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COMPREHENSIVE DOCUMENTATION OF THE DEVELOPMENT OF EMISSION REDUCTION COMMITMENTS (ERCS) FOR 2020-2029 AND FOR 2030 AND BEYOND FOR THE SIX WESTERN BALKAN ECONOMIES

TECHNICAL REPORT – FINAL

EU 4 Green Recovery:
Support the implementation of the Green Agenda for the Western Balkans

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ABBREVIATIONS

ALB……………	Albania
BIH……………	Bosnia and Herzegovina
CLE……………	Current Legislation scenario
CLRTAP…….	Convention on Long Range Transboundary Air Pollution (Air Convention)
EEA............	European Environment Agency
EF…………….	Emission factor
EMEP..........	European Monitoring and Evaluation Programme
EnC............	Energy Community
EU	European Union
ERC………….	Emission Reduction Commitment of the NEC directive
ESP………….	Electrostatic Precipitator
FAOSTAT....	United Nations Food and Agriculture Organization Statistics
FGD…………	Flue Gas Desulfurization
GAINS	Greenhouse gas - Air pollution Interactions and Synergies model
GHG…………	Greenhouse gas
HF……………	Hydrogen fluoride
ICE……………	Internal Combustion Engine
IEA.............	International Energy Agency
IFASTAT.......	International Fertilizer Association statistical database
IIASA...........	International Institute for Applied Systems Analysis
IIR…………….	Informative Inventory Report
Ind……………	Industry
I&M………….	Inspection & Maintenance
Kt………………	Kilotons, 10^3 tons
LRTAP..........	Convention on Long-range Transboundary Air Pollution
MET Norway	Norwegian Meteorological Institute
MTFR…………	Maximum Technically Feasible Reduction
MKD…………	North Macedonia
MNE…………	Montenegro
NECD..........	National Emissions reduction Commitments (NEC) Directive
NFME……….	Ferrochrome smelters
NFR………….	Nomenclature for Reporting
NH_3………….	Ammonia
NMVOC…….	Non-methane volatile organic compounds
NO_X………….	Nitrogen oxides
uEMEP........	urban European Monitoring and Evaluation Programme model
UNECE........	United Nations Economic Commission for Europe
$PM_{2.5}$……….	Fine particles with an aerodynamic diameter of less than 2.5 µm
PP…………….	Power Plants
PRIMES.......	Price-Induced Market Equilibrium System - Energy Systems model
PRODCOM..	PRODuction COMmunautaire
USGS..........	United States Geological Survey
S………………	Sulfur
SCR………….	Selective catalytic reduction
SO_2……………	Sulphur dioxide
SRB………….	Republic of Serbia
XXK………….	Republic of Kosovo
YOLLs……….	Years of Life Lost

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1 Introduction

The EU4Green project, implemented by the Environment Agency Austria aims to support Western Balkan economies in the implementation of the Green Agenda and the initiation of corresponding reforms, addressing decarbonization, circular economy, depollution, sustainable agriculture, and biodiversity.

Within this project Umweltbundesamt joint forces with IIASA on Depollution Air activities, the work provided by the IIASA team focused on the assessment of the current and likely future development of air pollutant emissions and potential for their mitigation in the Western Balkans. Activities started in 2023 and included support for the development of improved datasets representing past emissions of air pollutants from 2005 to 2020 as well as future projections until 2050 for emissions of SO_2, NO_x, NH_3, NMVOC and primary $PM_{2.5}$ for six Western Balkan economies (Albania, Serbia, Kosovo[1], Montenegro, North Macedonia and Bosnia and Herzegovina) through online consultation meetings. Information from these improved datasets were then integrated in the baseline of the GAINS (Greenhouse gas - Air pollution Interactions and Synergies) model[2,3]. This baseline was further used for the development of preliminary emission reduction commitments (ERCs) set as targets for SO_2, NOx, NH_3, NMVOC and $PM_{2.5}$ emissions for 2020-2029 and for 2030 and beyond for all six economies. The application of these targets would lead to a reduction of 50% of premature deaths attributable to air pollution between 2005 and 2030 for the whole Western Balkans region, in line with the approach of deriving national ERCs for 2030 set under the NECD[4].

Activities by the IIASA project team in 2025 complemented the previous work with additional consultation meetings where new information from each participating economy was evaluated and integrated in GAINS. This is of high importance as air emission inventories in the six economies are under development with new or more detailed information becoming available more frequently. Consideration of the new information in GAINS has further improved the representation of the most recent inventories, resulting in a more robust modelling dataset for updating the emission reduction target calculations.

Five of the six Western Balkan economies are Parties to the Convention on Long Range Transboundary Air Pollution (CLRTAP or Air Convention). Kosovo is not a Party to the Air Convention. Parties to the Air Convention are required to report air emission inventories of the main pollutants (SO_2, NO_x, NH_3, NMVOC and primary $PM_{2.5}$) and a range of other pollutants annually. The air emission inventories are reported in a standard Excel-base format known as NFR (Nomenclature for Reporting) table where emissions are split into 127 emission sources that together build the National Total. The NFR categories are aggregated into 13 GNFR (NFR Aggregation for Gridding and LPS) categories. The methods used by the Parties to

[1] This designation is without prejudice to positions on status, and it is in line with UNSCR 1244 and the ICJ Opinion on the Kosovo declaration of independence.

[2] https://gains.iiasa.ac.at/models/

[3] https://eu4green.eu/library/development-of-emission-reduction-commitments-for-2020-2029-and-for-2030-and-beyond-for-the-six-west-balkan-economies/

[4] National Emissions reduction Commitments (NEC) Directive; https://eur-lex.europa.eu/legal-content/EN/TXT/

estimate air emissions and further background information are provided in the IIRs (Informative Inventory Reports). The IIASA GAINS model provides independent estimates of air emissions of the main pollutants for these 13 GNFR categories.

2 Modelling Framework

IIASA has developed and maintains the GAINS model (Amann et al., 2011), an integrated assessment model that has been used in supporting discussion, development and evaluation of air quality and climate policies by the European Commission and by the UNECE LRTAP Contracting Parties. With GAINS, emission reduction potentials at various ambition levels can be identified. Furthermore, the GAINS model allows for calculation of ambient $PM_{2.5}$ and NO_x concentrations, consistent with the EMEP and uEMEP models (Denby et al., 2020) developed by the Norwegian Meteorological Institute (MET Norway) that have been regularly validated against the existing monitoring network (including the whole European UNECE area where respective monitoring data is available), therefore enabling a consistent atmospheric modelling framework, including cross scale analysis.

2.1 Scenario description

The starting point for the development of the baseline scenario was a scenario developed within the "EUCLIMIT-9East [5]" project in 2021-2022. This project focused on energy community (EnC) economies[6] and on different aspects of decarbonization. The scenario developed in this project created a basis for negotiations to set up climate mitigation targets[7], share of renewable energy, energy efficiency improvements, targets for transport fleet etc. These targets are defined in a similar way to EU targets, however, often with a 5-year delay.

The baseline also assumes implementation of the current national regulations for air pollutant sources, including emission limit values for power plants, industry, transport sector as well as regulations for agriculture. These were reviewed within EU4Green during the bilateral meetings and updated considering additional information provided by national experts.

2.2 Emission calculation

In GAINS, information on data for activities within sectors (e.g. power, industry, residential, agriculture and transport) such as data on fuel use, livestock numbers, fertilizer application, industrial production etc., is combined with pollutant and activity specific emission factors and a set of emission control strategies (see Equation 1). The latter includes the removal

[5] Service Contract ENER/A3/SER/2019-563/SI2.840866 - ENER/2020/OP/0005; Extension of the EU Energy and Climate Modelling Capacity to include the Energy Community and its Nine Contracting Parties

[6] Contracting parties: Albania, Bosnia and Herzegovina, Georgia, Kosovo, Moldova, Montenegro, North Macedonia, Serbia, Ukraine (https://www.energy-community.org/aboutus/whoweare.html)

[7] https://www.energy-community.org/implementation/package/CEP.html

efficiency of emission control measures and the extent to which such measures are applied. Emission control strategies are used to model current emission control practices and policies.

Historic activity data is collected from sources such as EUROSTAT, IEA, UN and World Bank. Additionally, there are different projections of this activity data until 2050 to describe the time dependent evolution of such activities shaped by the development of an economy and national as well as international policies. Such projections are usually provided by external sources such as the PRIMES model for energy and the CAPRI model for agriculture or developed from sources like the FAO Agricultural Outlook 2018 for agriculture (FAO, 2018). The emission calculation also takes into account structural information, e.g., data on the structure of installations in the residential sector, structure of fleets in the transport sector and farm sizes where available.

$$E_i = \sum_{j,k,m} E_{i,j,k,m} = \sum_{j,k,m} A_{i,j,k} ef_{i,j,k}(1 - eff_m) X_{i,j,k,m} \qquad \text{Equation 1}$$

i,j,k,m	Country, sector, fuel, abatement technology
E	Emissions in country *i*
A	Activity
ef	Unabated emission factor
eff	Reduction efficiency of the abatement technology *m*
X	Implementation rate of the considered abatement technology *m*

If there is national data available on activities, emission factors and policies that are either collected by IIASA experts or received through consultation meetings with national experts it is taken up in the model (Figure 1).

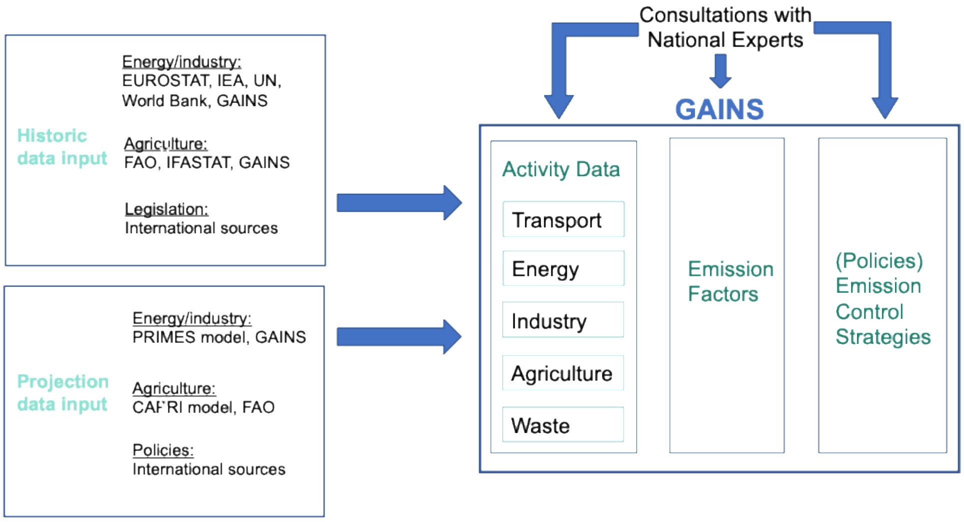

Figure 1 Inputs to the GAINS model and internal components that are combined to calculate emissions

2.3 Updates to the data and scenario assumptions

Some general modifications of the baseline scenario were done before and after the consultation meetings to include best available information/calculation methods for certain sectors.

From December 2023 to January 2024, six consultation meetings (one per economy) with good attendance took place online. A core task of these consultation meetings was to compare the air emission data reported by the Western Balkan economies (reported as NFR tables (Nomenclature for Reporting) and the IIASA GAINS estimates and to explore reasons for the differences between the emission estimates. Within the EU4Green project, IIASA and the economy teams communicated already before the actual consultations meetings and exchanged information about data on air quality monitoring stations, data on energy balances and information on policies affecting air pollution. As the meetings also served to identify areas where additional or more detailed information was needed, they were followed by further data exchange between the IIASA and the respective economy's experts. While IIASA provided details and background of certain GAINS calculations, the respective economy's experts provided information on national policies and more specific data on, e.g., emission factors, fuel characteristics, current and expected application of emission reduction measures.

In 2025, further consultation meetings with interested economies (Albania, Kosovo, North Macedonia and Serbia) took place to discuss remaining differences in emissions reported in national data, this time considering 2025 submissions of NFR and IIR, and the GAINS baseline. Economy specific updated information collected before or received during these meetings was integrated into the GAINS baseline.

The general procedure for updating the GAINS data in 2024 and 2025 for the various sectors is explained below, while more details on the economy specific modifications are described throughout section 3. The timing and extent to which the updates described below were implemented for each economy and sector depended on the respective data availability.

2.3.1 Agriculture

All emission factors for the calculation of NH_3 and NMVOC from agriculture were updated to fit the Tier II emission factors from the EMEP/EEA Guidebook 2023 (EMEP/EEA, 2023) in 2024. Historic activity data such as livestock numbers for each livestock type were adjusted to the respective economy's most recent statistics, NFR or IIR data if available and if differences to other sources such as FAOSTAT[8] were not too large. If larger differences between these statistics and additional sources were found, they were presented and discussed with the respective economy's experts at the consultation meetings. Historic data on nitrogen fertilizer consumption and urea shares in nitrogen fertilizers was updated to reflect either local statistics or FAOSTAT or IFASTAT data[9;10]. Projections were adjusted if information on policies leading to future emission changes was provided.

The applicability of NH_3 mitigation technologies was revised and adjusted to local conditions such as farm sizes, which give an implication of the feasibility of the implementation of certain technologies by a certain time.

2.3.2 Transport

Total fuel consumption in GAINS by each vehicle and technology type for the historical period was taken from IEA Statistics. For historical years, it was disaggregated into different vehicle categories based on assumptions of the average fuel consumption (fuel efficiency) and kilometers driven. This final data on the number of vehicles by category (two-wheelers, passenger cars, buses, light duty trucks and heavy-duty trucks) in fuel or technology (e.g., ICE gasoline, ICE diesel, electric, hybrid, hydrogen etc.) was compared with national statistical data. When national reports are unavailable, it is adjusted according to feedback given during and after the consultations.

To estimate emission standards, information on vehicle age was combined with the existing legislation in each economy and EURO emission standards implementation years. This enables the derivation of the distribution of emission standards within the vehicle fleet. Where economy level data on the age structure of the vehicle fleet was unavailable, information from the UNECE report '2022 Europe and North America Inland Road Transport' (UNECE, 2022) and the UNECE Statistical Database was adopted. These sources contain the average age of the vehicle fleet segregated for most economies by passenger cars, buses and

[8] https://www.fao.org/faostat/en/#data/QCL
[9] https://www.fao.org/faostat/en/#data/RFN
[10] https://www.ifastat.org/databases/plant-nutrition

trucks. Overall, the data was used to estimate the fleet structure for recent years and then scaled back for historic years (1990-2020).

For the baseline scenario and to estimate the penetration of new vehicles, assumptions were made on the share of new and newly registered but imported vehicles which were entering the vehicle fleet per year in each economy. For some economies, such as Montenegro and Serbia, this data was readily available. It was assumed that there would be similar infiltration rates across the Western Balkan region. Generally, in the Western Balkan economies, the proportion of newly registered vehicles is less than 5%. It is assumed that a large proportion of the vehicle fleet is imported, predominantly from the EU.

To develop a future scenario for the structure of emission standards in the vehicle fleet, current local legislation on emission limits was combined with assumptions on the turnover rates, based on the average vehicle age and historic EU legislation.

2.3.3 Residential Combustion

Data on emissions from residential combustion, especially from use of fuelwood for cooking and heating, are burdened with rather high uncertainties. Key reasons include lack or poor information about actual fuelwood use, limited availability of representative emission factors and of information about the structure of combustion installations (i.e., share of stoves, fireplaces, manual and automatic boilers, pellet stoves, etc.).

The GAINS model is relying on the available statistical information from IEA, Eurostat, OECD, review of several studies addressing residential and in general heating sector in Western Balkans. The two key studies that were used to validate GAINS data and assumptions was the UNECE/FAO (2019)[11] study on "Wood Energy in the UNECE Region" and the IBRD/World Bank (2018)[12] study on "Biomass-Based Heating in the Western Balkans – A Roadmap for Sustainable Development". Apart from estimates of total fuel wood use, the studies allowed for specification of how much fuel is used in urbanized vs rural areas and what is the likely structure of installations. This information allowed to apply Tier II approach in GAINS.

The above information has been shared with the Western Balkan economies during consultations and the assumptions made have been either confirmed by the respective economy's data or received as additional input to improve the economy's assessment.

Overall, the exchange of information has led to improved understanding of this sector, better representation of its emissions in GAINS, and possibly also in the national inventories submitted in the future. The atmospheric calculation in GAINS indicates that the estimates of residential emissions of $PM_{2.5}$ in GAINS are quite reasonable for most economies which is

[11] https://unece.org/fileadmin/DAM/timber/publications/SP-42-Interactive.pdf
[12] http://documents1.worldbank.org/curated/en/135831542022333083/pdf/Biomass-Based-Heating-in-the-Western-Balkans-A-Roadmap-for-Sustainable-Development.pdf

reflected in the acceptable match with the available measurements at several air quality monitoring stations across the region.

2.3.4 Power and Industry

Following comparison and discussion with the respective economy's experts, information about the activity levels, specifically fuel use in power plant and industrial boilers and furnaces and data on production/manufacturing of various commodities like cement, iron and steel, non-ferrous metals, pulp and paper, crude oil throughput, etc. were revised and updated, where necessary. In case such information was missing or incomplete, gaps were filled where possible with information from IEA and USGS statistics and the PRIMES model.

Emission factors were adjusted to reflect the best available economy level information on fuel characteristics, e.g., sulfur content, ash content and heat value of used coals (lignite).

The level of application (penetration) and efficiency of emission controls was revised and updated according to the economy's information. This specifically concerned the extent of application of technologies to reduce emissions of SO_2, i.e., Flue Gas Desulfurization (FGDs), technologies to reduce NO_x emissions like low-NO_x burners, and further control of particulate matter emissions by installation of electrostatic precipitators (ESPs).

3 Comparison between economy data and the GAINS baseline

The air emission data reported by the Western Balkan economies (reported as NFR tables (Nomenclature for Reporting) and the IIASA GAINS estimates of the original Baseline, created before the project start, the GAINS baseline that was adjusted in 2024, following more general updates as described in section 2.3 and taking into account information received from the national experts, and the GAINS baseline that was adjusted in 2025, reflecting most recent national data were compared and reasons for the differences between the emission estimates were explored.

3.1 Albania

Albania's air emission inventory is not complete with information for some sectors missing as the compilers are still looking for sector experts to complete their team. Hence a comparison between the GAINS baseline and national data is often not applicable.

3.1.1 SO_2

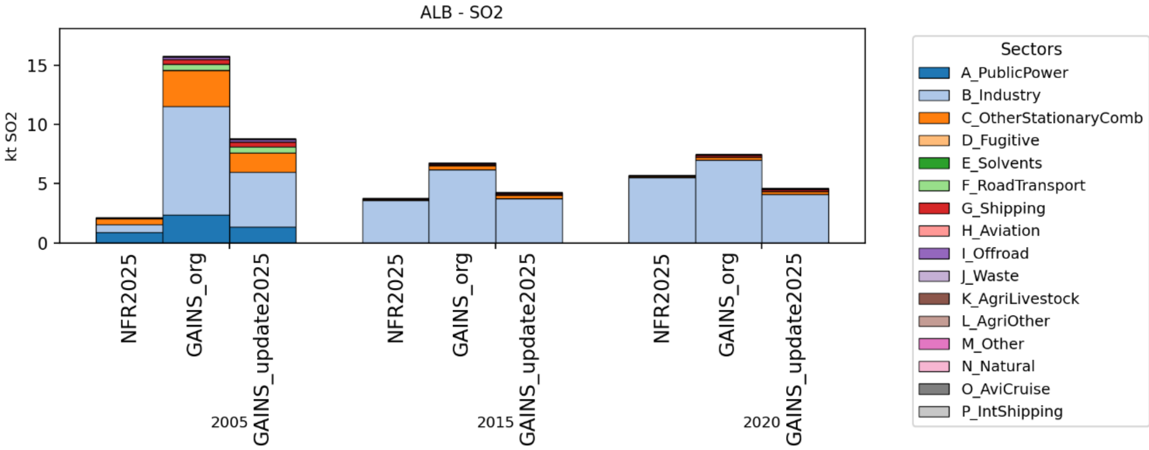

Figure 2 SO_2 emission comparison between NFR 2025 (NFR2025) as reported by Albania, the original GAINS baseline (GAINS_org) and the updated GAINS baseline in 2025 (GAINS_update2025)

3.1.1.1 Updates in 2024 and 2025

Activities in the power and industry sector such as fuel combustion and production levels were revised and updated in the case of missing or inconsistent values. Fuel characteristics of liquid fuels, more specifically the sulfur content in heavy fuel oil, was updated to 4% in 2024 due to a lack of further information and reduced to 2.5% in 2025 to stay within the range provided in the EMEP/EEA guidebook 2023, which is also consistent with the calculation of emission factors used in the national inventory (EMEP/EEA, 2023). Since the use of heavy fuel oil in the power sector and industry is significantly reduced after 2010, the effect of these changes is most apparent in 2005. To reflect provisions of DECISION No. 429[13] on the quality of some liquid and combustible substances after the year 2025, the application of controls was revised further in 2025 with a gradual uptake of low-S fuel oil.

3.1.1.2 Remaining differences in 2025

The biggest differences can be observed in the power and industry sector. Unreported process emissions from some industry sectors like cement, refineries and non-ferrous metals in the NFR are relevant in 2005 and 2015 but reduced in 2020 which explains the reduction of the difference between the GAINS baseline and national reporting. The remaining difference is related to the use of different emission factors as the national data was compiled using a Tier I emission factor while GAINS uses an approach comparable to Tier II.

[13] https://www.infrastruktura.gov.al/wp-content/uploads/2019/07/vendim-cilesia-e-lendeve-djegese-2019-06-26-429.pdf

3.1.2 NO_X

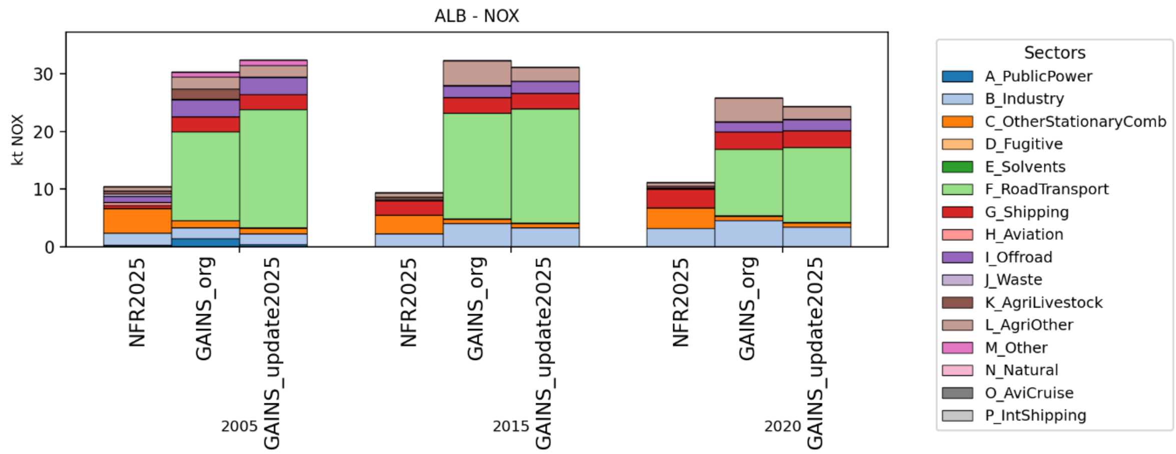

Figure 3 NO_X emission comparison between NFR 2025 (NFR2025) as reported by Albania, the original GAINS baseline (GAINS_org) and the updated GAINS baseline in 2025 (GAINS_update2025)

3.1.2.1 Updates in 2024 and 2025

Activity data for the number of vehicles by fuel type was updated in the road transport sector based on data received from national experts in 2024. GAINS estimates of vehicle emission standards were also updated based on an UNECE report which gave data on vehicle age structure in Albania (UNECE, 2024). Using this data combined with legislation on the implementation of vehicle standards allowed for the development of a vehicle fleet for the year 2020. For future stock turnover, the average age of the vehicles was again used to understand how quickly new emission standard vehicles may penetrate the vehicle fleet. No further changes were made in 2025.

Updates of mineral fertilizer and livestock as well as manure data in 2024 and 2025 as described in section 3.1.3.1 also influenced NO_X emissions from agriculture.

In 2024, the implementation of low-NO_X burners after 2020 was introduced in the power sector. In 2025, the De-NOx controls have been revised for the industrial combustion sources as well as they were introduced in the cement production sector.

3.1.2.2 Remaining differences in 2025

NO_x emissions from transport and soil are not reported, which leads to larger differences. Differences in emissions from shipping could be explained by different assumptions of fuel consumption. Differences in emissions from the residential sector are due to a difference in emission factors. GAINS applies a consistent set of emission factors across the region which reflect the typically lower efficiency combustion installations in residential sector resulting in relatively small NO_X emissions, which is consistent with reporting for other regions. We consider the NO_X from the residential sector in Albanian inventory as likely overestimated.

3.1.3 NH_3

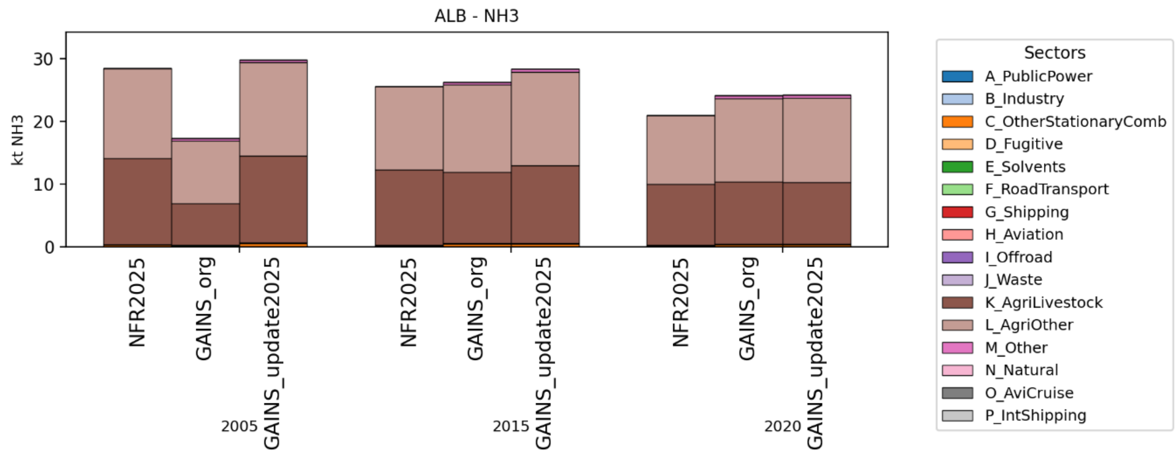

Figure 4 NH_3 emission comparison between NFR 2025 (NFR2025) as reported by Albania, the original GAINS baseline (GAINS_org) and the updated GAINS baseline in 2025 (GAINS_update2025)

3.1.3.1 Updates in 2024 and 2025

Livestock numbers in GAINS were updated using information from the NFR in 2024 and nitrogen excretion for dairy cattle was adjusted to EMEP/EEA Guidebook 2023 default excretion for Eastern Europe. Shares for liquid and solid manure management for cattle and pigs were updated to reflect information received in 2025. Fertilizer data was updated in 2025 to fit most recent IFASTAT (2025) data for urea and non-urea fertilizers. Nitrogen excretion for dairy cattle was adjusted to EMEP/EEA Guidebook 2023 default excretion for Eastern Europe. The urea shares in synthetic fertilizer use after 2025 was adjusted to reflect information from the National Energy and Climate Plan (version March 2024 received from national experts in 2025) that application of urea will be cut in half by 2030.

3.1.3.2 Remaining differences in 2025

There is a slightly bigger difference in 2020 due to differences in NH_3 emissions from mineral fertilizers and grazing. As no detailed national calculation was available this difference could not be resolved. Most recent national data have been integrated.

