TFIAM/CIAM 7th Policy Brief on potential targets to reduce risks for health and ecosystems

Informal document prepared by the Task Force on Integrated Assessment Modelling and the Centre for Integrated Assessment Modelling, November 2026.

Background

At its forty-fifth session the Executive Body (EB) of the Air Convention took note of the 6th version of the policy brief and reiterated that emission reduction commitments are the core element of the Protocol. Most Parties agreed to consider setting emission reduction commitments that require abatement beyond the current policies and measures in place. Parties that wish to use integrated assessment modelling for setting their emission reduction commitments, prefer using a main scenario with domain wide optimization with a base year of 2015 and target year of 2040, static population and combined health (based on $PM_{2.5}$)/biodiversity optimization and with different ranges of ambition as the basis for their negotiations. The Executive Body further agreed that all other variations of scenario modelling, such as dynamic population or health optimization only, or addition of ozone in health considerations, may continue to be modelled for information purposes, if resources allow. The Executive Body also noted that the cost-benefit analysis should be discussed by the Working Group on Strategies and Review (WGSR) at its sixty-fourth session, if possible, and at the Heads of Delegation (HoD) meeting (Leiden, the Netherlands, 5-7 October 2026), as appropriate. The WGSR encouraged collaboration of CIAM and the Task Force on Reactive Nitrogen with respect to integration of the updated data on ammonia mitigation costs in the GAINS model, and requested that updated scenario results, including on the baseline and optimized scenarios, be presented and discussed at the HOD meeting.

The main changes in this 7th policy brief compared to earlier versions are:

- Updated baseline scenario, including the most recent energy and agricultural projections and national comments, where appropriate;
- Updated cost-estimates and modelling for ammonia abatement;
- Correction for costs for residential solid fuel burning in non-EU countries.

This policy brief focusses on the attainability and associated costs of illustrative combined reduction targets for health risks due to exposure to particulate matter and for the risk of biodiversity loss. Parties are invited to take note of the results.

Compared to earlier policy briefs this version focuses on the key scenarios requested by EB45 in December 2025. Several subjects explored and discussed in earlier versions of the policy brief are not repeated here. They can be consulted in version 6 of the policy brief and the associated Summary for policy makers. Examples are: $PM_{2.5}$ exposure in cities and principal sources of exposure, information about the evolution of $PM_{2.5}$ and BC emissions, the level of acidification and eutrophication corresponding to the BL and MTFR scenarios, how results would change if dynamic demography instead of static 2015 population would be used in health target setting, analyses of gap closure and other "fairness" options to increase the likelihood of ratification, and how a baseline including more structural changes and behavioural measures (LOW) would imply additional health benefits at lower cost.

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Preamble

This is the seventh version of the TFIAM/CIAM Policy Brief in support of the revision of the Gothenburg Protocol. It explains the integrated assessment modelling performed to support policy makers and presents results from the latest scenario analyses, as well as the choices made prior to deriving the results. Earlier versions of the policy brief and related scenario results are available at the TFIAM web page: https://iiasa.ac.at/policy/applications/task-force-on-integrated-assessment-modelling-tfiam-under-lrtap-convention.

The analysis supporting the results uses the GAINS model, which has been peer reviewed on multiple occasions and used to inform air pollution policy discussions in the UNECE and the EU since the 1990s.

The GAINS model is used to identify the cost-effective way to meet collective overarching goals to reduce risks for health and biodiversity. This is done through optimization. GAINS relies on internationally consistent data and projections, also considering officially reported emissions and their projections by parties, source-receptor matrices from the EMEP atmospheric model indicating how a change in emissions in a given location translates into changes in concentrations and deposition of pollution over the UNECE region, harmonized exposure and ecosystem sensitivity data, and harmonized cost estimates of abatement measures, accounting nonetheless for national prices of operation and maintenance cost items. GAINS was used as decision support tool for the Gothenburg Protocol (1999) and the amended protocol (2012). These experiences show that GAINS results can help to define a coordinated abatement strategy that leads to considerably lower total costs than with flat rate national targets for emission or risk reduction.

Model results are not meant to be prescriptive but can be used as a starting point for negotiating emission reduction commitments. A model is never perfect and always a simplification of reality. The modelled least-cost national emissions reduction efforts are merely to indicate how a collective risk reduction goal would translate into a consistent set of national emission reductions at minimal overall domain-wide costs. Country-specific considerations may exist that are not part of the Europe-wide modelling. Therefore, parties are encouraged to double-check the results and do their own analyses. If the data used are acceptable, model results can help to give guidance during the negotiation of emission reduction commitments. Further estimates can be made about the extent to which actual national pledges for emission reduction would be sufficient to realize the collective risk reduction goal.

Emission data by scenario, country, pollutant and GNFR sector, for the baseline, MTFR and optimized scenarios are available at the CIAM website: https://iiasa.ac.at/policy/applications/centre-for-integrated-assessment-modelling-ciam. Additionally, CIAM has developed the GAINS-*Explorer* (https://gains.iiasa.ac.at/gains/GPV/index.login). Beyond viewing emissions, concentrations and resulting impacts for all discussed scenarios, it allows parties to consult and analyze used emission factors and application rates of technologies in the scenarios.

Tables showing emissions by year (the reference year 2015, the target years 2040 and 2050) for the baseline scenario, and the cost-effective solutions optimizing for various ambition levels of combined health and biodiversity risk reductions in 2040 and 2050 are presented in Annex 1 of this document. Further tables show the changes in health and biodiversity risks, as well as additional costs beyond CLE in 2040 and 2050 (as a percentage of GDP). In the main scenarios, targets are always set for the whole UNECE domain excluding North America. How results change if the three non-Parties to the Air Convention were excluded from the target setting is shown in Annex 2.

Parties are invited to analyze the data and compare them to national scenarios in preparation of future negotiations of the Gothenburg Protocol.

