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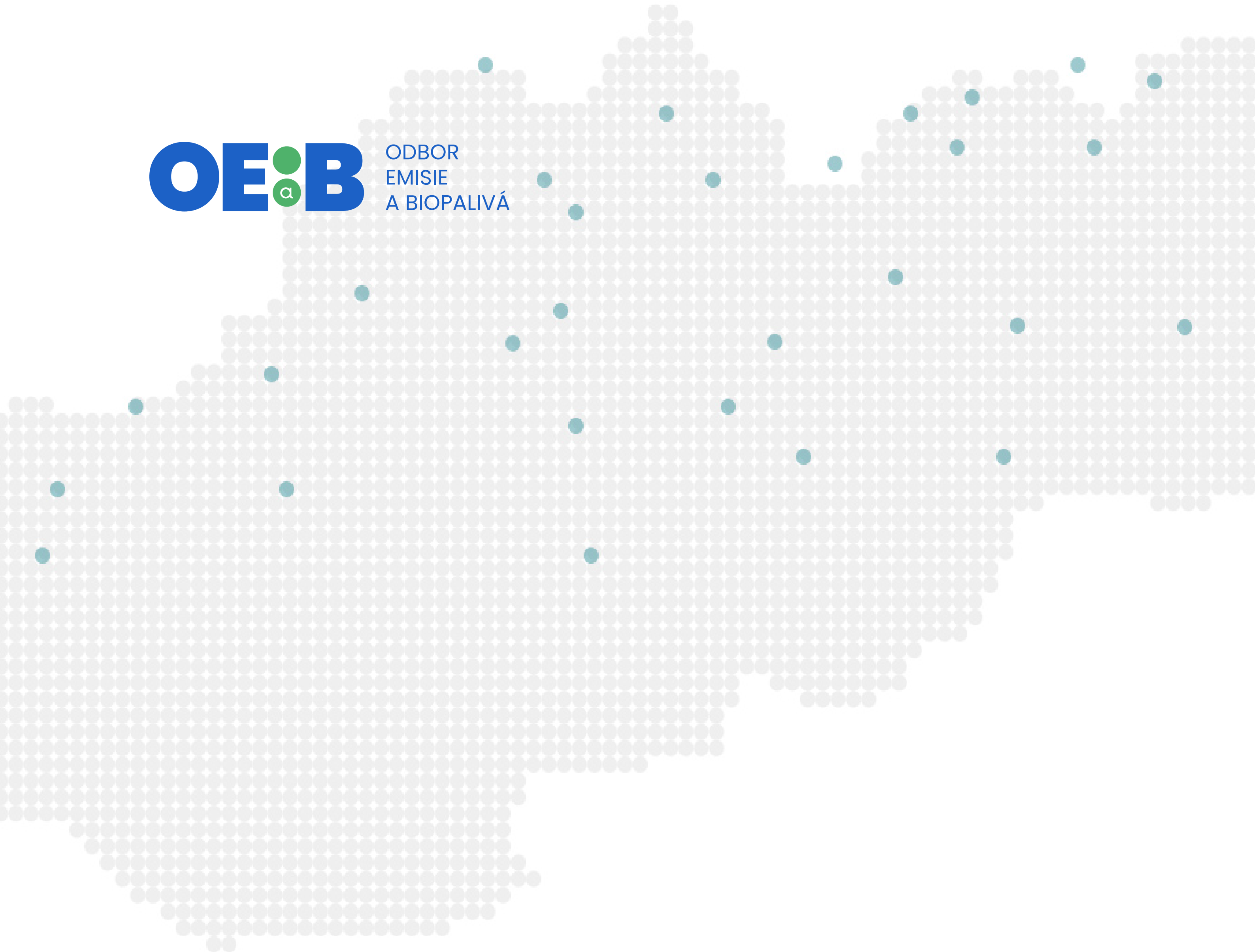

# Report on Air Pollutants Emission Projections 2023

**Bratislava**
**30. August 2023**

# DETAILS OF PREPARATION OF THE SUBMISSION

| TITLE OF REPORT | REPORT ON AIR POLLUTANTS EMISSION PROJECTION 2023 UNDER THE CRLTAP |
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| LEGAL GUARANTOR OF REPORT: | Ministry of the Environment of the Slovak Republic<br>Air Quality Protection Department |
| ADDRESS: | Námestie L. Štúra 1<br>812 35 Bratislava 1, Slovak Republic |
| CONTACT PERSONS: | Zuzana Kocúnová, Director of the Air Quality Protection Department |
| TELEPHONE NO: | +421-2-5956 2271 |
| E-MAIL: | zuzana.kocunova@enviro.gov.sk |

| | |
|---|---|
| EXPERT GUARANTOROF THE REPORT: | Slovak Hydrometeorological Institute<br>Department of Emissions and Biofuels |
| ADDRESS: | Jeséniova 17<br>833 15 Bratislava, Slovak Republic |
| CONTACT PERSONS: | Janka Szemesová, Head of the Dpt.<br>Marcel Zemko, Coordinator of emission projections |
| E-MAIL: | janka.szemesova@shmu.sk<br>marcel.zemko@shmu.sk |

| SECTOR | EXPERT |
|---|---|
| ENERGY | Marcel ZEMKO, Jozef OREČNÝ, Juraj LABOVSKÝ,<br>Jiří BALAJKA, Ján HORVÁTH, Roman MACH |
| TRANSPORT | Ján HORVÁTH |
| IPPU & SOLVENTS | Marcel ZEMKO, Jozef OREČNÝ, Roman MACH, Vladimír DANIELIK |
| AGRICULTURE | Kristína TONHAUZER |
| WASTE | Zuzana JONÁČEK, Marek HRABČÁK, Igor BODÍK, Kristína TONHAUZER |

In 2023, the Slovak Republic is submitting report on air pollutant emissions projections to the European Commission under the National Emission reduction Commitments Directive (NECD 2016/2284/EU)

The submission 2023 of the Slovak Republic comprises:

1. National projections of gas air pollutants emissions [2023] – online Tables
2. Chapter in Informative Inventory Report 2023

This version of the biennial AP emission projections is the official submission 2023 released to CDR EIONET repository.

The Slovakia inventory report tables for emission projections is possible to download from the following address: http://oeab.shmu.sk.

# OBSAH

# INTRODUCTION

The general methodology of the emission projections calculations was based on the same structure as the national emissions inventory of Air pollutants. The data structure for activities, input data, emission factors and emission calculations is based on the Nomenclature for Reporting (NFR). The outputs are aggregated.

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 AP emission projections, especially given the constant changes in the estimated development of macroeconomic indicators for the near future.

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.

The modelling of emission projections was provided consistent with the GHG emission projections reported on $15^{th}$ March 2023 under Regulation (EU) 2018/1999 of the European Parliament and of the Council of 11 December 2018 on Energy Union Governance and Climate Action.

Even use of a wide range of input data and improvement of methodological approach at activity projection in relevant sectors, the results are influenced by the uncertainties of future development, preferably in the case of the macro-economic data and elasticity of the final energy consumption. These uncertainties are predominantly related to the process of economic transformation and privatization and historical data can be hardly used for future development extrapolation.

The year 2019 was determined as the base year for modelling of emissions projections for the actualized scenario for which verified data sets were available from the national emission inventory reported in March 2023.

Projections of air pollutant emissions were prepared with the base year 2019 for the years 2020-2050 within the following scenarios:

With measures scenario (WEM) – projections reflect all measures implemented or adopted before the date of preparation of the projections (31 December 2021).

With additional measures scenario (WAM) – projections include WEM policies and measures and all other measures planned for an increase of air quality according to the national air pollution control program.

## KEY CHANGES IN UPDATED PROJECTIONS

Energy and Industry – The most important change was the wider implementation of the TIMES model in the calculation of emissions in these sectors. Changes were also driven based on new information from producers.

Transport – Actualization based on new methodology with model COPERT using new assumptions and data.

Agriculture – Changes were driven by the improvement of methodology

WAM scenario for NMVOC was included. Published policies and measures after 2020 from the national strategies were considered in the WAM scenario.

Waste – New calculations, and improved methodology together with GHG emission projections estimations.

# CHAPTER 1. AGGREGATED AIR POLLUTANTS EMISSION PROJECTIONS

The actualization of the emission projection led to some changes in comparison with previously reported projections. In the tables below are presented national totals of air pollutant emissions and a comparison to the absolute values of emission targets.

***Table 1.1:*** *WEM scenario emission projection trends and targets*

| TOTAL EMISSIONS OF SLOVAKIA (*kt*) | 2005 | 2010 | 2015 | 2020 | *TARGET 2020* | 2025 | 2030 | *TARGET 2030* | 2040 | 2050 |
|---|---|---|---|---|---|---|---|---|---|---|
| $NO_X$ | 106.06 | 87.86 | 67.86 | 56.00 | 67.88 | 57.46 | 50.57 | 53.03 | 42.74 | 39.68 |
| NMVOC | 141.03 | 117.28 | 104.88 | 88.37 | 115.64 | 94.20 | 85.57 | 95.90 | 77.67 | 69.31 |
| $SO_X$ | 86.22 | 67.71 | 66.79 | 13.30 | 37.07 | 14.28 | 12.93 | 15.52 | 12.41 | 11.63 |
| $NH_3$ | 32.49 | 27.91 | 28.41 | 26.77 | 27.62 | 26.28 | 26.12 | 22.75 | 25.80 | 25.78 |
| $PM_{2.5}$ | 35.76 | 26.23 | 20.58 | 17.3 | 22.89 | 15.22 | 13.25 | 18.24 | 10.96 | 9.09 |

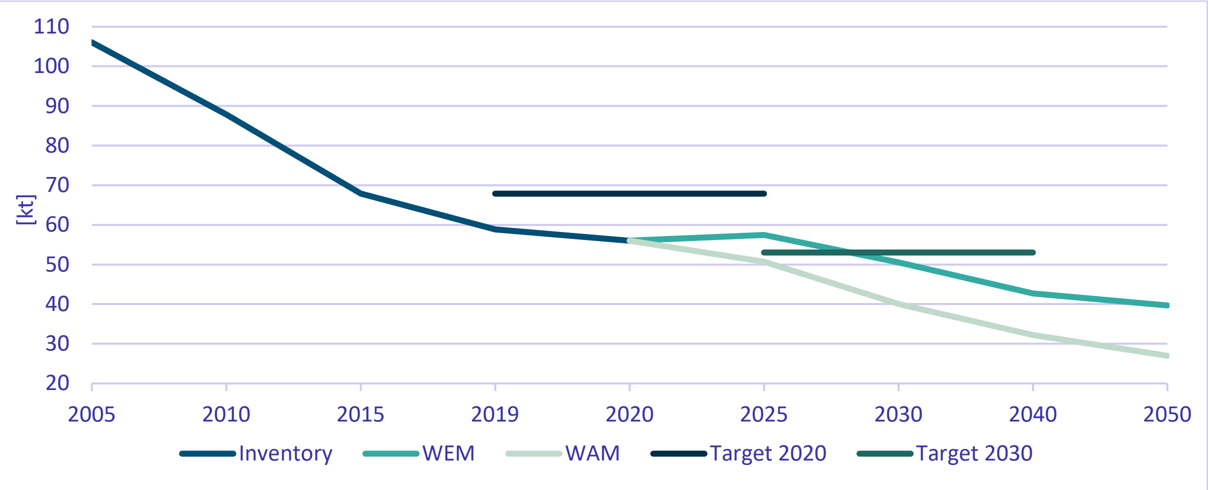
***Table 1.2:*** *WAM scenario emission projection trends and targets*

| TOTAL EMISSIONS OF SLOVAKIA (*kt*) | 2005 | 2010 | 2015 | 2020 | *TARGET 2020* | 2025 | 2030 | *TARGET 2030* | 2040 | 2050 |
|---|---|---|---|---|---|---|---|---|---|---|
| $NO_X$ | 106.06 | 87.86 | 67.86 | 56.00 | 67.88 | 50.72 | 40.01 | 53.03 | 32.18 | 26.99 |
| NMVOC | 141.03 | 117.28 | 104.88 | 88.37 | 115.64 | 96.15 | 84.01 | 95.90 | 73.64 | 64.59 |
| $SO_X$ | 86.22 | 67.71 | 66.79 | 13.30 | 37.07 | 13.56 | 8.81 | 15.52 | 8.05 | 6.83 |
| $NH_3$ | 32.49 | 27.91 | 28.41 | 26.77 | 27.62 | 21.80 | 21.57 | 22.75 | 20.81 | 20.35 |
| $PM_{2.5}$ | 35.76 | 26.23 | 20.58 | 17.3 | 22.89 | 15.83 | 13.26 | 18.24 | 10.20 | 7.73 |

## NOx emissions

***Figure 1.1*** shows a general view of trends of emissions NOx and estimated emissions projections based on encountered measures. Emissions slightly decrease and adopted and planned measures should be sufficient to meet the 2030 target will be very tight even in the WAM scenario.

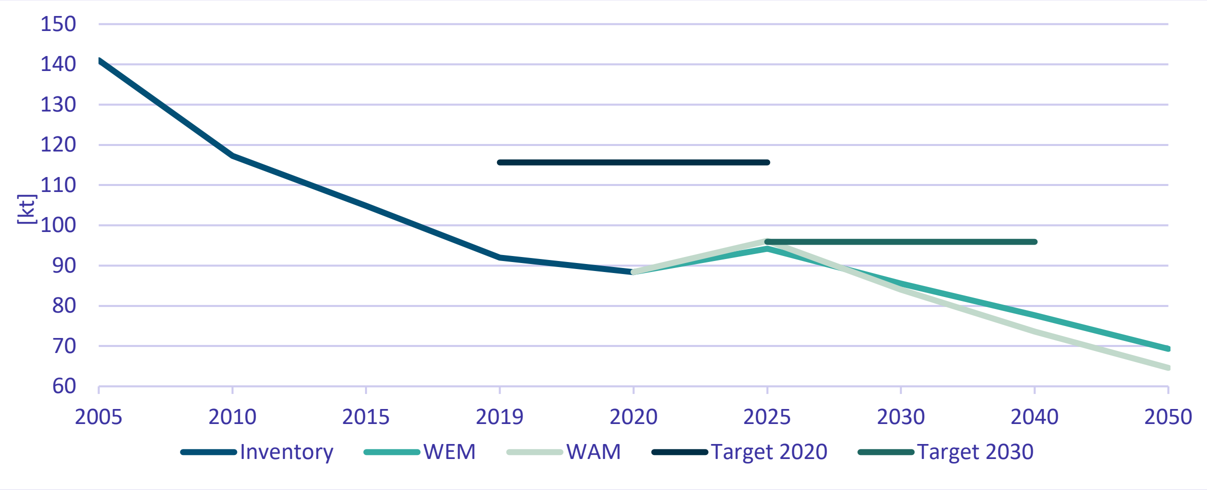
***Figure 1.1:*** *Emission projections trends for pollutant NOx*




## NMVOC emissions

***Figure 1.2*** shows a general view of trends of NMVOC emissions and estimated emissions projections based on encountered measures. Emissions show an overall decreasing trend and the 2030 target should be achieved in both scenarios.

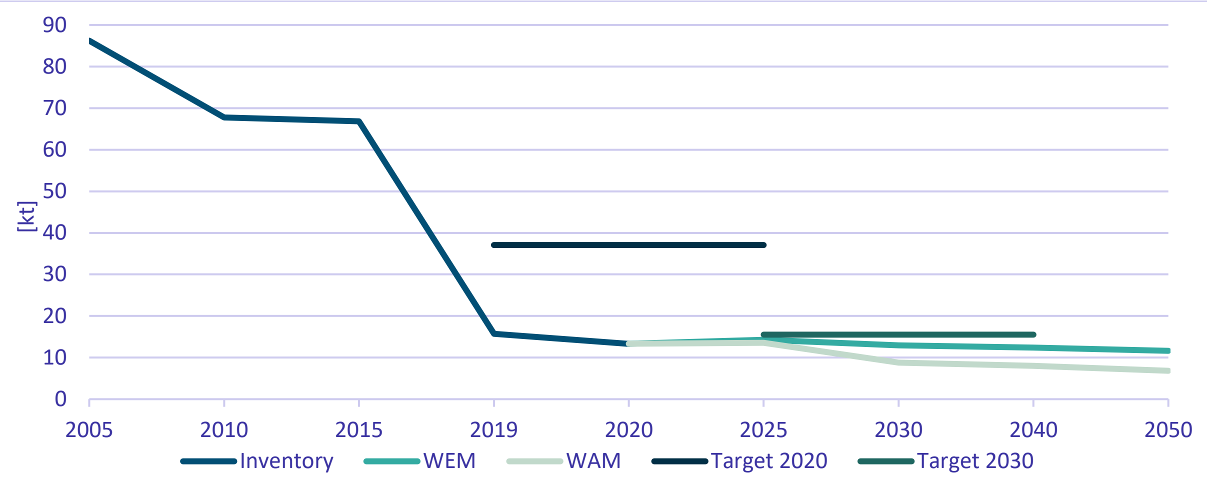
*Figure 1.2: Emission projections trends for pollutant NMVOC*




## SOx emissions

*Figure 1.3* shows the general view on trends of SOx emissions. After implementing strong measures in the energy sector Slovakia should achieve the 2030 target in the WAM scenario.

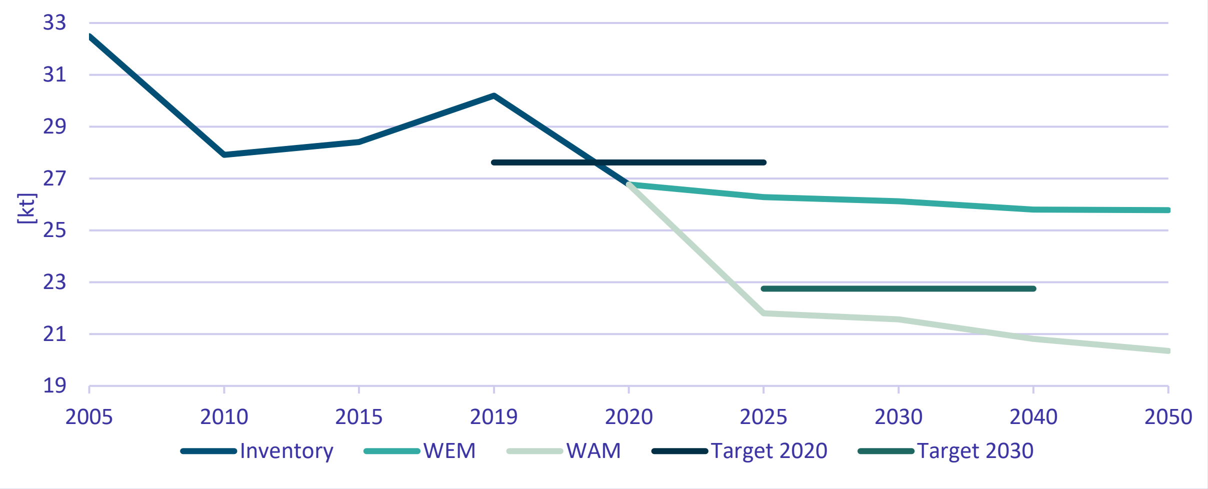
*Figure 1.3: Emission projections trends for pollutant SOx*




## $NH_3$ emissions

*Figure 1.4* shows a general view of trends in $NH_3$ emissions. According to the measures contained in both scenarios will be very hard to achieve the 2030 target. After implementing strong measures in the agriculture sector Slovakia should achieve the 2030 target in the WAM scenario.

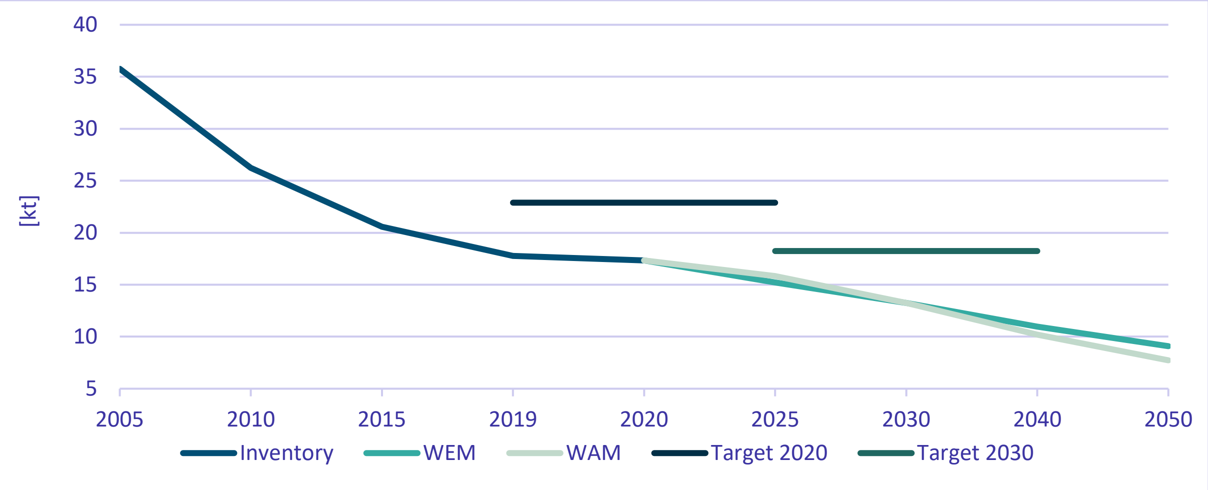
***Figure 1.4:*** *Emission projections trends for pollutant $NH_3$*




## $PM_{2.5}$ emissions

***Figure 1.5*** shows the estimated trend of $PM_{2.5}$ emissions. This is a key pollutant and the future target achievement mainly depends on development in the household and transport sector. For now, trends of emissions seem to be in the margin of the target 2030.

***Figure 1.5:*** *Emission projections trends for pollutant $PM_{2.5}$*



# CHAPTER 2. EMISSION PROJECTIONS IN THE ENERGY SECTOR

This chapter describes the methodology for calculating emission projections from NFR categories, which includes public heat and electricity production, including industrial energy, emissions from households and processing of fuels. This chapter excludes emissions from fuel consumption in transport. Emissions from small households not connected to a District Heating Network (DHN) were modelled separately and a description of the procedure is given at the end of this chapter.

The long-term development of emissions also depends on other parameters, such as energy market developments, technological developments and the trading of $CO_2$ emission allowances. The 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, not only on AP but also on GHG emissions. Nevertheless, the additional impact of this measure is limited due to the technical and economic potential.

Emission projections in the Energy sector were calculated separately for large and medium-sized energy appliances, households, transport and fugitive emission categories.

As in the previous emission projections, we also used the data based on the results from the CPS model (Compact-PRIMES for Slovakia). This model was directly developed, modified and operationalised by the Ministry of the Environment of the Slovak Republic, Institute for Environmental Policy. A description of this model and its use can be found in the previous report on emission projections (2021). The data from the CPS model were fed into the more structured TIMES model, which was developed and used by SHMÚ. The TIMES model is suitable for the projection reporting structure and greater detail. Along with the Energy sector, TIMES also calculates emissions from the industry sector which falls under the EU ETS.

## 2.1. Methodologies and Key Assumptions/Trends

### Energy and Industry model: TIMES

Input data for the calculation of AP projections in TIMES, from industry and energy are provided by the CPS + Macro economical model (IEP), which was developed for the needs of the Low Carbon Strategy. Other input data consist of EU ETS reports, National Energy statistics, NEIS and the NIMS.

Fuels data are  provided by (ÚRSO) - prices of tradable fuels, if possible also separately for sectors such as industry, households and others: Natural gas EUR/GJ, Heating oils, Brown coal, Black coal, Coke, Fuel wood, waste wood, wood chips EUR/ton or EUR/GJ;

RES technologies (Ministry of Economy or with the association of operators of renewable resources) – available input data on RES, their structure and time development. For individual types of resources, the following data are preliminary:

- Photovoltaics - the 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.
- Annual power distribution as in the case of photovoltaics.
- Biomass - biomass potential in TJ/year according to its type - wood, wood chips, etc.

- Geothermal - Potential TJ/year in geographical distribution, investment costs EUR/GW.

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

• Sources included in this group are the most significant stationary sources of GHG emissions, primarily $CO_2$.

• The new sets of NIMS tentatively show this trend, especially for sources that will switch from carbon leakage (CL) to nonCL.

• The analysis is based on the data of 2018, for which there are data from files processed for the preparation of NIMS after 2020. 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.

The main goal of the model is to find an energy system that meets all demands over the entire time period at the lowest costs. The scenarios are used specifically for regional needs 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 an 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.

Calculation includes various policies and measures (in numerical formulation) defined according to the WEM and WAM.

The model itself operates with several sectors:

- POWER (Public electricity and heat production)
- IRON (Iron and Steel)
- FAT (Food and Tobacco)
- CHE (Chemicals)
- NMM (Non Metallic mineral)
- NFM (Non Ferrous metal)
- PPP (Pulp paper and print)
- OTH (Other)
- SUPP (Refinery and Petrochemicals)

*Table 2.1: Main parameters applied in emission projections*

| Item | Units | 2019 | 2020 | 2025 | 2030 | 2035 | 2040 |
|---|---|---|---|---|---|---|---|
| Gross domestic product: Constant prices | EUR million | 89 677 | 86 650 | 98 663 | 107 598 | 116 760 | 124 636 |
| Population | 1 000 people | 5 458 | 5 458 | 5 468 | 5 441 | 5 385 | 5 312 |
| EU ETS carbon price | EUR/EUA | 25 | 24 | 80 | 80 | 82 | 85 |
| International coal import prices | EUR/MWh | 2.1 | 1.6 | 3.1 | 3.1 | 3.1 | 3.3 |
| International oil import prices | EUR/MWh | 10.2 | 6.4 | 15.4 | 15.4 | 15.4 | 16.3 |
| International gas import prices | EUR/MWh | 4.5 | 3.1 | 13.2 | 11.3 | 11.3 | 11.3 |

Even use of a wide range of input data and improvement of methodological approach at activity projection in relevant sectors, the results are influenced by the uncertainties of future development, preferably in the case of the macro-economic data and elasticity of the final energy consumption. These uncertainties are predominantly related to the process of economic transformation and privatization and historical data can be hardly used for future development extrapolation. The emission projections from the Energy sector will be influenced by the main pollutant and GHG emission caps in the new EU ETS regime. Decision 406/2009/EC on effort sharing in the sectors not included in the emission trading plays an important role.

