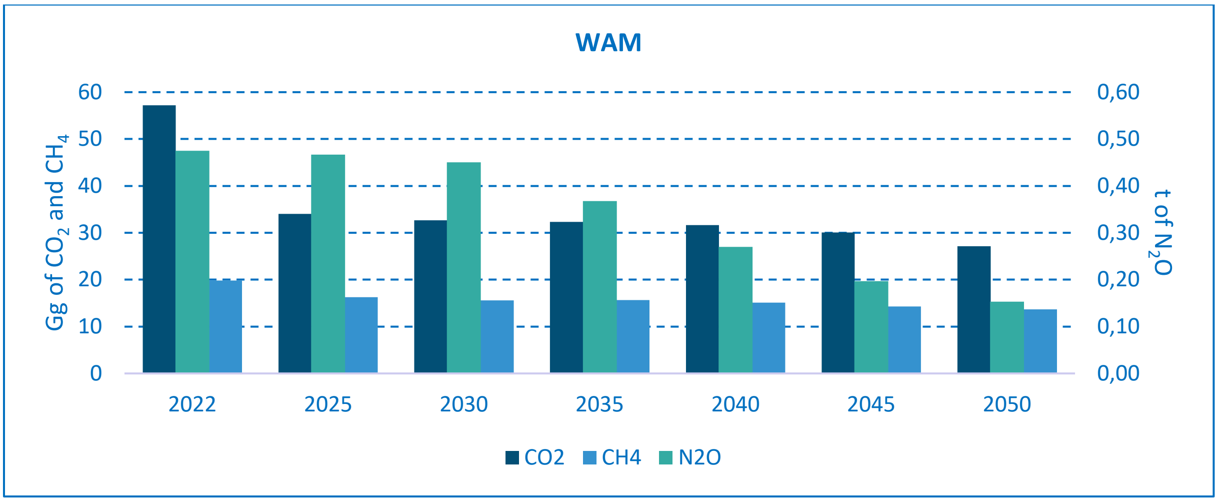


Figure 3.37: *Projections of GHG emissions by gas in WAM scenario up to 2050*



3.6.7. GHG EMISSION PROJECTIONS IN IPPU SECTOR

For the Industrial Processes, Product Use (IPPU) sector, we have prepared two distinct scenarios: with existing measures (WEM) and, with additional measures (WAM). These scenarios were designed to determine the 2030 and 2050 emissions targets for various industrial activities not currently covered by the EU Emissions Trading System (EU ETS). We have categorized IPPU activities into three primary groups based on their primary greenhouse gas emissions:

CO_2, CH_4, and N_2O emissions from categories 2.A to 2.D

- HFC emissions from category 2.F
- N_2O and SF6 emissions from category 2.G

Figure 3.38 and ***Table 3.32*** illustrate the emission trends projected by the WEM and WAM scenarios for each of these categories. The overall trend is largely influenced by the steel industry. The WEM scenario suggests a modest decline in emissions, primarily driven by anticipated technological advancements and efficiency improvements. However, due to the inherent challenges in reducing emissions from certain industrial processes, particularly in the mineral production and chemical industries, the overall reduction is limited. The WAM scenario presents a more strict approach, aiming for a 35% reduction in emissions. This significant decrease is primarily attributable to substantial measures implemented in the steel industry, such as increased use of low-carbon technologies and improved process efficiency. While the mineral production and chemical industries may experience some stabilization in emissions, the overall trend is expected to be downward due to anticipated policy measures and technological innovations.

Figure 3.38: *Total GHG emission projections in Gg of CO_2 eq. in the IPPU sector in WEM and WAM*

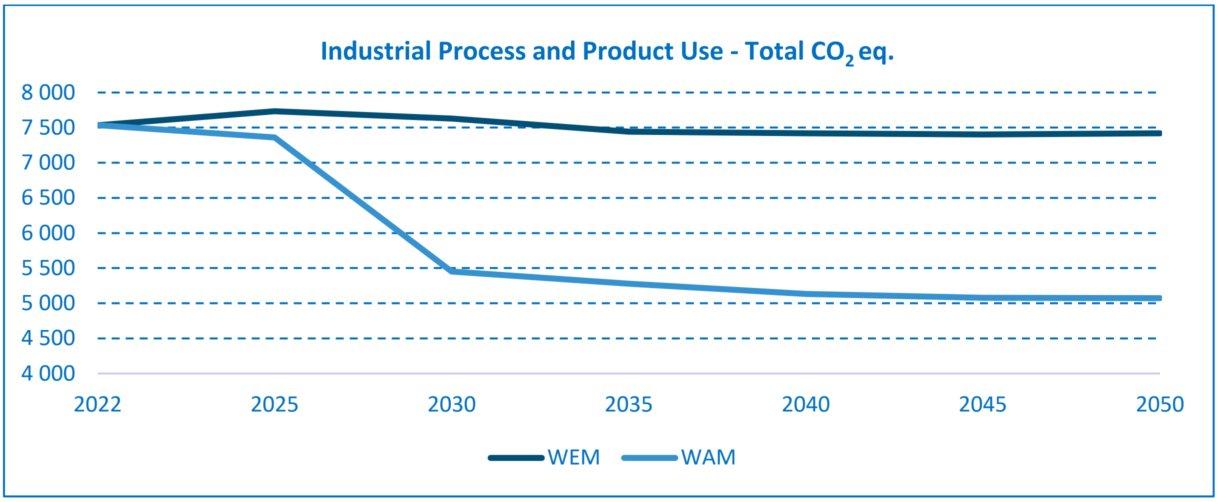


Table 3.32: *GHG emission projections in Gg of CO_2 eq. in the IPPU sector in WEM and WAM scenarios.*

WEM	2022*	2025	2030	2035	2040	2045	2050
2. Industrial processes	7 536.24	7 733.90	7 627.36	7 444.46	7 422.17	7 403.30	7 422.24
2.A. Mineral Industry	2 332.71	2 321.36	2 305.07	2 342.25	2 456.47	2 438.12	2 461.90
2.B. Chemical industry	1 076.42	1 133.47	1 145.17	1 132.94	1 129.69	1 131.06	1 127.13
2.C. Metal industry	3 533.08	3 692.81	3 696.64	3 701.66	3 705.16	3 706.53	0.00
2.D. Non-energy products	40.77	38.82	38.83	33.88	31.40	30.66	30.59
2.E. Electronics industry	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2.F. Product uses as subs. for ODS	480.89	466.67	377.92	175.14	42.03	39.73	39.90
2.G. Other product man. and use	72.38	70.80	67.56	63.62	60.92	58.56	56.19
2.H. Other	0.00	0.00	0.00	0.00	0.00	0.00	0.00

WAM	2022*	2025	2030	2035	2040	2045	2050
2. Industrial processes	7 536.24	7 363.04	5 453.83	5 276.95	5 131.44	5 076.97	5 073.26
2.A. Mineral Industry	2 332.71	1 932.19	1 919.06	1 949.59	2 044.15	2 029.18	2 049.08
2.B. Chemical industry	1 076.42	1 148.78	1 140.92	1 100.52	1 042.75	1 006.69	953.37
2.C. Metal industry	3 533.08	3 706.01	1 916.17	1 978.67	1 945.77	1 954.37	1 992.53
2.D. Non-energy products	40.77	38.82	38.83	33.88	31.40	30.66	30.59
2.E. Electronics industry	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2.F. Product uses as subs. for ODS	480.89	466.62	376.23	160.44	21.02	16.74	15.28
2.G. Other product man. and use	72.38	70.62	62.60	53.86	46.36	39.34	32.40
2.H. Other	0.00	0.00	0.00	0.00	0.00	0.00	0.00

***** Base year 2022; 2022 based on the GHG inventory submission 15. 3. 2024

3.6.7.1. Input Parameters for Emission Projections

A general assumption for the IPPU sector is the assumption of durability of equipment and availability of input materials (*Parametric-technical data*). The main driving force is the GDP trend respectively sectoral value added (SVA) represented in ***Table 3.34***. For industrial processes, the largest decline can usually only be expected as a result of a reduction in the production of a particular product.

The NIMs report, ETS Report and NEIS data described in chapter "Projection in Energy sector" encompassing granular production data for benchmark commodities, provides a robust foundation for modelling specific products ***Table 3.33*****.** Individual raw material inputs, installed capacity, annual availability and equipment-level emission factors are meticulously calculated for each EU-ETS installation. This granular level of detail ensures that the models accurately reflect the unique operational characteristics of each facility.

Moreover, to enhance the precision and reliability of these models, data was further refined through direct consultations with various operational unit-expert. These collaborative efforts enabled the development of tailored modelling approaches, ensuring that each EU-ETS installation is represented with a level of complexity commensurate with its specific production processes. By considering the intricacies of individual operations, the models provide more accurate projections of emissions and the potential impacts of mitigation measures.

The models process these parameters until mitigation measures, such as material substitution, are introduced. The effects of these measures are exogenously modelled as parametric scenarios, adjusting unit inputs or process emission factors accordingly. This allows for a comprehensive assessment of the potential environmental benefits of various mitigation strategies.

Further work in exogenous data and assumptions

Regarding the improvements in currently used data and assumptions, the most relevant improvements can be grouped as follows: demand for energy services and materials, energy transformation, electricity and heat generation technologies, end-use sectors and policy assumptions.

Table 3.33: *Subsectors and main input sources modelled in IPPU sector*

Industry subsector	Sources of Input parameters	Main processes considered in the model	Materials (modelled as Mt)
Iron and steel	National implementation measure files (NIMs), ETS Report, National Emissions Reporting System (NEIS), Inputs from plant operations	Iron Blast Furnace (charcoal or equivalent, direct coal injection), COREX, with and without CCS, Cyclone Convertor Furnace CCF, Argon Oxygen Furnace AOD. Regular, Blast Oxygen Furnace BOF, with and without CCS; Blast Oxygen Furnace with top gas recirculation, with and without CCS. Regular, Blast Oxygen Furnace BOF Scrap, EAF for DRI, with and without CCS, EAF for DRI	Steel plus the following intermediate materials: Ore, Pellet, Sinter, Raw Iron, DRI Iron, Scrap Iron, Oxygen, Quick Lime, Ferrochrome, Crude Steel
Aluminium		Heroult Inert Anodes	Aluminium plus the following intermediate materials: Bauxite, Scrap, Crude Aluminium
Copper		Standard process and process with recycling	Copper plus the following intermediate materials: Ore, Scrap
Ammonia		In general, ammonia production includes the currently adopted thermochemical (Haber–Bosch), electrochemical, and photochemical cycle processes - Steam reforming process	Ammonia
Chlorine		Standard Mercury, Standard Diaphragm, Standard Membrane, and Advanced Membrane	Chlorine
Cement		Dry clinker kiln, wet clinker kiln, advanced dry kiln regular and advanced kiln with CO2 capture.	Clinker and Blast Furnace Slag

Table 3.34: *Added value of industrial sectors in the years 2019 to 2030 (in millions of euros)*

Sectoral Value Added (in MEUR '19)	2025	2030	2035	2040	2045	2050
Iron & Steel	998	985	994	1 006	1 014	1 018
Non-Ferrous	307	316	336	346	347	346
Chemicals	777	812	855	897	932	956
Building Materials	840	914	988	1 051	1 100	1 139
Paper & Pulp	486	532	585	640	688	726
Food, Drink, Tobacco	1 216	1 336	1 484	1 613	1 700	1 749
Engineering	11 032	12 813	13 994	15 020	16 033	16 999
Textiles	661	640	608	555	478	415
Other Industries	2 997	3 262	3 540	3 755	3 970	4 174
Services	56 608	62 875	68 143	72 907	77 523	81 866
Agriculture	1 760	1 870	1 974	2 031	2 024	2 005

Source: IEP / GEM-E3 SK

3.6.7.2. Methodologies and Key Assumptions/Trends

The industrial sector is analysed in detail following an initial description that distinguishes between energy intensive industries and other industries. The energy intensive industries are: iron and steel, non-ferrous metals (aluminium, copper), chemical (ammonia, chlorine), non-metallic minerals (cement, lime, glass) and pulp, paper and printing. For each one of these industrial branches a detailed description of the production processes is being used in the model.

For each industry, a series of base-year technologies produce different industrial materials themselves used in the process chain. They are modelled using expert assumptions (NIMs) on input and output value. Emission projections from industrial processes come from processes other than fuel combustion. CO_2 emissions account for the largest share of total greenhouse gas emissions in this sector. A general assumption for the IPPU sector is the assumption of durability of equipment and availability of input materials. The main driving force is the GDP trend respectively sectoral value added (SVA). For industrial processes, the largest decline can usually only be expected as a result of a reduction in the production of a particular product. However, such a decline is not expected, but we can reduce or capture a significant amount of emissions through various modernisation processes. In Slovakia, iron and steel production accounts for the largest share of IPPU emissions.

For process-specific emissions, coefficients are declared at the process level and vary with the process' activity (e.g. Mt on produced cement clinker). This is the case of process emissions for cement, glass, ammonia and steel production and for the refining, petroleum products. Transport, fugitive emissions and Land-use emissions are not considered in the TIMES-Slovakia model. The emission coefficients considered in the model are the ones used in several national emission inventories. In the case of the industrial process emissions, the CO_2 emission coefficients will be technology dependent and will vary according to technologies' performance. For industry two types of exogenous demands are considered in TIMES-Slovakia: materials demand in Mt for the case of the energy intensive industries (cement, steel, glass, ammonia, aluminium, paper and chlorine) and useful energy demand for specific energy services in other industry: other Non-ferrous metals, other chemical and petrochemical, other non-metallic minerals, food, beverages and tobacco, textile and leather, transport equipment, machinery, and mining and quarrying and other non-energy-intensive industries. For these the following exogenous demands for energy services are considered: steam, process heat, machine drive, electrochemical processes and other processes. Each of the industry sub-sectors has a specific demand for each of these energy services (e.g. machine drive for other industry or process heat for other chemicals).

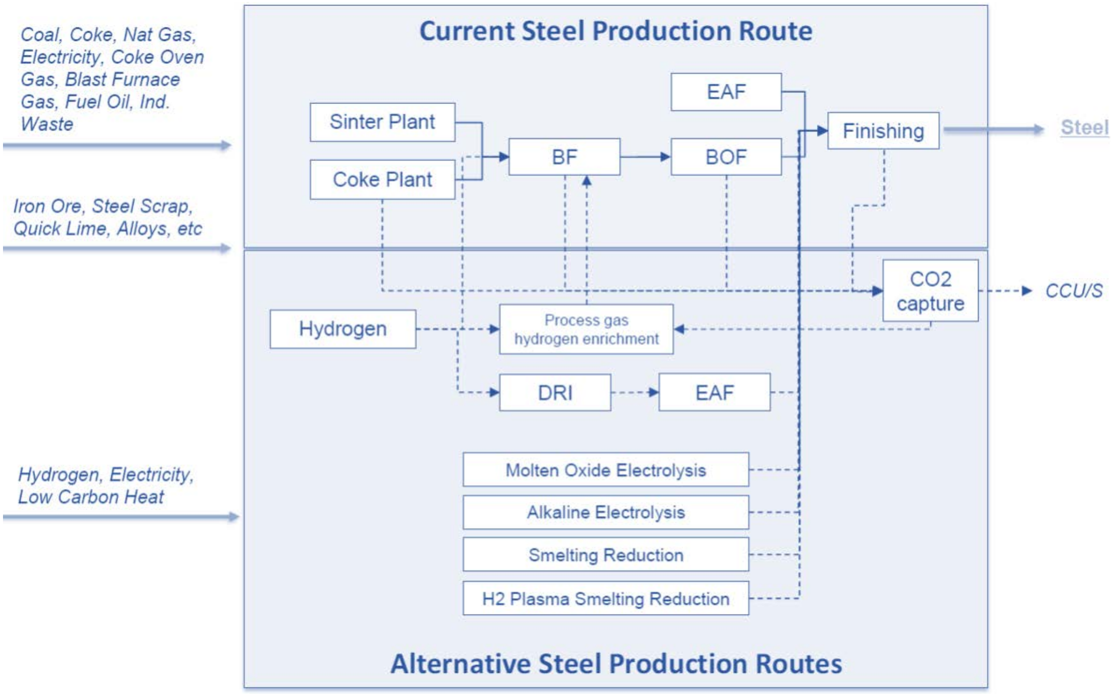
3.6.7.3. Predominant and Key Sectors in IPPU Modelled by TIMES-Slovakia

Steel production methodology

The existing steel production ***Table 3.35*** technologies in Slovakia (U. S. Steel Košice) are the Blast Furnace – Basic Oxygen Furnace (BF-BOF), which is assumed to be used for high-quality steel, and the electric arc furnace (EAF), used mostly for low-quality steel. The steel sector is generally divided into iron ore pre-treatment, iron reduction, steel production, rolling & casting, auxiliary processes and finishing and forming (this last process represents small and distributed companies at the end of the supply chain).

Process emissions are estimated to be around 50% of the total emissions in IPPU category. Moreover, the use of blast furnace gas for the production of electricity is accounted for in the power sector, which reduces the emissions allocated to the steel sector. There are two main paths for the steel sector: hydrogen for the direct reduction of iron (DRI) and CCUS.

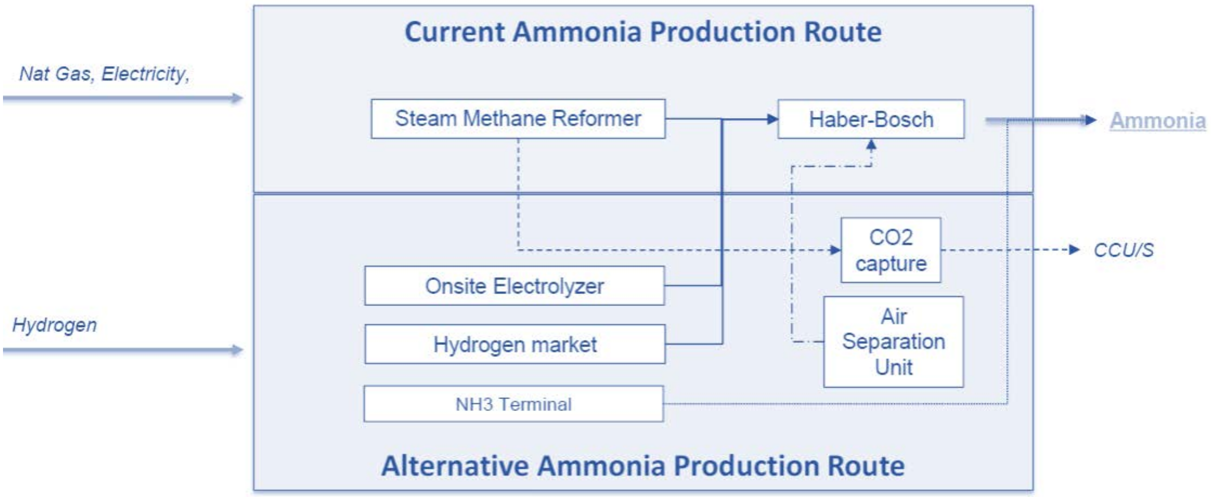
Table 3.35: *Steel current and alternative production routes in TIMES-Slovakia*



Ammonia production methodology

Ammonia production in Slovakia ***Table 3.36*** is done in single plant. It is represented in TIMES-Slovakia as one unique Haber-Bosch process coupled with a Steam Methane Reformer (NG/SMR). The options to decarbonize the production of ammonia include the integration of CCUS into the exiting processes –which already includes a CC unit to capture process-related emissions to prevent damaging the catalyst for the ammonia synthesis. This highly pure CO_2 stream is already captured and used in downstream utilizations such as urea production or the food industry. The remaining combustion emissions, which represent 1/3 of the total emissions, can be captured by installing an additional CC unit. This configuration (Natural Gas/Steam methane Reforming + carbon capture) produces the so-called blue hydrogen needed in the Haber-Bosch. A different alternative to grey hydrogen or blue hydrogen is the production of yellow hydrogen –hydrogen produced with grid electricity– both onsite or centralized, or the use of imported green hydrogen. In such cases, there is a need to provide nitrogen for ammonia synthesis using an Air Separation Unit (ASU). Nitrogen is currently obtained from steam methane reforming.

Table 3.36: *Ammonia current and alternative production routes in TIMES-Slovakia*



Chlorine production methodology

Chlorine production in Slovakia is done by (FORTISCHEM). The production is mostly done through membrane cell electrolysis (93%). Being the former the most recent and commonly used route worldwide. This process has already been fully electrified and produces hydrogen as a by-product. Consequently, chlorine production doesn't have direct CO_2 emissions. For this reason, in TIMES-Slovakia chlorine is always produced through the membrane cell electrolysis, and refurbishment of existing assets is considered. The hydrogen that is obtained as a by-product (0.9Kt/H_2) is assumed to currently be consumed within the industry and, thus, it is not available for new processes such as DRI steelmaking.

High-Value Chemicals

High-Value Chemical (HVC) production in (Slovnaft) heavily relies on energy-intensive processes like naphtha cracking and propane dehydrogenation. To reduce greenhouse gas emissions and transition to more sustainable practices, the industry is exploring options such as electrification, carbon capture, and utilization of renewable energy sources. While innovative technologies like methanol-to-olefins and methanol-to-aromatics are under development, the near-term focus remains on optimizing existing processes, including furnace electrification and carbon capture, to achieve significant emissions reductions.

Cement production methodology

The cement sector in Slovakia is spread across different regions, while clinker production is concentrated in different regions in mainly in eastern and western Slovakia. There are several types of cement based on their production characteristics as well as on their final use. Portland cement: The most common type of cement used in a wide variety of concrete mixes. White Portland cement: Used for the production of decorative concrete and plaster mixes. To simplify the cement production, TIMES-Slovakia considers only one type of cement demand, which is produced using blast furnace slag and clinker, with a clinker-to-cement ratio of 0.72. The production of cement in TIMES-Slovakia is modelled in such a way that represents the main steps, namely raw mill, kiln and precalcinator, and cement mill. The thermal consumption in the sector –almost entirely dedicated to the kiln & precalcinator– is provided by fossil fuels, while the remaining part comes from biofuels and waste.

These values are aligned with the European estimated average consumption. However, the increasing share of biomass and waste in the kiln has a limitation to reducing the emission of the cement sector, as roughly 2/3 of the emissions are attributed to the calcination of limestone, and these are the so-called process emissions. TIMES-Slovakia was designed to model process and combustion emissions separately, which allows the model to find alternatives to produce the heat needed in the kiln, while for the process emission CCUS options could be explored.

Table 3.37: *High-Value Chemicals current and alternative production routes in TIMES-Slovakia*

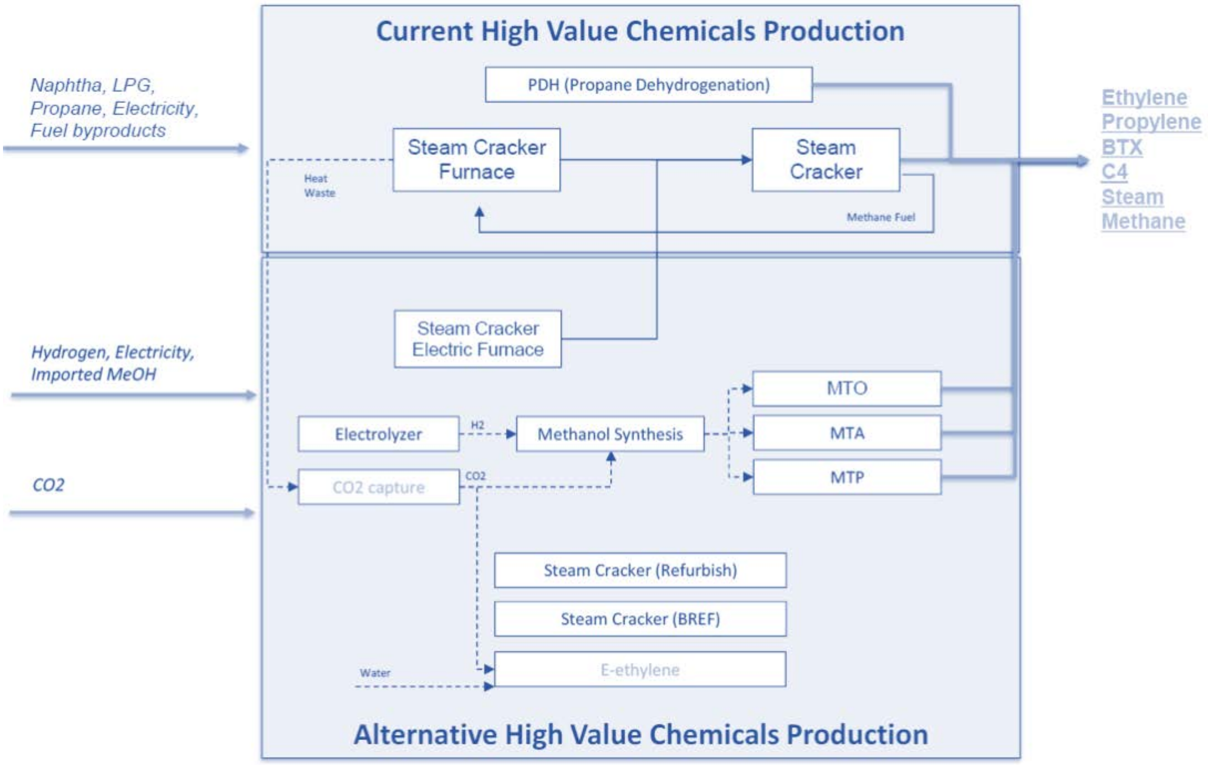
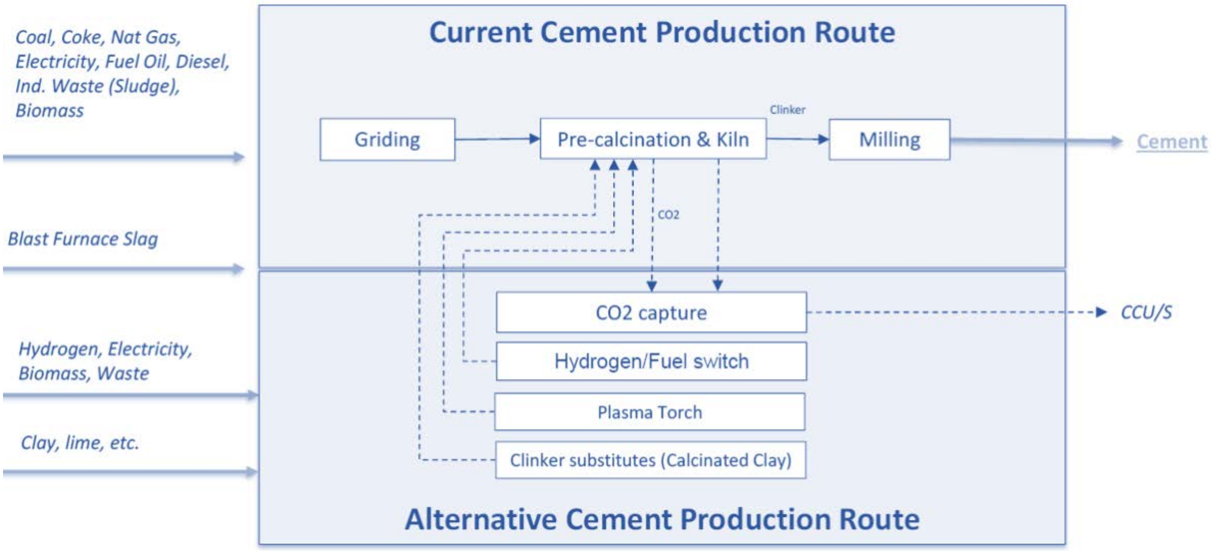


Table 3.38: *Cement current and alternative production routes in TIMES-Slovakia*



Possible areas for model expansion and possible future model applications:

- Expand the technology detail for dwelling, agriculture, transport and/or more industry sub-sectors,
- Include endogenous modelling of land competition between sectors (e.g. agriculture and energy) and among energy technologies (biomass, wind, solar)
- Include modelling of water uses for energy technologies;
- Endogenously model the use of materials (including critical materials) for energy technologies, including the linkages to the whole production chain (e.g. use of steel for wind turbines);
- Include non-CO_2 emissions (also process related), both for other GHG and for air pollutants;

3.6.7.4. Model Description

As the IPPU sector is interconnected within the industrial energy system, the TIMES-Slovakia model is also utilized for modelling industrial processes. A more detailed description of this model can be found in Chapter XY.

The model is built with a time horizon 2022 – 2050 (calibrated to 2022), with optimisation accounting for annual and sub-annual operations. TIMES-Slovakia provides annual outputs from 2025 until 2050 for every 5 years’ time step (e.g. 20025, 2030, 2035, etc.). At this stage 2055 is being used as a "dummy" year to avoid end of period distortions when obtaining results for 2050.

MS Excel tools were used for modelling emission projections in the sources outside of the EU-ETS system and for F-gases. Emission projections were prepared in accordance with the methodology of the Intergovernmental Panel on Climate Change from 2006, Chapter IV (IPCC 2006 Guidelines). The calculation analysis tool is based on the Excel platform and the calculation includes different policies and measures (in numerical formulation) defined according to the WEM and WAM scenarios. The model that was developed in connection with the implementation of Regulation (EU) 2018/841 of the European Parliament and of the Council of 30 May 2018 on the inclusion of greenhouse gas emissions and removals from land use, land use change and forestry in the 2030 climate and energy framework, and amending Regulation (EU) No 525/2013 and Decision No 529/2013/EU.

3.6.7.5. Scenarios, Parameters and PAMs

The IPPU sector allocates greenhouse gas emissions regulated by Directive 2003/87/EC of the European Parliament and of the Council of 13. October 2003 establishing a scheme for greenhouse gas emission allowance trading within the EU and amending Council Directive 96/61/EC28 (hereinafter referred to as EU ETS emissions) and non-EU ETS emissions allocated by Regulation (EU) 2018/842 of the European Parliament and of the Council of 30 May 2018 on binding annual greenhouse gas emission reductions by Member States of greenhouse gas emissions for the period 2021 to 2030 to contribute to climate action to meet their commitments under the Paris Agreement and amending Regulation (EU) No. 525/201327 (hereinafter referred to as the ESR emissions).

IPPU sector includes GHG emissions allocated under the revised EU ETS Directive and emissions from smaller industrial sources which are not allocated under the Directive.[43] Emissions projections from the non-EU ETS IPPU sources of emissions, mainly CO_2 ETS emissions, are projected together with the emissions from energy sector.

The following sources are considered as taking part in the EU-ETS scheme:

- Central electricity, CHP and heat producers
- Industrial auto-producers (electricity and CHP)
- Large industries: Steel, Cement, Glass, Pulp and Paper
- Process emissions from all industries

While EU ETS emissions have their reduction mechanisms set by the allocation of allowances at the operator level, ESR emissions are not sectoral regulated and the ESR reduction target is set only at the level of the country as a whole. It is therefore very important to identify potential areas for reduction, regulation or promotion. The report looks at projections of ESR emissions from the IPPU sector. This sector accounts for process (technological) emissions, i.e. not emissions from fossil fuel combustion (which are accounted for in the Energy or Buildings sectors). More on the methodology for allocating greenhouse gas emissions to the EU ETS and the ESR can be found in the report.

The projections of ESR emissions in categories 2.A-2.G were mainly prepared by forecasting the development of value added for the identified industrial category under one scenario WEM = WAM. In the absence of relevant direct policies and measures in these sectors, it is very difficult to predict developments up to 2050. It is likely to be influenced only by the availability of raw materials, energy and material prices, and supply and demand. We foresee regulation mainly at EU level. The nature of process (technological) emissions does not allow much room for manoeuvre for their regulation (they are dependent on chemical reactions and processes).

The base (reference) year for modelling the GHG emissions projection was the latest revised inventory year 2022 in all scenarios. Projections of greenhouse gas emissions for the EU ETS emissions component have been developed for the years 2020 – 2050 under the following scenarios:

Two scenarios, WEM and WAM, have been prepared for the purpose of determining the target for 2030 and subsequently for 2050 in the different categories of industrial activities not included in the EU ETS. Separately for all three groups of IPPU categories, namely CO_2, CH_4 and N_2O emissions in categories 2.A - 2.D, HFCs emissions in category 2.F and N_2O and SF_6 emissions in category 2.G.

The policies and measures taken into account in each scenario are based on a number of national documents:

- Low Carbon Development Strategy of the Slovak Republic until 2030 with a view to 2050 (NUS SR)
- National Air Pollution Control Programme (NAPCP)
- Integrated National Energy and Climate Plan of Slovakia (NECP)

---

[43] https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32018L0410&from=EN

In addition to these documents, separate laws and European legislation also intervene in the preparation of individual scenarios. Act No. 277/2020, which amends Act No. 309/2009 Coll. on the Promotion of Renewable Energy Sources and High Efficiency Combined Production, significantly interferes with the preparation of laws. Within the framework of common European legislation, these are mainly directives setting emission limits and the European Parliament's Energy Union Governance Regulation 2018/1999, complemented by Regulation 2021/1119, which establishes a framework for achieving climate neutrality.

The policies and measures used were taken from the Low Carbon Strategy of the Slovak Republic (LCDS) from the National Air Pollution Control Programme and from the Slovak Recovery Plan.

The reduction potential presented is based on the WEM and WAM scenarios reported for emission projections in 2021 under Regulation (EU) 2018/1999 of the European Parliament and of the Council on the Governance of the Energy Union and Climate Action.

The specification of the WAM scenario according to the Low Carbon Development Strategy of the Slovak Republic depends on the logic of the draft EU scenarios and in particular on the EUCO3030 scenario, which sets the EU target for energy efficiency for 2030 at 30%.

Most of the above measures were applied at the level of the CPS-PRIMES model, from which trends in energy consumption or other parameters were taken for modelling emissions in the TIMES model.

Existing Measures Scenario (WEM) - includes policies and measures adopted and implemented at EU and national level by the end of 2023. In industrial processes, improving energy efficiency is essential for productivity growth, which is part of sustainable growth in added value.

The scenario with additional measures (WAM) - is equivalent to the Dcarb2 scenario of the CPS-PRIMES model, in the IPPU sector the outputs from CPS-PRIMES were used to obtain trends in the different industry types.

Trend of the N_2O and PFCs emissions projections from the sources included in the EU ETS from the CRF categories 2.B and 2.C were prepared according to assumptions of GVA presented in the energy sector (WEM and WAM scenarios).Due to specific character of the emissions produced in the technological process, it is difficult to regulate or mitigate energy demand in these categories of industry. Moreover, the nitric acid production is at its emission limit, therefore, there is no difference between WEM a WAM scenarios). Thus, the trends in emissions strongly depend on the production. Increasing and also decreasing trend in emissions for WEM scenario is caused by the increase in production. Aluminium production finished in 2023, therefore we do not assume the PFC emissions from this source.

The trend of emission projections below the ESR in categories 2.A to 2.D is very complicated to express due to the lack of legislative and market mechanisms. . It is very difficult to influence these emissions by any policies and measures that are influencing the energy demand. The trend of emission projections depends on the technological processes, which are mainly influenced by the EU ETS Directive, therefore emission reductions cannot be expected as production grows. Changes in the trend of emissions projections are therefore caused mainly by changes in production.

Projections of F-Gases emissions were calculated based on the approved EU legislative - Regulation (EU) No 517/2014 of the European Parliament and of the Council of 16 April 2014 on fluorinated greenhouse gases and repealing Regulation (EC) No 842/2006, Annex III as follow (***Table 3.39***).

Table 3.39: *Annex III of EU Regulation No 517/2014 of the European Parliament*

Placing on the market prohibitions referred to in Article 11(1) Products and equipment Where relevant, the GWP of mixtures containing fluorinated greenhouse gases shall be calculated in accordance with Annex IV, as provided for in point 6 of Article 2		**Date of prohibition**
1. Non-refillable containers for fluorinated greenhouse gases used to service, maintain or fill refrigeration, air-conditioning or heat-pump equipment, fire protection systems or switchgear, or for use as solvents		4. July 2007
2. Non-confined direct evaporation systems that contain HFCs and PFCs as refrigerant		4. July 2007
3. Fire protection equipment	that contain PFCs	4. July 2007
	that contain HFC-23	1. January 2016
4. Windows for domestic use that contain fluorinated greenhouse gases		4. July 2007
5. Other windows that contain fluorinated greenhouse gases		4. July 2008
6. Footwear that contains fluorinated greenhouse gases		4. July 2006
7. Tyres that contain fluorinated greenhouse gases		4. July 2007
8. One-component foams, except when required to meet national safety standards, that contain fluorinated greenhouse gases with GWP of 150 or more		4. July 2008
9. Aerosol generators marketed and intended for sale to the general public for entertainment and decorative purposes, as listed in point 40 of Annex XVII to Regulation (EC) No 1907/2006, and signal horns, that contain HFCs with GWP of 150 or more		4. July 2009
10. Domestic refrigerators and freezers that contain HFCs with GWP of 150 or more		1. January 2015
11. Refrigerators and freezers for commercial use (hermetically sealed equipment)	that contain HFCs with GWP of 2 500 or more	1. January 2020
	that contain HFCs with GWP of 150 or more	1. January 2022
12. Stationary refrigeration equipment, that contains, or whose functioning relies upon, HFCs with GWP of 2 500 or more except equipment intended for application designed to cool products to temperatures below -50°C		1. January 2020
13. Multipack centralised refrigeration systems for commercial use with a rated capacity of 40 kW or more that contain, or whose functioning relies upon, fluorinated greenhouse gases with GWP of 150 or more, except in the primary refrigerant circuit of cascade systems where fluorinated greenhouse gases with a GWP of less than 1 500 may be used		1. January 2022
14. Movable room air-conditioning equipment (hermetically sealed equipment which is movable between rooms by the end user) that contain HFCs with GWP of 150 or more		1. January 2020
15. Single split air-conditioning systems containing less than 3 kg of fluorinated greenhouse gases, that contain, or whose functioning relies upon, fluorinated greenhouse gases with GWP of 750 or more		1. January 2025
16. Foams that contain HFCs with GWP of 150 or more except when required to meet national safety standard	Extruded polystyrene (XPS)	1. January 2020
	Other foams	1. January 2023
17. Technical aerosols that contain HFCs with GWP of 150 or more, except when required to meet national safety standards or when used for medical applications		1. January 2018

F-Gases emission projections in the category 2.F were prepared according to two scenarios – WEM and WAM.

Emissions projections according to the WEM scenario were followed directly the above-mentioned EU Regulation, Annex III. It was assumed that the gas R404A (GWP 3922) will be replaced with the gases R448A (GWP 1387), R449A (GWP 1397) and R452A (2410). The gas 410A will be replaced with R452B (GWP 698) and the gas R134a will be replaced with the gas R513A (GWP 631). Except of MAC when it will be replaced with the gas R1234YF. Later the gases with the GWP higher than 750 will be replaced with gases with GWP 150.

Emissions projections according to the WAM scenario were following the above-mentioned EU Regulation and in addition with the requirement that gases with the zero GWP (or by the supplementary gases) should replace all refrigerants the after 2033.

SF_6 and N_2O emissions projections in the category 2.G were prepared according to WEM and WAM scenarios. Emissions projections of the SF_6 in the WEM scenario were prepared by the extrapolation of the base year emissions (and considering time series consistency) with the assumption that the phase-out of obsolete equipment started. Emissions projections in the WAM scenario followed the restrictions on the utilisation of SF_6 gas in the new equipment after 2025. Emissions projections of N_2O in the category 2.G.3 were prepared according to extrapolated trend of the last 10 years (WEM). In the WAM scenario, a gradual replacement of N_2O in anaesthesia was assumed.

CCS technology was not considered as one of the real measures in Slovak conditions. Today's main barriers to CCS deployment include the need to demonstrate that geological storage is definitely safe and permanent, the need for international regulatory frameworks, possible social acceptance issues, the high investment and operation costs, and the lack of specific policies (incentives) for emission reduction via CCS. Emission trading system (EU ETS) alone are not enough to promote CCS as the current CO_2 price is low to compensate for the high cost and financial risk in most CCS applications.

3.6.7.6. GHG Emission Projections by Categories and Gases

Projections of CO_2 emissions in the IPPU Sector

Carbon dioxide (CO_2) emissions from the Industrial Processes and Product Use (IPPU) sector are primarily driven by emissions subject to the EU Emissions Trading System (EU ETS), particularly those originating from mineral and metal production. Additionally, emissions from the chemical industry and solvent use contribute significantly to the overall CO_2 footprint of the IPPU sector. The projected trends in CO_2 emissions from the IPPU sector, as modelled under the WEM and WAM scenarios, are presented in ***Figure 3.39*** and ***Table 3.40***

Figure 3.39: *Emission projections of CO_2 in Gg in the IPPU sector in WEM and WAM scenarios*

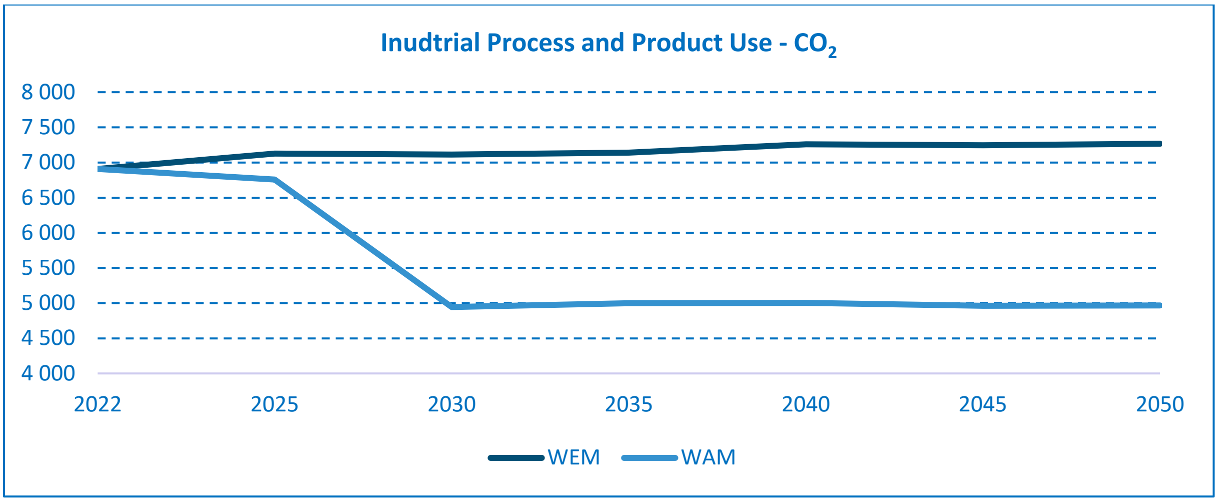


***Table 3.40:** Emission projections of CO_2 in Gg in the IPPU sector in WEM and WAM scenarios*

WEM	2022*	2025	2030	2035	2040	2045	2050
2. Industrial processes	6 908.01	7 128.73	7 111.72	7 141.59	7 258.30	7 245.00	7 266.51
A. Mineral processing	2 332.71	2 321.36	2 305.07	2 342.25	2 456.47	2 438.12	2 461.90
B. Chemical industry	1 022.93	1 080.69	1 089.99	1 082.33	1 081.46	1 083.42	1 079.76
C. Metal industry	3 511.61	3 687.85	3 677.83	3 683.12	3 688.97	3 692.80	3 694.26
D. Non-energy use of products	40.77	38.82	38.83	33.88	31.40	30.66	30.59
WAM	**2022***	**2025**	**2030**	**2035**	**2040**	**2045**	**2050**
2. Industrial processes	6 908.01	6 758.09	4 944.83	4 998.54	5 003.14	4 960.89	4 965.94
A. Mineral processing	2 332.71	1 932.19	1 919.06	1 949.59	2 044.15	2 029.18	2 049.08
B. Chemical industry	1 022.93	1 096.00	1 085.74	1 049.92	994.52	959.04	906.01
C. Metal industry	3 511.61	3 691.07	1 901.19	1 965.15	1 933.07	1 942.01	1 980.26
D. Non-energy use of products	40.77	38.82	38.83	33.88	31.40	30.66	30.59

* Base year 2022; 2022 based on the GHG inventory submission 15. 3. 2024

Projections of CH_4 emissions in the IPPU Sector

Methane (CH_4) emissions from the Industrial Processes and Product Use (IPPU) sector are predominantly linked to the production of ammonia and metal compounds. While significant within the IPPU sector, CH_4 emissions from these sources do not contribute substantially to total greenhouse gas emissions. The CH_4 emission projections were developed under a single scenario, WEM = WAM. ***Figure 3.40*** and ***Table 3.41*** present the projected trend in CH_4 emissions from the IPPU sector according to the WEM = WAM scenario.