1. Scenario framework

1. This policy brief includes emission scenarios up to 2050, as calculated with the GAINS model for the UNECE region, including EU27, EFTA (Iceland, Norway, Switzerland), United Kingdom, Türkiye, EECCA (Armenia, Azerbaijan, Kazakhstan, Kyrgyzstan, Uzbekistan, Turkmenistan, Tajikistan, Georgia, Ukraine, Belarus, Russia, Republic of Moldova), West-Balkan (Albania, Bosnia and Herzegovina, Kosovo, Republic of North Macedonia, Montenegro, Serbia), and North America (Canada, United States).
2. Emissions projections are based on assumptions of future developments in population and related economic activities such as energy use, transport and food, as well as future emission mitigation measures.
3. Population trends are based on the 2024 revision of the UN World Population Prospects[1]. Health impact assessment uses latest exposure-response functions from the WHO projects Health Risks of Air Pollution in Europe 2 (HRAPIE 2) and Estimating the Morbidity from Air Pollution and its Economic Costs (EMAPEC[2]) (WHO, 2025[3]). Biodiversity impacts are assessed based on data from the Co-ordination Centre for Effects (CCE). Impact scenarios and analyses including cost-effective optimization of abatement measures cover the whole European UNECE region, but exclude North America (NA), unless indicated otherwise.
4. Improvements in the GAINS and EMEP models since the review of the Gothenburg Protocol include local scale modelling, soil NOx and NMVOC emissions from agriculture and a consistent representation of the condensable fraction of particulate matter emissions from residential heating. GAINS has been prepared to assess the sensitivity of results for various policy goals and fairness criteria. Since v6 of the policy brief, mitigation potential and cost estimates for ammonia abatement have been updated in cooperation with TFRN and costs for residential solid fuel burning in non-EU countries have been corrected.
5. The policy scenarios address attainable policy targets for reducing health and biodiversity risks exploring mitigation potential for sulfur dioxide (SO_2), nitrogen oxides (NO_x), ammonia (NH_3), and fine particulate matter ($PM_{2.5}$) emissions, as well as ozone precursors, including non-methane volatile organic compounds (NMVOC) and methane (CH_4).

2. Choices applied for modelling policy targets

6. Prior to modelling effects of any given policy target, decisions are needed on several modelling options. This covers general questions of which targets to account for and how to model them, and also more specific questions of parametrization and levels of ambition.
7. EB Decision 2023/5 (ECE/EB.AIR/154) decided that the revision process of the Gothenburg Protocol would consider "Overarching, collective risk-based target(s) to reduce harmful effects to health and to ecosystems including biodiversity loss in the ECE region".

[1] https://population.un.org/wpp/

[2] https://www.who.int/activities/estimating-the-morbidity-from-air-pollution-and-its-economic-costs

[3] https://www.who.int/publications/i/item/9789289062633

2.1. ***Health risks***

8. Health impact assessment in the framework of the Gothenburg Protocol has traditionally relied on epidemiological evidence supported by recommendation of use of specific exposure-response functions by WHO. In 2025, WHO published its HRAPIE 2 (Health risks of air pollution in Europe) report. The HRAPIE 2 project has carried out systematic reviews on evidence of premature mortality associated with the pollutants $PM_{2.5}$, NO_2 and O_3. It also contains recommendations for response functions for morbidity effects of these pollutants developed in a parallel project (EMAPEC, Estimating morbidity from air pollution and its economic costs).
9. Premature mortality can be assessed according to two alternative approaches. The first approach quantifies premature mortality in terms of premature deaths attributable to air pollution and values them by the Value of a statistical life (VSL). Under this approach, each death is quantified equally, independent of the age at which death occurs. The second approach assesses premature mortality in terms of changes in life expectancy, quantifying a reduction of life expectancy in terms of years of life lost (YLL) and values them by the statistical value of a life year (VOLY). Although this second approach is often preferred in the domain of air pollution, both indicators have been traditionally used in the Air Convention.
10. For the ongoing revision of the Gothenburg Protocol, it was decided to use the indicator of premature deaths per 100,000 people for target setting with respect to the reduction of health risks. The level of the other health indicators, the alternative mortality indicator YLL and the complementary morbidity health endpoints, are calculated for all scenarios “ex post” to the optimization, of which they are not part.

2.2. ***Risks to biodiversity***

11. To quantify effects on biodiversity, ecosystem specific Empirical Critical Loads for nitrogen (CLempN) are used[4]. Exceedance (AAE) above these critical loads is used as an indicator for biodiversity risks in the optimization. The ecosystems are classified following the EUNIS classification system. Specific ecosystem types have a varying sensitivity. There are very sensitive ecosystems with low Critical Load values and less sensitive ecosystems with higher Critical Load values. These limit values are given in ranges to account for variability within each ecosystem type caused by different abiotic conditions, climate, nature management etc.
12. For the evaluation of the policy scenarios, the ranges of the empirical Critical Loads were attributed to the receptor map[5] of the Coordination Centre for Effects.
13. The Working Group on Effects sees the average amount of exceedance of critical loads in an area as a better indicator for the risk of biodiversity loss than the percentage of the area with a (sometimes very low) exceedance. Therefore, for the risk of biodiversity loss, the average accumulated exceedance (AAE) of the critical load in a nature area is used as indicator. The higher the exceedance, the higher the risk of species loss in an ecosystem.

[4] https://www.umweltbundesamt.de/publikationen/empirical-critical-loads-of-nitrogen-for-europe

[5] https://www.umweltbundesamt.de/publikationen/creation-of-a-harmonized-land-cover-map-as-an

14. For target setting, 50 EUNIS classes are distinguished for which CLempN are available and for which exceedances are assessed.

2.3. Modelling choices requested by WGSR and EB for this policy brief

15. 2015 is used as the base year in modelling, and the years 2040 and 2050 to achieve risk reduction targets. It should be noted that independent of this timeframe, resulting emission reductions could always be recalculated for a different base year, e.g. 2005 or 2025.

16. **Targets are modelled as least cost solution for the whole modelling domain.** The collective targets do not have to be met by all parties individually but should be met for all parties together. Policy brief v6 showed that it is cheaper to achieve the goal for the whole domain collectively without additional constraints (least cost solution) than requiring equal progress in all countries (gap closure approach). The domain-wide targets on health or biodiversity would not be feasible to achieve within each country individually (e.g. in countries with sensitive ecosystems).

17. In addition to the initial risk reduction target, halving the pollution related risks suggested as a target in the 2023 Saltsjöbaden workshop, this policy brief presents results for an analysis **exploring different combinations of feasible levels of risk reduction for health and biodiversity**.

18. **The scenarios presented here limit health risk reduction to $PM_{2.5}$ only.** Inclusion of ozone would make attainability harder, and it was discussed in policy brief v6. New information on ozone is planned for the 2027 update of the policy brief.

19. For health risk reduction, the risk of excess mortality attributable to $PM_{2.5}$ is used as indicator. The mortality attributable to anthropogenic $PM_{2.5}$ exposure per 100.000 inhabitants is used as risk-based indicator for target setting.

20. **Target setting in this policy brief uses static population of the year 2015**, thus excluding any demographic change from the target setting analysis. Why the use of static population makes the attainability of any given risk reduction target less ambitious than it would be using dynamic demography is explained in version 6 of the policy brief.