3.1.4 PM2.5

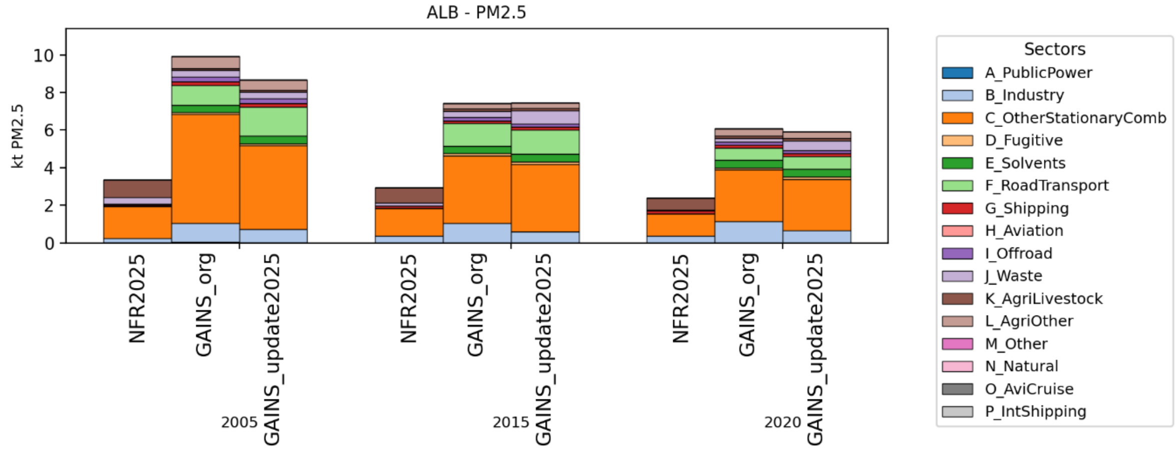

Figure 5 $PM_{2.5}$ emission comparison between NFR 2025 (NFR2025) as reported by Albania, the original GAINS baseline (GAINS_org) and the updated GAINS baseline in 2025 (GAINS_update2025)

3.1.4.1 Updates in 2024 and 2025

The implementation rate of technologies reducing emissions of PM in the power and industry sector was updated in 2025. Estimates of total fuel wood use and the structure of installations were adjusted for the residential sector in 2024 (see 2.3.3). Information for the residential sector was updated in 2024 using information from studies as described in section 2.3.3.

3.1.4.2 Remaining differences in 2025

Emissions from NFME (ferrochrome smelters) are not included in the NFR 2025. Neither are fugitive emissions from small industries, which leads to differences between national reporting and GAINS data in the industry sector. Additionally, there are different assumptions on the use of PM control technologies from cement production, while activity data are consistent.

Emissions from road transport are also not reported in the national inventory.

GAINS includes data on agricultural waste burning, based on remote sensing while no emissions from agricultural waste burning are reported in the national inventory.

Differences in emissions from the residential sector are due to a difference of emission factors. While national data is calculated using a Tier I emission factor that does not differentiate between different types of installations (boilers, stoves), GAINS calculations take the distribution of different installations according to a World Bank report into account (see 2.3.3). The latter results in a different implied emission factor for the sector and is changing over time, unlike the Tier I emission factor.

3.1.5 NMVOC

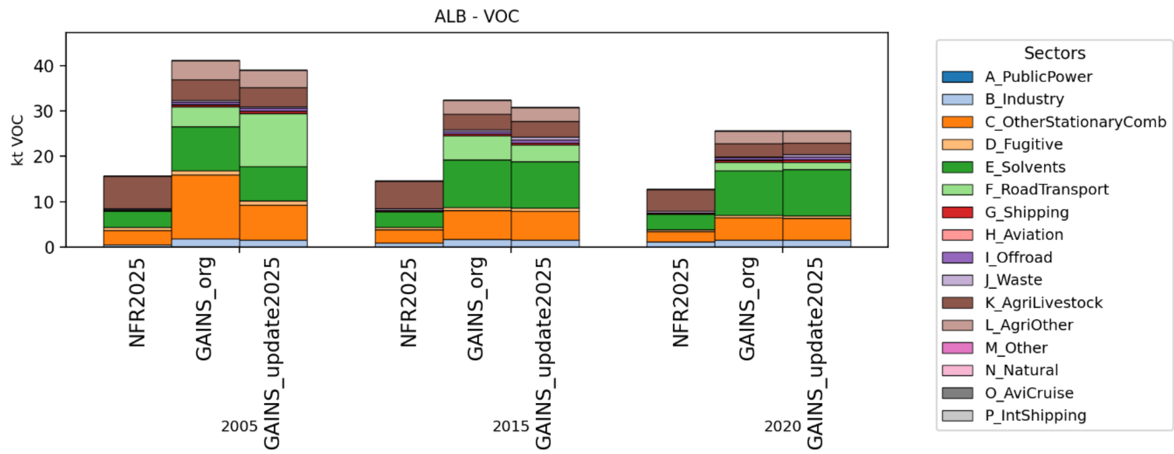

Figure 6 NMVOC emission comparison between NFR 2025 (NFR2025) as reported by Albania, the original GAINS baseline (GAINS_org) and the updated GAINS baseline in 2025 (GAINS_update2025)

3.1.5.1 Updates in 2024 and 2025

In general, both the solvents and fugitive sectors lack sufficient activity statistics for a comprehensive estimation. As a result, previously estimated activity levels based on historical patterns were retained without modification. The coating application category was updated in 2024 in accordance with the EMEP/EEA Air Pollutant Emission Inventory Guidebook (2023). For the coal mining sector, the emission factor for lignite was updated using the default emission factors provided in the Guidebook. For hard coal, the emission factor was updated by incorporating methane (CH_4) emission factors from GAINS. Information for the residential sector was updated in 2024 using information from studies as described in section 2.3.3.

3.1.5.2 Remaining differences in 2025

Differences are high because the 2025 economy specific data do not include road transport and several subcategories under “Other Solvent and Product Use” (category 2.D). Emissions from the residential sector differ due to a different use of emissions factors (Tier I vs Tier II in GAINS; see discussion in the PM section). Albania does not report any emissions in the L_AgriOther sector, and no details are given on the calculation of NMVOC emissions from the K_AgriLivestock sector. Thus, differences cannot be further analyzed.

3.2 Bosnia and Herzegovina

Bosnia and Herzegovina does not have a national air emission inventory, hence no comparison between national data and the GAINS baseline was possible. However, inventories will be developed on entity level. In República Srpska, the hydrometeorological institute is responsible for establishing the air inventory. The process has started, and training is in progress.

In the Federation of Bosnia and Herzegovina, a law was drafted which will oblige their hydrometeorological institute to develop the air emission inventory.

Experts stated that the base year 2005 for the ERC calculations is not representative for Bosnia and Herzegovina as emissions were low because energy and power sources were not fully operated. Therefore, 2014 was chosen as a base year for the NDC, and 2016 was chosen as a base year for the national energy and climate plan.

No consultation meeting took place in 2025 due to the unavailability of national experts.

3.2.1 SO_2

Activity data for the power and industry sector (fuel combustion and production levels) was revised and updated in case of missing values (source IEA, USGS, PRIMES). Fuel characteristics of solid fuels (heat value and sulfur content in lignite) were updated (new values 1.6-1.8%) for the power and industry sectors according to the 2015 National Economic Reform Programme of Bosnia and Herzegovina (NERP)[14]. The application of controls was revised with a gradual uptake of FGDs in coal power plants.

The overall trend in the past emissions in GAINS is consistent with UNECE (2018).

3.2.2 NO_x

The application of low-NO_X burners was introduced after 2025.

Activity data for the number of vehicles by fuel type was updated based on the UNECE statistical database (UNECE, 2024). GAINS estimates of vehicle emission standards were also updated based on the UNECE database which gave data on vehicle age structure in Bosnia and Herzegovina.

[14] http://www.dep.gov.ba/naslovna/?id=1657

3.2.3 NH_3

Livestock numbers were updated to national statistics[15] and fertilizer data was updated to fit IFASTAT data.

3.2.4 $PM_{2.5}$

Activity data for the power and industry sectors (fuel combustion and production levels) was revised and updated in case of missing values (source IEA, USGS, PRIMES) and the application of controls was revised.

3.2.5 NMVOC

The activity data for the solvent and fugitive sectors were largely retained as previously estimated, based on historical trends observed in industrial production (EUROSTAT, 2023) statistics. Updates are expected in the future as additional data become available from other statistical sources or model results.

3.3 Montenegro

No consultation meeting took place in 2025 due to the unavailability of national experts.

[15] bhas.gov.ba/Calendar/Category?id=23&page=3&statGroup=23&tabId=0

3.3.1 SO_2

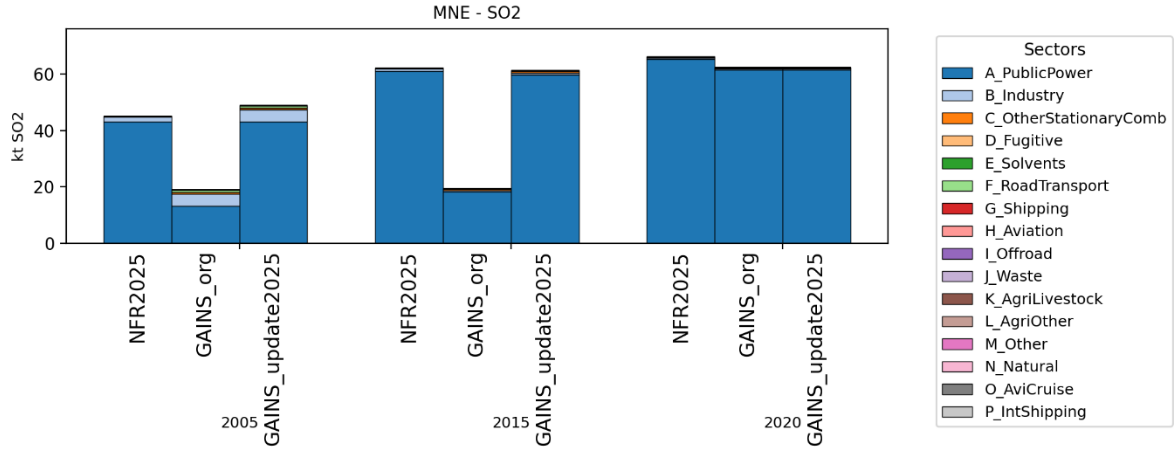

Figure 7 SO_2 emission comparison between NFR 2025 (NFR2025) as reported by Montenegro, the original GAINS baseline (GAINS_org) and the updated GAINS baseline in 2025 (GAINS_update2025)

3.3.1.1 Updates in 2024 and 2025

Activities in the industry and power sector such as fuel combustion and production levels have been revised and updated in the case of missing and inconsistent values (source IEA, USGS, PRIMES) in 2024. Fuel characteristics of solid fuels (heat value and sulfur content in lignite) were updated for power plants (new value for lignite 2.5%) and the industry sectors in 2024. No further updates were done in 2025.

3.3.1.2 Remaining differences in 2025

Differences are rather small and most up to date available data has been integrated.

3.3.2 NO_X

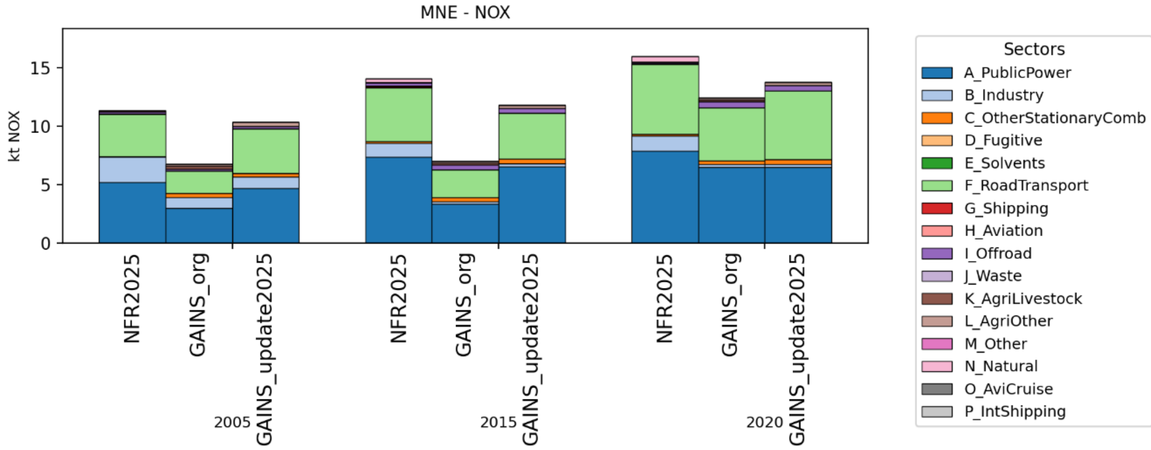

Figure 8 NO_X emission comparison between NFR 2025 (NFR2025) as reported by Montenegro, the original GAINS baseline (GAINS_org) and the updated GAINS baseline in 2025 (GAINS_update2025)

3.3.2.1 Updates in 2024 and 2025

The NO_x emission factors for power plants (lignite) and industry (liquid fuels) were updated using values from the IIR 2023 in 2024. The implementation of controls was revised in 2024 with a gradual uptake of low-NO_x burners after 2025.

Activity data for the road transport sector in GAINS (vehicle numbers) and emission standards of the vehicle fleet were updated in 2024 based on data available on the UNECE Statistical Database (UNECE, 2024) which gave the registration of vehicles each year. Using this data a basic stock turnover model was developed using data on the average age of vehicles in Montenegro taken from Vujadinovic et al. (2019). The same turnover model was used to predict the penetration rate of vehicles into the future and into the past. In 2025, the control strategy for diesel trucks and buses in 2020 was changed, considering information from the IIR 2025.

3.3.2.2 Remaining differences in 2025

Differences in the industry sector are the largest. Differences in the emissions from industries are associated with the use of different emission factors primarily in the non-ferrous metals and other subsectors. National data is calculated using Tier I emission factors as reported in the IIR while GAINS uses Tier II. The activity data (coal consumption) is in good agreement between the national data and GAINS. As GAINS assumes no controls for NO_x until 2020, but emissions are still lower than the national reporting there must be a discrepancy in emission factors.

3.3.3 NH_3

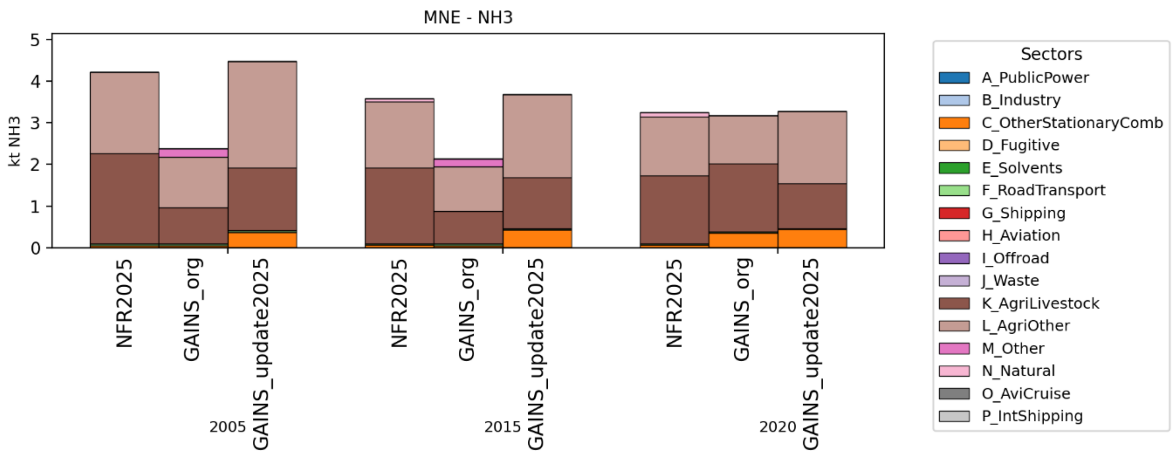

Figure 9 NH_3 emission comparison between NFR 2025 (NFR2025) as reported by Montenegro, the original GAINS baseline (GAINS_org) and the updated GAINS baseline in 2025 (GAINS_update2025)

3.3.3.1 Updates in 2024 and 2025

Livestock numbers were updated with information from the NFR in 2024. Nitrogen excretion as well as housing days were derived from FAOSTAT and the FAO 2018 report "Nitrogen inputs to agricultural soils from livestock manure - New statistics" (FAO, 2018b) (used by national inventory team) in 2024. Total synthetic N fertilizer was updated in 2025 to fit data from the NFR/IIR 2025. In 2025, the GAINS emission factor for livestock and fertilizer was revised. For synthetic fertilizer, data on synthetic fertilizer types used in 2011 from FAOSTAT combined with N content taken from the EMEP/EEA 2023 Guidebook was used to update the emission factor.

3.3.3.2 Remaining differences in 2025

Differences in emissions from the agricultural sector are most likely due to a difference in emission factors used (Tier I vs Tier II). However, there are no details on the calculation in the IIR and no consultation meeting took place so these differences could not be resolved.

Differences in the residential sector are due to emission factors used. Montenegro inventory was updated and relies on the emission factors proposed in the EEA/EMEP Guidebook version 2023 which are much lower than those in the older Guidebook and in several research papers published in the last decade. The new Guidebook numbers rely on the German study (DBFZ, 2023) that has tested a rather limited set of stoves and is likely reflecting emissions of well operated, efficient installations. GAINS uses a consistent set of emission factors across the whole Balkan region, and they are more in line with the older versions of EEA/EMEP Guidebook and a thorough review and comparison of measurements during evaluation and update of emission factors used in the Danish inventory (Nielsen et al., 2021).

3.3.4 $PM_{2.5}$

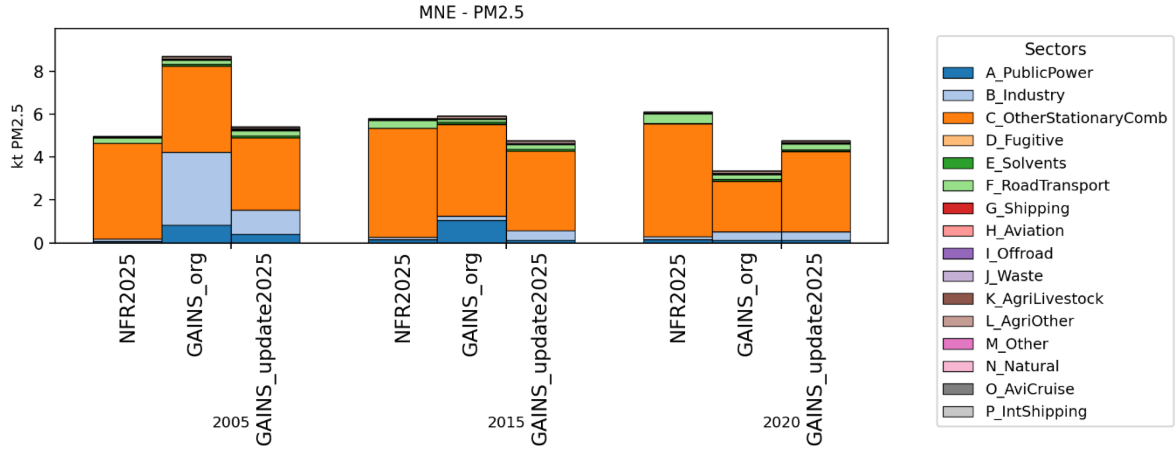

Figure 10 $PM_{2.5}$ emission comparison between NFR 2025 (NFR2025) as reported by Montenegro, the original GAINS baseline (GAINS_org) and the updated GAINS baseline in 2025 (GAINS_update2025)

3.3.4.1 Updates in 2024 and 2025

The application rates of $PM_{2.5}$ controls have been revised for past and future years, mainly for the industrial process activities (lime, aluminum, and steel production) as well as for the power sector in 2024. In 2025, minor additional adjustments have been made to the adoption of PM control technologies (electrostatic precipitators) in the same sectors for the year 2005. Earlier updates in power plants reflect the reconstruction of electrostatic precipitators in the Pljevlja power station in 2010.

Information for the residential sector was updated in 2024 using information from studies as described in section 2.3.3 and data on fuel use provided in the IIR 2024.

3.3.4.2 Remaining differences in 2025

Although GAINS has rather similar activities through the years, there are significant differences to national data in the power sector and industries in the year 2005. For the lignite combustion in power plants, the economy's estimate is based on a very low emission factor not achievable even with the best available technologies assumed in GAINS. The industrial emissions in the NFR 2023 (year 2005) were dominated by lime production. However, there was a numerical error in the emission factor applied in this sector (emission factor multiplied by 1000). This has been communicated to the national experts and was corrected in the submissions after 2023. Emissions from steel making were not reported in the NFR 2023 but are reported in the 2025 submission.

Emissions in the residential sector have been changing in national reporting with emissions reported in NFR 2023 and NFR 2024 being almost half of the original GAINS emissions and a strong increase in the 2025 submission, which resulted in higher estimate than current GAINS.

The revision in the national reporting is linked to the selection of different emission factors by national experts, however they still rely on Tier I methodology from the EEA/EMEP Guidebook and therefore emissions over time scale with fuel use. GAINS considers various installation types and therefore the trend is slightly different owing to increasing penetration of more efficient installations, although it is not a significant shift. Overall, emissions for residential sector compare reasonably.

3.3.5 NMVOC

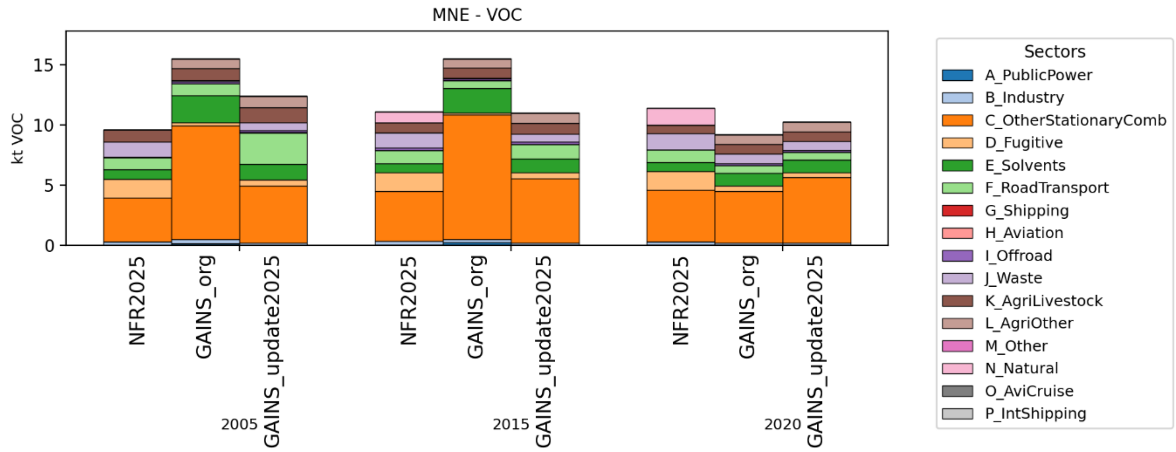

Figure 11 NMVOC emission comparison between NFR 2025 (NFR2025) as reported by Montenegro, the original GAINS baseline (GAINS_org) and the updated GAINS baseline in 2025 (GAINS_update2025)

3.3.5.1 Updates in 2024 and 2025

The activity data for the solvent (i.e 'coating application' and 'other solvent use categories') and fugitive sectors were updated in 2024, based on historical trends from PRODCOM(EUROSTAT, 2023). Updates in the transport sector as described under NO_X emissions, also affect NMVOC emissions in the updated GAINS baselines for 2024 and 2025. Estimates of total fuel wood use and the structure of installations were adjusted for the residential sector in 2024 (see 2.3.3).

3.3.5.2 Remaining differences in 2025

In GAINS, the activity data for coal mining in the model is shared across multiple substances within the model. The VOC emission factor for coal mining is not directly specified but was inferred based on the CH_4 emission factor used for the same sector. The coal mining sector in the model is disaggregated into deep mining and open-pit mining, with the emission factor for open-pit mining being lower than the default value provided in the EMEP/EEA Guidebook. This is the main reason for the significant discrepancies observed in the 'D_Fugitive' sector.

Further refinement would be possible in the future if higher Tier or locally specific emission factors can be obtained.

3.4 North Macedonia

3.4.1 SO_2

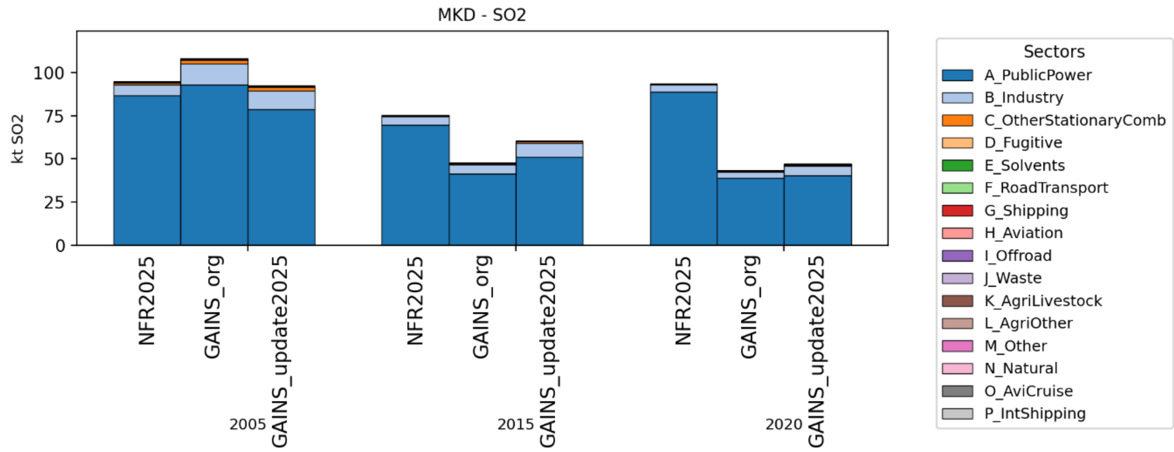

Figure 12 SO_2 emission comparison between NFR 2025 (NFR2025) as reported by North Macedonia, the original GAINS baseline (GAINS_org) and the updated GAINS baseline in 2025 (GAINS_update2025)

3.4.1.1 Updates in 2024 and 2025

Activities in the power and industry sector (fuel combustion and industrial production levels) were revised and updated in the case of missing and inconsistent values (source NFR, IEA, USGS, PRIMES) in 2024 and the application of controls was revised with a gradual uptake of low-S fuel oil. In 2025, fuel characteristics of solid fuels were reviewed and sulfur content and calorific value of lignite used in power plants was made consistent with data from IIR 2025. The application of controls was revised further in 2025 with a gradual uptake of low-S liquid fuels.

3.4.1.2 Remaining differences in 2025

There are larger discrepancies in SO_2 emissions from the power sector, especially in 2020. The reason for these differences is a difference in the calculation/reporting method. While data in the national inventory comes from measurements, GAINS data has been calculated from the collected input data. According to the national experts, the measurement data seems highly unreliable as the volume flow has fluctuated, and emission concentrations have differed substantially between 2015 and 2020 although the sulfur content remained comparable. There is no continuous measurement but monthly (one day per month) data.

3.4.2 NO_x

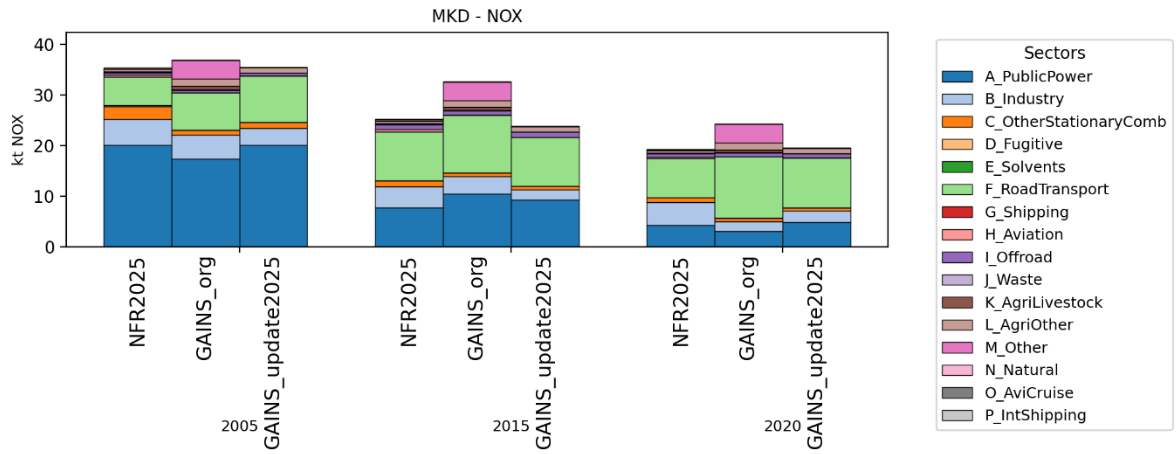

Figure 13 NO_x emission comparison between NFR 2025 (NFR2025) as reported by North Macedonia, the original GAINS baseline (GAINS_org) and the updated GAINS baseline in 2025 (GAINS_update2025)

3.4.2.1 Updates in 2024 and 2025

Activities in the power and industry sector (fuel combustion and industrial production levels) were revised and updated in the case of missing and inconsistent values (source NFR, IEA, USGS, PRIMES) in 2024 and the application of controls was revised with a gradual uptake of low-NO_x burners after 2025. GAINS emission factors for lignite and heavy fuel oil combustion in power plants were revised in 2025, based on IIR 2025 data. Minor adjustments have been also made to the De-NOx rates in industries for the years 2015 and 2020.