***Figure 3.40:** Emission projections of CH_4 in Gg in the IPPU sector in WEM and WAM scenarios*

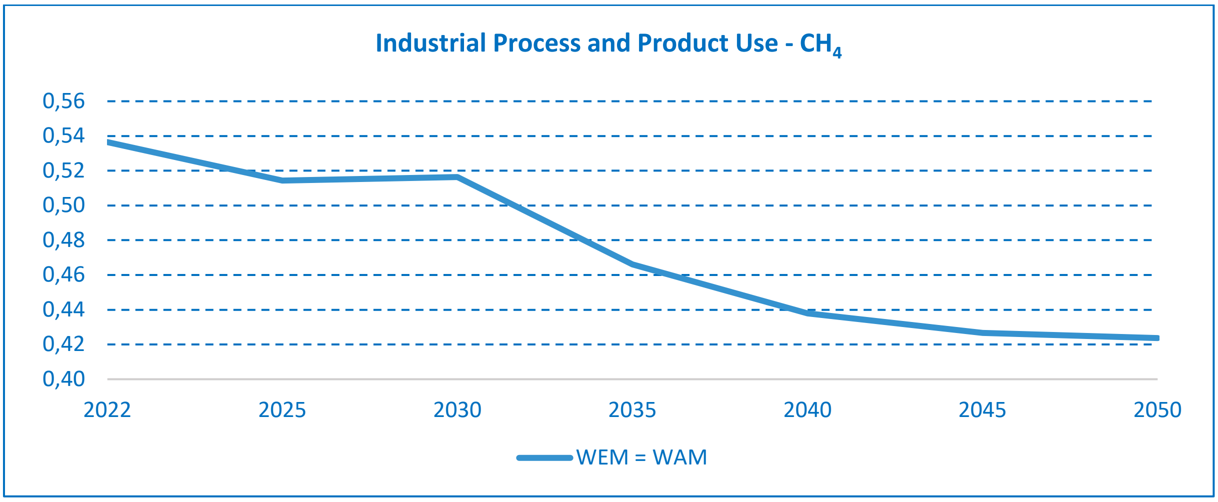


***Table 3.41:** Emission projections of CH_4 in Gg in the IPPU sector in WEM and WAM scenarios*

WEM = WAM	2022*	2025	2030	2035	2040	2045	2050
2. Industrial processes	0.54	0.51	0.52	0.47	0.44	0.43	0.42
B. Chemical industry	0.01	0.01	0.01	0.01	0.01	0.01	0.01
C. Metal industry	0.52	0.50	0.50	0.45	0.43	0.41	0.41

* Base year 2022; 2022 based on the GHG inventory submission 15. 3. 2024

Projections of N_2O emissions in the IPPU Sector

N_2O emissions within the IPPU sector originate primarily from the catalytic oxidation of ammonia to nitric acid. This process, essential for the production of fertilizers and other nitrogen-based products, can lead to significant N_2O emissions if not properly controlled. While N_2O emissions from the IPPU sector are relatively small compared to other sectors, such as agriculture, they nonetheless contribute to global warming and ozone depletion. ***Figure 3.41*** and ***Table 3.42*** provide a detailed breakdown of the projected N_2O emissions from the IPPU sector under the WEM and WAM scenarios, highlighting the potential impact of various mitigation strategies.

Figure 3.41: *Emission projections of N_2O in Gg in the IPPU sector in WEM and WAM scenarios*

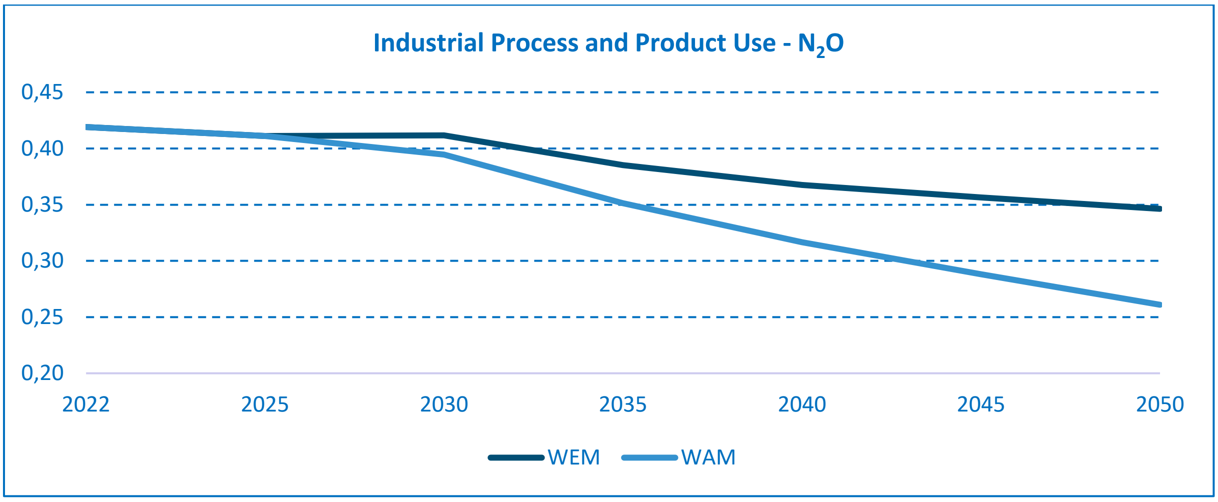


Table 3.42: *Emission projections of N_2O in Gg in the IPPU sector in WEM and WAM scenarios*

WEM	2022*	2025	2030	2035	2040	2045	2050
2. Industrial processes	0.42	0.41	0.41	0.39	0.37	0.36	0.35
B. Chemical industry	0.20	0.20	0.21	0.19	0.18	0.18	0.18
C. Metal industry	0.00	0.00	0.00	0.00	0.00	0.00	0.00
G. Other product man. and use	0.22	0.21	0.20	0.19	0.18	0.17	0.17
WAM	**2022***	**2025**	**2030**	**2035**	**2040**	**2045**	**2050**
2. Industrial processes	0.42	0.41	0.39	0.35	0.32	0.29	0.26
B. Chemical industry	0.20	0.20	0.21	0.19	0.18	0.18	0.18
C. Metal industry	0.00	0.00	0.00	0.00	0.00	0.00	0.00
G. Other product man. and use	0.22	0.21	0.18	0.16	0.13	0.11	0.08

* Base year 2022; 2022 based on the GHG inventory submission 15. 3. 2024

Projections of F-Gases emissions in the IPPU Sector

F-gas projections include emissions of PFCs (aluminium production), HFCs (use of refrigerators and air conditioners) and SF_6 (electronics production). They currently account for a relatively significant share but are projected to decrease significantly. The trends according to the WEM and WAM scenarios are provided in the ***Figure 3.42*** and in the ***Table 3.43***.

Figure 3.42: *Emission projections of F-gases in Gg of CO_2 eq. in the IPPU sector in WEM and WAM*

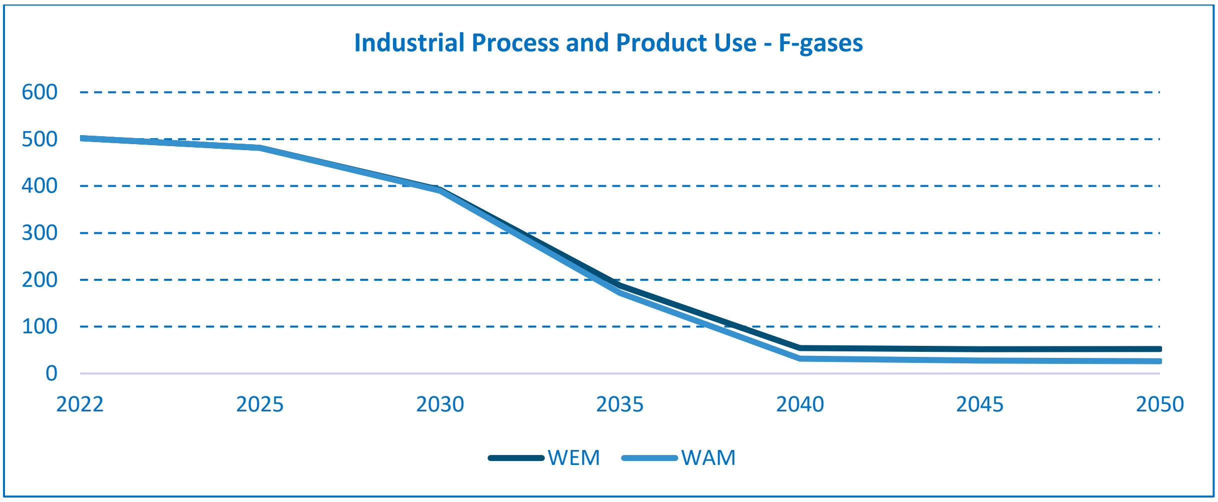


Table 3.43: *Emission projections of F-gases in Gg of CO_2 eq. in the IPPU sector in WEM and WAM scenarios up to 2050*

WEM	2022*	2025	2030	2035	2040	2045	2050
2. Industrial processes	502.15	481.83	392.12	187.71	54.23	51.93	52.10
C. Metal industry	5.88	0.00	0.00	0.00	0.00	0.00	0.00
F. Use of products to ODS replacements	480.89	466.67	377.92	175.14	42.03	39.73	39.90
G. Other processing and uses	15.38	15.16	14.20	12.57	12.20	12.20	12.20
WAM	**2022***	**2025**	**2030**	**2035**	**2040**	**2045**	**2050**
2. Industrial processes	502.15	481.60	389.96	172.23	32.16	27.75	26.30
C. Metal industry	5.88	0.00	0.00	0.00	0.00	0.00	0.00
F. Use of products to ODS replacements	480.89	466.62	376.23	160.44	21.02	16.74	15.28
G. Other processing and uses	15.38	14.98	13.73	11.79	11.14	11.02	11.02

***** Base year 2022; 2022 based on the GHG inventory submission 15. 3. 2024

3.6.8. GHG EMISSION PROJECTIONS IN AGRICULTURE SECTOR

In preparing the presented projections, long list of measures that have a detectable impact on the estimated emissions were analysed and quantification of their impact on the GHG inventory and pollutant inventory was possible. All other measures that were proposed in the strategies and not implemented in the projections do not have a measurable effect on the inventory but have an impact on agriculture as a whole in relation to the environment.

Subsequently, based on literature and expert consultations, the values of key parameters for these measures were determined to best reflect the conditions in Slovakia.

A comprehensive list of measures was proposed based on available literature, encompassing measures applicable to both crop and livestock production. In livestock production, the measures were further categorized by animal species: dairy cattle, non-dairy cattle, sheep, poultry, and pigs.

From this broader list, measures expected to be applicable in Slovakia for each animal species or land type were selected after consultations with experts from the National Agricultural and Food Centre

(NPPC), the Slovak Hydrometeorological Institute (SHMÚ), and the Ministry of Agriculture and Rural Development (MPRV SR).

Results of preparation revised projections consist into two scenarios were prepared for the development of emissions from agriculture after 2022: a scenario with existing measures (WEM scenario) and a scenario with additional measures (WAM scenario). The results of the emission projection modelling are presented in ***Figure 3.43*** and ***Table 3.44.***

In the WEM scenario, measures adopted by 2022 were implemented, while the WAM scenario included additional planned or discussed measures. The effect of the implemented measures is evident in the reduction of emission projections by 2050, with a 68% reduction in the WEM scenario and a 75% reduction in the WAM scenario compared to 1990. According to the WEM scenario, emissions in 2050 will increase by 27%, whereas in the WAM scenario, they will decrease by 49% compared to 2005.

To set national legislation, it is important to establish an emission reduction target for the agriculture sector for 2030, with 2005 as the base year. Emission projections for 2030 show an increase of 0.5% in the WEM scenario and a decrease of 6.8% in the WAM scenario compared to 2005.

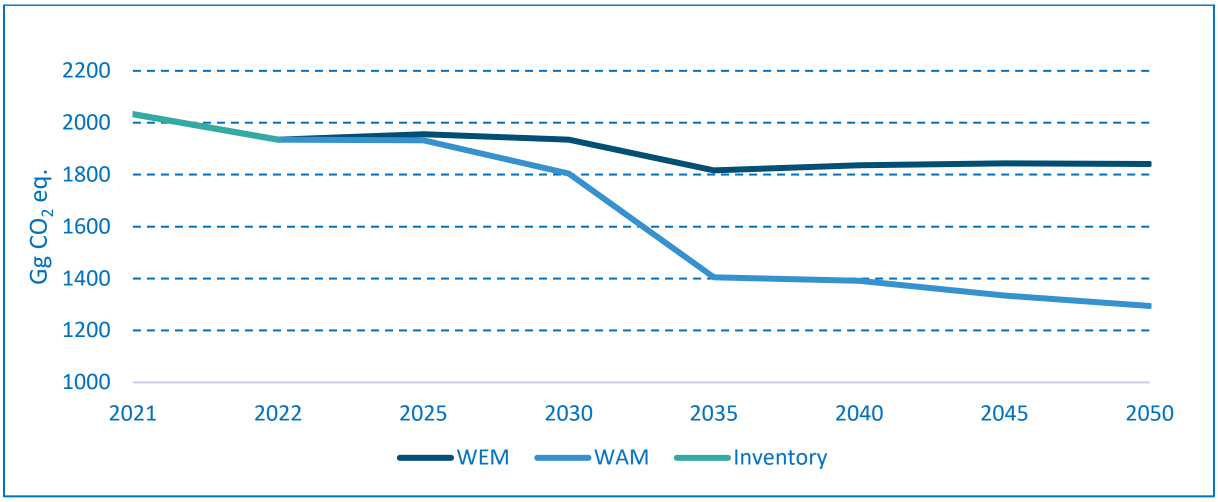
Table 3.44 and ***Figure 3.43*** show aggregated data on GHG emission projections in the agriculture sector.

Table 3.44: *GHG emission projections in Gg of CO_2 eq. in WEM and WAM scenario in Agriculture*

WEM	2022*	2025	2030	2035	2040	2045	2050
3. Agriculture	1 934.43	1 956.11	1 935.36	1 816.59	1 836.69	1 843.13	1 841.10
3.A Enteric fermentation	1 028.92	1 037.82	1 021.80	938.48	967.14	983.46	1 004.36
3.B.1 Manure management	100.79	99.04	98.23	87.80	88.67	87.60	87.27
3.B.2 Manure management	179.11	106.35	107.70	98.29	100.33	100.79	101.96
3.D Agricultural soils	564.77	553.56	541.64	523.25	504.60	492.58	466.65
3.G Limestone and dolomite	3.334	1.772	1.705	2.349	2.684	2.906	2.839
3.H Use of urea	56.62	73.73	79.36	81.61	86.11	87.23	87.23
WAM	**2022***	**2025**	**2030**	**2035**	**2040**	**2045**	**2050**
3. Agriculture	1 934.43	1 932.89	1 803.84	1 404.42	1 390.64	1 334.53	1 294.36
3.A Enteric fermentation	1 028.92	1 037.82	979.26	642.87	644.04	613.72	610.25
3.B.1 Manure management	100.79	99.04	98.23	86.47	87.37	86.33	85.88
3.B.2 Manure management	179.11	162.61	163.67	149.71	152.00	151.63	152.44
3.D Agricultural soils	564.77	540.75	470.28	436.38	420.83	410.80	389.18
3.G Limestone and dolomite	3.334	1.772	1.705	2.349	2.684	2.906	2.839
3.H Use of urea	56.62	73.73	71.42	65.29	60.28	43.62	26.17

***** Base year 2022; 1990 – 2022 based on the GHG inventory submission 13. 04. 2023

***Figure 3.43:** GHG emission projections in the Agriculture sector in WEM and WAM scenarios up to 2050*



3.6.8.1. Input Parameters for Emission Projections

To properly prepare the model for agricultural emissions projections, it is necessary to obtain a wide range of input data and parameters along with their historical time series. The available time series of input data have varied lengths (the longest covering the period 1970 – 2022, the shortest covering the period 2003 – 2022) and were obtained from various sources (Green Report of the Slovak Republic, Statistical Office of the Slovak Republic, situational and outlook reports of NPPC-VÚEPP, Central Control and Testing Institute of Agriculture - ÚKSUP).

The input data required for the preparation of projections are as follows:

- Number of cattle in the head (data available by regions for the period 1990-2020, source: Statistical Office of the Slovak Republic - ŠÚ SR)
- Number of pigs in the head (1990 – 2022, ŠÚ SR)
- Number of sheep in the head (1990 – 2022, ŠÚ SR)
- Number of poultry in the head (1990 – 2022, ŠÚ SR)
- Number of goats in head (1990 – 2022, ŠÚ SR)
- Number of horses in the head (1990 – 2022, ŠÚ SR)
- Milk yield per cow - average annual milk yield per dairy cow in kilograms (1990 – 2022, ŠÚ SR)
- Milk yield per ewe - average annual milk yield per dairy ewe in kilograms (1990 – 2022, ŠÚ SR)
- Consumption of nitrogen fertilizers in tons (1990 – 2022, sources: IFASTAT and ÚKSUP), data available for Slovakia by types
- Consumption of urea in tons (2000 – 2020, source: ÚKSUP)
- Consumption of ground limestone and dolomite in tons (2000 – 2020, source: ÚKSUP)

The input data for the given time period were subsequently processed for use in preparing projections of parameters in Slovak agriculture for 2020 – 2040. The exponential smoothing model SAS 9.3 was modelled at the Research Institute of Agricultural and Food Economics in Bratislava (NPPC-VÚEPP). Subsequently, projections of input parameters such as livestock populations and quantities of applied organic and mineral fertilizers were calculated until 2040-2050 at the Slovak Hydrometeorological Institute (SHMÚ) using the exponential smoothing function in MS Excel's forecasting tool, Projections. The principle of exponential smoothing is an adaptive method for forecasting time series, which means that the values of parameters in the model change over time. The forecast is based on smoothing weights that assign different importance to individual observations. The most recent observations have the highest weight, exponentially decreasing to the past. The values of the weights are optimized by the statistical software itself.

Slovakia still uses the Grade 1 method for estimating future livestock numbers due to the unavailability of public policies and strategies. In terms of data revision, SHMÚ conducted a review of livestock numbers and fertilizer consumption using exponential smoothing. The results underwent a thorough review process involving relevant ministries (Ministry of Environment of SR, Ministry of Agriculture and Rural Development of SR), research institutes (National Agriculture and Food System, Institute of Environmental Policy), and other entities such as breeding unions and NGOs.

The input from breeding unions provided a more accurate view of the development of livestock numbers in Slovakia. Furthermore, it is mentioned that future Common Agricultural Policy (CAP) measures are expected to impact increasing the mentioned livestock species, particularly through increased grazing breeding. Additionally, the consumption of inorganic fertilizers was modified based on planned European Farm to Fork Strategies and national measures to reduce urea use.

Methodologies and Key Assumptions/Trends

The list of measures was used as input for modelling in a model that simulated the use of individual measures based on the following assumptions:

- Baseline Emission Factors: The basic emission factors for each activity (e.g., pig farming) were determined based on the data from the 2023 Greenhouse Gas Emission reporting by 2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories, **Chapter IV.**
- Cost-Effectiveness Adjustments: The year of full availability for a measure is adjusted so that the cost per ton of emissions saved is lower than the carbon price in that year. Consequently, some measures may not be utilized at all.
- Application Potential Growth: The application potential of measures increases from zero to the maximum application potential linearly over five years, reaching the maximum in the year of full availability.
- Mutually Exclusive Measures: Measures that cannot be applied simultaneously (e.g., different feed additives) are not used together.
- Combined Measures: In cases where multiple measures are combined, the reduction potential of all measures, except the one with the highest potential, is reduced by 20% to account for possible overlap in effects.

Model Description

The model has been developed by E3-modelling with funding from the European Commission in order to provide analytical support to the Slovakian authorities, particularly with regard to the economics of climate change.

The GEM-E3-AGR is a satellite module designed to calculate GHG emissions and identify abatement options within the agricultural sector. This model assesses emissions from agriculture and determines the most cost-effective adoption of abatement technologies to meet specific emission reduction targets. Key outputs include GHG emissions, abatement technologies, and the total and unit costs of emission reduction.

The model accounts for GHG emissions from both animals and crops. It derives the demand for agricultural products from the GEM-E3 model and then employs a nested structure to represent substitution possibilities between different agricultural products. At the base level, all products are identified separately, and abatement technologies are chosen based on GHG emission reduction targets or carbon values.

Specifically, the model addresses the following GHG emissions: i) For animals, CH_4 and N_2O emissions from enteric fermentation and manure management, and ii) For crops, N_2O emissions from fertilizer application.

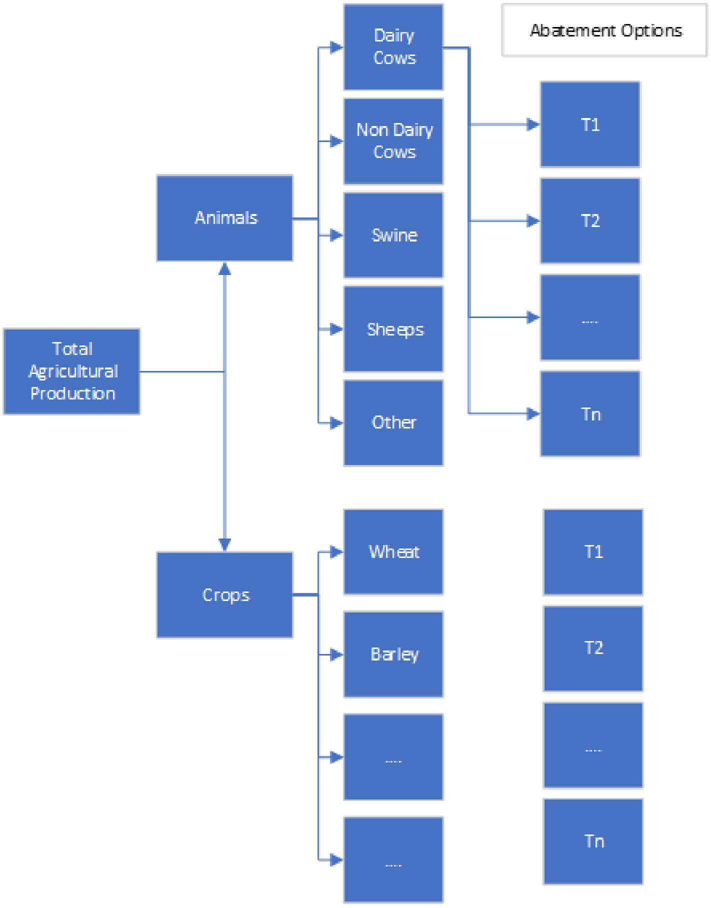
The structure of the model consists of three levels: The first level includes the combined production of all animals and crops. The second level differentiates between total animal production and total crop production. The third level details the production of each specific animal and crop. Abatement options are then calculated for each product.

The GEM-E3-SK model is written in GAMS while supported by scripts in R and visual basic macro commands.

Table 3.45: *SWAT analysis of the GEM-E3-AGR*

Strengths:	**Opportunities:**
Compatibility with emission model for emission inventories The national database used is compatible with EÚ data Data consistencies in the projection and estimation process	Incorporate to the model new technologies Versatile use of time-series
Treats:	**Weakness:**
Easy data entry Non-free Software licence Connected from macroeconomic models	Missing measurable indicators in national policies and strategies

The model in the agricultural sector optimizes the cost-effective selection of measures, including their mutual interactions in application, and calculates the reduction of greenhouse gas emissions until 2050. The measures were selected based on literature and consultations with national experts. Each measure has several basic parameters that determine the scope of possible implementation, the effect on emission reduction, and the cost. From the list of measures, the model selects based on two main factors – the availability of the measure (i.e., the earliest possible date when the measure can be applied) and the cost per ton of emissions saved, which includes all associated application costs and is compared with the price of emission allowances. Two scenarios are modelled – the reference (WEM) and the decarbonisation (WAM), which mainly differ in the availability and scope of measure application and the assumed price of emission allowances.



Scenarios, Parameters and PAMs

Data collection was undertaken in two steps. First, cost and mitigation data from existing literature was compiled. Second, a Slovak expert from the government adapted the mitigation estimates for some of the measures. To make these adjustments transparent, we provide in the below tables both data from literature and from expert judgment, when these differ. The estimates provided by the Slovak expert take into account the applicability of the measure (% of units to which the measure could realistically be applied), whereas the literature estimates do not.

For all measures, prices have been converted to euros and correlated with price from the 2015 year to ensure consistency. Mitigation potential is given per unit (head for livestock measures, hectares for crop measures) and total (per year, and for livestock measures based on number of heads for the year 2022).

The measures are divided 3.A and 3.B categories (Animal species) and 3.D Agriculture soils (Crop measures). For the former category, the specific livestock type to which the measure applies is specified.

Best practice examples were included alongside the description of the measure, where relevant.

- The WOM (BAU) scenario is identical to the scenario with existing WEM measures.

- The WEM scenario is a scenario with measures that include projections of anthropogenic emissions from agricultural sources, after taking into account the effects of policies and measures adopted by the end of 2022.

The WEM Scenario (With Existing Measures) is a scenario with measures that include projections of anthropogenic emissions from agricultural sources, after taking into account the effects of policies and measures adopted by the end of 2022 reference scenario utilizing measures that are currently partially implemented. The basic assumptions of the scenario are as follows:

The maximum application potential of many measures from the list is significantly limited or even zero, meaning some measures are not used at all.

The assumed carbon price increases only slightly (based on the European Commission's assumptions for the WEM scenario), resulting in a gradual implementation of measures, or their current application will not expand at all by 2050.

The WEM scenario took into account policies and measures from national strategies published in the past. The list of policies and measures used was taken from the National Programme for Pollutant Emission Reduction and the Low Carbon Strategy of the Slovak Republic. The stagnation (oil plants, soya, potato) in emission projections for the WEM scenarios after 2005 is due to the projected stagnating (potato, or decreasing (cereals, lantern) in hectare yields in the crop production part, which puts pressure on higher consumption of applied nitrogen fertilisers; the offsetting of organic matter and nutrients to the soil in the form of applied plant matter will also increase. Emissions will also rise in the livestock sector, particularly in beef cattle, sheep and goat farming. Other livestock species are projected to stagnate or decline. In the WEM scenario was also included anaerobic digesters for cattle, poultry and swine. This technic is very effective for reduction of emission from 3.B Manure management.

Daily removal of manure from animal housing systems and covering storage of manure and slurry in the form of isolation of excreta from the surrounding environment and by preventing soil contamination and nitrogen leaching from the stored waste, while contributing to the avoidance of NH_3 and N_2O emissions. This measure is reflected in both the WEM scenario and the WAM scenario. This measure can be found in several strategic documents and legislation, in particular in the Decree of the Ministry of the Environment of the Slovak Republic No. 146/2023 Coll.

The following measures are focused on reducing greenhouse gas emissions in livestock farming through various techniques applicable to dairy cattle, non-dairy cattle, and sheep thy were included into WEM and WAM scenario. These abatements can effectively reduce methane and N_2O emissions. Improved Animal Longevity aims to extend the lifespan of livestock by reducing mortality rates and delaying the culling date. It applies to dairy cattle, non-dairy cattle, and sheep, and can be implemented by livestock farmers through improved management practices such as enhancing animal health, well-being, and living conditions. Also lead to higher productivity by increasing the number of calves/lambs These improvements include ensuring sufficient space, better bedding quality, heat management, and hygiene. Improved Beef Live Weight Gains is designed to increase the live weight gains of beef cattle, primarily through genetic improvements such as crossbreeding. The use of sexed semen and cross-breeding in dairy cattle and sheep aims to improve productivity by increasing the ratio of female calves and sheep.

The WAM Scenario (With Additional Measures) is a decarbonisation scenario highlighting the potential for emission reduction through measures selected based on their increasing cost-effectiveness. The basic assumptions of the scenario are as follows:

The maximum application potential of measures is not limited; all measures that can be applied and are cost-effective are utilized each year (i.e., at least five years before reaching full availability).

The assumed carbon price increases based on the European Commission's assumptions for the WAM scenario, leading to an earlier year of full availability compared to the WEM scenario, and thus an accelerated implementation of individual measures compared to the WEM scenario.

Each measure is characterized by several parameters. Since these parameters are interconnected, only some were used as input parameters for each measure, while the others were calculated based on data on the number of individual species of animals or the extent of land:

- Reduction potential: Percentage reduction of emissions when using the measure.
- Unit reduction potential: Reduction of emissions (in kg) when using the measure at the unit level (per animal or hectare of agricultural land).
- Annual unit costs: Annual costs for implementing the measure at the unit level.
- Price per ton of emissions saved: Calculated as annual unit costs divided by unit reduction potential.
- Maximum application potential: The share of units for which the measure can be used, representing additional use beyond the current application scope.
- Application potential: The share of units for which the measure can be used in a given year.
- Year of full availability: The earliest year in which it is possible to reach the maximum application potential.
- Applied reduction potential: Calculated as reduction potential multiplied by application potential.
- Total reduction potential: Calculated as unit reduction potential multiplied by application potential and the number of units in the given category (e.g., number of animals).

Example of Measure Selection in the Model

In the list of measures for dairy cattle, the following three measures are included:

1. Addition of Nitrates as a Feed Additive:

Cost: 20.75 EUR per ton of emissions saved. Application potential: 30%. Reduction potential: 12%. Year of full availability: 2030.

2. Addition of 3-Nitrooxypropanol as a Feed Additive:

Cost: 123.15 EUR per ton of emissions saved. Application potential: 90%. Reduction potential: 20%. Year of full availability: 2025

3. Addition of Concentrate as a Feed Additive:

Cost: 150.33 EUR per ton of emissions saved. Application potential: 70%. Reduction potential: 10%. Year of full availability: 2032

Based on the assumed carbon price in the WAM scenario, the year of full availability for measure 2 is shifted to 2031 and for measure 3 to 2033.

Therefore, measure 1 is first activated in 2026. Subsequently, measure 2 is first activated in 2027. Since the use of different feed additives is mutually exclusive, only one of these measures can be activated. Given that the reduction potential of measure 2 is higher, measure 1 is deactivated.

Methane emissions from enteric fermentation in the WAM scenario were modelled by taking into account the measure proposed in the long list of measures. One of the measures in the Low Carbon Strategy is the use of additives (nitrates, tannins, lipids and fatty acids, 3-Nitrooxypropanol and amino acids) to reduce methane and nitrogen emissions. This measure impacts category 3.A Enteric Fermentation, 3.B Nitrous Oxide from manure and slurry management and has a partial impact on nitrous oxide emissions from category 3.D Agricultural soils.

Into WAM scenario was also included Zero Emissions Livestock Project (ZELP) Cattle Wearable Technology. This measure involves equipping cattle with a wearable device designed to neutralize methane emissions from exhalation, reducing methane emissions from 3.A Enteric fermentation.

Nitrous oxide and ammonia emissions from manure and slurry management (more efficient manure and slurry storage - Storage and covering of manure and slurry, Daily removal of manure from animal housing systems, low emission housing) in the WAM scenario. The measures are not included on all farms. Maximum application potential was taking into account the measure of introducing requirements to reduce emissions from livestock farms due to economic limitation of sector.

The Common Agricultural Policy (EU CAP) will support the fight against climate change through the Whole Farm Eco-Scheme intervention (31.1), which will ensure the improvement of the structure of arable land, expand unproductive areas in the grassland and grassy inter-rows in orchards and vineyards. The intervention Investments on farms to reduce greenhouse gas and ammonia emissions will support investments in reducing greenhouse gas and ammonia emissions on farms in the form of the intervention Animal welfare - Pastoral farming (31.2). Non-productive investments necessary for introducing measures in agricultural production will also be supported. The intervention "Precision Fertilization of Arable Land - Protection of Water Resources (70.05)" will optimise fertilization rates based on soil analyses and reduce nutrient leaching into groundwater (especially phosphorus and nitrogen). The Slovak Republic has, under Act No. 305/2015 Coll. on Protected Areas of Natural Accumulation, established protected water management areas. The share of utilized agricultural area (UAA) under-supported commitments related to better nutrient management is 16.87%. Precision farming aims to optimise returns on inputs while preserving resources. As this managerial system enables the farmer to, among other things, make better use of fertilisers and fuel use, it also directly contributes to reducing GHG.

The need to increase the share of the use of renewable energy sources in the total volume of energy in agriculture will be addressed by the intervention of Productive investments in agricultural holdings by investing in technologies and related construction investments aimed at energy transformation, in particular of agricultural by-products and biodegradable waste. Investments in equipment for the production of energy from other renewable sources to use all the energy produced on the farm or holding will also contribute to increasing the share of the use of renewable energy sources.

Another implemented measure that has an impact on N_2O and CH_4 emissions in category 3.B Manure and slurry management was the use of slurry and manure as feedstock in anaerobic digesters. This measure impacts emissions reductions through two main pathways - reducing fossil fuel carbon emissions through the production of energy sources and reducing direct nitrous oxide emissions from manure and slurry storage. Although anaerobic digestion does produce methane, it is captured and used in energy production, which has a positive impact on increasing the share of energy from renewable sources.

Additional measures were applied to the WAM scenario to reduce emissions from the categories 3.D.1 and 3.D.2, which include direct and indirect N_2O emissions from agricultural soils as well as ammonia emissions. Slovakia generates more emissions from agricultural soils than from livestock farming, making it necessary to implement more measures aimed at reducing N_2O emissions from the 3.D.1 and 3.D.2 categories. The Strategic Plan of the Common Agricultural Policy has allocated funds through a subsidy scheme for so-called Precision Agriculture, a management strategy based on observing, measuring, and responding to temporal and spatial variability to enhance the sustainability of agricultural production. This includes techniques such as integrated nutrient management. Other measures include the use of denitrification inhibitors. When urea is applied to soil, it dissolves rapidly, reacting ammonia (NH_3) and carbon dioxide (CO_2), and is then nitrified to NO^{3-}. The release of N_2O can also occur, primarily through nitrification and denitrification processes. Nitrification inhibitors can be used to slow down the conversion of ammonium into other forms that lead to nitrogen losses and negatively impact the environment. Both measures lead to a decrease in GHG emissions as with less nitrogen losses, and hence also to a reduction in fertiliser use. Urease inhibitors help reduce greenhouse gas emissions from these processes. Last measures in 3.D Agricultural soils is switch to other organic fertilizers at the expense of inorganic N- fertilizers. Compost, manure and sewage sludge, when properly incorporated into the soil, lead to less emissions than the application of inorganic fertilisers and removes emissions associated with the production of inorganic fertilisers. In addition, organic fertilisers improve soil health and biodiversity (in soil and on land), improve nutrient cycling, and decrease emissions from other stages of the value chain.

GHG Emission Projections by Categories and Gases

Projections of CO_2 emissions in the Agriculture sector

CO_2 emissions in Agriculture sector arise from categories 3.G - Liming and 3.H – Urea application, accounting for only 3% of total GHG emissions in 2022. Projections according to WEM and WAM scenarios are presented in ***Figure 3.44*** and ***Table 3.46***.

Figure 3.44: *CO_2 emission projections in Gg in the Agriculture sector in WEM and WAM scenarios up to 2050*

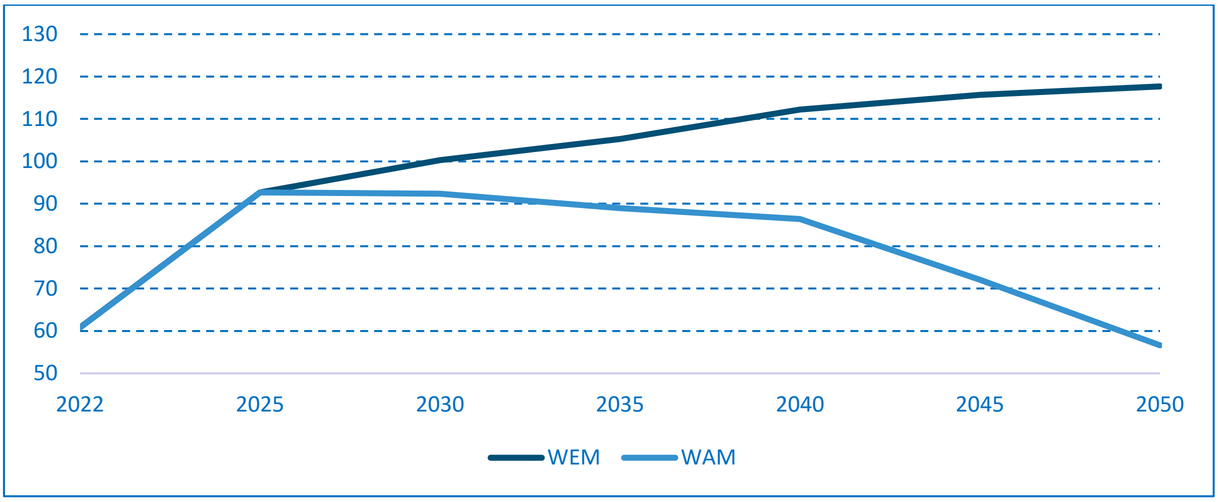


Table 3.46: *CO_2 emission projections in Gg in the Agriculture sector in WEM and WAM scenarios up to 2050*

WEM	2022*	2025	2030	2035	2040	2045	2050
3. Agriculture	60.84	92.68	100.33	105.31	112.23	115.66	117.68
3.G Limestone and dolomite	4.22	18.95	20.97	23.70	26.12	28.43	30.44
3.H Use of urea	56.62	73.73	79.36	81.61	86.11	87.23	87.23
WAM	**2022***	**2025**	**2030**	**2035**	**2040**	**2045**	**2050**
3. Agriculture	60.84	92.68	92.39	88.98	86.40	72.04	56.61
3.G Limestone and dolomite	4.22	18.95	20.97	23.70	26.12	28.43	30.44
3.H Use of urea	56.62	73.73	71.42	65.29	60.28	43.62	26.17

***** Base year 2022; 1990 – 2022 based on the GHG inventory submission 13. 04. 2023

Projections of CH_4 emissions in the Agriculture sector

CH_4 emissions in Agriculture sector arise from categories 3.A – Enteric fermentation and 3.B.1 – Manure management, accounting for 56% of total GHG emissions in 2022. Projections according to WEM and WAM scenarios are presented in ***Figure 3.45*** and ***Table 3.47*.**

Figure 3.45: *CH_4 emission projections in Gg in the Agriculture sector in WEM and WAM scenarios up to 2050*

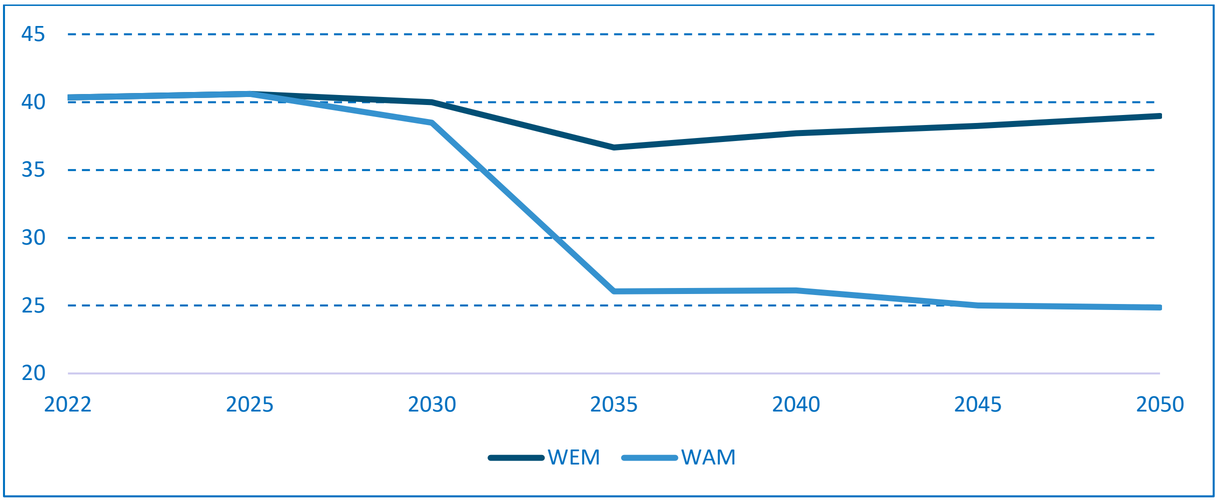


Table 3.47: *CH_4 emission projections in Gg of CO_2 eq. in the Agriculture sector in WEM and WAM scenarios up to 2050*

WEM	**2022***	**2025**	**2030**	**2035**	**2040**	**2045**	**2050**
3. Agriculture	1 934.43	1 956.11	1 935.36	1 816.590	1 836.693	1 843.13	1 841.10
3.A Enteric fermentation	1 028.92	1 037.82	1 021.80	938.48	967.14	983.46	1 004.36
3.B.1 Manure management	100.79	99.04	98.23	87.80	88.67	87.60	87.27
WAM	**2022***	**2025**	**2030**	**2035**	**2040**	**2045**	**2050**
3. Agriculture	1 934.43	1 932.89	1 803.84	1 404.42	1 390.64	1 334.53	1 294.36
3.A Enteric fermentation	1 028.92	1 037.82	979.26	642.87	644.04	613.72	610.25
3.B.1 Manure management	100.79	99.04	98.23	86.47	87.37	86.33	85.88

***** Base year 2022; 1990 – 2022 based on the GHG inventory submission 13. 04. 2023

Projections of N_2O emissions in the Agriculture sector

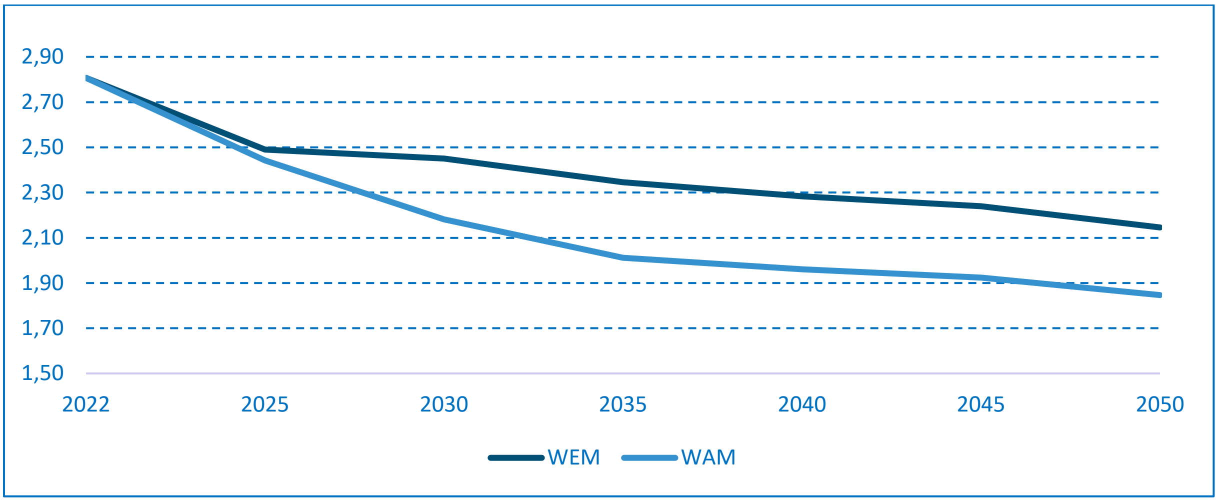
N_2O emissions in Agriculture sector arise from categories 3.B.2 – Manure management and 3.D – Agricultural soils, accounting for 41% of total GHG emissions in 2022. Projections according to WEM and WAM scenarios are presented in ***Figure 3.46*** and ***Table 3.48***.