21. **To quantify effects on biodiversity**, ecosystem specific Empirical Critical Loads for nitrogen are used, with ecosystems being classified by the level 3 of the EUNIS classification system. For the present analysis, this results in 50 ecosystems classes. For these, **the average accumulated exceedance (AAE) of the critical load in a nature area is used as indicator**. The higher the exceedance, the higher the risk of species loss in an ecosystem.

22. For the evaluation of the policy scenarios, **the minimum level of the ranges of the empirical Critical Loads is used**. These are hereafter referred to as 'CLempN min'. Why their use guarantees highest precaution and protection of the biodiversity of European ecosystems was explained in v6 of the policy brief.

23. While the modelling choices outlined in the previous paragraphs apply to target setting, **cost-benefit analysis (CBA) uses additional indicators**. Where target setting focuses on reducing health risk of mortality from $PM_{2.5}$, CBA includes all morbidity health risk indicators for which robust exposure-response functions are available. For mortality it focuses on life years lost (see chapter 5). And while target setting here uses static 2015 population, in the quantification of health benefits for CBA, projected population in 2040 needs to be used for consistency with the assumption of demographic change behind the assessment of emissions and economic activity by 2040 in the GAINS model.

3. Scenarios setting the scope for reductions

24. Two scenarios defining the scope for additional emission and risk reductions were updated for this policy brief by the Centre for Integrated Assessment Modelling (CIAM). The scenarios have been updated to latest activity projections, and the current scenario set (v7a) takes into account feedback by national experts.

    a. The Baseline scenario (CLE), considers trends and policies included in established national air pollution control programs and, for the EU27 it includes the revision of the IED, the current and planned policies in support of reaching the 2040 and 2050 climate targets, and results of the EU Member States (MS) consultation during the work supporting the European Commission fifth Clean Air Outlook. For West Balkan the Baseline was developed with the same modelling tools as used for EU27, including decarbonization targets and compliance with the Energy Community agreements, as well as results of the consultations with all countries within the EU4Green project[6]. For selected EECCA countries (Moldova, Ukraine, Georgia) the scenario uses the same modelling tools as for EU, and for Moldova additional information from consultations between CIAM and national experts in a project supported by the UNECE. For the UK, Switzerland, and Norway, updates are based on engagements in bilateral consultation meetings with CIAM. For the remaining countries, the scenario uses national submissions and reports, international statistics and projections based on recent IEA & FAO Outlooks[7]. The baseline includes air pollutants (SO_2, NO_X, $PM_{2.5}$, NH_3, NMVOC, as well as Black Carbon) and methane emissions up to 2050. The baseline assumes effective implementation of current legislation (CLE) and policy plans. This is not self-evident, as in past years several plans have been revised because of geopolitical developments, energy security issues and farmers' protests.

    b. The Maximum Technically Feasible Reductions (MTFR) scenario uses the same activity data as the baseline and includes implementation of technologies with lowest emission factors in the GAINS model database. These control options include measures to reduce ammonia emissions from agriculture, measures to reduce $PM_{2.5}$ and NMVOC emissions from residential solid fuel burning and agricultural waste burning, mitigation technologies to reduce emissions of SO_2, NO_x, and $PM_{2.5}$ from industrial combustion, process and transportation sources, measures to reduce NMVOC from solvent use and liquid fuels' storage and distribution. The MTFR scenario uses information about the age structure of installations to assess technical feasibility of emission control. Early shutdown or 'before end of life' scrapping of cars or boilers is not assumed. Consequently, the mitigation potential increases towards 2050.

25. While international shipping is included in the scenarios, there are no additional measures for this sector beyond the baseline. The reason is that countries are only responsible for emissions within their national boundaries. However, additional emission reductions from international shipping could further reduce risks to health and biodiversity in some parts of the EMEP-domain.

26. The LOW scenario (discussed in previous policy briefs) was not updated for this policy brief edition. The update will be developed in 2027.

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[6] https://eu4green.eu/wp-content/uploads/2026/06/EU4GreenPresentation_ERC_2025.pdf; https://eu4green.eu/wp-content/uploads/2025/12/EU4Green_TechnicalReport2025_Finalv2-Barrier-Free.pdf

[7] World Energy Outlook 2025 (IEA, 2025, https://iea.blob.core.windows.net/assets/dfe5daf4-dbc1-4533-abeb-fafb1faee0f9/WorldEnergyOutlook2025.pdf), The future of food and agriculture – Alternative pathways to 2050 (FAO, 2018, https://openknowledge.fao.org/server/api/core/bitstreams/3ea2aa72-7e4f-482a-9af0-2251e6d62984/content)

27. Three sensitivity scenarios assessing how different assumptions in activity projections for the residential, agricultural and transport sector would influence the feasibility of attaining reductions targets are provided in Annex 3 to this policy brief. These scenarios are assessed because of differences identified in various country projections compared to the Europe-wide activity projections relying on regional energy and agriculture development models. The sensitivity scenario for the agricultural sector freezes livestock numbers and mineral fertilizer use at the level in 2025, the one for the residential sector freezes the amount of wood burnt in residential heating in 2025. The third sensitivity scenario freezes the number of electric vehicles at the level of 2025 and assumes that in future years sales of electric vehicles (beyond the numbers for 2025) are replaced by gasoline vehicles.

28. A further sensitivity scenario, also presented in annex 3, assesses the impact of excluding those countries from the target setting for health in which the population-weighted mean $PM_{2.5}$ concentrations are below the WHO guideline value of 5µg/m^3 in 2040 in the baseline scenario.