## 2.2. Model Description

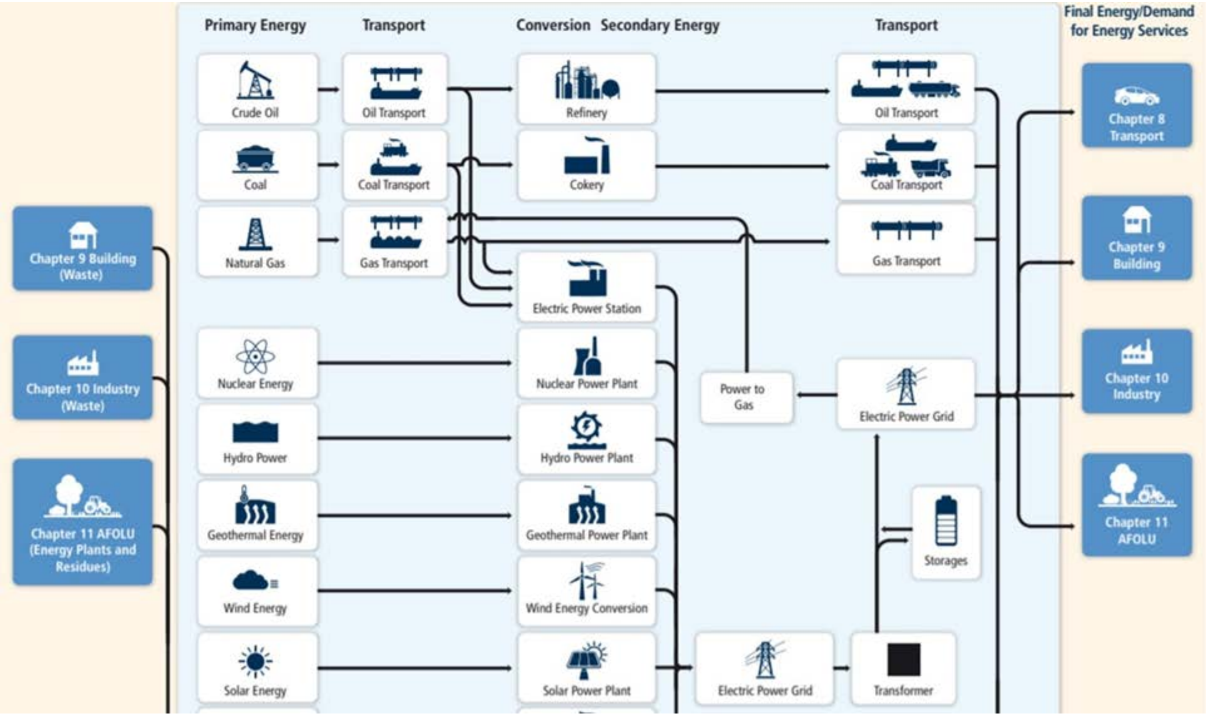
*Table 2.2: SWOT analysis of the TIMES model*

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

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 the conditions of Slovakia?
- What preliminary costs would the considered measures represent?

***Figure 2.1:*** *Different elements of the TIMES model*




## AP Emission Projections in Households – Excel Sheet Model

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

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

## 2.3. Scenarios, Parameters and PAMs

List of policies and measures which have been taken into account in the scenario with measures (WEM):

TIMES model is equivalent to the Reference Scenario of the CPS-PRIMES model. It includes policies and measures (PAMs) adopted and implemented at the EU and national levels by the end of 2021 and the measures being in place to achieve the national renewables (RES) and energy efficiency targets for the year 2021.

Following parameters and PAMs on the EU level were used in the projections of the Energy sector:

- Eco-design Framework Directive (Directive 2005/32/EC).
- Energy Labelling Directive (Directive 2010/30/EU).
- Energy Performance of Buildings Directive, Energy Efficiency Directive (Directive 2012/27/EU).
- Completion of the internal energy market, including provisions of the 3rd package (Directive 2009/73/EC, Directive 2009/72/EC) - Regulation (EC) No. 715/2009, Regulation (EC) No. 714/2009.
- Directive on the promotion of the use of energy from renewable sources - "RES Directive"- incl. amendment on ILUC (Directive 2009/28 EC as amended by Directive (EU) 2015/1513).
- EU ETS Directive 2003/87/EC as amended by Directive 2004/101/EC (international credits), Directive 2008/101/EC (aviation), Directive 2009/29/EC (revision for 2020 climate and energy package), Regulation (EU) No. 176/2014 (back-loading), Decision (EU) 2015/1814 (Market Stability Reserve), and implementing Decisions, in particular 2010/384/EU, 2010/634/EU, 2011/389/EU, 2013/448/EU (cap), 2011/278/EU, 2011/638/EU (benchmarking and carbon leakage list).
- Industrial emissions (Recast of Integrated Pollution and Prevention Control Directive 2008/1/EC and Large Combustion Plant Directive 2001/80/EC) - Directive 2010/75/EU.
- 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. 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.
- Optimisation 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 the District heating network (DHN), installing innovative district heating technologies, improving the supply of heat from combined heat and power plants).
- Specific emissions limits and specific technical conditions for MCP and LCP - Setting limits on concentration for specific air pollutants for particular combustion plants.
- National Air Pollution Control Program (NAPCP) – sectoral measures from NAPCP.
- Support for the replacement of old solid fuel boilers with low-emission ones - Replacement of old non-ecological solid fuel boilers with new ones, low-emission and more energy-efficient boilers in Households.
- The transition of households using solid fuel for heating to another low-emission heat source (e.g. natural gas) - The aim of the measure is to support the transition to low-emission methods of household heating. The measure assumes that households currently using solid fuel will be connected to a low-emission heat source.
- Awareness campaign and education on good practice in coal and biomass combustion - Raising people's awareness of the importance and risks of poor air quality. And also raising information on the possibilities and simple measures to improve proper heating methods, use of wood, etc.
- Transformation or phase-out of fossil fuel-fired power plants - transition to low-emission fuels. Phase-out of Novaky and Vojany Coal power plants.

With Additional Measures scenario (WAM) – is equivalent to scenario Dcarb2 of the CPS-PRIMES model. This is consistent with the results presented in the LCDS of Slovakia; however, the scenario was updated based on the latest input data and parameters assumption (including consideration of development with the COVID-19 situation).

WAM scenario have been designed as contrasting combinations of energy efficiency and renewable targets, representing the trade-offs between targets. The scenario includes Slovakia's participation in the EU ETS, and median targets for renewable energy efficiency involving the construction of new nuclear electricity-generation capacity, which will ensure continuity of the higher share of nuclear energy in the generation mix. To shape a range of possible contributions by the Slovak Republic in the achievement of the EU targets for 2030, at first a summary of possible flexibilities in targets using several trend-variants was quantified by using the CPS-PRIMES model. The Basic, Median and Ambitious categorisations refer to the possible intensiveness of the policy targets for the year 2030. The specification of the WAM scenario relies on the logic of the design of the EU scenarios and in particular, the EUCO30 scenario, which sets the 2030 targets at the EU level on GHG emissions reductions but also have impact on AP emissions. It contain:

- GHG emissions reduction;
- EU ETS $CO_2$ emissions reduction;
- Non-EU ETS GHG emissions reduction;
- RES share: 27% of gross final energy demand in 2030;
- Energy efficiency: reduction of primary energy by 30% (1 321 Mtoe – excluding non-energy consumption of energy products) in 2030 compared to the 2007 baseline;
- Continuing to reduce final energy consumption in all sectors after 2020. The measure puts emphasis on policies supporting the acceleration of the renewal of the building stock (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 2020 for new buildings.

In addition to the national policies included in the WAM scenario, the following national policies are also included:

- Earlier decommissioning of solid-fired utility power plants: Vojany and Nováky power plants are assumed to decommission in 2025 and 2023 respectively;
- RES support scheme in power generation: Eligible RES technologies are Solar PV, wind onshore turbines and biomass. The scenarios assume support of 50MW in the period 2021-2025, followed by the support of another 500 MW based on auctions;
- Further development of nuclear energy is possible based on economic optimality;
- Carbon capture and storage are excluded;
- 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 - Programme Slovakia, Green renovation;
- Awareness campaign and education on good coal and biomass combustion practices;
- Commissioning of new nuclear power sources: Mochovce unit 3 in 2023 and Mochovce unit 4 after 2025;
- Installation of 2 Electric Arc Furnace (EAF) processing iron scrap;

- Decommissioning of Coke oven battery;
- Decommissioning of Sinter installation;
- Continuous Casting;
- Decommissioning of two blast and oxygen furnaces;
- Reduction of energy coal consumption.

## 2.4. Emission Projections in Energy Sector

The modelling of emission projections in the Energy sector was based on sectoral trends and development from the CPS model and actualization was made by taking into account the results of model TIMES in the category of Public electricity and heat production (**1.A.1.a**). The outputs from modelling were determined also by the reduction potential of measures to reduce emissions.

The next tables show trends of emissions for individual pollutants.

### NOx emissions

***Table 2.3***: *NOx emissions in sector Energy*

| WEM | 2005 | 2010 | 2015 | 2020 | 2025 | 2030 | 2040 | 2050 |
|---|---|---|---|---|---|---|---|---|
| 1.A.1. | 19.10 | 13.04 | 8.49 | 5.47 | 3.64 | 3.23 | 3.03 | 2.93 |
| 1.A.2. | 15.32 | 11.74 | 10.85 | 8.41 | 10.60 | 9.65 | 9.28 | 9.04 |
| 1.A.4 | 9.19 | 8.89 | 8.90 | 8.48 | 8.62 | 8.10 | 7.46 | 7.04 |
| 1.A.5 | 0.20 | 0.13 | 0.48 | 0.45 | 0.58 | 0.59 | 0.59 | 0.56 |
| 1.B | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| **1 Energy** | **43.81** | **33.80** | **28.72** | **22.81** | **23.44** | **21.57** | **20.36** | **19.57** |

| WAM | 2005 | 2010 | 2015 | 2020 | 2025 | 2030 | 2040 | 2050 |
|---|---|---|---|---|---|---|---|---|
| 1.A.1. | 19.10 | 13.04 | 8.49 | 5.47 | 3.62 | 1.50 | 1.35 | 1.19 |
| 1.A.2. | 15.32 | 11.74 | 10.85 | 8.41 | 9.11 | 7.99 | 7.44 | 5.37 |
| 1.A.4 | 9.19 | 8.89 | 8.90 | 8.48 | 8.46 | 8.08 | 7.41 | 6.96 |
| 1.A.5 | 0.20 | 0.13 | 0.48 | 0.45 | 0.58 | 0.59 | 0.59 | 0.56 |
| 1.B | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| **1 Energy** | **43.81** | **33.80** | **28.72** | **22.81** | **21.77** | **18.16** | **16.80** | **14.08** |

### NMVOC emissions

***Table 2.4***: *NMVOC emissions in sector Energy*

| WEM | 2005 | 2010 | 2015 | 2020 | 2025 | 2030 | 2040 | 2050 |
|---|---|---|---|---|---|---|---|---|
| 1.A.1. | 2.68 | 1.92 | 1.83 | 1.19 | 1.12 | 0.99 | 0.92 | 0.86 |
| 1.A.2. | 5.33 | 4.91 | 5.72 | 5.69 | 7.43 | 6.96 | 6.94 | 6.63 |
| 1.A.4 | 49.24 | 47.58 | 38.40 | 33.92 | 30.37 | 26.26 | 21.32 | 17.30 |
| 1.A.5 | 0.47 | 0.57 | 0.82 | 0.55 | 0.71 | 0.72 | 0.72 | 0.69 |
| 1.B | 12.98 | 12.77 | 11.72 | 8.71 | 15.38 | 13.43 | 12.52 | 10.83 |
| **1 Energy** | **70.71** | **67.74** | **58.48** | **50.06** | **55.01** | **48.37** | **42.42** | **36.31** |

| WAM | 2005 | 2010 | 2015 | 2020 | 2025* | 2030* | 2040* | 2050* |
|---|---|---|---|---|---|---|---|---|
| 1.A.1. | 2.68 | 1.92 | 1.83 | 1.19 | 1.13 | 0.99 | 0.92 | 0.78 |
| 1.A.2. | 5.33 | 4.91 | 5.72 | 5.69 | 7.06 | 6.64 | 6.62 | 6.16 |
| 1.A.4 | 49.24 | 47.58 | 38.40 | 33.92 | 33.92 | 29.04 | 22.98 | 18.02 |
| 1.A.5 | 0.47 | 0.57 | 0.82 | 0.55 | 0.71 | 0.72 | 0.72 | 0.69 |
| 1.B | 12.98 | 12.77 | 11.72 | 8.71 | 15.38 | 13.43 | 12.52 | 10.83 |

| WAM | 2005 | 2010 | 2015 | 2020 | 2025* | 2030* | 2040* | 2050* |
|---|---|---|---|---|---|---|---|---|
| **1 Energy** | **70.71** | **67.74** | **58.48** | **50.06** | **58.21** | **50.83** | **43.76** | **36.47** |

**WAM scenario for NMVOC emissions are higher than WEM scenario due to higher biomass consumption in households projected with higher EFs.*

## SOx emissions

***Table 2.5:*** *SOx emissions in sector Energy*

| WEM | 2005 | 2010 | 2015 | 2020 | 2025 | 2030 | 2040 | 2050 |
|---|---|---|---|---|---|---|---|---|
| 1.A.1. | 60.82 | 52.75 | 52.04 | 3.22 | 2.26 | 2.03 | 1.89 | 1.83 |
| 1.A.2. | 10.01 | 4.94 | 3.29 | 1.47 | 1.85 | 1.67 | 1.59 | 1.55 |
| 1.A.4 | 3.40 | 2.34 | 1.94 | 1.60 | 1.67 | 1.54 | 1.38 | 1.25 |
| 1.A.5 | 0.32 | 0.10 | 0.21 | 0.19 | 0.25 | 0.25 | 0.25 | 0.24 |
| 1.B | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| **1 Energy** | **74.55** | **60.13** | **57.48** | **6.48** | **6.02** | **5.49** | **5.11** | **4.87** |

| WAM | 2005 | 2010 | 2015 | 2020 | 2025 | 2030 | 2040 | 2050 |
|---|---|---|---|---|---|---|---|---|
| 1.A.1. | 60.82 | 52.75 | 52.04 | 3.22 | 2.21 | 0.79 | 0.72 | 0.67 |
| 1.A.2. | 10.01 | 4.94 | 3.29 | 1.47 | 1.50 | 1.28 | 1.16 | 0.73 |
| 1.A.4 | 3.40 | 2.34 | 1.94 | 1.60 | 1.67 | 1.39 | 1.00 | 0.79 |
| 1.A.5 | 0.32 | 0.10 | 0.21 | 0.19 | 0.25 | 0.25 | 0.25 | 0.24 |
| 1.B | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| **1 Energy** | **74.55** | **60.13** | **57.48** | **6.48** | **5.63** | **3.72** | **3.13** | **2.43** |

## $NH_3$ emissions

***Table 2.6:*** *$NH_3$ emissions in sector Energy*

| WEM | 2005 | 2010 | 2015 | 2020 | 2025 | 2030 | 2040 | 2050 |
|---|---|---|---|---|---|---|---|---|
| 1.A.1. | 0.08 | 0.03 | 0.05 | 0.02 | 0.02 | 0.01 | 0.01 | 0.01 |
| 1.A.2. | 0.02 | 0.02 | 0.04 | 0.07 | 0.10 | 0.09 | 0.09 | 0.09 |
| 1.A.4 | 2.06 | 2.09 | 1.63 | 1.52 | 1.36 | 1.20 | 1.00 | 0.82 |
| 1.A.5 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 1.B | 0.01 | 0.01 | 0.01 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| **1 Energy** | **2.17** | **2.15** | **1.72** | **1.62** | **1.48** | **1.30** | **1.10** | **0.92** |

| WAM | 2005 | 2010 | 2015 | 2020 | 2025 | 2030 | 2040 | 2050 |
|---|---|---|---|---|---|---|---|---|
| 1.A.1. | 0.08 | 0.03 | 0.05 | 0.02 | 0.02 | 0.01 | 0.01 | 0.01 |
| 1.A.2. | 0.02 | 0.02 | 0.04 | 0.07 | 0.09 | 0.08 | 0.08 | 0.08 |
| 1.A.4 | 2.06 | 2.09 | 1.63 | 1.52 | 1.41 | 1.26 | 1.08 | 0.88 |
| 1.A.5 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 1.B | 0.01 | 0.01 | 0.01 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| **1 Energy** | **2.17** | **2.15** | **1.72** | **1.62** | **1.52** | **1.36** | **1.18** | **0.97** |

## $PM_{2.5}$ emissions

Households (**1.A.4**) are a dominant contributor to $PM_{2.5}$ emissions.

***Table 2.7:** $PM_{2.5}$ emissions in sector Energy*

| WEM | 2005 | 2010 | 2015 | 2020 | 2025 | 2030 | 2040 | 2050 |
|---|---|---|---|---|---|---|---|---|
| 1A1 | 8.08 | 0.89 | 0.67 | 0.27 | 0.26 | 0.22 | 0.21 | 0.20 |
| 1A2 | 0.72 | 0.41 | 0.23 | 0.25 | 0.31 | 0.27 | 0.24 | 0.24 |
| 1A4 | 22.44 | 20.99 | 16.44 | 14.34 | 12.73 | 10.99 | 8.87 | 7.09 |
| 1A5 | 0.02 | 0.01 | 0.02 | 0.01 | 0.02 | 0.02 | 0.02 | 0.02 |
| 1B | 0.21 | 0.19 | 0.17 | 0.11 | 0.05 | 0.01 | 0.01 | 0.01 |
| **1 Energy** | **31.47** | **22.49** | **17.54** | **14.98** | **13.37** | **11.52** | **9.35** | **7.56** |

| WAM | 2005 | 2010 | 2015 | 2020 | 2025 | 2030 | 2040 | 2050 |
|---|---|---|---|---|---|---|---|---|
| 1A1 | 8.08 | 0.89 | 0.67 | 0.27 | 0.26 | 0.13 | 0.12 | 0.09 |
| 1A2 | 0.72 | 0.41 | 0.23 | 0.25 | 0.30 | 0.27 | 0.24 | 0.23 |
| 1A4 | 22.44 | 20.99 | 16.44 | 14.34 | 13.05 | 10.81 | 8.08 | 5.86 |
| 1A5 | 0.02 | 0.01 | 0.02 | 0.01 | 0.02 | 0.02 | 0.02 | 0.02 |
| 1B | 0.21 | 0.19 | 0.17 | 0.11 | 0.05 | 0.01 | 0.01 | 0.01 |
| **1 Energy** | **31.47** | **22.49** | **17.54** | **14.98** | **13.68** | **11.25** | **8.47** | **6.21** |

# CHAPTER 3. EMISSION PROJECTIONS IN THE TRANSPORT SECTOR

The transport sector consists of five subcategories:

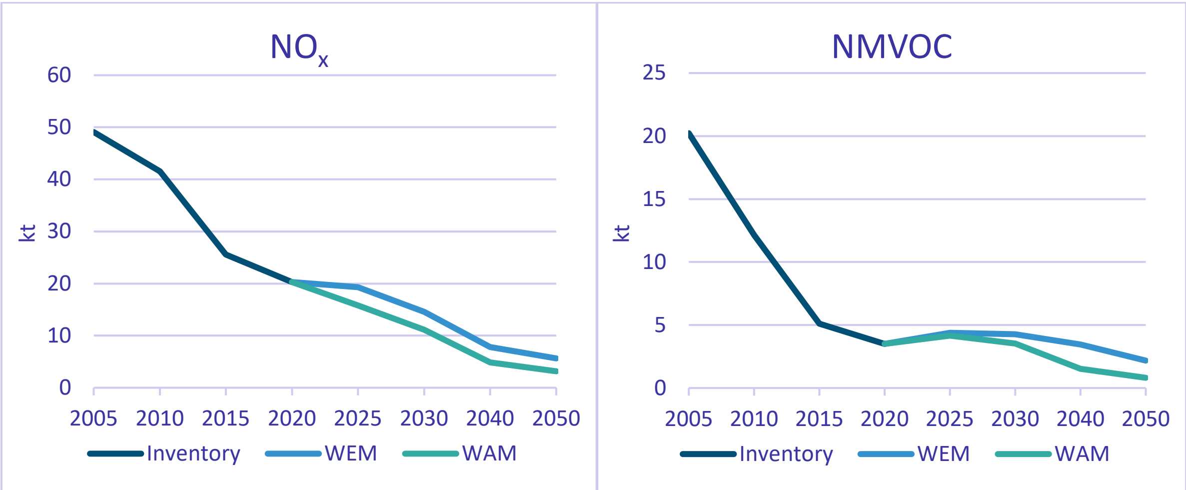
- 1.A.3.a Air transport (0.01%)
- 1.A.3.b Road transport (96.38%)
- 1.A.3.c Rail transport (1.15%)
- 1.A.3.d Water transport (0.08%)
- 1.A.3.e Other mode of transport (e.g. pipeline transport) (2.38%)

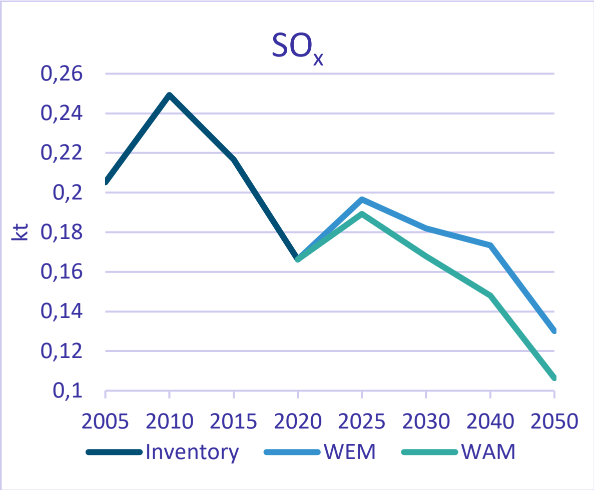
The largest contributor to air pollution in the transport sector is road transport, specifically the use of diesel heavy-duty vehicles (HDVs) and passenger cars. The transport sector includes emissions from various sources, including road transport (passenger cars, light-commercial vehicles, heavy-duty vehicles, buses, mopeds, and motorcycles), as well as emissions from petrol evaporation, tire and brake wear, and road abrasion. Additionally, it includes emissions from air, rail, maritime, and pipeline transport (such as the transportation of natural gas). However, the majority of emissions in 2019 originated from road transport. Therefore, Slovakia's focus and detailed analysis are primarily directed towards the potential reduction of emissions from road transport, while the ARIMA model is employed for other transportation categories.

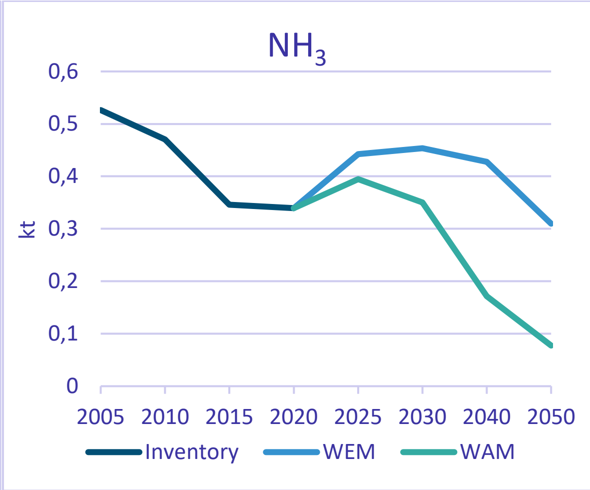
The starting point for gaining control over emissions is a thorough understanding of the current situation and an awareness of how emission trends have changed, both quantitatively and compositionally. By relying on official sources, a detailed, comprehensive, and consistent dataset on vehicles and their activity can be compiled. This dataset serves as the foundation for accurately calculating national-level emissions using advanced emissions modelling tools.

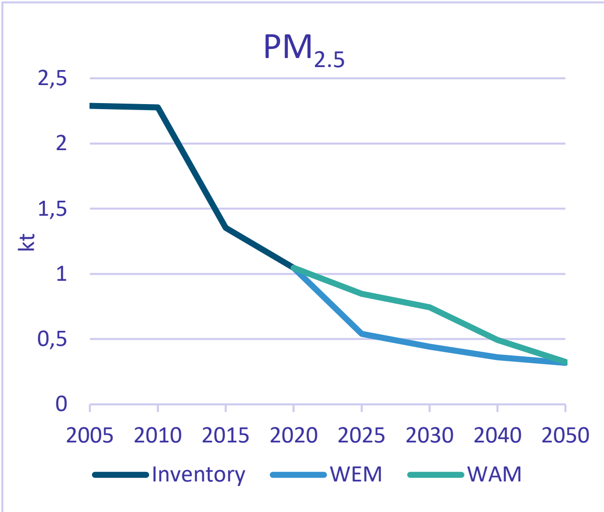
Both the WEM and WAM scenarios demonstrate diverse trends in terms of air pollutants. Emissions of $NO_x$, NMVOC, and the WAM scenario for $NH_3$ indicate a decrease in emissions, while other pollutants show an increase in emissions (***Figure 3.1***, ***Tables 3.1-3.5***) due to varying factors. The rising trend of $SO_x$ and $NH_3$ emissions is caused by the extensive use of diesel-fuelled vehicles, while the increase in $PM_{2.5}$ emissions is attributed to the introduction and expansion of electric vehicle usage. Electric vehicles, being heavier, result in higher tire and brake wear emissions.