Table 3.48: *N_2O emission projections in Gg of CO_2 eq. in the Agriculture sector in WEM and WAM scenarios up to 2050*

WEM	**2022***	**2025**	**2030**	**2035**	**2040**	**2045**	**2050**
3. Agriculture	1 934.43	1 956.11	1 935.360	1 816.590	1 836.693	1 843.13	1 841.10
3.B.2 Manure management	179.11	106.35	107.70	98.29	100.33	100.79	101.96
3.D Agricultural soils	564.77	553.56	541.64	523.25	504.60	492.58	466.65
WAM	**2022***	**2025**	**2030**	**2035**	**2040**	**2045**	**2050**
3. Agriculture	1 934.43	1 932.89	1 803.84	1 404.42	1 390.64	1 334.53	1 294.36
3.B.2 Manure management	179.11	162.61	163.67	149.71	152.00	151.63	152.44
3.D Agricultural soils	564.77	540.75	470.28	436.38	420.83	410.80	389.18

***** Base year 2022; 1990 – 2022 based on the GHG inventory submission 13. 04. 2023

Figure 3.46: *N_2O emission projections in Gg in the Agriculture sector in WEM and WAM scenarios up to 2050*



3.6.9. GHG EMISSION PROJECTIONS IN LULUCF SECTOR

This chapter discusses the effect of adopted, implemented and planned measures and policies and analyses their impact on projections of emissions/removals (CO_2, CH_4 and N_2O) of greenhouse gases (GHGs) in each land use category 4.A Forest Land, 4. B Cropland, 4.C Grassland, 4.D Wetlands, 4.E Settlements, 4.F Other Land and 4.G Harvested Wood Products (HWP), but also across the LULUCF sector.

The LULUCF sector is unique in terms of climate change, as it can primarily capture GHG emissions, and is only a small producer of GHG emissions. The latest published results of the GHG inventory in Slovakia for the year 2022 indicate that 37 012.71 Gg CO_2 eq. was produced. The LULUCF sector captured -7233.43 Gg CO_2 eq., representing 23.6% of all emissions produced. Forests are the most important category within LULUCF in Slovakia, accounting for more than 2/3 of the CO_2 sequestered in this sector. In addition to this category, the categories of Cropland and Grassland, as well as Harvested wood products, also show CO_2 sinks, but are much less significant from a balance sheet perspective. In contrast, CO_2, CH_4 and N_2O emissions are produced in the categories Settlements and Other land, also from biomass burning after forest harvesting, from forest fires, as well as from land mineralisation due to land use changes.

Figure 3.47: *GHG emissions/removals trend and projections in Gg of CO_2 eq. in the LULUCF sector in WEM and WAM scenarios up to 2050*

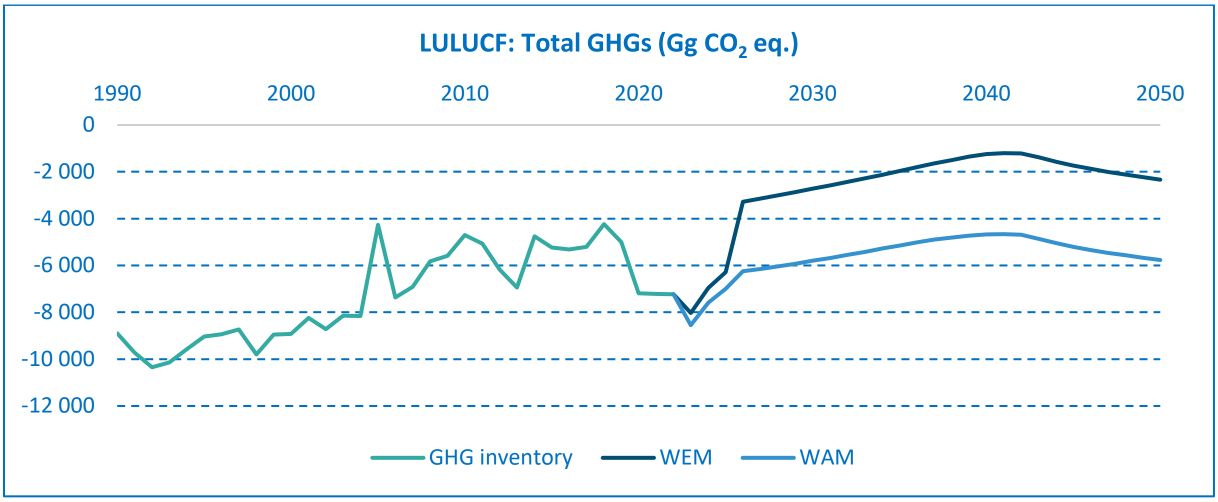


Table 3.49: *GHG emissions/removals trend and projections in the LULUCF sector in WEM and WAM scenarios up to 2050*

Year	WEM	WAM
	Gg CO_2 equivalents	
1990*	-8 894.27	-8 894.27
1995*	-9 028.55	-9 028.55
2000*	-8 923.24	-8 923.24
2005*	-4 266.40	-4 266.40
2010*	-4 705.39	-4 705.39
2015*	-5 237.00	-5 237.00
2020*	-7 181.97	-7 181.97
2022*	-7 233.43	-7 233.43
2025	-6 283.51	-6 990.42
2030	-2 721.47	-5 800.22
2035	-1 967.62	-5 144.73
2040	-1 246.26	-4 671.18
2045	-1 732.14	-5 202.41
2050	-2 341.62	-5 769.61

* Base year 2022; 1990 – 2022 based on the GHG inventory submission 15. 3. 2024

The modelling results above show that both scenarios show a reduction in removals from 1990 levels in 2030 and, conversely, the scenarios show a reduction in removals by 2050.

3.6.9.1. Input Parameters for Emission Projections

Projections of the main input parameters - area and changes in areas in each land use category in the LULUCF sector for the period 2023 – 2050 were determined either through the exponential smoothing function of MS Excel, in the Forecast tool (dynamic projections), or as average values from historical data (static projections). In particular for the WEM scenario, a stable development of the areas (or areas of transfers between categories) based on average values over the period 1990 – 2022 was considered. If there is a significant break in development or intensity during this period and the current value of transfers (e.g. in the last decade) is significantly different than the average over the whole period, the calculation of the average was based only on the last decade or period with the current, new level of values.

In addition, outputs from the FCarbon model, which was developed in the context of the implementation of Regulation (EU) 2018/841 of the European Parliament and of the Council of 30 May 2018 on the integration of greenhouse gas emissions and removals from land use, land-use change and forestry into the 2030[44] Framework for Climate and Energy Policies , amending Regulation (EU) No. 525/2013 and Decision No. 529/2013/EU, were used for the projection of input parameters in the Forests category. The main reasons for the development of the FCarbon[45] model were the requirements for consistency with GHG emissions/removals reporting and the inclusion of age-related forest dynamic characteristics.

This model simulating the future development of forests in Slovakia was developed at NLC according to the methodology proposed.[46] The model is able to simulate in each simulation step, which is 1 year, the development of the age structure of forests, stock changes through normal annual increments and harvesting rates (harvesting percentages). It is possible to model bare-root and understorey management. The simulation of forest growth in the FCarbon model is based on growth tables[47], which determine the increments of wood volume in m^3 for the main tree species in Slovakia (spruce, fir, pine, beech, oak and selected poplars). The volumes of clearance and recovery are calculated on the basis of the specified percentages of extraction from the stock. The model is optionally able to simulate changes in the area of trees and thus changes in the total forest area. The model requires the following input data (broken down by species and age class): stock (m^3), area (ha), suitability and harvesting percentage for thinning and regeneration (mean and standard deviation).

As input data for the simulation of the future development of Slovak forests were used summaries from central forestry databases, prepared for one calendar year (capturing the state at the end of the year), stratified by tree species and 10-year age stages. These summaries contained information on the area of each tree species and age class, stock (in m^3 of rough), stunting, stock rating, total normal increment and planned harvesting volume (educational and regeneration). The information from the Forest Economic Record (FER) on actual timber harvesting was broken down according to the Decree of the Ministry of Agriculture and Rural Development of the Slovak Republic No. 297/2011 Coll. on Forest Economic Record (FER) into deliberate (educational and restoration), extraordinary and accidental (executed, with timber left in the forest stand and not executed).

Area of the category Forest Land remaining Forest Land (4.A.1) - forest area and its trend are among the basic indicators of sustainable forest management. Society's demands on forests, which play an

---

[44] https://eur-lex.europa.eu/legal-content/SK/ALL/?uri=CELEX%3A32018R0841

[45] https://web.nlcsk.org/cafmocc-fcarbon/

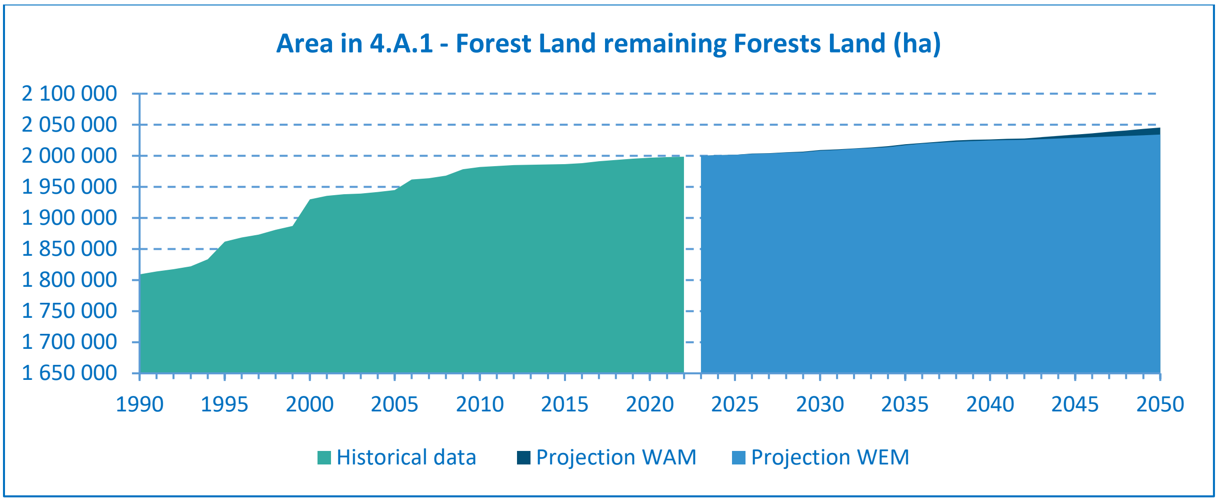
[46] Grassi, G.; Pilli, R. 2017. Projecting forest GHG emissions and removals based on the “continuation of current forest management”: the JRC method. EUR 28623 EN. Luxembourg (Luxembourg): Publications Office of the European Union; 2017. doi:10.2760/844243. http://publications.jrc.ec.europa.eu/repository/bitstream/JRC106814/jrc_report_frl.pdf; Forsell, N.; Korosuo, A.; Federici, S.; Gusti, M.; Rincón-Cristóbal, J.J.; Rüter, S.; Sánchez-Jiménez, B.; Dore, C.; Brajterman, O.; Gardiner, J. 2018. Guidance on developing and reporting Forest Reference Levels in accordance with Regulation (EU) 2018/841

[47] Halaj, J.; Petráš, R. 1998: Rastové tabuľky hlavných drevín/Yield tables of main tree species. Bratislava, Slovak Academic Press, 325 p.

important role in mitigating climate change, conserving biodiversity, protecting water resources, preventing floods, providing timber and non-timber forest products as well as other ecosystem services, are constantly increasing. Maintaining and increasing forest cover is therefore highly desirable. According to data from the Summary Information on the State of Forests (FIS source), there is a long-term trend of its increase. Since 1990, the area of forest cover has increased by 28.3 thousand ha, or 1.47%. The increase of approximately 975 ha per year over the period is mainly due to the change in land type. The total area of forest land in 2020 was 2 027 852 ha and has increased by 46.6 thousand ha since 1990 (i.e. by 2.36%). On average, it increased by 1 607 ha per year over the period. Forest cover, calculated as a percentage of the area of forest land in the total area of the Slovak Republic (4.903 million ha, including water areas), reached 41.3% in 2020. It has increased by 1.0% since 1990. There are 0.36 ha of forest per inhabitant of the Slovak Republic.

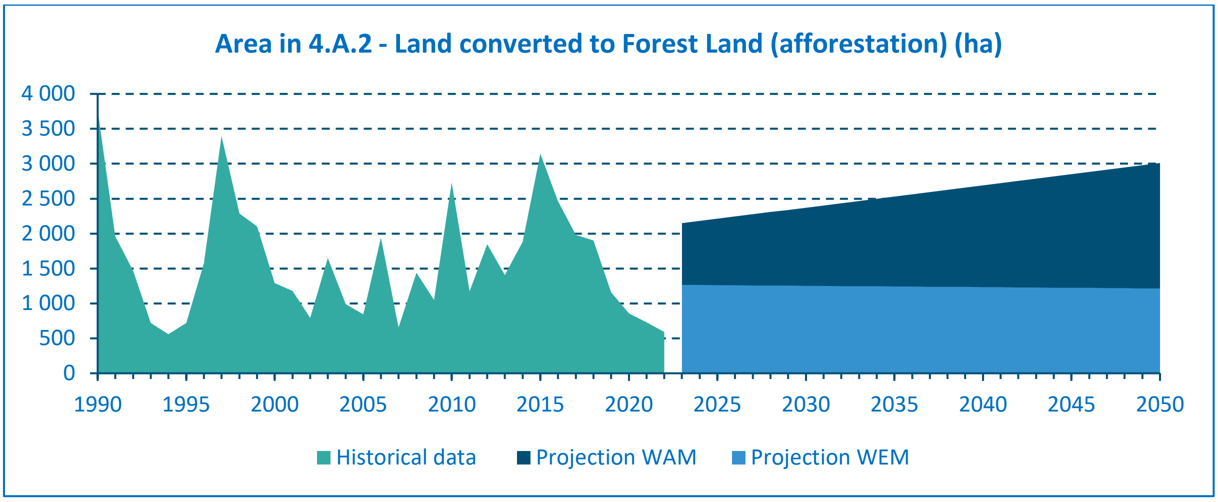
The development of acreage in the category Forest Land remaining Forest Land follows the above-mentioned trend of increasing acreage of forests in the Slovak Republic. For this reason, the projection assumes an increase in forest area after 2020, both in the WEM and WAM scenarios (***Figure 3.48***).

Figure 3.48: *Trend and projections of area in ha in 4.A.1 - Forest Land remaining Forests Land in WEM and WAM scenarios up to 2050*



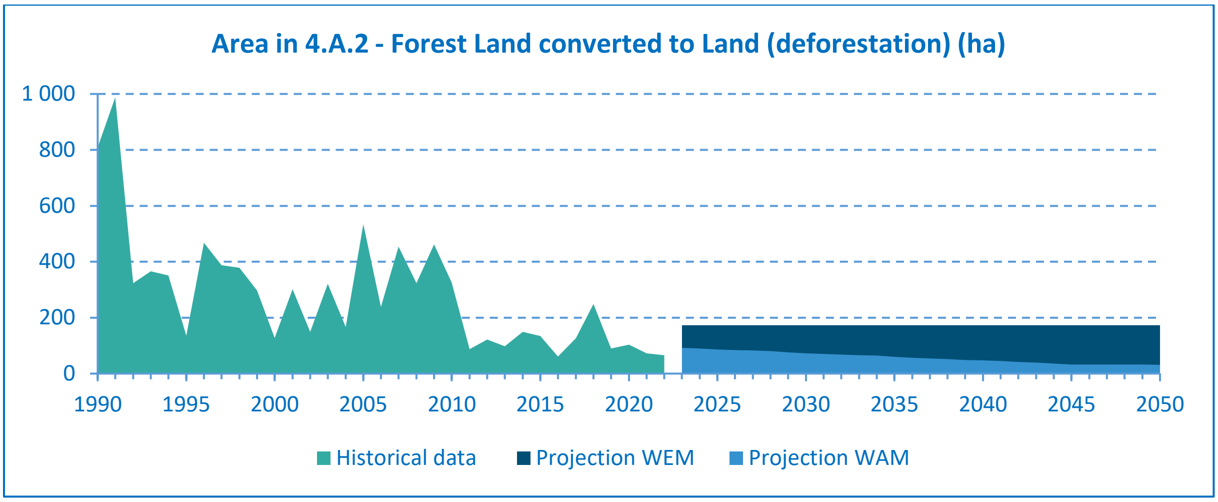
Area of the category Land converted to Forest Land (afforestation) (4.A.2) - historical acreage in this category shows a divergent pattern throughout the 1990 – 2020 period. The highest acreage value was recorded in 1990 at 3 770 ha and the lowest at 559 ha in 1994. The average value was 1 670 ha. The future trend shows a slightly decreasing trend (WEM) and an increasing trend (WAM) (***Figure 3.49***).

***Figure 3.49:** Trend and projections of area in ha in 4.A.2 - Land converted to Forest Land (afforestation) in WEM and WAM scenarios up to 2050*



Area of the category Forests converted to Land (deforestation) (4.A.2) - historical acreage in this category shows a divergent pattern throughout the 1990 – 2020 period. The highest acreage value was recorded in 1991 at 988 ha and the lowest at 61 ha in 2016. The average value was 301 ha. The future development shows a balanced trend (WEM) and a slightly decreasing trend (WAM) (***Figure 3.50***).

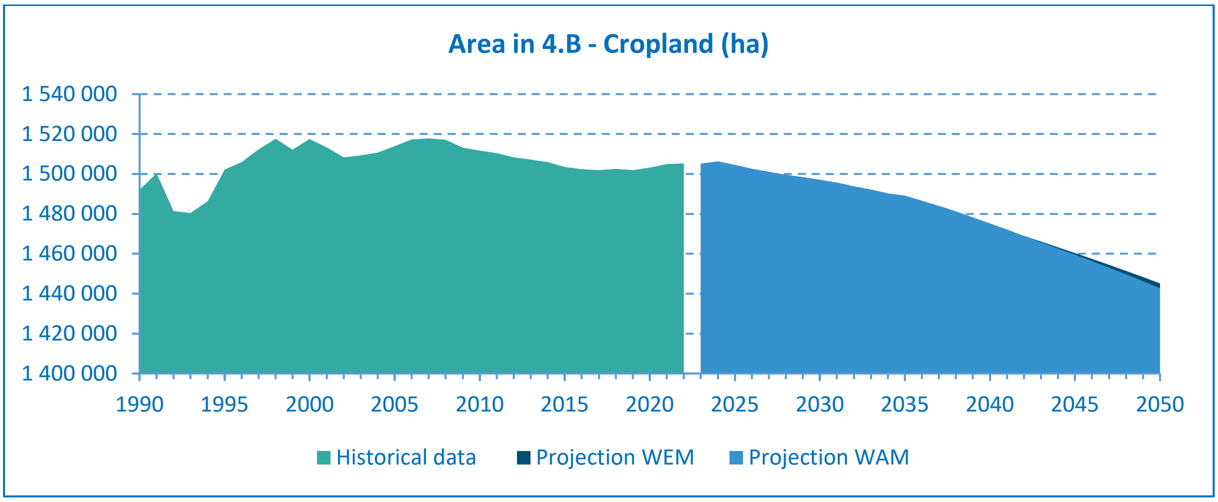
Figure 3.50: Trend and projections of area in ha in 4.A.2 - Forest Land converted to Land (deforestation) in WEM and WAM scenarios up to 2050



Area of the category Cropland (4.B) - historical area in this category shows a slightly fluctuating pattern throughout the 1990-2020 period and a steadily declining trend since 1998. The projected future development of the cropland category includes the fact that there will be conflicting factors influencing the development of areas in the coming years, which are likely to intensify over time. On the one hand, there will be pressure for the encroachment and development of cropland for residential areas, industrial, commercial and logistics centres, as well as roads. On the other hand, there will be increasing pressure to preserve cropland, to strengthen its productive functions, especially in relation to at least partially increased food self-sufficiency, and in particular to strengthen the non-productive functions of land, such as water storage in the land, erosion protection, biodiversity, land formation, and also mitigation of the negative impacts of change and adaptation to climate change. Significant positive impacts of this category are also envisaged in relation to emissions capture and carbon sequestration. Not only the EU's Common Agricultural Policy, but also other, particularly environmentally oriented EU policies such as the European Green Deal, are working towards this.

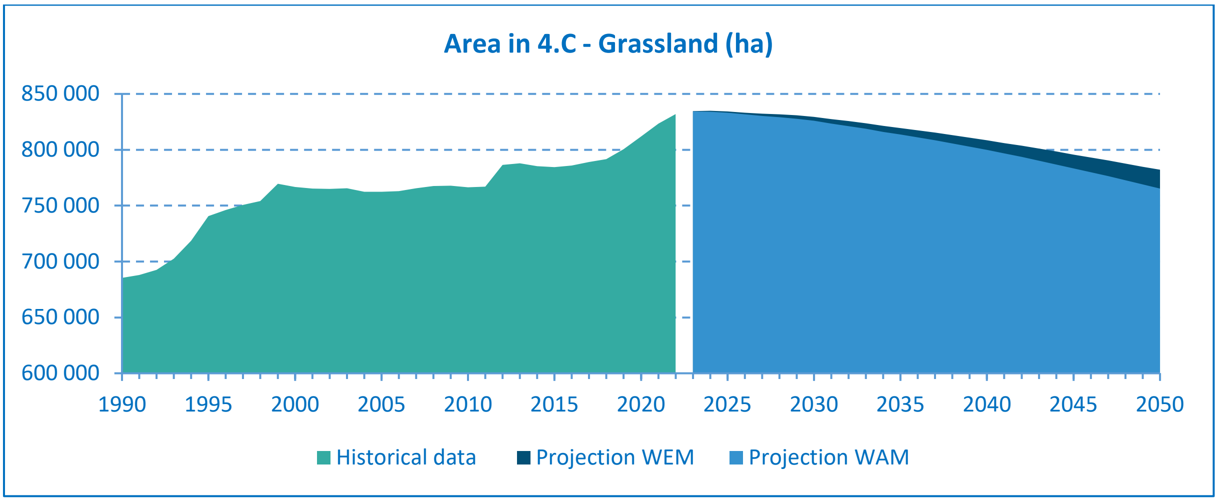
On the basis of the above, it is possible to assume a stabilisation of the area in this category, or a very slight decrease. As regards the internal structure, an increase in the area of individual permanent crops is expected, particularly orchards, vineyards and, it would be appropriate, hop-growing, since the products of all these crops make up a negative balance in the economic balance, and, in addition, in terms of GHG emissions, these crops show relatively high CO_2 removals. Alongside this, it is expected that within the arable sub-category there will be an increase in the proportion of land features and non-forest woody vegetation in the form of tree lines, borders, solitudes and trees in groups, which will enhance the fulfilment of the non-productive functions of the cropland and land. Future trends in cropland area show a declining trend (WEM) and a slightly declining trend (WAM) (***Figure 3.51***).

Figure 3.51: *Trend and projections of area in ha in 4.B – Cropland in WEM and WAM scenarios up to 2050*



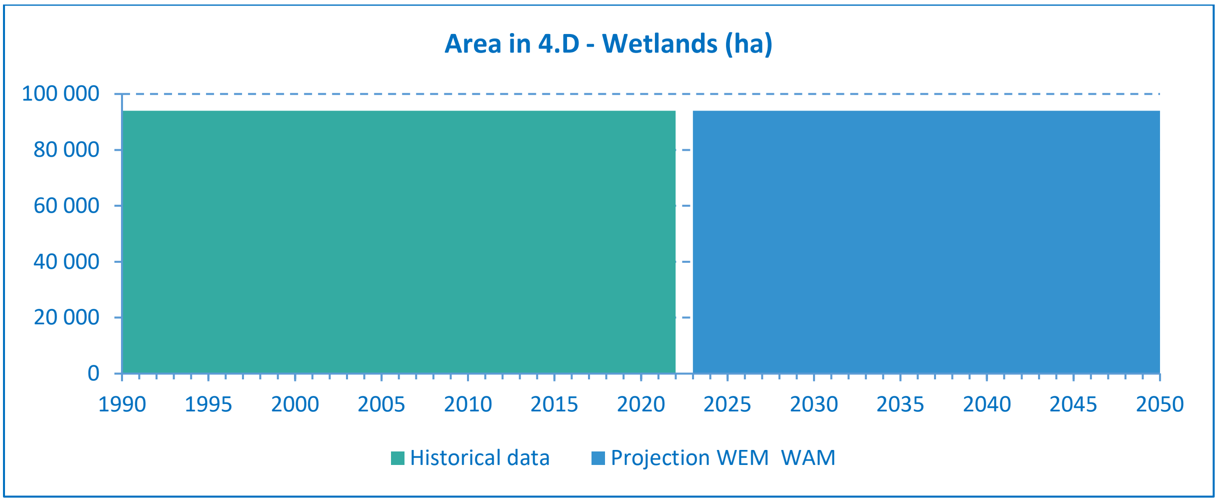
Area of the category Grassland (4.C) - the set trend gives an outlook that most probably the gradual reduction of the area of permanent grasslands will continue, mainly due to the transfer of unused and abandoned grasslands to the forest fund, ecological and water protection restrictions, the introduction of forest-pastoral systems, the transfer of land under the administration of national parks. If appropriate socio-economic and ecosystem measures or payments are introduced and applied in the land, the area in this category could be stabilised and its use improved. The trend of permanent grassland area in the future shows a decreasing trend for all scenarios (WEM and WAM) (***Figure 3.52***).

Figure 3.52: *Trend and projections of area in ha in 4.C – Grassland in WEM and WAM scenarios up to 2050*



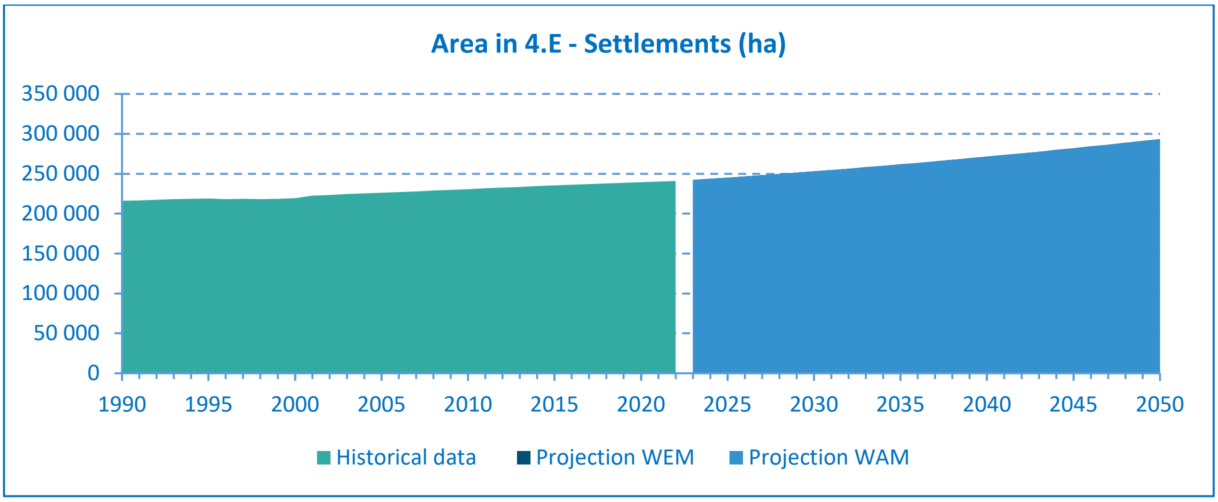
Area of the category Wetlands (4.D) - Slovakia shows no change in this category in the long term. It is realistic to assume that this will remain the case in the future, which is why the acreages for the WEM and WAM scenarios are identical (***Figure 3.53***).

Figure 3.53: *Trend and projections of area in ha in 4.D – Wetlands in WEM and WAM scenarios up to 2050*



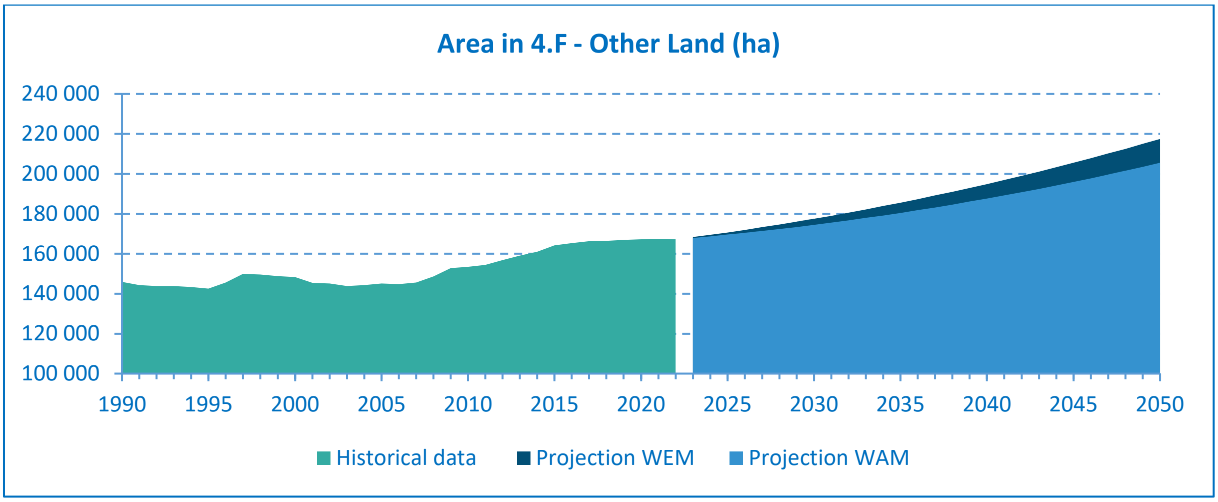
Area of the category Settlements (4.E) - the area of this land use category has shown a steadily increasing trend throughout the period. This situation is mostly due to the development of transport infrastructure, industrial areas, the development of towns and villages, the increase in the area of various infrastructure in the countryside. In Slovakia, it is very often associated with a decrease in the area of the category of cropland, as it is related to the occupation of good quality arable land. Future developments show an increasing trend for all scenarios (***Figure 3.54***).

Figure 3.54: *Trend and projections of area in ha in 4.E – Settlements in WEM and WAM scenarios up to 2050*



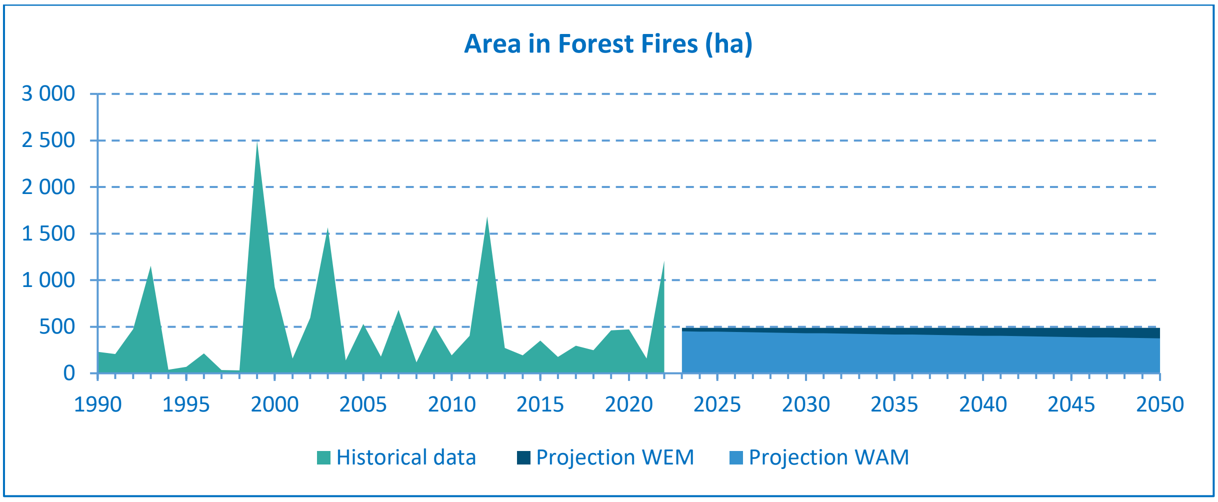
Area of the category Other Land (4.F) - the area of this land use category has shown a steadily increasing trend throughout the period. This situation is mostly due to the degradation of cropland, but also due to leaving the territory of Slovakia without active management. Future developments show an increasing trend for all scenarios are identical (***Figure 3.55***).

Figure 3.55: *Trend and projections of area in ha in 4.F – Other Land in WEM and WAM scenarios up to 2050*



Area of the category Forest Fires - historical forest fire acreage shows a discontinuous pattern throughout the period. The highest acreage value was recorded in 1999 at 2 496 ha and the lowest at 32 ha in 1998. The average value was 488 ha. The future development shows a steady trend (WEM) and a slightly decreasing trend in the WAM scenario (***Figure 3.56***).

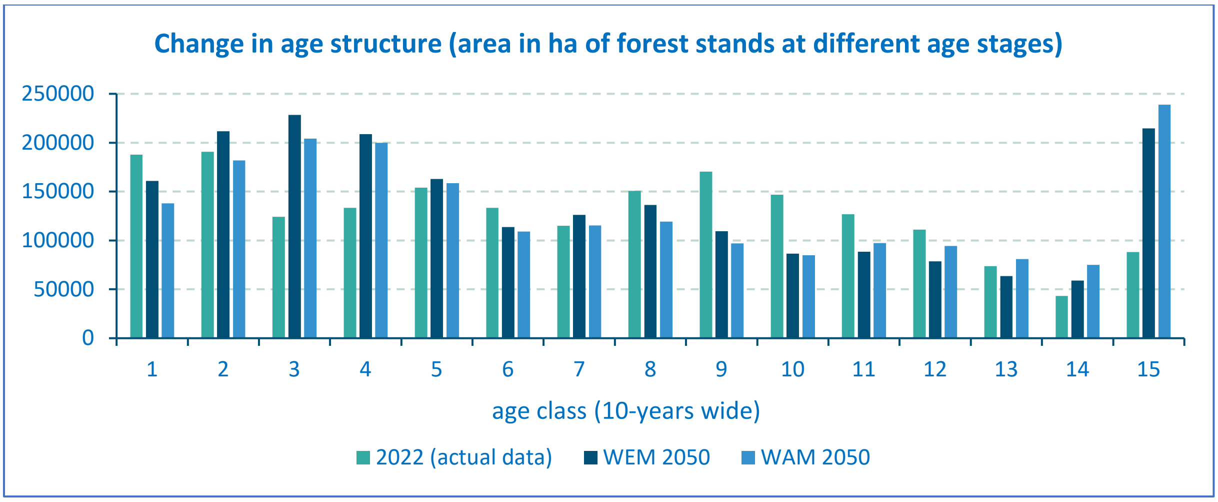
Figure 3.56: *Trend and projections of area in ha in Forest Fires in WEM and WAM scenarios up to 2050*



Trend of age structure, increments and timber harvests - future forest development was simulated using the FCarbon model for the period 2023 – 2050. Input data on forest condition were based on the summarised stand characteristics of individual tree species (age structure, stock (m^3), area (ha) and suitability) for the year 2022. The projections were refined for the years 2023-2025 based on the latest harvest data on 2023 and a realistic estimate for the near future. The estimate of the future amount of timber harvesting for the years 2024 and 2025 is based on current trends in timber harvesting, imports, exports and timber demand.

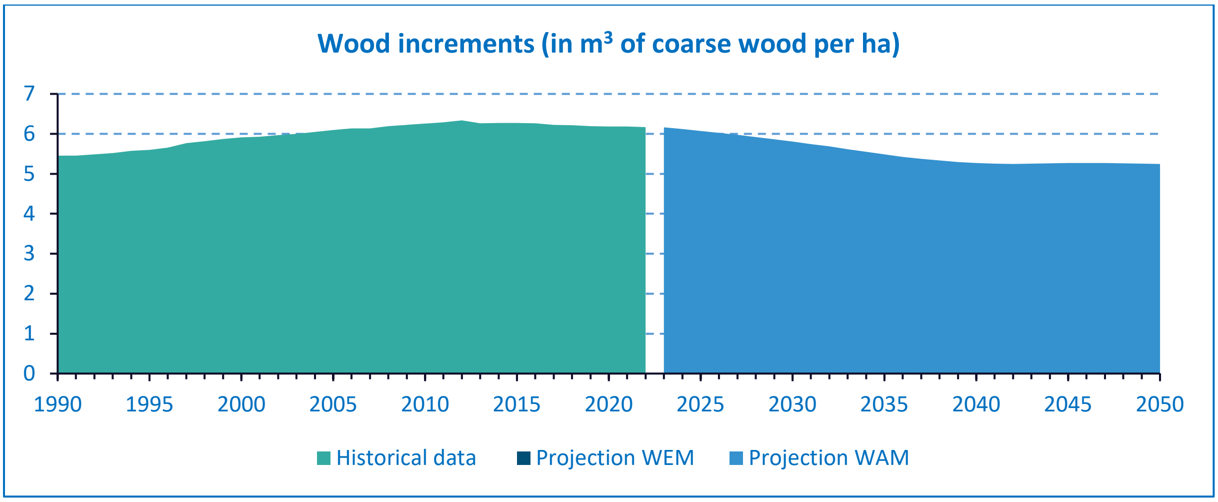
Harvesting percentages (percentage of annual coarse harvest of total stock) were derived from data for the period 2013 – 2022, which capture the current level of stand regeneration. They were determined separately for planned and actual harvests (***Figure 3.57***).

Figure 3.57: *Change in age structure (area in ha of forest stands at different age stages) in WEM and WAM scenarios from 2018 up to 2050*



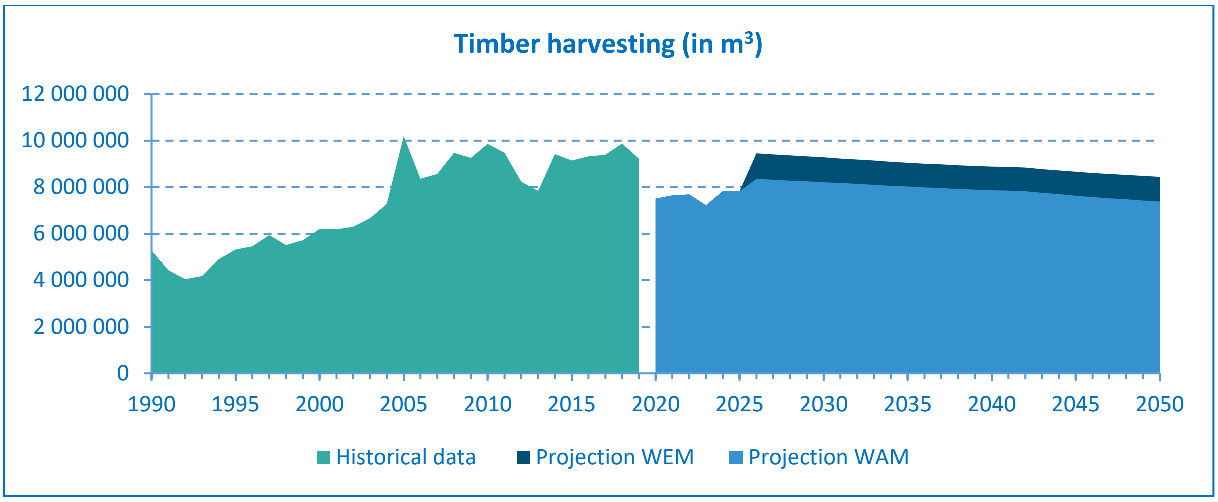
Based on these inputs, the FCarbon model calculated, at each time step (1 year) during the simulation, the trend of the age structure of the forest (by increasing the age, by transferring harvested areas to the youngest categories; (***Figure 3.57***), stock changes using current annual increments (***Figure 3.58***), and timber harvesting (via harvesting percentages; (***Figure 3.59***).

Figure 3.58: *Trend and projections of wood increments (in m^3 of coarse wood per hectare) in WEM and WAM scenarios up to 2050*



Depending on the species of tree species, the management method was also simulated, namely: holm oak (mainly pine and spruce in case of calamities), but mainly understorey method (the ratio of both methods determined on the basis of the proportion of natural regeneration from the Forest Management Plans). The FCarbon model also accounted for changes in tree cover (and also in tree composition) and thus changes in total forest area under the WAM and WEM scenarios. The calculated wood mass gains and losses served as input for the calculations of carbon stock changes (***Figure 3.59***).

Figure 3.59: *Trend and projections of timber harvesting (in m^3) in WEM and WAM scenarios up to 2050*



3.6.9.2. Methodologies and Key Assumptions/Trends

The National Forestry Centre (NLC) - Forestry Research Institute (FRI) in cooperation with the National Agricultural and Food Centre, the Research Institute of Soil Science and Soil Protection (NPPC-SRI) and the Research Institute of Grasslands and Mountain Agriculture (NPPC-SRI) have developed two scenarios for the development of emissions from 2022 to 2050 on the basis of available information, the scenario with existing measures (WEM) and the scenario with additional measures (WAM). The result of the modelling of the GHG emission/removals projections is presented in ***Figure 3.47*** and ***Table 3.49***. In the WEM scenario, the measures adopted and implemented up to 2022 have been implemented, these measures have not prevented a decrease in GHG removals of -74% compared to 1990. The WEM scenario took into account policies and measures from official national strategic documents and programmes valid in Slovakia until 2022, mainly from the National Forestry Programme of the Slovak Republic 2014 – 2020[48], Rural Development Programmes 2007 – 2013, 2014 – 2020[49] and from the Low Carbon Development Strategy of the Slovak Republic until 2030 with a view to 2050. The WAM scenario incorporates measures from available official national strategic documents and programmes valid in Slovakia after 2022[1] and the Environmental Policy Strategy of the Slovak Republic 2030. When additional measures were implemented in the WAM scenario, removals decreased by -35% compared to 1990.

Historically, the lowest CO_2 removals in the LULUCF sector were recorded in 2005, with the Forests category contributing significantly due to a major wind calamity in the High Tatras. Both the WEM and WAM scenarios show decreasing removals compared to 2005 (63% for the WEM scenario and 10% for the WAM scenario). The more pronounced decrease in projected removals after 2022 in the WEM scenario, compared to the WAM scenario, is due to a higher decrease in removals in the Forest, Cropland and Grassland categories and an increase in emissions from the Settlements and Other Land categories.

Projections of emissions/removals of GHGs in the LULUCF sector were modelled for the 6 main land use categories (Forest Land, Cropland, Grassland, Wetlands, Settlements, Other Land) and the Harvested Wood Products category, as well as for the different GHG emission gases (CO_2, CH_4, N_2O). The available time series of input data for the period 1990-2022 were used, which were obtained from various sources (Office of Geodesy Cartography and Cadastre, NLC, Statistical Office of the Slovak Republic, National Agriculture and Food Centre-Soil Science and Conservation Research Institute, National Agriculture and Food Centre-Grassland and Mountain Agriculture Research Institute, Fire Technical and Expert Institute of the Ministry of the Interior of the Slovak Republic, FAO database). All input data entering the accounting of GHGs emissions/removals in the LULUCF sector were used as input data for the projections.

---

[48] Ministry of Agriculture and Rural Development. "Forest Strategy 2030." [Online]. https://data.consilium.europa.eu/doc/document/ST-13537-2021-INIT/sk/pdf

[49] Ministry of Agriculture and Rural Development. "Rural development programme 2014-2020 extended until 2023". [Online]. https://agriculture.ec.europa.eu/common-agricultural-policy/rural-development_sk; Ministry of Agriculture and Rural Development. "Rural Development Programme 2023-2027. [Online]. https://agriculture.ec.europa.eu/common-agricultural-policy/rural-development_sk

Input data needed in the preparation of projections:

- acreages of individual land use categories - forests, cropland, permanent grasslands, wetlands, settlements, other land, (data for the period 1970 – 2022, source Statistical Yearbook of the Land Fund of the Slovak Republic, Office of Geodesy Cartography and Cadastre[50]), data available by regions, districts and cadastral territories,
- changes in acreage into and out of each land use category - forests, cropland, permanent grassland, wetlands, settlements, other land (data for the period 1970-2022), data available by county, district and cadastral area,
- annual tree growth in m^3/ha (1990 – 2022, source Summary Information on the State of Forests (SISL), as part of the Forestry Information System [51](FIS), data available by county,
- annual timber harvest in m^3 (1990 – 2022, source FIS), data available for Slovakia by tree species,
- area of individual trees in ha (1990 – 2022, source FIS), data available by county,
- representation of individual tree species in ha (1990-2022, source SFIS), data available by county,
- age structure of forests in ha (2014 – 2022, source FIS),
- area of forest fires in ha (1990 – 2022, source NLC in cooperation with the Fire Technical and Expertise Institute of the Ministry of the Interior of the Slovak Republic),
- Inputs for harvested wood products (1990 – 2022, source FAO database).