3.1. ***Emission reductions***

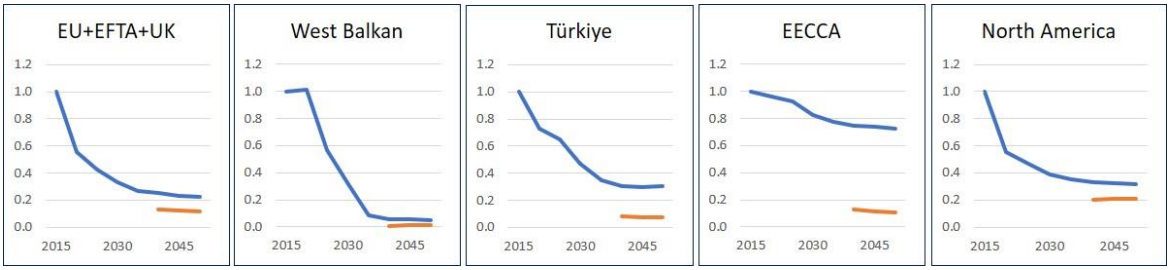
29. Figure 1 indicates the scope for emission reductions according to the different scenarios. The baseline scenario shows strong reductions of air pollutants between 2015 and 2040 (SO_2: -65% *to* -95%, NO_x: -50 *to* -70%, $PM_{2.5}$: -40 *to* -65%) in the EU, North America, and in West Balkan countries (owing to the Energy Community agreements that include commitments to strong reduction of emissions from stationary sources in the coming decades) as well as gradual decarbonization of the economies. Fossil fuel use and industrial production in EECCA countries continue to grow, however, due to ongoing technical progress, emissions of SO_2 are expected to be reduced over time, by approximately 25% between 2015 and 2040, although the development varies strongly for individual countries and for some, emissions are estimated to continue increasing. In the same period, an increase of about 7% is estimated for NOx since existing legislation is not able keep transport sector emissions in check. Also in Türkiye, only limited decline is estimated for NO_x (less than 10%). For NH_3, current abatement policies are modest and emissions continue to increase, while the estimated reductions in some countries are mainly due to projected decline in livestock numbers. Moderate reductions are expected for NMVOC in all regions ranging from 5% in EECCA and Türkiye to over 30% in the EU, EFTA, and UK. The trends highlighted for 2040 continue towards 2050.

30. The MTFR scenario shows that for SO_2 most of further mitigation potential is committed in the current legislation, except for EECCA and Türkiye (Figure 1). The picture for NOx is similar, although further potential is available. For NH_3, the mitigation potential beyond baseline is similar across all regions, however, for regions with modest regulation in transport and industry, the overall potential is smaller (compared to the baseline) than that for other air pollutants. Large further mitigation exists for $PM_{2.5}$, except for the EU+EFTA+UK region, especially in EECCA, Türkiye, and West Balkan. Further potential for mitigation of NMVOC emissions has been identified for all regions, and the relative magnitude is similar to that for NH_3.

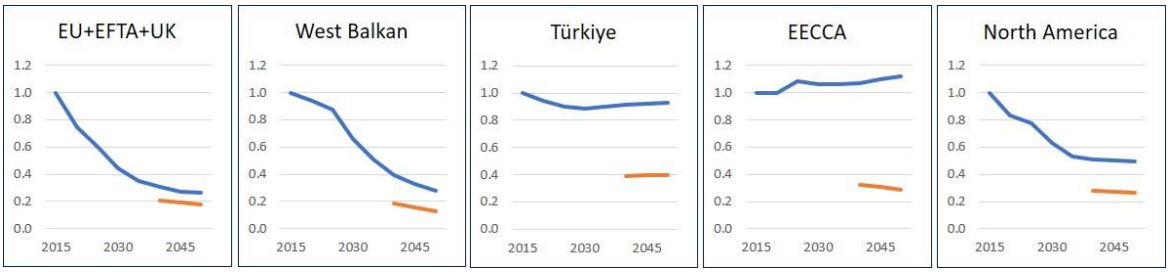
31. PM emissions consist of different substances, including inter alia heavy metals, organic carbon and elemental carbon (or black carbon). See the policy brief version 6 for further information of the impact of PM-abatement on black carbon emissions.

Figure 1: Emission trends, relative to 2015, in Baseline (CLE) and MTFR scenario; scenario set v7a

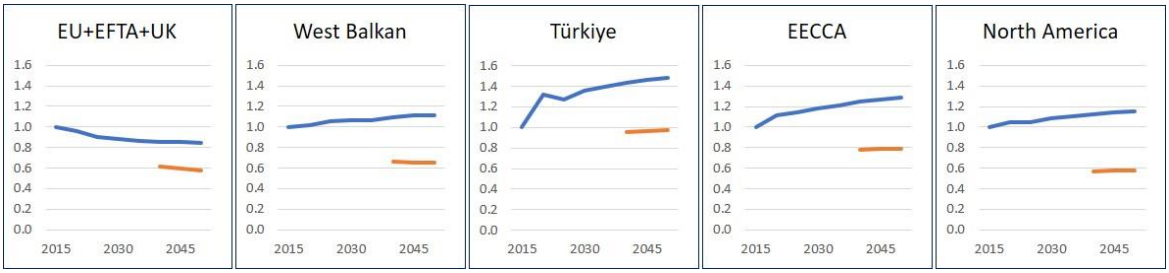
Sulfur dioxide (SO_2)



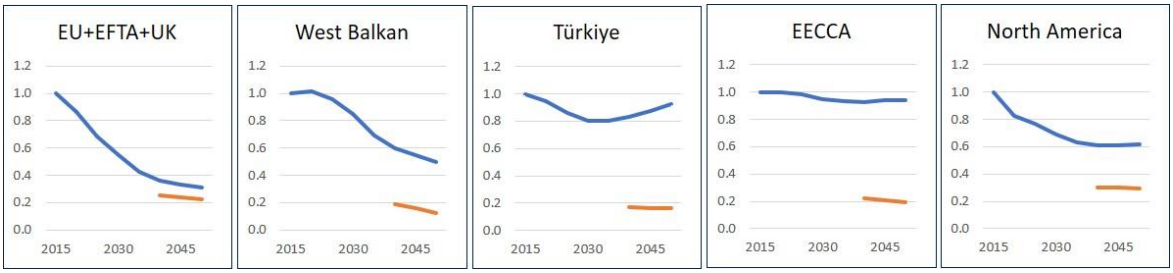
Nitrogen oxides (NO_x)



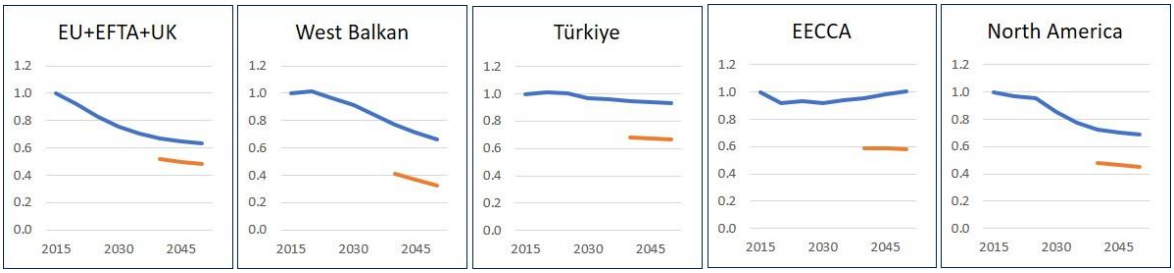
Ammonia (NH_3)