***Figure 3.1:*** *Air pollutants emissions trends in sector Transport*






## NOx emissions

***Table 3.1:*** *$NO_x$ emissions in sector Transport*

| WEM | 2005 | 2010 | 2015 | 2020 | 2025 | 2030 | 2040 | 2050 |
|---|---|---|---|---|---|---|---|---|
| 1.A.3.b road | 43.27 | 36.84 | 22.89 | 18.23 | 17.06 | 12.29 | 5.46 | 3.18 |
| 1.A.3.acde non road | 5.82 | 4.71 | 2.68 | 2.06 | 2.24 | 2.30 | 2.38 | 2.46 |
| **1.A.3** | **49.09** | **41.55** | **25.58** | **20.29** | **19.30** | **14.59** | **7.84** | **5.64** |

| WAM | 2005 | 2010 | 2015 | 2020 | 2025 | 2030 | 2040 | 2050 |
|---|---|---|---|---|---|---|---|---|
| 1.A.3.b road | 43.27 | 36.84 | 22.89 | 18.23 | 13.55 | 8.81 | 2.49 | 0.70 |
| 1.A.3.acde non road | 5.82 | 4.71 | 2.68 | 2.06 | 2.24 | 2.30 | 2.38 | 2.46 |
| **1.A.3** | **49.09** | **41.55** | **25.58** | **20.29** | **15.78** | **11.11** | **4.87** | **3.16** |

## NMVOC emissions

***Table 3.2:*** *NMVOC emissions in sector Transport*

| WEM | 2005 | 2010 | 2015 | 2020 | 2025 | 2030 | 2040 | 2050 |
|---|---|---|---|---|---|---|---|---|
| 1.A.3.b road | 19.83 | 11.79 | 4.72 | 3.15 | 4.22 | 4.11 | 3.28 | 1.99 |
| 1.A.3.acde non road | 0.39 | 0.36 | 0.40 | 0.35 | 0.16 | 0.17 | 0.18 | 0.19 |
| **1.A.3** | **20.23** | **12.14** | **5.12** | **3.50** | **4.38** | **4.28** | **3.46** | **2.18** |

| WAM | 2005 | 2010 | 2015 | 2020 | 2025 | 2030 | 2040 | 2050 |
|---|---|---|---|---|---|---|---|---|
| 1.A.3.b road | 19.83 | 11.79 | 4.72 | 3.15 | 4.00 | 3.37 | 1.35 | 0.63 |
| 1.A.3.acde non road | 0.39 | 0.36 | 0.40 | 0.35 | 0.16 | 0.17 | 0.18 | 0.19 |
| **1.A.3** | **20.23** | **12.14** | **5.12** | **3.50** | **4.16** | **3.54** | **1.53** | **0.81** |

## SOx emissions

***Table 3.3:*** *$SO_x$ emissions in sector Transport*

| WEM | 2005 | 2010 | 2015 | 2020 | 2025 | 2030 | 2040 | 2050 |
|---|---|---|---|---|---|---|---|---|
| 1.A.3.b road | 0.19 | 0.03 | 0.03 | 0.03 | 0.04 | 0.05 | 0.04 | 0.03 |
| 1.A.3.acde non road | 0.01 | 0.22 | 0.19 | 0.13 | 0.15 | 0.13 | 0.13 | 0.10 |
| **1.A.3** | **0.21** | **0.25** | **0.22** | **0.17** | **0.20** | **0.18** | **0.17** | **0.13** |

| WAM | 2005 | 2010 | 2015 | 2020 | 2025 | 2030 | 2040 | 2050 |
|---|---|---|---|---|---|---|---|---|
| 1.A.3.b road | 0.19 | 0.03 | 0.03 | 0.03 | 0.04 | 0.03 | 0.01 | 0.01 |
| 1.A.3.acde non road | 0.01 | 0.22 | 0.19 | 0.13 | 0.15 | 0.13 | 0.13 | 0.10 |
| **1.A.3** | **0.21** | **0.25** | **0.22** | **0.17** | **0.19** | **0.17** | **0.15** | **0.11** |

## $NH_3$ emissions

***Table 3.4***: *$NH_3$ emissions in sector Transport*

| WEM | 2005 | 2010 | 2015 | 2020 | 2025 | 2030 | 2040 | 2050 |
|---|---|---|---|---|---|---|---|---|
| 1.A.3.b road | 0.53 | 0.47 | 0.35 | 0.34 | 0.44 | 0.45 | 0.43 | 0.31 |
| 1.A.3.acde non road | 0.00 | 0.00 | 0.00 | 0.00 | NA[1] | NA[1] | NA[1] | NA[1] |
| **1.A.3** | **0.53** | **0.47** | **0.35** | **0.34** | **0.44**[1] | **0.45**[1] | **0.43**[1] | **0.31**[1] |

| WAM | 2005 | 2010 | 2015 | 2020 | 2025 | 2030 | 2040 | 2050 |
|---|---|---|---|---|---|---|---|---|
| 1.A.3.b road | 0.53 | 0.47 | 0.35 | 0.34 | 0.39 | 0.35 | 0.17 | 0.08 |
| 1.A.3.acde non road | 0.00 | 0.00 | 0.00 | 0.00 | NE[1] | NE[1] | NE[1] | NE[1] |
| **1.A.3** | **0.53** | **0.47** | **0.35** | **0.34** | **0.39**[1] | **0.35**[1] | **0.17**[1] | **0.08**[1] |

## $PM_{2.5}$ emissions

***Table 3.5:*** *$PM_{2.5}$ emissions in sector Transport*

| WEM | 2005 | 2010 | 2015 | 2020 | 2025 | 2030 | 2040 | 2050 |
|---|---|---|---|---|---|---|---|---|
| 1.A.3.b road | 2.24 | 2.18 | 1.27 | 0.98 | 0.54[1] | 0.44[1] | 0.36[1] | 0.32[1] |
| 1.A.3.acde non road | 0.05 | 0.10 | 0.08 | 0.07 | NA[1] | NA[1] | NA[1] | NA[1] |
| **1.A.3** | **2.29** | **2.28** | **1.35** | **1.05** | **0.54**[1] | **0.44**[1] | **0.36**[1] | **0.32**[1] |

| WAM | 2005 | 2010 | 2015 | 2020 | 2025 | 2030 | 2040 | 2050 |
|---|---|---|---|---|---|---|---|---|
| 1.A.3.b road | 2.24 | 2.18 | 1.27 | 0.98 | 0.85[1] | 0.74[1] | 0.49[1] | 0.33[1] |
| 1.A.3.acde non road | 0.05 | 0.10 | 0.08 | 0.07 | NE[1] | NE[1] | NE[1] | NE[1] |
| **1.A.3** | **2.29** | **2.28** | **1.35** | **1.05** | **0.85**[1] | **0.74**[1] | **0.49**[1] | **0.33**[1] |

# 3.1. Methodologies and Key Assumptions/Trends (Road transport)

Input (historical) data for the calculation of air pollution 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 Periodical Technical Inspection (PTI) 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

[1] Data were during NECD review 2023 identified as incorrect and will be corrected in the next submission

Policy of the Ministry of Environment of the Slovak Republic (IEP MŽP SR). 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 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 2013-2019. The data for this time period were obtained from IS EVO as a by-product of a project. 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”.

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 3.2*** (WEM scenario) and ***Figure 3.3*** for (WAM scenario).

***Figure 3.2:*** *Fleet development by fuel types in WEM scenario*

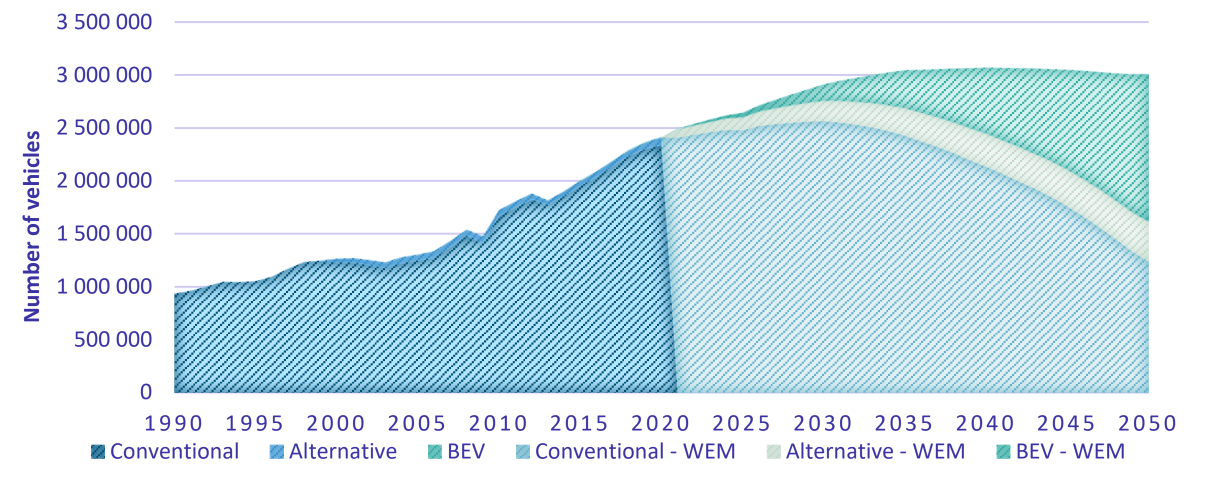
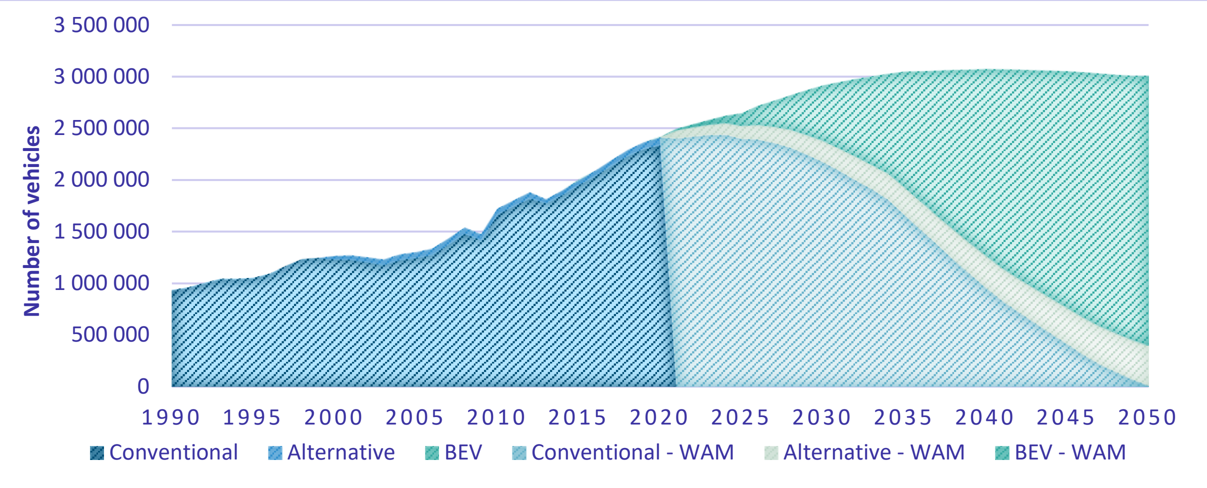



***Figure 3.3:*** *Fleet development by fuel types in WAM scenario*




## 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 the 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 3.4***). In the case of the WAM scenario, this peak could happen earlier, sometime around the year 2024. For alternative engines, there is a slightly lower increase in the WAM (***Figure 3.5***) and this is due to the greater weight given to BEV in the fleet development for this scenario (***Figure 3.6***), which have exponential growth up to 2050.

***Figure 3.4:*** *Development of conventional fuel passenger cars in WEM and WAM scenarios*

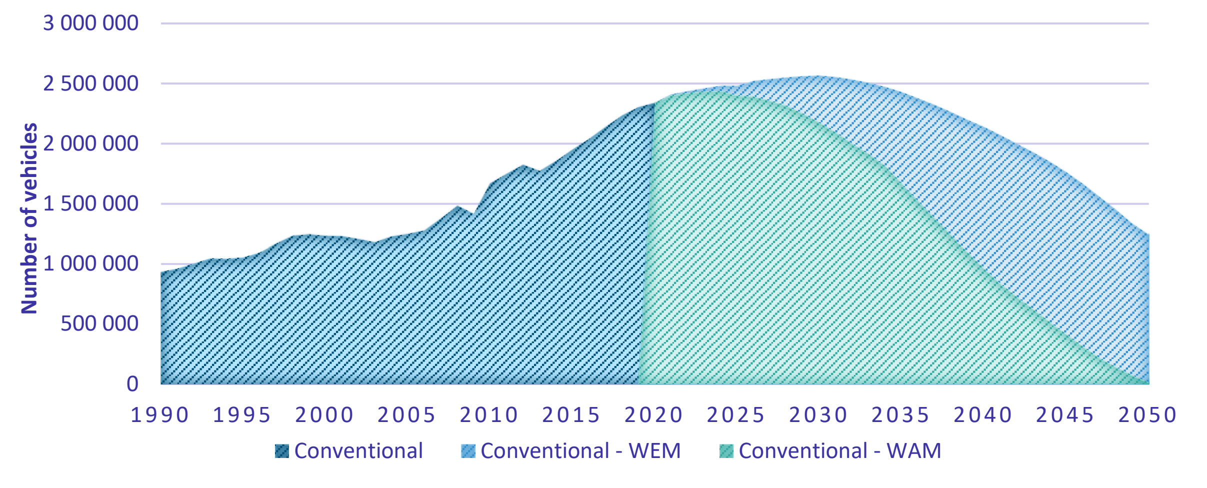



***Figure 3.5:*** *Development of alternative fuel passenger vehicles (CNG, LPG, LNG and hybrid) in WEM and WAM scenarios*

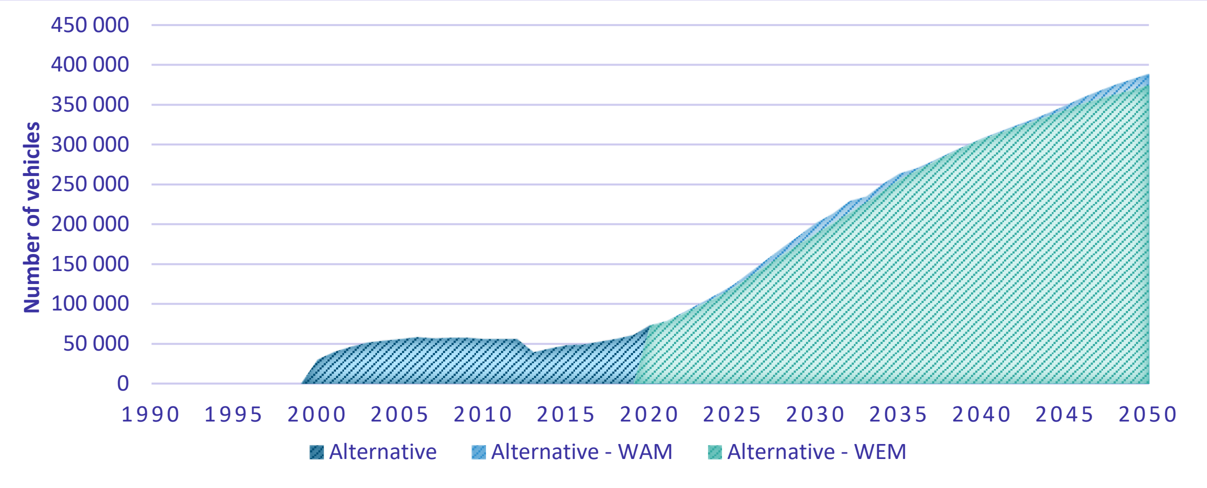
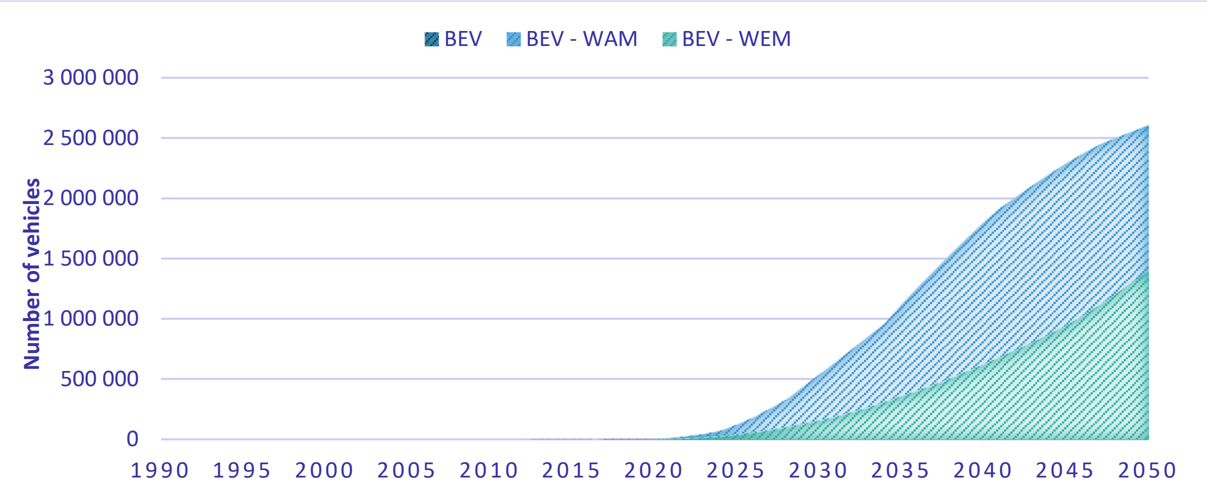



***Figure 3.6:*** *Development of electric and hydrogen powered passenger cars in WEM and WAM scenarios*



## 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 450,000 vehicles in 2050 (***Figure 3.7***). For LCVs, there is little expectation of a turnover to alternative fuels as there would be a reduction in transport space (***Figure 3.8***) and hence the WAM scenario will not affect this category. For the overall decarbonisation and lowering air pollution from road transport, it will be necessary to decarbonise in particular the 'last mile' in the form of zero-emission vehicles (***Figure 3.9***).

***Figure 3.7:*** *Development of light-commercial vehicles with conventional in WEM and WAM scenarios*

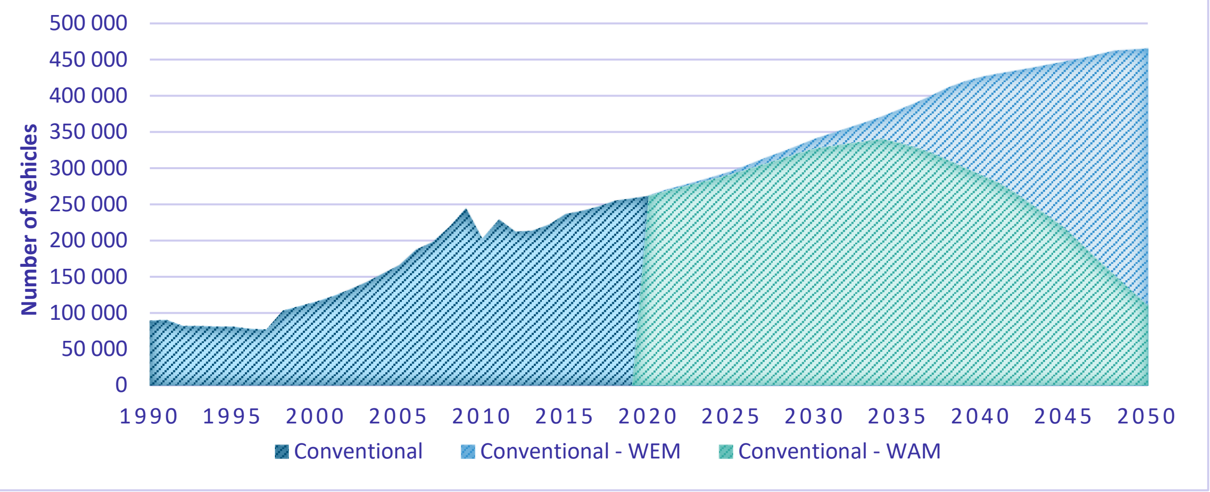



***Figure 3.8:*** *Development of light-commercial vehicles with alternative propulsion in WEM and WAM scenarios*

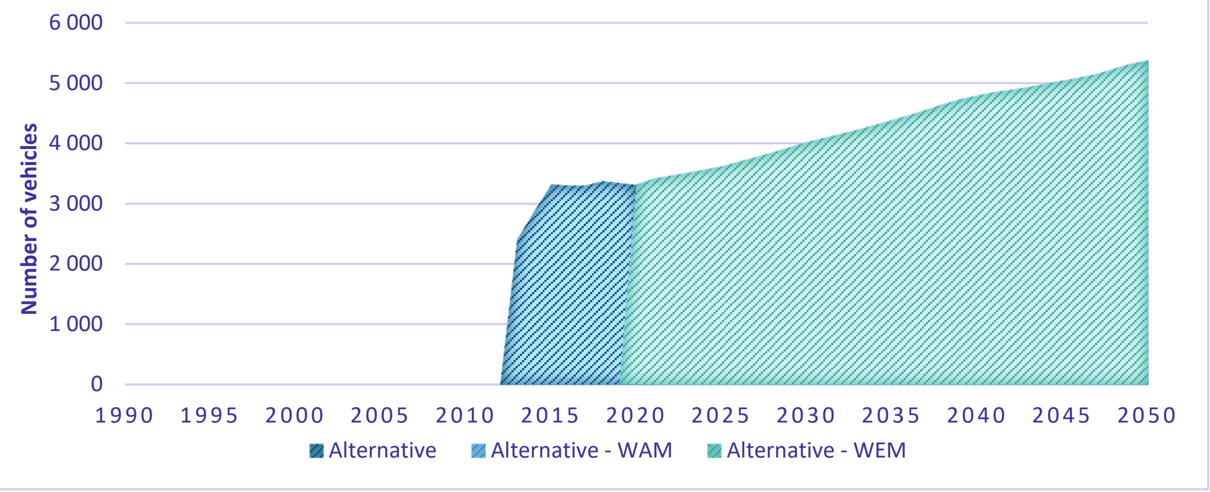
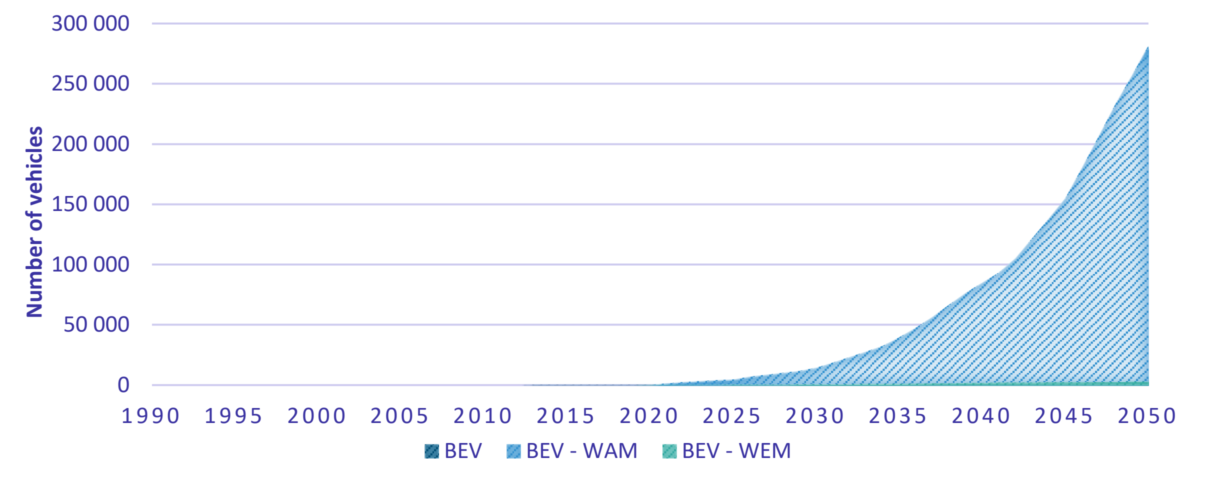


*Figure 3.9: Development of electric and hydrogen light-commercial vehicles in WEM and WAM scenarios*




## 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. At the same time, these projections yet do not reflect the European Commission's latest proposal to end the sales of GHG-emitting HDV around the year 2040.

In the WEM scenario, there is a steady increase in the number of HDVs (***Figure 3.10***) 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 (***Figure 3.11***) 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 (***Figure 3.12***). This is limited, as for the other categories, only by the production capacities of the car manufacturers.

*Figure 3.10: Development of HDV fleet with conventional engine in WEM and WAM scenarios*

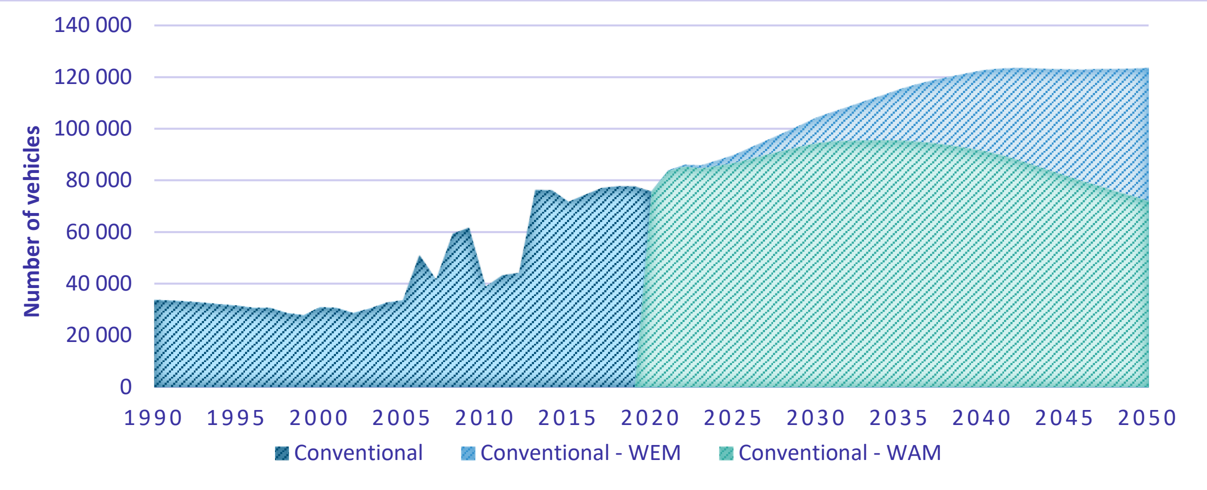


*Figure 3.11: Development of alternative fuel HDV fleet in WEM and WAM scenarios*

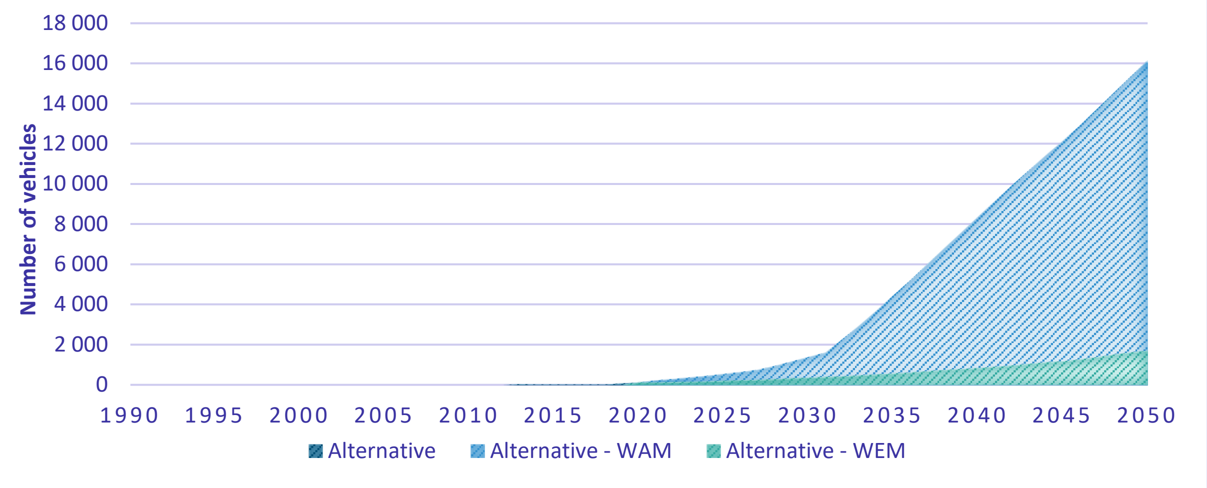
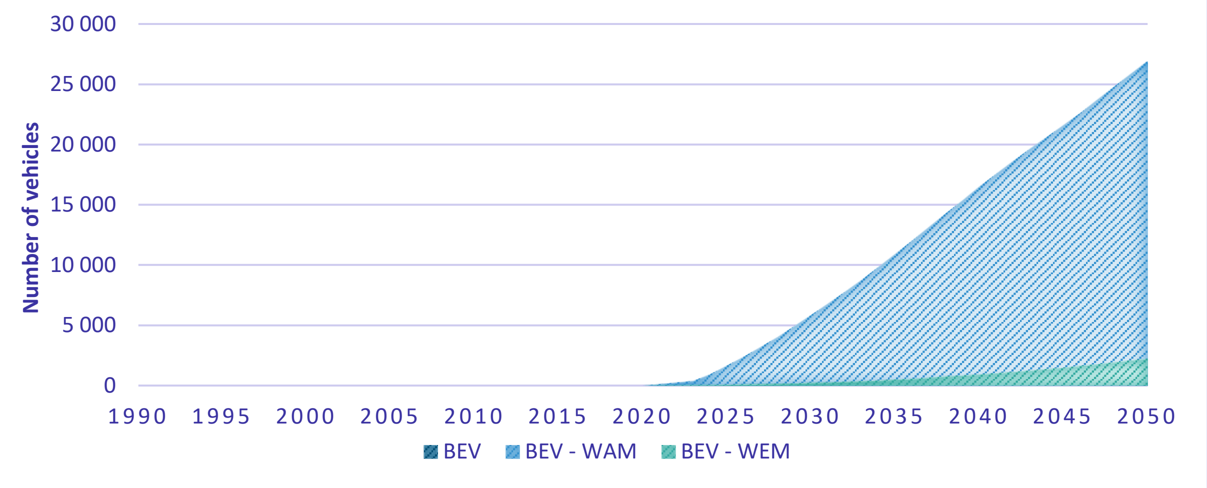