3.6.9.3. Model Description

GHG emission/removal projections in the LULUCF sector were prepared for 6 main land use categories (Forest land, Cropland, Grassland, Wetlands, Settlements, Other land) and category Harvested Wood Products, as well as for various greenhouse gas emissions (CO_2, CH_4, N_2O). Available time series of input data for the period 1990 – 2022 were used, which were obtained from official sources: Office of Geodesy of Cartography and Cadastre (Cadastre), National Forest Centre (NFC), Statistical Office of the Slovak Republic (SOSR), National Agricultural and Food Centre (NPPC), Fire Engineering and Expertise Institute of the Ministry of the Interior (FEEI), FAO database. Input data needed for the preparation of projections:

- areas of individual LU categories, including the changes in areas and transitions between the LU categories (1970 – 2022; Cadastre data available by region, districts and cadastral areas),
- current annual increment in m^3 ha^{-1} (NFC data available by region),
- annual harvested volume in m^3 (NFC data available for Slovakia by tree species),

---

[50] Statistical Yearbook on the Land Fund of the Slovak Republic, Office of Geodesy Cartography and Cadastre. https://www.skgeodesy.sk/sk/ugkk/kataster-nehnutelnosti/sumarne-udaje-katastra-podnom-fonde/

[51] https://gis.nlcsk.org/islhp/

- area of individual tree species in ha (NFC data available by regions),
- individual tree species composition in ha (NFC data available by regions),
- age structure of forests in ha (2014 – 2022; NFC data),
- area of forest fires in ha (NFC in cooperation with the FEEI),
- inputs for harvested timber products (FAO database).

Projections of the main input parameters - areas and changes in areas in individual land use categories in the LULUCF sector for the period 2022 – 2050 were determined either through the exponential balancing function in MS Excel (the Forecast tool) or as average values from historical data.

In addition, the outputs of the FCarbon forest growth model were used to project forest characteristics, used as the input parameters for GHG emissions/removals quantification in the Forest land category. This model simulating the future development of forests in Slovakia was developed in NFC according to the methodology proposed by Grassi & Pilli (2017) and Forsell et al. (2018).

The main reason for the development of the model was to fulfil the requirements for consistency with the reporting of GHG emissions/removals within the Slovak national emission inventory and also the inclusion of dynamics in forest growth through characteristics related to age structure. The model is able to simulate on an annual basis the development of the age structure of forests and growing stock changes, using annual increments and harvesting rates (logging percentages). It is possible to model the clear-cutting and shelter-wood forest management systems. The simulation of forest growth in the FCarbon model is based on yield tables (Halaj & Petráš 1998), which determine the current annual increments of growing stock in m^3 for the main tree species in Slovakia (spruce, fir, pine, beech, oak and breeding poplars). Harvested wood volumes (thinning, planned harvest and sanitary felling) are calculated applying harvesting rates (percentages set out according to extraction of wood volume from the growing stock in reference period). The model is optionally able to simulate changes in the area of tree species, as well as changes in the total forested area. The model requires the following input data (stratified by trees species and age classes): growing stock (m^3), area (ha), yield class, thinning and harvesting rate (average value and standard deviation, in %). These data were prepared by summarizing inputs from central forestry databases from the years 2013 – 2022. The whole procedure of simulation in the FCarbon model and calculation of CO_2 emissions is programmed in the Python language with data stored in the SQLite database.

Table 3.50: *SWAT analysis of the LULUCF-model*

Strengths	**Opportunities**
Compatibility with emission inventories Detailed data break down Database used is compatible with national data	Incorporate to the model new technologies Versatile use of time-series
Treats	**Weakness**
Bugs can be introduced if changes in the code are not thoroughly verified	Absence of user interface (set of scripts) Model not sensitive to climate change (based on empirical yield-tables)

The projections of emission/removals were prepared in accordance with the methodology of the Intergovernmental Panel on Climate Change of 2006 (IPCC 2006). The applied methodology is consistent with the methodology for estimating emissions under Article 26 of Regulation (EU) 2018/1999. The computational analytical tool is based on the MS Excel platform and the calculation includes various policies and measures (in numerical formulation) defined according to the WEM and WAM scenarios. Outputs of the FCarbon model, developed in connection with the application of Regulation (EU) 2018/841, are used for projections in the Forest land category. The FCarbon model was calibrated using data for the years 2014 – 2019, because the first usable data on the condition of forest stands from the reference period were valid at the end of 2013. The aim of the calibration was to increase the accuracy of the simulation process to be able to reproduce the resulting GHGs emissions/removals as accurately as possible. The calibrated model was used to simulate the development of the age structure of forests, increments and harvesting in the period 2022 – 2050.

The "Gain-Loss" method was used to quantify GHG emissions/removals in each land use category. This is based on estimates of the year-on-year change in biomass from the difference between its gains and losses, where gains represent an annual increase in carbon stocks due to biomass growth and losses represent an annual decrease in carbon stocks due to biomass removal (extraction). The simulation results for individual trees are summarized within each step and CO_2 emissions/removals in living biomass are calculated from the summary data.

The annual increment (m^3) is converted to biomass gain (dry weight) using wood density, biomass conversion expansion factor (BCEFI) and root-to-shoot ratio (R). The annual increase in carbon stocks is calculated by multiplying the dry weight by the average carbon content of the dry matter (50% for conifers and 49% for broadleaves; IPCC 2006 GL). Inter-annual losses in carbon stocks due to biomass loss are calculated from annual harvest volume (m^3), conversion and expansion factor (BCEFR), above-ground and underground biomass ratio (R) and average dry matter carbon content (IPCC 2006 GL). The resulting changes in carbon stocks (gains minus losses) are converted to CO_2 emissions/removals by multiplying the mass of carbon by -44/12. More detailed information on the methodology of emissions/removals calculations is published in the National Inventory Report (Szemesová et al. 2022).

3.6.9.4. Sensitivity Analysis

Emission projections were prepared in accordance with the 2006 Intergovernmental Panel on Climate Change Methodology, Chapter IV (IPCC 2006 Guidelines). The computational analytical tool is based on the MS Excel platform and the calculation includes various policies and measures (in numerical formulation) defined according to the WEM and WAM scenarios. The projections of emissions and removals in the Forest category used outputs from the FCarbon, model, which was developed in the context of the implementation of Regulation (EU) 2018/841 of the European Parliament and of the Council. The main reasons for the model development were the requirements for consistency with the reporting of GHG emissions and removals in national emission inventories and also the inclusion of forest dynamics through characteristics related to the age structure of the forest. The whole procedure of simulating the FCarbon model and calculating emission and sink projections is programmed in Python and the data are stored in an SQLite database.

In the context of a very exceptional situation in the LULUCF sector in 2020, caused by low extraction, dampened by anti-pandemic measures during the first wave of COVID-19, increased removals, and 2020 being an exceptional year outside of the long-term trend of high removals, the emission projections were calibrated to the 2014-2019 time period. This allowed to reduce the fluctuation of the emission projections and to relate them to the previous trend.

The model was calibrated using data for 2014 – 2019, as the first usable forest cover condition data from the reference period were valid at the end of 2013. The aim of the calibration was to increase the accuracy of the simulation process so that it is able to reproduce the resulting emissions and removals as faithfully as possible and to track the actual development of forest stands during the reference period. For each year of the simulation, deviations from the mean values of the thinning and harvesting percentages (both positive and negative, in %) were specified, so that the sum of the deviations over the calibration period was zero. After the first run of the model, total carbon stock gains and losses were calculated. It was found that the resulting average value of the increments (5 141.1 kt C) was higher by 2.68% and the average value of the simulated removals (-3 874.5 kt C) was lower by 0.05% compared to the average values of the national GHG emissions and removals inventory (5 006.9 kt C and -3 872.5 kt C, respectively). Carbon increments were compared by tree species and ratios of simulated to actual values were calculated. These ratios were used as multipliers to the volume increments determined from the tree-by-tree growth tables to adjust the total simulated biomass increments. The calibrated model was used to simulate the trend of forest age structure, increments and harvests over the period 2022 – 2050. Forest condition data valid at the end of 2022 were used as inputs to the model.

The "gains-losses" method was used to quantify emissions and removals in each category. This is based on estimates of the year-on-year change in biomass from the difference in biomass gains and losses, where gains represent the annual increase in carbon stocks due to biomass growth and losses represent the annual decrease in carbon stocks due to biomass removal (harvesting). The simulation results for each tree species are summarized within each step and the emissions and removals in living biomass are calculated from the summarized data. The annual increment of coarse biomass (m^3) is converted to biomass increment (dry weight) using wood density, Biomass Conversion Expansion Factor (BCEFI) and Root-to-Shoot Ratio (R). The annual carbon stock gain is calculated by multiplying the dry weight by the average dry carbon content (50% for conifers and 49% for broadleaves). The annual loss of carbon stocks due to biomass loss is calculated from the annual harvest volume (m^3), the conversion and expansion factor (BCEFR), the ratio of aboveground to belowground biomass (R), and the average dry carbon content. The resulting carbon stock changes (additions minus removals) are converted to CO_2 emissions and removals by multiplying the carbon mass by -44/12. More detailed information on the methodology for calculating emissions and removals is published in the National Inventory Report 2022.[52]

For category 4.A.1 Forest land remaining forest land, the projections have been treated as a continuation of forest management in the so-called reference period 2014-2019 for all scenarios.

In the WEM scenario, the trend of increments - gains, modelled on the basis of a scenario with dynamically increasing forest area (1 996 758 ha in 2020 to 2 024 599 ha in 2040 and 2 034 266 ha in 2050) and dynamically changing tree species composition for example a decrease of spruce from 22% in 2020 to 17% in 2040 and 15% in 2050, was assumed, beech increases from 35% in 2020 to 39% in

---

[52] https://oeab.shmu.sk/app/cmsSiteBoxAttachment.php?ID=105&cmsDataID=0

2040 and 41% in 2050). As for the losses, these have been modelled through harvesting. In the WEM scenario, the so-called planned harvests were modelled (6-8% higher than the realised harvests).

- Category 4.A.2 Land converted to forest land (afforestation):

The area and tree species composition were projected as static - the average value from historical data 1990-2022 was used (GL/FL - 836 ha, CL/FL - 83 ha, OL/FL - 353 ha) sm - 34%, bo - 15%, bk - 44%, db - 8%.

- Category 4.A.2 Forest land converted to other land (deforestation):

Both area and tree species composition were projected as static - the average value from historical data 1990-2022 was used (FL/GL - 22 ha, FL/CL - 2 ha, FL/S 45 ha, FL/OL - 104 ha. The average hectare stock was modelled as a dynamic variable.

- Category 4.B.1 Cropland:

The area of CLA/CLP (annual cropland/perennial cropland) and CLP/CLA (perennial cropland/annual cropland) transfers was projected as static and the average value from 1990-2022 historical data was used (CLA/CLP - 6 ha, CLP/CLA - 354 ha). The area of each sub-category of perennial cropland (orchards, gardens, vineyards and hop gardens) was projected as dynamic - determined using the exponential smoothing function of MS Excel, in the Forecast tool. The areas in the remaining categories (grassland, settlements, other land) were projected as dynamic. The harvested wood products (HWP) category was projected based on the volume of timber harvest calculated for the WEM and WAM scenarios, by the FCarbon model, with the distribution of harvest volume among the different product categories based on the current, realistic distribution (realistic model).

For category 4.A.1 Forest land remaining forest land, the projections have been treated as a continuation of forest management in the so-called reference period 2014-2019 for all scenarios.

In the WAM scenario, the projected development of gains was modelled on the basis of a scenario with dynamically increasing forest area (1 996 758 ha in 2020 to 2 026 463 ha in 2040 and 2 045 507 ha in 2050) as a result of afforestation (i.e. afforestation of formerly mainly cropland, its transfer to category 4.A.2 Land converted to forest land, after a 20-year period, to category 4.A.1 Forest land remaining forest land). The WAM scenario is also characterised by a dynamically changing tree species composition. As for the losses - losses, these were modelled through harvesting. In the WAM scenario, actual realised harvests were modelled (6-8% lower than planned).

- Category 4.A.2 Land converted to forest land (afforestation):

Area and tree species composition were projected as a combination of a static approach and a dynamic approach - the acreage determined by the exponential smoothing function of MS Excel was used, in the Forecast tool (GL/FL - from 639 ha in 2020 to 2224 ha in 2050, CL/FL - from 46 ha to 122 ha in 2050, OL/FL - 665 ha), spruce - from 46% in 2020 to 32% in 2040 to 29% in 2050, pine - from 18% in 2020 to 13% in 2040 to 14% in 2050, beech - from 33% in 2020 to 49% in 2040 to 49% in 2050, oak - from 3% in 2020 to 6% in 2040 to 7% in 2050, beech - from 33% in 2020 to 49% in 2040 to 49% in 2050.

- Category 4.A.2 Forest land converted to other land (deforestation):

Both area and tree species composition were projected as dynamic - the value determined by the MS Excel exponential smoothing function in the Forecast tool was used (FL/GL - 0 ha, FL/CL - from 2 ha in

2020 to 1 ha in 2050, FL/S - from 36 ha in 2020 to 31 ha in 2050, FL/OL - from 62 ha in 2020 to 0 ha in 2050. The average hectare stock was modelled as a dynamic variable.

- Category 4.B.1 Cropland:

The area of CLA/CLP (annual CL/perennial CL) and CLP/CLA (perennial CL/annual CL) transfers was projected as dynamic - using the value determined by the exponential smoothing function of MS Excel, in the Forecast tool (CLA/CLP from 27 hectares in 2020, through 48 hectares in 2040, to 59 hectares in 2050, CLP/CLA from 162 hectares in 2020, through 99 hectares in 2040, to 67 hectares in 2050). The area of the individual subcategories of perennial cropland (orchards, gardens, vineyards and hop gardens) was projected as dynamic - determined through the exponential smoothing function of MS Excel, in the forecast tool (dynamic projections). Acreages in the remaining categories (grassland, settlements, other land) were projected as dynamic. The harvested wood products (HWP) category was projected based on the timber harvest volume calculated for the WAM scenario by the FCarbon model, with the distribution of harvest volume among the different product categories based on an ideal distribution.[53]

3.6.9.5. Scenarios, Parameters and PAMs

In its conclusions of 23 and 24 October 2014, the European Council endorsed a binding target to reduce domestic greenhouse gas emissions across the economy by at least 40% by 2030 compared to 1990 levels, as part of its 2030 climate and energy policies. However, the current target is -55%, which has been increased through the European Green Deal. The implementation of Regulation (EU) 2023/839 as well as Regulation (EU) 2018/841 by individual Member States should also contribute to achieving this objective. This Regulation is part of the implementation of the Union's commitments under the Paris Agreement adopted under the United Nations Framework Convention on Climate Change (UNFCCC). The Union should continue to reduce its greenhouse gas emissions and increase removals in line with the Paris Agreement to the UNFCCC. Therefore, the condition of Regulation (EU) 2023/839 and Regulation (EU) 2018/841 of the EP and Council of the EU that each Member State shall ensure that emissions do not exceed removals (zero emissions) in the period 2021 to 2025 and 2026 to 2030, taking into account the flexibility instruments provided for in Articles 12 and 13, has also been incorporated in the development of GHG emission/removal projections for the LULUCF sector. Projections of emissions and removals were prepared for the two required scenarios of WEM and WAM development. The measures listed in ***Table 3.51*** were taken into account in the preparation of the LULUCF sector projections.

The scenario with existing measures (WEM) includes policies and measures adopted by the end of 2022 and their effect on LULUCF emissions/removals from 2022 onwards. As afforestation of cropland has a high carbon sequestration potential, this measure has been implemented under the individual RDP. In the first RDP 2004 – 2006, afforestation of unused cropland was supported by 15 projects with a total result of 100 ha of afforestation. In the following years, afforestation continued under the RDP 2007 – 2013 (28 projects with a total area of 133.35 ha) and the annual report on the RDP 2014 – 2020 for 2019 states that during the last two previous programming periods, planting of forest trees on

---

[53] Forsell, N.; Korosuo, A.; Federici, S.; Gusti, M.; Rincón-Cristóbal, J.J.; Rüter, S.; Sánchez-Jiménez, B.; Dore, C.; Brajterman, O.; Gardiner, J. 2018. Guidance on developing and reporting Forest Reference Levels in accordance with Regulation (EU) 2018/841

cropland with a total area of 332 ha was carried out in Slovakia. In addition, a project was implemented for the establishment of fast-growing tree plantations on 35 ha of cropland. According to the Annual Report 2008 of the RDP 2004 – 2006, 29 320 ha of arable land had been grassed in Slovakia by the end of 2008.

Scenario with additional measures (WAM) represents scenarios of LULUCF development with applied measures expected after 2022. For forestry, no new specific measures (quantification) are currently known. In 2019, the Ministry of Forests of the Slovak Republic started the preparation of a new strategic document - the National Forestry Programme of the Slovak Republic for the period 2022 – 2030 (measure 5.30.3), which follows the evaluation of the implementation of the National Forestry Programme of the Slovak Republic and the government-approved document. On this basis, the new National Forestry Programme of the Slovak Republic focus on the key societal themes of increasing the role of forests and the Slovak Forestry in the fight against climate change, the green economy, and the development of employment in rural areas. The National Forestry Programme of the Slovak Republic for the period 2022-2030 includes monitoring indicators (qualitative and quantitative), which will then enable their incorporation into future projections. The Low carbon strategy states that support for increasing sinks in the LULUCF sector in the short term will be mainly implemented through the Common Agricultural Policy and through adaptation measures under the 2nd programming priority in Slovakia funded from the EU budget.

As regards the other categories (cropland and permanent grassland), EU countries implement the 2023 - 27 Common Agricultural Policy (CAP) through tailored national CAP Strategic Plans, targeting local needs while supporting EU objectives and the European Green Deal.

A list of the policies and measures that have been taken into account in the projections of GHG emissions/removals in the LULUCF sector under each scenario and their effect is presented in ***Table 3.51.***

Table 3.51: *List of policies and measures implemented in the projections of GHG emissions/removals in LULUCF sector*

PAM	Scenario	Gas/Category	Measure	Effect of Measure
National Forestry Programme **RDP** **Low carbon strategy**	WEM	CO_2 / forest land, cropland, permanent grassland	Afforestation of unused cropland, establishment of stands of fast-growing trees on cropland, afforestation of cropland, measures to reduce fires	synergic
National Forestry Programme	WEM	CO_2 / forest land	Prevention of deforestation (as an integrated part of sustainable forest management)	Synergic
National Forestry Programme **RDP**	WEM	CO_2 / forest land	Protection of existing forests against natural disturbances (as an integrated part of sustainable forest management)	Synergic
National Forestry Programme	WAM	CO_2 / forest land	Promote measures to increase carbon sinks as part of sustainable forest management. Adjust tree species composition to increase the resilience of	Synergic

PAM	Scenario	Gas/Category	Measure	Effect of Measure
Adaptation strategy[54]			stands to drought and reduce vulnerability to biotic and abiotic agents.	
Low carbon strategy **Envirostrategy**	WAM	CO_2 / forest land	Increasing forest cover through afforestation of agriculturally unused land while maintaining the diversity of non-forest habitats Create conditions for the settlement of the status of the so-called white areas	synergic
Low carbon strategy	WAM	CO_2 / forest land	Maintaining vital forests by limiting the negative impacts of climate change on forests through measures aimed at forest adaptation (support for the use of alternative management models to adjust tree species composition, use of suitable provenances).	synergic
Low carbon strategy	WAM	CO_2 / Products of harvested wood	Increasing the share of long-life wood products (HWP), including for construction purposes.	synergic
Low carbon strategy	WAM	CO_2 / cropland	Implementation of measures to increase carbon sequestration in agricultural soils and maintain high levels of organic carbon in carbon-rich soils.	synergic
Low carbon strategy	WAM	CO_2 / permanent grassland	Maintenance and restoration of grasslands.	synergic

3.6.9.6. GHG Emission Projections by Categories and Gases

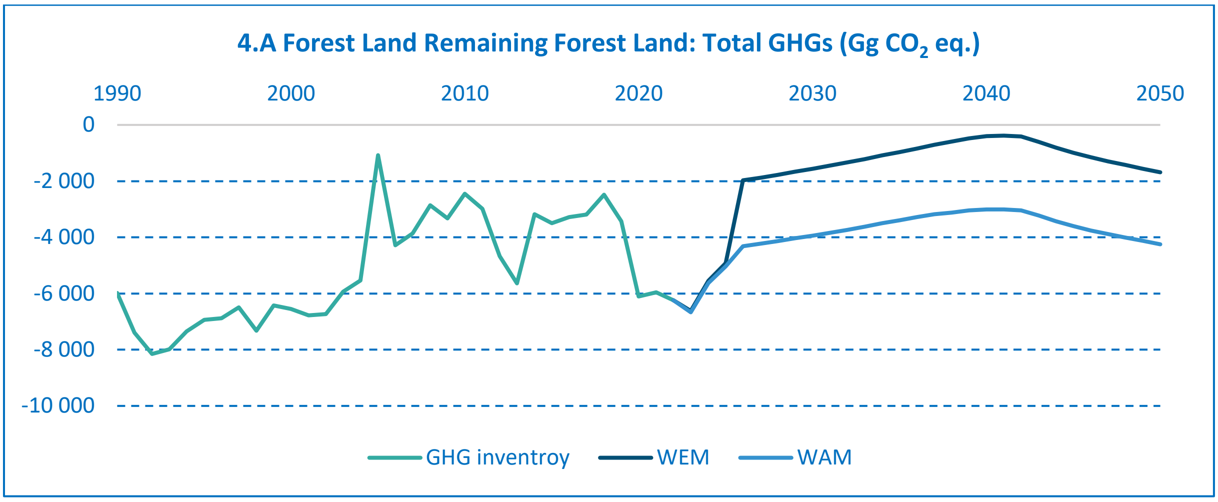
Projections of emissions and removals in Forest Land Remaining Forest Land - in this category, projections of emissions and removals of CO_2, CH_4, N_2O (Gg CO_2 eq.) were calculated for the WEM and WAM scenarios (***Figure 3.60***). CO_2 sinks are mainly from forest management, CH_4, N_2O emissions from forest fires. Assuming that forests are managed as they have been for the last 8 years (WEM), we can expect a significant decrease in CO_2 sinks between now and 2050. The cause is the current age structure of forest stands. Older stands are beginning to predominate in the forests, with lower annual wood mass growth compared to younger, fast-growing stands. The results of the WAM scenario based on harvesting of stands so far would lead to a higher level of CO_2 storage by living biomass in Slovak forests over the whole simulated period, despite an expected decrease in sinks from the current level of ~ -7 200 Gg CO_2 to ~ -4 700 by 2040 and a subsequent slight increase to ~ -5 800 Gg CO_2 in 2050. The WEM scenario is based on the implementation of planned extraction and may result in a larger decrease in CO_2 sinks, peaking in 2040 at ~ -1 200 Gg CO_2, followed by a slight increase to ~ -2 300 Gg CO_2 in 2050. Changes in the tree species composition of forests have a more pronounced effect on CO_2 sinks, compared to increasing forest area. In the WEM scenario, lower sinks occur due to lower

---

[54] Ministry of the Environment of the Slovak Republic, 2018: "Climate Change Adaptation Strategy - Update", Bratislava: s.n 2018. [Online]. http://www.minzp.sk/files/odbor-politiky-zmeny-klimy/strategia-adaptacie-sr-zmenu-klimy-aktualizacia.pdf

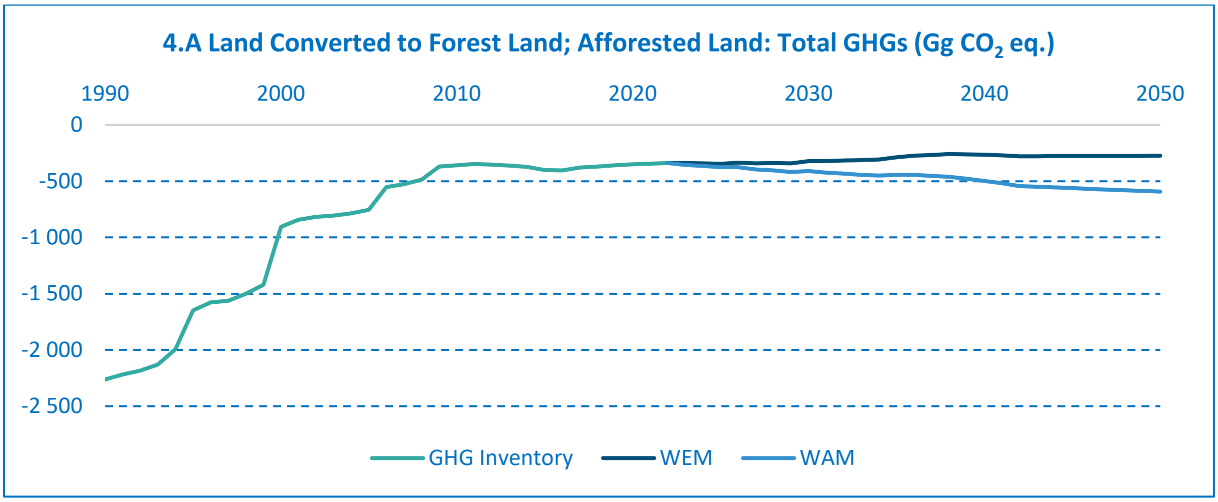
forest area, unchanged tree species composition and also higher CH_4 and N_2O emissions from forest fires. The WAM scenario shows higher CO_2 removals due to higher forest area, more favourable tree species composition and lower CH_4 and N_2O emissions from forest fires.

Figure 3.60: *Trend and projections of GHG emissions and removals in Gg of CO_2 eq. in 4.A.1 - Forest Land remaining Forest Land in WEM and WAM scenarios up to 2050*



Projections of emissions/removals in Land Converted to Forest Land - in this category, projections of emissions and removals of CO_2, CH_4, N_2O (Gg CO_2 eq.) were calculated for the WEM and WAM scenarios (***Figure 3.61***). When land is converted to forest (afforestation), significant carbon sequestration or CO_2 sinks occur, mainly through new forest biomass. In the WEM scenario, there are lower sinks due to decreasing area under afforestation, unchanged tree species composition and also higher emissions from forest fires. The WAM scenario shows higher removals mainly due to higher forest cover, more favourable tree species composition and assumed lower emissions from forest fires.

Figure 3.61: *Trend and projections of GHG emissions and removals in Gg of CO_2 eq. in 4.A.2 - Land converted to Forest Land in WEM and WAM scenarios up to 2050*



Projections of emissions/removals in the Cropland - this category shows net GHG sinks (Gg) for all scenarios (***Figure 5.62*** and ***Figure 5.63***). The CO_2 sinks occur mainly in the permanent crops category and are due to additions of woody biomass in orchards, vineyards and gardens. Also, mineral soil represents a CO_2 sink in this category. CO_2 emissions in this category occur when forests are converted to cropland (deforestation) and N_2O emissions occur when soils are mineralised as a result of land-use change. Deforestation removes tree biomass and also releases carbon sequestered in fallout and forest soil. The WEM scenario shows lower removals, due to lower areas of permanent crops, higher CO_2 emissions from deforestation and N_2O emissions from soil mineralisation, compared to the WAM scenario.

Figure 3.62: *Trend and projections of GHG emissions and removals in Gg of CO_2 eq. in 4.B.1 - Cropland remaining Cropland in WEM and WAM scenarios up to 2050*

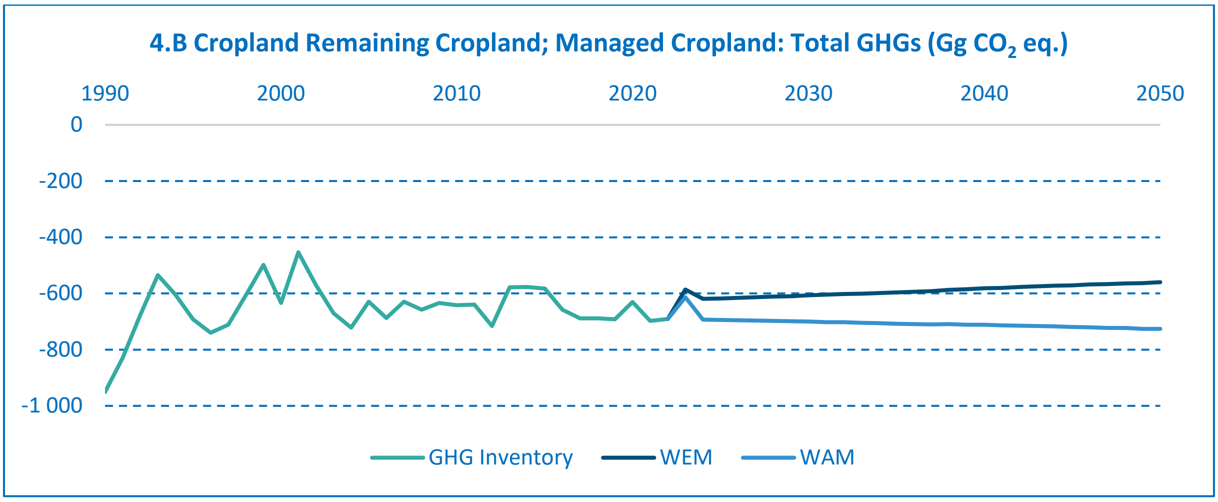
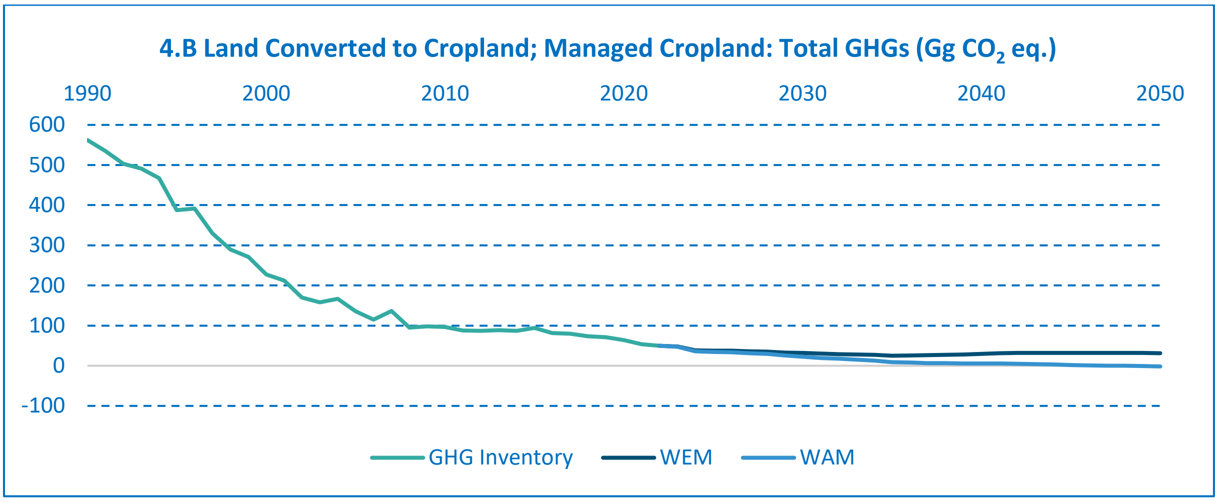
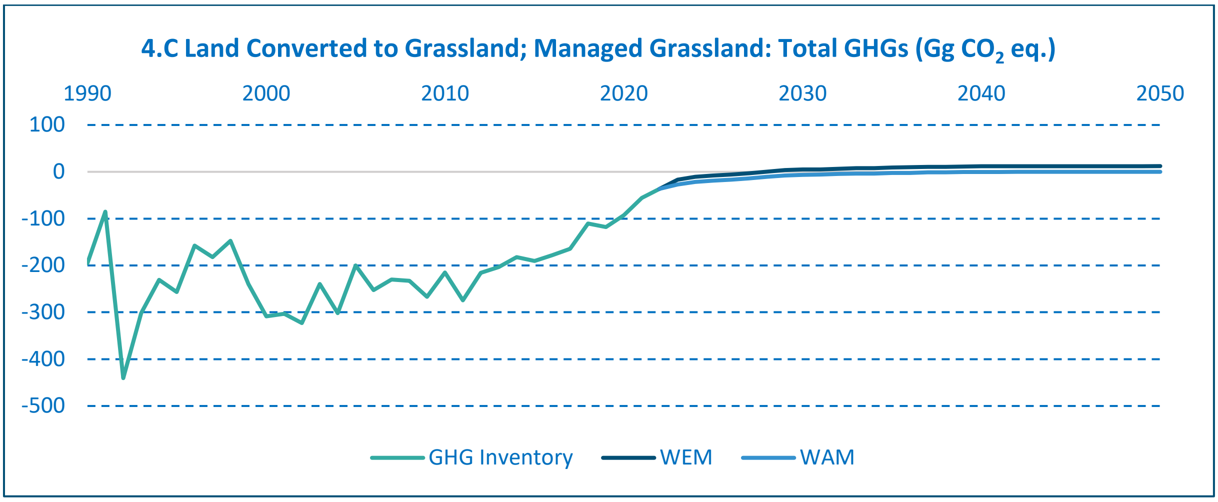


Figure 3.63: *Trend and projections of GHG emissions and removals in Gg of CO_2 eq. in 4.B.2 – Land converted to Cropland in WEM and WAM scenarios up to 2050*



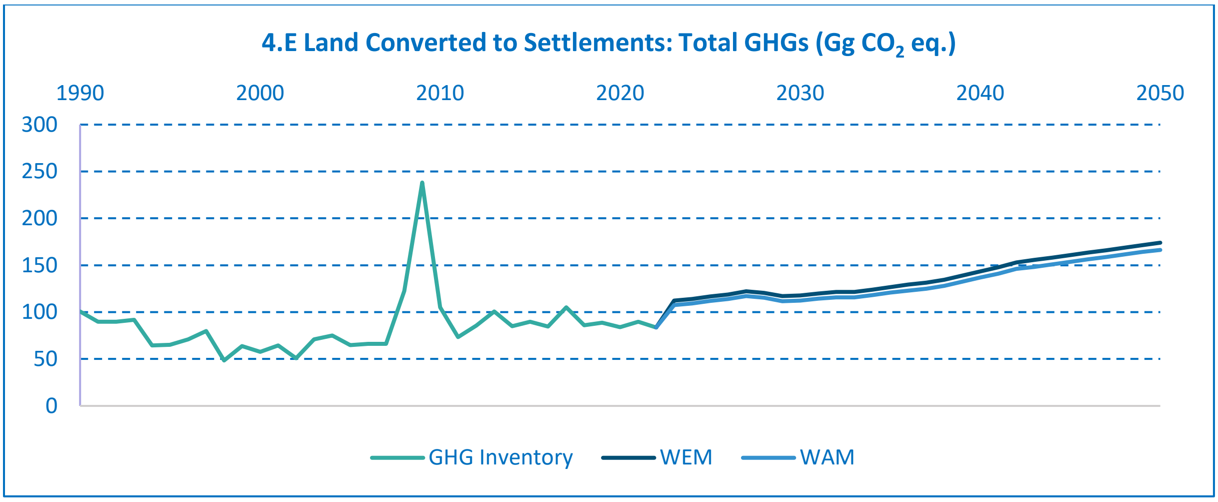
Projections of emissions/removals in Grassland - in this category, projections of CO_2 emissions and sinks (Gg) were determined for all scenarios, with the scenarios (***Figure 3.64***). Both scenarios show CO_2 sinks by 2050, but a significant decrease in sinks can be expected compared to historical data, mainly due to a decrease in acreage in this category. The WEM scenario shows slightly lower removals, due to lower areas of permanent grassland, higher CO_2 emissions from deforestation and N2O from soil mineralisation, compared to the WAM scenario. However, the differences in removals between the two scenarios are minimal.

Figure 3.64: *Trend and projections of GHG emissions and removals in Gg of CO_2 eq. in 4.C – Grassland in WEM and WAM scenarios up to 2050*



Projections of emissions/removals in Settlements - in this category, projections of CO_2 emissions (Gg) were determined for the WEM and WAM scenarios (***Figure 3.65***). Both scenarios show CO_2 emissions up to 2050 and can be expected to increase compared to historical data, mainly due to the increase in acreage in this category. This situation is mostly due to the development of transport infrastructure, industrial areas, urban and municipal development and the increase in the acreage of various infrastructure in the land. The WEM scenario shows slightly higher CO_2 emissions compared to the WAM scenario. Higher CO_2 emissions from deforestation and N_2O emissions from soil mineralisation contribute to this.

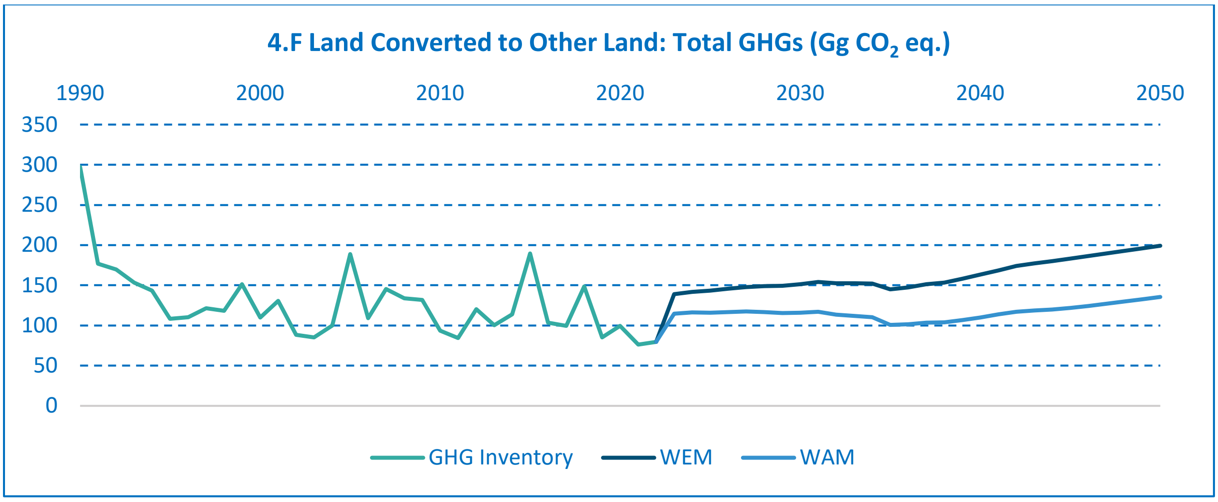
Figure 3.65: *Trend and projections of GHG emissions and removals in Gg of CO_2 eq. in 4.E – Settlements in WEM and WAM scenarios up to 2050*



Projections of emissions/removals in Other Land - in this category, projections of CO_2 emissions (Gg) were determined for the WEM and WAM scenarios (***Figure 3.66***). Both scenarios show emissions up to 2050, an increase in emissions can be expected compared to historical data, mainly due to the increase in acreage in this category. This situation is mostly due to degradation of cropland, but also to an increase in the acreage of various infrastructure in the land. The WEM scenario shows higher CO_2

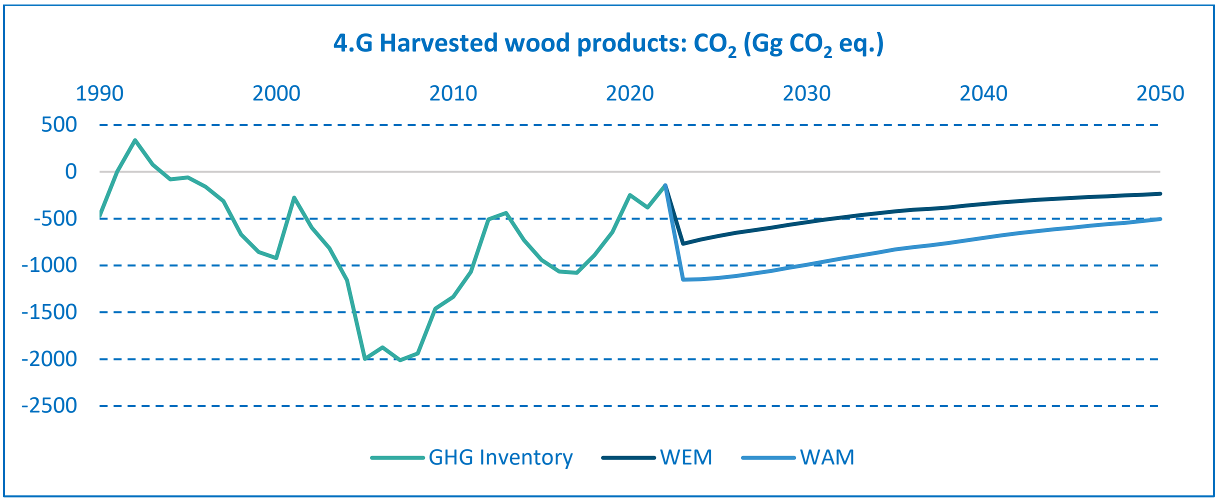
emissions compared to the WAM scenario. Higher CO_2 emissions from deforestation and N_2O emissions from soil mineralisation also contribute to this.

Figure 3.66: *Trend and projections of GHG emissions and removals in Gg of CO_2 eq. in 4.F – Other Land in WEM and WAM scenarios up to 2050*



Projections of emissions/removals in Harvested Wood Products - increased sustainable use of harvested wood products can significantly reduce emissions through substitution effects and improve the removal of greenhouse gases from the atmosphere. This category shows CO_2 removals (Gg) for the WEM and WAM scenarios (***Figure 3.67***). CO_2 sequestration occurs through carbon sequestration in the different wood product groups. While the storage period for paper products is 2 years, it is 25 years in wood panels and up to 35 years in lumber. The WEM scenario shows lower removals compared to the WAM scenario, mainly due to the higher share of products with shorter carbon storage times.

Figure 3.67: *Trend and projections of CO_2 removals p in Gg in 4.G - Harvested Wood Products in WEM and WAM scenarios up to 2050*



3.6.10. GHG EMISSION PROJECTIONS IN WASTE SECTOR

In general, the more waste we produce, the more we have to get rid of. Some waste disposal methods release both pollutants and greenhouse gases into the air. Recycling is one method of reducing the impact of waste disposal on the air and the climate. However, there are also ways of managing waste that are more environmentally friendly.

The waste management sector consists of the following categories:

- 5.A Solid waste Disposal Sites
- 5.B Biological Treatment of Solid Waste
- 5.C Waste Incineration
- 5.D Wastewater Treatment

The most common disposal methods are landfill and, to a lesser extent, incineration. When waste from landfills decomposes, non-methane volatile organic compounds (NMVOCs) and methane are released into the air, and particulate emissions are released when waste is handled (PM).

Incineration is the second most common method of waste disposal in the Slovak Republic. In the past energy from incineration was not often used and waste was only disposed of. Modern plants now use waste as a fuel in the production of energy or heat, and waste is also recovered in this way. In this case, the emissions from incineration are classified in the energy sector. In our country, waste incineration contributes significantly to the number of dioxins and furans (PCDDs/PCDFs) that are emitted into the air. Since dioxins are virtually unbreakable in nature and can persist for hundreds of years, they are deposited in animal tissues and thus enter the human food chain. Dietary intake, especially of meat, fish, eggs, milk and fats, is the most important route of entry of dioxins into the human body. Incineration of waste also releases high levels of heavy metal emissions into the air. Modern waste incineration plants capture these pollutants efficiently, but this was not common practice in the past. Heavy metals are deposited in the soil and subsequently in organisms, from which they are difficult to break down. Through the food chain, contamination of organisms gradually increases. Animals at the end of the food chain, and therefore humans, are particularly at risk from heavy metals. The risk is particularly higher in coastal areas, where seafood consumption is generally higher.

Recycling is not the only sustainable way to recover waste. Composting any organic waste, such as food and garden waste, is one of them. Organic waste decomposes into mulch in a matter of weeks, which can be used as fertilizer for the soil. Many households practise small-scale composting, large-scale composting systems are also being developed with the collection of organic waste from parks and urban amenities. Similar types of organic waste can also be treated in biogas plants. Unlike composting, here the waste is decomposed anaerobically (without air access) and biogas is produced which can be further burned to generate energy that can be used for heating.