Particulate matter ($PM_{2.5}$)



Non-Methane Volatile Organic Compounds (NMVOC)



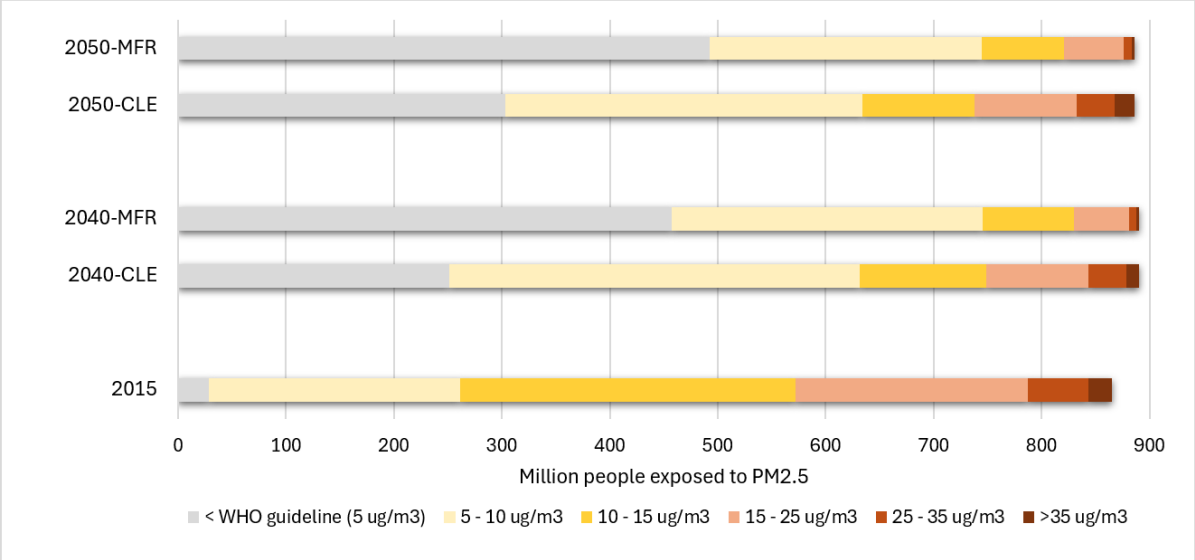


Source: GAINS model (CIAM, dataset v7a*)*

3.2. Reductions in anthropogenic $PM_{2.5}$ exposure

32. Anthropogenic $PM_{2.5}$ concentrations result from the emissions of primary $PM_{2.5}$ as well as secondary $PM_{2.5}$ that is formed in the atmosphere from emissions of SO_2, NOx, NH_3 and NMVOC. Calculations with the GAINS model show that policies in the baseline scenario result in 2040 in concentrations below 25 µg/m^3 for more than 90% of the population in the UNECE domain (excluding North America). Elevated concentrations persist in West Balkan, EECCA countries, and Türkiye. However, more than 75% of the population in the UNECE domain (excl. North America) lives in 2040 in areas where annual average anthropogenic $PM_{2.5}$-concentrations are above the current WHO guideline value of 5 µg/m^3 (see Figure 2). The MTFR scenario for 2040 and 2050 brings strong improvement reducing exposure and health impacts: The number of people exposed to $PM_{2.5}$ levels below the WHO guideline level almost doubles compared to the Baseline (CLE), reaching over 50% of the population in the UNECE region (excl. NA).

Figure 2: Population exposure to $PM_{2.5}$ in the UNECE (excluding North America)

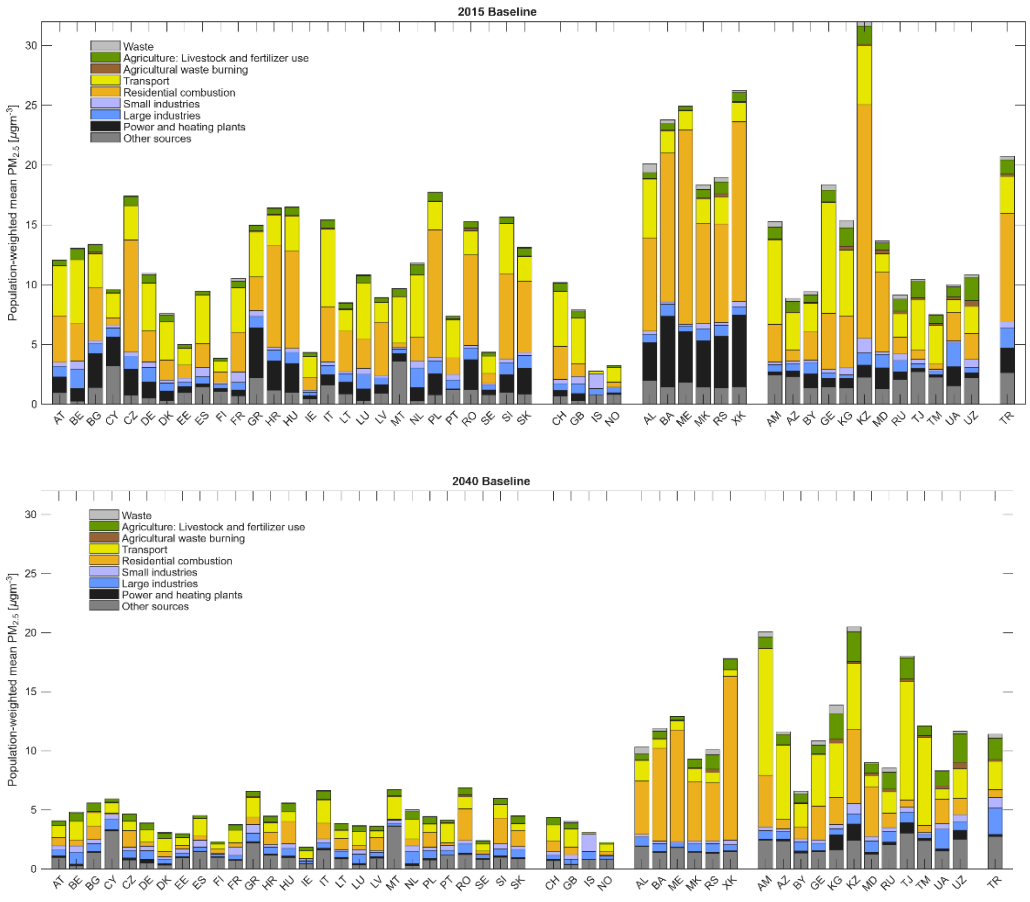


Source: GAINS model (CIAM, ***dataset v7a***)

33. The baseline for 2050 shows further improvements, yet the WHO guideline level would only be attained for about 30% of the population. MTFR brings large scale improvements, also across the Balkan region, as there is enough time to introduce further technical measures.