*Figure 3.12: Electric and hydrogen HDV fleet development in WEM and WAM scenarios*




## 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. 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. In the WEM scenario, emissions from PPT account for about 3.1% of total emissions, and in the WAM scenario, they are projected to account for about 3.7% in 2030 after annual rise of mileage. Given the small share in road transport, no major interventions in the form of measures to change the bus fleet 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 3.13: Development of conventional fuel buses in WEM and WAM scenarios*

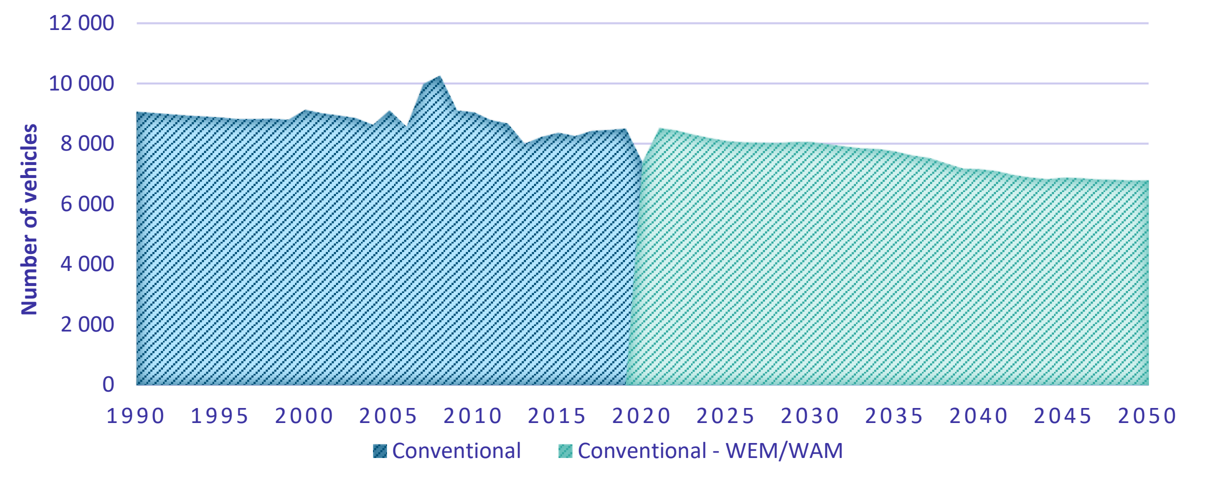



*Figure 3.14: Development of alternative fuel buses in WEM and WAM scenarios*

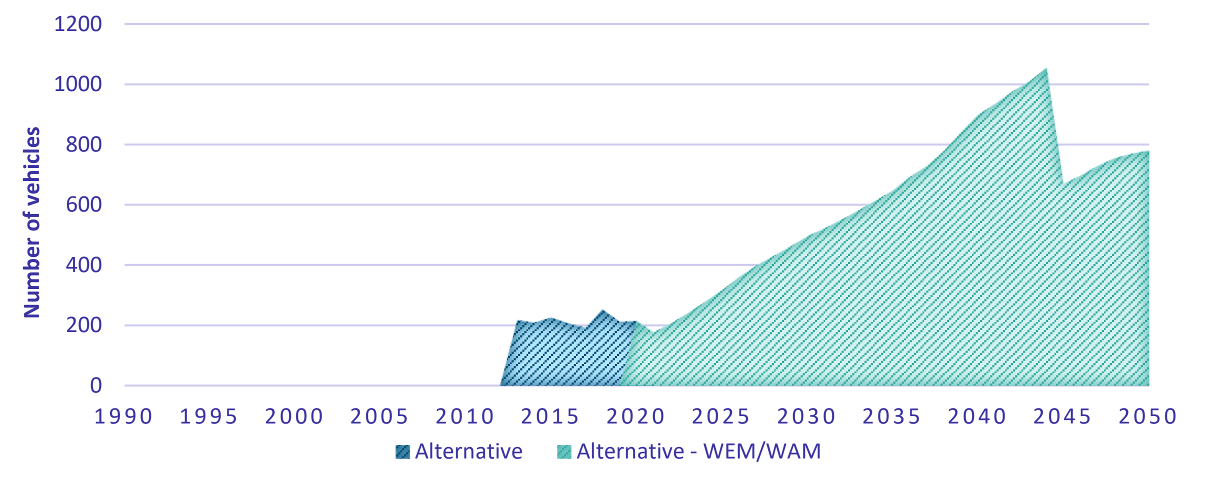
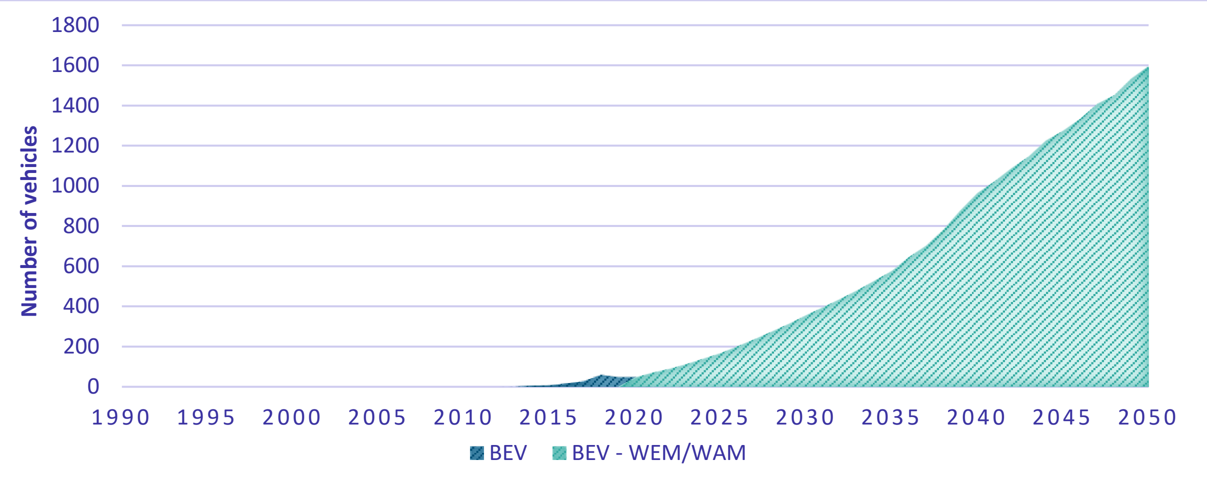



*Figure 3.15: Development of electric and hydrogen buses in WEM and WAM scenarios*




### L-category (L1 toL7)

This category includes all two-and three-wheel vehicles. In addition to these, all-terrain vehicles (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.

***Figure 3.16:*** *Evolution of L-category conventionally powered vehicles in scenarios WEM = WAM*

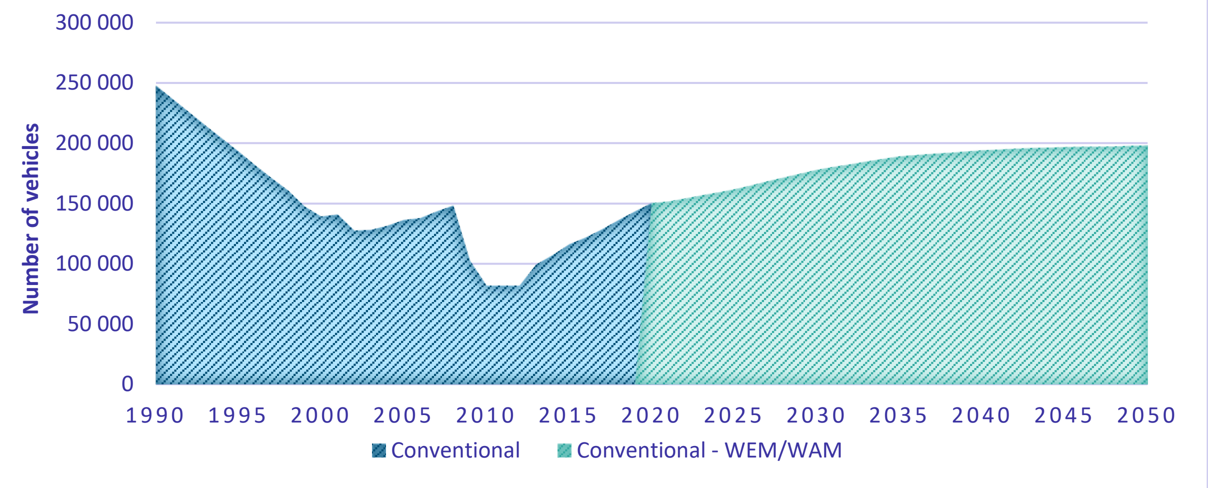
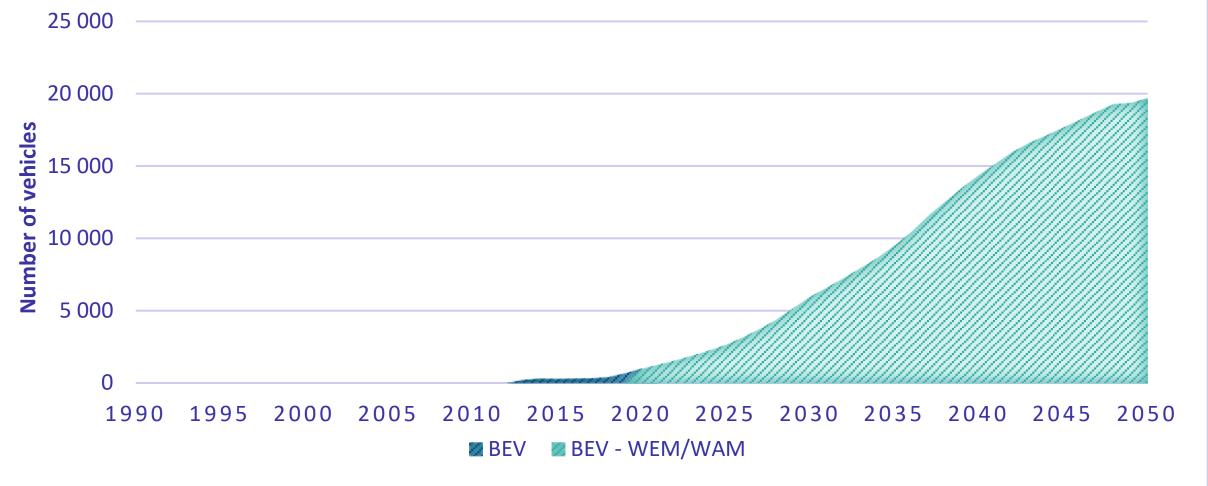



***Figure 3.17:*** *Development of electric and hydrogen L-category vehicles in scenarios WEM = WAM*




## 3.2. Model Description (Road transport)

Input data for the calculation of emission 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 2013-2020. 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 2013-2020, 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 3.6:*** *SWOT analysis of the COPERT CLI model*

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

Estimates for the period 2021-2050 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 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 based on data from the above-mentioned projects and EUROSTAT data.

The COPERT model is used for the actual calculation using the CLI module (Command Line Interface), 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 2021 (EMEP GB 2021) 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 air pollutant separately. Actual values for 2020 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.

## 3.3. Scenarios, Parameters and PAMs (Road transport)

Slovakia prepared two scenarios for road transport: WEM and WAM scenario. The WEM scenario describes the development of vehicle fleet and air pollutants using only existing measures in force until 2020.

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 2019 (the year 2020 was excluded as a pandemic year and thus unusual year).

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 air 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 2019. All measures are contained directly in the Low Carbon Strategy of the Slovak Republic (NUS SR) and subsequently in the National Energy and Climate Plan (NECP) or the NECP directly refers to other strategies where these measures are found (including the NAPCP). 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 Directive (EU) 2018/2001 of the European Parliament and of the Council (RED II) 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 (electric cars or fuel-cell electric vehicles)
- 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 II Directive on the promotion and use of energy from renewable sources is currently still not fully transposed into national legislation (was done in the course of 2022). Its validity and inclusion in the WEM scenario was necessary and mandatory based on the scenario preparation framework. The revised RED II Directive sets new targets for the blending of renewable fuels (biofuels) into fossil fuels. The new, increased targets are:

| 2020 | 2021 | 2022 | 2023 | 2024 | 2025 | 2026 | 2027 | 2028 | 2029 | 2030 |
|---|---|---|---|---|---|---|---|---|---|---|
| 7.6% | 8.0% | 8.2% | 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 promotion of electromobility can be seen in ***Figures 3.14*** and ***3.17***. The projected share of low- and zero-emission vehicles (BEV) in the fleet can be seen in the ***Figure 3.18***. Passenger cars account for the largest share of electromobility, accounting for 89% in 2020, 98% in 2025 and up to 99% of all electric vehicles on the road in 2030.

***irFigure 3.18:*** *Share of zero-emission vehicles in the total vehicle fleet of the Slovak Republic - historical development and projections to 2050*


The estimated percentage of electric vehicles (EVs) in the passenger car category is shown in ***Table 3.7***. This is a more conservative estimate of the number of EVs in 2030 than in the EU Reference Scenario. According to the EU Reference Scenario, the share of EVs in the EU as a whole is expected to reach 25% in 2030.

***Table 3.7:*** *Share of electric vehicles in the passenger car fleet according to historical data and projected development*

| Years | 2015 | 2020 | 2025 | 2030 | 2035 | 2040 | 2045 | 2050 |
|---|---|---|---|---|---|---|---|---|
| EV share on passenger cars | 0.01% | 0.08% | 1.58% | 5.40% | 11.74% | 20.18% | 30.53% | 45.47% |
| Number of EV (*pcs*) | 194 | 2 644 | 41 844 | 157 304 | 357 644 | 619 698 | 930 934 | 1 366 982 |

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 air pollutants. Both EU regulations (2019/631 and 2019/1242) are also incorporated into the model this way. ***Table 3.8*** shows the coefficient used for selected vehicle groups in the model for new vehicles.

**Table 3.8:** *Energy efficiency coefficients for selected groups of new vehicles*

| Years/Category | 2020 | 2025 | 2030 | 2035 | 2040 | 2045 | 2050 |
|---|---|---|---|---|---|---|---|
| Passenger vehicles | 0.6% | 1.9% | 3.4% | 4.5% | 5.2% | 5.7% | 6.1% |
| Light-commercial vehicles | 0.9% | 2.8% | 4.6% | 6.1% | 7.2% | 8.2% | 9.2% |
| Heavy-duty vehicles | 0.7% | 3.0% | 5.2% | 6.7% | 7.8% | 8.6% | 9.3% |
| Buses | 0.6% | 2.9% | 5.1% | 6.6% | 7.6% | 8.4% | 9.1% |
| L-category | 0.7% | 2.8% | 4.7% | 5.9% | 6.4% | 6.8% | 7.3% |

## 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 2020. The list of policies and measures used is summarised in ***Table 3.9***.

**Table 3.9:** *List of policies and measures used in WAM scenario*

| PAMS | Source (strategy, action plan, etc.) | Quantifiable (yes/no) |
|---|---|---|
| **Continued direct support for the use of low-emission vehicles** | Action plan for the development of electric vehicles in the Slovak Republic | Yes |
| **Long-term financial mechanism to support the development of charging infrastructure** | Action plan for the development of electric vehicles in the Slovak Republic | No, supporting |
| **Setting stricter requirements for periodic technical inspections of vehicles** | National Air Pollution Control Program | Yes |
| **Vehicle registration fee based on g $CO_2$/km emissions** | Act in preparation at the Ministry of Finance of the Slovak Republic | Yes |
| **Information campaign** | Action plan for the development of electric vehicles in the Slovak Republic | No, supporting |
| **Education in schools; awareness of new skills and knowledge in education** | Review and update of the National Policy Framework for the Development of the Alternative Fuels Market | No, supporting |
| **Modal shift in passenger transport** | Strategic Transport Development Plan 2030 | yes |
| **Modal shift in the transport of goods** | Strategic Transport Development Plan 2030 | Yes |
| **Introduction and promotion of hydrogen powered vehicles (FCEV)** | European Hydrogen Strategy | Yes |
| **Addition of biomethane to CNG and LNG** | RED II, Act No. 309/2009 Coll. (adopted in 2022) | yes |

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. It is expected that further significant subsidy schemes will be introduced and that the share of electric vehicles will increase to 65% between 2025 and 2050. ***Table 3.10*** shows how the more significant increase is reflected in the number of EVs in the fleet.

**Table 3.10:** *Share of electric vehicles in the passenger car fleet after the introduction of the measure "Continued direct support for the use of low-emission vehicles"*

| Years | 2020 | 2025 | 2030 | 2035 | 2040 | 2045 | 2050 |
|---|---|---|---|---|---|---|---|
| **Share of electric vehicles in the passenger car fleet** | 0.19% | 3.80% | 13.88% | 26.78% | 39.67% | 52.57% | 65.47% |
| **Number of electric vehicles (pcs)** | 4 544 | 100 427 | 404 332 | 815 529 | 1 218 148 | 1 603 241 | 1 968 268 |

A suggested indicator of the implementation of this measure and also an indicator for the trajectory of the reduction of $CO_2$ emissions from new passenger vehicles is the share of new battery electric vehicles (BEVs) in the total sales of new passenger vehicles. The share that would need to be met each year to meet the 55% reduction target in g $CO_2$/km for newly registered vehicles by 2030 and was agreed as part of the Fit for 55 package. This share can be seen in ***Table 3.11***. Legislation limiting emissions from new vehicles to 100% comes into force in 2035.

***Table 3.11:*** *Indicator of progress towards the Fit for 55 target*

| Years | Share of new BEV | Share of subsidised BEV Of new BEV |
|---|---|---|
| **2021** | 8.38% | 27.8% |
| **2022** | 11.69% | 100.0% |
| **2023** | 19.46% | 14.1% |
| **2024** | 23.57% | 26.7% |
| **2025** | 37.05% | 71.3% |
| **2026** | 43.89% | 67.2% |
| **2027** | 47.96% | 66.4% |
| **2028** | 49.64% | 74.4% |
| **2029** | 65.01% | 55.5% |
| **2030** | 62.69% | 64.0% |
| **2031** | 65.15% | 57.7% |
| **2032** | 64.66% | 60.1% |
| **2033** | 69.10% | 51.3% |
| **2034** | 67.23% | 56.1% |
| **2035** | 64.22% | 63.8% |

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 expert estimates, the introduction of additional inspection mechanisms could help to phase out between 0.01% and 0.05% of vehicles older than 15 years per year. 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.

The introduction of a new registration fee, or "environmental tax", takes into account the production of $CO_2$ emissions by passenger cars and is expertly estimated at between 0.1% and 0.3% of the end-of-life passenger cars with the highest emissions. These are mostly older vehicles, as are the technical and emissions inspections. The effect of this measure is reflected in the model in the change in the age structure of passenger cars. A gradual fading will also be observed for this measure.

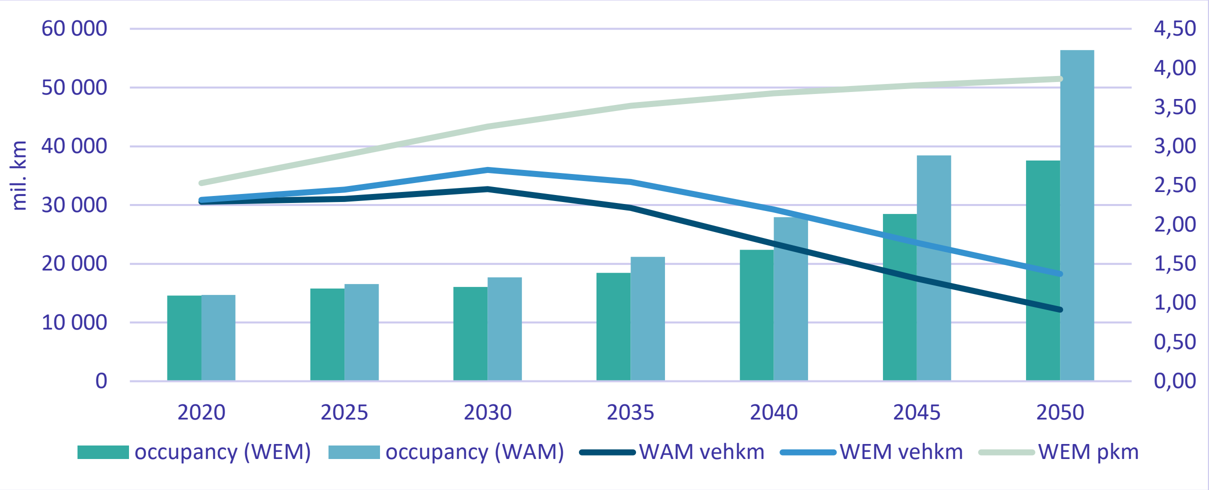
Modal shift in passenger transport implies a shift of passengers from passenger vehicle transport to public passenger transport (PPT). As a result, the occupancy rate of passenger vehicles is expected to increase by 50% compared to 2020, reducing in particular the amount of kilometres travelled by passenger 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 3.19***).

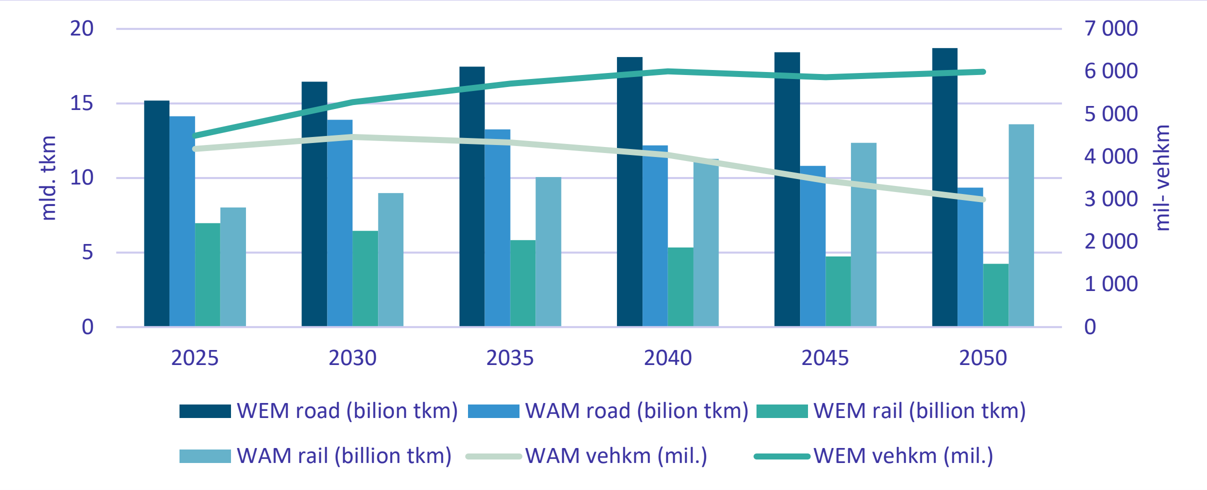
***Figure 3.19:*** *Changes in passenger vehicle occupancy, annual passenger vehicle miles travelled, and passenger vehicle miles travelled by CPS+ model*




<u>Modal shift in freight transport</u> 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 3.20***).

***Figure 3.20:*** *Changes in freight transport, annual boarding and goods transported by road and rail (billion tkm)*

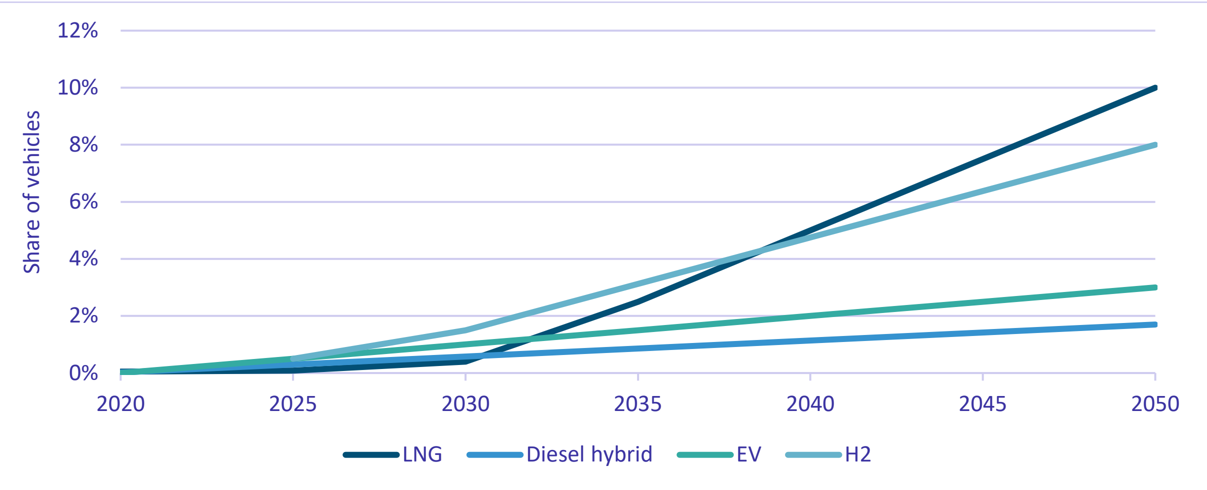



The most effective measure in this scenario appears to be the phasing out of fossil fuelled cars and light-commercial vehicles and their replacement by electric and hydrogen vehicles, especially for last mile goods movements. A complete ban on the sale of these pure fossil fuel vehicles (diesel and petrol) 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 could also facilitate the introduction of low emission zones in cities. The low emission zones measure is not part of the package of measures for the WAM scenario as the quantification of such a measure would be difficult and burdened with high uncertainty due to regional differences.

Similarly, traditional fossil fuel trucks are expected to be phased out and replaced by hybrid, electric, hydrogen or LNG vehicles. To support this measure, the same subsidy mechanism will need to be put in place as for passenger cars. The uptake of these engines is generally slow and only becomes apparent after the year 2030. In the case of hydrogen engines, the European Hydrogen Strategy mentions of a maximum hydrogen deployment rate of 16% by 2050 within heavy-duty vehicles. In Slovakia, this level is set at 8% in the WAM scenario, based on a consensus of experts in the field. Hybrid and electric motorisation is at 4.7% by 2050. The uptake of LNG vehicles is projected at 10% by 2050 (***Figure 3.21***). This growth is assumed to be in addition to the natural growth of alternative and zero-emission trucks.

***Figure 3.21:*** *Percentage growth of additional trucks using alternative and BEV fuels*



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.