This sector also includes cremations of human and animal remains, which are also a source of air pollution through emissions of heavy metals and POPs.

Wastewater treatment also releases pollutants and greenhouse gases (both CH_4 and N_2O). In general, emissions of POPs as well as NMVOCs, CO and NH_3 occur in wastewater treatment plants, but in most cases, these are negligible amounts.

The waste sector is the most important source of methane emissions, accounting for almost 46% of total emissions in 2022. Methane emissions from this sector have increased by more than 35% compared to 1990 due to the use of a new cumulative methodology (FOD) in the solid waste landfilling category instead of the original annual methodology (Zero Order). Landfilling of waste is a significant source of methane emissions, which is released in the form of landfill gas. The volume of emissions from landfills strongly depends on the amount of landfilled waste, the content of organically degradable carbon (DOC) in this waste, and also on the capture and use of landfill gas. Methane production from landfills takes place over a period of 10 - 30 years, depending on the half-life of organic carbon in the waste. Since only very few landfills in Slovakia (11 establishments) have a built-in system for capturing and recovering landfill gas, it is released directly into the atmosphere at most landfills.

The trend in emissions from waste management has been balanced over the entire period under review since 1990. Methane is the most important gas, accounting for more than 89% of the sector's GHG emissions, followed by N_2O with almost 11%. Most emissions come from landfilling, followed by wastewater.

The Waste sector accounted for over 5% of total greenhouse gas emissions in 2022. According to WEM scenario, it can be concluded that after recalculating all four main waste treatment categories, there will be a 6% increase in GHG emissions in 2030 compared to 2005 and a 22% increase compared to 1990. Compared to 1990 a 10% increase is expected in emissions from the waste sector in 2050. In the WAM scenario there will be a 1% reduction in GHG emissions by 2030 compared to 2005 and a 14% increase compared to 1990. In 2050 a 22% reduction is expected in emissions from the waste sector compared to 1990. The trends according to the WEM and WAM scenarios are provided in the ***Table 3.52*, *Figures 3.68*** and ***3.69***.

Table 3.52: *Trend and projections of GHG emissions in Gg od CO_2 eq. for Waste sector in WEM and WAM scenarios up to 2050*

Sector 5 - Waste								
WEM	**2005***	**2022***	**2025**	**2030**	**2035**	**2040**	**2045**	**2050**
	Gg CO_2 eq.							
	1 610.13	1 929.92	1 827.68	1 704.41	1 641.37	1 567.32	1 574.55	1 528.04

Sector 5 - Waste								
WAM	**2005***	**2022***	**2025**	**2030**	**2035**	**2040**	**2045**	**2050**
	Gg CO_2 eq.							
	1 610.13	1 929.92	1 783.95	1 590.79	1 446.58	1 342.05	1 287.03	1 250.70

* Base year 2022; 2022 based on the GHG inventory submission 15. 3. 2024

Figure 3.68: *Trend and projections of GHG emissions in Gg of CO_2 eq. for Waste sector by categories in WEM scenario up to 2050*

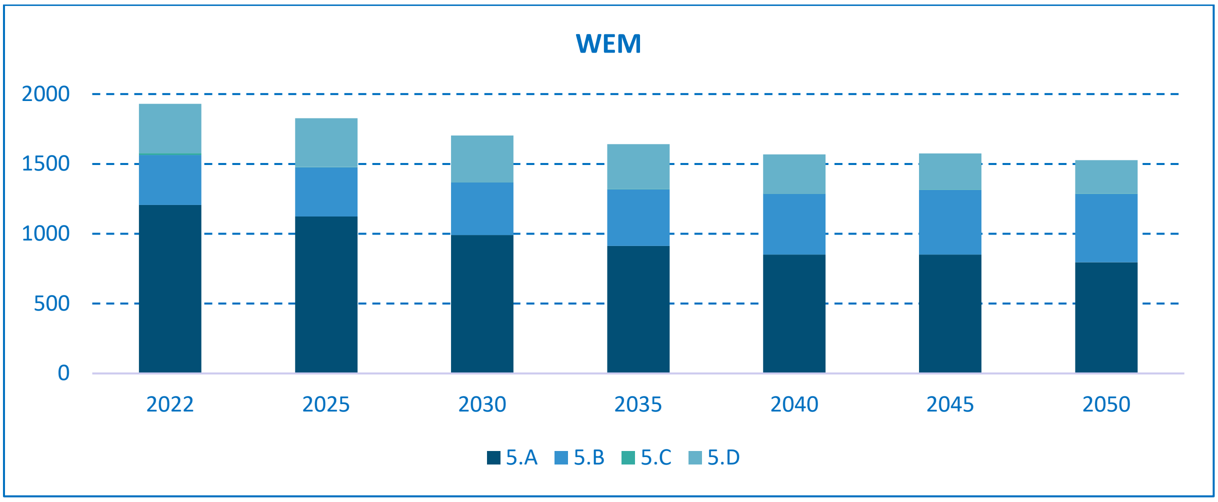
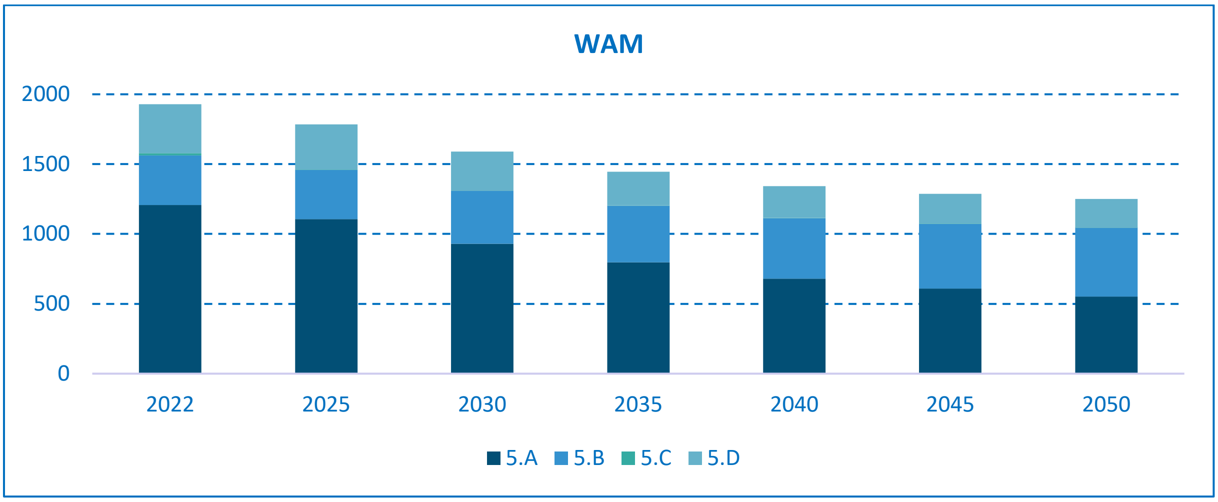


Figure 3.69: *Trend and projections of GHG emissions in Gg of CO_2 eq. for Waste sector by categories in WAM scenario up to 2050*



3.6.10.1. Historical Data of Input Parameters for Projections in Waste Sector

Municipal solid waste (MSW) production - When determining methane emissions from municipal waste landfills, according to the IPCC 2006 Guidelines methodology, key input parameters are defined as follows:

- Number of inhabitants of the country for the monitored period
- Municipal waste production in kg per inhabitant per year
- Share of landfilled waste in the total production of municipal waste per year
- Composition of landfilled municipal waste and its DOC content

The first value represents the so-called average state per year, the other two values are exactly given by calculation and the last value is more or less empirical.

The development of the population in Slovakia since 1990, together with the forecast of development until 2050, are the basic input parameters for determining greenhouse gas emissions in this category. ***Table 3.53*** shows the historical data used in the emission inventory from 1990 – 2022 according to the documents provided by the Slovak Ministry of Education.

Table 3.53: *Statistical information on the population of Slovakia for the years 1990 – 2022*

Year	1990	1995	2000	2005	2010	2015	2020	2022
Number of inhabitants	5 297 774	5 363 676	5 400 679	5 387 285	5 431 024	5 423 800	5 460 136	5 428 792

According to the IPCC 2006 methodology, the second important data for calculating emissions from landfilling is municipal waste production. In general, according to the IPCC methodology, it is recalculated according to the country's GDP data. For Slovakia, where the data is directly tracked statistically, we start from the database of the ŠÚ SR. In the calculations, we take statistical data on the total amount of municipal waste produced in Slovakia. ***Table 3.54*** shows the data converted into kilograms per person per year.

Table 3.54: *Statistical information on the production of municipal waste for the years 1990 – 2022*

Year	Unit	1990	1995	2000	2005	2010	2015	2020	2022
Unit production MSW	kg/capita	287	236	248	289	333	348	476	479

With the growing environmental awareness of the population and the improving economic situation, there is a shift from landfilling to the recovery of municipal waste, either through material recycling, energy recovery or classic composting. This progress is best signalled by the decrease in the share of landfilled municipal waste to the total production of this waste. The amount of landfilled waste is evaluated by the ŠÚ SR on the basis of documents from the Ministry of the Environment of the Slovak Republic according to the records of individual landfill operators. ***Table 3.55*** shows data on the percentage share of landfilled municipal waste for a given year as a ratio of produced waste and landfilled waste according to the ŠÚ SR.

Table 3.55: *Share of landfilled municipal solid waste in total MSW production for the years 1990 – 2022*

Year	1990	1995	2000	2005	2010	2015	2020	2022
Proportion of landfilling from MSW	90%	88%	79%	79%	78%	69%	41%	39%

The last important data for determining emissions from landfilling is the composition of the landfilled waste and the resulting value of DOC - degradable organic carbon. Due to the small number of analyses of the composition of municipal waste from the past, which are not sufficiently representative of the entire landfilled amount of MSW, this value was more or less only estimated. ***Table 3.56*** shows the DOC values of landfilled municipal waste for a given year.

Table 3.56: *DOC value of landfilled MSW for the years 1990 – 2022*

Year	1990	1995	2000	2005	2010	2015	2020	2022
DOC value	0.124	0.124	0.141	0.141	0.143	0.129	0.120	0.120

Industrial solid waste (ISW) production - Similar to municipal waste, the input data for the calculation of emissions from industrial waste landfills are the following parameters:

- Production of industrial waste in tons per year
- The share of landfilled waste in the total production of industrial waste per year
- Amount of landfilled industrial waste with DOC content > 0

Even though the production of ISW represents a much more significant amount of waste in Slovakia than MSW (10 593 124 t / 2 597 457 t in 2022), their share in landfilling is much lower. According to data from the Waste Information System (IS Odpady), administered by the Ministry of the Environment of the Slovak Republic, over the past 15 years, solid waste has made up around 81 to 89% of the total amount of waste produced in Slovakia. Since 2014, the amount of landfilled industrial waste has decreased significantly from the original 46% to the current 16% (2022) of the total amount of ISW produced. ***Table 3.57*** shows the amounts of landfilled industrial waste for a given year.

Table 3.57: *Total production of industrial waste and amount of landfilled industrial waste for the years 2005 – 2022 (t/y)*

Year	2005	2010	2015	2020	2022
Amount of ISW	9 346 816	7 814887	8 782 522	10 516 841	10 593 124
Amount of landfilled ISW	2 888 366	2 483 878	2 707 543	1 832 869	1 721 583

For the calculation of emissions from landfilling of industrial waste, only those types of industrial waste that have a non-zero content of DOC - degradable organic carbon are important. Based on exact knowledge, individual types of waste were selected from the entire Waste Catalogue, which were assigned to individual groups according to the IPCC breakdown - Food, Wood, Paper, Textile, Sludge, Mix_package, C+D_waste. The group Wood, for example, includes all landfilled wood from individual subgroups 03 +15 +17 +19 of the Waste Catalogue. Landfill industrial wastes with a DOC content > 0 form only a minimal share of the total production of ISW and their share gradually decreases from the original 4% to the current approx. 1%. ***Table 3.58*** shows the amounts of landfilled industrial waste with a DOC content > 0 for a given year.

Table 3.58: *Amount of landfilled industrial waste with DOC > 0 for the years 1990 – 2022*

Year	1990	1995	2000	2005	2010	2015	2020	2022
Σ (t/y):	212 825	223 681	235 091	191 407	209 183	157 388	129 265	65 898

Wastewater - The development of the population in Slovakia, together with the share of connections to wastewater treatment plants since 1990, are the basic input parameters for determining greenhouse gas emissions in this category. The distribution of the population according to additional methods of wastewater management is also important. ***Table 3.59*** presents the historical data used in the emission inventory from 1990 – 2022.

Table 3.59: *Statistical information on the distribution of wastewater treatment for the years 1990 – 2022*

Year	Demography	Connected to public sewerage*	Connected to public sewerage and WWTP	Public sewerage (not connected to the WWTP)	Cesspools	Domestic WWTP	Latrines
1990	5 297 774	2 688 800	2 283 800	405 000	1 923 700	-	685 274
1995	5 363 676	2 817 800	2 592 700	225 100	1 922 699	-	623 177
2000	5 400 679	2 956 300	2 695 900	260 400	1 921 661	-	522 718
2005	5 387 285	3 075 500	2 971 400	104 100	1 845 112	26 883	439 790
2010	5 431 024	3 281 700	3 202 900	78 800	1 749 686	61 298	338 340
2015	5 423 800	3 534 341	3 495 177	39 164	1 654 260	87 453	147 745
2020	5 460 136	3 805 330	3 782 220	23 110	1 538 834	109 938	6 034
2022	5 428 792	3 856 104	3 839 074	17 030	1 455 800	112 850	4 038

3.6.10.2. Projections of Input Data and Parameters

Projections of emissions are based on the assumption of the demographic development of the Slovak population according to the Aging report for the years 2023 to 2050. According to this scenario, the population of Slovakia will decrease by 2% in 2030, by 4% in 2040 and by 7% in 2050. ***Table 3.60*** shows the assumption of demographic development in Slovakia.

Table 3.60: *Projections of demographic development in Slovakia up to 2050*

Year	2022	2025	2030	2035	2040	2045	2050
Total (median state)	5 428 792	5 410 167	5 339 138	5 260 065	5 194 922	5 135 372	5 075 429

Source: Ageing report 2024

Municipal solid waste (MSW) production per capita/year in kg - for the purposes of forecasting the average production of municipal solid waste, the standard model of the annual increase in municipal waste according to the OECD was used, which is highly correlated with GDP growth (0.69% of GDP). For Slovakia, we used the GDP growth forecast in the Aging report for the years 2023 to 2050 (potential growth rate GDP). The municipal waste production forecast for the emissions projection is in ***Table 3.61***. It should be noted that this forecast is highly debatable and uncertain, as it is based on only one indicator (GDP). Published knowledge on the growth of municipal waste points to a higher correlation of MSW with the growth of household final consumption than only with the growth of GDP. However, we do not have a forecast of this data until 2050. Secondly, it should be noted that in the years 2016 - 2021, the production of municipal waste in Slovakia grew by approximately 66 000 t per year, mainly due to significant economic growth (GDP ≈ +6% per year). According to the NBS, the gross annual income of a typical Slovak household increased by up to 31% between 2017 and 2021, which was reflected in the increase in the production of municipal waste by 27%. The second reason for the growth of MSW was also some administrative changes in the classification of waste. For the years 2024 – 2050, the annual GDP growth is only in the range of 1.50% - 2.15%. This results in the assumption of annual growth of municipal waste in the given period to a maximum of 30 000 t/y. Considering the knowledge from the last economic crisis and COVID, one can even expect a decrease or stagnation in the creation of KO or real year-on-year growth of only up to 10 000 t/y until 2040. It then follows that the specific production of MSW could be significantly lower - for the year 2030 only 493 kg/capita and for the year 2040 only 536 kg/capita.

Table 3.61: *Specific production of MSW in Slovakia by 2050*

Year	Unit	2022	2025	2030	2035	2040	2045	2050
Unit production MSW	kg/capita	480	479	515	560	604	623	635*

*the value represents only an expert estimate

Share of landfilled municipal solid waste in total MSW production - in the years 2005 – 2012, Slovakia maintained the amount of landfilled MSW at a level of approx. 1.3 million tons per year. It was only after 2018 that the amount of landfilled MSW began to decrease to the level of approximately 1.0 million tons per year. The share of landfilled municipal waste thus fell from the original 75% to the current 39%. The forecast for the years 2025 – 2050 is very uncertain and represents only an expert estimate (***Table 3.62***).

Table 3.62: *Projections of the development of the MSW landfill fraction in Slovakia until 2050*

Year	2022	2025	2030	2035	2040	2045	2050
Proportion of landfilling from MSW	39%	36%	31%	26%	21%	16%	11%

MSW composition and degradable organic carbon (DOC) content of landfilled waste - based on the available data on the representation of biodegradable components in MSW in Slovakia, the expected DOC values for the next period were determined. The calculated DOC values are presented in ***Table 3.63***.

Table 3.63: *Projections of DOC value of landfilled MSW until 2050*

Year	2022	2025	2030	2035	2040	2045	2050
DOC value	0.120	0.107	0.107	0.107	0.107	0.107	0.107

When projecting methane emissions from landfilling of ISW waste in Slovakia, the key calculation parameters are defined by the following indicators:

GDP (economic development of a country as an indicator of waste production) – trend in GDP is generally considered to be a basic indicator of waste production - as GDP increases, the amount of waste increases. According to the OECD it is characteristic for developing countries (where Slovakia still belongs) that for every 1% increase in GDP, MSW production increases by 0.69%. However, COVID-19 and its associated measures have apparently brought a change in this paradigm. GDP growth has slowed to a halt over the last two years, yet for some types of waste (sanitary, medical, packaging) there has been a significant increase in their production or a change in the way they are managed (D1 > R1). One possible explanation is that some recycling plants were not functioning properly, or that the sharp increase in specific wastes was dealt with in the cheapest economic way (landfilling instead of recycling).

It is very difficult to predict how GDP will develop in Slovakia in the years 2025 – 2030 (2050) in connection with the current energy crisis or changes in the structure of the economy (automotive industry), as well as the consequences of some climate measures. The recession will probably dampen the growth of industrial waste production. Based on these facts, we expect the production of ISW in Slovakia to be stabilized or only very slightly growing in the coming years.

Based on these facts, we assume that ISW production in Slovakia will be stable or slightly increasing in the coming years. From the current approx. 10.6 million tonnes, we expect a stagnant state by 2030 and an increase to approx. 11.0 million tons by 2040 and 2050.

SWDS (share of landfilled ISW in total industrial waste production) - SWDS is an indicator of how much of the waste generated ends up in landfills. Despite the significantly larger production of industrial waste, the share of landfilled ISW is significantly lower than that of MSW. In Slovakia, the share of landfilled ISW has been significantly reduced from 31 - 46% in 2005 – 2015 to less than 16% today. In terms of weight, this represents a decrease in ISW landfilling from the original 2.5 to 4.3 million tons to the current approx. 1.637 million tons. In the next period, we do not expect a significant decrease in the share of landfilling, which will probably stabilize at the level of approx. 16%, which will represent about 1.718 million tons per year.

SWDS + DOC>0 (share of landfilled industrial waste containing biodegradable carbon) - SWDS + DOC > 0 represents only that part of landfilled industrial wastes which, due to their organic degradable carbon content, contribute directly to methane emissions from landfilling. In Slovakia, these types of MSW represent only a relatively small proportion of the total amount of MSW produced. The maximum of 4% was in 2009, the share has fallen below 3% since 2012 and below 2% since 2014. It has remained just above 1% since 2017. In absolute terms, this represents a decrease from the original approx. 290 000 t/y to the current approx. 100 000 t/y, although in the last three years it has even dropped below 70 000 t/y. We assume that the total amount of landfilled ISW with DOC > 0 will stabilize at around 92 000 t per year for the years 2025 to 2050.

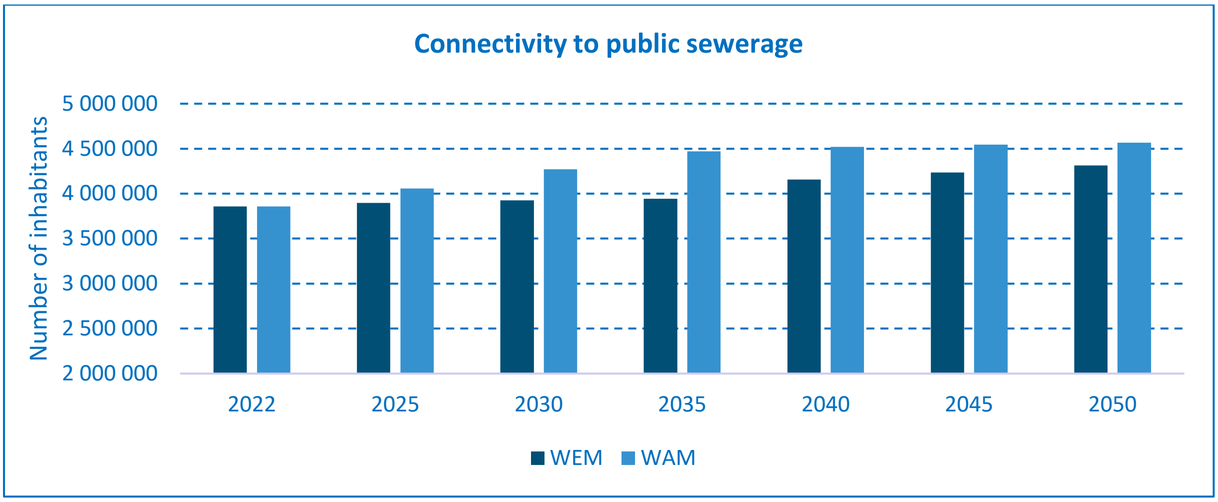
A very important input parameter for the correct estimation of GHG emissions projections from wastewater is the proportion of households connected to public sewerage and wastewater treatment plants. These estimates under the two scenarios are shown in ***Figure 3.64***.

Table 3.64: *Projections of demographic development in Slovakia until 2050*

Year	Demography	Connected to public sewerage*	Connected to public sewerage and WWTP	Public sewerage (not connected to the WWTP)	Cesspools	Domestic WWTP	Latrines
Source	**EU REF 2024**	**Water Research Institute/Blue Report. expert estimates**					
WEM							
2022	5 428 792	3 856 104	3 839 074	17 030	1 455 800	112 850	4 038
2025	5 410 167	3 895 400	3 876 400	19 000	1 393 700	117 700	3 367
2030	5 339 138	3 924 300	3 907 300	17 000	1 293 900	118 000	2 938
2035	5 260 065	3 945 100	3 930 100	15 000	1 192 200	120 000	2 765
2040	5 194 922	4 156 000	4 142 000	14 000	911 800	125 000	2 122
2045	5 135 372	4 236 700	4 223 700	13 000	769 800	127 000	1 872
2050	5 075 429	4 314 200	4 302 200	12 000	631 200	128 300	1 729

Year	Demography	Connected to public sewerage*	Connected to public sewerage and WWTP	Public sewerage (not connected to the WWTP)	Cesspools	Domestic WWTP	Latrines
Source	**EU REF 2024**	**Water Research Institute/Blue Report. expert estimates**					
WAM							
2022	5 428 792	3 856 104	3 839 074	17 030	1 455 800	112 850	4 038
2025	5 410 167	4 057 700	4 038 700	19 000	1 231 000	118 000	3 467
2030	5 339 138	4 271 400	4 255 400	16 000	943 400	121 000	3 338
2035	5 260 065	4 471 100	4 457 100	14 000	663 900	122 000	3 065
2040	5 194 922	4 519 600	4 507 600	12 000	546 600	126 000	2 722
2045	5 135 372	4 544 900	4 533 900	11 000	460 100	128 000	2 372
2050	5 075 429	4 567 900	4 557 900	10 000	375 600	130 800	1 129

Figure 3.70: *Trend of the number of connections to public sewerage in WEM and WAM scenarios up to 2050*



3.6.10.3. Methodologies, Key Assumptions/Trends and Model Description

Projections of emissions were prepared in accordance with the methodology of the Intergovernmental Panel on Climate Change from 2006 IPCC Guidelines 2006, the methodology is consistent with the methodology for estimating emissions under Article 26 par. 3 of Regulation (EU) 2018/1999. The calculation analysis tool is based on the MS Excel platform and the calculation includes various policies and measures (in numerical formulation) defined according to the WEM and WAM scenarios. Detailed calculations of emissions projections of individual gases were carried out according to the new modified methodology "2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories – Chapter 6 Wastewater Treatment and discharge". By changing the methodology for calculating emissions of methane and nitrous oxide, both the initial and future projections of both greenhouse gases were changed. Therefore, virtually all relevant data is different (usually higher) compared to the 2022 report.

There are several specially developed mathematical models for the preparation of emission projections, but due to the need for complex input data including economic and energy indicators, it is currently not possible to use them for the purposes of reporting national projections. The small Slovak economy would need its own model developed exactly for our conditions.

Further improvements in the preparation of emissions projections from the waste sector should enable the entire calculation process to be automated, which should reduce the calculation time and create space for the creation of a larger number of scenarios and the processing of sensitivity analysis.

From the previous description of the key parameters for calculating methane emissions from landfilling, it follows that two of them are of an objective nature - the development of the population over the monitored period as well as the total production of waste. These parameters are influenced by social and economic factors, which we still do not know how to regulate or guide significantly. Their future values for the monitored period are therefore relatively difficult to predict and burdened with a relatively high degree of uncertainty. The other three parameters (proportion of landfilled waste, composition of waste, capture and use of methane) are more or less subjective in nature and can be influenced by external interventions and state policies. Some of these parameters may (but may not) act synergistically and increase their impact on overall methane emissions from landfilling. For example, the construction and operation of additional waste-to-energy facilities ("incinerators" = WtE) will in any case contribute to a decrease in the amount of landfilled waste as we can see, for example, in the data from BSK and KSK. More intensive separation of waste components will lead to a decrease of DOC in landfilled waste. The construction and operation of new MBU facilities will combine both of these parameters. However, it should be noted that the residue from MBU facilities (ending up in landfills) has a higher DOC > 0 than the residue from WtE (DOC < 0). The resulting impact of the measures on these parameters will depend on the capacity of the new facilities and their operational efficiency. However, from a time point of view, it is necessary to think with a horizon of at least 5 - 10 years, so that these policies are also reflected at the output. The last parameter - "Recovery methane" is probably also a very important and underappreciated component. Based on knowledge from European countries, where there has already been a shift away from landfilling, it is clear that the production of landfill gas and thus the amount of usable methane from landfills will subsequently decrease. On the other hand, according to the EEA report from May 2021, Slovakia is among the EU27 countries with the lowest use of landfill gas (only 5%), while the EU average is around 39%. Due to the lack of data, it is not possible to more precisely quantify the total potential of usable methane from landfills and the current efficiency of its capture and processing.

When describing the preparation of emission projections, it should be noted that according to the methodology of the IPCC 2006 Guidelines, emissions from landfilling are calculated according to the components of the landfilled waste (food, wood, paper, textiles, sludge...) and not according to the type of landfills in the sense of the Directive on landfills (2018/850 or 1999/31/EC). Considering the different development and production of municipal and industrial waste in Slovakia, as well as the requirement in previous revisions of the national inventory, emission projections were calculated separately with industrial waste = ISW (sk. 01 to 19 EWC) and separately with municipal waste = MSW (sk. 20 EWC). The resulting emission projections from the waste landfill category (5.A) are then the sum of both sub-categories.

***Table 3.65:** SWAT analysis of the Waste-model*

Strengths	Opportunities
Compatibility with emission inventories Detailed data break down Database used is compatible with national data Model is free of charge	Incorporate to the model new technologies Versatile use of time-series
Treats	**Weakness**
Bugs can be introduced if data is incorporated manually Lack of input data introduce high uncertainty	Disconnected from macroeconomic models Too much pre-calculations needed Missing measurable indicators in national policies and strategies Data consistencies in the projection estimation process

3.6.10.4. Scenarios, Parameters and PAMs

Two scenarios have been prepared to model the emission projections for categories 5.A - Landfills and 5.D - Wastewater:

- WEM – scenario with existing measures (realistic)
- WAM – scenario with additional measures (optimistic)

For the modelling of emission projections from categories 5.B - Composting of non-biogenic waste and 5.C - Incineration of waste without energy recovery, only one scenario was prepared, namely WEM = WAM, due to the lack of relevant PAMs.

The scenario with existing measures (realistic) scenario, or also called BAU = Business as Usual, is based on the expectation that developments in solid waste landfill management will continue as observed in other EU countries undergoing economic transition.

Municipal waste production - the WEM scenario presents a projection of methane emissions from MSW with the continuation of current trends and policies in waste management in Slovakia without taking into account more significant externalities or radical economic collapses. The production of municipal waste for the years 2023 – 2050 copies the expected development of GDP with annual growth in the range of 1.48%-1.03%. At the same time, we assume that the current significant decrease in the share of landfilled waste to the total production of MSW (-3.1% per year or -40 300 t/y) will slow down and stabilize at 1% per year (-20 000 t/y). Methane emissions from landfilling of municipal waste are shown in ***Table 3.66*** below.

***Table 3.66:** Trend projections of parameters and methane emissions from MSW in WEM scenario up to 2050*

Year	Unit	2022*	2025	2030	2035	2040	2045	2050
MSW	kilo tonnes	2 597.46	2 592.79	2 750.77	2 943.83	3 137.35	3 196.77	3 524.17
MSW-> SWDS	kilo tonnes	1 021.58	941.97	861.82	775.12	669.20	521.07	400.29
CH_4 Emissions	Gg	37.94	35.26	30.87	28.40	26.45	26.51	24.59

* Base year 2022; 2022 based on the GHG inventory submission 15. 3. 2024

Production of industrial waste - the WEM scenario represents a projection with a continuation of the current trends given by the policies and measures in the waste management in Slovakia without taking into account more significant externalities or radical economic collapses. The amount of landfilled industrial waste containing biodegradable carbon stabilises at around 92 000 t/year. Methane emissions from landfilling of industrial waste are shown in ***Table 3.67*** below.

Table 3.67: *Trend and projections of methane parameters and emissions from ISW in WEM scenario up to 2050*

Year	**Unit**	**2022***	**2025**	**2030**	**2035**	**2040**	**2045**	**2050**
ISW -> SWDS	kilo tonnes	65.90	90.27	89.40	91.14	92.02	93.61	95.07
CH_4 emissions	Gg	5.18	4.84	4.49	4.22	3.98	3.89	3.81

* Base year 2022; 2022 based on the GHG inventory submission 15. 3. 2024

The WAM scenario presents a projection of the future development of methane emissions from waste landfills in Slovakia when new policies in waste management are introduced and applied without taking into account significant external influences (economic crisis, war, another pandemic, etc.). The scenario with additional measures (optimistic) is based on the expectation that additional supporting measures will be implemented in the waste management sector in Slovakia to increase the rate of waste recovery and reduce the amount of landfilled waste (MBU, WtE, etc.).

Municipal waste production – in the WAM scenario is expected a decrease of the “FOOD” component in municipal waste due to separate collection of kitchen waste. Similarly, the separate collection of textiles from 1.1.2025 will contribute to the reduction of this component in the MSW landfilled. Further intensification of separate collection, support of composting and aerobic digestion will also bring a decrease in the components of paper and garden waste in landfilled MSW. The deposit system of returnable packaging will probably be reflected in the reduction of the production of mixed packaging, which represents a significant share of landfilled waste. The introduction of mandatory treatment of municipal waste before landfilling and an increase in the share of waste that can be used for energy will also have a significant impact on reducing the amount of landfilled municipal waste. By 2050, there could thus be a substantial decrease in landfilled bio-degradable carbon, which also represents an adequate decrease in the DOC value by about 35% and, ultimately, a decrease in methane production from landfills. This scenario assumes a significant decrease in the amount of landfilled municipal waste, i.e. diversion of mixed MSW to other (new) facilities gradually by approx. 80 000 t per year until 2050. In accordance with goals of European Commission for waste management, the goal for 2035 is set: landfill less than 10% of MSW and recover more than 60% MSW. The 2030 environmental strategy has a set goal for the year 2030 to landfill max. 25% and evaluate min. 60%. The WAM scenario envisages reaching the landfill goal of max. 25% in 2030 and max. 15% of MSW in 2035 with a gradual reduction of landfilled MSW from 2023 by approx. 42 000 tons per year. Methane emissions from landfilling of municipal waste are shown in the following ***Table 3.68***.

Table 3.68: *Trend and projections of parameters and methane emissions from MSW in WAM scenario up to 2050*

Year	**Unit**	**2022***	**2025**	**2030**	**2035**	**2040**	**2045**	**2050**
MSW	kilo tonnes	2 597.46	2 592.79	2 750.77	2 943.83	3 137.35	3 196.77	3 524.17
MSW-> SWDS	kilo tonnes	1 021.58	886.22	684.61	482.99	281.38	206.11	146.97
CH_4 Emissions	Gg	37.94	34.81	28.83	24.38	20.43	18.37	16.75

* Base year 2022; 2022 based on the GHG inventory submission 15. 3. 2024

Production of industrial waste - WAM scenario represents a projection of the future development of methane emissions from landfilling of industrial waste in Slovakia with a slight decrease in the amount of landfilled ISW. Methane emissions from landfilling of industrial waste are shown in the following ***Table 69***.

Table 3.69: *Trend and projections of methane parameters and emissions from ISW in WAM scenario up to 2050*

Year	Unit	2022*	2025	2030	2035	2040	2045	2050
ISW -> SWDS	kilo tonnes	65.90	66.55	77.18	72.67	69.66	66.13	62.87
CH_4 emissions	Gg	5.18	4.69	4.35	4.10	3.86	3.40	2.97

* Base year 2022; 2022 based on the GHG inventory submission 15. 3. 2024

Wastewater treatment (5.D) – the scenario with existing measures (realistic) or also called BAU = Business as Usual, is based on the expectation that wastewater management developments will continue as observed over the last decade. According to these assumptions, the development of the wastewater sector is characterized by an increase in the share of the population covered by sewerage systems, with the aim of reaching 85% coverage in 2050. This scenario corresponds with the information from the Envirostrategy 2030[55], as well as with the recently adopted document "Concept of water policy of the Slovak Republic until 2030 with a view to 2050"[56]. Similar visions are also declared in the Plan for the Development of Public Sewers for the Slovak Republic[57]. This goal is also indirectly stated in the frequent statements that all agglomerations with population of over 2000 and half of the agglomerations with population of up to 2000 are planned to be part of sewage network, which in total gives the value of about 85% of population connected to sewage system. This development can be characterised by the continuous development of sewerage systems and the modernisation of wastewater treatment plants to meet the requirements of the EU water sector strategies.

The scenario assumes that the number of inhabitants using storage tanks (cesspools) will decrease (from 26% in 2022 to 12% in 2050) due to the expansion of the sewerage network from 71 to 85% and also by increasing the number of domestic wastewater treatment plants from the current 2 to 3%.

The scenario with additional measures (optimistic) is based on the expectation that developments in the wastewater sector will continue with increased financial support from the Slovak government as well as EU support under the Recovery Plan for Europe. This development is characterised by an accelerated increase in the share of the population connected to sewerage systems, with a target of 90% connection in 2050. This scenario corresponds to the aspiration to achieve a level of sewerage connection as high as in the developed Western European countries (at least 90% connection to sewers and wastewater treatment plants).

The scenario assumes that the number of inhabitants using septic tanks will decrease (from 26% in 2022 to 7% in 2050) as a result of the intensive expansion of sewerage from 71 to 90% and the

---

[55] https://www.minzp.sk/files/iep/03_vlastny_material_envirostrategia2030_def.pdf

[56] https://www.minzp.sk/files/sekcia-vod/koncepcia-vodnej-politiky/koncepcia-vodnej-politiky.pdf

[57] https://www.minzp.sk/voda/verejne-vodovody-verejne-kanalizacie/

construction of decentralised domestic wastewater treatment plants from 2 to 3%. This strategy corresponds to the strict requirement of the European Commission, as stated in procedure No 2016/2191, for non-compliance with certain articles of Council Regulation 91/271/EEC of 21 May 1991 concerning urban wastewater treatment. These measures are expected to contribute to a reduction of methane emissions in the municipal sector by almost 70% and in the industrial sector by 76% in 2050 compared to 2005.

3.6.10.5. GHG Emission Projections by Categories and Gases

Methane from category 5.A – waste landfills had until recently an annual upward trend due to changes in the way landfills are operated (controlled anaerobic landfills) and the increasing amount of landfilled waste. It was only after 2010 that the amount of landfilled waste with a non-zero DOC content decreased, which was manifested with a time delay of 8 years (decomposition half-time) by stopping the growth of total methane emissions from landfills. From 2021, there is already a decrease in these emissions.

In order to be able to draw up a projection of emissions, in accordance with the IPCC 2019 methodology for emissions from landfills, we need to know the following variables: demographic development and population, economic growth (GDP) and related waste production (t/y), share of landfilling (%) on overall waste management and the content of biodegradable components in landfilled waste (DOC). Each of these components is more or less independent, and its development for the projected period is conditioned by many external factors, which may be very difficult to decipher and forecast. In addition to GDP growth (and the related growth in waste production), all other factors will probably show a decline in the projected period.

These changes will lead to a decrease in methane emissions from landfills in Slovakia (together expressed as greenhouse gas emissions in CO_2 eq.).

Landfilling is a significant source of methane emissions, which are released as landfill gas. As very few landfills in Slovakia have sophisticated landfill gas capture and recovery systems, landfill gas is released directly into the atmosphere. Methane also escapes from closed landfills, from layers of waste stored for up to about 30 years, so it is very important to prevent landfilling.

Total CH_4 gas emissions from landfills in the WEM scenario reach a reduction of 3% in 2030 compared to 2005 and 22% in 2050 compared to 2005 (***Table 3.71***).

Table 3.70: *Trend and projections of methane emissions from category 5.A - SWDS in WEM scenario up to 2050*

WEM Scenario	UNIT	2005*	2022*	2025	2030	2035	2040	2050
Emissions from MSW	Gg	29.36	37.94	35.26	30.87	28.40	26.45	24.59
Emissions from ISW	Gg	7.11	5.18	4.84	4.49	4.22	3.98	3.81
Emissions ΣCH_4	Gg	36.47	43.11	40.09	35.36	32.62	30.43	28.40

*Base year 2022; 2022 based on the GHG inventory submission 15. 3. 2024

Total CH_4 gas emissions from landfills in the WAM scenario reach a reduction of 9% in 2030 compared to 2005 and 46% in 2050 compared to 2005 (***Table 3.71***).

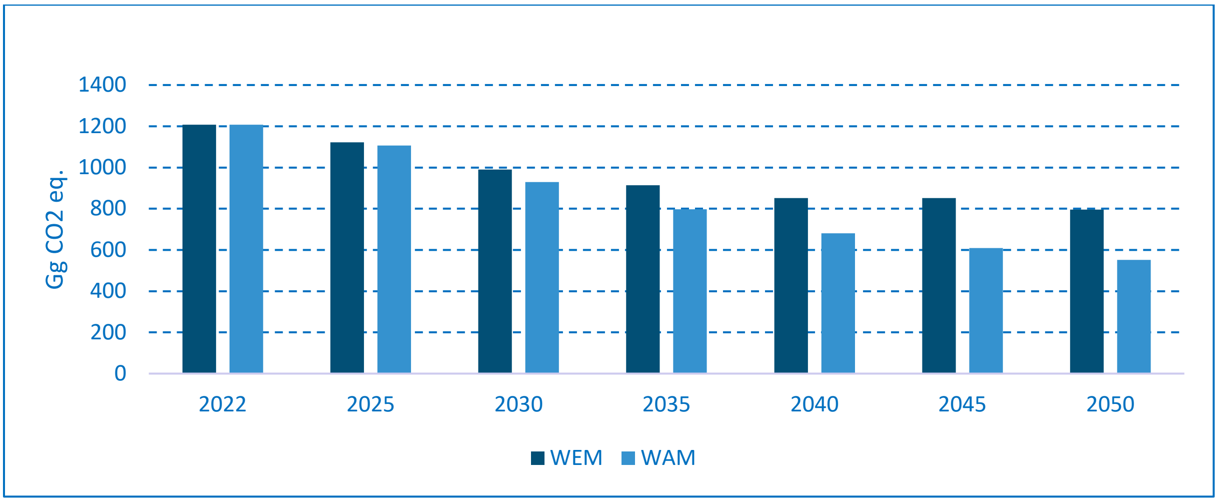
Table 3.71: *Trend and projections of methane emissions from category 5.A - SWDS in WAM scenario up to 2050*

WAM Scenario	UNIT	2005*	2022*	2025	2030	2035	2040	2050
Emissions from MSW	Gg	29.36	37.94	34.81	28.83	24.38	20.43	16.75
Emissions from ISW	Gg	7.11	5.18	4.69	4.35	4.10	3.86	2.97
Emissions ΣCH_4	Gg	36.47	43.11	39.50	33.18	28.47	24.28	19.72

*Base year 2022; 2022 based on the GHG inventory submission 15. 3. 2024

Trends of total GHG emission projections according to WEM and WAM scenarios in category 5.A – Solid waste disposal are provided in ***Figure 3.71***.

Figure 3.71: *Projections of GHG emissions in 5.A - SWDS in WEM and WAM scenarios up to 2050*



Total GHG emissions from 5.B – Biological treatment of solid waste in the WEM = WAM scenario reach an increase of 200% in 2030 compared to 2005 and an increase of 290% in 2050 compared to 2005 (***Figure 3.72***, ***Table 3.72***). Compared to the 1990 base year, they will increase by 232% in 2030 and 332% in 2050.

Figure 3.72: *Trend and projections of GHG emissions in 5.B – Biological treatment of solid waste in WEM = WAM scenario up to 2050*

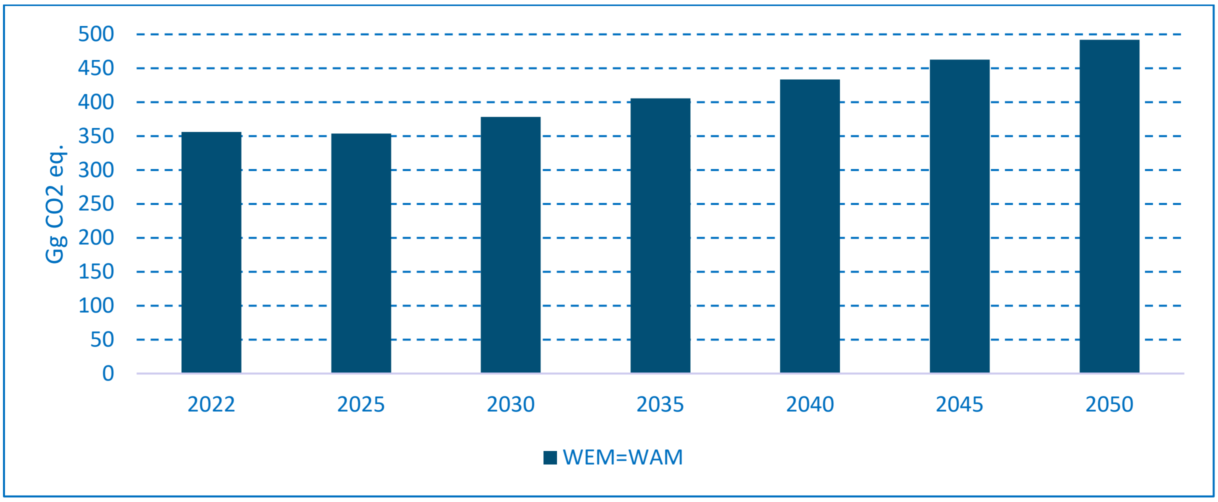


Table 3.72: *GHG emission projections in Gg of CO_2 eq. in 5.B - Biological treatment of solid waste in WEM = WAM scenario up to 2050*

WEM = WAM	2022*	2025	2030	2035	2040	2045	2050
5.B Biological treatment of solid waste	356.31	353.91	378.36	405.48	433.74	462.66	492.02
5.B.1 Composting	322.18	335.97	358.95	381.94	404.92	427.90	450.88
5.B.2 Anaerobic digestion at biogas facilities	34.12	17.94	19.41	23.55	28.82	34.76	41.14

* Base year 2022; 2022 based on the GHG inventory submission 15. 3. 2024

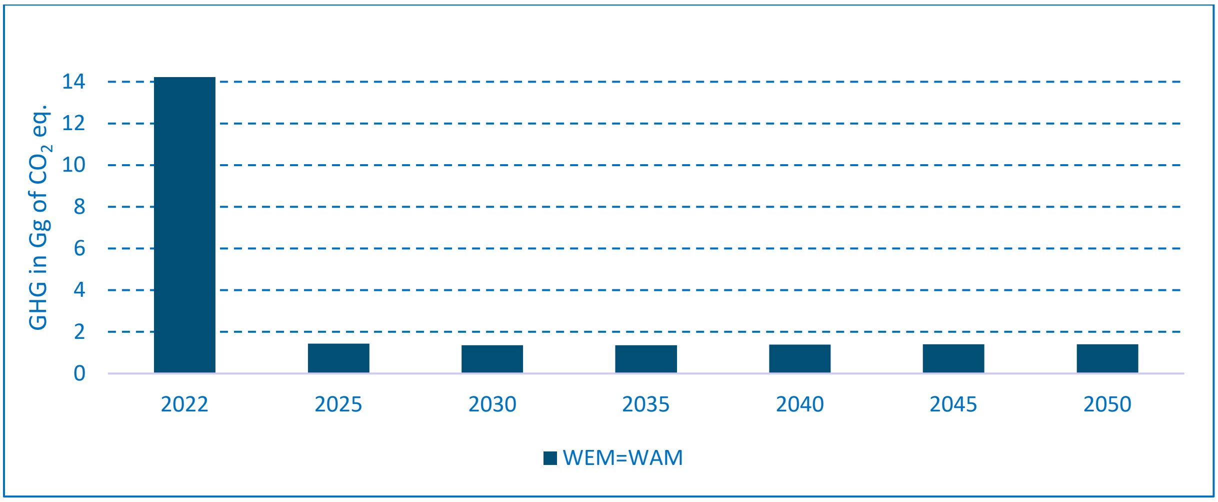
The trends of total GHG emissions from 5.C – Incineration and open burning of waste in the WEM = WAM scenario are provided in ***Figure 3.73*** and ***Table 3.73***.