34. The contribution of sectors to $PM_{2.5}$ exposure differs strongly among countries. See Figure 3 for the average contribution of sectors in 2015 and 2040 in the baseline scenario.

Figure 3: Sector contributions to population weighted country mean anthropogenic $PM_{2.5}$ concentrations in 2015 (top) and according to the baseline in 2040 (bottom), updated to include the sub-grid increment for the full domain



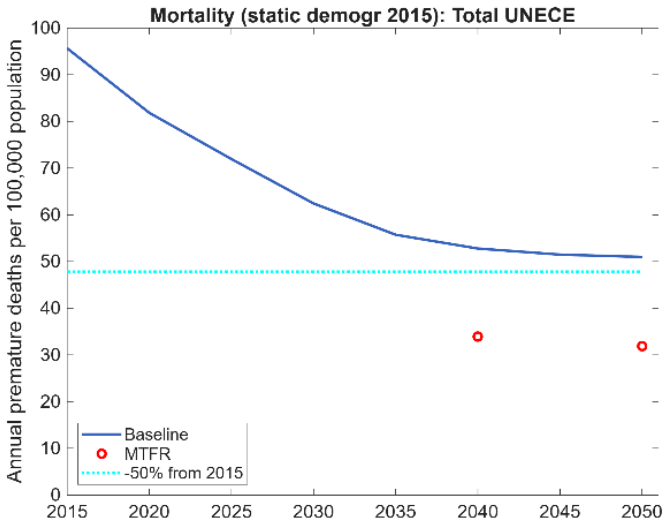
Source: GAINS model (CIAM), v7a dataset

35. Moving from 2015 (top chart in Figure 3) to the baseline in 2040 (bottom chart) shows that strong reductions in contributions to $PM_{2.5}$ exposure are expected in West Balkan from the power sector, and to some extent from the transport sector. In some EECCA countries, reductions are expected from the residential sector. The relative importance of the agricultural sector increases between 2015 and 2040 in this region. In many countries significant health benefits beyond the baseline cannot be reached without addressing residential combustion and transport.

3.3. $PM_{2.5}$ health risk reduction

36. Figure 4 shows the scope for reducing health risks (premature deaths per 100.000 inhabitants) related to anthropogenic $PM_{2.5}$ in the whole UNECE (incl. North America) as estimated with the GAINS model. This scope for additional measures is given by the space between the baseline scenario and the MTFR scenario. Existing policies as accounted for in the baseline scenario contribute to approximately 45% reduction in mortality in 2040 (from the 2015 level), with static population. See the policy brief version 6 for a comparison of mortality risks for static and dynamic population.

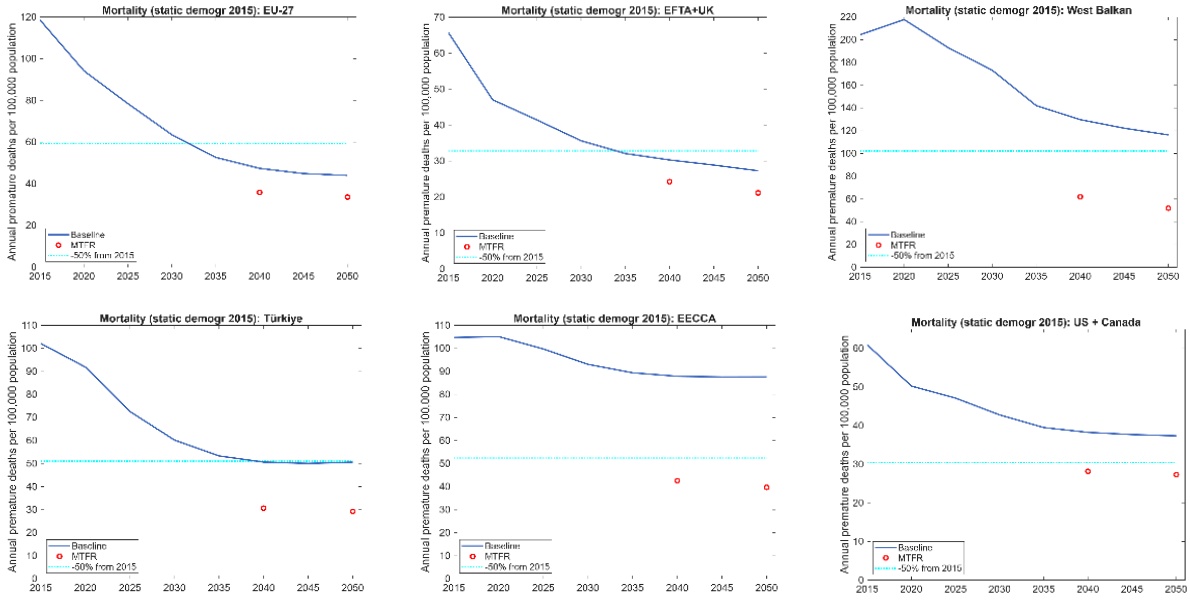
Figure 4: Mortality risk due to anthropogenic $PM_{2.5}$ (annual premature deaths per 100.000 population) in the UNECE-region (incl. North America), using static population. Note: Population data are from UN World Population Prospects 2024 and risk functions from Orellano et al (2024). The illustrative 50% risk reduction target compared to 2015 is shown as the dotted cyan line



*Source: GAINS model, (CIAM, **dataset v7a**)*

37. The scope for reductions varies amongst the sub-regions. In some (EU27, EFTA+UK) the 50% risk reduction target is already met in the baseline before 2040. In Türkiye it would just be achieved in 2040 according to baseline assumptions. In West Balkan, EECCA and in North America, more effort would be required (see Figure 5).

Figure 5: Change in $PM_{2.5}$ mortality risks (for the 2015 static population)



Source: GAINS model, (CIAM, dataset v7a)

3.4. Reduction of biodiversity risks

38. Figure 6 shows the scope for reducing the risk of biodiversity loss, expressed as a percentage reduction of the average accumulated exceedance (AAE).