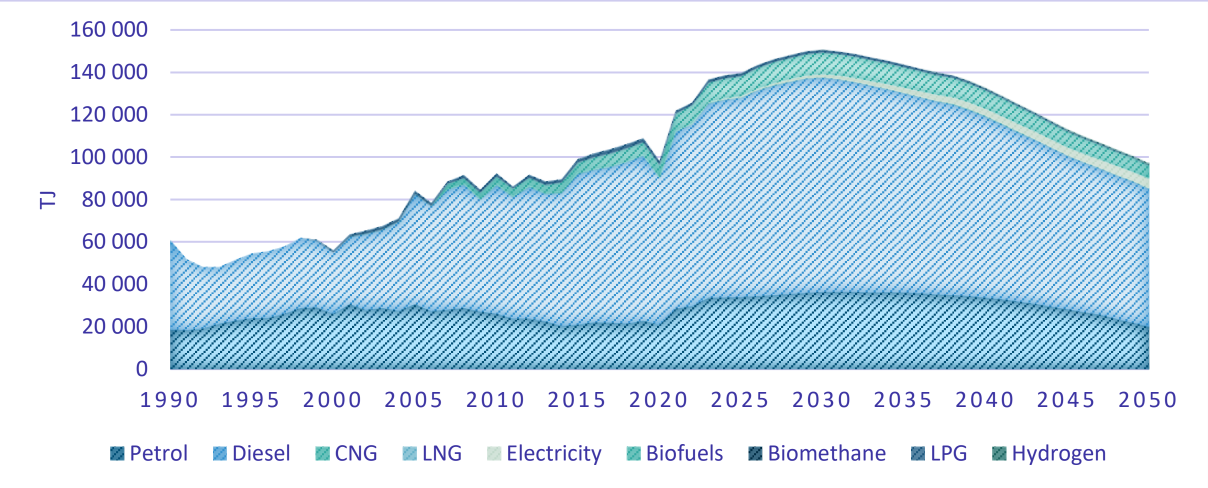
The addition of bio-based methane (bio-methane) to vehicle fuels is now common practice in other EU countries. In Slovakia, this obligation will be introduced by the amendment of Act No. 309/2009 on the Promotion of Renewable Energy Sources and High Efficiency Combined Production. As the amendment was not adopted before 31 December 2019, it could not be implemented as a WEM scenario measure. 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.

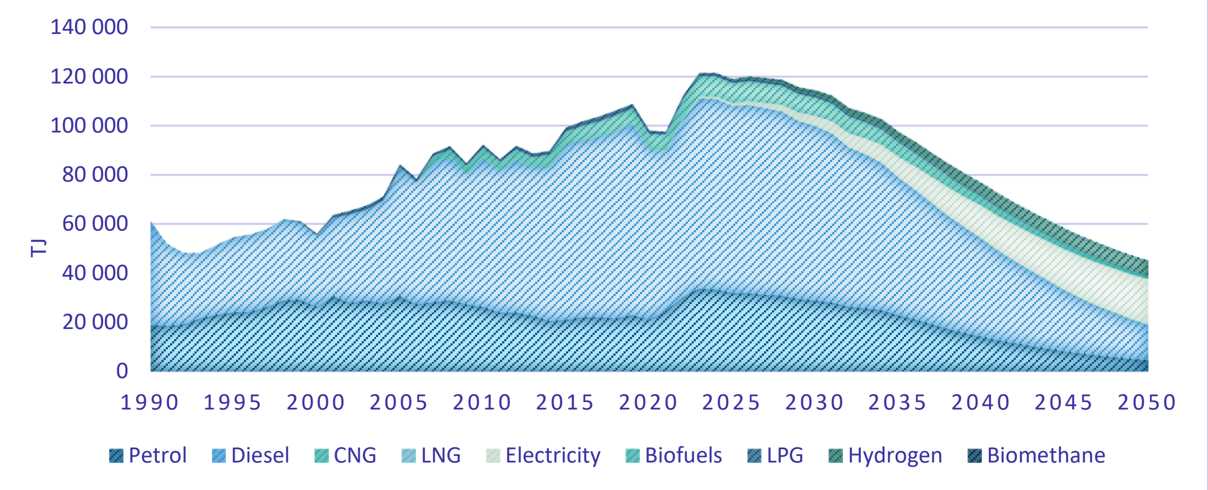
Energy consumption: in terms of energy, according to the WEM scenario, in Slovakia will dominate consumption of diesel oil until 2050. Its consumption will slowly decrease in this scenario but will still account for up to 67% of the total energy consumption of road transport in 2050. From other alternative fuels will be the most dominant electricity consumption, rising gradually from a share of 1% (1 200 TJ or 330 GWh) in 2030 to around 5% (4 450 TJ or 1 230 GWh) in 2050 (***Figure 3.22***).

***Figure 3.22:*** *Historical evolution of the energy demand for road transport for the years 1990-2020 and WEM scenario 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 3% (4 000 TJ or 1 100 GWh) in 2030 and up to 40% (18 300 TJ or 5 000 GWh) of the total energy demand in 2050 (***Figure 3.23***). Diesel oil will still have a similarly important but significantly smaller share, with a share of 62% in 2030, falling to half (31%) in 2050. This significant share, despite strong decarbonisation, is mainly due to the truck category, which is extremely difficult to decarbonise while maintaining the parameters required of them.

***Figure 3.23:*** *Historical evolution of the energy demand for road transport for the years 1990-2020 and assumed evolution under the WAM scenario*




## 3.4. Emission Projections in other Transport

### $NO_x$ emissions

The NOx emissions are continuously decreasing (***Figure 3.24***), and according to the WEM scenario, 86% of the remaining emissions in 2050 are from freight transport. The decrease in emissions is based on fleet turnover towards newer technologies (EURO 6 D/E) but with only a minor inclination towards alternative fuels.

On the other hand, the WAM scenario shows a higher diversification of fuel technologies and a significant reduction in emissions by 2050 (***Figure 3.25***).

***Figure 3.24:*** *Historical emissions and projections of NOx emissions according to WEM scenario*

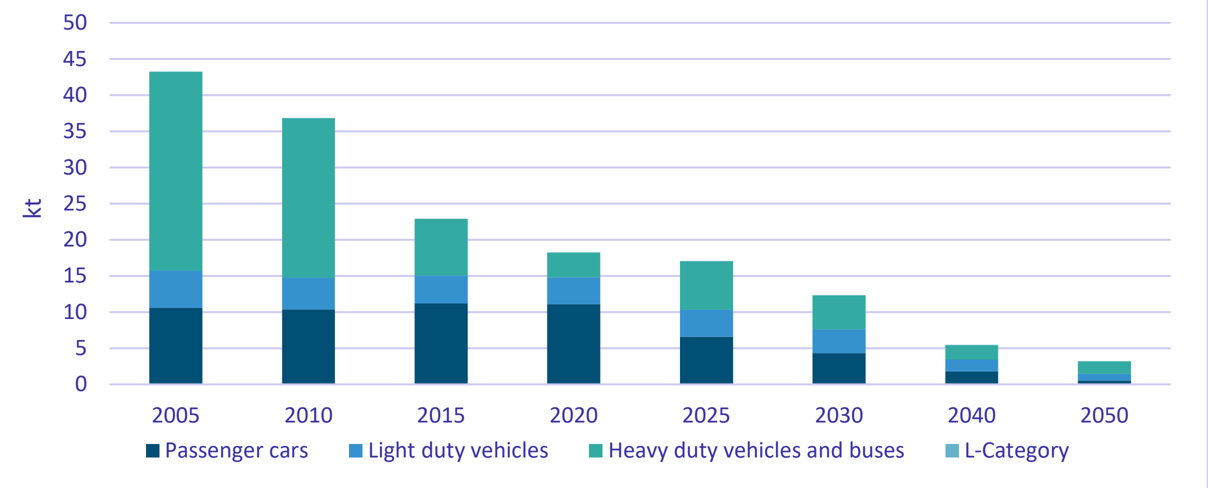
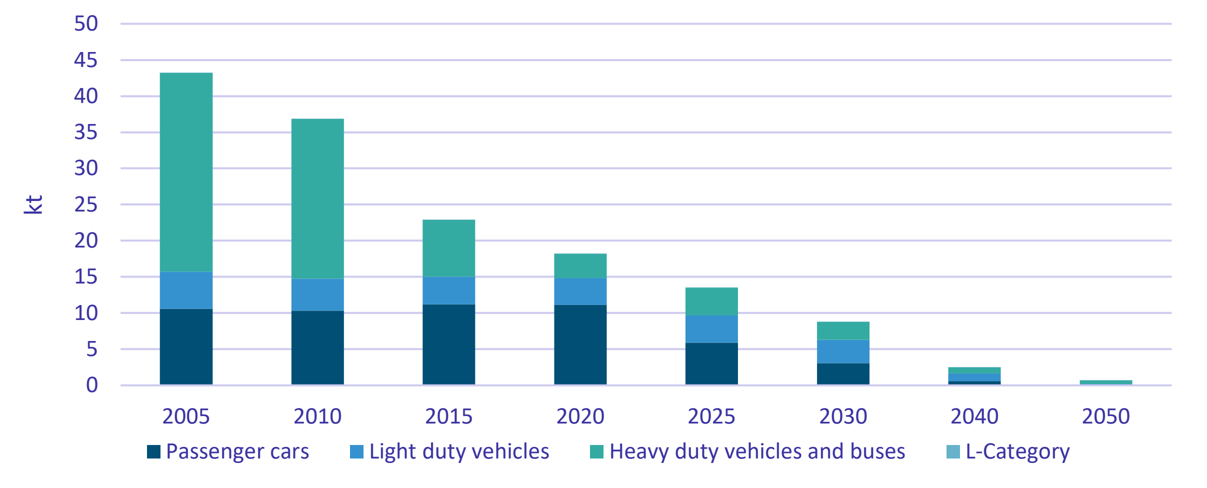


*Figure 3.25: Historical emissions and projections of NOx emissions according to WAM scenario*




## $PM_{2.5}$ emissions

Most of the $PM_{2.5}$ emissions come from tire and brake wear abrasion, and road abrasion. Reduction of these emissions is possible only by decreasing the total traffic. In the WAM scenario (***Figure 3.27***), these emissions from electric and fuel cell electric vehicles are accounted for in the vehicle category since the COPERT model is currently unable to distinguish between exhaust and non-exhaust emissions for new vehicle categories. Even though the total emissions are 50% lower than the emissions in the WEM scenario (***Figure 3.26***).

A fraction of PM is also reported as black carbon (BC). There is a slight increase in these emissions in the WAM scenario from passenger cars. This increase is a result of the aforementioned missing capability of the COPERT model and higher average mileage. In the WAM scenario, it is assumed that there will be a more radical turnover of the vehicle fleet, which temporarily increases the total mileage of the fleet. BC is calculated as a fraction of $PM_{2.5}$, and these emissions come not only from exhaust emissions but also from brake and tire wear and road abrasion. The emissions from the last source depend only on the total mileage of the vehicle fleet, thus these emissions will be temporarily higher. With the predicted decrease in traffic after 2030, the emissions of $PM_{2.5}$ and BC will also decrease.

*Figure 3.26: Historical emissions and projections of $PM_{2.5}$ emissions according to WEM scenario*

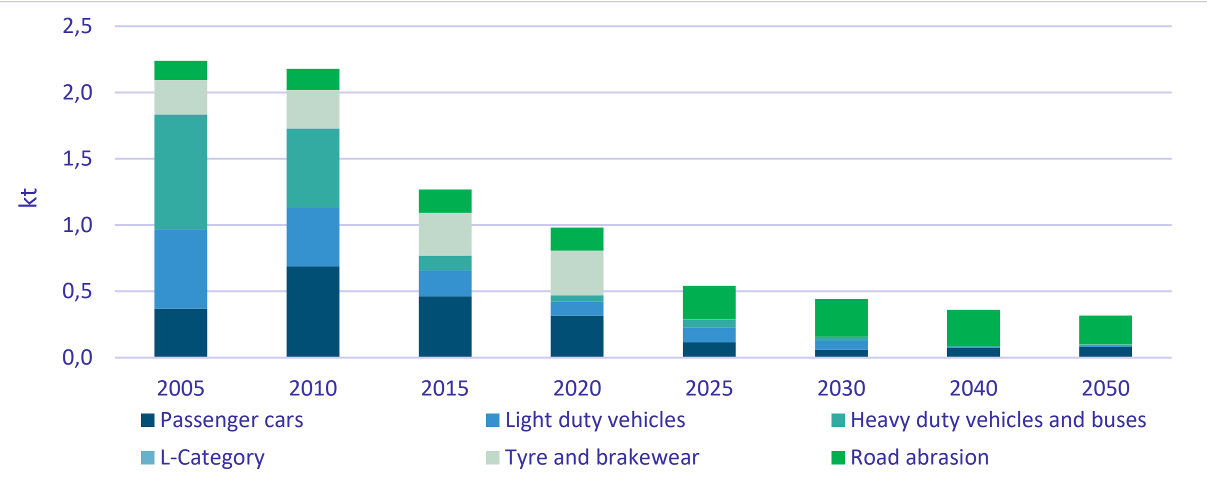
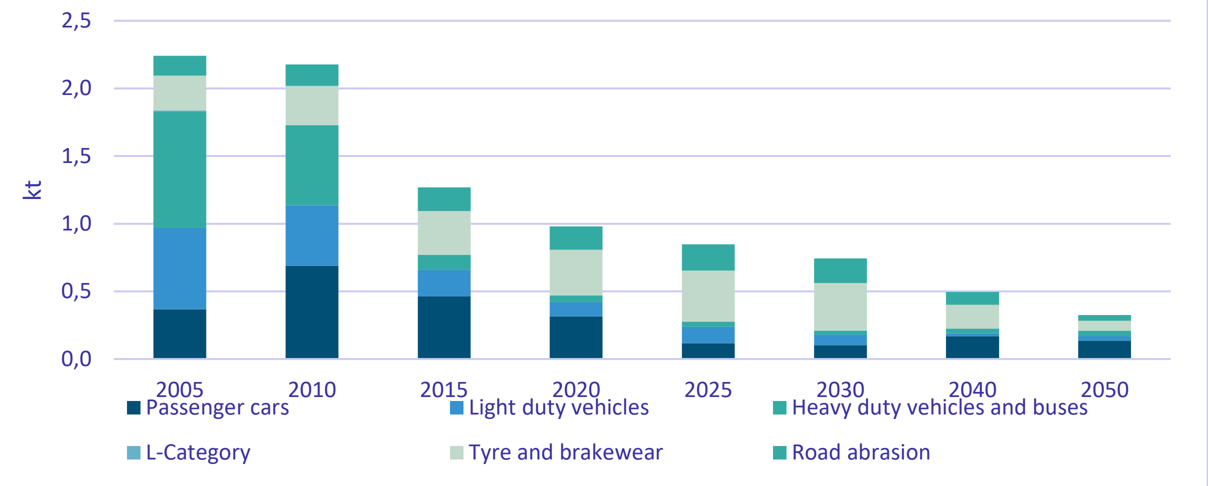


**_Figure 3.27:_** _Historical emissions and projections of $PM_{2.5}$ emissions according to WAM scenario_




## NMVOC emissions

The most important source of NMVOC emissions from road transport is gasoline evaporation and passenger cars. These emissions depend on technological advantage of the vehicle and ambient temperature. There is a predicted decrease in NMVOC emission in the WEM scenario, but only a slight change in the ratio between the two major categories (**_Figure 3.28_**). In the WAM scenario (**_Figure 3.29_**), passenger cars (38%) and gasoline evaporation (55%) are responsible for 93% of NMVOC emissions in 2030, while in 2050, 83% of NMVOC emissions come from gasoline evaporation. At the same time, there is a significant decrease in these emissions, which is caused by the electrification of road transport.

**_Figure 3.28:_** _Historical emissions and projections of NMVOC emissions according to WEM scenario_

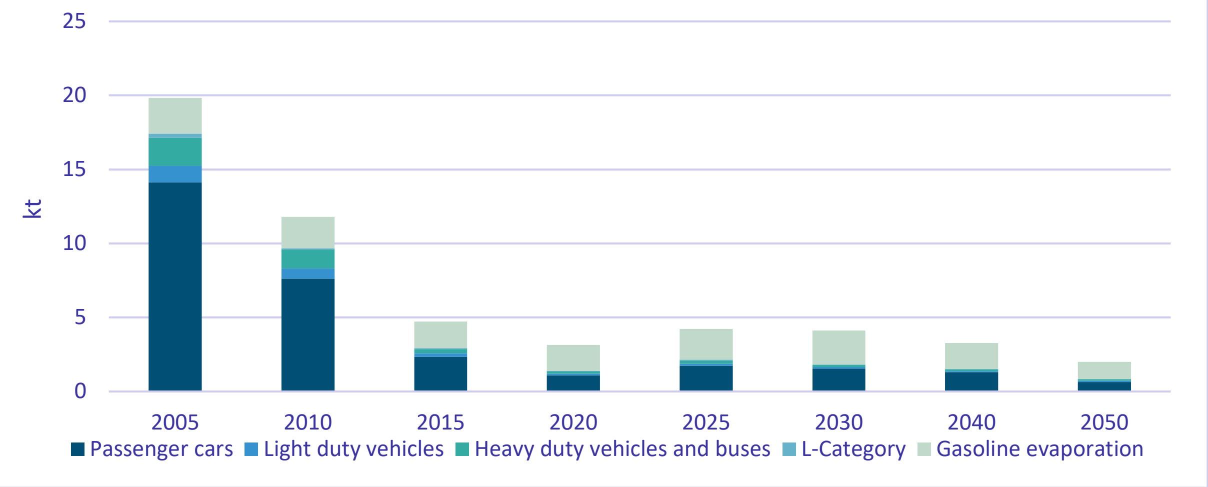
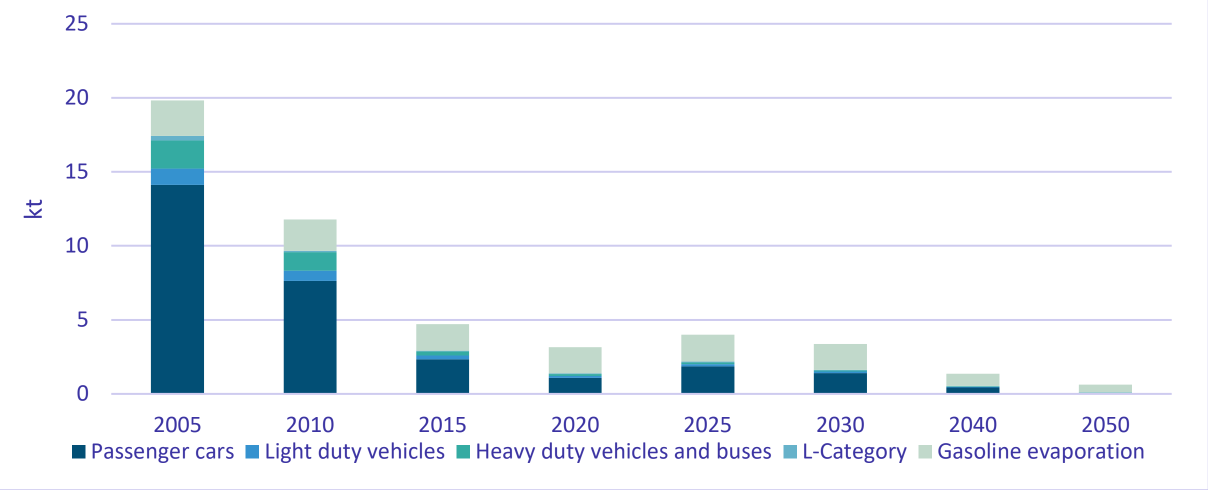


**Figure 3.29:** *Historical emissions and projections of NMVOC emissions according to WAM scenario*




## $SO_X$ emissions

Sulphur oxide emissions significantly decreased after 2005 as a result to banning high-sulphur content fuels. These emissions depend on the fuel consumption, and in the WEM scenario (***Figure 3.30***), a decrease of $SO_X$ is assumed after 2030. The tipping point of $SO_X$ in the WAM scenario (***Figure 3.31***) is assumed to be much earlier, around the year 2025.

**Figure 3.30:** *Historical emissions and projections of $SO_X$ emissions according to WEM scenario*

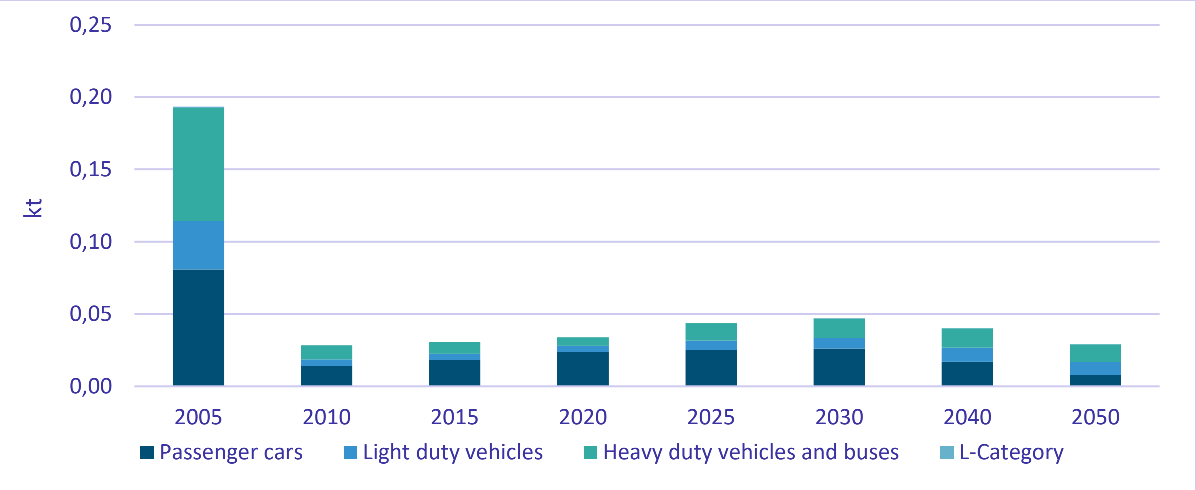
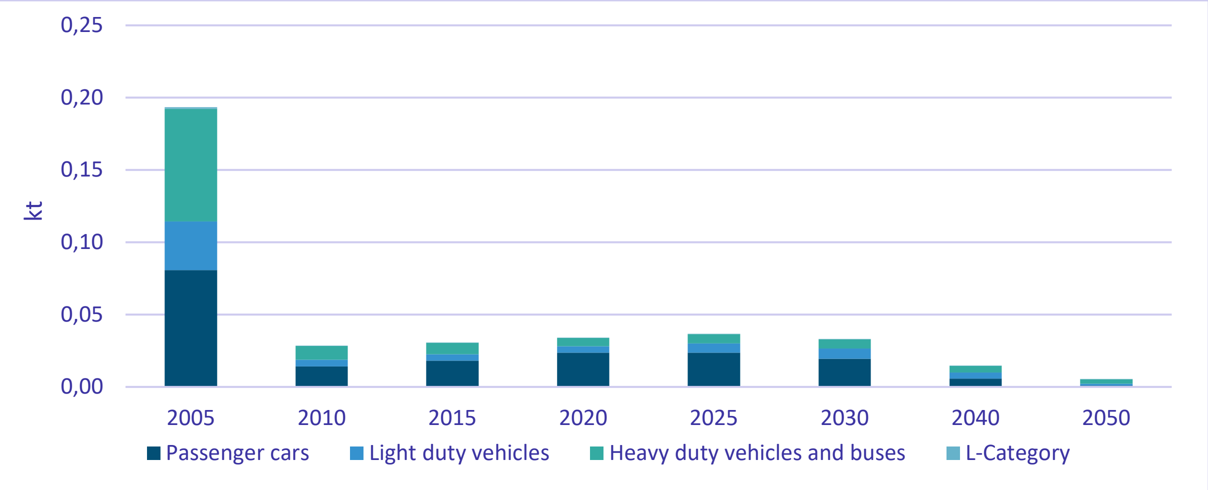



**Figure 3.31:** *Historical emissions and projections of $SO_X$ emissions according to WAM scenario*



### $NH_3$ emissions

Ammonia emission trends are mainly a result of a phenomenon is known as "emission control technology rebound" or "emission shifting." This phenomenon slows down the possible reduction of ammonia emissions in the road transport. This will cause the ammonia emission according to the WEM scenario, to stay at the same level as in 2020 (***Figure 3.32***). In the WAM scenario (***Figure 3.33***) alternative fuels (electricity and hydrogen) are introduced, and ammonia emissions will fall to 25% of the emissions compared to the WEM scenario by 2050.

***Figure 3.32:*** *Historical emissions and projections of $NH_3$ emissions according to WEM scenario*

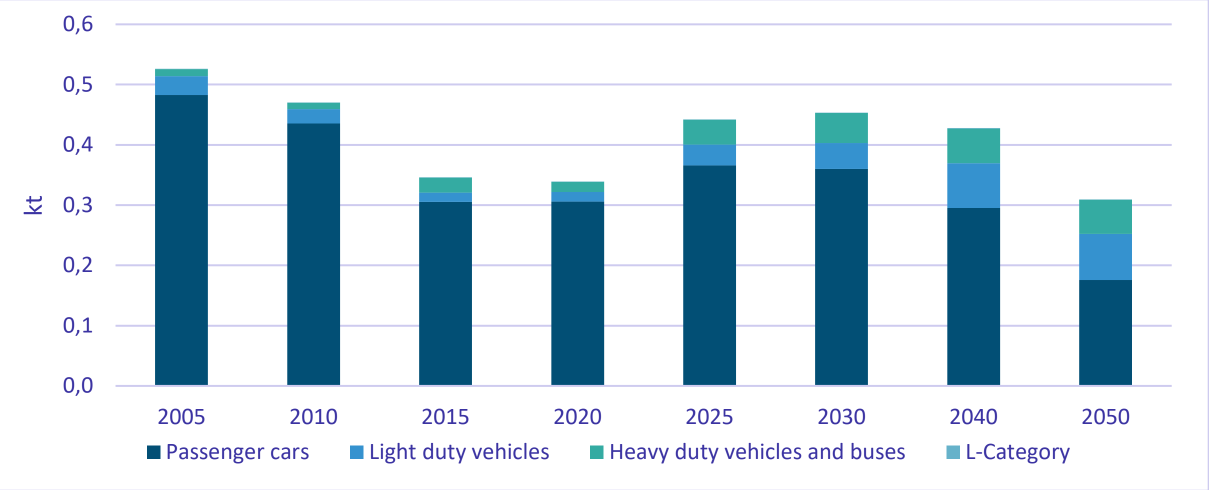
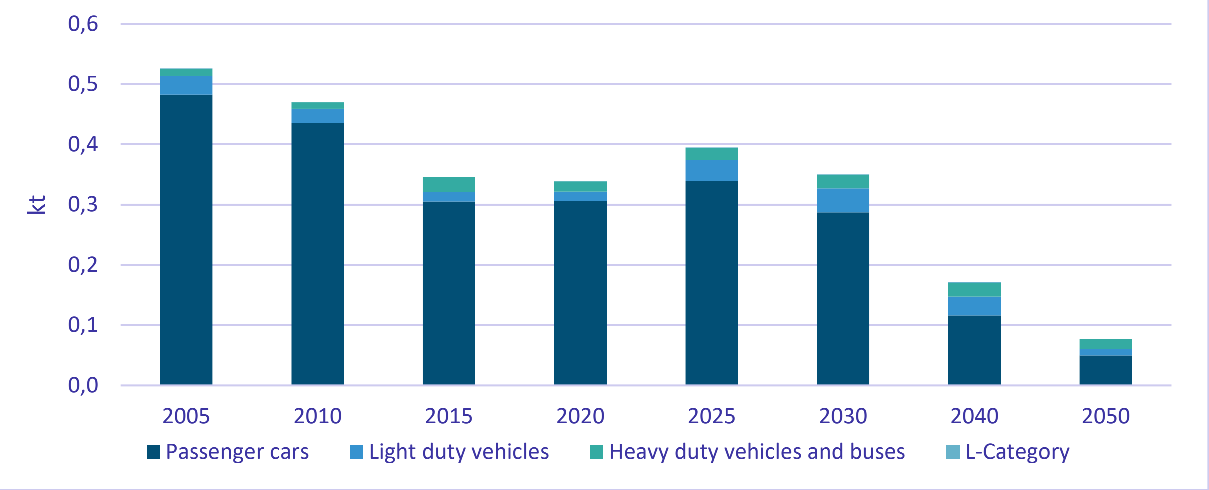



***Figure 3.33:*** *Historical emissions and projections of $NH_3$ emissions according to WAM scenario*




## 3.5. Emission Projections in other Transport Categories (1.A.3.a, c, d, e)

In addition, projections of air pollutants from non-road transport in the Slovak Republic have been prepared, but their relevance to overall air pollution emission projections are negligible, so only the WEM scenario has been prepared. Highest ratio of non-road transport have the $NO_X$ with a 12% share (excluding $SO_X$ as these emission from the whole transport are negligible).