Table 3.73: *Trend and projections of GHG emissions in 5.C – Incineration and open burning of waste in WEM = WAM scenario up to 2050*

5.C – Incineration and Open Burning of Waste								
5.C	2005*	2022*	2025	2030	2035	2040	2045	2050
	Gg CO_2 eq.							
	52.57	14.22	1.43	1.36	1.36	1.38	1.40	1.40

* Base year 2022; 2022 based on the GHG inventory submission 15. 3. 2024

Figure 3.73: *Trend and projections of GHG emissions in 5.C – Incineration and open burning of waste in WEM = WAM scenario up to 2050*



The most well-known greenhouse gases that arise when handling wastewater are methane (CH_4) and nitrous oxide (N_2O). Methane is mainly produced by the accumulation of wastewater in cesspools and septic tanks, as well as in the anaerobic digestion of sewage sludge in the production of biogas. Nitrous oxide is produced by processes of nitrogen removal from wastewater in nitrification-denitrification processes. Emissions of these gases from wastewater treatment are influenced by demographics, the level of sewerage connections and the way a country's wastewater is handled and treated.

The presented long-term projections of methane emissions from wastewater are based on the gradually increasing number of people connected to public sewerage in the near future and, on the other hand, on the reduction of the share of residents using individual systems, mainly septic tanks and cesspools. This development is implemented within the framework of financing by municipalities or water companies as operators of wastewater treatment plants. Significant aid is provided by the Government of the Slovak Republic through the Envirofond, while this aid has grown significantly especially in recent years (from 10 - 15 million to 40 million per year). Between 2020 and 2023, the Environmental Fund of Slovakia allocated considerable funds for the construction of sewerage and wastewater treatment plants. In 2021 alone, around €11.6 million has been made available through the Cohesion Fund, with a total of €96 million expected for wastewater and water infrastructure projects. These funds were part of a larger Operational Program Environmental Quality (OP KŽP) aimed at solving the urgent infrastructure needs of the country. In addition, under the new funding rounds for 2021 – 2027, almost EUR 160 million will be allocated to such projects.

These changes should lead to a significant decrease in methane emissions and N_2O emissions from wastewater treatment in Slovakia (together expressed as greenhouse gas emissions in CO_2 eq.).

Total emissions from category 5.D Wastewater expressed as CO_2 eq. for the year 2050 show a decrease of 38% in the WEM scenario compared to 2005, compared to 1990 it is even a decrease of 47%. Total greenhouse gas emissions in the WAM scenario will reach a reduction of 28% in 2030 compared to 2005 and 46% in 2050 compared to 2005.

The WEM scenario will reduce municipal water methane emissions (CRF category 5.D.1) by 29% in 2030 compared to 2005 and by approximately 58% in 2050 compared to 2005. Methane emissions from industrial wastewater (CRT category 5.D.2) are currently significantly lower than methane emissions from municipal wastewater, yet we expect further reductions in methane emissions in 2030 of approximately 71% compared to 2005 and in 2050 by approximately 74% compared to 2005. The reduction is expected mainly due to the recycling of wastewater and the reduction of organic pollution production in industrial production. N_2O emissions from households as well as from the industrial wastewater sector are relatively low, but we still expect emissions to decrease by 24% in 2030 and by approximately 24% in 2050 compared to 2005 in the WEM scenario. N_2O emissions have a slightly increasing trend, which is caused by the application of a new methodology (IPCC 2019 Refinement), which also includes the formation of nitrous oxide in the process of nitrogen removal (nitrification-denitrification) in the biological stage of the WWTP.

The WAM will reduce municipal water methane emissions (CRT category 5.D.1) by 45% in 2030 compared to 2005 and by approximately 70% in 2050 compared to 2005. From industrial wastewater (CRF category 5.D.2) we expect further reductions in methane emissions in 2030 of approximately 28% compared to 2005 and in 2050 by approximately 46% compared to 2005.

In the WAM scenario, we expect an increase in N_2O emissions from the municipal as well as the industrial wastewater sector by 54% in 2030 and by about 66% in 2050 compared to 2005. This increase is caused by the already mentioned inclusion of N_2O production in the process of biological nitrogen removal at the WWTP.

The trends according to the WEM and WAM scenarios are provided in the ***Figure 3.74*** and in the ***Table 3.74***.

Figure 3.74: *GHG emission projections in Gg of CO_2 eq. from Wastewater treatment and discharge in WEM and WAM scenarios up to 2050*

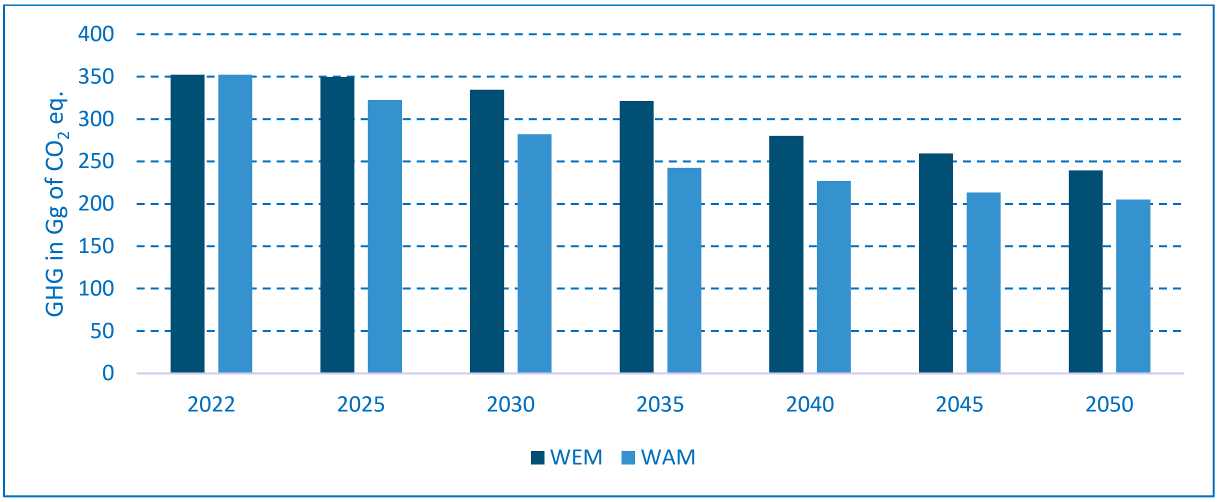


Table 3.74: *GHG emission projections in Gg of CO_2 eq. from Wastewater treatment and discharge in WEM and WAM scenarios up to 2050*

WEM	**2022***	**2025**	**2030**	**2035**	**2040**	**2045**	**2050**
5.D Wastewater	352.31	349.53	334.61	321.17	280.17	259.30	239.42
5.D.1 Municipal wastewater	345.35	342.68	327.84	314.49	273.64	252.86	233.06
5.D.2 Industrial wastewater	6.96	6.85	6.77	6.69	6.52	6.44	6.36
WAM	**2022***	**2025**	**2030**	**2035**	**2040**	**2045**	**2050**
5.D Wastewater	352.31	322.61	282.03	242.30	226.82	213.42	205.11
5.D.1 Municipal wastewater	345.35	315.83	275.41	235.76	220.42	207.14	198.95
5.D.2 Industrial wastewater	6.96	6.78	6.62	6.55	6.39	6.28	6.16

* Base year 2022; 2022 based on the GHG inventory submission 15. 3. 2024

3.6.10.6. Projections of CO_2 Emissions in the Waste Sector

The only source of CO_2 emissions in Waste sector is category 5.C – Incineration and open burning of waste. In 2022 CO_2 emissions accounted only for less than 1% of total GHG emissions in the Waste sector. The trends according to the WEM and WAM scenarios are provided in the ***Figure 3.75*** and in the ***Table 3.75***.

Figure 3.75: *Emission projections of CO_2 in Gg in the Waste sector in WEM and WAM scenarios up to 2050*

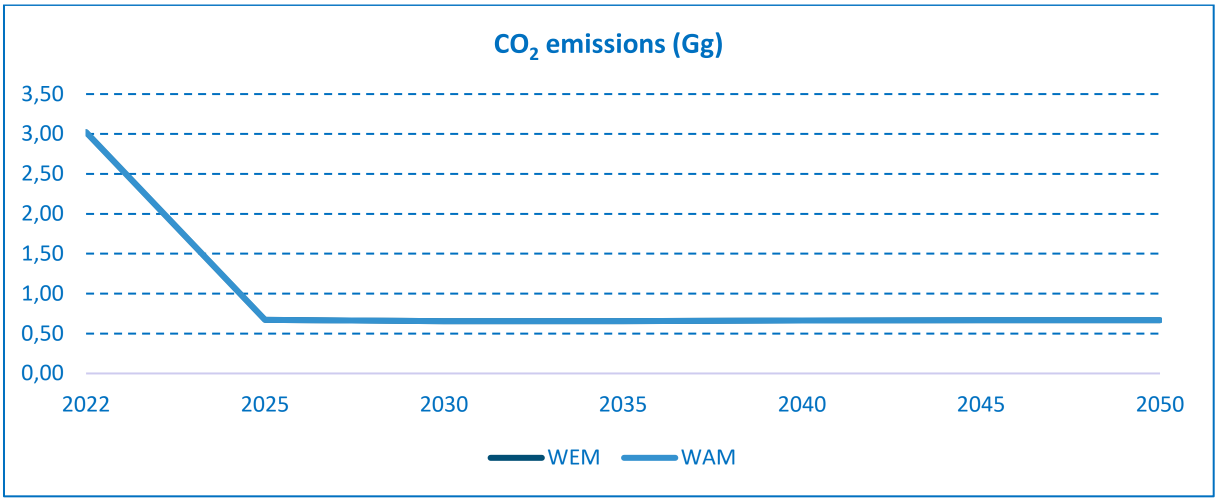


Table 3.75: *Emission projections of CO_2 in Gg in the Waste sector in WEM and WAM scenarios up to 2050*

WEM	**2022***	**2025**	**2030**	**2035**	**2040**	**2045**	**2050**
5. Waste	3.02	3.02	0.67	0.65	0.66	0.66	0.67
C. Incineration and open burning of waste	3.02	3.02	0.67	0.65	0.66	0.66	0.67
WAM	**2022***	**2025**	**2030**	**2035**	**2040**	**2045**	**2050**
5. Waste	3.02	3.02	0.67	0.65	0.66	0.66	0.67
C. Incineration and open burning of waste	3.02	3.02	0.67	0.65	0.66	0.66	0.67

* Base year 2022; 2022 based on the GHG inventory submission 15. 3. 2024

3.6.10.7. Projections of CH_4 Emissions in the Waste Sector

Methane CH_4 is the most important greenhouse gas in the Waste sector accounting for more than 89% of total GHG emissions in 2022. In the WEM scenario, methane emissions will reach 1% decrease in 2030 and 15% decrease in 2050 compared to year 2005. Compared to 1990 emissions will increase by 16% in 2030 and decrease by 1% in 2050. In the WAM scenario, methane emissions will reach 8% decrease in 2030 and 34% decrease in 2050 compared to year 2005. Compared to 1990 emissions will increase by 7% in 2030 and decrease by 23% in 2050. The trends according to the WEM and WAM scenarios are provided in the ***Figure 3.76*** and in the ***Table 3.76***.

Figure 3.76: *Emission projections of CH_4 in Gg in the Waste sector in WEM and WAM scenarios up to 2050*

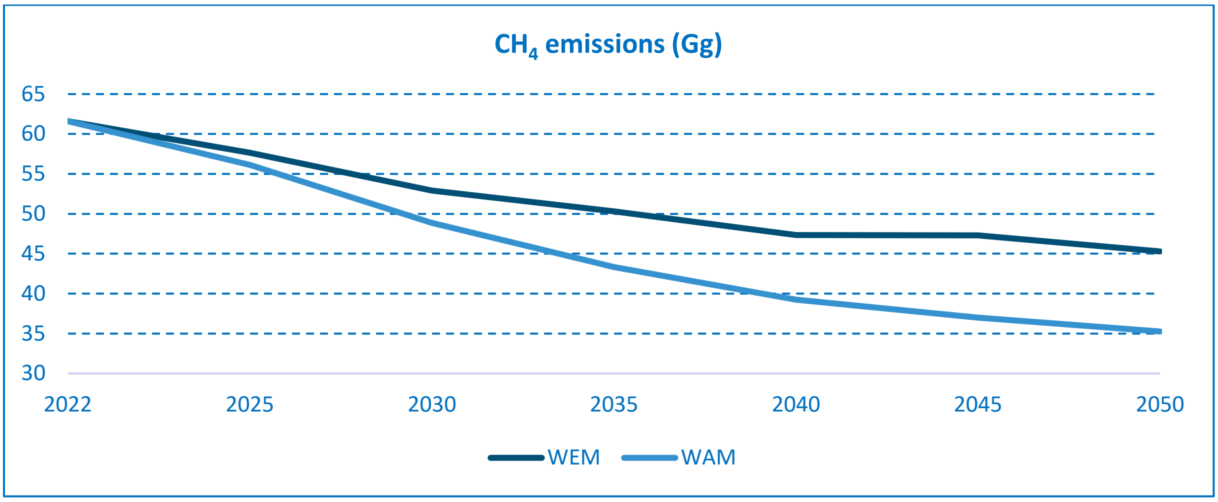


Table 3.76: *Emission projections of CH_4 in Gg in the Waste sector in WEM and WAM scenarios up to 2050*

WEM	**2022***	**2025**	**2030**	**2035**	**2040**	**2045**	**2050**
5. Waste	61.60	57.64	52.92	50.32	47.34	47.28	45.29
A. Solid waste disposal	43.11	40.10	35.36	32.62	30.43	30.40	28.40
B. Biological treatment of solid waste	8.56	8.29	8.87	9.54	10.25	10.99	11.74
C. Incineration and open burning of waste	0.39	0.00	0.00	0.00	0.00	0.00	0.00
D. Wastewater treatment and discharge	9.54	9.24	8.69	8.16	6.66	5.89	5.14
WAM	**2022***	**2025**	**2030**	**2035**	**2040**	**2045**	**2050**
5. Waste	61.60	56.13	48.85	43.34	39.24	36.99	35.26
A. Solid waste disposal	43.11	39.50	33.18	28.48	24.29	21.77	19.72
B. Biological treatment of solid waste	8.56	8.29	8.87	9.54	10.25	10.99	11.74
C. Incineration and open burning of waste	0.39	0.00	0.00	0.00	0.00	0.00	0.00
D. Wastewater treatment and discharge	9.54	8.33	6.80	5.32	4.69	4.23	3.79

* Base year 2022; 2022 based on the GHG inventory submission 15. 3. 2024

3.6.10.8. Projections of N_2O Emissions in the Waste Sector

N_2O emissions in the Waste sector arise mostly from biological treatment of solid waste and wastewater treatment and discharge. The trends according to the WEM and WAM scenarios are provided in the ***Figure 3.77*** and in the ***Table 3.77***.

Figure 3.77: *Emission projections of N_2O in Gg in the Waste sector in WEM and WAM scenarios up to 2050*

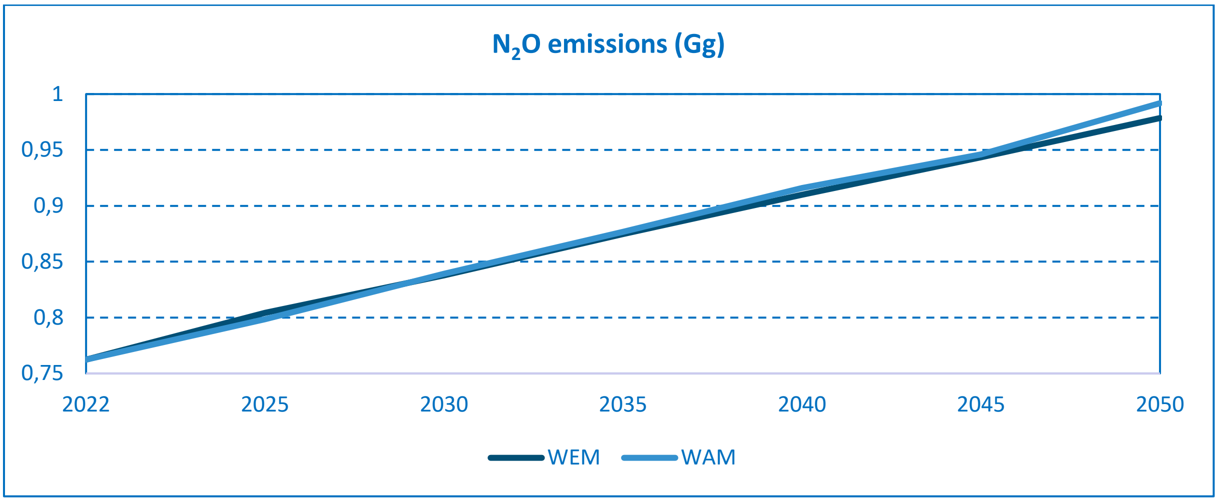


Table 3.77: *Emission projections of N_2O in Gg in the Waste sector in WEM and WAM scenarios up to 2050*

WEM	**2022***	**2025**	**2030**	**2035**	**2040**	**2045**	**2050**
5. Waste	0.76	0.80	0.84	0.87	0.91	0.94	0.98
B. Biological treatment of solid waste	0.44	0.46	0.49	0.52	0.55	0.58	0.62
C. Incineration and open burning of waste	0.00	0.00	0.00	0.00	0.00	0.00	0.00
D. Wastewater treatment and discharge	0.32	0.34	0.34	0.35	0.35	0.36	0.36
WAM	**2022***	**2025**	**2030**	**2035**	**2040**	**2045**	**2050**
5. Waste	0.76	0.80	0.84	0.88	0.92	0.95	0.99
B. Biological treatment of solid waste	0.44	0.46	0.49	0.52	0.55	0.58	0.62
C. Incineration and open burning of waste	0.00	0.00	0.00	0.00	0.00	0.00	0.00
D. Wastewater treatment and discharge	0.32	0.34	0.35	0.35	0.36	0.36	0.37

* Base year 2022; 2022 based on the GHG inventory submission 15. 3. 2024

3.6.11. TOTAL EFFECTS OF IMPLEMENTATION OF POLICIES AND MEASURES

In this chapter are presented the policies and measures used in the WEM and WAM scenarios for individual sectors, along with a quantification of their total mitigation potential on GHG emissions (***Table 3.78*** – ***3.87***).

3.6.11.1. Energy (Excluding Transport)

The development of projected emissions relies on assumptions about macroeconomic trends and sectoral concepts. Recent global political and economic shifts have complicated GHG emission projections, especially given fluctuating macroeconomic forecasts. Long-term emissions are also influenced by energy market dynamics, technological advancements, and CO_2 emissions trading. The Emissions Trading System (ETS), implemented before the base year, will continue to impact future emissions. However, its additional effect is limited by technical and economic constraints. Despite these challenges, achieving emission reduction targets and paving the way for further reductions post-2022 remains possible.

The WEM and WAM scenarios incorporate changes to the fuel mix in existing combined heat and power (CHP) plants, which are the primary heat sources for district heating systems. Some CHP facilities can implement fuel blending, a process that involves co-combusting biomass with natural gas or solid fuels like hard coal and lignite, without requiring significant technological upgrades. This is particularly applicable to facilities equipped with fluid boilers. Both scenarios also involve fuel switching, where a complete shift to a different fuel mix occurs. This change is implemented in CHP facilities that primarily rely on solid fuel combustion, which are typically the largest producers of district heat subject to EU-ETS regulations.

The most significant facilities subject to the Emissions Trading System (ETS) are slated for fuel mix changes in the cities of Košice, Martin, Zvolen, Žilina, and Žiar nad Hronom. Due to geographical variations, biomass availability differs across these locations. In certain cases, particularly in the major cities of Bratislava and Košice, along with other regional centres, complete natural gas phase-out for district heating is currently infeasible due to insufficient biomass supply. Natural gas also serves as a stabilizing agent in combustion processes. Additionally, LULUCF sector measures limit domestic biomass availability in both scenarios, further restricting natural gas reduction potential. Consequently, increased utilization of alternative fuels (TAP) in heat production facilities is anticipated.

However, the current WAM scenario still lacks sufficient technical data for accurate modelling. The subsequent tables illustrate examples of measure selection within the model:

Table 3.78: *Total effect of implementation of PAMs in Energy sector (excluding transport) in WEM scenario*

Sector	**Energy (Transport excluded)**
Measures	Substitution of coal combustion for natural gas and other alternative fuels Substitution of coal combustion for natural gas and biomass Substitution of coal combustion for natural gas and other alternative fuels Energy recovery of biomass by highly efficient production of heat and electricity Construction of a device for cleaning bio-gas from gasifiers and subsequent combustion in a new source with the possibility of gasification of sorted waste (TAP) Decommissioning of the Vojany coal-fired power plant Decommissioning of the Nováky coal-fired power plant Effort Sharing Regulation – Energy savings Change of fuel base in manufacture industries combustion (cement industrial energy production) Improving of energy efficiency in building sector – Effort sharing regulation – Measure include District heating building only.
GAS	GHG emission in kt CO_2 eq.
Scenario	WEM
Mitigation potential (reduction in 2050 compared to 2022)	5 337.11 kt

Table 3.79: *Total effect of implementation of PAMs in Energy sector (excluding transport) in WAM scenario*

Sector	**Energy (Transport excluded)**
Measures	Substitution of coal combustion for natural gas and other alternative fuels Substitution of coal combustion for natural gas and biomass Substitution of coal combustion for natural gas and other alternative fuels Energy recovery of biomass by highly efficient production of heat and electricity Construction of a device for cleaning bio-gas from gasifiers and subsequent combustion in a new source with the possibility of gasification of sorted waste (TAP) Decommissioning of the Vojany coal-fired power plant Decommissioning of the Nováky coal-fired power plant Decarbonisation of lime production in a rotary lime kiln Effort Sharing Regulation – Energy savings Change of fuel base in manufacture industries combustion (cement industrial energy production) Improving of energy efficiency in building sector – Effort sharing regulation – Measure include District heating building only. Reducing CO_2 by phase-out the burning of coal in coal-fired boilers in industrial energy combustion – Steel production The shutdown of coke production by processing coking coal is planned as part of decarbonisation for 2026. Decarbonizing - (Households – Building insulation) Decarbonizing - (Households ESR – Energy savings) Decarbonizing - (Households ESR – NG blending)
GAS	GHG emission in kt CO_2 eq.
Scenario	WAM
Mitigation potential (reduction in 2050 compared to 2022)	12 097.68 kt

3.6.11.3. Energy Sector - Transport

The policies and measures used in the WEM and WAM scenarios in the Energy sector - Transport, along with a quantification of their total mitigation potential on GHG emissions are presented in ***Table 3.80*** and ***Table 3.81***.

Table 3.80: *Total effect of implementation of PAMs in Energy sector - Transport in WEM scenario*

Sector	**Transport**
Measures	Regulation for CO_2 emission standards for new passenger cars & light commercial vehicles Freight Modal Shift Support for the use of low-emission vehicles Promotion of biofuels Setting stricter requirements for regular technical inspections
GAS	GHG emission in kt CO_2 eq.
Scenario	WEM
Mitigation potential (reduction in 2050 compared to 2022)	2 357.73 kt

Table 3.81: Total effect of implementation of PAMs in Energy sector - Transport in WAM scenario

Sector	Transport
Measures	Regulation for CO_2 emission standards for new passenger cars & light commercial vehicles Regulation for CO_2 emission standards for new heavy-duty vehicles Freight Modal Shift Passenger Modal Shift Euro 7: Council adopts new rules on emission limits for cars, vans and trucks Support for the use of low-emission vehicles Promotion of biofuels Low-emission zones in cities Setting stricter requirements for regular technical inspections
GAS	GHG emission in kt CO_2 eq.
Scenario	WAM
Mitigation potential (reduction in 2050 compared to 2022)	5 771.47 kt

3.6.11.4. Industrial Processes (IPPU)

Decarbonising of Mineral Industry

Cement, a ubiquitous building material, is produced from readily available natural resources and has a long-standing tradition of simple application.

The production of cement is associated with significant carbon dioxide emissions, stemming both from the energy consumption of the manufacturing process and the decomposition of carbonate minerals in the raw materials. To quantify the potential for emission reductions, the relative contributions of these two sources can be analysed.

In the case of cement, lime, brick, and ceramic production, CO_2 emissions are directly linked to the chemical decomposition of carbonates. For the production of glass and other non-metallic products, emissions can be reduced through recycling, which also decreases the energy required for the manufacturing process.

One of the most effective strategies for reducing emissions in the cement industry is the use of alternative raw materials. Certain types of industrial waste, such as fly ash, bottom ash from power plants, foundry sands, and construction waste, can replace virgin materials like limestone or clay. Many of these alternatives also contribute to lower CO_2 emissions. For instance, substituting 1.4 tons of blast furnace slag for limestone can reduce CO_2 emissions by 0.44 tons.

In WAM scenario we applied substitution of traditional raw materials (limestone, clay sand) as alternative sources. These are materials with a higher calcium oxide (CaO) content as a potential substitute for limestone; a higher content of Al-Fe-Si oxides as a substitute for the clay; materials containing SiO_2 - substitution of sand. Raw material mixture with the share of alternative materials is characterized by lower energy intensity for firing, at the same time saving natural resources of traditional materials and reducing the production of emissions, including CO_2 emissions, which in the cement industry are the result of thermal decomposition of limestone:

Reducing the consumption of the raw material mixture represents a saving of about 300 000 tons of limestone per year by replacing it with about 700 000 tons of alternative materials.

Decarbonising of Chemical Sector

The trend in the chemical industry is influenced by different segments. Slovakia has a strong tradition in all major segments of the chemical industry, including oil refining, fertilizer production, rubber and plastics production. The product portfolio is also influenced by the strong automotive and electronic sectors in Slovakia, which serve as permanent clients with high capacity for various companies in the field of chemicals and plastics production.

No closure of existing chemical facilities is currently expected or planned. As for the trend in the development of emissions from the chemical industry, it is expected to be relatively constant and a significant decrease is not expected. However, the biggest reduction could occur in this sector as a result of reducing production or fuel consumption by cars and trucks, or by reducing the consumption of artificial fertilizers in agriculture. By transforming the production of fuels from oil to the production of green hydrogen as a fuel using RES, or by the production of more advanced biofuels and bioplastics.

Decarbonising of Metal Industry

Decarbonisation of Steel production falls under the WAM scenario (With Additional Measures). In preparing this scenario, we relied on data from steelwork operator U.S. Steel Košice. It is important to mention that the steelworks have its own decarbonisation scenarios, considering various alternatives. We used the most accessible scenario at that time, which included the basic and most effective measures for reducing emissions not only of GHG (greenhouse gases) but also air pollutants.

The current production flow includes: Coke Plant, Sinter Production, Blast Furnaces, Energy, Hot and Cold Rolling Mills, and other divisional plants where decarbonisation will not be significantly evident. Production flow after decarbonisation: The anticipated year for decarbonisation was planned for 2026. In this scenario, several technological measures were applied, such as:

- shutdown of Coke Batteries (responsible for approximately 16% of GHG emissions),
- Shutdown of Sinter Production (responsible for approximately 7% of GHG emissions),
- Shutdown of two Blast Furnaces (responsible for approximately 30% of GHG emissions).
- Installation of two electric arc furnaces was intended to replace the blast furnaces in the same proportion. Additionally, an endless casting line was planned to.

To maintain production flexibility, one blast furnace and two electric arc furnaces (which can only process scrap metal, not iron ore) were to remain operational. The application of these measures would, of course, lead to changes in the flow of energy carriers and materials. Due to confidentiality, we cannot currently provide specific data.

Currently, the steelwork is one of the largest producers of CO_2 in Slovakia and at the same time the most energy-intensive consumer.

Replacements of two blast furnaces is planned in WAM scenario after 2026 with two electric arc furnaces (EAF) and equipment for endless casting and rolling with a capacity of about 3.5 million tons per year.

The consumption of iron scrap, natural gas and electricity will increase significantly. Average annual electricity consumption will increase from 4.6 PJ to 11.5 PJ. Increase of natural gas consumption is due to shortage of coke oven gas produced in coking battery. And also blast furnace gas and oxygen furnace gas production decrease due to decommissioning of two blast furnaces.

The decrease in CO_2 emissions due to the applied of decarbonisation measures is significant. A decrease of approximately 60% can be expected while maintaining average steel production. With the current conditions of the EU ETS when purchasing EUA, it has dropped from approx. 2.2 mil. tons per year to 0.4 million tons per year.

The transition to electric arc furnaces can significantly contribute to the decarbonisation of steel production in Slovakia, thereby improving the environmental sustainability and competitiveness of this industry. Reduction of GHG in IPPU sector are shown in following tables:

Table 3.82: *Total effect of implementation of PAMs in IPPU sector in WAM scenario*

Sector	**IPPU (Industrial Process and Product Use)**
Measures	Installation of two electric arc furnaces was intended to replace the blast furnaces in the same proportion. Additionally, an endless casting line was planned to. Substitution of traditional raw materials (limestone, clay sand) as alternative sources. These are materials with a higher calcium oxide (CaO) content as a potential substitute for limestone; a higher content of Al-Fe-Si oxides as a substitute for the clay; materials containing SiO_2 - substitution of sand Injection of natural gas into blast furnaces Decommissioning of agglomerate production technology (sinter)
GAS	GHG emission in kt CO_2 eq.
Scenario	WAM
Mitigation potential (reduction in 2050 compared to 2022)	2 462.98 kt

3.6.11.5. Agriculture

The policies and measures used in the WEM and WAM scenarios in the Agriculture sector, along with a quantification of their total mitigation potential on GHG emissions are presented in ***Table 3.83*** and ***Table 3.84***.

Table 3.83: *Total effect of implementation of PAMs in Agriculture sector in WEM scenario*

Sector	**Agriculture**
Measures	Daily removal of manure from animal housing systems Anaerobic digestion Improved beef live weight gains Low protein diet for poultry Sexed semen and cross-breeding Forage quality and management Feed additive: Amino-acids Optimally-balanced ration Storage and covering of manure and slurry Switch to organic fertilisers
GAS	GHG emissions in kt CO_2 eq.
Scenario	WEM
Mitigation potential (reduction in 2050 compared to 2022)	93.33 kt

Table 3.84: *Total effect of implementation of PAMs in Agriculture sector in WAM scenario*

Sector	**Agriculture**
Measures	Improved animal longevity Daily removal of manure from animal housing systems Anaerobic digestion Improved beef live weight gains Low protein diet for poultry Sexed semen and cross-breeding Forage quality and management Low emission housing Zero Emissions Livestock Project (ZELP) cattle wearable technology Feed additive: nitrate Feed additive: Plant bioactive compounds (tannins) Feed additive: adding lipids/fatty acids to diets Feeding practices: Concentrate inclusion in ration Feed additives: 3-Nitrooxypropanol Feed additive: Amino-acids Optimally-balanced ration Improved beef maternal traits Storage and covering of manure and slurry Precision agriculture techniques Use of nitrification inhibitors Use of urease inhibitor Switch to organic fertilisers
GAS	GHG emissions in kt CO_2 eq.
Scenario	WAM
Mitigation potential (reduction in 2050 compared to 2022)	640.07 kt

3.6.11.6. LULUCF

The policies and measures used in the WEM and WAM scenarios in the LULUCF sector, along with a quantification of their total mitigation potential on GHG emissions are presented in ***Table 3.85*** and ***Table 3.86***.

Table 3.85: *Total effect of implementation of PAMs in LULUCF sector in WEM scenario*

Sector	**LULUCF**
Measures	Slovak Rural Development Programme for the period 2023-2027 Afforestation of non-utilised agricultural land
GAS	GHG emissions in kt CO_2 eq.
Scenario	WEM
Mitigation potential (reduction in 2050 compared to 2022)	-4 884.12 kt

Table 3.86: *Total effect of implementation of PAMs in LULUCF sector in WAM scenario*

Sector	**LULUCF**
Measures	Slovak Rural Development Programme for the period 2023 – 2027 Afforestation of non-utilised agricultural land National Forestry Programme of the Slovak Republic 2022 – 2030 Implementation of measures to increase carbon sequestration in agricultural soils Increasing the share of long-life wood products (HWP), including for construction purposes Motivating forest managers to start the process of conversion to nature-friendly forms of forest management Grassland maintenance and restoration Climate Change Adaptation Strategy – Update
GAS	GHG emissions in kt CO_2 eq.
Scenario	WAM
Mitigation potential (reduction in 2050 compared to 2022)	-1 456.13 kt

3.6.11.7. Waste

The policies and measures used in the WEM and WAM scenarios in the Waste sector, along with a quantification of their total mitigation potential on GHG emissions are presented in ***Table 3.87***.

Table 3.87: *Total effect of implementation of PAMs in Waste sector in WEM and WAM scenarios*

Sector	**Waste**
Measures	Act No. 79/2015 on Waste – emphasis on the sorting of packaging and recyclable materials. Change of the funding scheme for separate collection. Waste Management Programme of the Slovak republic for 2021-2025 – diversion of waste from landfill disposal and increase in recycling with improved sorted collection. Concept of Water Policy of the Slovak Republic until 2030 with a view to 2050 Back-up of Disposable Beverage Packaging Financial support for increasing the number of inhabitants connected to public sewerage
GAS	GHG emissions in kt CO_2 eq.
Scenario	WEM
Mitigation potential (reduction in 2050 compared to 2022)	679.22 kt
Scenario	WAM
Mitigation potential (reduction in 2050 compared to 2022)	401.88 kt

3.7. Other information

All relevant information can be found in **Chapters 3.1** to **3.7**, above. Hence, no additional information is provided here.

4. INFORMATION RELATED TO CLIMATE CHANGE IMPACTS AND ADAPTATION UNDER ARTICLE 7 OF THE PARIS AGREEMENT

Impacts of climate change and global warming are also significantly manifested in Slovakia. The observed upward trend in the Earth's surface temperature is the most noticeable manifestation of ongoing climate change, especially since the second half of the 1980s, and in Slovakia especially since the early 1990s.

Slovakia has seen a significant increase in above-normal temperature years since 1991, with 2018 and 2019 being extremely warm. In the period 2001 – 2022, dry, rainfall-free periods have been shown to occur more frequently, which, combined with warmer average climatic conditions, leads to more frequent and more widespread soil drought. A major problem in Central Europe and Slovakia is the significant change in the temporal and spatial distribution of precipitation and snow cover. Precipitation in the warm part of the year occurs more often in the form of intense torrential downpours and in the cold part of the year more often in liquid form. The climate change scenarios described in this report assume comparable increases in monthly and annual temperatures of 1.5 to 4.7 °C in Slovakia. While the temperature scenarios are very similar in all Slovak locations, the precipitation scenarios show some regional differences. Higher increases in annual precipitation totals are expected in the north of the country, with summer decreases in precipitation more significant in the southern lowlands. A comparable increase (decrease) is also projected for daily maximum precipitation totals.

4.1. National Circumstances and Institutional Arrangements

The Slovak Republic fully respects the reports of the Intergovernmental Panel on Climate Change (IPCC) and accepts the international commitments on climate change adaptation as defined in the UN Framework Convention on Climate Change, the Paris Agreement and is also part of the implementation of the new EU Strategy on Adaptation to Climate Change of 24 February 2021.

The Ministry of Environment (hereinafter referred to as the "MŽP SR") worked on a draft law on climate change and low-carbon transformation of the Slovak Republic in 2022 – 2023. The draft law reflects the EU climate goals, the binding nature of climate plans, the obligation to develop strategies and action plans at the regional and local level, and the way adaptation strategies, implementation plans and other adaptation documents are developed at the national level. Work on the law is currently suspended.

The Ministry of Environment of the Slovak Republic in cooperation with SAŽP has implemented a project to create a wider range of methodological guidelines for better implementation of adaptation and mitigation measures. It is a set of 10 methodological guidelines mainly in the areas of planning, data collection and evaluation, risk and vulnerability assessment (available only in Slovak: https://www.klima-adapt.sk/metodicke-usmernenia).

The Slovak Republic defines adaptation to climate change as its priority in the strategic document Envirostrategy 2030. The main instrument for increasing the adaptive capacity of the Slovak Republic is the update of the Strategy for Adaptation of the Slovak Republic to the Adverse Impacts of Climate Change from 2014, called the Strategy for Adaptation of the Slovak Republic to Climate Change - Update (hereinafter referred to as the "NAS"), which was adopted in 2018. The Ministry of Environment of the Slovak Republic has also prepared an Action Plan for the implementation of the Strategy for Adaptation of the Slovak Republic to Climate Change (hereinafter referred to as the "NAP"), which is an implementation document of the NAS.

4.2. Impacts, Risks and Vulnerabilities, as Appropriate

4.2.1. IMPACTS OF CLIMATE CHANGE ON THE AGRICULTURAL SECTOR

Agriculture in the Slovak Republic has undergone fundamental changes over the last 20 years. The structure of crop production has changed through the application of some of the principles of the European Union's Common Agricultural Policy. Climate change is expected to have a major impact on the conditions under which agricultural production takes place. Various indicators give us an indication of the possible consequences that are already being felt and the trend that is continuing.

Agricultural production is mainly influenced by the following climatic factors: increase in average air temperature, change in precipitation and its distribution, increase in CO_2 concentration and the occurrence of weather extremes. Agriculture is very sensitive to climatic fluctuations and weather extremes such as droughts, storms, cloudbursts and floods. Crop production may benefit from a warmer climate, but the occurrence of weather extremes and an increase in their intensity will cause other problems.

The effects of climate change, in particular the occurrence of droughts and more frequent floods, are causing changes in agricultural production in the Slovak Republic. The summer season is getting longer due to the warming trend not only in the south but also in other regions of the Slovak Republic. Higher air temperature accelerates the intensity of physiological processes. The phenological phases change and the crops ripen faster. The changed climate affects not only the regional distribution of cultivated crops (the spread of thermophilic crops to the more northern parts of the Slovak Republic), but also the qualitative characteristics of the soil.

A negative change in the water status of the soil is reflected in the water capacity available for crops. As a result of the increase in soil aridity, there is a significant tendency for the groundwater reserves available for crop use to decrease, and this can be seen most markedly in the light soils. The decrease in soil water is caused by increasing evapotranspiration due to rising temperatures.

Climate change and the global rise in average annual temperatures will also affect livestock welfare. Rising temperatures in stables will also increase CO_2 and NH_3 levels. Similarly, we can expect to see the emergence of parasites and diseases in livestock, which need higher temperatures to exist. We also expect new crop pests to emerge, leading to increased pesticide use and a possible negative impact on bees. The effects of climate change on crop production will also affect food for livestock production. Warmer temperatures, drought periods and changes in rainfall can affect forage crops and the production of natural pastures. Climate change may also contribute to the loss of natural water sources for livestock. The increase in average annual temperature causes the number of summer days to increase and the period of consistently high air temperatures to become longer. Animals are expected to experience temperature stress.

We also expect positive effects of climate change in the northern regions of the Slovak Republic. A warmer climate will bring more favourable conditions for the production of thermophilic forage crops. This could have a positive impact on the economics of livestock farming, with farmers in northern areas no longer having to buy expensive feed and being able to grow it themselves. Increased CO_2 concentration can have an impact on phytomass production. The so-called fertilizing effect of CO_2 causes more intensive photosynthesis and consequently more water consumption in plants. A higher rate of photosynthesis brings an increase in phytomass.

4.2.1.1. Vulnerability Assessment in the Agricultural Sector

Climate change is affecting land cover in the Slovak Republic. There are obviously some regional differences, but in general we can say that winters will be milder and wetter, summers will be warmer and drier, and weather extremes will be more intense. The impacts of climate change on agriculture are related to water. Increased water and soil erosion is expected, as well as deterioration of soil structure, poorer water availability in the soil profile and intensified salinisation and sodification processes.

In dry and windy periods, wind erosion will occur on open ground. Increased water erosion is expected during torrential rains. As a result of more frequent occurrence and increased intensity of torrential rainfall and reduced anti-erosion effect of crop vegetation, the occurrence of gully erosion is also expected. In this respect, shallow soils in mountainous areas in particular are among the soil types at risk.

Climate change also fundamentally affects the direction and rate of accumulation and transformation of soil organic matter. Higher temperatures can affect the decomposition of soil organic matter and the mineralisation process will overwhelm the wetting processes. This can cause soil acidification. This will also affect the deterioration of the physical properties of the soil, such as its structure, and may also lead to soil compaction.

We can also expect a major impact of climate change on the country’s water regime. Higher temperatures and increased evaporation, as well as a gradual increase in groundwater mineralisation, will cause an increased accumulation of salts in the middle and surface layers of the soil. Areas with saline soils are expected to expand.

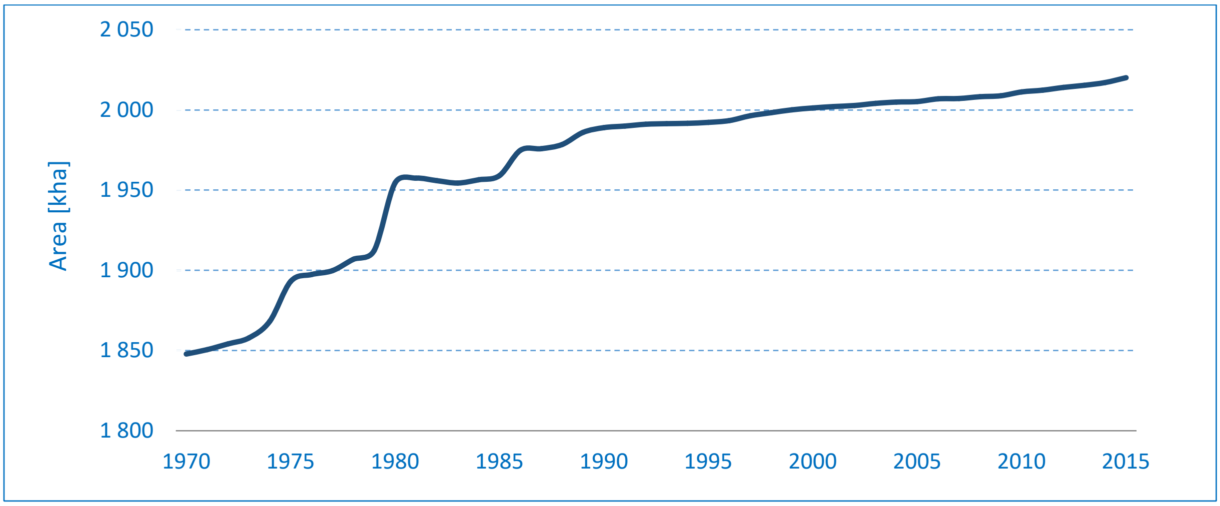
Major impacts can be expected in intensive livestock production, where animals are more sensitive to changes in environmental conditions and less resistant to parasites and diseases. This causes losses in production as well as ill health. This type of production relies heavily on the production of high quality forage. Their availability can be problematic in areas where droughts are more freq.uent. Changes in rainfall will also affect extensive livestock production dependent on natural pastures. In the future, there will be an increased demand for cooling systems in livestock production, which is associated with higher costs and may cause high economic losses on farms.