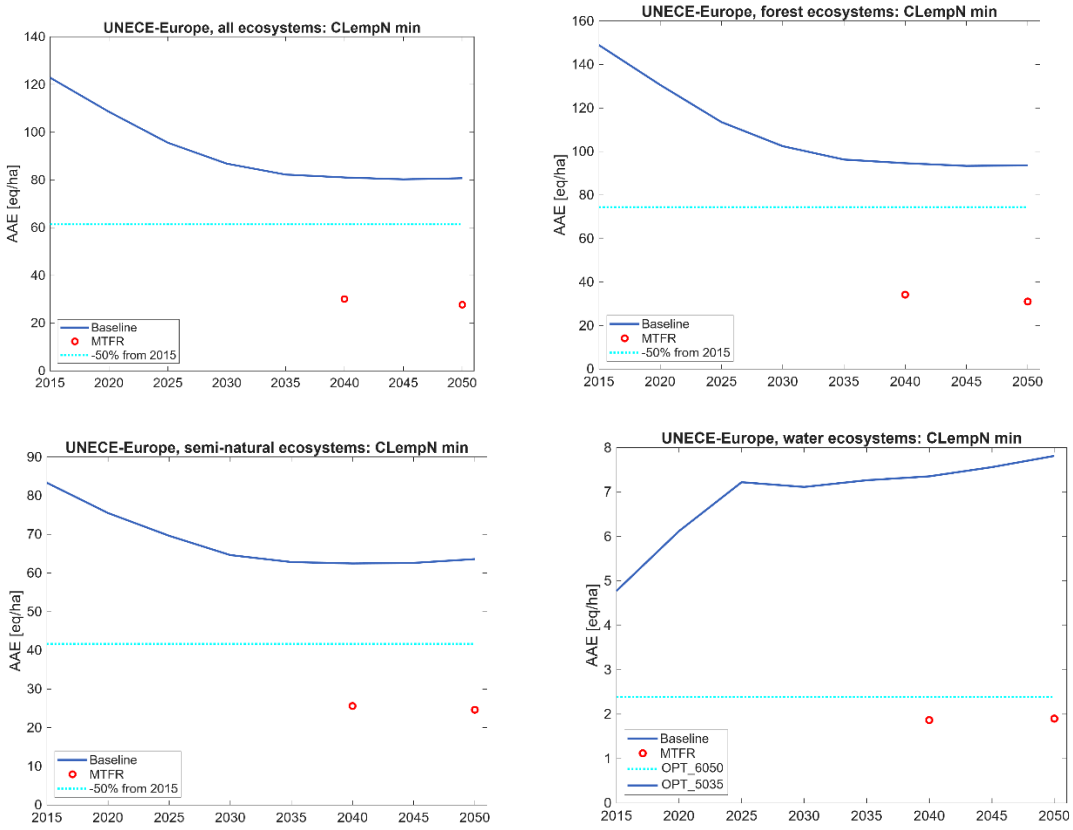
39. The figure shows the development of AAE between 2005 and 2050 for all ecosystems in the UNECE (excl. North America), for forest ecosystems, semi-natural ecosystems and for water ecosystems, using the minimum levels of nitrogen critical loads. The dotted line (cyan) shows the illustrative 50% reduction target compared to 2015.

40. The scope for reduction of biodiversity risks differs among aggregated ecosystem types.

41. For all ecosystems and forest ecosystems, the baseline shows decreasing biodiversity risks, although levelling out after 2040, and for semi-natural ecosystems there is a slight increase towards 2050. For water ecosystems AAE increases over time in the baseline

42. Additional efforts would be needed to reach a 50% risk reduction relative to 2015 for the total of all ecosystems combined, but also for forests, semi-natural ecosystems (such as heathlands, mountain meadows and dunes) and water ecosystems individually. Additional ammonia and nitrogen oxides emissions reduction would play a key role here. MTFR measures could offer sufficient scope for meeting the 50% target in these aggregated ecosystems classes as shown in Figure 6.

Figure 6: Attainability of 50% reduction of the average accumulated exceedance of the minimum nitrogen critical loads (CLempN min) for specific ecosystems in the UNECE (excl. NA, but including non-Parties to the Air Convention[8])



Source: GAINS model (CIAM, dataset v7a)

43. The results presented in Figure 6 include three members of the UNECE that are not parties to the Air Convention (Tajikistan, Turkmenistan and Uzbekistan). Some ecosystems identified in these countries limit the feasible risk reduction potential. Policy makers should decide whether the non-Parties to the Air Convention should be excluded from the modelling in support of the target setting.

44. There is higher uncertainty in the eastern part of the UNECE, both with respect to classification and spatialization of ecosystems.

[8] Tajikistan, Turkmenistan and Uzbekistan.

4. Target setting - combined $PM_{2.5}$ health and biodiversity risk reduction

4.1. Overview of costs for the v7a optimized scenarios

45. Different combinations of ambition levels for risk reductions respectively for health and biodiversity were modelled for the combined health and biodiversity optimisation. Figure 7 shows the resulting additional abatement costs (beyond the baseline scenario) for combinations of four ambition levels for health risk reduction relative to 2015 (-50%, -55%, -60%, -65%) and four ambition levels for biodiversity risk reduction (-35%, -40%, -45%, -50%). For biodiversity, the target is set for each EUNIS ecosystem type individually, excluding four types of grasslands[9] for which a 50% reduction of AAE is not within the feasible range in 2040.

46. The updated scenarios indicate lower costs than the previous scenarios (scenario group v6b, see policy brief v6) for comparable ambition levels. Figure 7 shows a strong growth of costs for the highest ambition levels for both health and biodiversity risk reduction, nearing in fact MTFR technology levels in many regions. It also shows a very strong reduction of costs in 2050 (relative to 2040) for the highest ambition level for health (65%), and costs for mid-ambition (-55%) to be only marginally higher than for the -50% case (both for 2040 and 2050). This applies across all biodiversity targets. While 65% health risk reduction is technically feasible, there is a sharp increase in costs beyond the 60% health risk reduction target.