GAINS data on the transport sector (vehicle numbers and emission standards) for 2018 were updated in 2024 using the National Transport Emission Inventory Report (Zdraveva and Dimitrovski, 2019). For previous years (2005, 2010) back casting was performed using assumptions about the ages of the vehicles in each category. For 2020, the vehicle number was updated according to UNECE Statistics Database. Future projections of emission standards of the vehicle fleet were also based on assumptions of vehicle age and national legislation which was discussed during the consultations. In 2025 control strategies for the transport sector were updated according to data shared by North Macedonia in COPERT format.

The GAINS 'M_Other' sector represents sources covered in the NFR that are not represented in GAINS. In 2025, a revision of this sector showed that all emissions reported in the NFR are covered by GAINS which lead to the removal of this sector in the GAINS baseline.

3.4.2.2 Remaining differences in 2025

Differences in the power and industry sector can again be explained by the difference in calculation/reporting method due to national data originating from measurements (see explanations given for SO_2).

Although control strategies in the transport sector were updated according to data shared by North Macedonia in COPERT format, emissions estimated by GAINS remain approximately 27% higher than national estimates.

3.4.3 NH_3

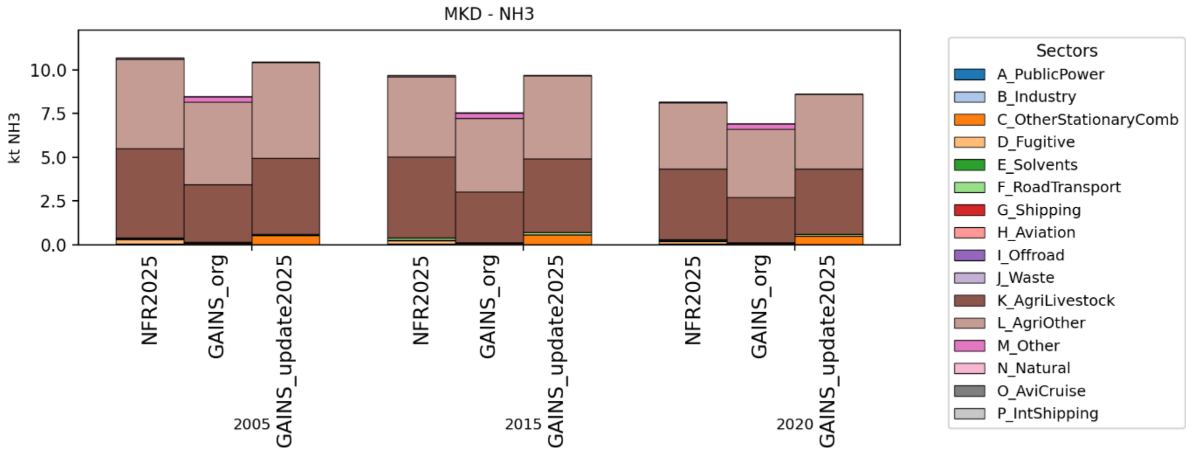

Figure 14 NH_3 emission comparison between NFR 2025 (NFR2025) as reported by North Macedonia, the original GAINS baseline (GAINS_org) and the updated GAINS baseline in 2025 (GAINS_update2025)

3.4.3.1 Updates in 2024 and 2025

Livestock numbers, manure management and mineral fertilizer consumption were updated in 2024 using data from the IIR 2023. Applicability for NH_3 reduction technologies were updated taking farm sizes according to economy specific information into account. As farm sizes, especially for cattle are mostly small according to personal communication after the consultation meetings the feasibility to implement mitigation technologies was reduced. In 2025,the NH_3 emission factor was adjusted using national information on tied livestock received by national experts.

3.4.3.2 Remaining differences in 2025

In the agriculture sector, differences in NH_3 emissions are due to the use of different emission factors. While Tier I is used in national reporting, GAINS uses a Tier II methodology where more detailed information on tied livestock, yard time and direct application of manure is considered.

While not very significant overall, emissions from residential combustion differ significantly due to different emission factors used; see discussion in section 3.3.3.2.

3.4.4 $PM_{2.5}$

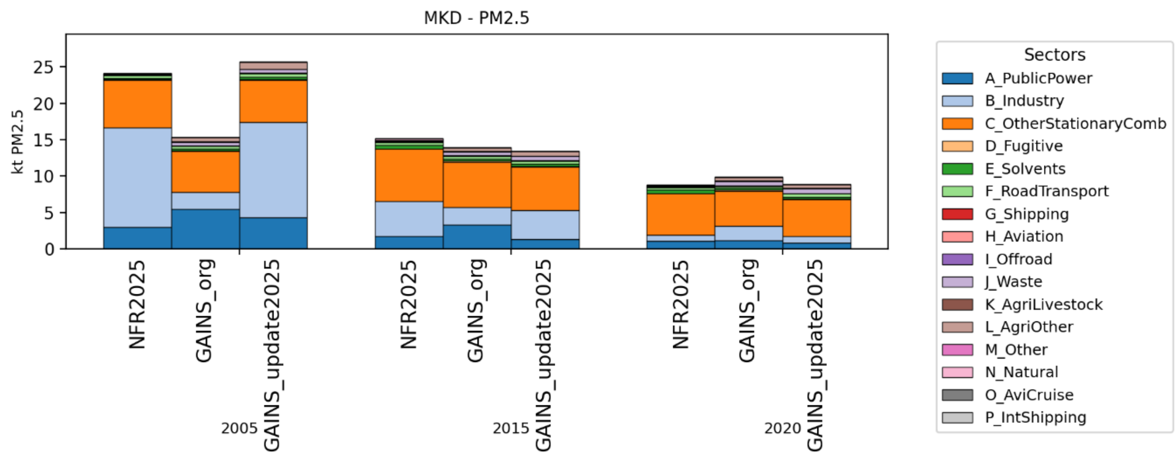

Figure 15 $PM_{2.5}$ emission comparison between NFR 2025 (NFR2025) as reported by North Macedonia, the original GAINS baseline (GAINS_org) and the updated GAINS baseline in 2025 (GAINS_update2025)

3.4.4.1 Updates in 2024 and 2025

Activities in the power and industry sector (fuel combustion and industrial production levels) were revised and updated in the case of missing and inconsistent values (source NFR, IEA, USGS, PRIMES) in 2024 and the application of $PM_{2.5}$ controls was revised. The emission calculation for ferroalloy production in the industry sector, a major source of $PM_{2.5}$ emissions, has been updated in 2025 with more detailed national data received from an expert after the consultation meeting. This resulted in the use of updated $PM_{2.5}$ emission factors reflecting changes in the production mix. The application rates of $PM_{2.5}$ controls introduced in 2024 have been revised in 2025 for the past and future years, mainly for the industrial process activities (iron and steel sector). In addition, the application of highly efficient technologies to reduce PM emissions after 2015 in the lignite power plants has been revised based on the information provided in IIR.

National experts sent detailed reports assessing activities and emissions in the residential sector for the period prior to 2003 and then a detailed study for 2019 where characteristic and structure of the household sector are presented at the subnational level. This information has been integrated in 2024.

3.4.4.2 Remaining differences in 2025

Like for SO_2 and NO_x differences in the power and industry sector can again be explained by the difference in calculation/reporting method due to national data originating from measurements.

3.4.5 NMVOC

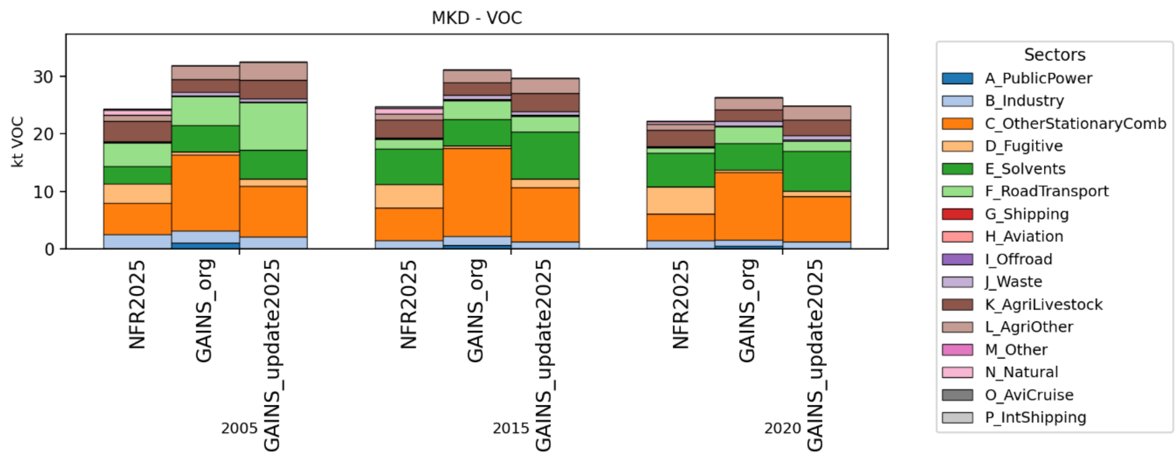

Figure 16 NMVOC emission comparison between NFR 2025 (NFR2025) as reported by North Macedonia, the original GAINS baseline (GAINS_org) and the updated GAINS baseline in 2025 (GAINS_update2025)

3.4.5.1 Updates in 2024 and 2025

The activity data for coating applications were updated in 2024 using the paint consumption figures provided in the IIR document and were largely retained without significant changes in 2025. Oil distribution emissions were adjusted in 2025 by applying the recently revised methodology and emission factors received from national experts. Estimates of total fuel wood use and the structure of installations were adjusted for the residential sector in 2024 (see 2.3.3). Changes in agricultural NMVOC emissions are due to the updates described in section 3.4.3.1.

For the residential sector, further details about structure of installations (see section on $PM_{2.5}$) have been taken into account.

3.4.5.2 Remaining differences in 2025

The discrepancy in emissions from the residential sector comes from the different assumptions on installation structure and respective assumptions about the emission factors, i.e, Tier I vs Tier II approach. Higher differences within the Fugitive sector are due to different assumptions about the distribution of oil products (1.B.2.a.v). The implementation rates of technologies (e.g., Stage II vapor recovery) were reflected based on available data; however, for the emission distribution of oil products (1.B.2.a.v), there remains potential for further updates to the emission factors as more detailed technical information becomes available.

The remaining difference for residential combustion is due to assumptions about emission factors, where GAINS considered higher granularity of technology-specific factors.

3.5 Kosovo

3.5.1 SO_2

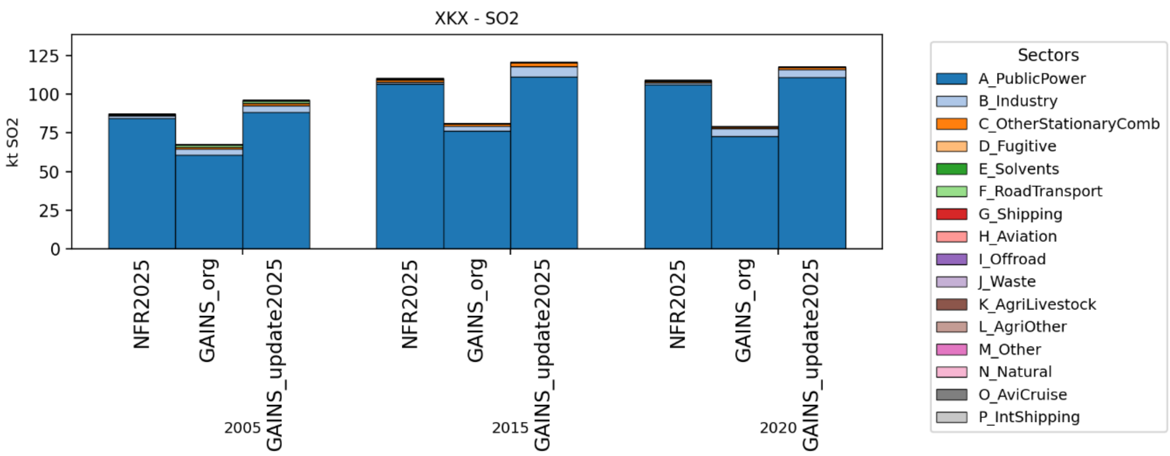

Figure 17 SO_2 emission comparison between national data from 2025 (NFR2025) as reported by Kosovo, the original GAINS baseline (GAINS_org) and the updated GAINS baseline in 2025 (GAINS_update2025)

3.5.1.1 Updates in 2024 and 2025

Activities in the power and industry sector (fuel combustion and industrial production levels) were revised and updated in 2024 in case of missing values (source IEA, USGS, PRIMES). Fuel characteristics of solid fuels (heat value and sulfur content in lignite) were updated in 2024 for the power and industry sector. A high CaO content in lignite, which reduces the emission factor, was taken up in GAINS, reflecting most recent information from the IIR. The implementation of controls was revised with a future uptake of flue gas desulfurization in coal power plants in 2024. The timing of the adoption of desulfurization measures in the Kosovo A and Kosovo B power plants has been adjusted in 2025 for the future years after the input received from the consultation meeting.

3.5.1.2 Remaining differences in 2025

The remaining differences in emissions are rather small.

3.5.2 NO_X

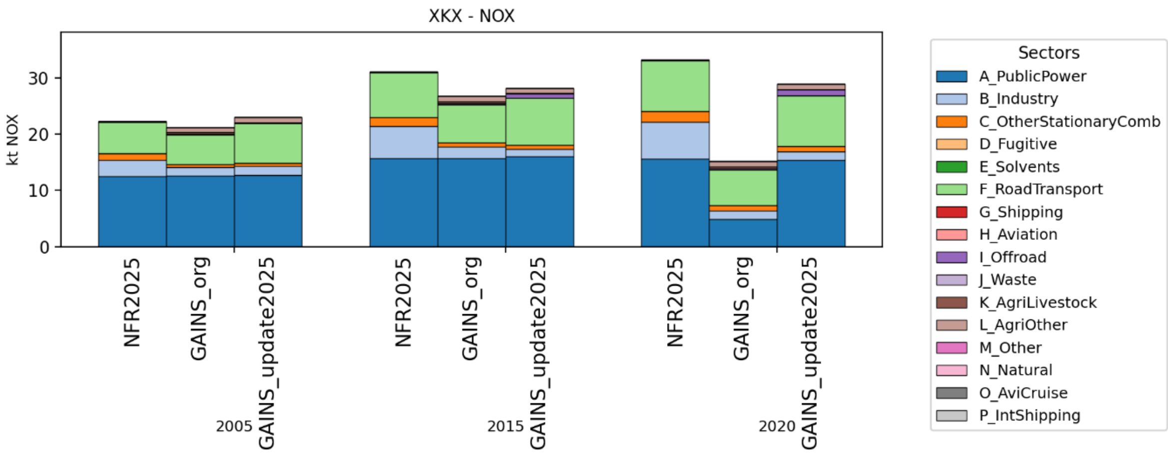

Figure 18 NO_X emission comparison between national data 2025 (NFR2025) as reported by Kosovo, the original GAINS baseline (GAINS_org) and the updated GAINS baseline in 2025 (GAINS_update2025)

3.5.2.1 Updates in 2024 and 2025

Low-NO_X burners were introduced in 2024 in the power sector as of 2025. The timing of the adoption of SCR technologies in the lignite-fired power plants has been adjusted in 2025 for the future years after the input received from the consultation meeting.

Activity data in the transport sector on vehicles by fuel type and emission standard of the vehicle fleet was updated in 2024 from the Report "Kosovo: A Future of Green Transport and Clean Air" (World Bank 2019) for 2015 and 2020. For future years data on average vehicle age and current and future legislation was used to estimate the change in emission standards of the vehicle fleet in the future. Vehicle numbers and fuel consumption are based on the PRIMES model.

Changes in emissions from agriculture are due to updates in livestock numbers and fertilizer use as described in section 3.5.3.1.

No further updates were made in 2025.

3.5.2.2 Remaining differences in 2025

Differences in the industrial sector are most likely due to different methodological approaches. As activity data matches well between GAINS and national reporting, no emission control is assumed in GAINS, but emissions are still lower than national reporting, a difference in emission factor must be the reason for the observed discrepancies.

3.5.3 NH_3

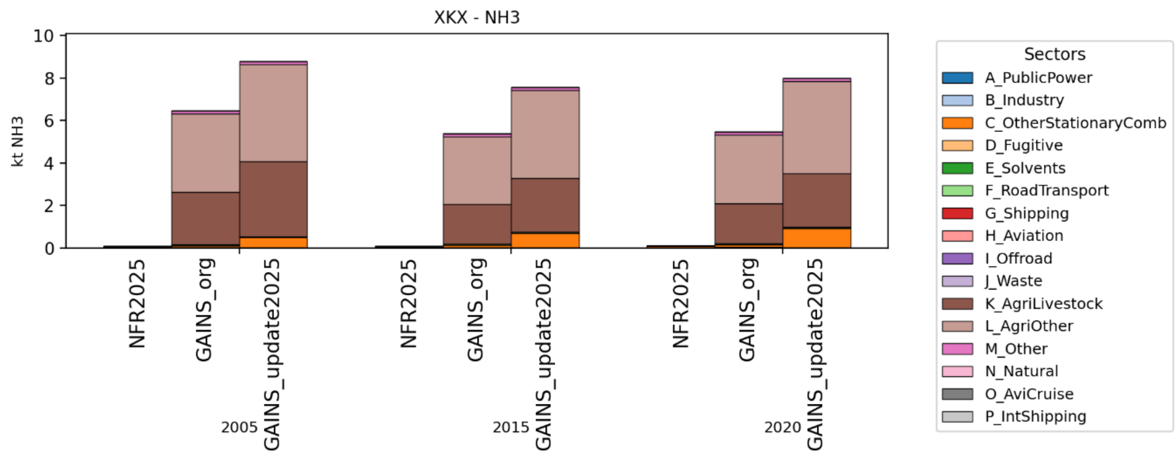

Figure 19 NH_3 emission comparison between national data from 2025 (NFR2025) as reported by Kosovo, the original GAINS baseline (GAINS_org) and the updated GAINS baseline in 2025 (GAINS_update2025)

3.5.3.1 Updates in 2024 and 2025

Livestock numbers were updated to economy specific statistics in 2024, and fertilizer data was updated using the agricultural holdings survey for the years 2005-2023 (Kosovo Agency of Statistics, 2025; Ministry of Agriculture, Forestry and Rural Development, 2025) in 2025.

3.5.3.2 Remaining differences in 2025

NH_3 emissions cannot be compared as agriculture, the biggest source, is missing from national reporting.

3.5.4 $PM_{2.5}$

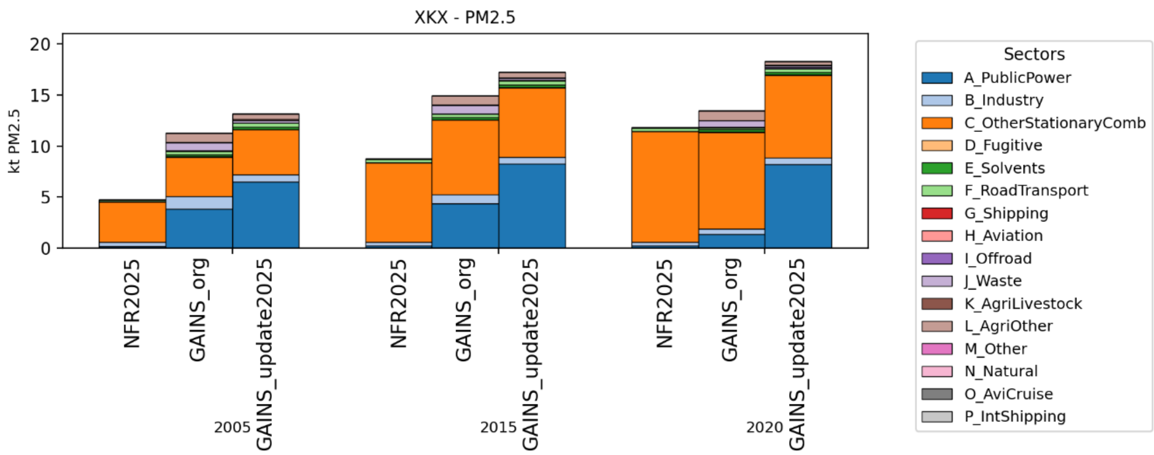

Figure 20 $PM_{2.5}$ emission comparison between national data from 2025 (NFR2025) as reported by Kosovo, the original GAINS baseline (GAINS_org) and the updated GAINS baseline in 2025 (GAINS_update2025)

3.5.4.1 Updates in 2024 and 2025

In GAINS the application of highly efficient dust filters was introduced in the power sector in 2024 for 2020 and beyond. In 2025, assumptions for the de-dusting technologies were identified as overoptimistic and they have been revised (i.e. relaxed) for the past years (2005-2020) as well as for the future based on the inputs from the expert consultations. These updates are reflected in the emission levels computed in GAINS for the years 2005/2015/2020. While it is considered in GAINS that the lignite power plants operate currently with some PM controls (Kosovo A), major reductions can be expected after the planned upgrade of Kosovo B (followed by Kosovo A) with more efficient electrostatic precipitators as of the year 2030.

3.5.4.2 Remaining differences in 2025

Between 2015 and 2020 there seems to be a change in emissions from the residential sector in the data reported by Kosovo. In 2020 the national estimate is higher while it is similar to GAINS in the years before. As Tier I is used for national calculations, this explains the differences as the structure of installations is not reflected in this methodology while GAINS takes such information into account.

Differences in the power sector could only be explained by an issue with units used in the emission factors or by other methodological differences as activity data is consistent, but GAINS cannot match national emissions even when assuming the implementation of the best available mitigation technologies.

3.5.5 NMVOC

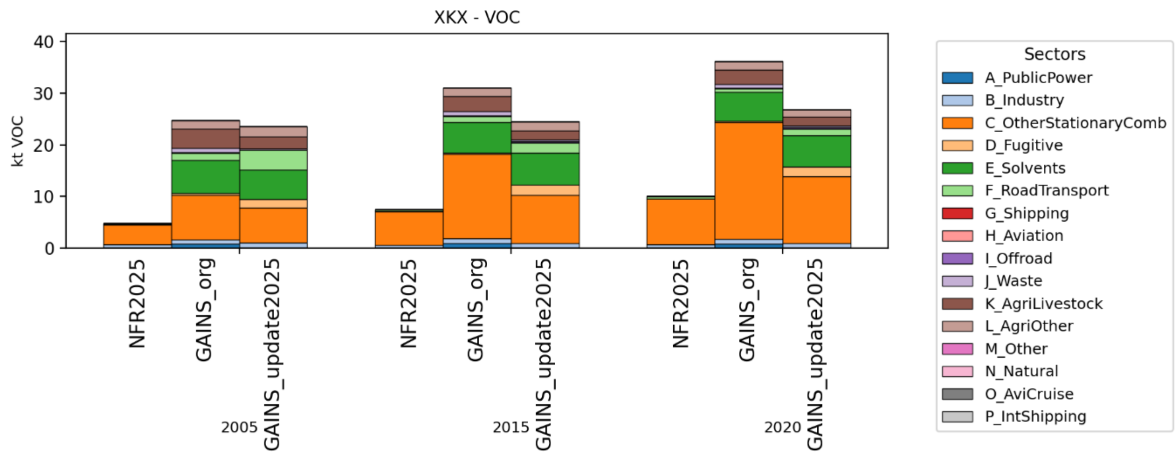

Figure 21 NMVOC emission comparison between national data from 2025 (NFR2025) as reported by Kosovo, the original GAINS baseline (GAINS_org) and the updated GAINS baseline in 2025 (GAINS_update2025)

3.5.5.1 *Updates in 2024 and 2025*

Calculations for emissions from the solvent sector were slightly revised based on information from the National Statistics[16] in 2025. The change for residential sector is due to harmonization of emission factors actors the region but also use of information provided in studies describing regional structure as discussed in section 2.3.3.

3.5.5.2 *Remaining differences in 2025*

Differences are high due to the national data only including energy related combustion sources and agriculture.

[16] https://askdata.rks-gov.net/

3.6 Serbia

3.6.1 SO_2

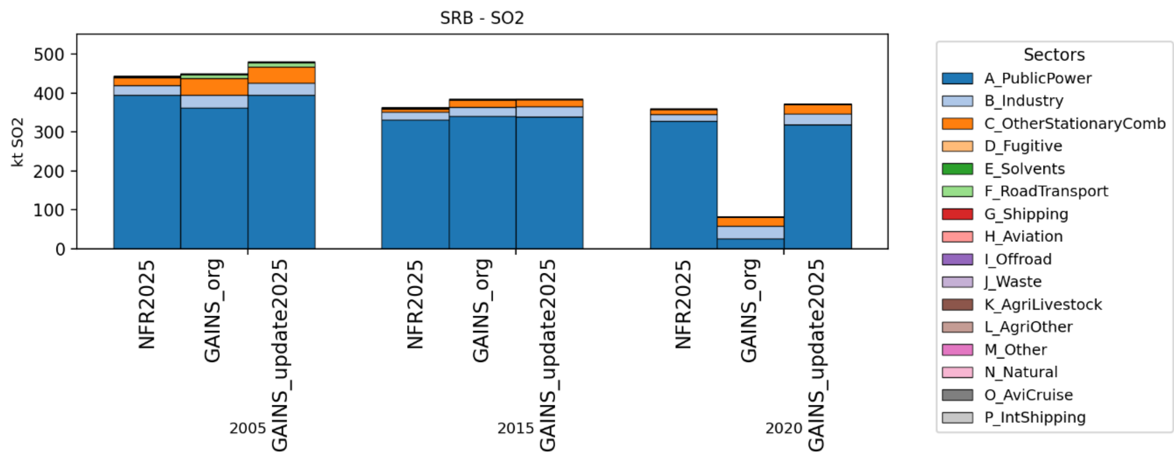

Figure 22 SO_2 emission comparison between NFR 2025 (NFR2025) as reported by Serbia, the original GAINS baseline (GAINS_org) and the updated GAINS baseline in 2025 (GAINS_update2025)

3.6.1.1 Updates in 2024 and 2025

Activities in the power and industry sector (fuel combustion and production levels) were revised and updated in the case of missing and inconsistent values (source NFR, IEA, USGS, PRIMES) in 2024. Fuel characteristics of solid fuels (heat value and sulfur content in lignite) were updated for power plants (new S-content value for lignite 0.6%) and the industry sectors in 2024 as new information became available. The application of SO_2 controls was revised in 2024 and in 2025 with a gradual uptake of flue gas desulfurization after 2020. In 2025, the timing of the adoption of desulfurization measures in lignite-fired power plants has been also adjusted for the past and future years after the input received from the consultation meeting. It is assumed that by 2020 some capacity of power plants (up to 20%) are equipped with De-SOx measures, while in 2025 and beyond nearly all large plants are operated with FGD systems. Based on the air quality programme of the Republic of Serbia[17], an assumption is made in GAINS that some industrial processes (namely copper smelting and sulfuric acid production) will implement desulfurization measures as of 2030 to comply with the national standards.

3.6.1.2 Remaining differences in 2025

There is generally a good match between GAINS and national data.

[17] https://www.ekologija.gov.rs/sites/default/files/2023-03/en_aq_programme_adopted_version.pdf

3.6.2 NO_X

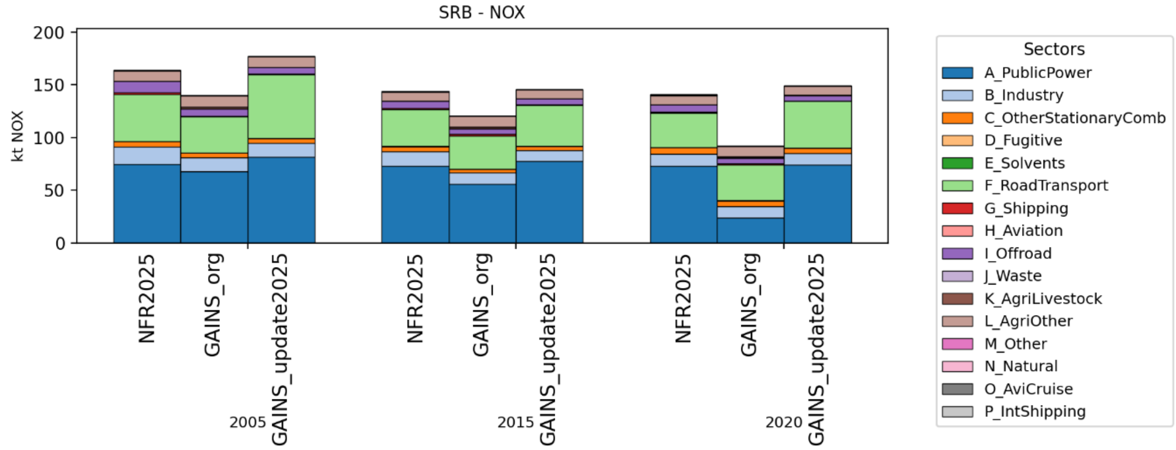

Figure 23 NO_X emission comparison between NFR 2025 (NFR2025) as reported by Serbia, the original GAINS baseline (GAINS_org) and the updated GAINS baseline in 2025 (GAINS_update2025)

3.6.2.1 Updates in 2024 and 2025

Activities in the power and industry sector (fuel combustion and production levels) were revised and updated in the case of missing and inconsistent values (source NFR, IEA, USGS, PRIMES) in 2024. The application of controls in the power sector was revised in 2024 with a gradual uptake of low-NO_X burners after 2025. Similarly to SO_2, a new assumption has been applied in 2025 that by 2030 all large power stations will be retrofitted with De-NOx installations.