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. The outcome are in ***Tables 3.1-3.5***.

# CHAPTER 4. EMISSION PROJECTIONS IN THE IPPU SECTOR

## 4.1. Methodologies and Key Assumptions/Trends

Emission projections from industrial processes come from processes other than fuel combustion. 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. 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.

Metal production has a long history in Slovakia and a decline in production is not expected. However, iron and steel production reflects the economic situation. After the COVID-19 crisis in 2020, there is a clear decline in production (-40%) and thus in emissions produced. However, the amount of iron and steel produced has increased after 2020 and the intention is to maintain it in the future.

Issues in the IPPU generally reflect any economic crisis. This can also be seen in steel production in 2020, when iron and steel production declined due to the COVID-19 pandemic. However, no major changes in production are expected in the coming years.

In the iron and steel sector, it is possible to reduce AP emissions by reducing the consumption of coke as a fuel for energy processes and as a reducing agent in blast furnaces. However, this would result in a reduction in steel production and hence economic problems for the region. One of the most recent measures in the iron and steel sector is electric arc furnaces. The current set of measures foresees investments in technology, which should lead to significant emission savings in the sector.

The share of enterprises in the non-metallic and chemical industries is also significant.

One of the most effective measures in reducing emissions in the non-metallic industry is waste recovery. Specific waste mineral wastes can, by their chemical composition, replace natural raw materials such as limestone or clay that have to be extracted from nature. Many of them also contribute to reducing emissions of air pollutants.

The trend in the chemical industry is influenced by various segments. Slovakia has a strong tradition in all major segments of the chemical industry including oil refining, fertilizer production, rubber and plastics. The product portfolio is also influenced by the strong automotive and electronics sectors in Slovakia, which serve as regular high-capacity clients for various companies in the chemicals and plastics industries.

No closure of existing chemical facilities is currently anticipated or planned. As regards the trend in emissions from the chemical industry, it is expected to be fairly constant and no significant decrease is foreseen. However, the largest reductions in this sector could be due to reductions in the production or consumption of fuels by cars and trucks, or reductions in the consumption of artificial fertilisers in agriculture. By transforming the production of petroleum-based fuels to the production of green hydrogen as a fuel using RES, or by producing more advanced biofuels and bioplastics.

Sectors 2D and 2G are key sources for NMVOC emissions. The calculation of emission projections are based on following parameters: gross value added for relevant sector, expected population trend and extrapolation of trends from the past. Since these are key categories, in the future it will be necessary to improve the methodology for calculating emissions projections.

## 4.2. Model Description

Model description used for the EU ETS part of IPPU emissions (large sources of technological emissions) is provided in the **Chapter 2.2**. MS Excel tools were used for modelling emission projections in the sources outside of the EU ETS system. Emission projections were prepared in accordance with the methodology of the EMEP/EEA air pollutant emission inventory guidebook 2016. 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

## 4.3. Scenarios, Parameters and PAMs

The IPPU sector allocates emissions from sources regulated by EU ETS Directive 2003/87/EC of the European Parliament and of the Council and non-EU ETS sources (ESR).

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. 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).

ESR emissions in categories 2.A-2.I were mainly prepared by forecasting the development of value added for the identified industrial category and also based on population trends. 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 AP emission projections was the latest revised inventory year 2019 in all scenarios.

Projections of air pollutants 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.

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)

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 2021. 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.

The trend of emission projections below the ESR in categories 2.A to 2.I is very complicated to express due to the lack of legislative and market mechanisms, which are mainly driven by energy policy. The trend of emission projections depends on the technologies used, which are mainly influenced by the EU ETS Directive, therefore emission reductions cannot be expected as production grows.

## 4.4. Emission Projections in the IPPU Sector

The modelling of emission projections in the IPPU sector was based on sectoral trends and development from the CPS model and actualization was made by taking into account results of model TIMES and new information from producers. Significant impact has planned new installations in steel production.

### NOx emissions

The $NO_X$ emission projections in the IPPU sector are mostly driven with the EU ETS emissions from metal production, in addition with the chemical industry. The trends according to the WEM and WAM scenarios are provided in the ***Table 4.1***.

***Table 4.1:*** *NOx emissions in sector Industry*

| WEM | 2005 | 2010 | 2015 | 2020 | 2025 | 2030 | 2040 | 2050 |
|---|---|---|---|---|---|---|---|---|
| 2.A,B,C,H,I,J,K,L | 6.70 | 5.91 | 6.48 | 5.74 | 7.07 | 6.60 | 6.52 | 6.09 |
| 2.D, 2.G | 0.01 | 0.02 | 0.02 | 0.01 | 0.02 | 0.01 | 0.01 | 0.01 |
| **2 Industry** | **6.71** | **5.92** | **6.50** | **5.75** | **7.08** | **6.61** | **6.53** | **6.11** |

| WAM | 2005 | 2010 | 2015 | 2020 | 2025 | 2030 | 2040 | 2050 |
|---|---|---|---|---|---|---|---|---|
| 2.A,B,C,H,I,J,K,L | 6.70 | 5.91 | 6.48 | 5.74 | 6.85 | 4.41 | 4.28 | 3.86 |
| 2.D, 2.G | 0.01 | 0.02 | 0.02 | 0.01 | 0.02 | 0.01 | 0.01 | 0.01 |
| **2 Industry** | **6.71** | **5.92** | **6.50** | **5.75** | **6.86** | **4.42** | **4.30** | **3.87** |

### NMVOC emissions

NMVOC emission projections in the IPPU sector arise mainly from the Coating applications, Domestic solvent use and Degreasing. Significant impact have also Food and beverages industry. The trends according to the WEM and WAM scenarios are provided in the ***Table 4.2***.

**Table 4.2:** *NMVOC emissions in sector Industry*

| WEM | 2005 | 2010 | 2015 | 2020 | 2025 | 2030 | 2040 | 2050 |
|---|---|---|---|---|---|---|---|---|
| 2.A,B,C,H,I,J,K,L | 7.32 | 5.32 | 6.23 | 5.88 | 7.38 | 7.02 | 6.93 | 6.48 |
| 2.D, 2.G | 30.76 | 22.46 | 25.68 | 20.89 | 19.58 | 18.23 | 17.82 | 17.50 |
| **2 Industry** | **38.08** | **27.78** | **31.91** | **26.77** | **26.97** | **25.25** | **24.75** | **23.98** |

| WAM | 2005 | 2010 | 2015 | 2020 | 2025 | 2030 | 2040 | 2050 |
|---|---|---|---|---|---|---|---|---|
| 2.A,B,C,H,I,J,K,L | 7.32 | 5.32 | 6.23 | 5.88 | 7.17 | 4.73 | 4.63 | 4.24 |
| 2.D, 2.G | 30.76 | 22.46 | 25.68 | 20.89 | 19.49 | 18.05 | 17.47 | 16.98 |
| **2 Industry** | **38.08** | **27.78** | **31.91** | **26.77** | **26.65** | **22.78** | **22.10** | **21.22** |

## $SO_X$ emissions

The $SO_X$ emission projections in the IPPU sector are mostly driven by the emissions from metal production and in addition with the chemical industry. The trends according to the WEM and WAM scenarios are provided in the ***Table 4.3***.

**Table 4.3:** *$SO_X$ emissions in sector Industry*

| WEM | 2005 | 2010 | 2015 | 2020 | 2025 | 2030 | 2040 | 2050 |
|---|---|---|---|---|---|---|---|---|
| 2.A,B,C,H,I,J,K,L | 11.43 | 7.30 | 9.05 | 6.63 | 8.03 | 7.23 | 7.10 | 6.61 |
| 2.D, 2.G | 0.02 | 0.03 | 0.03 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 |
| **2 Industry** | **11.45** | **7.33** | **9.09** | **6.65** | **8.05** | **7.25** | **7.12** | **6.63** |

| WAM | 2005 | 2010 | 2015 | 2020 | 2025 | 2030 | 2040 | 2050 |
|---|---|---|---|---|---|---|---|---|
| 2.A,B,C,H,I,J,K,L | 11.43 | 7.30 | 9.05 | 6.63 | 7.71 | 4.89 | 4.74 | 4.26 |
| 2.D, 2.G | 0.02 | 0.03 | 0.03 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 |
| **2 Industry** | **11.45** | **7.33** | **9.09** | **6.65** | **7.74** | **4.91** | **4.76** | **4.28** |

## $NH_3$ emissions

The $NH_3$ emission projections in the IPPU sector are in general negligible, the largest share comes from the chemical industry. The trends of emissions are provided in the ***Table 4.4***.

**Table 4.4:** *$NH_3$ emissions in sector Industry*

| WEM | 2005 | 2010 | 2015 | 2020 | 2025 | 2030 | 2040 | 2050 |
|---|---|---|---|---|---|---|---|---|
| 2.A,B,C,H,I,J,K,L | 0.24 | 0.09 | 0.13 | 0.24 | 0.24 | 0.25 | 0.24 | 0.23 |
| 2.D, 2.G | 0.03 | 0.04 | 0.04 | 0.03 | 0.04 | 0.03 | 0.03 | 0.03 |
| **2 Industry** | **0.27** | **0.12** | **0.17** | **0.27** | **0.28** | **0.28** | **0.27** | **0.26** |

| WAM | 2005 | 2010 | 2015 | 2020 | 2025 | 2030 | 2040 | 2050 |
|---|---|---|---|---|---|---|---|---|
| 2.A,B,C,H,I,J,K,L | 0.24 | 0.09 | 0.13 | 0.24 | 0.24 | 0.24 | 0.23 | 0.22 |
| 2.D, 2.G | 0.03 | 0.04 | 0.04 | 0.03 | 0.04 | 0.03 | 0.03 | 0.03 |
| **2 Industry** | **0.27** | **0.12** | **0.17** | **0.27** | **0.28** | **0.27** | **0.27** | **0.25** |

## $PM_{2.5}$ emissions

The $PM_{2.5}$ emission projections in the IPPU sector do not have a significant source and also their share in the national totals are very small. The trends of emissions are provided in the ***Table 4.5***.

***Table 4.5:*** *$PM_{2.5}$ emissions in sector Industry*

| WEM | 2005 | 2010 | 2015 | 2020 | 2025 | 2030 | 2040 | 2050 |
|---|---|---|---|---|---|---|---|---|
| 2.A,B,C,H,I,J,K,L | 1.30 | 0.71 | 0.95 | 0.62 | 0.63 | 0.64 | 0.63 | 0.61 |
| 2.D, 2.G | 0.18 | 0.24 | 0.23 | 0.21 | 0.23 | 0.21 | 0.21 | 0.20 |
| **2 Industry** | **1.48** | **0.96** | **1.18** | **0.83** | **0.86** | **0.85** | **0.84** | **0.81** |

| WAM | 2005 | 2010 | 2015 | 2020 | 2025 | 2030 | 2040 | 2050 |
|---|---|---|---|---|---|---|---|---|
| 2.A,B,C,H,I,J,K,L | 1.30 | 0.71 | 0.95 | 0.62 | 0.63 | 0.63 | 0.62 | 0.59 |
| 2.D, 2.G | 0.18 | 0.24 | 0.23 | 0.21 | 0.23 | 0.21 | 0.21 | 0.20 |
| **2 Industry** | **1.48** | **0.96** | **1.18** | **0.83** | **0.86** | **0.84** | **0.82** | **0.79** |

# CHAPTER 5. EMISSION PROJECTIONS IN THE AGRICULTURE SECTOR

## 5.1. Methodologies and Key Assumptions/Trends

Emission calculation: The Slovak Hydrometeorological Institute compiles an annual emissions balance and uses emission factors according to the EMEP/EEA $GB_{2019}$. During the preparation of projected emissions of ammonia were considered the same input data and policies and measures as in the preparation of projected GHG emissions. Emissions of NOx and $NH_3$ from manure storage and application were estimated taking into account the abatements requirements to reduce emissions from livestock farms.

$PM_{2.5}$, emissions from manure management and agricultural soils were calculated using the default Tier 1 emissions factors for each category of farm animals. $PM_{2.5}$ from 3.D Agricultural soils are calculated with Tier 2 methodology and emission factors for wet climate outlined in EMEP/EEA $GB_{2019.}$ The same emissions factors were used for all years.

NMVOC was estimated by the available parameters time of housing feeding situation – the amount of silage in the ration and gross feed intake. Dairy cattle and non-dairy cattle have been calculated using Tier 2 methodology by EMEP/EEA $GB_{2016}$. NMVOC emissions from other animal categories were calculated using the Tier 1 methodology and emission factors outlined in the EMEP/EEA $GB_{2019}$. NMVOC emissions from Agricultural soils were calculated using the Tier 1 methodology and emission factors outlined in EMEP/EEA $GB_{2019.}$

The $NH_3$, NOx emission projections were estimated according to the EMEP/EEA $GB_{2019}$ Guidebook methodologies, the Slovak Republic did not use the specific model for forecasting emissions. $NH_3$ and NOx emission projections were modelled following the Tier 2 approach based on analysing the nitrogen cycle. To 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. (Selected activity data is available in Annex of this report according to the NECD recommendation). Emissions projections have been modelled in various areas of the agricultural sector for different pollutants ($NH_3$, NMVOC, PM, NOx, TSP).

### Activity data

The available time series of input data have varied lengths (the longest covering the period 1970-2020, the shortest covering the period 2003-2020) 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 (1990-2019, ŠÚ SR, data available by regions)
- Number of sheep in the head (1990-2019, ŠÚ SR, data available by regions)
- Number of poultry in the head (1990-2019, ŠÚ SR, data available by regions)
- Number of goats in the head (1990-2019, ŠÚ SR, data available by regions)
- Number of horses in the head (1990-2019, ŠÚ SR, data available by regions)
- Milk yield per cow - average annual milk yield per dairy cow in kilograms (1990-2019, ŠÚ SR, data available by regions)
- Milk yield per ewe - average annual milk yield per dairy ewe in kilograms (1990-2019, ŠÚ SR, data available by regions)
- Consumption of nitrogen fertilizers in tons (1990-2019, sources: IFASTAT and ÚKSUP), data available for Slovakia by types

- Consumption of urea in tons (2000-2019, 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 in the 2023 submission 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.

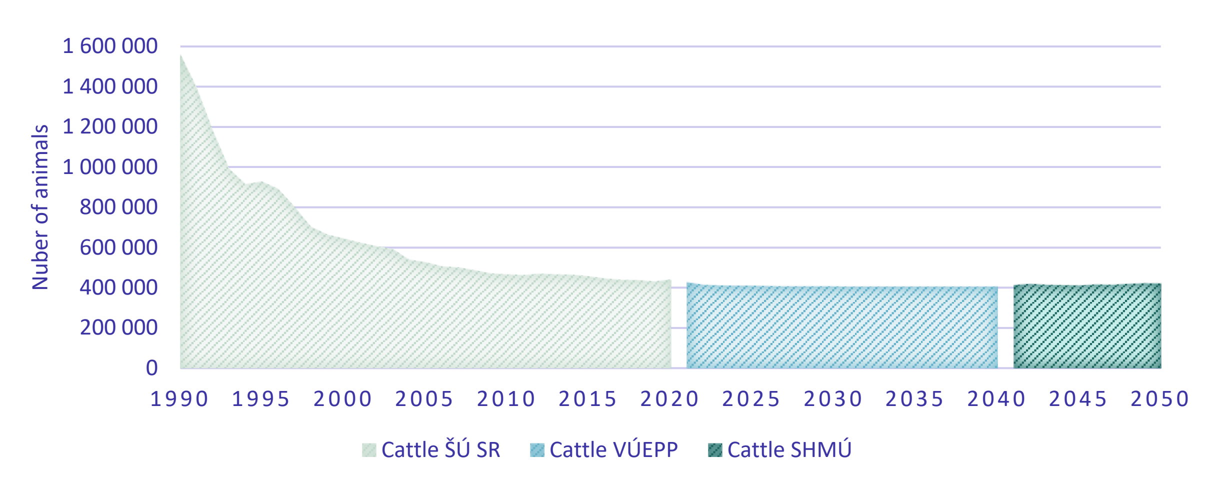
The input from breeding unions provided a more accurate view of the development of livestock numbers in Slovakia. Furthermore, it is mentioned that future Common Agricultural Policy (CAP) measures are expected to impact increasing the mentioned livestock species, particularly through increased grazing breeding. Additionally, the consumption of inorganic fertilizers was modified based on planned European Farm to Fork Strategies and national measures to reduce urea use.

### 5.1.1. Number of cattle

Due to the transformation of the Slovak Republic into a market economy, there was a significant decline in the cattle population compared to the base year of 1990, especially in the first four years. The population dropped to approximately 993 000 head in 1993, and although at a slower pace, this downward trend continued in the following years. By 2004 (Slovakia's accession to the EU), the cattle population was already only about one-third of the 1990 level, reaching 540 000 head. Thanks to higher subsidies under the EU Common Agricultural Policy, this decline was mitigated, and in 2020, Slovakia recorded 442 000 head of cattle, representing a decrease of approximately 72% compared to 1990.

According to an analysis that was conducted, the cattle population, especially the meat breeds predominantly raised on pasture, is expected to increase. Given the current state of the cattle population, the dairy cattle population is likely to decline while the meat cattle population is projected to increase to around 321 000 head by 2050.

*__Figure 5.1:__ Development of number of cattle (1990-2020) and their projections until 2050*

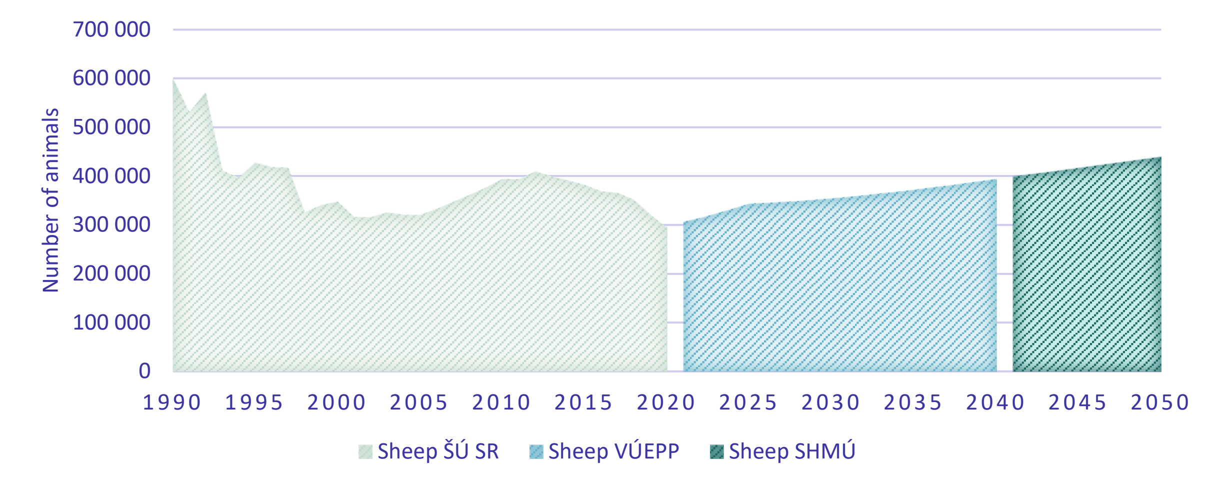



### 5.1.2. Number of sheep

Slovakia had the highest number of sheep in the 1990s, as the centrally planned economy system was coming to end, with the population reaching approximately double the current level (***Figure 5.2***). However, their development exhibited a cyclical pattern. After a decline from 698 000 head in 1970 to 541 000 head in 1976, there was a gradual increase to nearly 600 000 head in 1990, followed by another decline to around 400 000 head in 2001 and 2002. After reaching this minimum, the sheep population in Slovakia began to stabilize, reaching almost 410 000 head in 2012. In recent years, there has been a decline to less than 321 000 head in 2020, which is just over half of the population at the beginning of the observation period.

Sheep farming in Slovakia has a tradition mainly due to favourable conditions and an abundance of pastures. The model predicts an increase in the sheep population, expecting 440 000 head in Slovakia by 2050.

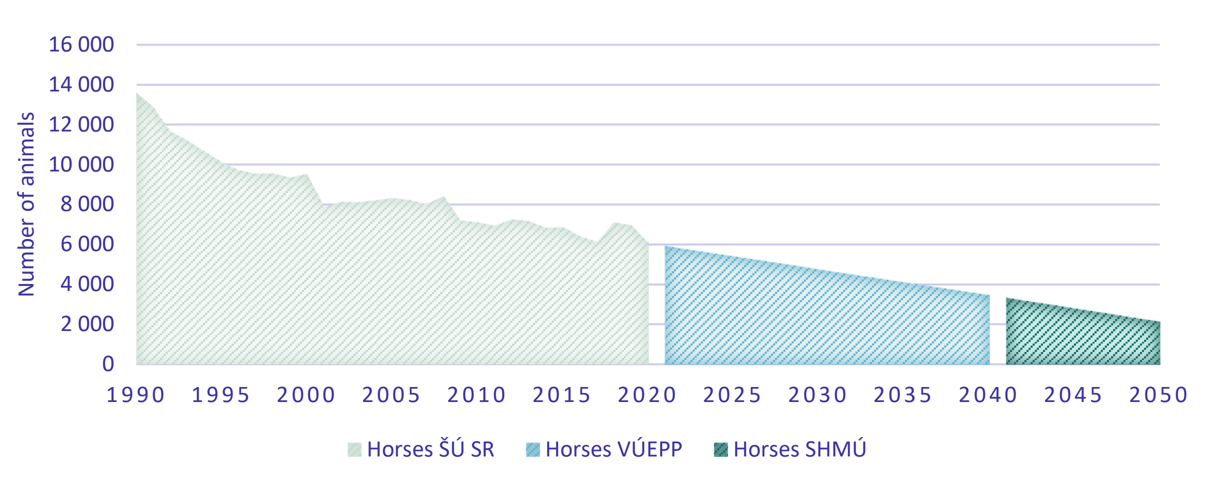
*__Figure 5.2:__ Development of number of sheep (1990-2020) and their projections until 2050*




### 5.1.3. Number of horses

The highest number of horses in Slovakia was recorded in 1990 (13 595 head). Throughout the observed period, it is evident that the horse population has generally had a declining trend. This downward trend can be attributed to the transformation of the agricultural sector after 1990 and the transition to a market mechanism. The decline represents approximately two-thirds compared to the level at the beginning of the observation period (1990). The declining trend during the observed period (***Figure 5.3***) also had an impact on the analysis of projections until 2050, which indicates that the horse population in Slovakia is expected to continue to decline. By 2050, the projected number of horses in Slovakia is only 2 132 head (-84%).

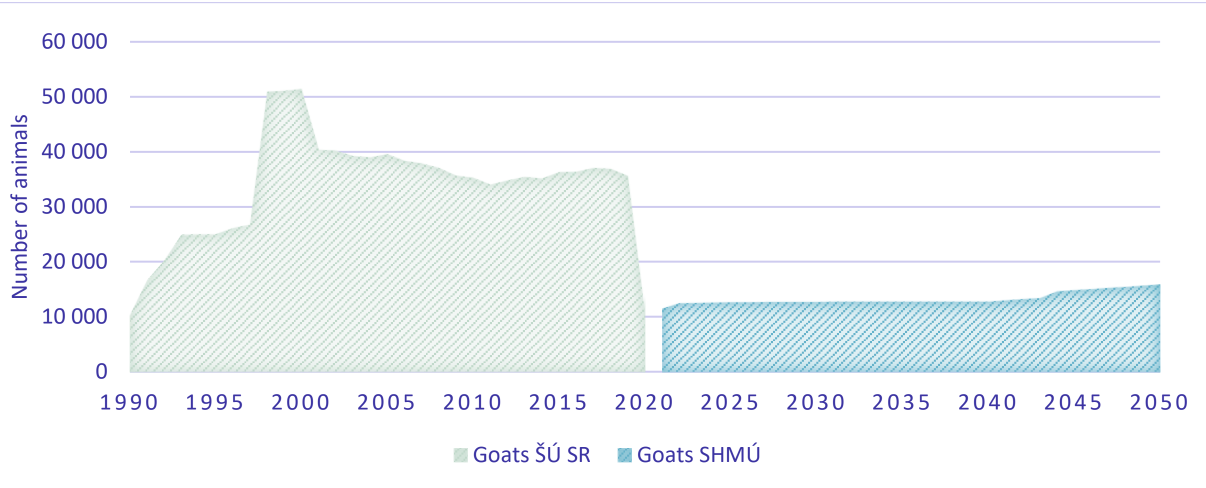
***Figure 5.3:*** *Development of a number of horses (1990-2020) and their projections until 2050*




### 5.1.4. Number of goats

The data for goat populations in Slovakia is available from 2000 onwards, with extrapolated data for the period from 1990 to 2000 based on ŠÚ SR records. The number of goats decreased by more than a fifth in 2001 compared to the previous year (from 51.4 thousand to 40.4 thousand head) (***Figure 5.4***). Following this sharp decline, there was a gradual decrease in the goat population throughout the next decade, stabilizing at just over 34 thousand head in 2011. In 2020, the goat population further decreased to 11 thousand head. This decline continued in 2021 (10 thousand head) and was caused by the poor economic situation among breeders. Compared to 1990, this represents an increase of 3%. Based on the annual fluctuations in population, the model predicts a gradual increase in the goat population in Slovakia in the future, albeit at a slower pace. From the level of 10.6 thousand head in 2020, the goat population is projected to reach approximately 15.9 thousand head by 2050. The increase in population will also be supported by financial subsidies for pastoral farming methods from the upcoming EU Common Agricultural Policy (CAP) for the years 2023-2027.