4.2.2. IMPACTS OF CLIMATE CHANGE ON THE FORESTRY SECTOR

The forested area in the Slovak Republic has increased steadily over the last decades, with an increase of almost 10% over the last 45 years. The species composition of trees has also undergone changes in recent times, which can be considered favourable for the inherent adaptation mechanisms of forests. The proportion of highly sensitive Norway spruce has declined by 2.9% (from 26.3% to 23.4%) over the last decade, the decline was caused by increasing damage from a range of biotic and abiotic factors. At the same time, the proportion of less sensitive broadleaved trees has increased, for example the recent increase in the proportion of beech by up to 2.2%.

Forest stands with higher diversity and better horizontal and vertical structure can be considered more adaptable to climate change. The proportion of single-species coniferous forest stands in the Slovak Republic is considerably lower than in other Central European countries and the composition of tree species is more natural. However, existing forest stands with inappropriate structure are more susceptible to the spread of pests and mechanical damage, especially by wind. The proportion of over-mature forest stands is also quite high and their susceptibility to damage is high.

Figure 4.1: *Development of forest area in the Slovak Republic (kha, ha^3) in the period 1970 – 2015 (based on data from the Geodesy, Cartography and Cadastre Authority of the Slovak Republic)*



In recent decades, forest damage in the Slovak Republic has been steadily increasing, and this increase corresponds to increasing disturbances across Europe. In the Slovak Republic, most of the damage was caused by wind and bark beetle. In particular, the forests were significantly affected by two storms, in 2004 and 2014, as well as by subsequent secondary damage caused by biotic agents. High damage typically occurs especially in regions affected by the continuous retreat of spruce forests, namely in the regions of Kysuce and Orava (north-west of the Slovak Republic), Spiš, the Low Tatras and the High Tatras (centre to east of the Slovak Republic).

The impacts of climate change on forests are direct impacts, which are directly related to changes in air temperature, precipitation distribution, increased CO_2 concentrations or prolonged growing seasons, and indirect impacts, which are mostly manifested by changes in forest disturbance regimes.

Forest productivity is expected to be significantly affected by climate change and such change may have major implications for the quality of ecosystem services provided, including timber production, as well as for forest management.

4.2.2.1. Vulnerability Assessment in the Forestry Sector

We present a simplified vulnerability assessment using natural zonation of forest communities in the Slovak Republic. The zones addressed are:

- low to middle elevations, where deciduous species are predominant and the effects of drought are expected to be most pronounced;
- medium to high altitudes, which contain a high proportion of vulnerable secondary spruce forests and where accelerated forest dynamics can be expected;
- the mountainous area naturally dominated by conifers with protective and other regulating functions, and climate change can be beneficial to forest vegetation.

The assessment presented here takes into account all three components of vulnerability - climate exposure, ecosystem sensitivity and adaptive capacity. The latter component mainly takes into account adaptive capacity related to forest management, although the adaptive mechanisms of species and communities themselves are also taken into account.

The fact that forest communities in low-lying areas of the Slovak Republic are expected to face the highest climatic challenges in terms of increasing water scarcity and increasing frequency and intensity of hot spells increases the overall vulnerability of forests. On the other hand, the tree species and forest communities here show a high degree of heat and drought tolerance, but it is very likely that projected climate change will exceed these limits. The biotic vulnerability of the forests could be considered low, provided that no new pests emerge. In particular, forestry adaptation should include the promotion of drought-tolerant species and forestry interventions that maintain water and nutrient regimes. In the future, the introduction of drought-tolerant tree species with a higher drought tolerance than native species could be considered, but current legislation does not allow such action. The high vulnerability of these ecosystems is mainly determined by exposure to climate impacts and limited opportunities to promote drought tolerance of these ecosystems with new species from other areas. The relative sensitivity on the scale of the Slovak Republic can be considered moderate.

The vulnerability of mid- to high-altitude forests is mainly determined by the altered species composition and the high proportion of secondary stands of Norway spruce, which exhibit high biotic and mechanical vulnerability. It is likely that forests will be increasingly destroyed in the future in response to the physiological weakening of tree defences due to adverse climate and the potential influx of new pests. The adaptive capacity of forest management is likely to be insufficient to adequately cope with increasing damage. Adaptive capacity may also be undermined by a lack of awareness of climate change risks and adaptation options, as well as the persistent spruce-focused orientation of the economy. These facts can hinder timely, prudent and effective action. The relative vulnerability of these forests on the scale of the Slovak Republic can be considered high.

Mountain forests can be expected to benefit from a longer growing season, a shorter period of frozen ground and increased nutrient supply due to accelerated decomposition. It is likely that such processes, in addition to sufficient rainfall, will maintain the vitality of these forests. On the other hand, the increased frequency of storms and the spread of pests from lower elevations can undermine the vitality of these ecosystems. The spread of tree species from lower elevations may pose a risk to biodiversity. As large parts of these forests are unmanaged and provide protective and other regulatory functions, the ability of forest management to adapt these forests is uncertain. The relative vulnerability of these forests can be considered moderate.

4.2.3. IMPACTS OF CLIMATE CHANGE ON THE BIODIVERSITY SECTOR

It is now widely recognised that climate change and biodiversity are linked. Climate change affects biodiversity, with negative consequences for human well-being, but biodiversity also makes an important contribution to climate change mitigation and adaptation through the provision of specific ecosystem services. Therefore, the conservation and sustainable management of biodiversity is critically important in addressing climate change. Natural processes take place in ecosystems that provide benefits for both natural and human activities. The scale and nature of climate change may reach levels where natural adaptation of ecosystems will no longer be possible. The consequences of climate change on natural systems could therefore have far-reaching impacts, namely the loss of biodiversity in terms of species and habitats.

The basic document dealing with biodiversity is the National Strategy for Biodiversity Conservation in Slovakia, approved by the Government of the Slovak Republic in 1996, a new updated version of the National Strategy was approved in 2014.

It is generally assumed that biodiversity will be reduced by a number of factors, mainly as a result of increased intensity of land use and the associated destruction of natural habitats or natural sites. These pressures on biodiversity occur independently of climate change and it is therefore questionable to what extent climate change can enhance or exacerbate biodiversity loss.

All current evidence suggests that, in general, the impact on biodiversity will be negative, due to the increasing effect of global climate change on forest, agricultural and aquatic ecosystems. Vulnerable ecosystems such as pine forests in the mountains, swamp ecosystems in the foothills and mountains as well as aquatic systems are most at risk. Based on the changes in ecosystems that are already recognised and predicted, the following climate change impacts are expected:

- Increasing threats to climate-sensitive species with a narrow ecological niche.
- Changing climatic conditions of specific plant and animal species.
- Potential migration of species.
- Threats to autochthonous fauna and flora from invasive species.

Databases documenting the current status of ecosystems already exist and cover mainly forestry. National inventory and monitoring of Slovak forest were carried out in 2005 – 2006. The second round of inventory and monitoring took place in 2015 – 2016. The third round of inventory and monitoring is expected in 2025 – 2026. This allows us to quantify changes in the biodiversity of forest ecosystems in relation to the number of species, their abundance as well as the recognition of invasive species.

4.2.3.1. Vulnerability Assessment in the Biodiversity Sector

The current global biota has been affected by fluctuating Pleistocene (last 1.8 million years) concentrations of atmospheric carbon dioxide, temperature, and precipitation, has undergone evolutionary changes, and has adopted natural adaptive strategies. However, such climate change took place over a longer period of time, in a landscape that was not as fragmented as it is today, and with little or no additional pressure from human activities. Habitat fragmentation has trapped many species in relatively small areas within their previous range, resulting in lower genetic variation.

The current rate and magnitude of species extinctions exceeds the standard course of evolution. Human activity has already caused losses in biodiversity and could therefore affect ecosystem services crucial to human well-being. The rate and magnitude of climate change caused by greenhouse gas emissions has affected and will continue to affect biodiversity, either directly or in combination with other factors.

4.2.3.2. Links Between Biodiversity and Climate Change

There is strong evidence that climate change is affecting biodiversity. According to the Millennium Ecosystem Assessment, climate change is likely to become one of the most important drivers of biodiversity loss by the end of the century. Climate change is already forcing biodiversity to adapt, either through habitat shifts, changes in life cycles or the evolution of new physical traits. The conservation of natural terrestrial, freshwater and marine ecosystems and the restoration of disturbed ecosystems (including their genetic and species diversity) is fundamental to the overall objectives of both the Convention on Biological Diversity and the UN Framework Convention on Climate Change, as ecosystems play a key role in the global carbon cycle and in adaptation to climate change, while also providing a wide range of ecosystem services essential for human well-being. The Slovak Republic has been a party to the Convention on Biological Diversity and the UN Framework Convention on Climate Change since 1994.

4.2.4. IMPACTS OF CLIMATE CHANGE IN THE PUBLIC HEALTH SECTOR

The public health implications of climate change are influenced primarily by environmental factors, but also by socio-economic developments and the implementation of effective adaptation measures.

The basic document in the field of environmental health within the public health system in the Slovak Republic is the National Environmental and Health Action Plan of the Slovak Republic (NEHAP V). It is a national plan adopted by the Government of the Slovak Republic by Resolution No. 3/2019. The main objective is to implement concrete actions to protect environmental health. One of the areas of focus is climate change and its impact in relation to public health. A national review of the implementation of the activities implemented under this Action Plan is prepared every two years.

Biometeorological conditions can significantly affect human health in specific situations, specifically for people suffering from cardiovascular problems. Long periods with high temperatures are almost critical. Days with maximum temperatures above 30°C are called tropical days and have the potential to adversely affect people. Large cities and urban agglomerations in southern Slovakia are particularly vulnerable to heat waves, due to the heat island effect in these urban zones. Air-conditioned spaces are still not a common feature of private or public buildings, and even rooms in hospitals are rarely air-conditioned.

Climate change is undoubtedly multiplying global human health problems and increasing cases of premature death due to natural phenomena. The type and nature of events depends on conditions in different parts of the world.

The findings of several studies, projects and national surveys on the effects of weather on human health suggest that people will be exposed to severe impacts of climate change in the form of extreme conditions in the next decade. Other forms of health impacts can be seen in worsened malnutrition in regions where people depend on crops and livestock production. Other forms of such effects include changes in the spread of infectious diseases, the spread of diseases caused by polluted water (especially in regions where personal hygiene and sanitation are very low), the spread of respiratory diseases due to air pollution and pollen distribution, etc. The most common impacts of climate change in Europe and their health consequences are described in ***Table 4.1*.**

Table 4.1: *The most common climate change impacts expected in Europe and their health implications*

Phenomenon	**Health impacts**
Floods	Deaths, injuries, infectious diseases
Air temperature fluctuations (extremely high air temperature, very low air temperature) combined with polluted air and higher ground-level ozone	Deteriorating health in people with cardiovascular and respiratory diseases, asthma, premature death, dehydration
Vector for transmission of infectious diseases (mosquitoes, ticks)	Malaria, yellow fever, Lyme disease, encephalitis, West Nile fever
Waterborne diseases	Hepatitis, diarrhoea
UV radiation	Skin diseases
Pollen allergens	Allergic sensitivity, worsening of allergic symptoms, increased number of asthma attacks
Food	Cases of salmonellosis

According to the latest climate scenario in the Slovak Republic, we expect the population to suffer from the direct impacts of climate change, such as higher air temperatures in summer and heat waves at the end of the 21st century. Typical features of a heat wave are extreme air temperatures during the day and relatively high air temperatures at night. The more extremely warm days there are, the more their effects will be felt. The most at risk areas are cities, southern parts of the Slovak Republic and areas with higher concentrations of PM_{10} and $PM_{2.5}$. At times when there is an extremely warm day and at the same time a higher concentration of ground-level ozone, people who suffer from any disease are at least twice as likely to die. According to studies in many European cities, people aged between 75 and 84 are the most at risk. People in this group are usually lonely and do not have the means to ensure a basic standard of living.

Table 4.2: *Consequences of climate change and their impacts on public health predicted for the Slovak Republic at the end of 2100*

Phenomena	**Probability according to projections**	**Impact on human health**
Extreme air temperature, higher frequency of occurrence, length of heat waves	Very probably	Higher heat-related mortality and morbidity, especially among the elderly, chronically ill, very young and lonely
Increased number of warm days/nights	Very probably	General deterioration in health, the most affected will be elderly and lonely individuals aged over 75, children, the mentally and physically handicapped
Periods of high rainfall, torrential rain, thunderstorms, tornadoes, floods	Very probably	Higher risk of death, flood injuries, respiratory diseases, diseases from polluted water (hepatitis) and food (salmonellosis)
Droughts	Probably	Higher risk of infectious diseases caused by water and food
Occurrence of rapid weather changes/fluctuations	Probably	Higher risk of deaths, mental illnesses
Extension of the pollen season	Probably	Asthma, allergies, respiratory diseases
Prevalence of infectious disease transmission vectors	Probably	Malaria, Lyme disease, tick-borne encephalitis, West Nile fever
Higher UV radiation, ground-level ozone and PM_{10} concentrations	Very probably	Higher risk of cancer, deaths from respiratory diseases

4.2.5. IMPACTS OF CLIMATE CHANGE ON WATER MANAGEMENT

Climate models indicate a change in the distribution of atmospheric precipitation on Earth and a change in the frequency and intensity of extreme weather events. It is expected that there will be a much more uneven distribution of precipitation totals throughout the year and in different regions of Slovakia. This will also be reflected in the development of runoff conditions in Slovakia. According to different climate scenarios, a change in the long-term average annual runoff can be expected over most of the territory, with a more pronounced decrease expected especially in the lowland area. In particular, changes in long-term monthly flows are expected, with an increase in winter and spring runoff and a decrease in summer and autumn runoff, especially in the growing season.

These scenarios suggest that prolonged periods of drought in the summer and autumn months, associated with water scarcity, may be an important manifestation of climate change in our area. This phenomenon can occur as a result of a significant loss of snow in winter and its earlier melting in spring, an earlier onset of the growing season and thus a more pronounced evaporation in the spring months, but also as a result of lower precipitation and higher temperatures in the summer period. The result is a significant lack of soil moisture in the second half of summer and early autumn.

Dry periods may be interrupted by several days of high rainfall, or by heavy storm activity with intense precipitation.

Key documents on the integration of the assessment of the impacts of climate change on water bodies include Directive 2000/60/EC of the European Parliament and of the Council establishing a framework for Community action in the field of water policy and Directive 2007/60/EC on the assessment and management of flood risks, with an emphasis on the need to assess and predict water status, including the long-term management of water resources and the provision of flood protection.

The most important hydrological indicator is the average annual flow, which is the main hydrological characteristic of surface streams. The annual flow depends mainly on the amount of precipitation and evaporation, but its annual pattern is altered by several other factors, such as vegetation cover as well as the fraction of water that infiltrates below the surface of the ground and becomes groundwater. The presence of water in springs or streams during the winter and the winter runoff regime influence the retarding effects of the runoff process caused by the rocky and soil environment in individual river basins.

The most important conclusions that can be drawn from the current climate scenarios, and which may consequently have relatively significant impacts on water management, are as follows:

1. increased runoff in the cold half of the year and loss of winter precipitation naturally accumulated in the form of snow;
2. a decrease in soil moisture and a reduction in groundwater runoff during the warm half of the year;
3. Increased surface runoff during the warm half of the year during torrential rainfall (which can lead to increased soil erosion and faster silting of water reservoirs);
4. increase and extension of drought;
5. reduction of usable water resources.

4.2.6. VULNERABILITY ASSESSMENT IN THE WATER MANAGEMENT SECTOR

Based on the analysis of current knowledge and understanding of hydrological conditions of water management in the Slovak Republic, we estimated the level of risk of negative impacts of climate change on the water management sector for selected geomorphological units (***Table 4.3***).

Table 4.3: *Risk of negative impact of climate change on the water management sector for selected geomorphological units*

Region	Geomorphological units	Risk
1	Malé Karpaty (Little Carpathians), Biele Karpaty (White Carpathians), Považský Inovec Mountain Range, Záhorská nížina Lowland, Podunajská nížina (Danubian Lowland), Považské podolie Basin, Podunajská pahorkatina Hills, Pohronský Inovec Mountain Range	*
2	Lučensko-košická zníženina (Lučenec-Košice Depression), Krupinská planina (Krupina Plateau), Javorie Mountains, Matransko-slanská oblasť (Matra-Slanec Area) and adjacent basins	***
3	Východoslovenská nížina (Eastern Slovak Lowland), Vihorlatské vrchy (Vihorlat Mountains)	**
4	Poloniny Mountains, Nízke Beskydy (Low Beskids), Východné Beskydy (Eastern Beskids), Spišská Magura Mountain Range	**
5	Stredné Beskydy (Central Beskids), Západné Beskydy (Western Beskids), Javorníky Mountain Range	**
6	Tatry (Tatra Mountains), Nízke Tatry (Low Tatras), Chočské vrchy Mountains, Malá Fatra-Krivánska Mountains and adjacent basins	*
7	Slovenské Rudohorie (Slovak Ore Mountains), Branisko Mountain Range and adjacent basins	***

Region	Geomorphological units	Risk
8	Veľká Fatra Mountain Range, Malá Fatra-Lúčanská Mountain Range, Kremnické vrchy (Kremnica Mountains), Štiavnické vrchy (Štiavnica Mountains), Starohorské vrchy (Staré Hory Mountains), Poľana Mountain Range and adjacent basins	*
9	Vtáčnik Mountains, Tríbeč Mountains, Strážovské vrchy (Strážov mountains), Žiar Mountain Range	*

Risk of negative impact of climate change: 0 – minimum risk, *medium risk **high risk ***very high risk

Prolonged drought in the summer and autumn months associated with water scarcity may be a major consequence of climate change in the Slovak Republic. These dry periods may be punctuated by brief episodes of torrential rain or heavy storm activity with rain, causing flooding to occur.

Long droughts can cause significant water shortages. Based on current trends, climate change is likely to have a significant negative impact on local water resources with low water volumes, particularly in the southern regions of the Slovak Republic, depending on a wide range of other underlying factors (both natural and anthropogenic). Changes in the hydrological regime show an increased need for redistribution of runoff from areas between the north and south of the Slovak Republic (in other words, between higher and lower altitudes), i.e. redistribution of runoff inter-annually or over the course of the year. It is also important for water supply and electricity generation by exploiting hydropower potential. The measure will cover the decrease in yield from water resources, especially in the lowland parts of central and eastern Slovakia during the summer months.

Changes in precipitation and runoff patterns, and an increase in the number and intensity of extreme hydrometeorological and hydrological events due to climate change can have a major impact on the health and life of the population. In addition to the direct threat to life and health during floods, risks associated with the deterioration of the quality of water resources as well as epidemiological risks are expected to become more frequent. The effects of flooding can cause chemical contamination of water bodies and groundwater sources intended for human consumption. During periods of low water levels, the risk of eutrophication and increased water temperature can affect water quality.

4.2.7. IMPACTS OF CLIMATE CHANGE IN THE ENERGY SECTOR

Temperature change, windy conditions, precipitation, heat or cold waves, storms, drought, floods, snow and ice, as well as landslides.

As a result of warming, a reduction in energy intensity in the winter months can be expected due to a reduction in heating requirements. This will lead to a deterioration in energy efficiency due to oversized district heating systems. At the same time, warming would lead to an increase in energy intensity in the summer months due to an increase in the energy needed for air conditioning and cooling. Cold waves/freezes can episodically lead to increased loads on the heat distribution system. Changing weather events can threaten the generated output of existing wind farms. Flow volume fluctuations on watercourses can have a negative impact on the operation of hydro-power plants. Drought can lead to increased demands for process water within the energy infrastructure. The need to pump water for irrigation will lead to increased demands on electricity generation and distribution capacity. Windstorms, snow loads, floods or landslides can cause equipment failures and damage, power outages, increased repair complications, increased damages caused by power outages to customers.

The same impacts as those identified today are expected to persist in the future.

In the energy sector, potential environmental and operational risks arise from the nature of individual plants, facilities and processes, where the manifestations and consequences of climate change may pose a potential threat to business continuity (and hence continuity of production or energy supply), major industrial accidents or threats to human health and safety.

It is in the general interest of society as a whole to ensure that climate change adaptation measures and mechanisms are taken into account in the preparation of initial plans that represent large and long-term investment projects. In existing plants, they are in fact mainly applied in the context of the expansion of production capacities, the introduction of major technological changes or the renewal of larger technological units.

Adaptation of the energy system is seen as the process of adapting all components of the energy system to actual or expected climate change and its consequences.

4.2.8. IMPACTS OF CLIMATE CHANGE IN THE TOURISM SECTOR

In the Slovak Republic, the tourism sector is determined by the diverse topography and mild climatic conditions of the country. Several types of tourism can be recognised in Slovakia: summer tourism, winter tourism, spa and health tourism, cultural and urban tourism, conference tourism, rural tourism, agritourism, ecotourism or geotourism.

In the near future, according to experts, the vegetation zones are expected to shift towards the poles. Temperatures are expected to rise in winter. The decrease in the number of days with continuous snow cover will be felt by ski resort operators through lower revenues and higher costs for artificial snowmaking. Although on the one hand less energy will be used for heating, on the other hand there will be higher costs for air conditioning in the summer months. Tropical summers will occur more frequently. The years 2011 – 2016, with the exception of 2014, were characterised by heat waves. Lower rainfall is expected in the summer months, which will affect the scarcity of water, which is the most exploited raw material in the tourism sector.

Regional manifestations of climate change will affect both tourist destinations and tourists, as climate and weather conditions are a significant factor in tourists' destination choices. The climate primarily defines the length and quality of the tourist season. The tourism sector is highly dependent on seasonality and climatic conditions change the environmental setting of tourist destinations. Tourists choose the climate that matches their holiday plans. The gradual change in climate is causing a search for other destinations and travel in season.

While tourists can change their behaviour relatively easily, service providers in the tourism sector are less flexible and climate change will have the worst impact on their business. The highly competitive environment in the tourism sector and low margins must also be taken into account. The consequences of climate change require more costs for artificial snow, irrigation and air conditioning. Tourists and tour operators can adapt to climate change more easily than local tourism service providers and local economies dependent on tourism revenues.

Loss of snow cover - A territorial study of climate change in the Slovak Republic suggests that global warming in our area may be reflected in an average increase in air temperature of 2-4°C in 2075. At altitudes below 1 100 metres above sea level, continuous snow cover is unlikely to occur. 76% of the ski resorts in the Slovak Republic are below 1 100 metres above sea level, 16% of them for the most part and only 6% are above this altitude. The construction and operation of ski resorts in most mountain areas is cost and energy intensive due to the need for artificial snow. Experts say a 1.8°C rise in temperature would mean that at an altitude of 1 500 metres above sea level, snow would remain on the ground for a period shorter by about 40 days. With a warming of 1°C, there is a threat of up to a 60 % reduction in natural snow. The period of continuous snow cover will start later, the snow cover on mountain heights will be much lower, which also increases the number of avalanches. In mountain resorts, winter can be shortened by up to three weeks. The cost of operating lifts is rising, especially for smaller companies investing in new technologies, and this could have a negative impact, especially with uncertain forecasts. Snow guns are priced in the hundreds of thousands of euros and have a huge energy and water consumption. Artificial snow melts more slowly and shifts the growing season of the local flora due to its unnatural composition, which enriches the soil differently compared to natural snow, affecting the species composition. Seasonal attractions are becoming increasingly important in mountain areas.

Increased number of tropical days - in 2015, the Slovak Hydrometeorological Institute issued the first temperature warning of the highest degree for the entire territory of the Slovak Republic for several consecutive days. By 2050, the occurrence and duration of heat waves is likely to expand by three days. The number of days with temperatures above 35-40°C is expected to increase in areas with drier conditions and lower vapour cooling. Temperatures above 40°C are not only uncomfortable but can also lead to heart attacks from the heat. Rainfall is expected to decrease in the summer months, which will be reflected in water scarcity.

Vacationers will therefore shift their travel to later or earlier in the year when the heat is not as intense. This is particularly reflected in domestic tourism, which will move to the fringes of the summer season. Overheated buildings require increased electricity and water consumption. Forest fires caused by heat waves can destroy natural attractions and tourist infrastructure.

Increased activity and intensity of rainfall - cities are at risk of flooding during heavy rainfall because the water does not dry out quickly due to impermeable surfaces. Old sewerage systems struggle to accommodate more water, causing damage to transport infrastructure, impairing traffic flow on closed roads and railways, and delaying services. Tourists react sensitively to information about floods. Over the last 10-12 years, extreme daily rainfall events have been on an increasing trend, causing localised flooding in different parts of the country, posing risks to tourist facilities and increasing insurance costs.

Storms - severe weather conditions can be expected to recur and will have a negative impact on tourist safety.

Changes in soil composition - erosion, changes in soil acidity and moisture can, in extreme cases, mean the destruction of archaeological sites and natural resources.

New diseases - warming causes the migration of animals that are not typical of our climate and are likely to spread diseases (e.g. malaria). Increased incidence of infectious diseases, tick-borne diseases and prolonged pollen season should also be expected. Increased numbers of pests that survive milder winters may cause an increase in the price of agricultural production and thus reduce household disposable income.

Threats to biodiversity - a reduction in environmental and aesthetic values automatically means a reduction in interest in a tourist destination.

4.2.8.1. The Impact of Tourism on Climate Change

The tourism sector has a significant impact on climate change. The biggest emitters of greenhouse gases are air transport and accommodation facilities that use heating and air conditioning. Tourists become both agents and victims of climate change. They contribute to climate change during transport to destinations, accommodation, meals, activities, excursions and shopping.

In the Slovak Republic, tourists use cars for transport to holiday destinations, although the intensity of car transport for other purposes (commuting, business trips, shopping, etc.) is much higher. The number of visitors to the Slovak Republic arriving by air is insignificant compared to the total volume of air transport. However, the increasing standard of living and purchasing power of the Slovak population predict an increased use of car and air transport for tourism purposes. The transport of raw materials (e.g. for food preparation) is particularly intensive in areas with limited local resources.

Tourism in general overuses water resources to operate hotels, water parks, swimming pools, golf courses, ski slopes with artificial snow and tourist consumption. The effects of climate change are exacerbated when mismanagement of a destination leads to incorrect location of facilities. Soil and vegetation erosion occur, which greatly reduces plant vigour and changes the composition of the flora in the area.

4.2.8.2. Vulnerability Assessment in the Tourism Sector

The impacts of climate change on the tourism sector could be both negative and positive, depending on the type of tourism.

Positive impacts:

- summer tourism - an increased number of summer days will help to develop summer tourism in areas with a suitable location.

Negative impacts:

- winter tourism - a reduction in the number of days with snow cover will push the boundary of ski resorts to higher altitudes and bring a shorter winter season to resorts at lower altitudes;
- summer tourism in the southern parts of the Slovak Republic - drought may affect summer water sports;
- spa and health tourism - extending the growing and flowering season will reduce the number of days suitable for this type of recreation, which may reduce the number of visitors due to unfavourable conditions;
- cultural and urban tourism - heat waves and extreme weather conditions will affect the climatic comfort of visitors;
- rural tourism and agritourism - this type of tourism indirectly reflects the impact of climate change on crop and livestock production.

4.2.9. IMPACTS OF CLIMATE CHANGE IN THE TRANSPORT SECTOR

The geographical location of the Slovak Republic in Central Europe and its location in relation to most of the major economic centres and ports of Europe means that the Slovak Republic is a crossroads of major transcontinental transport routes:

- the north-south route, which connects the ports on the northern Adriatic coast with St. Petersburg and the Baltic Sea ports;
- west-east route, which connects traditional centres in Western Europe with centres in Russia and Ukraine;
- the connection between north-western Europe and the south-eastern part of the continent (connection between North Sea ports and ports on the Balkan peninsula).

The Slovak Republic is therefore a very important transit territory and its transit role is further strengthened by its peripheral location within the European Union, where it serves as the EU's gateway to the economically interesting part of Eastern Europe (Ukraine and other countries of the former Soviet Union).

Adverse weather phenomena can increase the transport time for goods and people and increase the risk of accidents. Extreme weather phenomena (high and low temperatures, severe storms, heavy snow) can cause serious difficulties in almost all types of transport. A comprehensive analysis of the potential consequences of climate change on various sectors, including the transport sector, has been prepared by the Ecological & Forestry Research Agency and is summarised in ***Table 4.4***.

Table 4.4: *Potential consequences of climate change on transport*

Transport	**Impact of weather**	**Consequences**
Road transport	Extreme weather (storms, floods)	Road closures, detours, damage to road infrastructure
	Adverse weather conditions (rain, snow, black ice, fog)	Reduced safety and traffic flow, traffic congestion
	Adverse weather conditions (rain, snow, black ice, fog)	Increased winter maintenance requirements, damage to road surfaces
Air transport	Extreme weather (storms, floods)	Disruption of airport services, damage to facilities, flight delays
	Adverse weather conditions (rain, snow, black ice, fog)	Flight delays
Railway transport	Extreme weather (storms, floods)	Disruption of traffic, damage to infrastructure
	Adverse winter conditions (frequent snowfall, wind, long winter)	Increased winter maintenance requirements, damage to rails and sidings
Water transport	Extreme weather (storms, floods)	Disruption of traffic, damage to infrastructure
	Frequent snowfall, wind, long winter	Freezing of rivers - disruption of waterways

Under the conditions of the Slovak Republic, the following impacts of climate change on transport are expected:

- the main road routes will be negatively affected in the future, especially in winter (e.g. by snow cover, ice, wind) and in mountain passes at higher altitudes, especially in the central and northern parts of the Slovak Republic (e.g. Donovaly, Čertovica, Besník, Šturec, Cesta Slobody

(Road of Freedom) in the High Tatras - especially their western part from Smokovec to Podbanské);

- in the highest parts of the road corridors near Štrbské pleso and Čertovica we can expect a higher amount of precipitation in winter;
- a decrease in snowfall in the country's lowlands, in the number of days with frost and in the number of days with black ice;
- the variability of climate impacts on road transport will increase - from positive in the lowlands to negative at higher altitudes;
- positive impacts of climate change, such as increases in air temperatures, in the mountains and river basins, will be felt in railway transport. The negative impacts of climate change will occur during heat waves, especially in the lowlands in summer;
- as regards railway transport in relation to precipitation, higher precipitation in winter, in river basins and in the mountains, could have a negative impact;
- inland waterways on the Danube, Morava and Váh runoff will be adversely affected due to low flows in summer and freezing water levels in winter;
- aviation will be more sensitive to extreme weather conditions. Bratislava and Košice airports will be negatively affected by dangerous climatic phenomena in winter (e.g. black ice, snow cover);
- the predicted effects of climate change are not expected to affect underground transport (pipelines);
- the mode of transport most vulnerable to climate change is probably road transport (as it is today);
- the most vulnerable regions of the Slovak Republic in terms of transport are river basins and higher altitudes in the northern, central and eastern parts of the country;
- some shorter sections of roads above 1,200 m above sea level are likely to suffer from higher precipitations in winter and other modes of transport are also likely to be problematic in these sections.

4.2.9.1. Vulnerability Assessment in the Transport Sector

Based on an analysis of current knowledge and information on transport in the Slovak Republic, we have estimated the level of risk for all modes of transport (with road transport being the most affected), including their infrastructure (with road and railway transport being the most affected). ***Table 4.5*** shows the level of risk expressed in four grades in each city region.

Table 4.5: *Risk of climate change impacts on transport in individual city regions*

Transport type	**Higher territorial unit**							
	BA-SK	**TT-SK**	**NR-SK**	**TN-SK**	**BB-SK**	**ZA-SK**	**PO-SK**	**KE-SK**
Road transport	**	*	*	*	**	**	**	**
Railway transport	*	*	*	*	*	**	**	**
Air transport	*	0	0	0	*	0	*	*
Water transport	*	*	*	0	0	0	0	0
Pipeline transport	0	0	0	0	0	0	0	0

Risk of negative impact of climate change on transport, 0 – minimum risk, *medium risk **high risk ***very high risk

4.3. Adaptation Priorities and Barriers

In 2021, the MŽP SR started the implementation phase of the NAP. The NAP distinguishes seven distinct policy domains that are associated with specific principles, objectives, and specific tasks. The six strategic priorities of the NAP are presented in ***Figure 4.2***.

Figure 4.2: *NAP strategic priorities*

1. Support adaptation as a strategic priority in political and legal frameworks, strengthening it in national and sectoral plans and programs
2. Strengthen implementation of adaptation policies and legislation, reducing bureaucratic burdens, enhancing transparency, competencies, and enforcement mechanisms
3. Establish an effective, subsidiarity-based system for adaptation involving relevant stakeholders and the public
4. Develop knowledge, databases, monitoring systems, and research related to data dissemination and information sharing, including systemizing open data
5. Promote climate change education and solutions through education at all levels, raising public awareness about adaptation
6. Promote and develop a multisource financing system for adaptation initiatives

The main barriers to successful adaptation are, funding sources and poor information. Both the Slovakia Programme and the Recovery and Resilience Plan provide us with a framework within which we can implement a spectrum of adaptation measures, but the priority focus is on landscape planning reform and the reform of nature conservation and water management in the countryside

Proper and efficient financing of adaptation measures and tasks is a prerequisite for their implementation and will be guided by the principle of multi-source financing. The key will be the use of the resources of the state budget, municipalities in combination with allocated resources from EU funds, CAP measures and the aforementioned Recovery and Resilience Plan, including their national co-financing.

Achievement of the main objective of adaptation of the NAS and NAP should contribute to the fulfilment of the sub-objectives, which are: ensuring active development of national adaptation policy, implementation of adaptation measures and monitoring of their effectiveness, strengthening the reflection of the objectives and recommendations of the NAS in the framework of multilevel governance and business support, raising public awareness of climate change issues, promoting synergies between adaptation and mitigation measures and the use of the ecosystem approach in the implementation of adaptation measures, and promoting the reflection of the objectives and recommendations of the 2030 Agenda, the Convention and the PA. In these activities, however, we must also not forget the open discussion of all possible solutions and the importance of raising public awareness on the subject. Also, the implementation of the individual NAP targets by 2027 and subsequently the new NAS can contribute substantially to increasing adaptive capacity and reducing climate vulnerability to the adverse impacts of climate change.

Table 4.6: *Analysis summary (Report on the state of play of the climate adaptation policies and governance framework and proposal for a stakeholder engagement plan – as part of the project Revision and update of the national strategy on adaptation to climate change in Cyprus and Slovakia funded by the European Union via the Technical Support Instrument, managed by the European Commission Directorate-General for Structural Reform Support).*

Aspect	Issue/barrier
Policy & Governance Framework	• Lack of a longer-term vision in the NAS, failing to anticipate climate risks and their socio-economic implications up to the year 2050.
	• Lack of structured MRE framework which hinders transparency and accountability in adaptation efforts.
	• Specific gaps in EU climate adaptation policy transposition into SK context, including LULUCF-related regulation.
	• The current NAS (and NAP) is extensive and prescriptive, potentially limiting subnational autonomy and flexibility in developing locally tailored adaptation strategies. • Lack of clarity or direction regarding the requirement or recommendation for sub-national adaptation strategies (current NAP only indirectly mentions it in the form of creating an enabling environment for the creation and implementation of adaptation strategies).
	• Potential duplication and misalignment of efforts due to decentralised source of information for policy documents.
	• Lack of emphasis in NAP on actions related to insurance, risk-sharing instruments, and the establishment or revision of contingency funds for emergencies.
	• Failure to articulate the co-benefits of adaptation measures, including links with climate mitigation.
Knowledge	• Limited data and information leading to gaps in understanding climate vulnerabilities.
	• Inconsistent coverage of actions in NAP targeting knowledge and behavioural change. • In particular, in the forest management sector, interviews underlined the need to bridge knowledge gaps regarding how individual forest species respond to changing environmental conditions.

Aspect	Issue/barrier
Finance	• Insufficient financial estimation for adaptation actions hinders the planning and implementation of adaptation measures due to a lack of clear financial requirements and allocations. • Neglect of actions related to insurance, risk-sharing instruments, and contingency funds.
Stakeholder engagement	• Lack of measures linked to coordination, cooperation, and networks across sectors.
Others	• Lack of specificity in implementation tasks inefficiencies in resource allocation and implementation due to lack of clarity/specificity.

4.4. Adaptation Strategies, Policies, Plans, Goals and Actions to Integrate Adaptation into National Policies and Strategies

4.4.1. STRATEGY FOR ADAPTATION OF THE SLOVAK REPUBLIC TO THE ADVERSE IMPACTS OF CLIMATE CHANGE (2014)

The first more comprehensive document in this area, which sought to link scenarios and possible consequences of climate change with proposals for appropriate proactive adaptation measures in the widest possible range of areas and sectors, was the Strategy for Adaptation of the Slovak Republic to the Adverse Impacts of Climate Change[58], which was approved by Government Resolution of the Slovak Republic No. 148/2014. The strategy considered the following to be priorities: dissemination of information and knowledge on adaptation issues at all levels of governance as well as for the general public; strengthening of the institutional framework for adaptation processes in the Slovak Republic; elaboration and development of methodologies for a comprehensive assessment of climate change risks from the national to the local level; development and application of methodologies for the economic assessment of adaptation measures (macroeconomic impacts); and elaboration and implementation of a tool for the selection of investment priorities on the basis of the assessment of cross-sectoral aspects of adaptation measures.

4.4.2. STRATEGY FOR ADAPTATION OF THE SLOVAK REPUBLIC TO CLIMATE CHANGE - UPDATE (2018)

The Government Resolution of the Slovak Republic No. 148/2014 required the Slovak Government to submit an update of the National Adaptation Strategy to the Slovak Government for discussion, taking into account the latest scientific knowledge in the field of climate change. The Strategy for Adaptation of the Slovak Republic to Climate Change - Update[59] was approved on 17 October 2018 by Government Resolution of the Slovak Republic No. 478/2018.

The main objective of the NAS is to improve the preparedness of Slovakia to face the adverse effects of climate change, to provide the broadest possible information on the current adaptation processes,

---

[58] https://www.minzp.sk/files/oblasti/politika-zmeny-klimy/nas-sr-2014.pdf

[59] https://www.minzp.sk/files/odbor-politiky-zmeny-klimy/strategia-adaptacie-sr-zmenu-klimy-aktualizacia.pdf

and based on their analysis, to establish an institutional framework and coordination mechanism to ensure effective implementation of adaptation measures at all levels and in all areas, as well as to increase the overall awareness of this issue.

To ensure the fulfilment of this main objective, the NAS established six sub-objectives accompanied by framework measures:

1. Active development of national adaptation policy.
    - Assess and update adaptation policy periodically.
    - Enhance institutional framework and coordination mechanisms.
    - Adapt legislative framework to support the adaptation process.
    - Incorporate current science and research findings into policy-making.
2. Effective implementation of adaptation measures.
    - Ensure sustainable funding for priority adaptation measures.
    - Develop indicators for monitoring and evaluating adaptation measures.
3. Mainstreaming adaptation objectives and recommendations.
    - Translate adaptation into sectoral, socioeconomic and territorial policies.
    - Strengthen adaptation at regional and local levels.
    - Increase the resilience of businesses to climate change impacts.
4. Raising public awareness and building knowledge for adaptation.
    - Promote public-private dialogue and awareness, training and education.
    - Establish an official web portal among others for verified information on adaptation.
5. Promoting synergies between adaptation and mitigation measures and using the ecosystem approach where applicable in adaptation measures.
6. Promoting the implementation of international legal instruments.

The NAS's key principles emphasise a proactive adaptation approach aimed at continuously enhancing resilience to climate change. This process begins with preparing the ground for adaptation, followed by an assessment of climate risks and vulnerabilities. Subsequently, adaptation solutions are identified and then implemented, with careful monitoring and evaluation of their effectiveness. Based on the outcomes of this evaluation, adjustments may be made, leading back to the preparation of the adaptation setting. This iterative process ensures that adaptation measures remain relevant and effective in the face of evolving climate challenges.

The NAS key principles encompass several elements. These include prioritising no-regret and win-win measures (mutually beneficial) avoiding maladaptation, ensuring coherence between mitigation and adaptation efforts as well as applying an integrated approach across environmental, economic, and social domains.

The Government Resolution of the Slovak Republic No. 478/2018 imposes the task of submitting an update of the National Adaptation Strategy to the Government of the Slovak Republic for discussion by 31 December 2025, taking into account the latest scientific knowledge in the field of climate change.

4.4.3. ACTION PLAN FOR THE IMPLEMENTATION OF THE STRATEGY FOR ADAPTATION OF THE SLOVAK REPUBLIC TO CLIMATE CHANGE (2021)

The preparation of the Action Plan for the implementation of the Strategy for Adaptation of the Slovak Republic to Climate Change[60] (hereinafter referred to as the "NAP"), which started in 2018, was covered by the Ministry of Environment of the Slovak Republic in cooperation with the Prognostic Institute of the Slovak Academy of Sciences. Based on qualitative and quantitative analyses, adaptation measures were prioritised in the NAP. The prioritisation was based on the results of a participatory process involving all relevant stakeholders. The Action Plan identified short-term targets for the period 2021-2023 and medium-term targets for the period 2024 – 2027. Actions were prioritised according to importance, feasibility and availability of financial resources. The Action Plan should contribute to a better translation of adaptation measures into the sectoral policies of the ministries concerned. It also includes a proposal for a vulnerability monitoring system, a proposal for a system of mid-term evaluation of the adaptation process in the conditions of the Slovak Republic, including tracking the links between costs and benefits, and a proposal for a platform for the publication and sharing of positive experience. The Action Plan was approved on 31 August 2021 by Government Resolution of the Slovak Republic No. 476/2021.

With the overarching goal of enhancing Slovakia's resilience to the detrimental impacts of climate change, the NAP delineates 5 overarching cross-cutting measures:

Strengthening the policy and legislative framework adaptation and effective setting up of financial mechanisms for the implementation of adaptation measures. Tasks under this measure include conducting an assessment report to guide adaptation strategies in alignment with broader development goals, enhancing compliance and enforcement of existing policies, and identifying and addressing legislative barriers to implementing agroforestry land management systems. Additionally, there is a focus on integrating adaptation measures into sectoral policies across ministries and considering the introduction of a "Climate Clause" in legislative rules to address climate change systematically.

Establishing a national Information System for climate data, utilising existing state administration capacities and external funding from EU sources. This entails progressively capturing missing climate adaptation data and updating existing information while developing mechanisms for data collection, management, and communication. Activities include developing climate change scenarios, mapping, and modelling climate impacts.

Effective climate change risk management, underscoring the importance of a functional system, integrating climate knowledge, future scenarios, and security risks. The primary focus areas include floods, landslides, snow calamities, wind storms, fires, and hazards related to substances.

---

[60] https://www.minzp.sk/files/odbor-politiky-zmeny-klimy/akcny-plan-implementaciu-nas.pdf

Establishing a functional framework to support science, education and awareness-raising on adaptation which includes promoting climate change education across all levels of education, integrating adaptation into relevant research supported by domestic grant agencies, and facilitating data and information sharing. Additionally, outputs from science and research efforts will be utilised to educate on adaptation and mitigation measures, fostering professional capacity building within higher education institutions and across all levels of the education system.