Vehicle activity data (number of vehicles) in the transport sector was updated using data provided by the Ministry of Transport in 2024. Data was provided by national experts in 2024 in COPERT format, from where total vehicle numbers per category and technology (fuel) were extracted. Control strategies were also updated according to the COPERT data received from Serbia's experts in 2025.

NO_X emissions from agriculture were affected by the updates of livestock numbers and fertilizer application as described in section 3.6.3.1.

3.6.2.2 Differences

There is generally a good match between GAINS and national data.

3.6.3 NH_3

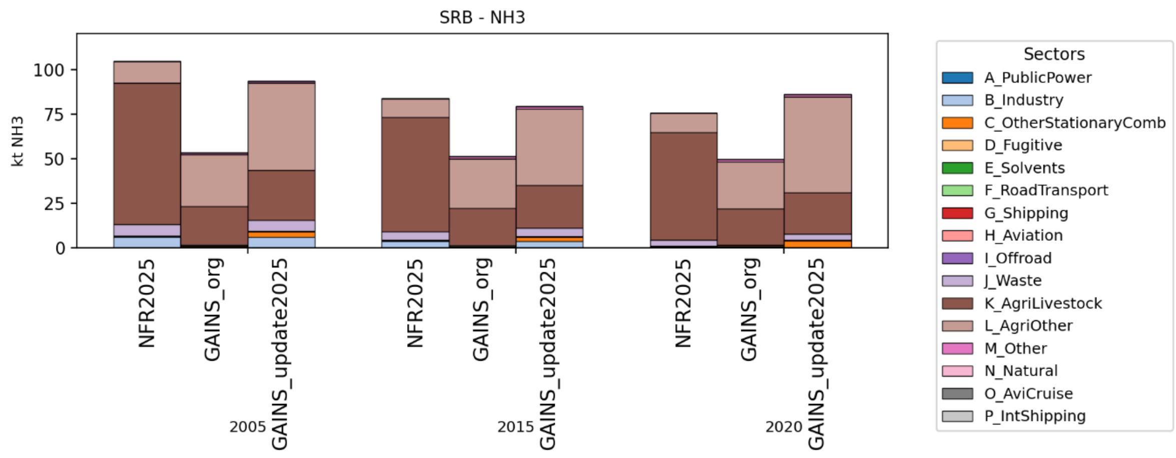

Figure 24 NH_3 emission comparison between NFR 2025 (NFR2025) as reported by Serbia, the original GAINS baseline (GAINS_org and the updated GAINS baseline in 2025 (GAINS_update2025)

3.6.3.1 Updates in 2024 and 2025

Livestock numbers, manure management and mineral fertilizer consumption were updated in 2024 using data from IIR 2023. Urea shares were updated in 2025, considering national information shared after the consultation meeting. Applicability for the implementation of NH_3 reduction technologies was updated to fit farm sizes, considering data from national statistics (Statistical Office of the Republic of Serbia, 2024). In 2025, the emission factor was revised leading to a slightly different distribution between the 'K_AgriLivestock sector', which includes emissions from manure management (housing and storage) and the 'L_AgriOther_sector', which includes emissions from manure and synthetic fertilizer application. Additionally, adjustments in emission controls until 2030 have been made to consider the reduction of 9% of NH_3 emissions from manure management and 31% of NH_3 emissions from manure application in 2030 compared to 2015 as foreseen in the air quality programme of the Republic of Serbia.

3.6.3.2 Remaining differences in 2025

Only synthetic fertilizer use is categorized under 'L_AgriOther' in the NFR which leads to a discrepancy between the categorization of agricultural emissions between national data and GAINS. However, the remaining differences in agricultural emissions remain close to 10%.

3.6.4 $PM_{2.5}$

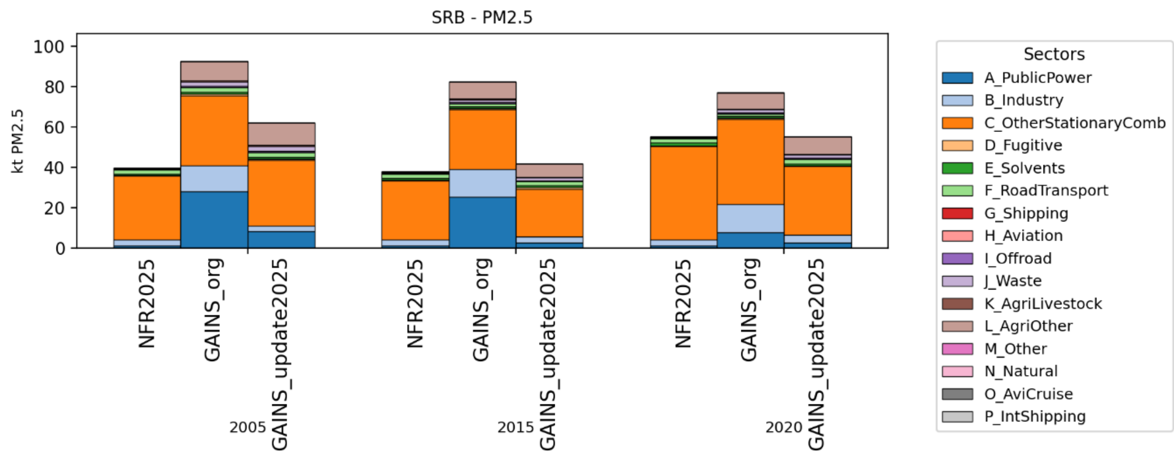

Figure 25 $PM_{2.5}$ emission comparison between NFR 2025 (NFR2025) as reported by Serbia, the original GAINS baseline (GAINS_org) and the updated GAINS baseline in 2025 (GAINS_update2025)

3.6.4.1 Updates in 2024 and 2025

Application rates of $PM_{2.5}$ controls have been revised in 2024 for the past and future years, mainly for the industrial process activities (cement, refineries, metals production) as well as in the power sector. The updates in power plants reflect the installation of highly efficient electrostatic precipitators in the power stations from 2005 onwards. In 2025, future developments in the residential sector were revised based on the air quality programme of the Republic of Serbia as well as the information for 2020 on energy consumption in households (PBC, 2021). However, the pace of replacing stoves and boilers with more efficient installations as stated in the air quality programme was adjusted taking into account lifetimes of installations; this resulted in slower replacement rates of installations than proposed in the air quality programme.

3.6.4.2 Remaining differences in 2025

Emissions from power plants are very low in national reporting. GAINS estimates are already using the best available dust removal technology but are still higher, which points to a difference in emission factors. The GAINS emission factor is a result of several input parameters, namely ash content, net calorific value and bottom ash. The ash content assumed (14.7%) is within the range provided by the European Association for Coal and Lignite[18], and the net calorific value (6.85 GJ/t) is consistent with values reported in the IIR. National reporting uses the EMEP guidebook 2023 EF (Tier I) based on an ash content of 5% and a net

[18] https://euracoal.eu/library/archive/serbia-7/

calorific value of about 14.5 GJ/t - which results in a much lower unabated emission factor in 2005. It was decided to keep the GAINS estimate.

In GAINS, as opposed to national reporting, there is no increase in emissions from the domestic sector from 2015 to 2020, despite the consistent assumptions on biomass use. The reason for discrepancies could be different assumptions on the distribution of different types of stoves and boilers but also assumptions about the emission factors and installation of cyclones on commercial sector coal boilers. Serbia provided comments and some additional information for the residential sector in 2024, but use Tier I in their inventory which does not take differentiated assumptions on the distribution of different types of stoves and boilers into account. Consequently, emissions grow proportionally to fuel use. As described in Section 2.3.3, a Tier II approach is used in GAINS thanks to details on the structure of installations provided in the IBRD/World Bank (2018) study.

Reported emissions from open burning of agricultural residues are very small (included in L_AgriOther) while GAINS results compare reasonably well to remote sensing products, e.g, FINN[19].

3.6.5 NMVOC

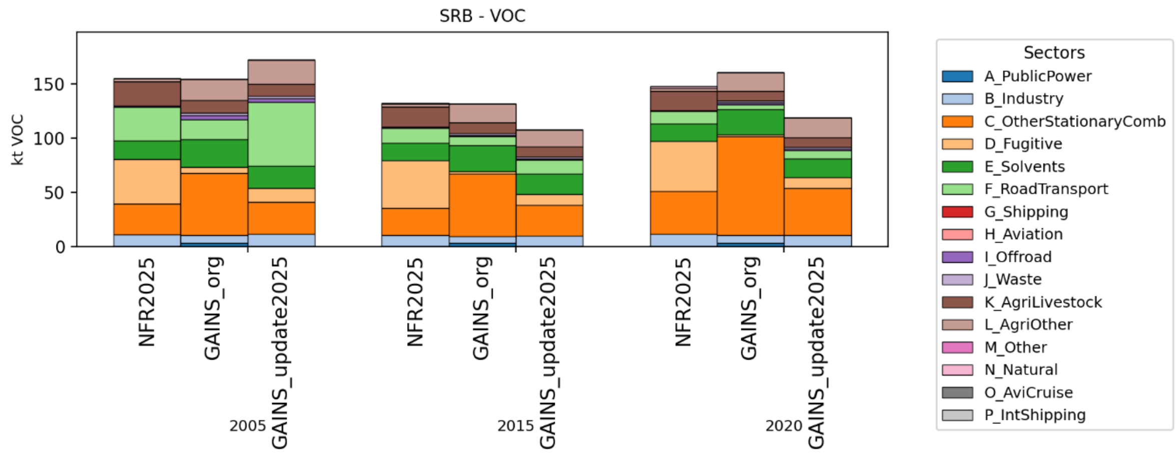

Figure 26 NMVOC emission comparison between NFR 2025 (NFR2025) as reported by Serbia, the original GAINS baseline (GAINS_org) and the updated GAINS baseline in 2025 (GAINS_update2025)

3.6.5.1 Updates in 2024 and 2025

Activity data for ‘coating application’ category and ‘other solvent use’ category in the ‘E_Solvents’ sector were updated in 2024 using data from the IIR 2023.

[19] https://www2.acom.ucar.edu/modeling/finn-fire-inventory-ncar

Information for the residential sector was updated in 2024 using information from studies as described in section 2.3.3.

3.6.5.2 *Remaining differences in 2025*

In the coal mining sector, GAINS applies the default emission factors from the EMEP/EEA Guidebook (2023) for brown coal (BC). For hard coal (HC), however, the emission factors were derived by considering methane (CH_4) emission factors, leading to values that differ from the Guidebook defaults. As a result, differences remain between GAINS estimates and national inventories due to the use of different emission factors.

GAINS emissions from the transport sector after the update in 2025 show a large difference when compared to GAINS updates conducted in 2024 for the year 2005. This difference is due to updated control strategies based on COPERT data shared by Serbia's experts in 2025. GAINS estimates in 2024 were based on the fleet's vehicle age. Despite this increase in 2005, emissions in 2015 and 2020 are consistent with national reporting.

4 Validation of atmospheric calculations

GAINS calculates ambient $PM_{2.5}$ concentrations at a resolution of 0.1°×0.1° (approximately 8km × 11km). To represent local increments, a downscaling approach is applied based on high-resolution output generated with the uEMEP model at 100×100m resolution. To establish credibility of the calculations, modelled concentrations need to be compared against monitoring data. Ambient concentrations modelled for 2020 overlaid with observations 2019-2021 are shown in Figure 27.

Monitoring data have been collected from internationally available sources (EEA AirBase, US Embassies) as well as local monitoring networks. When comparing modelled concentrations from GAINS to observations, two things need to be kept in mind, both of which are related to the purpose of GAINS to represent long-term average population exposure to $PM_{2.5}$:

1) GAINS uses five-year average meteorology from the years 2016-2020 so for any individual monitoring year there can be deviations due to inter-annual variations in meteorological conditions, and
2) GAINS is supposed to represent average population exposure within each grid cell, but not the concentrations at any given location. If there are strong local variations, for example due to solid fuel use in residential heating, the grid average, even when considering the exposure increment included in GAINS, can be off.

Furthermore, the quality of ambient $PM_{2.5}$ calculations relies largely on the spatial distribution of precursor emissions. For the Western Balkan economies, the emission distributions were produced by IIASA based on the best information available, but in several cases such information was not available.

A scatter plot of model versus observations in the whole region is shown in Figure 28. Given all the limitations mentioned above, the model performs well in comparison to the observed $PM_{2.5}$ concentrations. Most stations are well within the factor 2 margins indicated by dashed lines. The bias between model and observations depends on the economy.

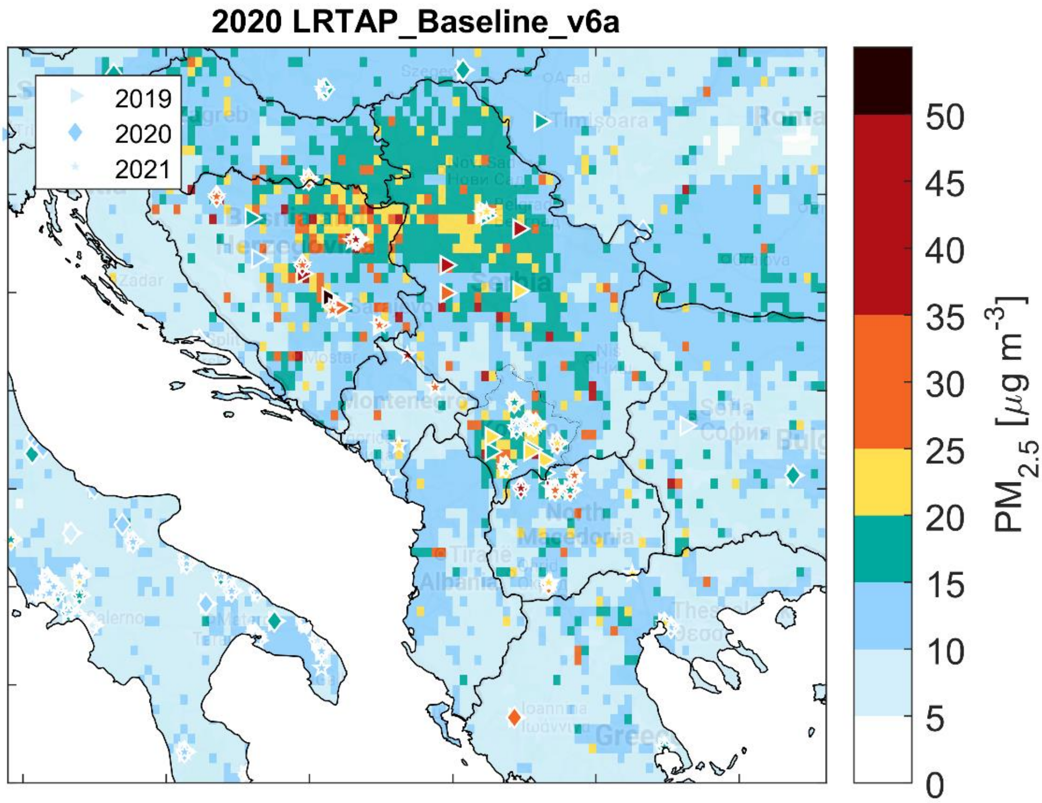

Figure 27 Ambient $PM_{2.5}$ concentrations modelled with GAINS for 2020, overlaid with monitoring data for the years 2019-2021.

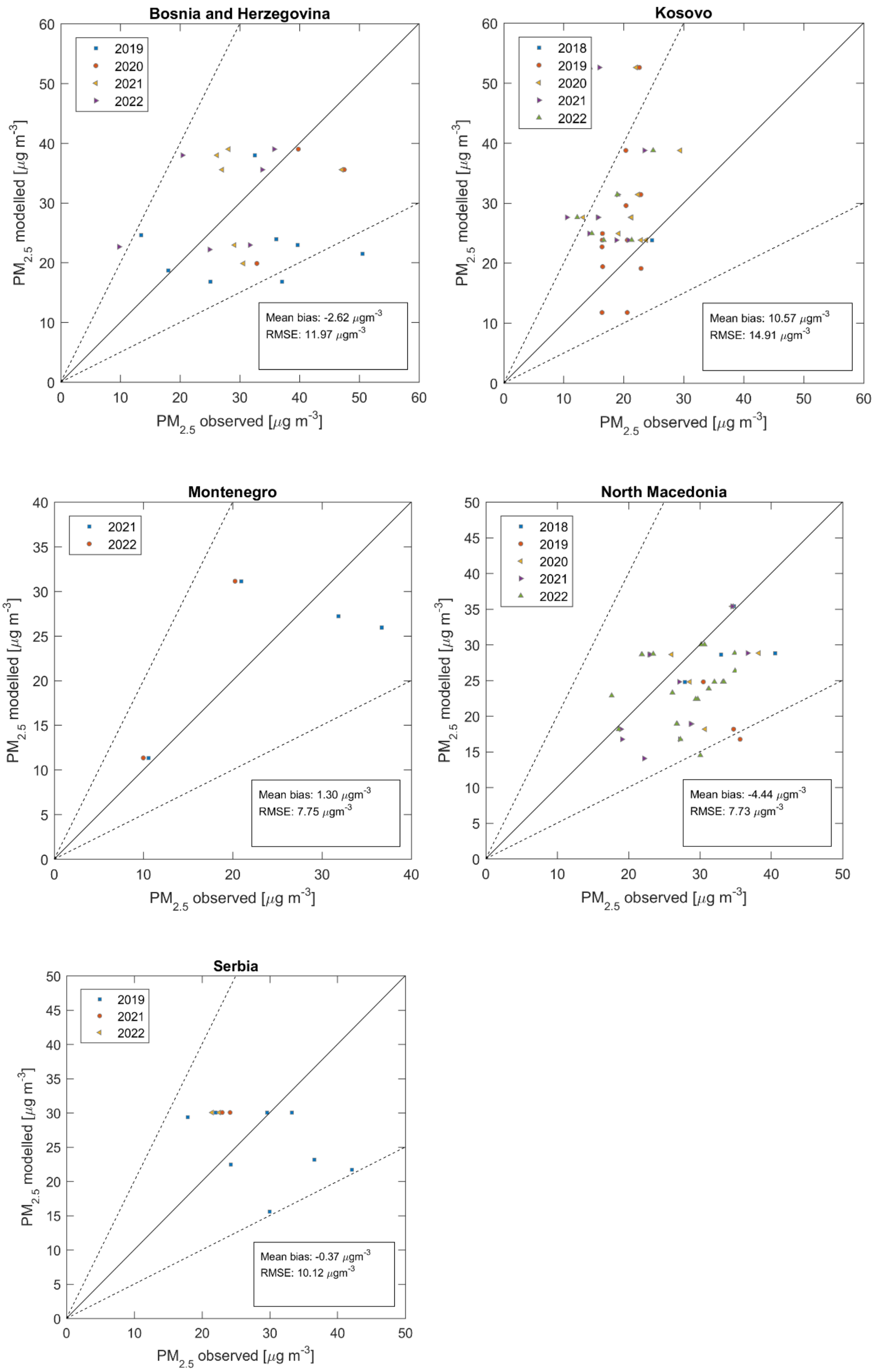

Figure 28 Comparison of annual means modelled against measured $PM_{2.5}$ at monitoring sites across the Western Balkan region. Modelled $PM_{2.5}$ is for 2020, measurements for different years are distinguished by symbols. Each dot represents one station.

5 Developing ERCs

After the consultation process, the updated GAINS baseline and the validated atmospheric calculations were used as the starting point for the derivation of a set of cost-effective emission reduction commitments (ERCs) per pollutant and economy using the GAINS model. A target of a 50% reduction in premature deaths from $PM_{2.5}$ exposure by the year 2030 (relative to 2005) for the aggregate of the Western Balkan region, similar to the EU27 NECD, was set and analyzed. During an optimization process, a cost-optimal portfolio of pollutant and sector specific emission reduction technologies (also referred to as control strategy) per economy is generated that lead to emission reductions that ensure reaching the target of a 50% reduction in premature deaths from $PM_{2.5}$ exposure by the year 2030 for the whole region. These sector specific emission reduction technologies per economy are detailed in section 5.4 below. The levels to which emissions can be reduced for each pollutant and economy with these cost-optimal control strategies are then defined as ERCs.

5.1 Overview of the optimization

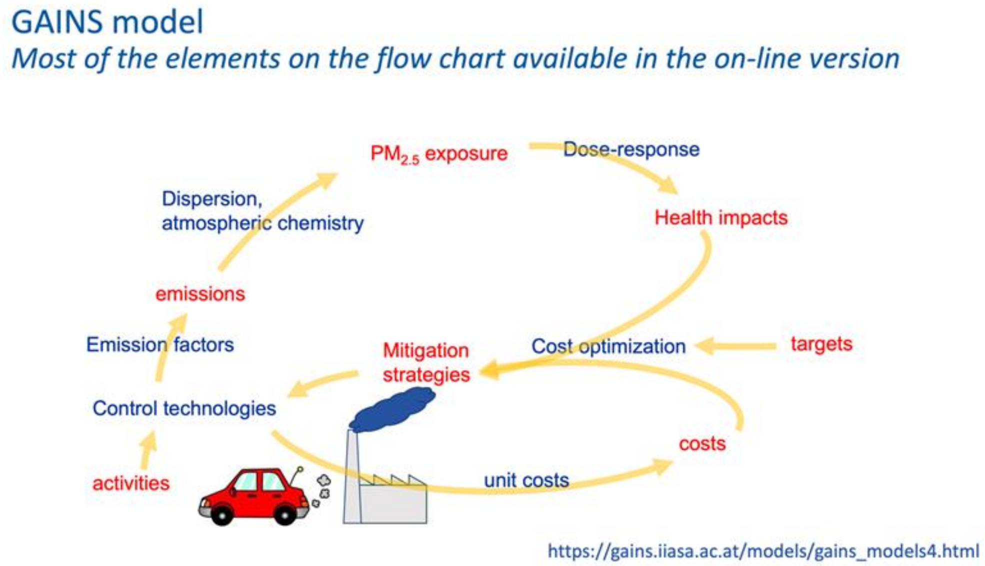

Figure 29 Overview of the flow of information and data in the GAINS model.

Figure 29 illustrates schematically the flow of information in the GAINS model. The upper part of the loop diagram focusses on the emission and impact pathway, while the lower part covers the part that assesses the cost for a set of air pollution control measures. Moving from left to right in the diagram corresponds to a simulation of a given emission control strategy/scenario in terms of emissions, impacts and costs. In contrast, starting from the right-hand side and moving to the left corresponds to translating an overall goal or target that might be formulated for a group of countries (e.g. the EU27 or the six Western Balkan economies) into a feasible and cost-effective control strategy for each economy, sector, source and pollutant.

In particular, the figure illustrates that there are two separate topics:

(1) **The setting of targets.** This requires a specification of several aspects that are discussed in the next section
(2) **The identification of cost-effective mitigation strategies** that meet the targets that have been formulated above in the most cost-effective way.

Both processes, target setting and cost-optimization, need to be considered in conjunction. Setting an overall target on an impact indicator does not automatically translate into a specific set of measurable targets on emissions of different pollutants – there are many different sets of emissions that are consistent with a given target, and many different control strategies are typically consistent with these emission sets. Some of these strategies are preferable over others. Cost-optimization makes sure that the focus is set on options that achieve the target in the most economical way.

Pertinently, cost-optimization is another way of saying that we are searching for and finding a solution (i.e. a specific set of economy and pollutant specific emission ceilings and, equivalently, ECRs) and control strategies that are most cost-effective (in the model), i.e. most economical. Conversely, a cost-effectiveness analysis requires that targets are defined to which the model should respond. Thus, in summary, for our purposes **a policy analysis in the context of the GAINS model means target setting *plus* cost-effectiveness analysis**.

5.2 Setting the target and scene for optimization

A number of options for these indicators for which target(s) should be set had been discussed by stakeholders in the EU in the run up to the NECD (e.g. $PM_{2.5}$-related premature deaths, ecosystem impacts, etc). In the context of this project the relevant indicator to be considered is the number of premature deaths that can be attributed to the exposure to $PM_{2.5}$ concentrations.

For such an indicator there are certain restrictions on what values can be reached by applying certain emission control strategies, depending on what is technically feasible. These restrictions need to be identified and respected in the target setting procedure. To establish the range of feasible and sensible targets, the GAINS analysis typically proceeds by not only establishing the current legislation (CLE) scenario, but also the maximum technically feasible reduction (MTFR) scenario. The value of a given indicator in the CLE scenario for a given target year represents the situation that is expected to materialize under Baseline assumptions. Thus, setting a target value on a given indicator that lies *above* the value for that indicator in the CLE does not result in additional measures been taken beyond the CLE – the target value would be met “anyway”, i.e. because of current policies. From a certain perspective it does not make sense to set such a target, because it does not make any difference to the cost-effectiveness analysis and might as well be ignored. On the other hand, a target value for the indicator that lies below the MTFR scenario would not be feasible, i.e. could not be reached with the use of additional technologies (by definition). Thus, the feasible and sensible space of target values is the range between the values of the CLE and MTFR scenarios, respectively. Before running the cost-effectiveness analysis, it needs to be established whether the set of targets considered fall within the feasible ranges.

In terms of meeting the targets it needs to be noted that if a set of targets is used in the GAINS model, the model also allows that some of these targets are potentially over-achieved – to achieve all other targets for different pollutants, sectors and economies. In other words, the resulting impacts are not necessarily exactly equal to the targets that were specified, but it may happen that some impacts in a cost-effectiveness analysis are over-achieved. This is particularly relevant for this case where a target is set for the whole Western Balkan region and cooperation between parties can, under certain circumstances, lead to overachievement of targets of certain economies and pollutants. A target thus must be understood as a constraint in the form on an inequality ("less or equal") rather than an equality ("exactly equal to"). Such cooperation between parties as a joint approach to air quality management may result not only in common but differentiated responsibilities to control emissions (and implied costs) but will also result in a particular distribution of benefits across countries (e.g. reduction in the number of premature deaths by country).

5.3 The cost-effectiveness analysis

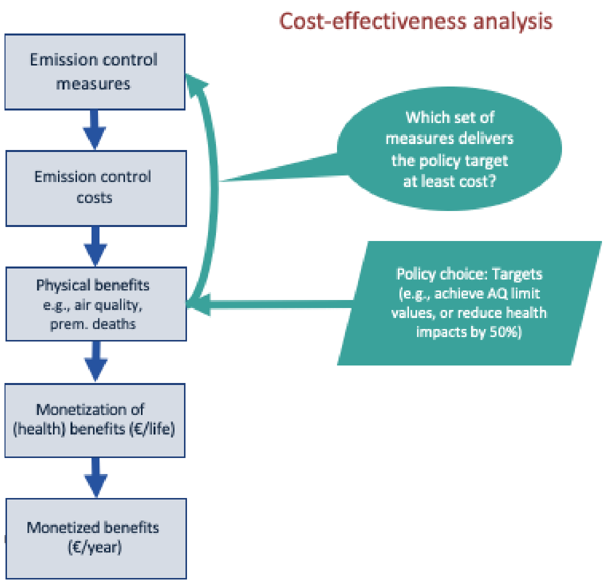

Figure 30 The main concept of a cost-effectiveness analysis

For the **cost-effectiveness analysis** (Figure 30) the starting point is a set of emission controls that represent current policies in a certain region in the target year (CLE). In our case this is the set of emission controls taken from the Baseline scenario for the year 2030. Emission control costs and all relevant physical impacts or benefits that result from this set of policies and measures (e.g. the number of premature deaths to be expected resulting from that policy) are then calculated using GAINS. Using cost-effectiveness analysis, the emission controls are modified through iteration in the most economical way to reach the target of reducing premature deaths.