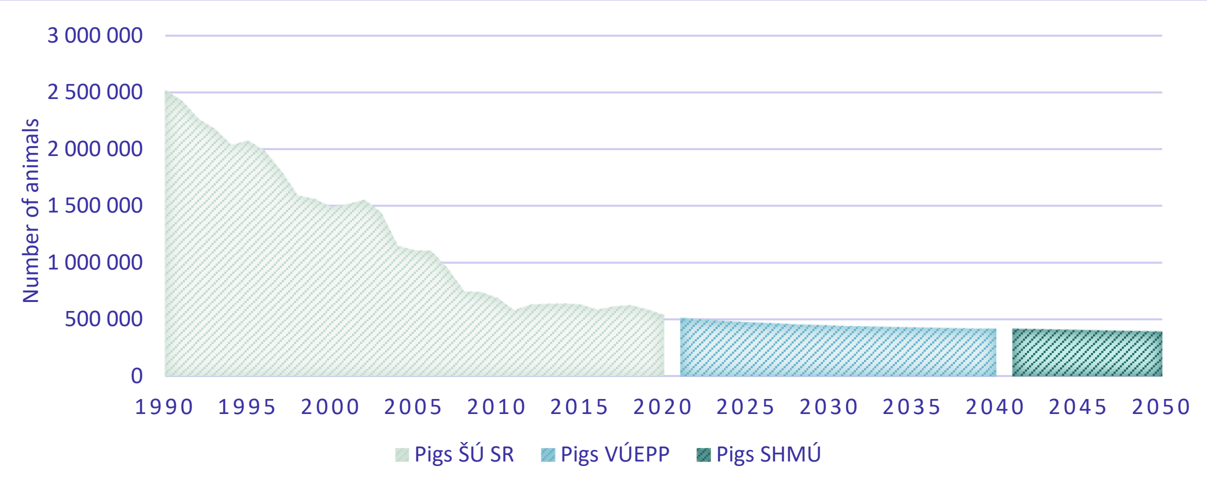
***Figure 5.4:*** *Development of number of goats (1990-2020) and their projections until 2050*




### 5.1.5. Number of pigs

Similarly to the stocks of cattle and sheep, we can observe high numbers of pigs in the 1990s (***Figure 5.5***). In 1990, there were 2.52 million pigs registered in Slovakia, reaching the maximum level. Since 1991, during the transformation to a market economy, there has been a continuous decline in the pig population from the level of 2.43 million pigs, which continued even after the country's accession to the EU (1.15 million pigs in 2004), until reaching the lowest point in 2016 (586 000 pigs), representing a decrease of almost 76% compared to 1990. Only in recent years, in 2017 and 2018, we can observe a slight increase in the pig population, with 627 000 pigs recorded in Slovakia in 2018. In 2019, a decline in pig numbers was recorded. The reasons for this decline are of an economic nature. Based on the results of the modelling, a decrease in pig numbers can be expected from the level of 538 000 pigs in 2020 to approximately 393 000 pigs in 2050.

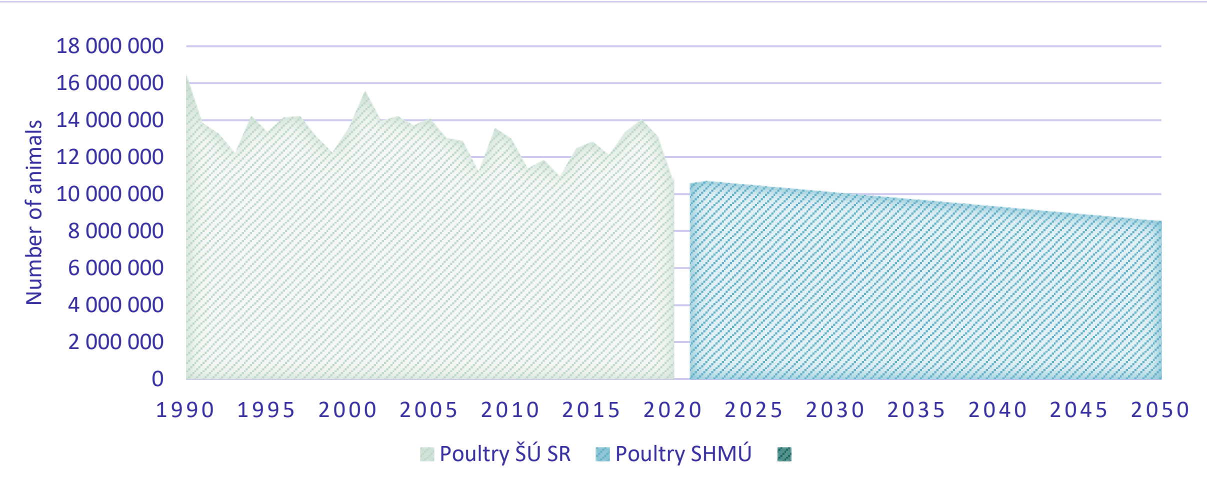
***Figure 5.5:*** *Development of number of pigs (1990-2020) and their projections until 2050*




### 5.1.6. Number of poultry

A relatively dynamic trend can be observed in the poultry stocks (***Figure 5.6***). In the period leading up to 1990, poultry numbers remained at around 16.3-16.6 million birds, but in the following three years, they decreased by approximately a quarter (to 12.2 million birds in 1993). This was followed by a period of frequent fluctuations in poultry stocks in Slovakia, with the peak level after 1990 reached in 2001 (15.6 million birds) and the lowest point recorded in 2019 (less than 11 million birds). In 2020, the poultry population was at the level of 10.6 million birds, which is roughly 36% compared to the beginning of the analysed period. The results of projection modelling suggest that poultry numbers will decrease to approximately 9.3 million birds by 2040 and to less than 8.5 million birds by 2050.

***Figure 5.6:*** *Development of number of poultry (1990-2020) and their projections until 2050*

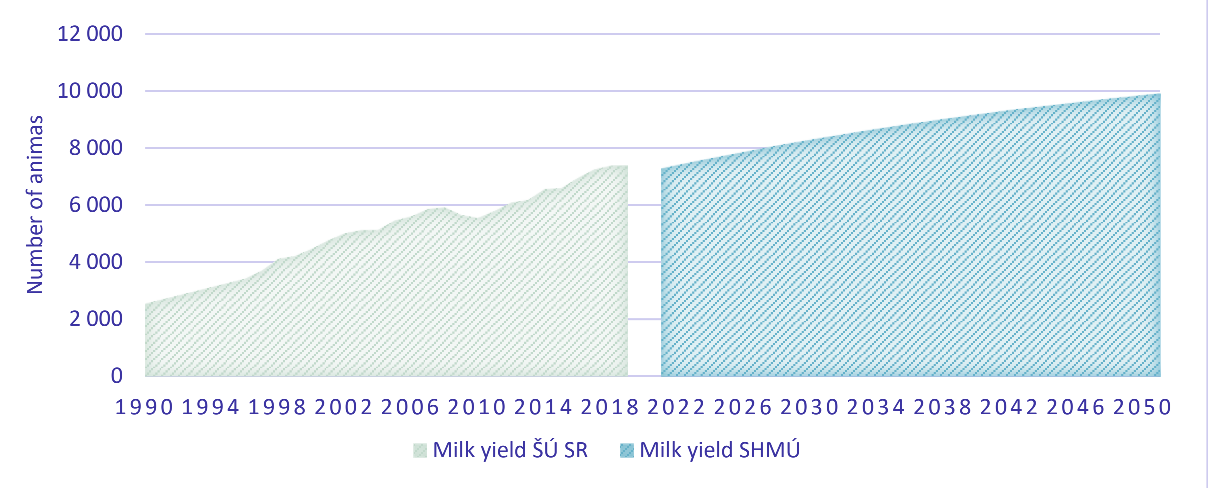



### 5.1.7. Milk yield of cows

This parameter was forecasted at the regional level. The model results indicate a growing trend in milk production per cow, which is expected to continue in the coming years. The average value could increase from 7 379 liters per cow in 2020 to nearly 9 919 liters per cow in 2050. ***Figure 5.7*** illustrates the trend of average milking yield for the entire Slovak Republic.

The increase in milking yield until 2050 will depend on several factors, primarily the composition of the cattle population in Slovakia in terms of the prevalence of meat or dairy breeds. Nutrition is also a crucial factor in increasing milking yield. Modernizing and improving housing conditions also play a significant role in enhancing cow productivity.

***Figure 5.7:*** *Development of milk yield (1990-2020) and their projections until 2050*

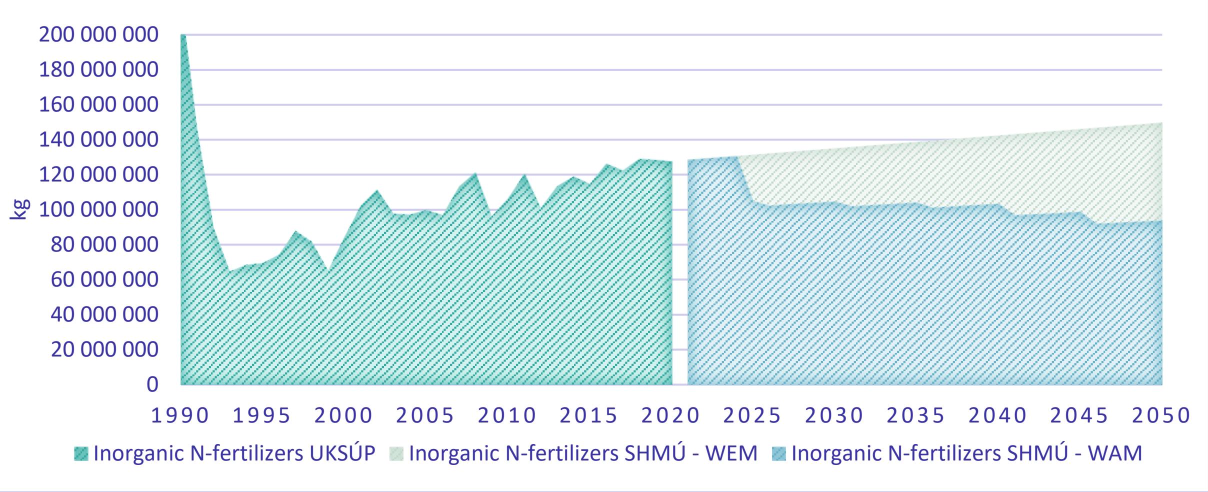



## 5.1.8. Consumption of Inorganic nitrogen fertilizers

Data on the consumption of inorganic nitrogen fertilizers were available in the database of the Statistical Office of the Slovak Republic (ŠÚ SR) from 1990 to 2020. The consumption of nitrogen fertilizers in the first year of observation was 69.6 thousand tons of pure nitrogen nutrients, characterized by alternating periods of growth and decline with a slight upward trend (***Figure 5.8***). The minimum consumption of nitrogen fertilizers, 65.4 thousand tons, was recorded in Slovakia in 1999. Particularly in the recent years of the observed period, this indicator was significantly above average and reached its maximum level in 2018 at 129 thousand tons, representing an increase of almost 59% compared to 2005. In comparison to 1990, their consumption decreased by 42%.

It is expected that the consumption of nitrogen fertilizers will continue to increase until 2023, stabilizing at a level of approximately 149 thousand tons. In the WAM scenario, the consumption of fertilizers is projected to decline after 2024 to a level similar to that of 2001, at approximately 105 thousand tons. Subsequently, by 2050, fertilizer consumption is expected to decrease to 93.9 thousand tons of pure nitrogen applied to the soil.

**Figure 5.8:** *Development of Inorganic N-fertilizers consumption (with urea) (1990 - 2020) and their projections until 2050*




## 5.2. Model Description

The principle of exponential smoothing is based on adaptive methods for time series parameters projections; the projections of parameters made according to exponential smoothing. Exponential smoothing is the weighted average of the past data, with the recent data points given more weight than earlier data points. The weights decay exponentially towards the earlier data points (NPPC, 2017).

The whole model of calculating emissions from livestock breeding is based on regional differences, which means that the input parameters and stocks of animals had to be re-modelled at the level of smaller territorial units - regions. Projections of the number of livestock, which were delivered to NPPC-VÚEPP only at the level of the Slovak summary, were distributed by the SHMÚ to the regional level and only after this re-division were they implemented into the calculations of emission projections.

At the time of preparation of projections of emissions from agriculture, there was no national strategic document, except for a case study prepared by the NPPC-VÚEPP, which would model the development of livestock numbers and consumption of fertilizers in the Slovak Republic.

The algorithm in the system Python was developed, which is an automated version of the N-Tool, developed following the methodology EMEP/EEA GB 2019.

The calculation model is based on regional differences, which means the input parameters and number of livestock was modelled on a regional (district) level. After, this redistribution was implement to calculate emission projections.

*Table 5.1: SWOT analysis of the Agri-model*

| Strengths | Opportunities |
|---|---|
| Compatibility with emission model for emission inventories<br>Detailed data break down<br>National database used is compatible with EU data | Incorporate to the model new technologies<br>Versatile use of time-series |
| **Treats** | **Weakness** |
| Easy data entry<br>Basic software is free | Disconnected from macroeconomic models<br>Too much pre-calculations needed<br>Missing measurable indicators in national policies and strategies<br>Data consistencies in the projection estimation process |

Most implemented measures have a measurable effect on the emission inventory. List of policies and measures taken into account in emissions by individual scenarios and their effect (antagonistic, synergic). The limiting factor during the preparation of projections was the lack of details of the measures and their implementation plans within the Agriculture sector. Lack of information makes it difficult to implement and evaluate their impact. For this reason, an expert estimate of selected parameters was used during the preparation of the projections or European goals were used. It is therefore necessary to supplement the further specification of measures in the future for a more correct setting of models:

- Mechanism of implementation.
- Supporting resources requirements.
- Monitoring of implemented measures at the farm level, respectively business entity.

## 5.3. Scenarios, Parameters and PAMs

A review of actual and planned policies and measures was done. The forthcoming EU food strategy aims to reduce the use of pesticides, fertilizers and antibiotics in agriculture. By 2030, the consumption of hazardous pesticides should be reduced by 50% and the consumption of inorganic fertilizers should decrease by 20%. Targets were set for the entire European Union, the Slovak Republic has not set binding reduction resulting from the Farm to Fork strategy.

The Low Carbon Strategy of the Slovak Republic aims to identify measures, including achieving climate neutrality in the Slovak Republic in 2050 and achieving a 55% emission reduction in 2030 compared to 1990. This ambitious goal was formally defined in the last stage of the Low Carbon Strategy. Other less ambitious emission reduction scenarios were analysed in detail.

In preparing projections, measures were selected and analysed to detectable impact on the estimated emissions and their quantified impact on the greenhouse gas inventory and inventory of pollutants as possible. All other measures proposed in the Low Carbon Strategy are not implemented in the projections due to a lack of measurable effect on inventory but have an impact on the whole concerning the environment.

Based on the qualification of the probable impact of mitigation measures on emission inventories, we distinguish:

1. Measures having an identifiable impact on emissions. This impact can be specifically attributed to the implementation of mitigation measures. They are measurable and effective, this type of measure has been used in the preparation of emission projections.

2. Measures that have an impact on emissions are reported in inventories, but this impact cannot be specifically attributed to a specific mitigation measure. This includes measures that are difficult to measure and often have different synergistic or antagonistic effects.

3. Measures whose impact on emissions reported in inventories is possible because emission reductions are visible. The effect of these measures depends on other factors.

4. Measures that do not have a direct impact on emissions but which may have a positive impact on farmers' behaviour or the environment in the sector.

In the context of this document were prepared two scenarios:

The **WEM** scenario is a measures scenario that includes projections of anthropogenic emissions from agricultural sources, taking into account the effects of policies and measures adopted by the end of 2020. The measures considered in the **WEM** scenario prevent $NH_3$ emissions by storing manure and manure more efficiently by isolating them from the environment. This measure can be found in several strategic documents, especially in the Decree of the Ministry of the Environment of the Slovak Republic no. 248/2023 Coll., which implements certain provisions of the Air Act. The implementation of this measure has an impact on $NH_3$ and NOx from category 3B Manure and slurry management.

The **WEM** scenario takes into account the estimated consumption trend of nitrogenous organic and inorganic fertilizers based on exponential equalization by analysing previous emission trends. The **WEM** scenario has an increasing trend of nitrogen oxide emission projections, mainly due to Slovakia's expected continued revival of crop production. After 2020, the consumption of inorganic fertilizers is expected to increase by 50% compared to 2005. We assume that the consumption of inorganic fertilizers will increase, which will be necessary to compensate for the lack of organic nitrogen due to the decrease in the number of farm animals until 2050. The increase will be caused mainly by the growth in the number of grazing animals (meat species of cattle, sheep and goats). The increase in emissions projections in the **WEM** scenario is also visible in the category of applied other organic waste, namely compost and digestate. The amount of applied matter from cultivated plants to the soil will also increase.

The measure, taken from the Farm to Fork strategy, is to limit the use of pesticides, fertilizers and antibiotics in agriculture. This strategy was developed in synergy with the European Green Deal, which set itself the goal of reducing the environmental and climate footprint of the European food system. Within the **WAM** scenario, a target of reducing nitrogen fertilizer consumption by 20% by 2030 was implemented. The **WAM** scenario is a scenario with additional measures containing projections of emissions from agricultural sources, which include the effects of policies and measures adopted and implemented after 2020. The **WAM** scenario was modelled on strategic documents prepared by the Ministry of Environment of the Slovak Republic in cooperation with the Ministry of Agriculture and Rural Development of the Slovak Republic. A transition period was implemented in the emission projections, which aligns with the transition period for limiting urea (2020-2025) – ***Table 5.4.*** It is likely that the Slovak Republic will negotiate its own percentage reduction in fertilizer consumption and will claim a transitional period that will be legislated at the national level. After the legislative process, it will be necessary to adjust the emission projections in accordance with the future valid state strategy. Even though planned mitigation measures have been implemented, emissions are projected to increase by 2030 and 2050, creating pressure for much more ambitious measures. The urea reduction had a gradual trend, shown in the ***Table 5.4***. Limiting urea also affects $CO_2$ emissions from agriculture and especially on $NH_3$ emissions.

The **WAM** scenario includes two mitigation measures that have a synergistic effect. The measure adopted from NUS SR recommends a legislative restriction on the application of urea-based nitrogen fertilizers. The implementation of this measure has an impact on the reduction of ammonia emissions, mainly due to the high volatility of ammonia from urea fertilizers. By limiting the consumption of urea, nitrogen oxide emissions will also be prevented based on the reduction of the total consumption of inorganic fertilizers in the resulting sum of consumption. The information on the validity of the legislation was unavailable. Therefore, an expert judgement was used.

The potential for reducing ammonia emission, NMVOC and nitrogen oxides emissions in agriculture is mainly related to the efficiency of manure management, in particular the handling and storage of manure and slurry and their application to the soil in a low-emission manner. Some measures are included in Decree No. 248/2023 Coll. of the Ministry of the Environment of the Slovak Republic and are also valid for farms classified under Act No. 39/2013 Coll. on Integrated Pollution Prevention and Control. Mitigation measures included in the current legislation have been included in the WEM scenario. Currently, a revision of the Decree of the MŽP SR No. 248/2023 Coll. is underway, as well as an amendment to the Air Act No. 146/2023 Coll., in order to introduce the obligation to comply with the principles of Good Agricultural Practice also in medium-sized agricultural units. ***Table 5.2*** shows the percentage distribution of farms that have been reported in the National Emissions Information System.

***Table 5.2:*** *Percentage distribution of medium, large and small farms in the Slovak Republic in 2019*

| Species of animal | Pigs | Poultry | Cattle | Sheep | Horses | Goats |
|---|---|---|---|---|---|---|
| Share of large farms | 2% | 30% | 3% | 0% | 0% | 0% |
| Share of medium-sized farms | 2% | 20% | 5% | 10% | 1% | 0% |
| Share of small farms | 96% | 50% | 92% | 90% | 99% | 100% |

*Source: National Emissions Information System*

The WAM scenario also contains measures of increased processing of animal waste in biogas plants to produce biogas, which can be used as a local energy source. This measure included in the Low Carbon Strategy of the Slovak Republic does not contain details such as animal species, percentages of recovered waste and others that would provide measurable indicators potentially usable in the calculation of emission projections. As part of the preparation of emission projections, this information was additionally expertly estimated. For this analysis, it was considered that 10% of organic manure from cattle and pigs would be recovered in biogas plants. Cattle and pigs are key categories of animals with the highest emission recovery potential, the 10% potential was chosen as expert judgement. Biogas from stations is a promising source of renewable electricity and heat, which can be used at the local level.

***Table 5.3:*** *Efficiency of used abatements*

| Abatement efficiency of measures | Efficiency of abatements | Source of Efficient |
|---|---|---|
| Storage of Manure or Slurries | | |
| Fixed hatch or roof | 80% | Code Good Agricultural Practice* |
| Covering the surface of the tank with straw | 40% | |
| Covering the surface of the tanks with foil | 60% | |
| Slurry/liquid with natural crust cover | 40% | |
| **Application of manure Or Slurries** | | |
| Furrow injection | 40% | Code Good Agricultural Practice* |
| Deep injection | 90% | |
| Incorporation within 12 hours | 50% | |
| Incorporation within 24 hours | 30% | |

*In Slovak

The **WAM** scenario contains measures that are in synergy and can be implemented in the calculation model. This is the use of amino acids in the ration reducing the nitrogen excretion of animals, it was implemented in the model through a more precise optimization of nitrogen substances in the ration. The measure was used in the estimation of nitrogen excretion per 1 animal per year in cattle. Based on the meta-analysis, the estimate of the mitigation potential compared to the reference value was in the range of 17±6% $N_{EX}$.

Emissions of NOx and $NH_3$ from manure and manure storage in the WAM scenario were modelled by taking into account the measure of introducing requirements to reduce emissions from livestock farms classified as a medium source of emissions to air. This measure was proposed in the National Air Emission Control Programme and implemented into the calculation of $NH_3$ and NOx emissions by implementing low-emission systems for manure and manure storage. This measure has an impact on category 3.B Manure and slurry management.

Another implemented measure, which has an impact on $NH_3$ and NOx emissions in category 3.B Manure and manure management, was the use of manure as a feedstock into biogas plants. The impact on reducing emissions in two main ways - reducing carbon emissions from fossil fuels through the production of energy sources and reducing direct emissions of methane and nitrous oxide from manure and sludge 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.

Emissions of $NH_3$ and NOx from the application of inorganic nitrogen fertilizers (category 3.D Agricultural soils) were modelled in the **WAM** scenario based on a measure implemented from the Low Carbon Strategy of the Slovak Republic. This measure recommends the transition or legislative restriction on the application of nitrogen fertilizers to urea bases. This measure's implementation impacts the reduction of $NH_3$ and NOx emissions, mainly due to the high volatility of ammonia from urea fertilizers. At the same time, limiting urea consumption will prevent carbon dioxide emissions. Nitrous oxide emissions are limited based on reducing the total consumption of inorganic fertilizers in the resulting consumption summary.

The last implemented measure was taken from the European Green Deal and mentioned in the Farm to Fork strategy. This measure recommended a 20% reduction in inorganic fertilizers consumption by 2030. This measure has an impact on $NH_3$ and NOx.

The implemented measure taken from the Low Carbon Strategy recommends the transition or legislative restriction on the application of urea-based nitrogen fertilizers. The implementation of this measure has an impact on the reduction of ammonia emissions, mainly due to the high volatility of ammonia from urea fertilizers. Limiting the consumption of urea also avoids NOx emissions by reducing the total consumption of inorganic fertilizers in the resulting consumption summary. The information on the validity of the legislation was unavailable. Therefore, an expert judgement was used. The reduction of urea had a gradual course, which is shown in ***Table 5.4.***

***Table 5.4:*** *Limitation of urea consumption from 2025 to 2050 according to the WAM scenario*

| YEAR OF IMPLEMENTATION | PERCENT OF UREA CONSUMPTION REDUCTION |
|---|---|
| 2020-2025 | The transition period, time to implement legislation |
| 2026-2030 | 10 % |
| 2031-2035 | 20 % |
| 2036-2040 | 30 % |
| 2041-2045 | 50 % |
| 2046-2050 | 70 % |

The list of policies and measures that have been taken into account in the emission projections according to the individual scenarios and their effect is given in ***Table 5.5***.

*Table 5.5: List of implemented policies and measures into projections according to the scenarios*

| STRATEGIC DOCUMENT LEGISLATION | SCENARIO | GAS / CATEGORY | MEASURE | EFFECT OF THE MEASURE |
|---|---|---|---|---|
| Code of good agricultural practice<br>National Air Pollution Control Programme<br>Low carbon strategy<br>Decree of the Ministry of the Environment of the Slovak Republic No. 248/2023 Coll. | WEM | $NH_3$, NOx- 3.B Manure management | Efficient storage of animal waste, specifically storage of liquids in isolated tanks from the environment or in tanks with access to oxygen and storage of manure in plastic bags without or with minimal addition of water | synergistic |
| Code of good agricultural practice | WAM | $NH_3$, NOx – Manure management | Application of amino acids into feeding doses | synergistic |
| National Air Pollution Control Programme | WAM | $NH_3$,NOx - agricultural land | Obligation to comply with measures to reduce ammonia emissions even at medium sources of pollution | synergistic |
| Low carbon strategy | WAM | $NH_3$, NOx - storage of manure and manure | Effectively process animal waste and use biogas, especially as a local energy source | synergistic |
| | WAM | $NH_3$,NOx - agricultural land | Intensification of the use of nitrogen fertilizers with stabilized nitrogen at the expense of the use of urea | synergistic |
| Farm to fork strategy | WAM | $NH_3$,NOx - agricultural land | Reduction of inorganic nitrogen fertilizers by 20 % compared to 2030 | synergistic |

## 5.4. Emission Projections in the Agriculture Sector

### NMVOC emissions

NMVOC emission projections were prepared using the WEM scenario. The emission projections decreased mainly due to a decrease in the projected number of livestock and intensive feeding with active substances in dairy cattle, sheep and swine categories. Predictions by the WEM scenario followed the Ordinance of the Government of the Slovak Republic No. 248/20232 Coll.