Building green infrastructure and green networks, which includes diversifying landscape structures in agricultural, forest, and urban areas to mitigate risks and establish ecological corridors. Legislative protection for designated areas, particularly concerning water retention in settlements, is highlighted under relevant acts.

The scope and focus of the NAP are based on the NAS and build on its contents. Central to the NAP are 7 specific focus areas: water protection, management, and utilization; sustainable agriculture; adaptive forestry; preservation of the natural environment and biodiversity; ensuring health and well-being of populations; enhancing the resilience of the built environment; and implementing technical, economic, and social measures. In order to meet the main objective and strategic priorities, and also to provide a framework for the implementation of the specific objectives for each area, 5 cross-cutting actions will be supported through 18 tasks. In total, 45 specific measures and 169 associated tasks have been identified for the duration of the NAP's validity until 2027.

1. **Specific objective on the protection, management and use of water**: Improve the adaptive capacity of the country to protect, manage and use water through better management of water as a key challenge under climate change, while enhancing public safety, protection of critical infrastructure and the landscape, relying, inter alia, on the reform of landscape planning and the amendment of the Water Act;
2. **Specific objective on sustainable agriculture:** Increase the adaptive capacity of agricultural landscape management by applying measures aimed at protecting soil, natural resources and promoting the biodiversity of agricultural landscapes and encouraging sustainable crop and livestock production;
3. **Specific objective on adapted forest management:** Enhance the adaptive capacity of forests to ongoing climate change through a comprehensive and holistic approach;
4. **Specific objective on the natural environment and biodiversity:** Enhance the adaptive capacity and ecological stability of landscapes through better water management for biodiversity and improved adaptive management of all types of territories, taking into account the dynamics of ecosystem development;
5. **Specific objective on health and healthy population:** Respond proactively and preventively to changing climatic conditions and ensure an adequate healthy environment for living, working, housing and recreation;
6. **Specific objective on the residential environment:** Contribute to the creation of a quality legislative, institutional, professional and financial environment for systematic and comprehensive actions of local governments in the process of adaptation to climate change in the residential environment (in cities and municipalities);

7. **Specific objective on technical, economic and social measures:** Strengthening the understanding of adaptation as an economic and social challenge, involving other affected sectors of the economy and improving the implementation framework for cross-cutting and specific actions;

4.4.4. OVERVIEW OF VARIOUS POLICY DOCUMENTS RELATED TO CLIMATE ADAPTATION IN SLOVAKIA

The New Action Plan for the Environment and Health of the Inhabitants of the Slovak Republic (NEHAP V.) aims to minimise risks from environmental factors that can harm and endanger public health. It underscores the need to bolster efforts in addressing primary environmental determinants impacting both individual and population health, including air and water pollution, inadequate drinking water supply, hazardous chemicals, noise pollution, waste management, contaminated sites, and climate change. The action plan was developed through inter-ministerial collaboration, engaging partners from key government departments. The term for implementation varies with some measures planned to be implemented until 2030.

The most relevant priority for climate change adaption in NEHAP V is Priority (e), which focuses on strengthening adaptive capacity and resilience to climate-related health risks while supporting actions to mitigate climate change in accordance with the Paris Agreement.

The proposed objectives under this priority aim to address the challenges posed by climate change and enhance public health resilience. Firstly, there is an emphasis on systematically preparing for climate change impacts, focusing on reducing vulnerability and increasing adaptive capacity among citizens, health personnel, and public institutions. This also includes raising awareness of climate change. Additionally, the plan aims to strengthen collaboration between environmental and health authorities and provide accurate information on allergenic organic particles through services like the Pollen Information Service to facilitate informed decision-making. Attention is also directed towards reducing the negative trend in vector-borne disease morbidity. The Annex of the NEHAP presents the list of specific activities under each priority objective, including responsible body, deadline, estimated financial impact and source of funds. Activities are listed for priority (e):

1. Monitoring the evolution of vector-borne diseases
2. Monitoring of tick-borne encephalitis agent in ticks captured in selected risk areas in Slovakia
3. Regular tick prevention campaigns
4. Update and approve the national invasive species strategy and subsequently prepare an action plan for the implementation of measures
5. Identify invasive species in Slovakia, ensure their inventory, prioritisation, research and mapping
6. Renew and expand the network of monitoring stations for monitoring the concentration of biological allergenic particles in the outdoor air
7. Develop information transfer tools, intensify public communication, and awareness-raising campaigns on health and climate change

8. Strengthen dialogue between institutions responsible for public health, nature and biodiversity conservation, and emergency management
9. Prioritise areas with invasive non-native allergenic plant species for eradication and control
10. Develop an Information System (IS) for drinking water, swimming pools and bathing water
11. Creation of an information leaflet on the impact of climate change on human health and its distribution to the general public

The National Forestry Program (NFP) of the Slovak Republic serves as a fundamental document for forestry policy, facilitating sustainable forest management. The NFP operates as an inter-ministerial tool for forestry policy, covering planning, implementation, financing, monitoring, and evaluation. NFP also contributes to fulfilling international obligations, such as those outlined in the EU Forest Strategy and other global agreements. It builds on the National Forestry Programme of the Slovak Republic 2022 – 2030.

Under the vision “Forests for Society”, one of the three global goals outlined in the NFP SR 2025 – 2030 focuses on adaptation: Diversified forests better prepared to withstand and mitigate climate change. These objectives will be achieved through strategic and specific objectives (SO), most of which are directly relevant to climate adaptation, in particular, Strategic Objective I:

Strategic objective I: Implement adaptation measures in forests vulnerable to climate change.

SO 1.1: Improve the effectiveness of forest protection measures in the most threatened stands

SO 1.2: Achieve the conversion of 10% ha of forests with inappropriate tree species composition to more resilient mixed forests

SO 1.3: Ensure the conservation of the forest tree gene pool

In addition, SOI II revolves around the introduction of nature-friendly forest management and SOIII targets the utilisation of tree species on non-forest land for landscape adaptation to climate change.

The 2018 Action Plan (H2odnota je voda) aims to prevent drought and mitigate its negative consequences, particularly in light of climate change. It is structured around three main areas: (1) Enhancing monitoring and establishing a warning system to mitigate drought effects; (2) Supporting research, development, and modelling to prioritise water supply during prolonged water scarcity; (3) Implementing measures across various sectors, including agriculture, forestry, water retention in river basins and landscapes, and improvements in the built environment.

The Action Plan is accompanied by a Programme of Measures, categorised into preventive, operational, and crisis measures. The estimated cost of implementing selected measures from 2018 to 2020 is approximately EUR 140 million. Measures included in the Action Plan are planned to be implemented until 2025.

Examples of relevant adaptation measures include reassessing the composition of tree species in forests to enhance resilience to drought and reduce vulnerability to environmental stressors in agriculture and forestry. Another measure involves developing a "Master Plan of Sites for the Accumulation and Retention of Surface Water", which identifies suitable locations based on geological and hydrogeological criteria to mitigate floods and droughts. Additionally, the plan envisages the promotion of research in soil science focusing on soil functions and adaptation to extreme weather events and climate change.

Furthermore, the Action Plan includes measures aimed at capturing and infiltrating rainwater using a combination of nature-based and technical features. Examples cited include the planting of vegetation, installation of vegetated roofs and walls, as well as the implementation of underground retention basins for rainwater utilisation. The plan also underscores the importance of environmental education, public awareness campaigns, and research support.

The Urban Development Policy of the Slovak Republic by 2030 marks the country's approach to urban development matters. Emphasising the imperative for urban authorities to adopt a systematic approach towards climate change adaptation, the document underscores the importance of integrating climate considerations early in urban planning regulations. It stresses the critical need to assess the vulnerability of territories and anticipate potential climate-related risks across all key areas, as a prerequisite for proposing effective adaptation measures at the local level.

Measure 5 of the Urban Development Policy centres on fostering adaptation to climate change's adverse effects and advocating for the integration of adaptation measures into urban planning. The implementation timeline is ongoing, with the Ministry of Environment of the Slovak Republic designated as the responsible authority; additionally, collaboration with the Ministry of Health of the Slovak Republic is emphasised for effective execution.

The core vision of the **Envirostrategy 2030** is to enhance environmental quality and foster sustainable economic practices, emphasising robust protection of natural resources and minimising the use of non-renewable resources and harmful substances. This approach aims to enhance public health while promoting environmental consciousness among citizens and policymakers. Efforts to mitigate and adapt to climate change are integral, with specific focus areas outlined in the strategy.

The Low-Carbon Development Strategy of the Slovak Republic until 2030 with a View to 2050 outlines a long-term roadmap for transitioning to a low-carbon economy, with the ultimate goal of achieving climate neutrality by 2050. The strategy emphasises the need for cost-effective measures to reduce emissions while considering economic and social impacts. It acknowledges that current measures alone will not achieve climate neutrality by 2050 and proposes additional measures to bridge the gap. Implementation will require collaboration across sectors and society, with horizontal implementation overseen by the Council of the Government of the Slovak Republic for the European Green Deal and Low-Carbon Transformation.

Slovakia's draft updated National Energy and Climate Plan ('the draft updated NECP') was submitted on 23 August 2023. Among others, key targets in the draft updated NECP for 2030 include a reduction of 22.7% in greenhouse gas (GHG) emissions for non-ETS sectors and a 23% incorporation of renewable energy sources in final energy consumption. It also establishes a target of national contribution in energy efficiency at 30.3% and a national electricity interconnection of at least 15%. Furthermore, alongside these, the draft updated NECP emphasises implementing measures to enhance the security of energy supply and ensure affordability.

The draft updated NECP explicitly references the 2018 NAS and the NAP and emphasises their prioritisation for adaptation actions. It does not outline additional adaptation policies or measures.

Slovakia's Recovery and Resilience Plan (RRP), approved by the Council in July 2021 and updated in July 2023, encompasses reforms and investments aligning with REPowerEU objectives. Valued at €6.408 billion and entirely financed by RRF grants, it comprises 64 investment streams and 70 reforms. Notably, 46% of the plan focuses on climate objectives, with 21% targeting the digital transition. The plan addresses key challenges related to the green transition, emphasising renewable energy, energy efficiency, transport, industry decarbonisation, and climate adaptation. The climate adaptation measures, which amount to almost €150 million, encompass a combination of investments and reforms in nature protection, water management, and landscape planning. Their overarching goals are to conserve biodiversity and foster a sustainable local economy. As part of these efforts, approximately 90 kilometres of watercourses will undergo renaturation processes. All measures must be implemented within a strict time frame, as mandated by the Regulation which stipulates that all milestones and targets must be achieved by August 2026.

Component 5 of the RRP focuses on adaptation measures, specifically addressing climate change. This component includes two reforms and one investment:

Reform 1: Landscape Planning Reform This reform aims to establish a framework for protecting landscape structures, ecological stability, and biodiversity within spatial planning documentation and subsequent approval processes for building permits and activities. Methodological documents and map documents will be developed to serve as a professional basis for spatial planning, ensuring the preservation of landscape structures and biodiversity.

Reform 2: Entry into Force of Amended Nature and Landscape Protection Act and Water Legislation This reform targets the enhancement of habitats in protected areas to bolster their long-term contribution to landscape protection and resilience against climate change. Amendments to the Nature and Landscape Conservation Act and water legislation will strengthen institutional nature protection, streamline protected area management, and integrate national parks. The reformed legislation will prioritise nature and biodiversity conservation.

Investment 1: Adaptation of regions to climate change with an emphasis on nature conservation and biodiversity development. For investment 1, three distinct components are essential to support climate change adaptation: revitalisation of watercourses, property settlements with non-state owners of land in protected areas, and development projects in the Poloniny and Muránska planina. Due to the thematic complexity of these components, several departments within the Ministry of E (MŽP SR) are involved. The estimated contribution is EUR 35 million.

The Water Plan of Slovakia, aligned with the EU Water Framework Directive, addresses national-level water management. A dedicated chapter focuses on climate change adaptation, evaluating its impacts on surface water and groundwater quantity and quality. Approved by the government of the Slovak Republic on May 11, 2022, this plan includes specific measures for the Danube and Vistula river basins.

The Water Policy Concept aims to translate the commitments and objectives of water protection and management into actionable strategies. It intends to facilitate the continued implementation of the Water Framework Directive through river basin management plans and the Water Plan of Slovakia. The development of the Water Policy Concept was a collaborative effort undertaken from 2020 to 2021, involving key experts from various sectors. A Working Group was established to oversee the development process. The implementation of the concept will be evaluated in the second third of the implementation of the concept (2027) and at the end of the validity of the concept (2030) when the update of the concept of water policy of Slovakia is planned to be elaborated.

The implementation of the Water Policy Concept adheres to a set of guiding principles, one of which is Adapting to climate change. In line with this, it delineates several specific objectives and corresponding measures aimed at bolstering Slovakia's capacity to adapt to climate change. These objectives include:

Objective 1.1: A country capable of retaining water and mitigating the effects of climate change, which involves implementing integrated landscape management practices at the sub-basin level, where adherence to principles of sustainable water management becomes legally obligatory. It also entails supporting measures aimed at slowing down water runoff and retaining it in the cultural landscape in line with the 2018 NAS. It prioritises nature-based water retention measures.

Objective 2.1: A new approach to stormwater management in urban areas, which involves clarifying and differentiating the permitting process for simple water conservation and adaptation measures, particularly concerning their location within urban settings.

Objective 2.3: Protection of property, health, and lives against floods in agglomerations, which includes implementing new modifications of watercourses in urban areas, accompanied by revitalisation and adaptation efforts. This includes the installation of migration barriers on watercourses for fish and aquatic animals, measures to preserve aquatic habitats during periods of low water flow, and the enhancement of public spaces around rivers.

Objective 6.1: Systematic restoration of watercourses, including riparian wetlands, and mitigation of adverse impacts of water use, which includes the development and implementation of revitalisation projects aimed at restoring the original character of watercourses and retaining water in the landscape. Among others, this seeks to improve adaptation to the negative effects of climate change.

Objectives 10.5 Finance adaptation measures to increase water sector resilience which includes promoting measures that maintain ecosystem services even amidst changing climate conditions, without increasing operational costs, and establishing financial mechanisms and legislative frameworks to support adaptation activities in water and landscape management, encouraging private sector involvement.

4.5. Progress on Implementation of Adaptation

At the core of the NAP are 7 specific areas: water protection, management and use, sustainable agriculture, adapted forestry, natural environment and biodiversity, health and healthy populations, the built environment, and technical, economic and social measures. Progress on priorities by area has been made as follows:

1. *In the field of water protection, management and use*

Resolution of the Government of the Slovak Republic No. 372/2022 approved the Water Policy Concept until 2030 with a view to 2050. Resolution of the Government of the Slovak Republic No. 319/2022 approved the document Water Plan of Slovakia for the years 2022 – 2027.

2. In the field of sustainable agriculture

Resolution of the Government of the Slovak Republic No. 94/2022 approved the Strategic Plan of the Common Agricultural Policy for 2023 – 2027 (CAP). It is the basic programming document of the EU's Common Agricultural Policy to support the sustainable development of agriculture, food, forestry and rural areas.

3. In the field of adapted forest management

Resolution of the Government of the Slovak Republic No. 143/2024 approved the National Forestry Programme for 2025 – 2030 „Forests for Society“.

4. In the field of natural environment and biodiversity

Currently, the Ministry of Environment of the Slovak Republic is working on the update of the Biodiversity Conservation Strategy 2030.

Update of the Slovak Wetland Care Programme until 2024 and the Wetland Action Plan for 2019 – 2021: The Slovak Wetlands Management Programme is the basic strategic document for the implementation of the Ramsar Convention obligations and is primarily based on the Ramsar Strategic Plan.

5. In the area of health and healthy populations

Government Resolution No. 3/2019 of 9 January 2019 approved the National Environment and Human Health Action Plan V (NEHAP V). The primary objective of NEHAP V is to minimize risks from the environment that may harm and endanger human health through the proposed activities of each priority area, which includes climate change. NEHAP VI is currently under development.

6. In the field of the built environment

The new Act No. 200/2022 Coll. on spatial planning, as amended, remembers the protected interests of the state in the process of creating spatial planning documentation. A new feature is that the landscape plan, the flood risk map or the principles of protection of conservation areas will also become binding for the creation of spatial plans.

7. In the field of technical, economic and social measures

The importance of the insurance sector's role in protecting against climate and environmental risks is underlined by the new EU Climate Change Adaptation Strategy, which also implies the need to involve the insurance sector in the collection of data on climate change claims. This issue was reflected in the NAP and in 2022 the first discussions of the Ministry of the Environment of the Slovak Republic with the Slovak Association of Insurance Companies and the National Bank of Slovakia started.

The issue of adaptation to climate change is part of several strategic documents adopted in the Slovak Republic. Adaptation measures are also becoming part of the implementation documents of other ministries and organisations. In the context of climate change adaptation, projects that increase adaptive capacity are supported through various financial mechanisms.

At present, the Slovak Republic lacks an information system that would comprehensively assess how measures and implemented projects contribute to increasing adaptive capacity. Progress in this area should be brought by the implementation of methodological procedures for obtaining, collecting and evaluating data and information in the field of climate change adaptation for the purpose of fulfilling reporting obligations at the national and European level, which will propose a mechanism for cooperation between the relevant responsible ministries, a proposal for the creation of a functional network of cooperating institutions and the professional strengthening of the provision of information support. Setting up cooperation with local authorities in order to systematically obtain information on activities implemented at the local government level (level of policies, plans, implementation of specific measures). The new web platform for adaptation to climate change Klima-adapt https://www.klima-adapt.sk/ has established by Slovak environmental agency in 2024 and is still being worked on.

The SHMÚ project "Development of comprehensive (2030/2050) climate change scenarios with a focus on the vulnerability of selected sectors in relation to adaptation measures" aims to improve the linkage of climate change scenarios with the development of policies and strategies in selected sectors at the national to local level, and also to provide a basis for future risk management. Scenario analysis within the project will focus on scenarios that integrate climate change into the broader context of environmental change. Climate resilient development pathways will then generalise the concept of adaptation processes and focus on future development models that make societies more resilient to climate change.

However, there is no comprehensive and up-to-date assessment of vulnerability and risks due to climate change in the territory of the Slovak Republic. Building on the SHMÚ project and in the context of the preparation of the new NAS, the MŽP SR will also focus on climate change vulnerability and risk assessment as part of the TSI "flagship" project on climate change adaptation, which provides the basis for planning, implementation, monitoring and evaluation of climate change adaptation.

4.6. Monitoring and Evaluation of Adaptation Actions and Processes

The main responsibility for the implementation, monitoring and reporting on the Strategy for Adaptation of the Slovak Republic to Climate Change - Update and its implementation tool - the National Action Plan lies with the Ministry of Environment of the Slovak Republic, which has a coordinating function within the inter-ministerial and cross-cutting tasks. Inter-ministerial coordination at the highest level was through the Commission for Climate Change Policy Coordination at the level of Secretaries of State. Operational coordination of implementation is carried out through the Adaptation Working Group, whose members are nominated representatives of individual ministries and other central government bodies, other general government organisations, academia, NGOs, or other interested groups. After the approval of the NAP by the Government of the Slovak Republic, a joint coordination, monitoring and evaluation mechanism was prepared, which is an operational document of the Adaptation Working Group and will serve for the ongoing coordination of the work of the group in the implementation of the NAP. At the level of individual sectors, it is recommended that the responsible ministries incorporate the individual NAP tasks in which they will participate into their planning documents, including financial support, at the level of ministries and their organisations, and in the case of other general government organisations, into their planning procedures. It is advisable to prepare stacks of projects (which will be the elaboration of individual tasks in the form of projects) and applications for non-repayable financial contribution. Based on the monitoring of the indicators of individual areas and tasks, the Adaptation Working Group will continuously assess the risks to the implementation of the NAP and propose procedures to eliminate these risks. The Adaptation Working Group will also be regularly informed on the monitored NAP implementation indicators and will contribute to the preparation of the next National Adaptation Strategy and NAP.

Monitoring and analysis of the state of adaptation of the Slovak Republic to climate change will follow 2 main objectives. First and foremost, it is an assessment of the effectiveness of the NAP and the results achieved, which will also serve as a basis for further actions and policies beyond the period of validity of the plan. At the same time, Slovakia's membership in the EU implies strict reporting obligations, monitoring and evaluation of the NAP implementation status, which will also serve for the preparation of evaluation reports. The Action Plan is prepared for the period up to 2027. The expected outcome is an improvement in the horizontal approach to adaptation (cross-cutting priorities) and in each of the seven strategic priorities. The fulfilment of the specific objectives of all identified 5 cross-cutting, 45 specific measures and 169 tasks within them will be subsequently evaluated. Cross-ministerial coordination and cooperation between all stakeholders will be key to achieving the objectives of the NAP. The inter-ministerial working group of the Ministry of Environment of the Slovak Republic for adaptation to climate change at the expert level will ensure coordination in the implementation of the plan and will also serve for the needs of monitoring and evaluation. The Council of the Government of the Slovak Republic for the European Green Deal will also participate in the inter-ministerial coordination as appropriate. Cross-ministerial coordination will work towards integrating climate change into sectoral policies. This means strengthening the policy and legal framework for adaptation and incorporating adaptation themes and approaches into existing national and sectoral plans and programmes. An important fact of implementation will therefore be the need for clear coordination and leadership of the process, whereby all sectors and stakeholders need to be motivated to participate in the implementation of the identified actions and tasks.

The central government, as the coordinator of the overall implementation environment and the main source of funding, is crucial for the successful implementation of the NAP. A major part of the measures and future steps will take place in the residential environment. On the one hand, the local government is the implementer and guarantor of the measures, on the other hand, it needs political, legislative and financial support from the Government of the Slovak Republic for successful implementation. Other stakeholders that have and will have an impact on the achievement of the NAP objectives are the business sector, the academic sector, education, NGOs and the media. The task for all the concerned coordinators in fulfilling the tasks will be to ensure a detailed assessment of the submitted proposals in order to include (proposed) support schemes to compensate for their negative impacts on vulnerable population groups, if such impacts are identified. This may mean submitting proposals for measures, proposals for new policies or changes to them to meet the tasks and objectives of the proposed material that will have a more substantial negative impact on the economy of vulnerable households, or measures that, because of the high investment required, will be inaccessible to vulnerable groups and therefore will not have a positive impact on their quality of life. In line with EU requirements, the Ministry of Environment of the Slovak Republic will assess the overall situation in the field of adaptation at regular intervals based on the defined framework and the evaluation of the effectiveness and sustainability of the adaptation approach. For the NAP assessment, this means an aggregated assessment based on three criteria:

- How have the adopted and implemented measures and tasks increased the resilience of the Slovak Republic and reduced the adverse impacts of climate change?
- How effective were the measures and tasks adopted and implemented?
- In which areas are the measures and tasks adopted and implemented proving insufficient to avert adverse impacts?

Adaptation of the Slovak Republic to climate change is a challenging and long-term process. The main focus of monitoring and evaluation will be at the level of strategic priorities, specific objectives and tasks. Each task is assigned an indicator(s) that will be evaluated on an ongoing basis. At the same time, on the basis of the evaluation of these indicators and on the basis of the assessment of the state in the field, a qualitative assessment will be made of the situation in the implementation of the strategic priorities and specific objectives. Based on the indicators and the results of the assessment, the situation will be evaluated in the context of trends in adaptation.

The following approach is chosen to quantify the proposed indicators: In the case of identifiers assigned to measures or tasks, which in adaptation terminology are called “soft approaches” (methodologies, information systems, information and awareness-raising activities, development of analysis, development of a documented procedure, etc.), it is appropriate to choose a binary classification, i.e. in case the baseline value of the indicator is 0 and the target value is 1 when a given “soft approach” has been implemented (methodology developed, information and awareness-raising activity implemented, information system put into operation, analysis carried out, documented procedure developed, etc.). In the case of identifiers assigned to other measures or tasks, e.g. related to elements of grey, blue or green infrastructure, the task coordinator shall propose a specific solution of the measure or task (a specific project) to meet the cost-effectiveness criteria and on the basis of the precisely defined substantive content of the project, its cost quantification and the specified time horizon of the solution they shall determine the baseline and target value of the indicator. In so doing, they will also take into account whether data relevant to the value of the indicator can be collected efficiently, as data collection should not be more costly than the value of the information it provides. On the one hand, there is a requirement for a transparent and straightforward methodology for calculating the indicator value, but on the other hand, objectively, there are a number of other influences, mainly related to the fact that it is not always possible to collect hard data and measurements. In this case, the use of indicator values in the form of linguistic variables or a Likert scale may be considered if possible or appropriate.

The National Action Plan is conceived as a document that focuses more on guiding the activities and investments towards the objectives increasing the adaptive capacity of the Slovak Republic and reducing the risks arising from climate change. The quantification of some outputs thus faces a high degree of uncertainty, which is related to the fact that it is not possible to decide or specify within the NAP how many investments and how targeted in adaptation will be supported by EU and SP CAP funds, which are key for the implementation of adaptation measures as sources of funding. The NAP thus provides a framework (as was the case with the Recovery and Resilience Plan) for targeting investments, where it is already possible to operate with quantifiable values linked to specific resource allocations.

At the task level, the achievement/non-achievement of the indicators will be assessed. These, together with an analysis of sector-specific contextual indicators, will then provide data for assessing the situation over time:

- Has there been an improvement or deterioration in the policy/legislative framework for adaptation and in the financial mechanisms for the implementation of adaptation measures?
- Is the situation with regard to an effective information system for the provision of climate information better than it was before the start of NAP implementation?
- Does the Slovak Republic improve the crisis management system at all levels of governance?
- Has there been improvement in support for science, education and awareness development on adaptation issues?
- Is the situation improving or worsening with regard to the specific objectives of water conservation, management and use, sustainable agriculture, forestry, natural environment and biodiversity, health and healthy population?
- Is the current state of implementation of technical, economic and social measures better or worse?

For the first time, the coordinators of the individual measures or tasks will also evaluate the quantitative implementation of these measures and tasks using the relevant indicators by 31 December 2022, and every two years thereafter by 31 December of the respective year, with the understanding that the Ministry of Environment has used and will continue to use these evaluations in the preparation and reporting to the EC on national adaptation measures pursuant to Article 19(1) of Regulation (EU) 2018/1999 of the European Parliament and of the Council of 11 December 2018 on the Governance of the Energy Union and Climate Action (according to the wording of the regulation for the first time by 15 March 2021 and every two years thereafter). In accordance with this requirement, the Ministry of Environment of the Slovak Republic prepared a Report for the European Commission as of 15 March 2021, which was subsequently resubmitted in May 2021, using the Reportnet 3 tool prepared by the European Environment Agency (the report in English, including annexes, is available at the following address: https://reportnet.europa.eu/public/country/SK).

The coordinators will also monitor the effectiveness and efficiency of the measures implemented, with the possible development of relevant recommendations for practice. An important part of the evaluation will also be to assess the extent to which the public has been involved in the implementation process, the “co-ownership” of the topic by different stakeholders and the sustainability of the approaches at national and local government level.

Responsibility for individual measures and tasks in the NAP is directly determined in accordance with Act 575/2001 Coll. on the organisation of the activities of the Government of the Slovak Republic and the organisation of the central government of the Slovak Republic and also establishes the relevant timetable.

Information on the progress made in meeting the short-term objectives of the NAP was submitted to the Government of the Slovak Republic in 21 June 2024, as stipulated in Government Resolution of the Slovak Republic No. 476/2021.

The Report on the state of play of the climate adaptation policies and governance framework and proposal for a stakeholder engagement plan as part of the project Revision and update of the national strategy on adaptation to climate change in Cyprus and Slovakia funded by the European Union via the Technical Support Instrument, managed by the European Commission Directorate-General for Structural Reform Support has been delivered to MŽP SR in May 2024, under the EC Contract No REFORM/2021/OP/0006 Lot 1 - TSIC-RoC-20036.

4.7. Information Related to Averting, Minimizing and Addressing Loss and Damage Associated with Climate Change Impacts

Incorporating climate change impacts and adaptation planning into disaster risk management frameworks and vice versa in the Slovak Republic is one of the new challenges. The Ministry of the Interior of the Slovak Republic is working on disaster risk management tasks at both national (adoption of a strategy, action plan and disaster risk assessment) and international level – reporting to the EC. Resolution of the Government of the Slovak Republic No. 65/2022 approved the National Strategy for Security Threat Risk Management of the Slovak Republic, which aims to strengthen the effective management of security risks, which is directly related to the increase of resilience and strengthening of the security system of the state.

4.8. Cooperation, Good Practices, Experience and Lessons Learned

Green Economy Information Platform

Green Economy Information Platform – enables the presentation and sharing of solutions in the areas of climate change adaptation, energy efficiency and sustainable use of resources, waste management, water management, green buildings and housing, etc. It is intended for businesses, municipalities, NGOs and the public. The platform provides general information, a database of companies and their environmental solutions in line with the principles of the green economy.

Village Renewal Grant Programme

Village Renewal Grant Programme – creates the economic, organisational and professional prerequisites to support rural communities in their harmonious development. The programme supports specific activities aimed at addressing the acute problems of rural municipalities in the care of the rural environment, in particular green infrastructure and adaptation measures to mitigate the effects of climate change and care for the countryside.

5. IFORMATION ON FINANCIAL, TECHNOLOGY DEVELOPMENT AND TRANSFER AND CAPACITY-BUILIDNG SUPPORT PROVIDED AND MOBILEZED UNDER ARTICLES 9 – 11 OF THE PARIS AGREEMENT

The chapter provides information on the provision of financial, technological and capacity-building support to developing countries. It embraces information on climate related financial support, which Slovakia provided to developing countries during the years 2021 and 2022. It also gives the overview of relevant climate related projects specifically aimed at addressing climate change or related activities that were primarily designed for other purposes, but are also contributing to the area of mitigation or adaptation process. Of the total portfolio, following activities were selected: activities in the field of climate change adaptation, mitigation projects, technology transfer support and capacity building projects for water, waste management, ecological agriculture, food security, afforestation and renewable energy sources development.

5.1. National Circumstances and Institutional Arrangements

Slovakia became a member of the community of donors providing assistance to developing countries with its accession to the OECD (2000), European Union (2004) and the OECD Development Assistance Committee – DAC (2013). Preparatory process and the membership in these organizations have made a significant contribution to the creation of the mechanism of the Slovak Official Development Assistance (ODA). Development cooperation of the Slovak Republic is governed by Act No. 392/2015 on development cooperation.

Development cooperation of the Slovak Republic represented by the SlovakAid brand is an integral part of the foreign policy of the Slovak Republic. It serves as an expression of solidarity with developing countries and as a contribution to tackling global challenges. Through development cooperation and humanitarian aid, Slovakia, as a responsible member of the international community, contributes to the support of sustainable development in the world, to the improvement of the living conditions of residents in partner countries, the elimination of poverty and inequalities, the support of democracy and reforms, the rescue and reduction of the suffering of people affected by natural disasters or conflicts, and to ensuring stability and peace in the world.

The key national institutions involved in the bilateral ODA are: the Ministry of Foreign and European Affairs of the Slovak Republic (MFEA) as a coordinator of the development cooperation and the Slovak Agency for International Development Cooperation (SAIDC) - responsible for contracting and administering bilateral programmes and development projects in the recipient countries. Apart from the mentioned, the bilateral aid is provided by other ministries as well. The implementation of bilateral

ODA is carried out by national bodies, such as, governmental and academic institutions, non–governmental organizations, and business entities.

Multilateral development assistance includes development programmes and development projects, financed by Slovakia, performed by an international organization, whereas the contributions are paid by Slovakia to international organizations to finance their development activities. Most of the Slovak Republic´s ODA is delivered multilaterally through the EU institutions.

The Export - Import Bank of the Slovak Republic (EXIMBANKA SR) is a specialized financial institution combining banking, guarantees and insurance activities with the aim of supporting export. EXIMBANKA SR offers i.a. concessional loans to foreign buyer or insurance of the concessional loan provided by the commercial bank. This type of loan gives the Slovak exporter opportunity to offer concessional financing to his foreign public buyer (e.g. Ministries, towns, cities, etc.) in selected developing countries.

The core planning document of the Slovak ODA is the Medium-Term Strategy for Development Cooperation of the Slovak Republic. The Medium-Term Strategy for Development Cooperation of the Slovak Republic for 2019 – 2023, which was extended until 2024 is anchored in three main commitments adopted by the UN in 2015 – from the 2030 Agenda for Sustainable Development, the Addis Ababa Action Agenda on financing for development, and the UN Framework Convention on Climate Change and Paris Agreement.

New Medium-Term Strategy for Development Cooperation of the Slovak Republic for years 2025 – 2030 is being prepared and is planned to be adopted by the Slovak government at the end of the year 2024.

The new strategy builds on the previous Medium-term strategy for the development cooperation of the Slovak Republic for the years 2019 – 2024 and the achieved successes and ongoing challenges of the development cooperation of the Slovak Republic. Among the main achievements for the previous periods are the adoption of strategies for development cooperation with three program partner countries (Georgia, Kenya, Moldova); strengthening the activities of the Coordination Committee for Development Cooperation of the Slovak Republic through working groups; implementation of a wider range of tools by the Ministry of Foreign and European Affairs of the Slovak Republic and the Ministry of Finance of the Slovak Republic for involving entrepreneurs in development cooperation; successful completion of the in-depth audit of the European Commission (the so-called Pillar Assessment) by the SAIDC and EXIMBANKA SR and the involvement of the SAIDC in the management of EU development funds within the so-called delegated cooperation of the EU. First strategic partnerships (for Kenya and Moldova) with the aim of more predictable and financially efficient financing of long-term development interventions were implemented, too. Efforts to increase the concentration of Slovak development cooperation on a smaller number of territories and on less developed regions of the receiving countries continued. Guidelines for the implementation of cross-cutting themes (equality between women and men; environment and climate change) into development cooperation projects were also prepared. The first independent evaluations of Slovak development interventions were carried out by external evaluators.

In the narrower environment of the European Union, the Strategy follows up the New European Consensus on Development Our World, Our Dignity, Our Future from 2017.

In years 2019 – 2024, the bilateral aid was implemented mainly through eight main SlovakAid programmes and instruments:

1. Development Interventions Programme;
2. Sharing Slovak Expertise Programme;
3. Business Partnership Programme;
4. Humanitarian Aid;
5. Governmental Scholarships Programme;
6. Programme for Sending Volunteers to Developing Countries;
7. Global and Development Education Programme;
8. Capacity Building Programme.

In years 2019 – 2024 the main territorial priorities of the Slovak ODA were:

1. programme countries: Kenya, Moldova, Georgia;
2. Western Balkans (Albania, Bosnia and Herzegovina, Montenegro, Kosovo, North Macedonia, Serbia),
3. countries of the Eastern Partnership of the EU (Belarus, Georgia, Moldova, Ukraine),
4. Eastern sub-Saharan Africa (Burundi, Ethiopia, Eritrea, South Sudan, Kenya, Rwanda, Somalia, Tanzania and Uganda)
5. Middle East (Iraq, Jordan, Lebanon, Syria),
6. Afghanistan.

Slovak development cooperation was implemented in the following six sectors:

- Quality education
- Good health
- good governance and building civil society
- food safety and agriculture
- infrastructure and sustainable use of natural resources
- supporting creation of market conditions

The main tools of the Slovak bilateral ODA were:

- subsidies;
- financial contributions;
- Sharing Slovak Expertise;
- Humanitarian assistance;
- Slovak government scholarships.

The Slovak Republic also participates in development activities of the international community through the EU and international organisations and institutions. Multilateral development cooperation can be perceived as an instrument for support of those developing countries and sectors in which it is not effective for the Slovak Republic to act on a bilateral basis. Assistance in the form of multilateral contributions has made up approximately 75% of the total Slovak ODA. Priority of the Slovak Republic in multilateral development assistance is to increase the engagement of Slovak entities in the programmes and projects of the EU, UN and other international organisations and international financial institutions. The goal of the Slovak Republic is to actively participate in the decision-making process of the EU, multilateral organisations and institutions to which it contributes, and which reflect Slovak attitudes, values and priorities of foreign policy and development cooperation in specific activities of these international organisations.61

5.2. Underlying Assumption, Definitions and Methodologies

This Report embraces information on financial support which Slovakia provided to developing countries during the year 2021 and 2022 focused on relevant climate related projects and other support. All the Slovak bilateral and multilateral climate financial support provided to developing countries in 2021 and 2022 was channelled through the Official Development Assistance (ODA) in accordance with the OECD DAC methodology.

The relevant values have been calculated using the Euro reference exchange rates (European Central Bank); 1 USD = 0,88 EUR (31.12.2021), 1 USD = 0,94 EUR (30.12.2022).[62]

Development and humanitarian activities administered by the SAIDC are considered to be a key part of Slovak bilateral cooperation. Programme countries for years 2019 – 2024 are Kenya, Moldova and Georgia. For each of these countries a separate strategy for development cooperation was developed (the so called CSP). CSP specifies the goals, priorities and modalities of bilateral development cooperation. Development cooperation activities are also implemented in other partner countries and regions. Environment and climate change is one of the cross-cutting issues and is therefore the subject of methodological guidelines of the Slovak Agency for International Development Cooperation.

As promotion of sustainable economic growth, job creation, as well as the promotion of the mobilization of domestic resources and entrepreneurship represent a key factor in development, the private sector engagement is necessary for the success of development activities. Within the Private Sector Engagement Programme, the interest is in seeking synergies between the development goals of SK ODA and the business goals of Slovak companies, especially small and medium-sized enterprises, in developing countries. The basic sectoral priorities for the development activities of Slovak business entities include energy (production and distribution of energy, support of sustainable energy sources, energy efficiency of buildings); infrastructure (building transport, logistics and communication infrastructure); environment (supply, treatment and distribution of drinking water, waste

---

[61] https://www.mzv.sk/web/en/foreign_policy/slovak_aid

[62] https://nbs.sk/en/statistics/exchange-rates/calculator/?currency=%22USD%22&date=%222024-11-04%22

management, ecological technologies, protection against natural disasters); hydrogeology and drinking water supply, agriculture (forestry, management of agricultural production, increasing the profitability of agricultural production, building irrigation systems, food security); social infrastructure (activities in the field of education and supply of medical facilities).

Sharing Slovak Expertise (SSE) is a tool of official development cooperation to offer and transfer expertise, experience and recommendations from successful governance reforms in various areas where Slovakia has comparative advantages. In terms of territorial focus, the SSE focuses on the ODA programme countries, in particular Moldova and Georgia, and the partner regions and countries - the Western Balkans (Albania, Bosnia and Herzegovina, Montenegro, Kosovo, Macedonia, Serbia) and the Eastern Partnership (Belarus, Georgia, Moldova, Ukraine). In justified cases, the tool can also be used in other developing countries from the DAC/OECD list, in which the Slovak Republic has an Embassy. This tool could be used for environment and climate change as cross-cutting theme.

In response to the recommendations resulting from the OECD DAC Peer Review in 2018, in 2021, the MFEA SR, in cooperation with the United Nations Development Programme (UNDP), external experts and other partners, ensured the development of manuals for the implementation of cross-cutting topics to be applied in all development interventions of the Slovak Republic. One of the cross-cutting topics is the environment and climate change. The manuals provide guidance and recommendations for the systematic integration of cross-cutting topics into the process of planning, management, implementation and evaluation of development cooperation activities of the Slovak Republic. Cross-cutting topics are also the subject of methodological guidelines of the SAIDC, as well as training for relevant development cooperation actors. The degree of the integration of cross-cutting topics is also one of the evaluation criteria when deciding to support an application within calls for proposals.

The Ministry of Finance of the Slovak Republic supports the implementation of several initiatives relevant to the Paris Agreement, notably the Slovak Transformation Fund with the UNDP aimed to deploy innovative solutions in development, i.a. tackle complex urban challenges including climate change; and contributing to initiatives of International financing institutions, such as E5P Energy Efficiency Fund of the European Bank for Reconstruction and Development.

5.3. Information on Financial Support Provided and Mobilized under Article 9 of the Paris Agreement

The summary of Slovakia´s public support, which amounted to 21,8 mil. € during 2021 and 2022, is as follows – the total amount of public financial support in 2021 was approximately 10,5 mil. € with approximately 8 mil. € through multilateral channels and approximately 2,53 mil. € through bilateral channels. The total amount of public financial support in 2022 was approximately 11.24 mil. € with approximately 8.9 mil. € through multilateral channels and approximately 2.3 mil. € through bilateral channels.

5.3.1. PROVISION OF FINANCIAL SUPPORT THROUGH MULTILATERAL CHANNELS

Slovakia defines those financial contributions as being climate specific, which funded climate relative activity defined as mitigation, adaptation, cross-cutting or other climate specific activity. If there are climate specific contributions reported in Fifth Biennial Report, core/general and climate specific data should be mutually exclusive – funds should only be reported in one of the categories. By core we understand an un-earmarked support to the general budget of the organisation. Slovakia concerns some of the multilateral as well as bilateral contributions as climate specific. Climate specific category concerns contributions to multilateral climate funds and dedicated projects managed by multilateral institutions. In 2021 and 2022 Slovakia contributed to the Montreal Protocol Multilateral Fund, the Montreal Protocol Trust Fund, the International Finance Corporation, the World Meteorological Organisation (WMO), International Investment Bank and funded projects through the European Bank for Reconstruction and Development (EBRD).

The total climate specific financial contribution provided by the Slovak republic to developing countries through multilateral channels in the years 2021 – 2022 was 5 468 862 € (5 906 370 USD). Of this support, 750 615 € (825 621 USD) was directed to mitigation, 191 438 € (210 544 USD) to adaptation and 4 526 809 € (4 958 549 USD) to cross-cutting support. In 2021 – 2022 Slovakia provided 11 487 290 € (12 626 514 USD) core/general finance contributions to multilateral organizations.

5.3.2. Provision of financial support through bilateral channels

With respect to bilateral contribution, Slovakia funded climate related study programmes for foreign students and capacity building projects in different developing countries. The total support by the Slovak Republic to developing country Parties to the UNFCCC through bilateral channels in 2021 and 2022 was 4 851 558,3 € (5344790 USD). Of this support, 2 564 103,7 € (2 837 993 USD) was directed to mitigation, 1 124 908,8 € (1 202 966,8 USD) to adaptation and 1 162 545 € (1 303 829,5USD) to cross-cutting activities.

5.3.3. PROVISION OF FINANCIAL SUPPORT THROUGH PRIVATE CHANNELS

The Slovak Republic did not report any information on climate related private finance mobilization in 2021 and 2022, therefore this report embraces only the financial support from public sources.

5.4. Information on Capacity-Building Support Provided under Article 11 of the Paris Agreement

In the years 2021 – 2022, the Slovak Republic supported 98 capacity-building projects or projects focused on both capacity-building and technology transfer. Capacity-building is provided mainly in the form of bilateral cooperation through volunteers sending projects, Sharing Slovak Expertise, scholarships as well as several development or humanitarian projects supported through open calls for proposals announced by the SAIDC. Volunteers provide their (professional) knowledge in the field of development, cooperation, and humanitarian aid. They are also involved in building NGO's capacities, public education, health institutions, and communities in partner developing countries.

Another example is the Sharing Slovak Expertise Programme (SSE). The main aim of SSE is to offer and to pass on (through study visits, sending of experts, internships, roundtables and seminars) Slovak expertise, experience and recommendations from public sector reforms in various areas.

Several development or humanitarian projects also include activities aimed at capacity building.

Another form of support are scholarships provided by the Ministry of Education, Research, Development and Youth of the Slovak Republic to students from developing countries. Scholarships provided to students whose study programme was environmental oriented, focused mainly on the processing of agricultural products, environmental science, geodesy and cartography, land protection and land use, environmental planning, etc. In addition, there were also projects implemented through multilateral channels, in particular through the European Bank for Reconstruction and Development.

In 2021 – 2022, the Slovak Republic did not report any information on climate related private finance mobilization, therefore this BTR embraces only the financial support from the public sector.

6. IMPROVEMENTS IN REPORTING

As per the modalities, procedure and guidelines, each Party should, to the extent possible, identify, regularly update and include as part of its biennial transparency report information on areas of improvement in relation to its reporting. Slovakia will improve its biennial transparency report continuously.

As this BTR is the first report under the Paris Agreement, Slovakia is planning to further improve its reporting in subsequent BTRs according to the technical expert review team´s recommendations.