For example, assume that we have a mix of technologies already present in the CLE scenario and now we can choose between two technologies, A and B, which both reduce the same amount of emissions, but differ in costs (Figure 31).

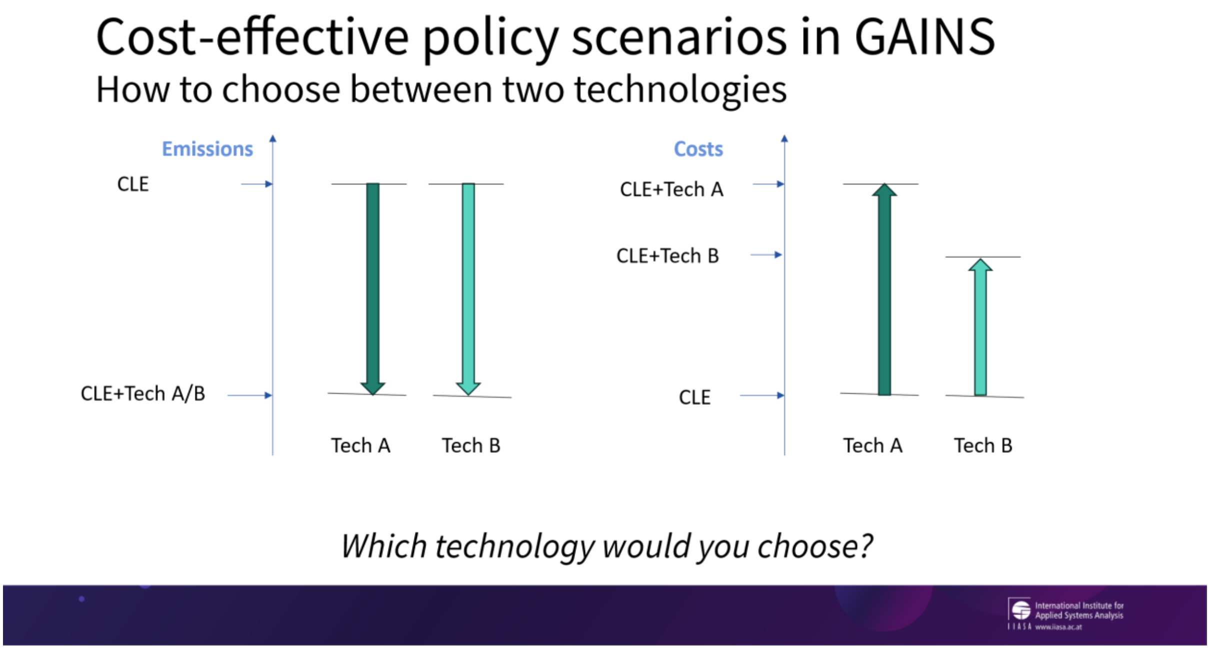

Figure 31 Example of how to choose between two technologies, according to their cost-effectiveness.

In this case it is easy to establish the cost-effectiveness: both reduce the same amount of emissions, but technology B is associated with lower costs, so it is better to select technology B. Analogously, if there are two technologies that are associated with the same costs, but reduce different amounts of emissions, it is more cost-effective to choose the technology that is associated with lower emissions first (and only chose the other one, on top of the first one, if further emission reductions are needed).

However, the choice is not so obvious when we need to compare two technologies that not only differ in the amount of emissions they reduce, but also in the costs (Figure 32).

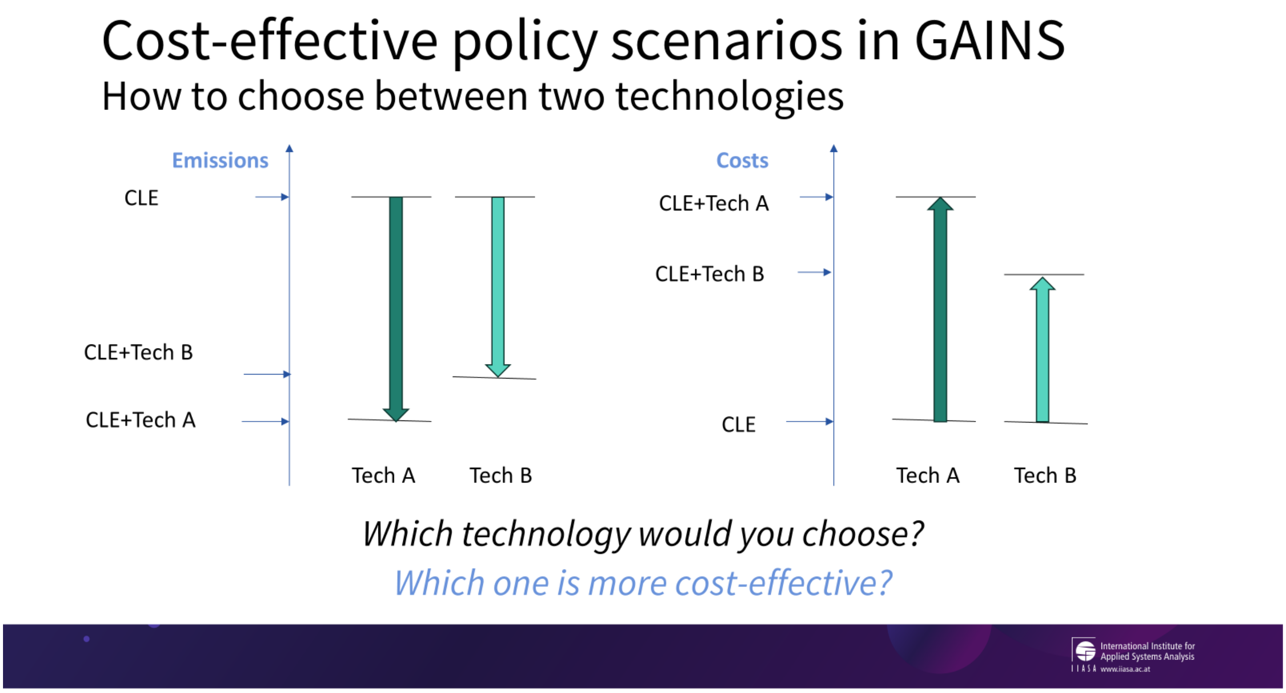

Figure 32 Example of a situation in which a choice needs to be made between two technologies that differ not only by the amount of emission reduced, but also by the costs.

While technology A reduces emissions further than technology B, it is also more expensive, which puts the decision maker into an apparent dilemma. This dilemma is easily resolved by focusing on the so-called marginal cost of reduction (Figure 33). This marginal cost of reduction is established by calculating the extra cost it takes to implement a technology and dividing the result by the amount of emissions reduced. Graphically, the marginal cost of emission reduction (or marginal cost, for short) is the slope of the line that compares the emissions and costs with and without the technology.

In Figure 33 we find that the slope of the line corresponding to technology B is lower than for technology A, and thus technology B is the more cost-effective technology of the two, starting from CLE – a result that, as we have seen, could not have been established from either the left-hand side or the right-hand side of Figure 32 alone – both pieces of information were needed.

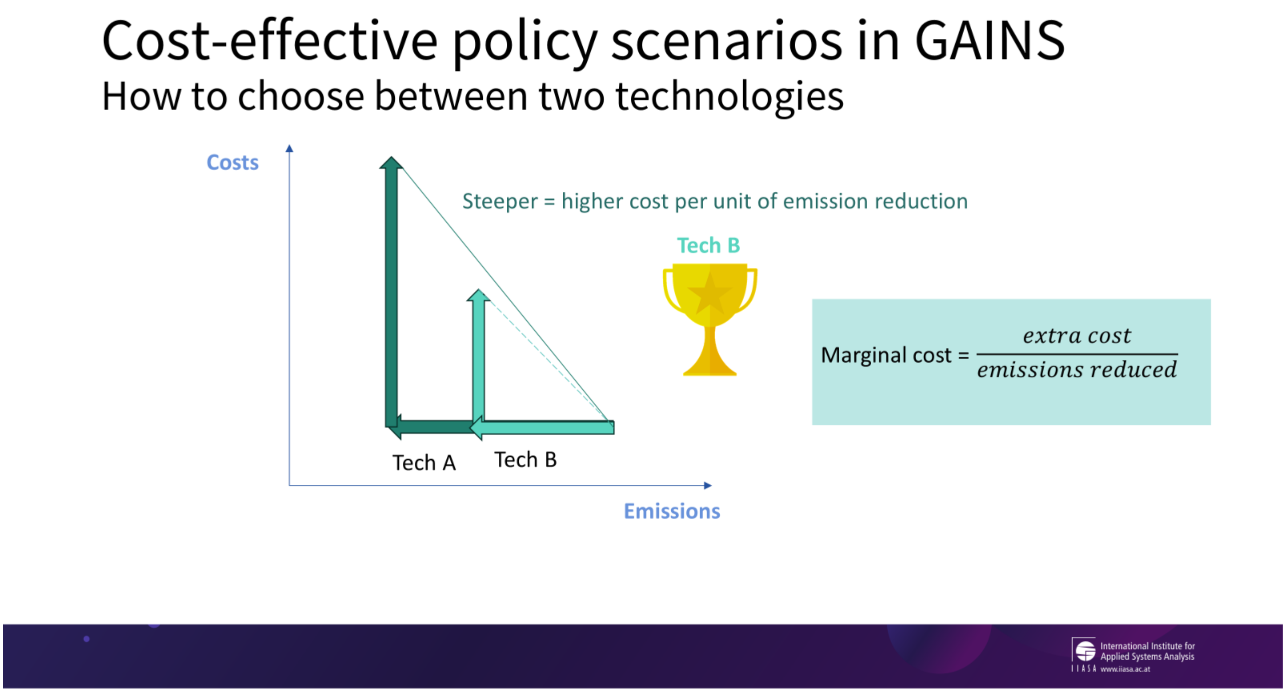

Figure 33 The concept of the marginal cost of reduction. This can be interpreted as the slope of the line in an emission-cost diagram.

The above conceptual example represented a choice between two technologies that can be applied to a particular source. This process can be repeated for each source and each country, and the results can be collated into what is called a marginal abatement cost curve, as illustrated in Figure 34.

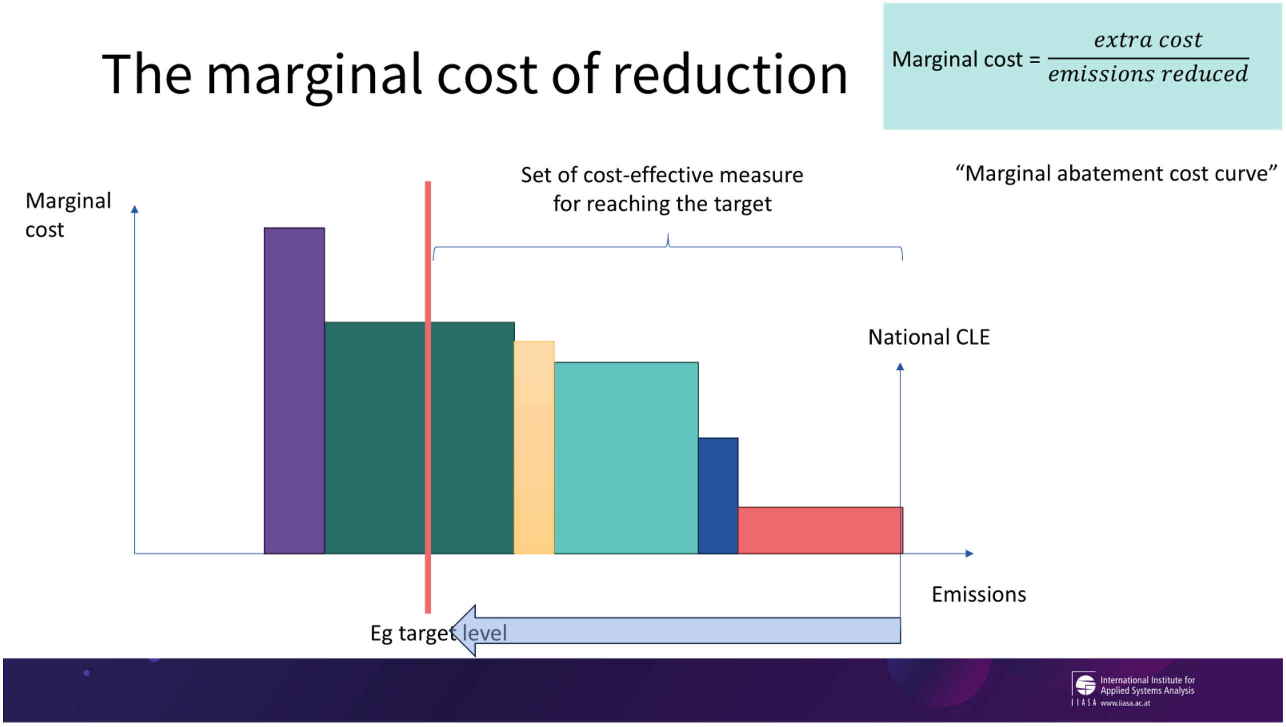

Figure 34 Concept of a marginal abatement cost curve.

Each bar in this marginal abatement cost curve corresponds to a single measure: each bar is characterized by its height, which corresponds to its marginal abatement cost, and its width, which corresponds to the reduction potential of this measure. The bars are ordered according to their marginal cost from right to left in increasing order. The starting point of the curve on the right-hand side is the CLE level. If a target is set (e.g. cf. the red vertical line in Figure 34), then one can read off the set of cost-effective measures (those to the right of the target). This also illustrates that the set of cost-effective measures is always relative to a specific target. What is considered a cost-effective measure for one target may not be cost-effective for another, more lenient target (while the opposite is typically true: a measure that is cost-effective for a given target is typically also cost-effective for a more ambitious target - though there are exceptions in a multi-pollutant, multi-region framework).

One can summarize the above by saying that the cost-effectiveness analysis (and the GAINS optimization algorithm) is *essentially* a sorting algorithm for control options, where the ordering is done by the marginal cost of reduction. In practice, the cost-effective set of technologies is identified using an optimization algorithm which is equivalent to a marginal abatement cost curve approach. We start with CLE and modify the control strategy step by step always choosing the technology with the next-lowest marginal cost. Optimization is a mathematical approach that follows a different, but in the result exactly equivalent approach. It does not first establish systematically all marginal costs, but simply formalizes all the relevant mathematical relationships in the system (e.g. how to calculate cost and emissions, sets of inequalities to reflect the targets, etc) and then simply solves this set of relations and an objective function that needs to be minimized with a particular mathematical algorithm, the details of which are not important here.

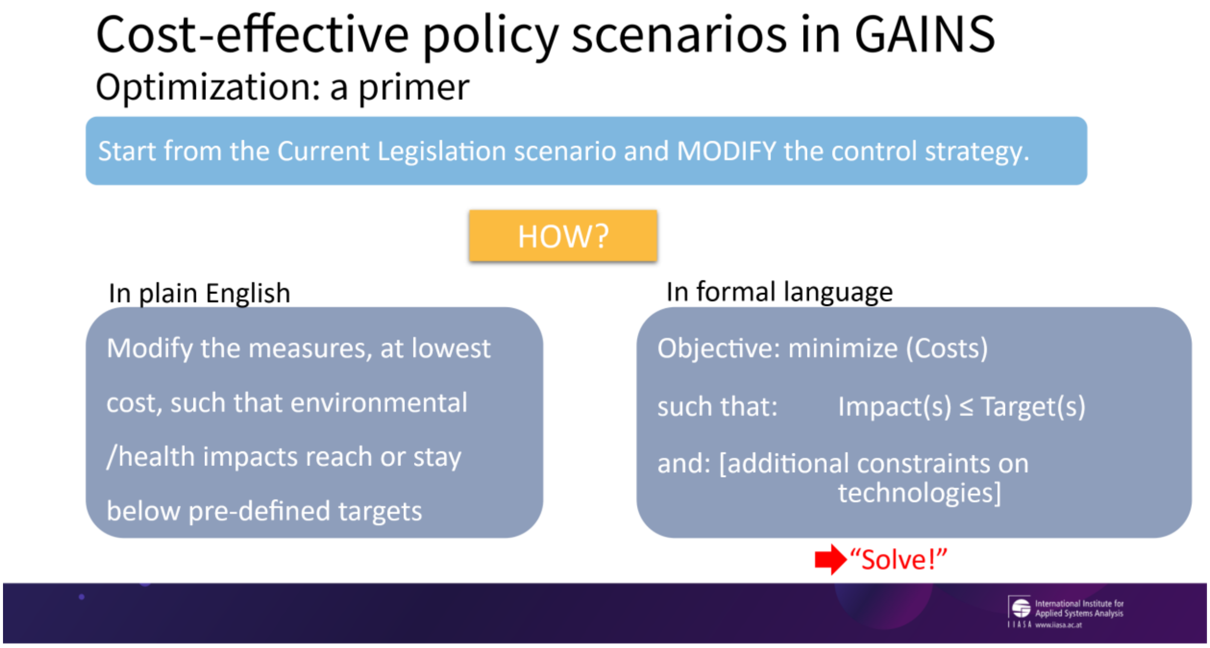

Figure 35 Comparing the intuitive approach of gradually modifying the CLE control strategy using cost-effective steps versus the more abstract mathematical formulation of the set of equations and constraints, that can be solved using standard optimization algorithms.

The technology constraints that we need to respect in the GAINS model relate to the characteristics of the technologies that are represented in the model, i.e. those that govern to what extent a technology can be deployed, how quickly it can be replaced once deployed, and which technologies can be replaced by which other technology.

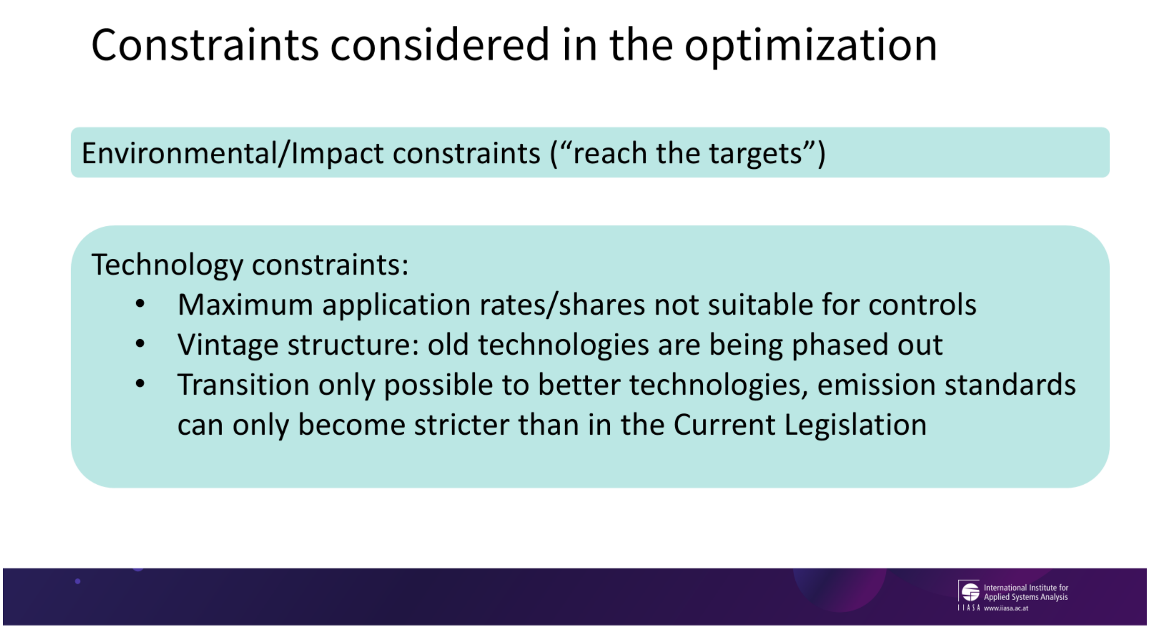

Figure 36 Summary of the types of constraints used in the GAINS model optimization

The GAINS optimization is implemented in a commercial software package called GAMS (General Algebraic Modelling System) that was developed originally at the World Bank and has become a professional standard for economists and engineers that deal with large-scale complex optimization problems.

As previously discussed, GAINS optimization is used to identify the most cost-effective portfolio of technologies that reach a given (set of) target(s). The tool is also routinely used to construct the MTFR scenario. This is the scenario in which emission reductions are maximized, i.e. the emissions themselves are minimized. This is an important scenario as it delineates the space of feasible solutions (and sensible control strategies) from the infeasible set of targets. In order to calculate the MTFR scenario, the GAINS model uses the same principles and same data as in the regular cost-effectiveness analysis, only in this case the so-called *objective function* in the optimization is different than in the standard optimization after target setting (Figure 37). While for a policy analysis we are setting a target and subsequently ask for a solution with minimal costs, for the MTFR scenario we do not set a target at all, and only require that the emissions are minimized, irrespective of costs. The resulting scenario is consistent with all other technological constraints (cf. Figure 36).

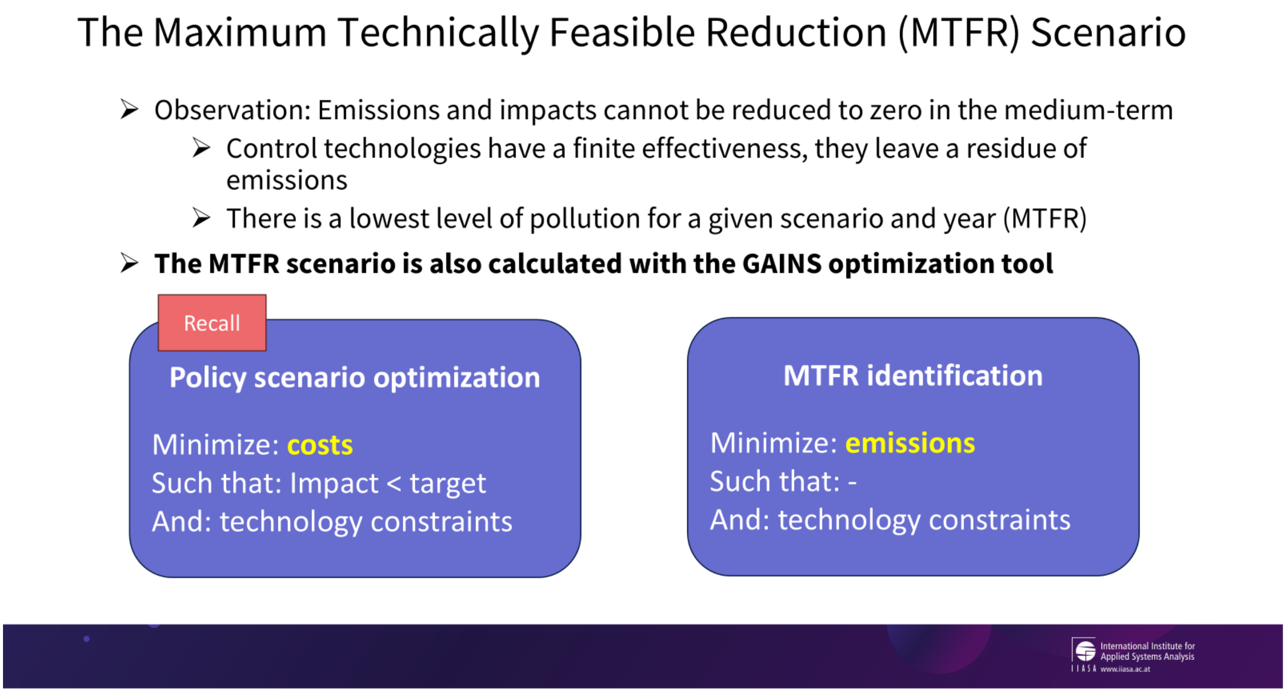

Figure 37 Comparison of the setups for calculating a policy scenario (responding to a target) and an MTFR scenario.

5.4 ERCs and emission reduction measures

Rather than prescribing the sector specific emission reduction technologies that are identified in the model to reach the target of a 50% reduction in premature deaths from $PM_{2.5}$ exposure for the whole Western Balkan region, the focus here is on the levels to which emissions can be reduced for each pollutant and economy, set by economy and pollutant specific ERCs. This approach has the following advantage: the target of a 50% reduction in premature deaths from $PM_{2.5}$ exposure is specific enough to ensure that when the ERCs are reached (by all economies) the target is achieved with high confidence. At the same time an ERC at the national level is a relatively flexible commitment to sign up to, compared to a portfolio of measures, in the sense that there are many ways to reach the ECR – not just by implementing the measures identified by the model. Thus, the modeling exercise establishes a proof of concept, illustrating that reaching the target is feasible under all the assumptions made about technologies and measures that feed into the GAINS model; and second, a cost-effective distribution of emission reduction commitments between economies is established.

As a preliminary step of the analysis, the GAINS model was used to confirm that a target of a 50% reduction in premature deaths from $PM_{2.5}$ exposure by the year 2030 (relative to 2005) for the aggregate of the Western Balkan region is technically feasible. Figure 38 illustrates that in all six economies, premature deaths related to $PM_{2.5}$ exposure are expected to decline between 2005 and 2030 in the current legislation scenario (CLE, light orange). The dark orange bar represents the maximum technically feasible reduction scenario (MTFR). The 50%

reduction relative to 2005 is technically feasible for the Western Balkan region as a whole, as can be seen from the fact that the dark orange bar in the last set of bars, "Whole domain", crosses the red dotted line, i.e., the target lies between the CLE and the MTFR scenario. Hence a technically feasible set of ERCs for each economy can be found that reaches the aggregate target for the whole region. However, a 50% reduction in premature deaths cannot be achieved in each economy assessed individually (see the maximum technically feasible scenarios, MTFR, dark orange bars per economy: not all of them cross the red dotted target line). For example, in Kosovo, the maximum reduction in premature deaths that can be reached technically, is only around 27% relative to 2005.

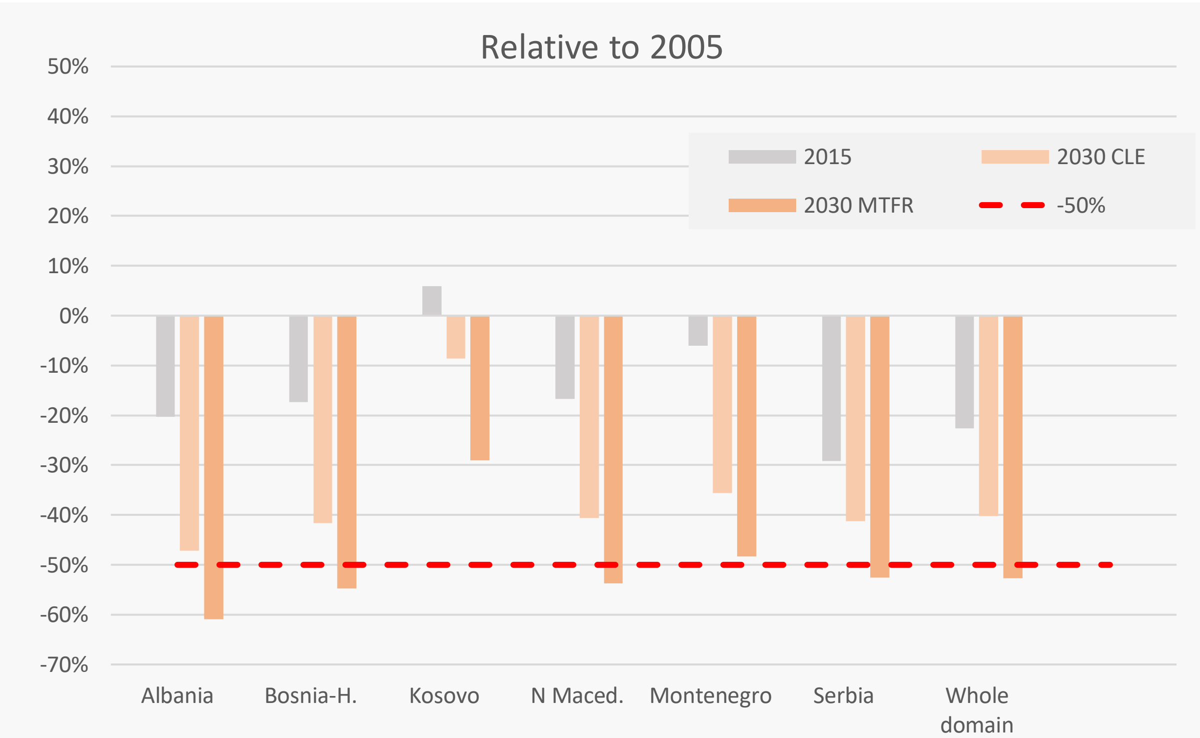

Figure 38 Changes in premature deaths from $PM_{2.5}$, relative to 2005, in the six Western Balkan economies and the region as a whole

In the next step, a whole series of scenarios (a cost curve) was generated to offer context for the specific policy scenario that was further analyzed.