***Figure 5.9:*** *Emission projections trends for pollutant NMVOC in sector Agriculture*

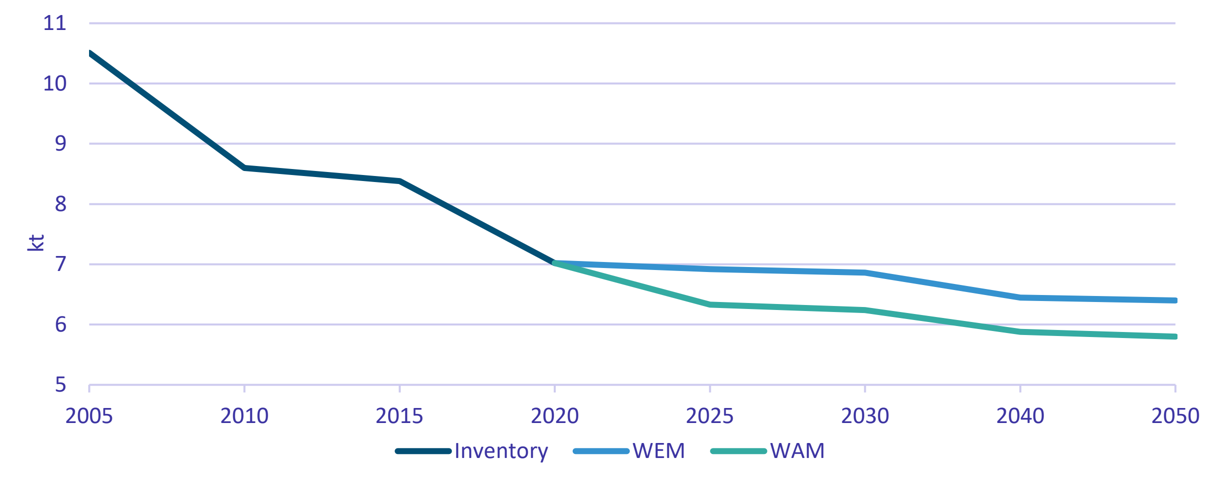



***Table 5.6****: NMVOC emissions in sector Agriculture*

| WEM | 2005 | 2010 | 2015 | 2020 | 2025 | 2030 | 2040 | 2050 |
|---|---|---|---|---|---|---|---|---|
| 3.B | 10.35 | 8.44 | 8.22 | 6.86 | 6.78 | 6.72 | 6.31 | 6.26 |
| 3.D | 0.16 | 0.16 | 0.16 | 0.16 | 0.14 | 0.14 | 0.14 | 0.14 |
| **3 Agriculture** | **10.51** | **8.60** | **8.38** | **7.02** | **6.92** | **6.86** | **6.45** | **6.40** |

| WAM | 2005 | 2010 | 2015 | 2020 | 2025 | 2030 | 2040 | 2050 |
|---|---|---|---|---|---|---|---|---|
| 3.B | 10.35 | 8.44 | 8.22 | 6.86 | 6.19 | 6.10 | 5.74 | 5.66 |
| 3.D | 0.16 | 0.16 | 0.16 | 0.16 | 0.14 | 0.14 | 0.14 | 0.14 |
| **3 Agriculture** | **10.51** | **8.60** | **8.38** | **7.02** | **6.33** | **6.24** | **5.88** | **5.80** |

## $NH_3$ and NOx emissions

Sector agriculture is a dominant contributor to $NH_3$ emissions, approximately 90% share of the national total. The largest share of ammonia emissions was generated by 3.D Agricultural soils, which produced approximately 70% of $NH_3$ within the sector. The key source in Agricultural Soils in the Animal manure applied to soils where were implemented abatements (Incorporation within 12 and 24 hours, deep injection of manure), followed by the category Inorganic N-fertilizers representing approximately 20% of the total $NH_3$ emissions, there are no abatements were implemented, due to missing policies. Emissions from 3.B.1 Cattle, 3.B.3 Swine and 3.B.2 Sheep are key emission sources of $NH_3$.

Projections of $NH_3$ and NOx emissions from manure and manure management and agricultural soils were prepared in the WEM and WAM scenarios.

The WEM scenario is conservative and does not envisage further measures to reduce emissions. The emission trend in WEM scenario has stable increasing trend (***Figure 5.11***) of NOx emissions. In the WEM scenario, higher consumption of inorganic nitrogen fertilizers is included compared to the recorded values in historical years. The year 2020 and 2021 was particularly affected by the pandemic, which led to higher prices of natural gas and subsequently increased prices of inorganic N-fertilizers. As a result, farmers reduced their consumption of these fertilizers.

For the projection, the impact of the pandemic year was avoided, and the projection was prepared without considering the influence of the pandemic. Similar trends were observed in animal production, where there was a decrease in the number of pigs, goats, and poultry. If this negative trend continues beyond the after-pandemic years, the projections will be adjusted accordingly in future submissions.

*Figure 5.10: Emission projections trends for pollutant $NH_3$ in sector Agriculture*

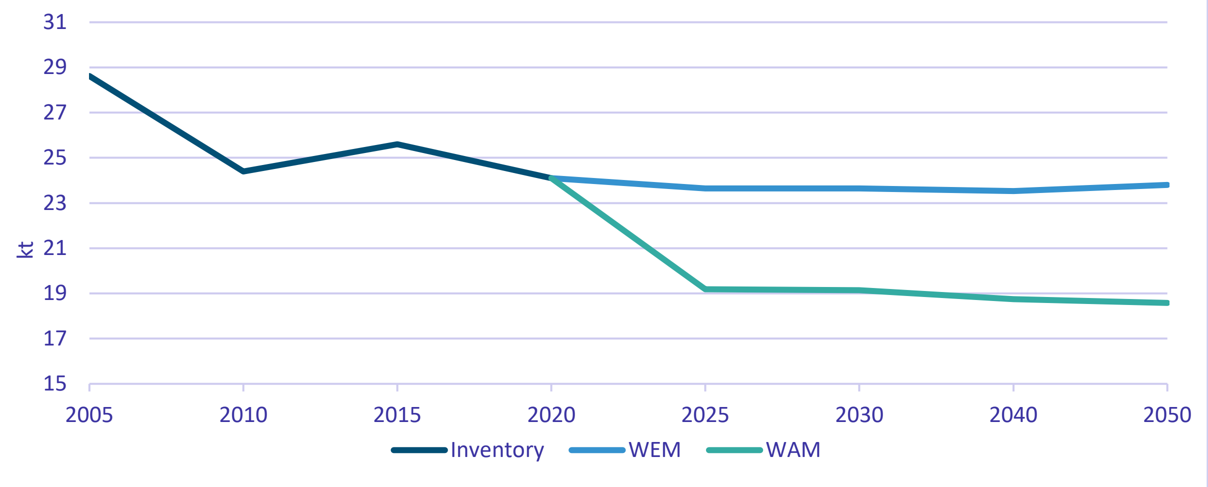



*Table 5.7: $NH_3$ emissions in sector Agriculture*

| WEM | 2005 | 2010 | 2015 | 2020 | 2025 | 2030 | 2040 | 2050 |
|---|---|---|---|---|---|---|---|---|
| 3.B | 8.90 | 7.21 | 6.98 | 5.96 | 5.98 | 5.85 | 5.66 | 5.51 |
| 3.D | 19.72 | 17.19 | 18.62 | 18.14 | 17.67 | 17.79 | 17.88 | 18.29 |
| **3 Agriculture** | **28.62** | **24.40** | **25.60** | **24.10** | **23.65** | **23.64** | **23.53** | **23.80** |

| WAM | 2005 | 2010 | 2015 | 2020 | 2025 | 2030 | 2040 | 2050 |
|---|---|---|---|---|---|---|---|---|
| 3.B | 8.90 | 7.21 | 6.98 | 5.96 | 5.31 | 5.23 | 5.03 | 4.87 |
| 3.D | 19.72 | 17.19 | 18.62 | 18.14 | 13.86 | 13.92 | 13.71 | 13.71 |
| **3 Agriculture** | **28.62** | **24.40** | **25.60** | **24.10** | **19.18** | **19.15** | **18.75** | **18.58** |

Agricultural NOx emissions have increased. The NOx emissions from agricultural soils especially Inorganic N-fertilizers application is a key source of emission. The emission projections increased due to the increasing consumption of nitrogen N-fertilizers, which will be needed to replace the lack of organic nitrogen in soils due to livestock decreasing. Agriculture is an insignificant source of NOx emissions and no policies and measures are available.

*Figure 5.11: Emission projections trends for pollutant NOx in sector Agriculture*

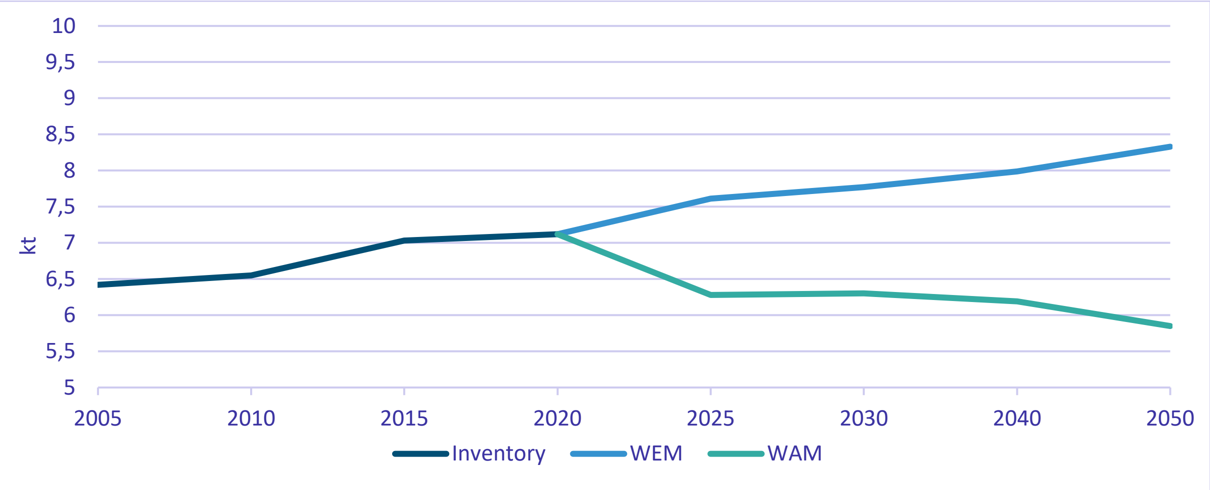


**Table 5.8:** *NOx emissions in sector Agriculture*

| WEM | 2005 | 2010 | 2015 | 2020 | 2025 | 2030 | 2040 | 2050 |
|---|---|---|---|---|---|---|---|---|
| 3.B | 0.18 | 0.15 | 0.15 | 0.14 | 0.13 | 0.13 | 0.12 | 0.12 |
| 3.D | 6.24 | 6.40 | 6.89 | 6.98 | 7.48 | 7.64 | 7.86 | 8.21 |
| **3 Agriculture** | **6.42** | **6.55** | **7.03** | **7.12** | **7.61** | **7.77** | **7.99** | **8.33** |

| WAM | 2005 | 2010 | 2015 | 2020 | 2025 | 2030 | 2040 | 2050 |
|---|---|---|---|---|---|---|---|---|
| 3.B | 0.18 | 0.15 | 0.15 | 0.14 | 0.10 | 0.10 | 0.10 | 0.10 |
| 3.D | 6.24 | 6.40 | 6.89 | 6.98 | 6.18 | 6.20 | 6.09 | 5.76 |
| **3 Agriculture** | **6.42** | **6.55** | **7.03** | **7.12** | **6.28** | **6.30** | **6.19** | **5.85** |

The decrease in emissions by 2040 in the WEM scenario compared to 1990 is at the level of -51.6% and compared to 2005 at the level of -7%.

## $PM_{2.5}$ emissions

The $PM_{2.5}$ emissions were calculated in one scenario due to missing strategical documents and mitigation measures. The agricultural $PM_{2.5}$ emissions have decreased trend from 2005 to 2020 and the decrease will continue until 2050 due to a decrease in cropped areas of oat, barley and rye. Agriculture is an insignificant source of $PM_{2.5}$ emissions and no policies and measures are available. The decrease in emissions by 2050 in the WAM scenario compared to 1990 is at the level of -68% and then decreases by 39% compared to 2005.

**Table 5.9**: *$PM_{2.5}$ emissions in sector Agriculture*

| WEM=WAM | 2005 | 2010 | 2015 | 2020 | 2025 | 2030 | 2040 | 2050 |
|---|---|---|---|---|---|---|---|---|
| 3.B | 0.15 | 0.13 | 0.12 | 0.10 | 0.10 | 0.10 | 0.10 | 0.10 |
| 3.D | 0.20 | 0.18 | 0.18 | 0.18 | 0.16 | 0.16 | 0.14 | 0.14 |
| **3 Agriculture** | **0.35** | **0.31** | **0.30** | **0.28** | **0.26** | **0.26** | **0.24** | **0.24** |

# CHAPTER 6. EMISSION PROJECTIONS IN THE WASTE SECTOR

## 6.1. Methodologies and Key Assumptions/Trends

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 NFR categories:

- 5.A Solid Waste Disposal on Land
- 5.B Biological Treatment of Solid Waste
- 5.C Waste Incineration an Open Burning of Waste
- 5.D Wastewater Handling
- 5.E Other Waste

### 6.2. Model Description

Projections of emissions were prepared in accordance with the methodology of EMEP GB 2019, the methodology is consistent with the methodology of estimating emissions in Waste sector. 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. Calculations of emissions projections of individual gases were carried out in consistency with the GHG emission projection from waste activities.

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, or at least specifying the specific national parameters that enter the calculations (ideally up to tier 3 level). We are currently working partly at the level of tier 1 and partly already at the level of tier 2 (national data on production and waste management), as we lack the necessary statistical data specific to Slovakia.

Improving the quality and timely availability of input data as well as further improvements in the preparation of emissions projections from the waste sector should enable the entire calculation process to be automated, which should bring a reduction in calculation time and create space for the creation of a larger number of scenarios and the processing of sensitivity analysis.

Calculating of NMVOC emission projections from landfilling is connected with the methane emissions and it follows that two of parameters used 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 landfill gas) 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 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, for example, in the data from BSK and KSK. More intensive separated collection 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. 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 NMVOC 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 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 6.1:*** *SWOT analysis of the Waste-model*

| Strengths | Opportunities |
|---|---|
| Compatibility with emission inventories<br>Detailed data break down<br>Database used is compatible with national data<br>Models are free of charge | Incorporate to the model new technologies<br>Versatile use of time-series |
| **Treats** | **Weakness** |
| Bugs can be introduced if data is incorporated manually<br>Lack of input data introduce high uncertainty | Disconnected from macroeconomic models<br>Too much pre-calculations needed<br>Missing measurable indicators in national policies and strategies<br>Data consistencies in the projection estimation process |

## 6.3. Scenarios, Parameters and PAMs

Current policies of the MŽP SR (collection of biodegradable waste, advance packaging system, collection of kitchen waste, collection of textiles):

- Each of these policies will have an impact on some of the parameters affecting the calculation of emissions from landfilling in Slovakia. Separate collection of kitchen waste will reduce the share of the "FOOD" component in mixed municipal waste. A decrease of -40% is foreseen in the projections. Similarly, separate collection of textiles could reduce the share of this component in landfilled MSW by 50%. Continued separate collection will result in a decrease in the paper and garden waste components of around 20%. The deposit system for returnable packaging may also result in a reduction in the production of mixed packaging, which accounts for a significant proportion of landfilled waste. This could lead to a reduction in DOC of around 30% by 2050, which also represents an adequate reduction in landfilled bio-degradable carbon and ultimately a reduction in methane emissions from landfills**.**

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 and 5.C - Incineration of waste without energy recovery, only one scenario was prepared, namely WEM = WAM, due to the lack of relevant PAMs.

WEM scenario - the business-as-usual (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. GDP growth will be accompanied by growth in waste production, but this will gradually slow down. Conversely, in line with the "Environmental Kuznets Curve" (EKC) theory, the environmental behaviour of the population and firms will increase, leading to more sophisticated waste management practices - less landfilling, more recovery and, ultimately, waste prevention.

Landfill waste production (5.A) - the WEM scenario presents a projections of NMVOC 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 WEM scenario assumes that the landfilling target of a maximum of 10% of MSW is achieved in 2035 with a gradual diversion of about 1.0 million tonnes of MSW to new MBT facilities.

***Table 6.2:*** *Trend projections of parameters and NMVOC emissions from MSW in WEM scenario up to 2050*

| Year | Unit | 2019* | 2020* | 2030 | 2040 | 2050 |
|---|---|---|---|---|---|---|
| **MSW** | *kilo tonnes* | 2 369.73 | 2 434.04 | 2 631.14 | 2 906.55 | 3 127.04 |
| **MSW->MBT** | *tonnes* | 0 | 0 | 330 000 | 660 000 | 1 000 000 |
| **MSW-> SWDS** | *kilo tonnes* | 1 198.25 | 1 307.21 | 590.25 | 290.66 | 300.00 |
| **NMVOC Emissions** | *Gg* | 0.715 | 0.710 | 0.568 | 0.374 | 0.293 |

** Base year 2019; 1990-2020 based on the national emission inventory submission 14. 3. 2023*

Municipal waste production (5.A.1) - the WAM scenario presents a projections of the future development of NMVOC emissions from landfilling in Slovakia with the introduction and application of new policies in waste management without taking into account more significant external influences (economic crisis, impact of pandemics, etc.). This scenario assumes a significant decrease in the amount of landfilled municipal waste, i.e. diversion of mixed MSW, to new MBTs (gradually 330 000 t to 1.0 million t in 2050). In terms of the EC targets for waste management by 2035 (D1<10% MSW and R>60% MSW) and maintaining the current level of energy recovery of MSW (approx. 195 000 t/y), there is still approx. 850 000 t of MSW for which additional facilities or technological procedures are needed to divert MSW from landfilling and reduce emissions. Other policies and measures that, based on knowledge from abroad, can lead to significant changes in the parameters affecting the calculation of landfill emissions include:

- Construction and operation of new WtE (waste-to-energy plants = WEEE). All original EU countries ("old EU15") that have achieved a reduction of landfill emissions of about 60-80% in the past show a minimum share of MSW energy recovery above 40% (Slovakia shows only about 8% i.e. about 200 000 t/y).
- Increased use of LFG for energy production or combustion or oxidation of methane on biofilters. Slovakia is at the very bottom of the ranking according to the European National Greenhouse Gas Inventory Report 2022 (5%2) in the share of LFG use for energy production or "recovery methane" (EU28 average = 39%). Despite the relatively high similarity of landfilling in the V4 countries (landfill capacity, collection area, MSW composition), Slovakia shows only about one third (CR) to one half (PL) of the recovered methane per tonne of landfilled MSW. Alternatively, additional policies for LFG for electricity generation, flaring or oxidation on biofilters, (or active

[2] European Union National Inventory Report EU27+UK, page 789, Figure 7.9

landfill aeration under the "2019 Refinement IPCC GL") have the potential to significantly increase this amount and thus further reduce final methane emissions.

***Table 6.3:*** *Trend and projections of parameters and NMVOC emissions from MSW in WAM scenario up to 2050*

| Year | Unit | 2019* | 2020* | 2030 | 2040 | 2050 |
|---|---|---|---|---|---|---|
| **MSW** | *kilo tonnes* | 2 369.73 | 2 434.04 | 2 631.14 | 2 906.55 | 3 127.04 |
| **NMVOC Emissions** | *Gg* | 0.715 | 0.710 | 0.403 | 0.228 | 0.164 |

** Base year 2019; 1990-2020 based on the national emission inventory submission 14. 3. 2023*

Biological treatment of solid waste (5.B) – Category was calculated in scenario with existing measures (WEM) scenario due to missing strategical documents and mitigation measures after 2021. The WEM scenario with existing measures is based on the expectation that the development of waste composting will continue to increase, as observed in the last decade. This trend was mainly determined by the adopted Strategy for Reducing the Disposal of Biodegradable Waste in Landfills, developed in accordance with Article 5(1) of Directive 1999/31/EC. The goal of this strategy, as per Article 5(1) of the Waste Landfill Directive, is to limit the amount of biodegradable municipal waste disposed of in landfills and propose measures to achieve the goals set out in Article 5(2), primarily through recycling, composting, biogas production, or the use of waste as a source of secondary raw materials and energy.

In Slovakia, basic legal conditions were established to fulfil this requirement in Section 5(1)(d) of the Ministry of Environment of the Slovak Republic Decree No. 283/2001 Coll. This section stipulates that the binding part of the waste management program of the relevant state administration authorities should include measures to reduce the amount of biodegradable municipal waste deposited in landfills. This reduction is expressed in units of weight in the baseline and target years, with the aim of achieving a reduction in the disposal of such waste in landfills in the following manner:

- Within 9 years from the effective date of Decree No. 283/2001 Coll., the amount of biodegradable municipal waste deposited in landfills will be reduced to 75% (-25%) of the Strategy for Reducing the Disposal of Biodegradable Waste in Landfills Ministry of the Environment of the Slovak Republic 8 total amount (weight) of biodegradable municipal waste generated between 1995-2010.
- Within 12 years from the effective date of Decree No. 283/2001 Coll., the amount of biodegradable municipal waste deposited in landfills will be reduced to 50% (-50%) of the total amount of biodegradable municipal waste generated between 1995-2013.
- Within 19 years from the effective date of Decree No. 283/2001 Coll., the amount of biodegradable municipal waste deposited in landfills will be reduced to 35% (-65%) of the total amount (weight) of biodegradable municipal waste generated between 1995-2020.

***Table 6.4:*** *Projections of activity data on composting in WEM scenario*

| Year | Unit | 2019* | 2020* | 2030 | 2040 | 2050 |
|---|---|---|---|---|---|---|
| **MSW** | *kilo tonnes of dm* | 176.75 | 265.15 | 264.10 | 310.64 | 357.18 |
| **Other SW** | *kilo tonnes of dm* | 262.04 | 315.78 | 306.70 | 322.77 | 338.84 |

** Base year 2019; 1990-2020 based on the national emission inventory submission 14. 3. 2023*

Waste incineration (5.C) - Currently, no strategy addresses the construction of new incineration plants for non-municipal waste without energy recovery. According to the Environmental Strategy 2030, the recycling rate of municipal waste, including its preparation for reuse, should increase to 60% in Slovakia by 2030, and the rate of landfilling should decrease to less than 25% by 2035. The Waste Management Program for 2020-2025 does not anticipate the construction of new incineration capacities. Increasing the recycling rate and reducing the amount of waste landfilled will not have a significant impact on the amount of waste incinerated without energy recovery. For modelling emission projections, one scenario was prepared only one scenario based on existing measures (realistic), also known as BAU (Business as Usual), is founded on the expectation that the trend in incinerating industrial waste without energy recovery will continue as observed over the past decade.

Wastewater treatment (5.D) - the business-as-usual (realistic) scenario, 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[3], as well as with the recently adopted document "Concept of water policy of the Slovak Republic until 2030 with a view to 2050"[4]. 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 the current 30% to 11.45% in 2050) due to the expansion of the sewerage network from the current 70% to 85% and also by increasing the number of domestic wastewater treatment plants from the current 2% to 3.5%.

WAM scenario is based on the expectation that developments in the waste management sector will continue with increased financial support from the Slovak government as well as EU support under the Recovery Plan for Europe. At the same time, some new knowledge and trends from other EU countries, which have led to a shift away from landfilling as well as a reduction in emissions from landfills, will be implemented in the Slovak waste management sector.

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 30% today to 5% in 2050) as a result of the intensive expansion of sewerage from 70% today to 90% and the construction of decentralised domestic wastewater treatment plants from 2% today to 5%. 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 waste water treatment. These measures are expected to contribute to a reduction of methane emissions in the municipal sector by almost 86% and in the industrial sector by 69% in 2050 compared to 2005.

## 6.4. Emission Projections in the Waste Sector

Emissions from the Waste sector do not have a key impact on overall emissions. Projection emissions are estimated based on new calculations for AP emissions projections in this sector. A significant share of total emissions is for NMVOC and $NH_3$, however emission projections of $SO_X$, $NH_3$ a $PM_{2,5}$ are also prepared (***Tables 6.5-6.9***).

[3] https://www.minzp.sk/files/iep/03_vlastny_material_envirostrategia2030_def.pdf

[4] https://www.minzp.sk/files/sekcia-vod/koncepcia-vodnej-politiky/koncepcia-vodnej-politiky.pdf

## NOx emissions

***Table 6.5:*** *NOx emissions in sector Waste (kt)*

| WEM | 2005 | 2010 | 2015 | 2020 | 2025 | 2030 | 2040 | 2050 |
|---|---|---|---|---|---|---|---|---|
| 5 Waste | 0.03 | 0.03 | 0.03 | 0.03 | 0.03 | 0.03 | 0.03 | 0.03 |

| WAM | 2005 | 2010 | 2015 | 2020 | 2025 | 2030 | 2040 | 2050 |
|---|---|---|---|---|---|---|---|---|
| 5 Waste | 0.03 | 0.03 | 0.03 | 0.03 | 0.03 | 0.03 | 0.02 | 0.02 |

## NMVOC emissions

***Table 6.6:*** *NMVOC emissions in sector Waste (kt)*

| WEM | 2005 | 2010 | 2015 | 2020 | 2025 | 2030 | 2040 | 2050 |
|---|---|---|---|---|---|---|---|---|
| 5 Waste | 1.51 | 1.01 | 0.98 | 1.02 | 0.91 | 0.81 | 0.58 | 0.45 |

| WAM | 2005 | 2010 | 2015 | 2020 | 2025 | 2030 | 2040 | 2050 |
|---|---|---|---|---|---|---|---|---|
| 5 Waste | 1.51 | 1.01 | 0.98 | 1.02 | 0.81 | 0.61 | 0.37 | 0.27 |

## SOx emissions

***Table 6.7:*** *SOx emissions in sector Waste (kt)*

| WEM | 2005 | 2010 | 2015 | 2020 | 2025 | 2030 | 2040 | 2050 |
|---|---|---|---|---|---|---|---|---|
| 5 Waste | 0.00 | 0.00 | 0.01 | 0.01 | 0.01 | 0.00 | 0.00 | 0.00 |

| WAM | 2005 | 2010 | 2015 | 2020 | 2025 | 2030 | 2040 | 2050 |
|---|---|---|---|---|---|---|---|---|
| 5 Waste | 0.00 | 0.00 | 0.01 | 0.01 | 0.01 | 0.00 | 0.00 | 0.00 |

## $NH_3$ emissions

***Table 6.8:*** *$NH_3$ emissions in sector Waste (kt)*

| WEM | 2005 | 2010 | 2015 | 2020 | 2025 | 2030 | 2040 | 2050 |
|---|---|---|---|---|---|---|---|---|
| 5 Waste | 0.91 | 0.77 | 0.58 | 0.45 | 0.43 | 0.44 | 0.47 | 0.49 |

| WAM | 2005 | 2010 | 2015 | 2020 | 2025 | 2030 | 2040 | 2050 |
|---|---|---|---|---|---|---|---|---|
| 5 Waste | 0.91 | 0.77 | 0.58 | 0.45 | 0.43 | 0.43 | 0.45 | 0.48 |

## $PM_{2.5}$ emissions

***Table 6.9:*** *$PM_{2.5}$ emissions in sector Waste (kt)*

| WEM | 2005 | 2010 | 2015 | 2020 | 2025 | 2030 | 2040 | 2050 |
|---|---|---|---|---|---|---|---|---|
| 5 Waste | 0.17 | 0.20 | 0.21 | 0.19 | 0.18 | 0.18 | 0.17 | 0.17 |

| WAM | 2005 | 2010 | 2015 | 2020 | 2025 | 2030 | 2040 | 2050 |
|---|---|---|---|---|---|---|---|---|
| 5 Waste | 0.17 | 0.20 | 0.21 | 0.19 | 0.18 | 0.17 | 0.17 | 0.17 |

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Authors: HORVÁTH JÁN
JONÁČEK ZUZANA
LABOVSKÝ JURAJ
MACH ROMAN
OREČNÝ JOZEF
SZEMESOVÁ JANKA
TONHAUZER KRISTÍNA
ZEMKO MARCEL

Editor ZETOCHOVÁ LENKA

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