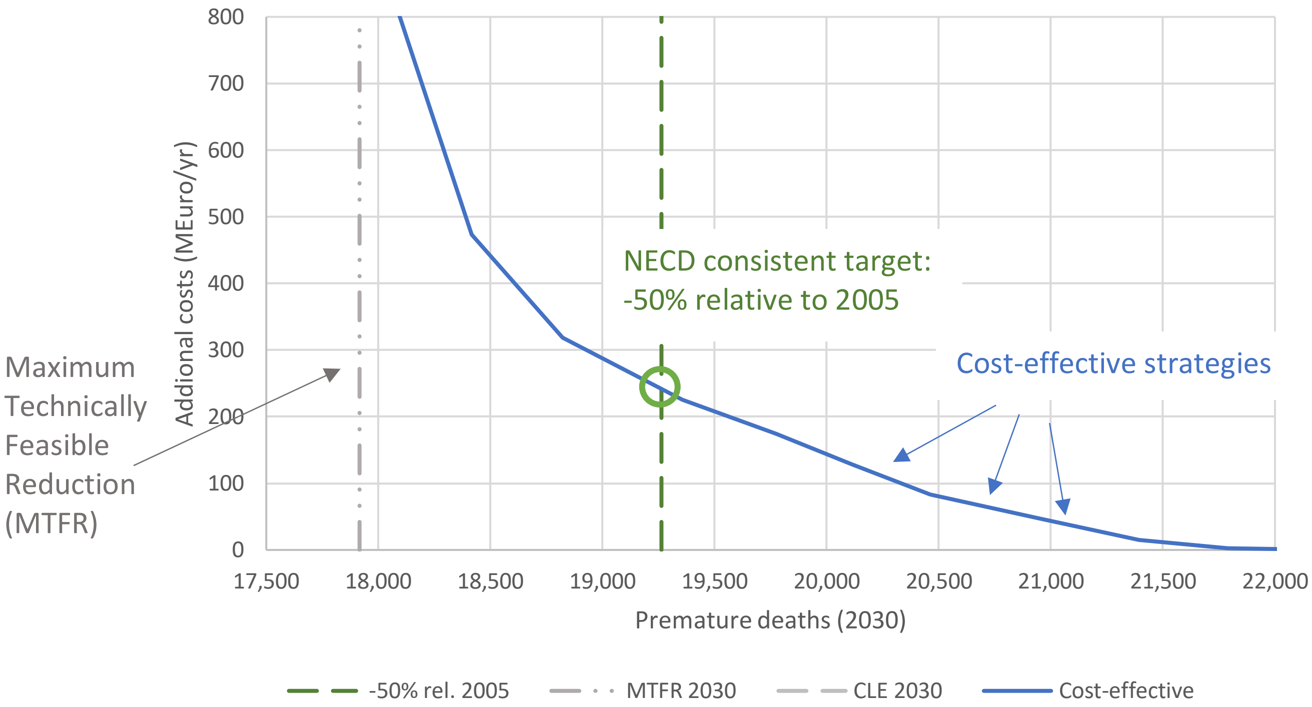

Figure 39 Cost curve for reducing $PM_{2.5}$ premature deaths

Figure 39 illustrates that the 50% reduction target can be achieved at a cost of approx. 230 million Euros/year for the whole region. From this particular solution, economy specific information can be extracted, in particular the cost-effective ERCs and sets of technical measures that would achieve these ERCs.

Table 1 shows the ERCs both in absolute terms as well as in comparison to 2005 and 2020, and it shows the corresponding reduction in 2030 in the policy scenario compared to the 2030 emission levels under current legislation (CLE), taking into account current future commitments such as the targets developed by the energy community (Section 2.1). Table 2 shows a comparison between emissions in 2030 under the current legislation scenario (CLE) and the emissions when applying the respective technical measures to meet the ERCs for each economy, sector and pollutant.

Table 1 Calculated ERCs for 2030 from the modeling exercise

Albania

Item	unit	SO2	NOx	PM2.5	NH3	VOCs
Absolute target	kt	2.86	27.75	5.04	24.61	23.64
Reduction rel. 2005	kt	-5.94	-4.65	-3.66	-5.19	-15.36
	%	-68%	-14%	-42%	-17%	-39%
Reduction rel. 2020	kt	-1.74	3.45	-0.86	0.31	-1.96
	%	-38%	14%	-15%	1%	-8%
Reduction rel. 2030 (CLE)	kt	-3.24	-2.15	-1.06	-2.19	-1.86
	%	-53%	-7%	-17%	-8%	-7%

Bosnia and Herzegovina

Item	unit	SO2	NOx	PM2.5	NH3	VOCs
Absolute target	kt	21.35	39.12	20.08	25.17	51.54
Reduction rel. 2005	kt	-311.95	-21.48	-23.22	-0.63	-22.96
	%	-94%	-35%	-54%	-2%	-31%
Reduction rel. 2020	kt	-380.65	-9.88	-13.42	-1.33	-15.26
	%	-95%	-20%	-40%	-5%	-23%
Reduction rel. 2030 (CLE)	kt	-110.95	-1.48	-6.22	-2.33	-5.46
	%	-84%	-4%	-24%	-8%	-10%

Kosovo

Item	unit	SO2	NOx	PM2.5	NH3	VOCs
Absolute target	kt	7.67	17.27	7.90	7.78	22.50
Reduction rel. 2005	kt	-88.43	-5.73	-5.30	-1.02	-1.10
	%	-92%	-25%	-40%	-12%	-5%
Reduction rel. 2020	kt	-110.23	-11.53	-10.40	-0.22	-4.30
	%	-93%	-40%	-57%	-3%	-16%
Reduction rel. 2030 (CLE)	kt	-95.43	-0.73	-6.40	-0.32	-1.20
	%	-93%	-4%	-45%	-4%	-5%

North Macedonia

Item	unit	SO2	NOx	PM2.5	NH3	VOCs
Absolute target	kt	2.47	17.75	6.05	8.28	27.44

Reduction rel. 2005	kt	-89.83	-21.55	-20.35	-2.52	-12.86
	%	-97%	-55%	-77%	-23%	-32%
Reduction rel. 2020	kt	-44.43	-9.05	-4.25	-0.72	-5.86
	%	-95%	-34%	-41%	-8%	-18%
Reduction rel. 2030 (CLE)	kt	-1.63	-5.55	-2.85	-1.12	-5.96
	%	-40%	-24%	-32%	-12%	-18%

Montenegro

Item	unit	SO2	NOx	PM2.5	NH3	VOCs
Absolute target	kt	0.58	5.91	2.43	3.48	7.87
Reduction rel. 2005	kt	-48.42	-4.49	-2.37	-1.02	-4.63
	%	-99%	-43%	-49%	-23%	-37%
Reduction rel. 2020	kt	-61.92	-7.79	-0.97	0.28	-1.23
	%	-99%	-57%	-29%	9%	-14%
Reduction rel. 2030 (CLE)	kt	-0.32	-0.59	-0.67	-0.12	-0.63
	%	-36%	-9%	-22%	-3%	-7%

Serbia

Item	unit	SO2	NOx	PM2.5	NH3	VOCs
Absolute target	kt	50.32	78.74	37.36	64.44	92.67
Reduction rel. 2005	kt	-429.58	-98.26	-24.54	-29.16	-79.33
	%	-90%	-56%	-40%	-31%	-46%
Reduction rel. 2020	kt	-322.98	-70.36	-17.14	-21.66	-24.93
	%	-87%	-47%	-31%	-25%	-21%
Reduction rel. 2030 (CLE)	kt	-16.28	-6.76	-12.54	-29.96	-16.23
	%	-24%	-8%	-25%	-32%	-15%

Table 2 Emissions (kt) per GNFR category and pollutant in Baseline (CLE) and cost-effective (ERC) scenario for all Western Balkan economies[20]

[20] Emissions from the power sector are projected to decline substantially until 20230 due to the EnC Clean Energy Package targets which. The goal for climate neutrality, for example, is projected to be reached in 2050. Coal will be phased out by 2040 and the natural gas infrastructure will be improved until 2050.

	Albania									
	SO2		PM2.5		NOX		NMVOC		NH3	
	CLE	ERC	CLE	ERC	CLE	ERC	CLE	ERC	CLE	ERC
GNFR codes	2030	2030	2030	2030	2030	2030	2030	2030	2030	2030
A_PublicPower	-	-	-	-	0.0	0.0	-	-	-	-
B_Industry	5.5	2.3	1.0	0.7	6.5	6.4	1.6	1.6	0.0	0.0
C_OtherStationaryComb	0.4	0.4	2.9	2.5	0.8	0.8	4.9	4.2	0.4	0.4
D_Fugitive	-	-	0.1	0.1	0.0	0.0	0.7	0.7	-	-
E_Solvents	n.a	n.a	0.3	0.2	n.a	n.a	9.5	8.9	n.a	n.a
F_RoadTransport	0.0	0.0	0.7	0.5	16.1	14.1	1.8	1.5	0.1	0.1
G_Shipping	0.1	0.1	0.1	0.1	2.6	2.5	0.4	0.4	0.0	0.0
H_Aviation	0.0	0.0	-	-	0.0	0.0	0.0	0.0	n.a	n.a
I_Offroad	0.1	0.1	0.1	0.1	1.4	1.3	0.4	0.4	0.0	0.0
J_Waste	0.0	0.0	0.5	0.4	0.1	0.1	0.5	0.4	n.a	n.a
K_AgriLivestock	n.a	n.a	0.1	0.1	1.3	1.3	4.7	4.7	23.6	21.4
L_AgriOther	0.0	0.0	0.3	0.2	1.1	1.1	1.1	0.8	2.2	2.2
M_Other	n.a	n.a	n.a		n.a	n.a	n.a	n.a	0.5	0.5

	Bosnia and Herzegovina									
	SO2		PM2.5		NOX		NMVOC		NH3	
	CLE	ERC	CLE	ERC	CLE	ERC	CLE	ERC	CLE	ERC
GNFR codes	2030	2030	2030	2030	2030	2030	2030	2030	2030	2030
A_PublicPower	103.6	14.3	2.6	0.7	6.1	6.1	0.1	0.1	0.0	0.0
B_Industry	22.8	3.5	3.6	1.2	5.3	5.3	3.5	3.3	0.0	0.0
C_OtherStationaryComb	5.7	3.4	16.8	15.7	2.8	2.8	29.5	26.1	2.9	2.9
D_Fugitive	-	-	0.1	0.1	-	-	4.4	4.4	-	-
E_Solvents	n.a	n.a	0.4	0.3	n.a	n.a	7.6	7.1	n.a	n.a
F_RoadTransport	0.0	0.0	0.8	0.7	21.3	19.9	2.0	1.6	0.2	0.2
G_Shipping	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a
H_Aviation	0.0	0.0	-	-	0.0	0.0	0.0	0.0	n.a	n.a
I_Offroad	0.1	0.1	0.1	0.1	1.3	1.3	0.3	0.3	0.0	0.0
J_Waste	0.0	0.0	0.7	0.7	0.1	0.1	1.2	1.2	n.a	n.a
K_AgriLivestock	n.a	n.a	0.3	0.3	1.5	1.5	5.9	5.9	21.9	19.8
L_AgriOther	0.0	0.0	0.9	0.3	0.8	0.7	2.4	1.6	1.8	1.7
M_Other	n.a	n.a	n.a	n.a	1.5	1.5	n.a	n.a	0.6	0.6

	Kosovo									
	SO2		PM2.5		NOX		NMVOC		NH3	
	CLE	ERC	CLE	ERC	CLE	ERC	CLE	ERC	CLE	ERC
GNFR codes	2030	2030	2030	2030	2030	2030	2030	2030	2030	2030
A_PublicPower	94.2	4.7	5.7	0.5	6.1	6.1	0.1	0.1	0.0	0.0
B_Industry	7.6	1.6	0.8	0.3	2.5	2.4	0.9	0.9	0.0	0.0
C_OtherStationaryComb	1.2	1.2	6.9	6.5	0.9	0.9	11.0	10.3	0.9	0.9
D_Fugitive	n.a	n.a	0.0	0.0	n.a	n.a	1.9	1.9	n.a	n.a
E_Solvents	n.a	n.a	0.2	0.2	n.a	n.a	5.6	5.5	n.a	n.a
F_RoadTransport	0.0	0.0	0.2	0.2	6.6	6.0	0.6	0.5	0.1	0.1
G_Shipping	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a
H_Aviation	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a
I_Offroad	0.1	0.1	0.1	0.1	0.9	0.9	0.4	0.4	0.0	0.0
J_Waste	n.a	n.a	n.a	n.a	0.0	0.0	0.1	0.1	n.a	n.a
K_AgriLivestock	n.a	n.a	0.0	0.0	0.4	0.4	2.4	2.4	4.6	4.3
L_AgriOther	0.0	0.0	0.3	0.1	0.5	0.5	0.8	0.5	2.4	2.3
M_Other	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	0.2	0.2

	Montenegro									
	SO2		PM2.5		NOX		NMVOC		NH3	
	CLE	ERC	CLE	ERC	CLE	ERC	CLE	ERC	CLE	ERC
GNFR codes	2030	2030	2030	2030	2030	2030	2030	2030	2030	2030
A_PublicPower	0.0	0.0	0.0	0.0	0.0	c	0.0	0.0	0.0	0.0
B_Industry	0.5	0.1	0.5	0.1	0.3	0.3	0.2	0.2	0.0	0.0
C_OtherStationaryComb	0.4	0.4	2.1	2.0	0.3	0.3	4.0	3.5	0.4	0.4
D_Fugitive	-	-	0.0	0.0	-	-	0.2	0.2	-	-
E_Solvents	n.a	n.a	0.1	0.1	n.a	n.a	1.0	1.0	n.a	n.a
F_RoadTransport	0.0	0.0	0.2	0.2	5.2	4.7	0.5	0.4	0.0	0.0
G_Shipping	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a
H_Aviation	0.0	0.0	-	-	0.0	0.0	0.0	0.0	n.a	n.a
I_Offroad	0.0	0.0	0.0	0.0	0.3	0.3	0.2	0.1	-	-
J_Waste	-	-	0.0	0.0	0.0	0.0	0.8	0.8	n.a	n.a
K_AgriLivestock	n.a	n.a	0.0	0.0	0.2	0.2	1.2	1.2	3.1	3.0
L_AgriOther	-	-	0.1	0.1	0.0	0.0	0.5	0.5	0.1	0.1
M_Other	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	

	North Macedonia									
	SO2		PM2.5		NOX		NMVOC		NH3	
	CLE	ERC	CLE	ERC	CLE	ERC	CLE	ERC	CLE	ERC
GNFR codes	2030	2030	2030	2030	2030	2030	2030	2030	2030	2030
A_PublicPower	0.0	0.0	0.0	0.0	0.6	0.6	0.0	0.0	0.0	0.0
B_Industry	3.4	1.9	1.0	0.4	1.9	1.9	1.2	1.2	0.0	0.0
C_OtherStationaryComb	0.5	0.5	4.3	4.2	0.6	0.6	10.2	10.0	0.5	0.5
D_Fugitive	-	-	0.0	0.0	-	-	1.0	1.0	-	-
E_Solvents	n.a	n.a	0.3	0.2	n.a	n.a	7.8	7.7	n.a	n.a
F_RoadTransport	0.0	0.0	0.6	0.5	14.6	13.0	2.1	1.7	0.1	0.1
G_Shipping	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a
H_Aviation	0.0	0.0	-	-	0.0	0.0	0.0	0.0	n.a	n.a
I_Offroad	0.0	0.0	0.0	0.0	0.6	0.6	0.1	0.1	-	-
J_Waste	0.0	0.0	0.4	0.4	0.1	0.1	0.5	0.5	n.a	n.a
K_AgriLivestock	n.a	n.a	0.0	0.0	0.5	0.5	4.1	4.1	7.3	6.7
L_AgriOther	0.0	0.0	0.6	0.2	0.5	0.5	1.5	1.0	1.1	1.0
M_Other	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a

	Serbia									
	SO2		PM2.5		NOX		NMVOC		NH3	
	CLE	ERC	CLE	ERC	CLE	ERC	CLE	ERC	CLE	ERC
GNFR codes	2030	2030	2030	2030	2030	2030	2030	2030	2030	2030
A_PublicPower	21.2	21.2	1.5	1.5	12.4	12.2	0.3	0.3	0.2	0.2
B_Industry	22.5	8.1	4.2	2.2	11.1	11.1	8.6	8.1	0.1	0.1
C_OtherStationaryComb	20.8	20.6	28.2	26.4	5.0	5.0	37.8	34.4	4.1	4.1
D_Fugitive	0.0	0.0	0.4	0.4	0.1	0.1	9.2	9.2	-	-
E_Solvents	n.a	n.a	0.8	0.5	n.a	n.a	14.9	14.5	n.a	n.a
F_RoadTransport	0.1	0.1	1.4	1.1	42.0	36.0	5.0	4.4	0.2	0.2
G_Shipping	n.a	n.a	0.0	0.0	0.3	0.3	0.1	0.0	-	-
H_Aviation	0.0	0.0	0.0	0.0	0.1	0.1	0.3	0.3	n.a	n.a
I_Offroad	0.2	0.2	0.3	0.3	4.3	4.2	1.7	1.6	0.0	0.0
J_Waste	0.0	0.0	1.5	1.4	0.2	0.2	1.5	1.4	3.1	3.1
K_AgriLivestock	n.a	n.a	0.5	0.5	3.0	3.0	12.1	12.1	38.9	36.3
L_AgriOther	0.3	0.1	9.7	2.9	6.9	6.7	15.4	6.4	40.9	19.5
M_Other	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	1.1	1.1

Finally, Figure 40 illustrates for primary $PM_{2.5}$ and Western Balkan as a whole, and by aggregated sectors, the baseline development of emissions (current legislation) in 2030 relative to 2020, the additional reduction potential (maximum technically feasible reduction, MTFR) and the cost-effective measures in the proposed 50% reduction target case.

This type of illustrations shows the change in emissions (in absolute terms – kt of pollutant) from the emissions in 2020 to the target year 2030, for three scenarios which are shown as three columns for each sector, with the different colours indicating key measures to achieve the reductions:

- ➔ in the first column (BLACK bar, 'Current legislation' in legend) the change in emissions in this sector between 2020 and 2030 Baseline is shown. This can be zero (no black bar appears), an increase (above 0) or decrease shown as a reduction in negative numbers,
- ➔ the second column (COLOURS, 'cost-effective emission reductions') shows for each sector the necessary reductions in emissions of a given pollutant to achieve the target for health. These changes (reductions) are always shown in relation to the BLACK BAR and so start at its 'end' which represents the Baseline in 2030. The values can be either zero and so there is 'no change shown' or no second bar or show a bar which can have several colours reflecting different types of measures and the sum of all of them cannot be larger than the length of the third column bar.
- ➔ the third column (hatched, 'MTFR') illustrates the maximum mitigation potential calculated in GAINS (MTFR) and it shows the impact of implementing ALL defined measures in GAINS, to the extent that is technically feasible.[21] The reductions are shown as a stacked bar starting at the Baseline 2030, and so at the 'end' of the black bar, just like the second column, and are typically longer than the second column illustrating that the potential for mitigation is larger than emission reductions needed to attain the set health target.

[21] In the GAINS model the maximum use of a particular emission reduction technology may be constrained to a share of less than 100% of the total underlying activity, either for technical, pragmatic or other reasons. This maximum share may change over time. For example, it is not possible to equip the whole vehicle fleet with the highest EURO standard. The share of the fleet that can be equipped with a given emission standard depends on the year in which the standard is adopted, the vehicle stock turnover rate and the year under consideration. Thus, in a future year (2030) typically only for a small share of the fleet the emission standard is still undetermined and could be modified from a CLE assumption to a more ambitious level. This small share is bounded by the maximum application rate, a value that is stored in the GAINS database and can be reviewed. Not all technologies are bounded by maximum application rates.

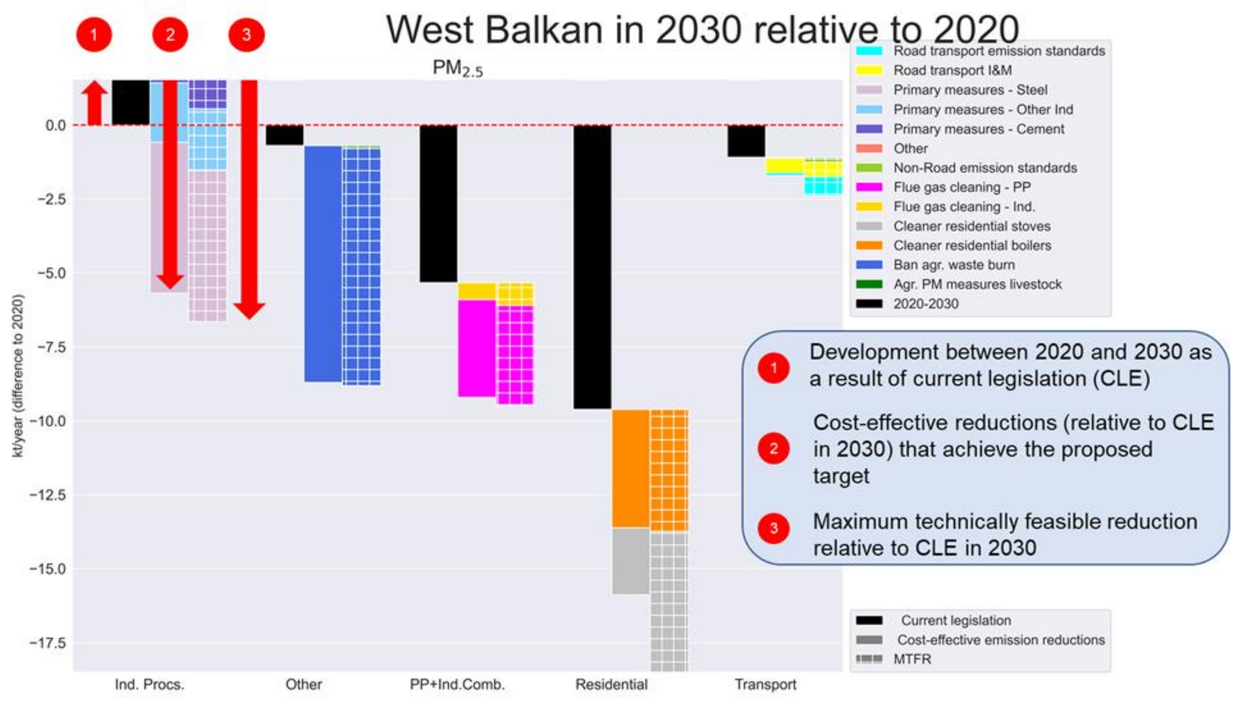

Figure 40 Primary $PM_{2.5}$ emissions: Baseline development, additional potential and cost-effective measures for reaching a 50% reduction in premature deaths from $PM_{2.5}$ in Western Balkan. For details see text.

Figure 40 shows that current legislation in the Western Balkan region leads to the highest $PM_{2.5}$ emission reduction in the residential sector and in power plants and industrial combustion (PP + Ind. Comb.) from 2020 to 2030, while emissions from Industrial Processes (Ind. Proc.) are slightly increasing in the same period. To reach the health target in 2030, additional measures are needed in all sectors. For industrial/combustion processes, for example, the installation of cleaner residential stoves and primary measures such as filters or scrubbers to clean flue gas would lead to a cost-effective reduction of emissions. Fixing high emitting vehicles by identifying and fixing them through an enforced inspection and maintenance (Road Transport I&M) program could also contribute to reduce $PM_{2.5}$ emissions from the transport sector. Largest additional potential for further $PM_{2.5}$ reductions beyond the target (MTFR) was identified in the residential sector when installing cleaner residential stoves and boilers.

Since the ERCs are defined on a national level, such a pollutant specific cost-effective and MTFR set of measures was derived for all Western Balkan economies individually and is shown throughout Figure 41 to Figure 70. More details on the specific measures shown in each graph can be found in section 5.5. Again, these measures are not to be understood as prescribed but as the most cost-effective options to reach the ERCs and therefore the health target. They have been presented to each economy during the consultation meetings in 2025 and sent as power point to the economies that could not take part in the consultation meetings to collect feedback.

5.4.1 Albania

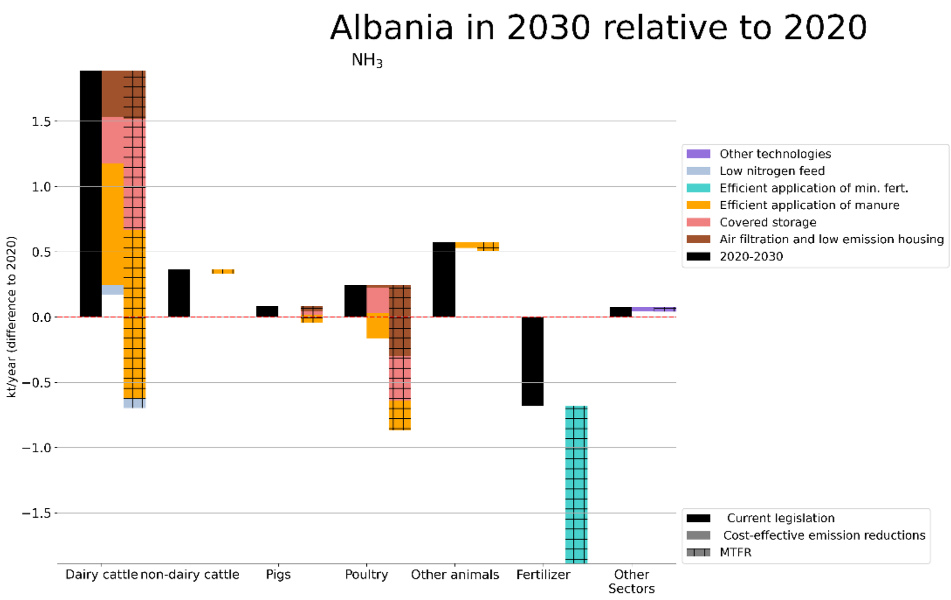

Figure 41 Baseline development, cost-effective measures for reaching the ERC for NH_3 in Albania and additional potential in 2030 relative to 2020.

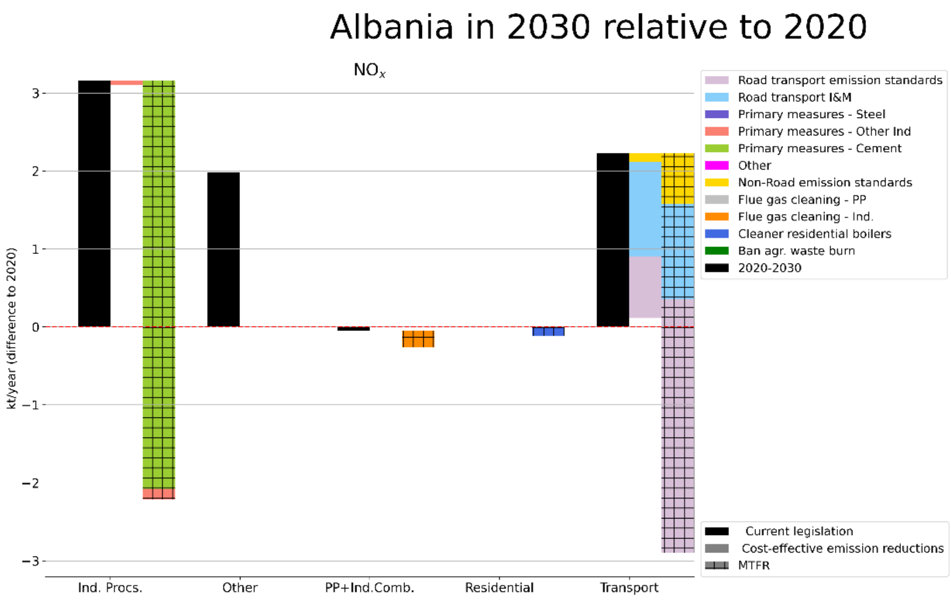

Figure 42 Baseline development, cost-effective measures for reaching the ERC for NO_X in Albania and additional potential in 2030 relative to 2020.

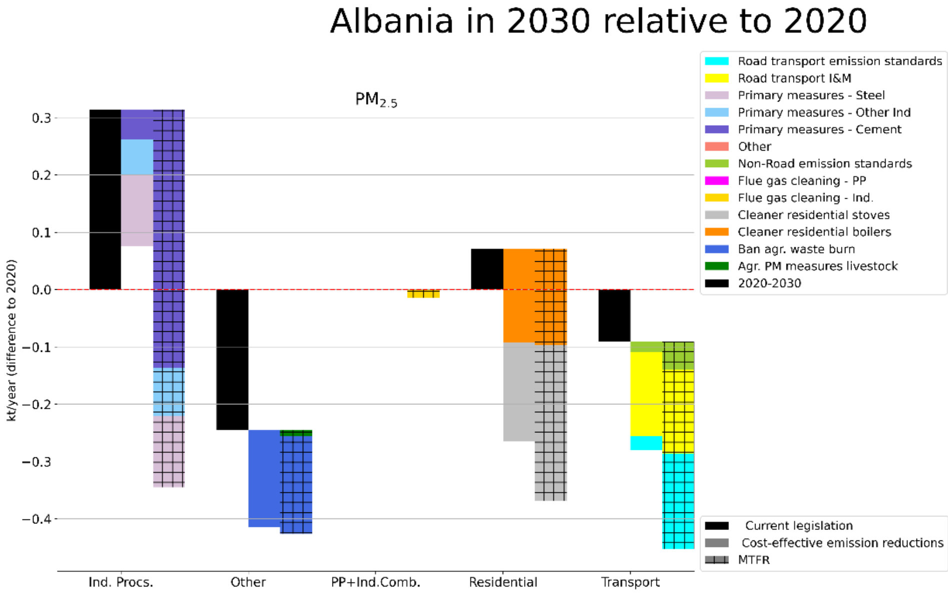

Figure 43 Baseline development, cost-effective measures for reaching the ERC for $PM_{2.5}$ in Albania and additional potential in 2030 relative to 2020.

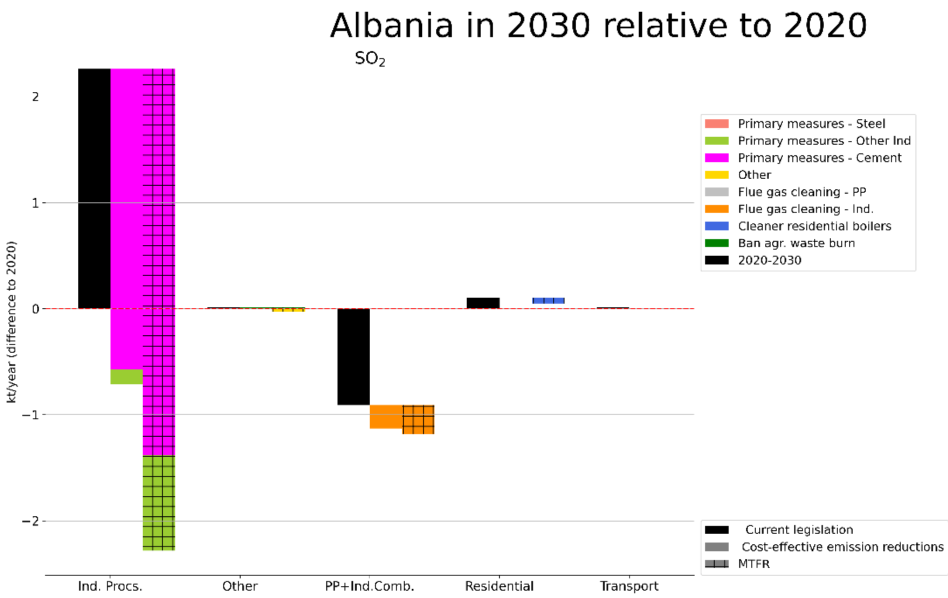

Figure 44 Baseline development, cost-effective measures for reaching the ERC for SO_2 in Albania and additional potential in 2030 relative to 2020.

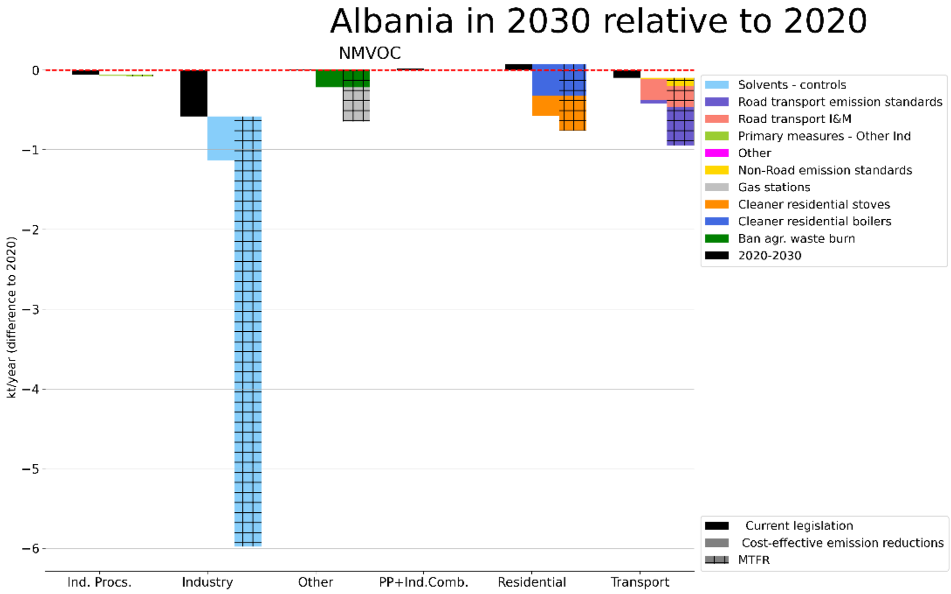

Figure 45 Baseline development, cost-effective measures for reaching the ERC for NMVOC in Albania and additional potential in 2030 relative to 2020.

5.4.2 Bosnia and Herzegovina

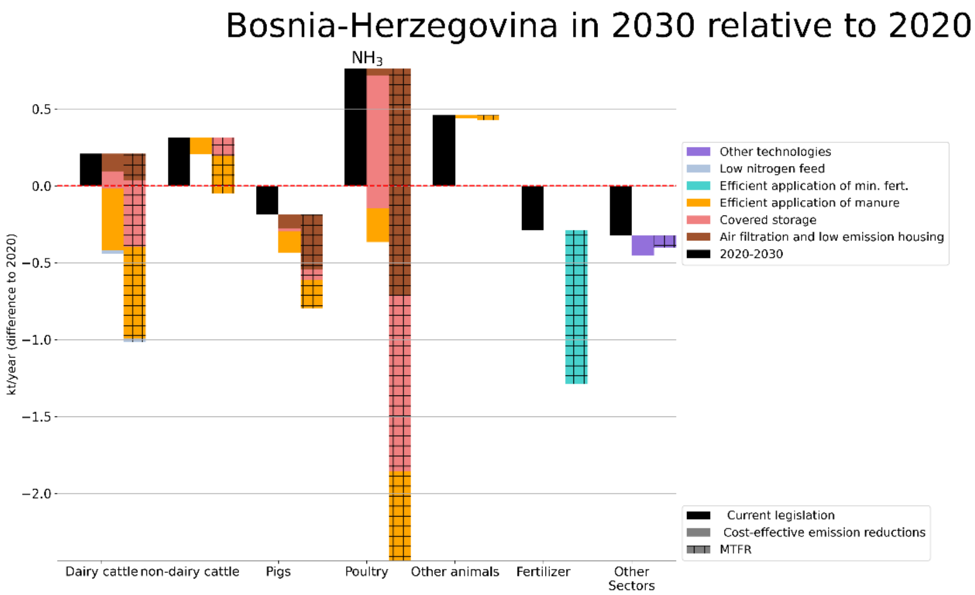

Figure 46 Baseline development, cost-effective measures for reaching the ERC for NH_3 in Bosnia and Herzegovina and additional potential in 2030 relative to 2020.

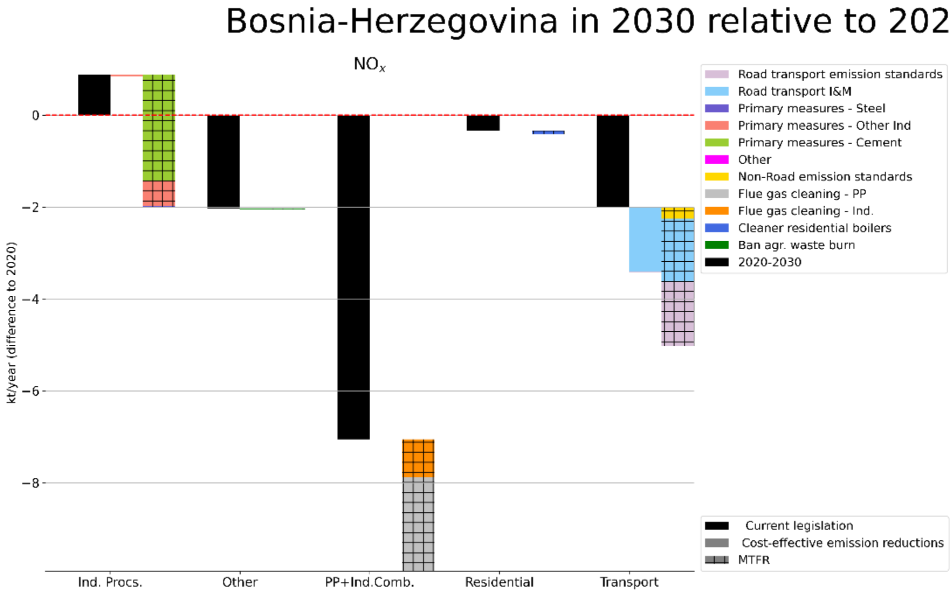

Figure 47 Baseline development, cost-effective measures for reaching the ERC for NO_X in Bosnia and Herzegovina and additional potential in 2030 relative to 2020.

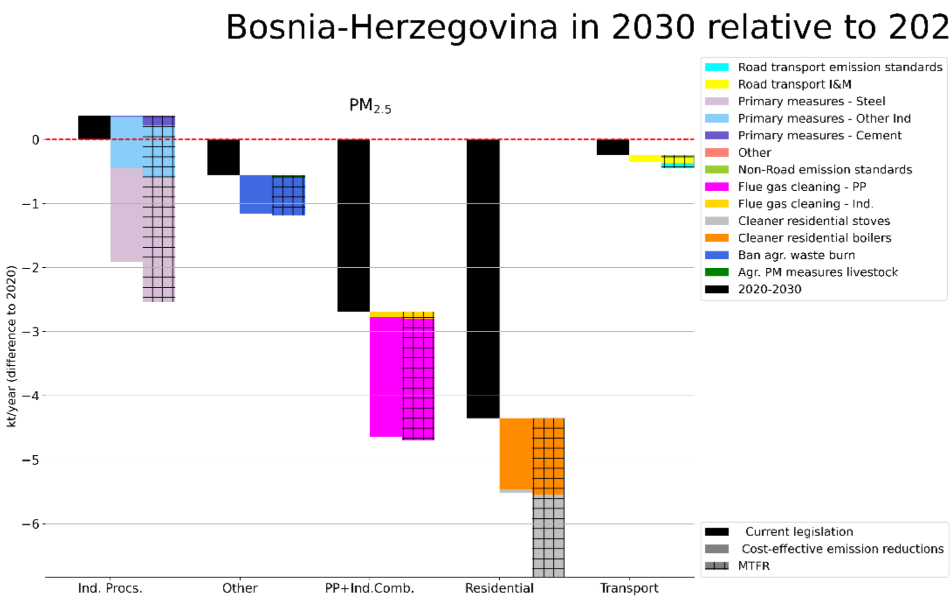

Figure 48 Baseline development, cost-effective measures for reaching the ERC for $PM_{2.5}$ in Bosnia and Herzegovina and additional potential in 2030 relative to 2020

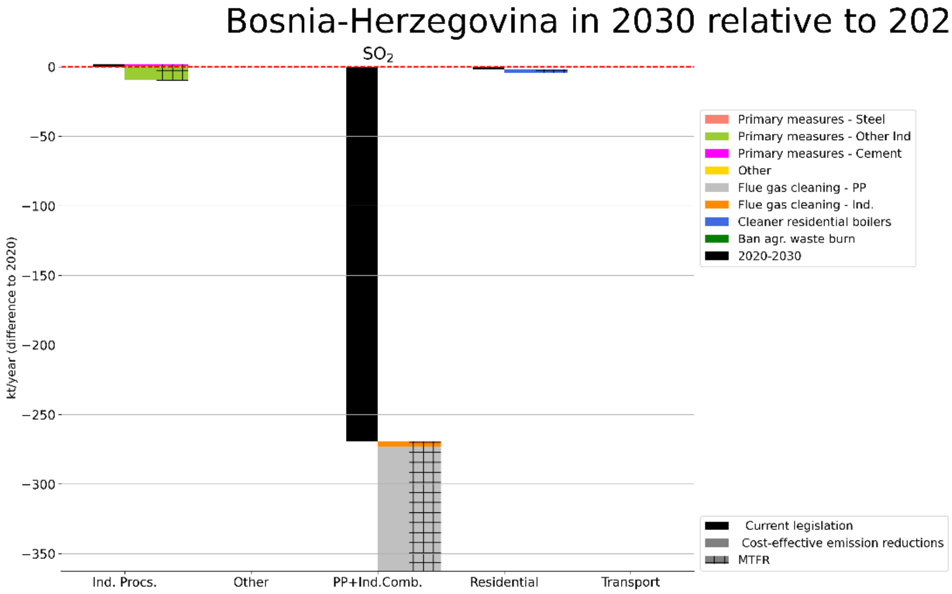

Figure 49 Baseline development, cost-effective measures for reaching the ERC for SO_2 in Bosnia and Herzegovina and additional potential in 2030 relative to 2020

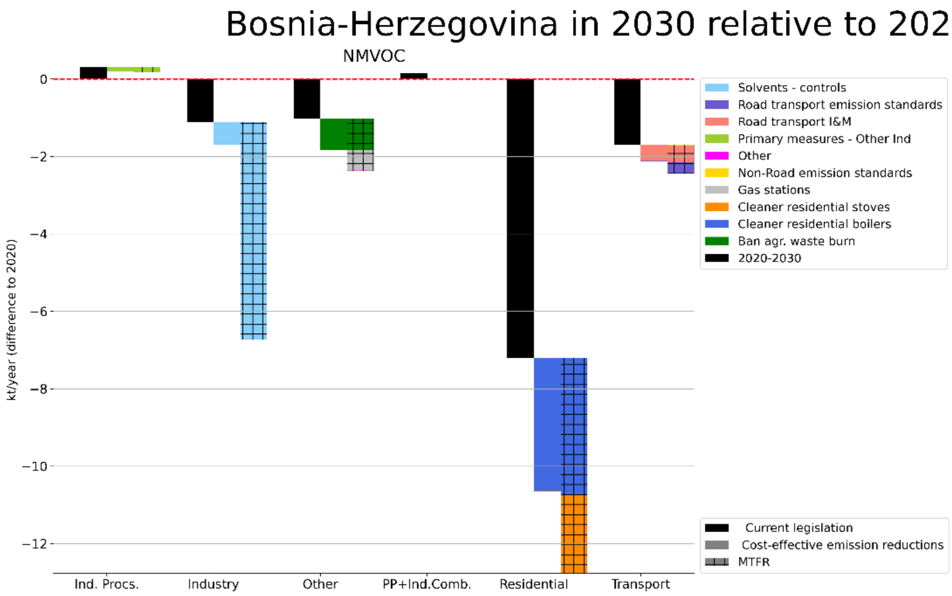

Figure 50 Baseline development, cost-effective measures for reaching the ERC for NMVOC in Bosnia and Herzegovina and additional potential in 2030 relative to 2020

5.4.3 Kosovo

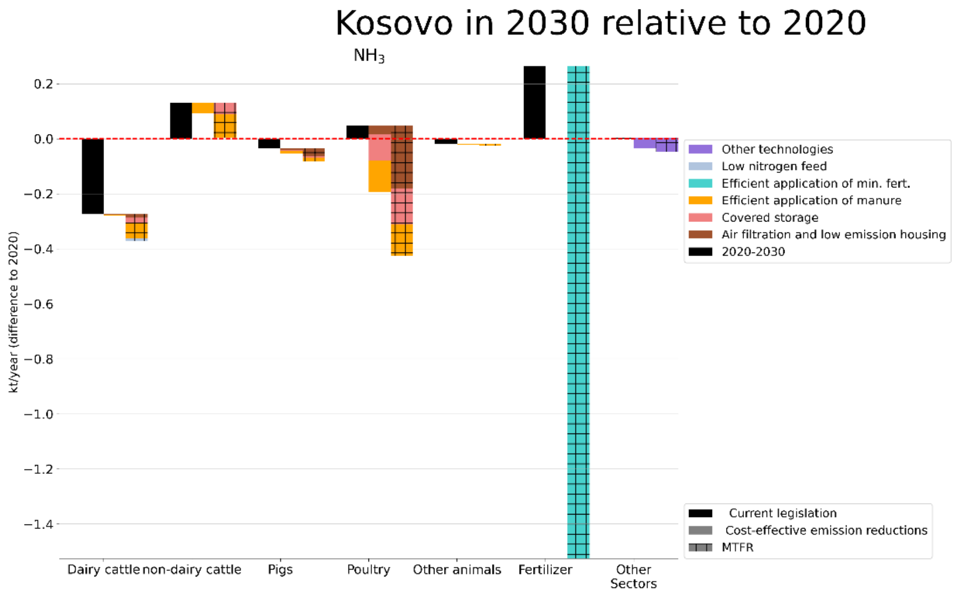

Figure 51 Baseline development, cost-effective measures for reaching the ERC for NH_3 in Kosovo and additional potential in 2030 relative to 2020

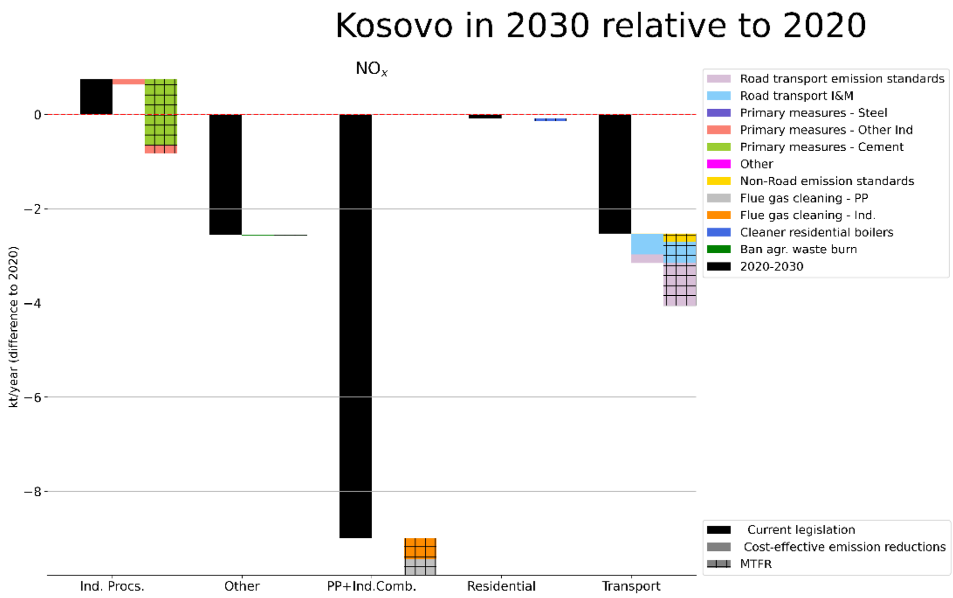

Figure 52 Baseline development, cost-effective measures for reaching the ERC for NO_X in Kosovo and additional potential in 2030 relative to 2020

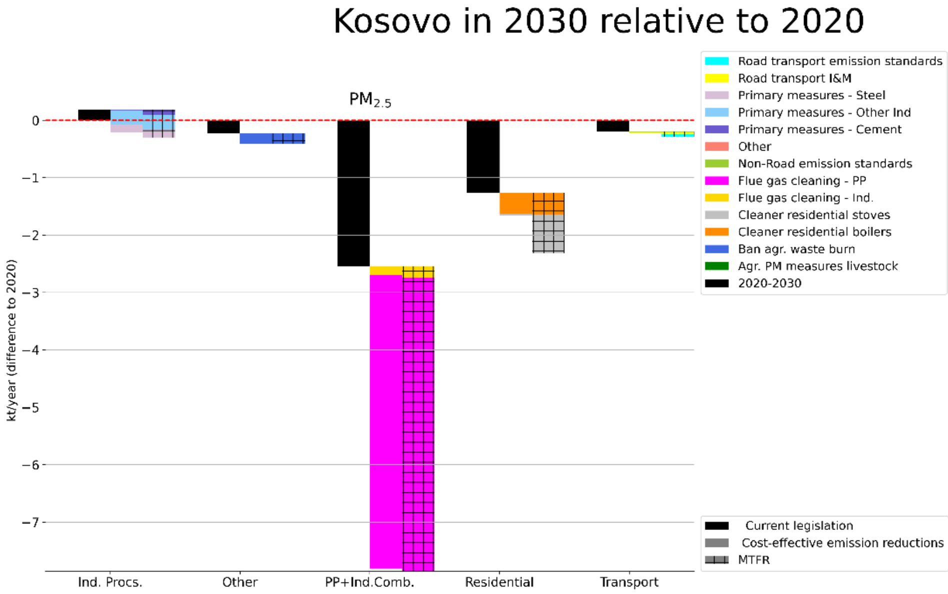

Figure 53 Baseline development, cost-effective measures for reaching the ERC for $PM_{2.5}$ in Kosovo and additional potential in 2030 relative to 2020

Figure 54 Baseline development, cost-effective measures for reaching the ERC for SO_2 in Kosovo and additional potential in 2030 relative to 2020

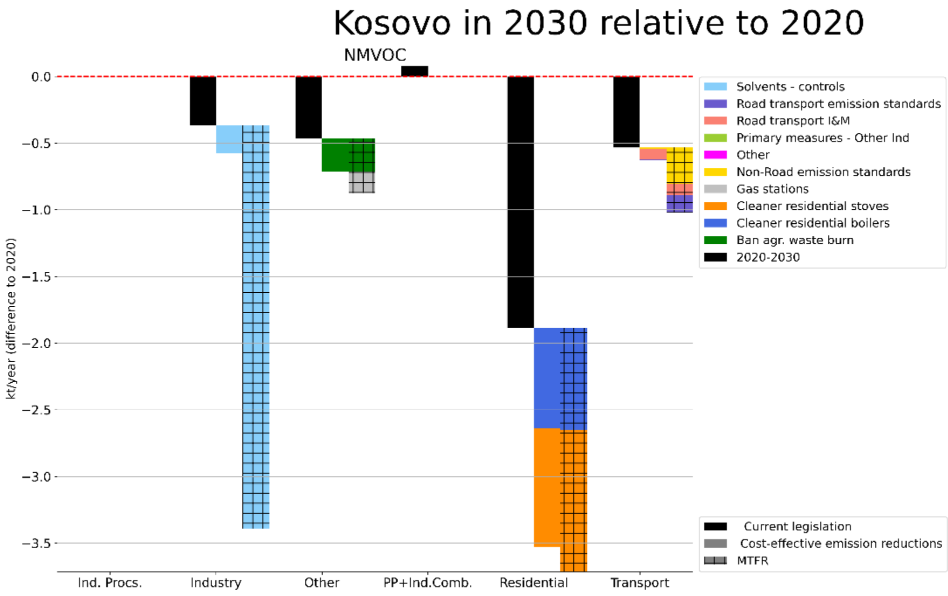

Figure 55 Baseline development, cost-effective measures for reaching the ERC for NMVOC in Kosovo and additional potential in 2030 relative to 2020

5.4.4 Montenegro

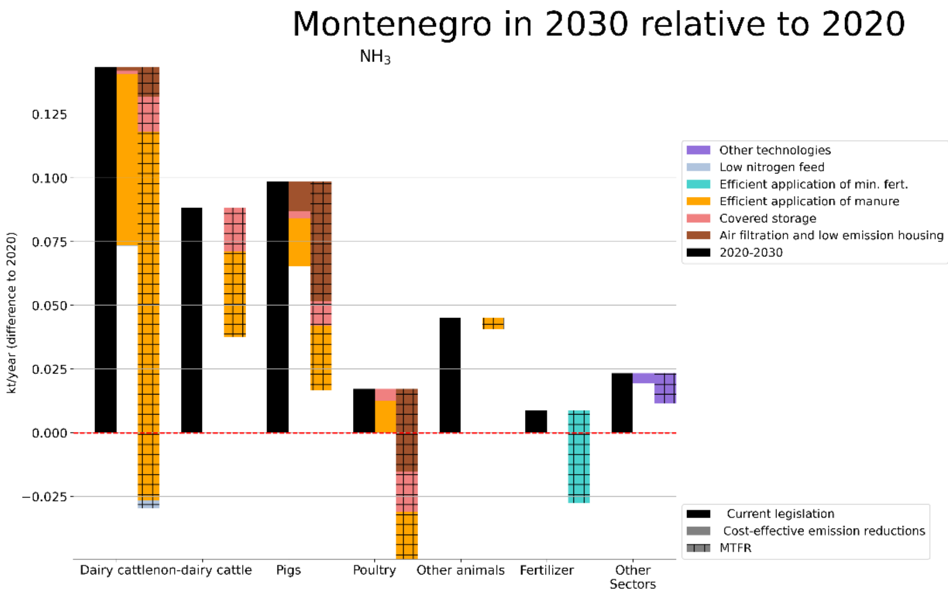

Figure 56 Baseline development, cost-effective measures for reaching the ERC for NH_3 in Montenegro and additional potential in 2030 relative to 2020

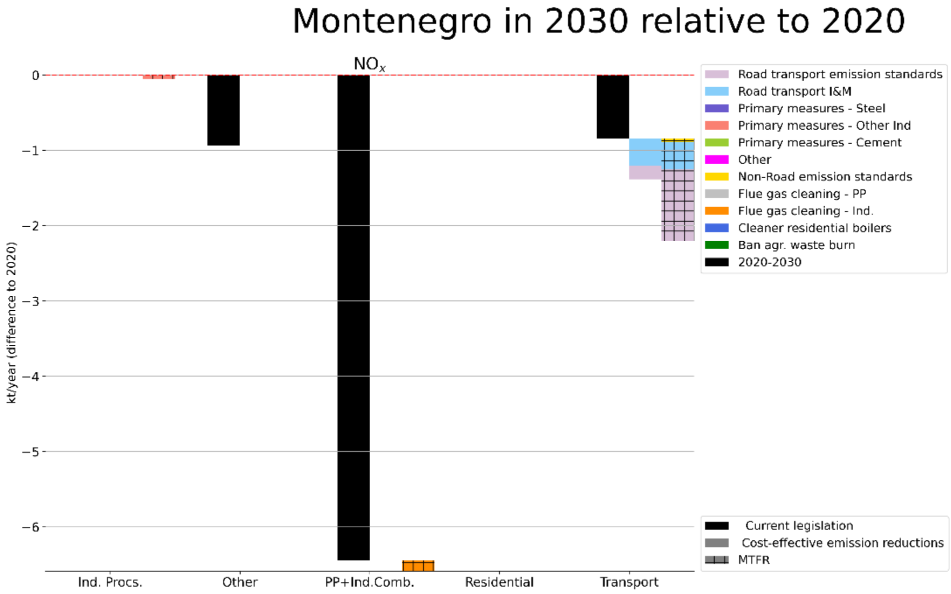

Figure 57 Baseline development, cost-effective measures for reaching the ERC for NO_X in Montenegro and additional potential in 2030 relative to 2020

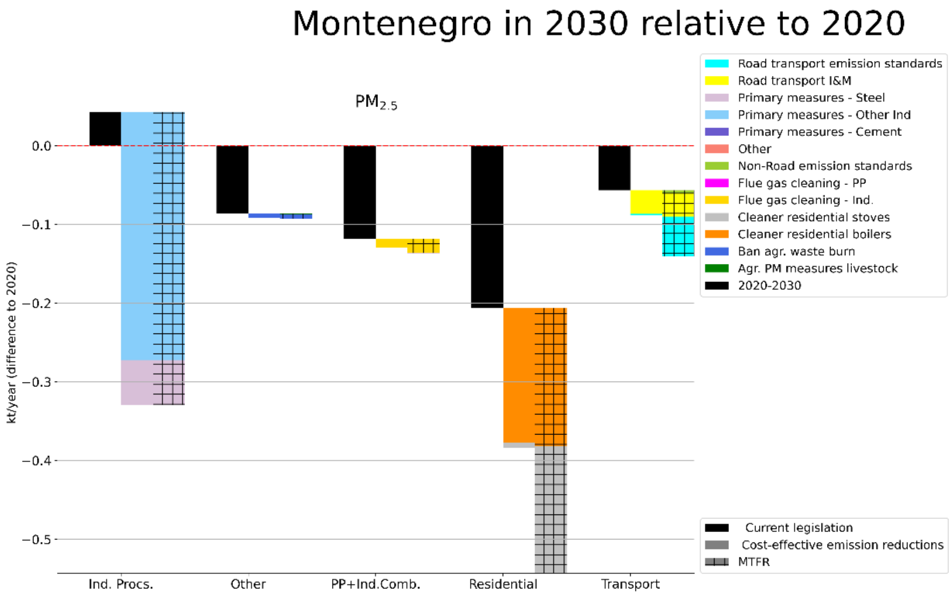

Figure 58 Baseline development, cost-effective measures for reaching the ERC for $PM_{2.5}$ in Montenegro and additional potential in 2030 relative to 2020

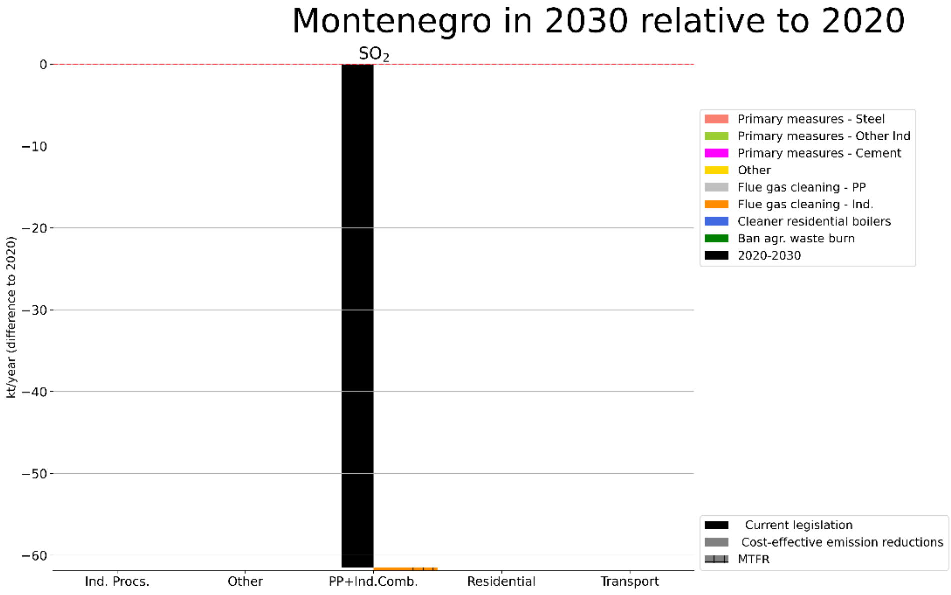

Figure 59 Baseline development, cost-effective measures for reaching the ERC for SO_2 in Montenegro and additional potential in 2030 relative to 2020

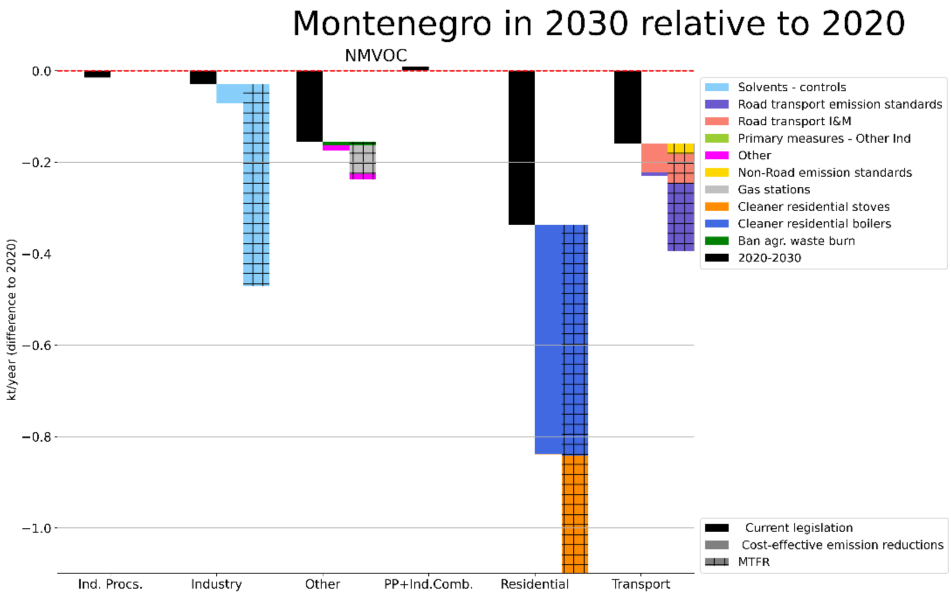

Figure 60 Baseline development, cost-effective measures for reaching the ERC for NMVOC in Montenegro and additional potential in 2030 relative to 2020

5.4.5 North Macedonia

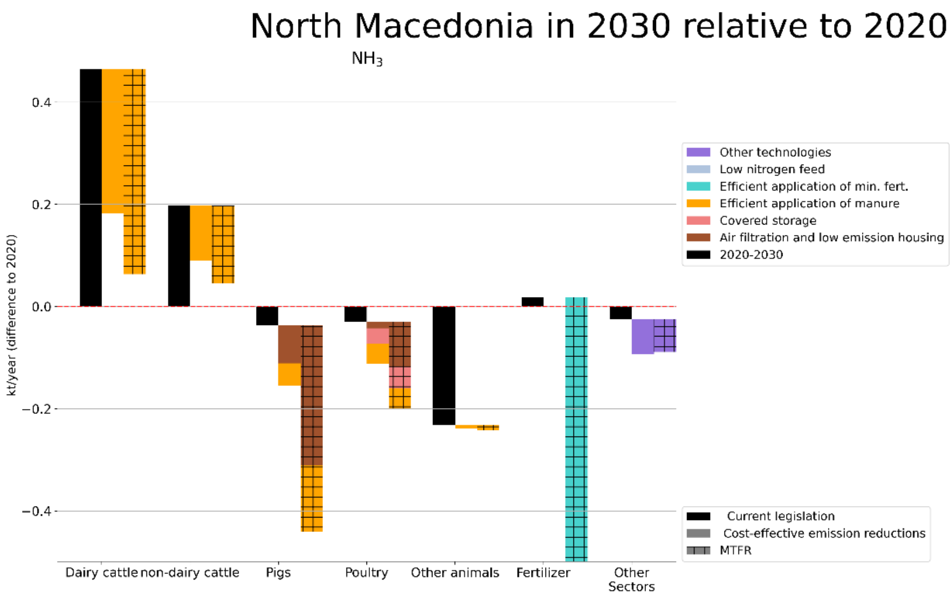

Figure 61 Baseline development, cost-effective measures for reaching the ERC for NH_3 in North Macedonia and additional potential in 2030 relative to 2020

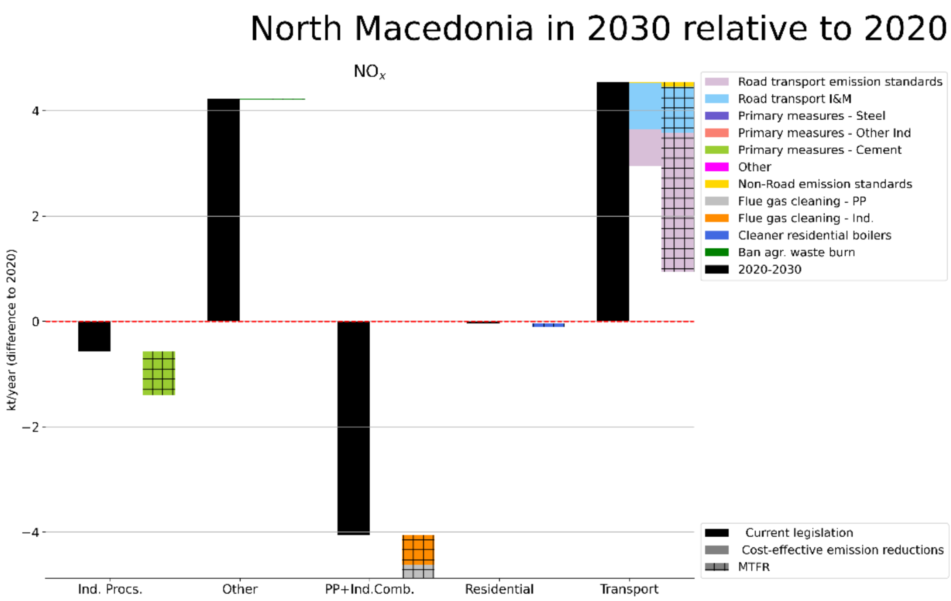

Figure 62 Baseline development, cost-effective measures for reaching the ERC for NO_X in North Macedonia and additional potential in 2030 relative to 2020

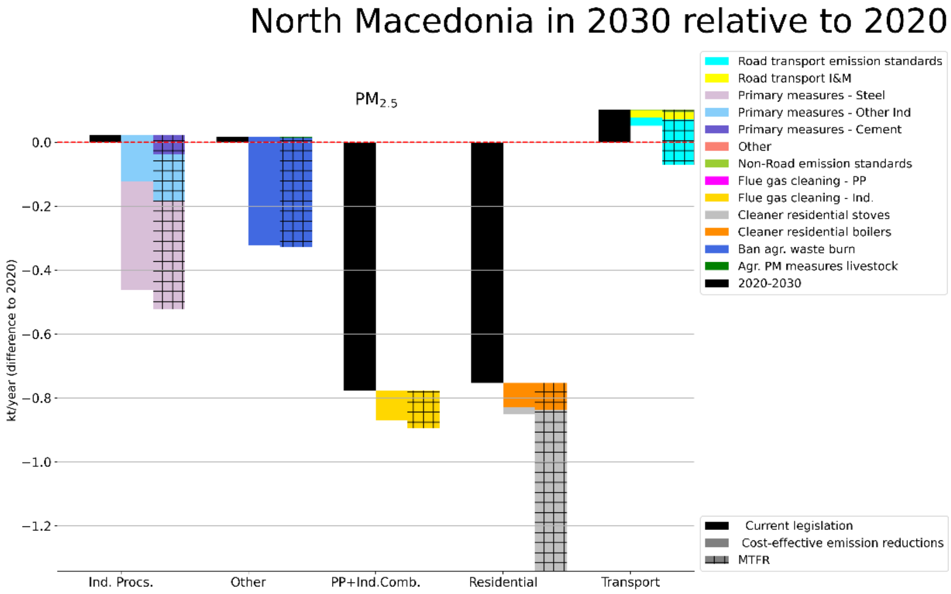

Figure 63 Baseline development, cost-effective measures for reaching the ERC for $PM_{2.5}$ in North Macedonia and additional potential in 2030 relative to 2020

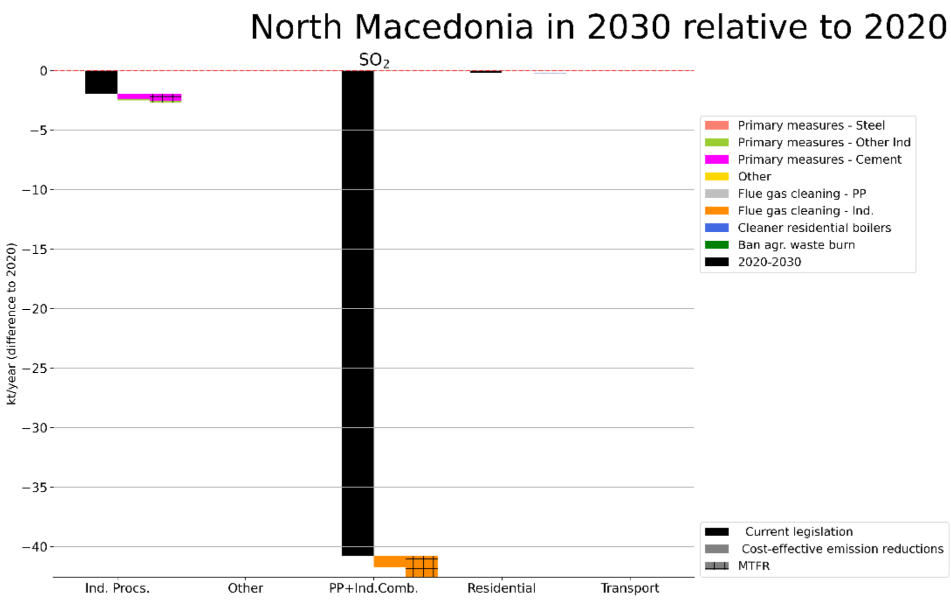

Figure 64 Baseline development, cost-effective measures for reaching the ERC for SO_2 in North Macedonia and additional potential in 2030 relative to 2020

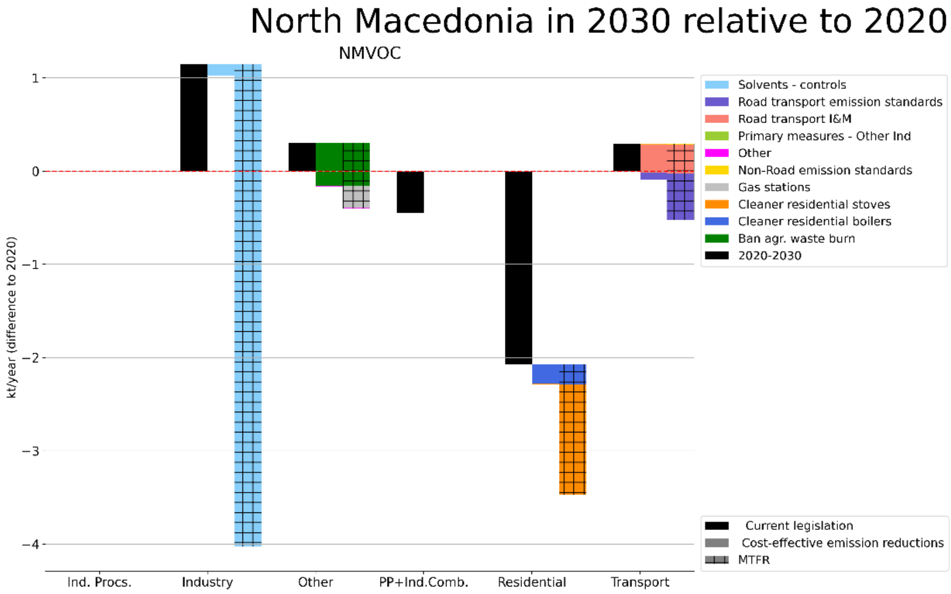

Figure 65 Baseline development, cost-effective measures for reaching the ERC for NMVOC in North Macedonia and additional potential in 2030 relative to 2020

5.4.6 Serbia

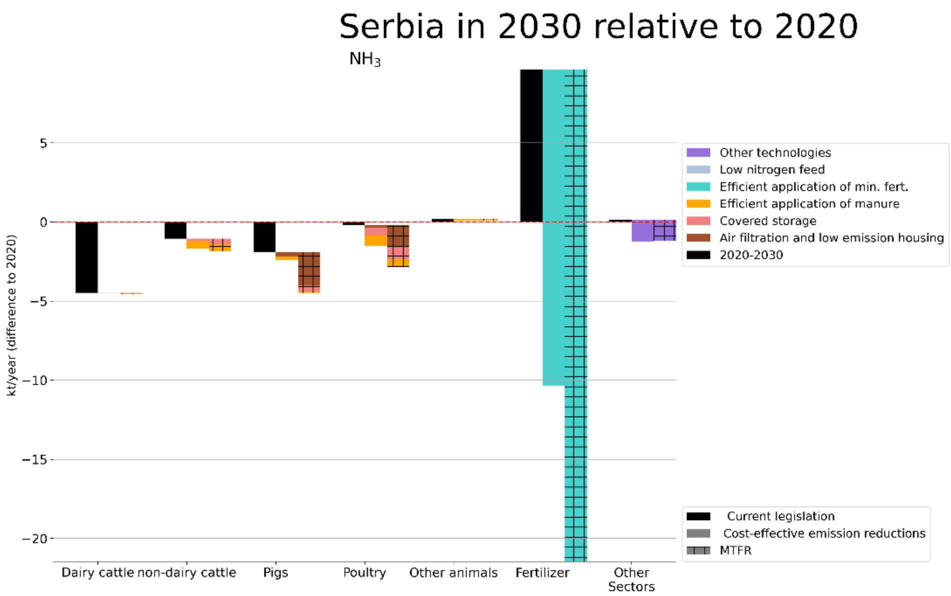

Figure 66 Baseline development, cost-effective measures for reaching the ERC for NH_3 in Serbia and additional potential in 2030 relative to 2020

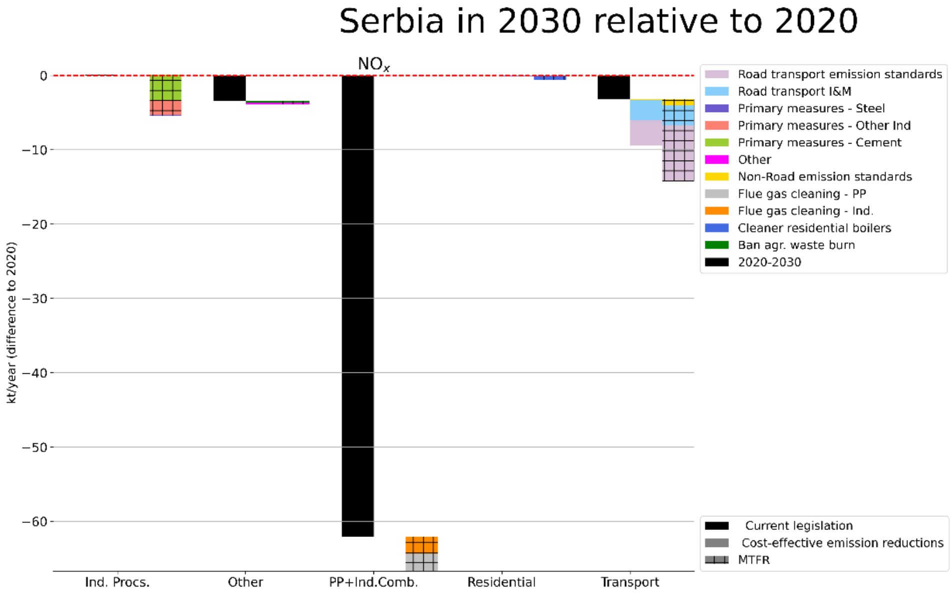

Figure 67 Baseline development, cost-effective measures for reaching the ERC for NO_X in Serbia and additional potential in 2030 relative to 2020

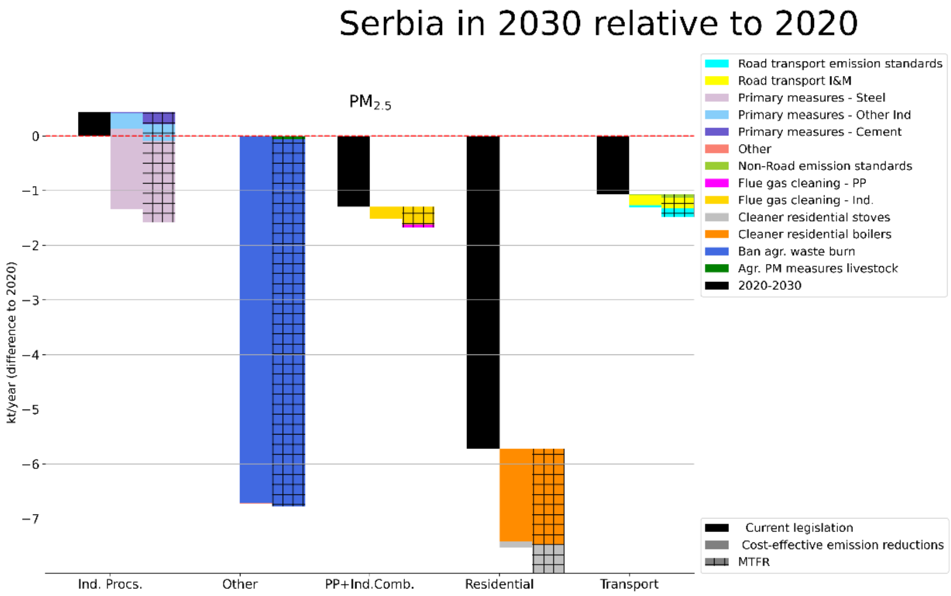

Figure 68 Baseline development, cost-effective measures for reaching the ERC for $PM_{2.5}$ in Serbia and additional potential in 2030 relative to 2020

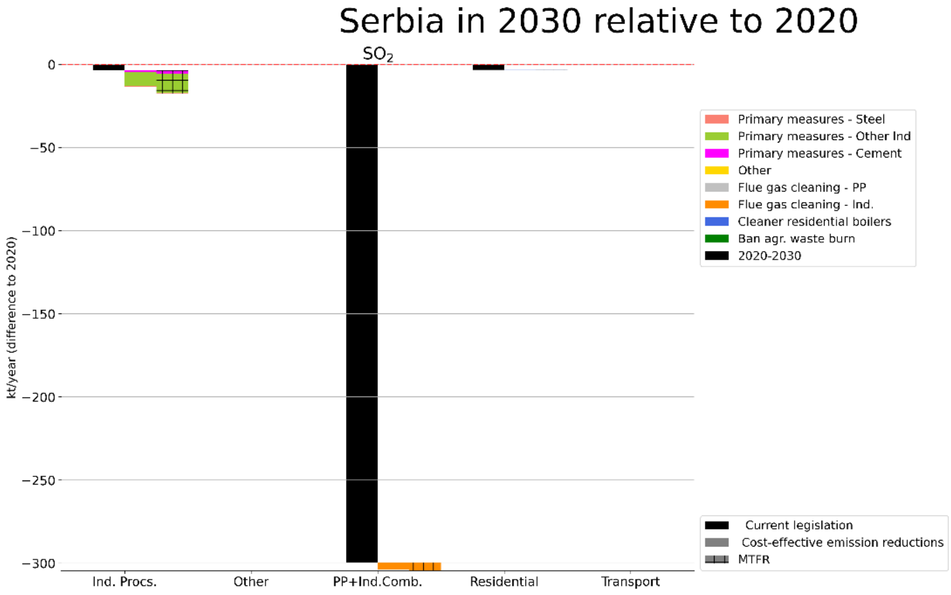

Figure 69 Baseline development, cost-effective measures for reaching the ERC for SO_2 in Serbia and additional potential in 2030 relative to 2020

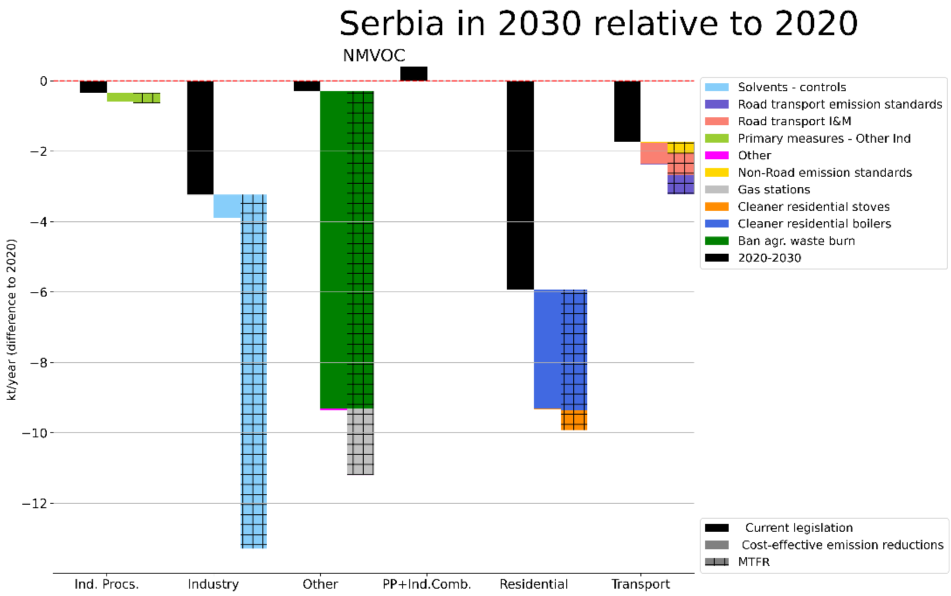

Figure 70 Baseline development, cost-effective measures for reaching the ERC for NMVOC in Serbia and additional potential in 2030 relative to 2020

5.5 Technical Measures

NH_3

Other technologies … includes e.g. improved waste management

Low nitrogen feed … includes feeding low nitrogen feed

Efficient application of min. fert (mineral fertilizer) … includes e.g. efficient application of mineral fertilizer, use of nitrification inhibitors and urea substitution

Efficient application of manure … includes e.g. trailing hose, trailing shoe, fast incorporation in soil, deep injection

Covered storage … includes e.g. natural crust, floating covers, fixed covers

Air filtration and low emission housing … includes air filtration and housing with several implemented measures that lead to a reduction in NH_3 emissions in every stage

NO_X

Road transport emission standards … includes the improvement of introduced emission standards for trucks, buses, cars and mopeds from stage 1 to stage 7

Road transport I&M … includes enforced inspection and maintenance of road transport

Primary measures – Steel … includes the installation of filters/scrubbers to clean flue gases (de-NO_X) in steel production

Primary measures – Other ind (Other industry) … includes the installation of filters/scrubbers to clean flue gases (de-NO_X) in other industries

Primary measures – Cement … includes the installation of filters/scrubbers to clean flue gases (de-NO_X) in cement production

Other … includes improved waste treatment and improvements of commercial boilers

Non-road emission standards … includes the improvement of introduced emission standards for non-road machinery like agricultural and construction machinery and ships from stage 1 to stage 7

Flue gas cleaning – PP … includes the installation of filters/scrubbers to clean flue gases (de-NO_X)

Flue gas cleaning – Ind … includes the installation of filters/scrubbers to clean flue gases (de-NO_X)

Cleaner residential boilers … includes the combustion modification on gas and gasoil use

Ban agr. Waste burn … banning open burning of agricultural and residential waste

$PM_{2.5}$

Road transport emission standards … includes the improvement of introduced emission standards for trucks, buses, cars and mopeds from stage 1 to stage 7

Road transport I&M … includes enforced inspection and maintenance of road transport

Primary measures – Steel … includes the installation of PM controls and electrostatic precipitators in steel production

Primary measures – Other ind (Other industry) … includes the installation of PM controls and electrostatic precipitators in other industry

Primary measures – Cement … includes the installation of PM controls and electrostatic precipitators in cement production

Other … Improvement of residential stoves and replacement of kerosene lamps and improved waste management

Non-road emission standards … includes the improvement of introduced emission standards for non-road machinery like agricultural and construction machinery and ships from stage 1 to stage 7

Flue gas cleaning – PP … includes the installation of PM controls and electrostatic precipitators in power plants

Flue gas cleaning – Ind … includes the installation of PM controls and electrostatic precipitators

Cleaner residential boilers … includes the installation of PM controls for single house boilers as well as the switch to pellet boilers

Ban agr. Waste burn … banning open burning of agricultural and residential waste

Agr PM measures livestock … includes feed modifications and low-till farming and alternative cereal harvesting

SO_2

Primary measures – Steel … switch coal to gas

Primary measures – Other ind (Other industry) … switch coal to gas

Primary measures – Cement … switch coal to gas

Other … Switch to low sulphur gasoline, diesel and fuel oil, doubling of leak control frequency of gas distribution network

Flue gas cleaning – PP … includes the installation of wet flue gases desulphurization

Flue gas cleaning – Ind … includes the installation of wet flue gases desulphurization

Cleaner residential boilers … Switch to low sulphur gasoline, diesel and fuel oil

Ban agr. Waste burn (agricultural waste burning) … banning open burning of agricultural and residential waste

NMVOC

Solvents – controls … includes measures such as vapour balancing on tankers and loading facilities, alternatives for venting and flaring, Schumacher type desolventiser-toaster-dryer-cooler plus an old hexane recovery section, Improved ignition systems on flares

Road transport emission standards… includes the improvement of introduced emission standards for trucks, buses, cars and mopeds from stage 1 to stage 7

Road transport I&M … includes enforced inspection and maintenance of road transport

Primary measures – Other ind (Other industry) …includes measures such as switch from cutback to emulsion bitumens (road paving), Process modification, substitution, adsorption, incineration

Non-road emission standards … includes the improvement of introduced emission standards for non-road machinery like agricultural and construction machinery and ships from stage 1 to stage 7

Gas stations … includes measures such as control of solvent in gas stations such as double stage at gasoline depots

Cleaner residential stoves … switching to cleaner residential stoves

Ban agr. Waste burn … banning open burning of agricultural and residential waste

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