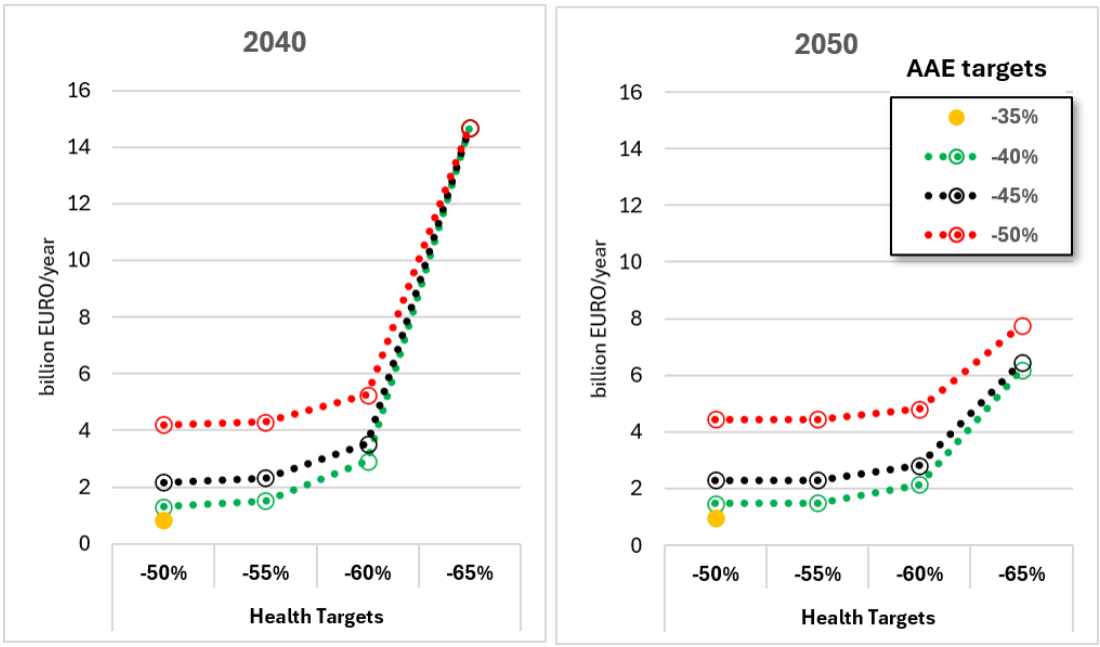
47. Reduction of the risk of biodiversity loss by 50% would require for many ecosystems MTFR measures and high abatement costs relative to the three alternative risk reduction levels (-45%, -40%, -35%). Lowering this ambition level to 45% would halve the combined health and biodiversity mitigation costs. A mid ambition scenario combining 55% health risk reduction with 45% risk reduction for biodiversity, entails only half the costs of a scenario aimed at 50% risk reduction for both. An ambition combination of 50% health risk reduction and 35% risk reduction for loss of biodiversity would entail limited additional costs to reduce emissions of reactive nitrogen to reach the biodiversity target as the current legislation scenario is expected to meet the health objective.

48. For all 10 combinations of health risk and biodiversity risk reductions, the least-cost solution for emission reductions is presented in the GAINS-Explorer and on the TFIAM and CIAM web-pages at the country level. This includes remaining emissions, abatement costs and reduced health and biodiversity risks. Additionally, results for the MTFR are presented, while the policy cases with health ambition level of 65% are not included in the detailed results. In the remainder, this report is focused on 3 core scenarios:

    a. 50% health/50% biodiversity risk reduction (reference case),
    b. 55% health/45% biodiversity risk reduction (mid ambition),
    c. 60% health/45% biodiversity risk reduction (high ambition).

[9] R1E (Mediterranean tall perennial dry grassland), R1M (Lowland to montane, dry to mesic grassland usually dominated by Nardus stricta), R1P (Oceanic to subcontinental inland sand grassland on dry acid and neutral soils), R42 (Boreal and arctic acidophilous alpine grassland).

Figure 7: Costs for the range of optimised scenarios in 2040 and 2050 with health ambitions (50-65% risk reduction) on the X-axis. Coloured lines refer to different ambition levels for biodiversity (35-50% risk reduction of AAE)



Source: GAINS model (CIAM, dataset v7a)

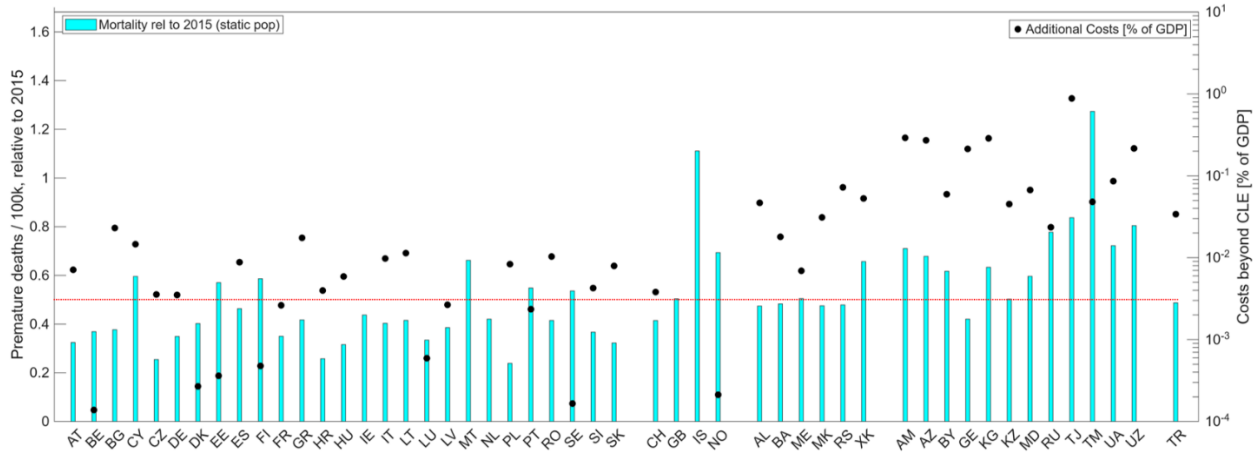
4.2. Results for combined health and biodiversity risk reduction for core ambition levels

49. The core ambition scenarios exclude scenarios that would lead to a sharp increase in abatement costs at the UNECE level. They also prevent additional costs from being more than 0.3% of GDP at the country level for Convention parties, with the majority well below 0.1% of GDP.

50. This section presents the implications for emission reductions in the UNECE (excl. NA) of achieving jointly and at least-cost (i) a reference case with 50% reduction in mortality risks from $PM_{2.5}$ and a 50% reduction in the risk of biodiversity loss; (ii) jointly reaching a 55% reduction in the risks for health and 45% reduction in the risk of biodiversity loss; and (iii) jointly reaching a 60% reduction of health risks and 45% reduction in the risk of biodiversity loss. Least cost results for these ambition levels are presented by country in Figure 8, Figure 9 and Figure 10 for 2040, and in Figure 11, Figure 12 and Figure 13 for 2050. The bars indicate the reduction in mortality relative to 2015 and refer to the left Y-axis. Where bars are below 1, premature mortality decreases in 2040 (or 2050, respectively) relative to 2015, where it exceeds 1, premature mortality increases. The black dots indicate the additional abatement costs (beyond the baseline) as percentage of GDP and refer to the right Y-axis.

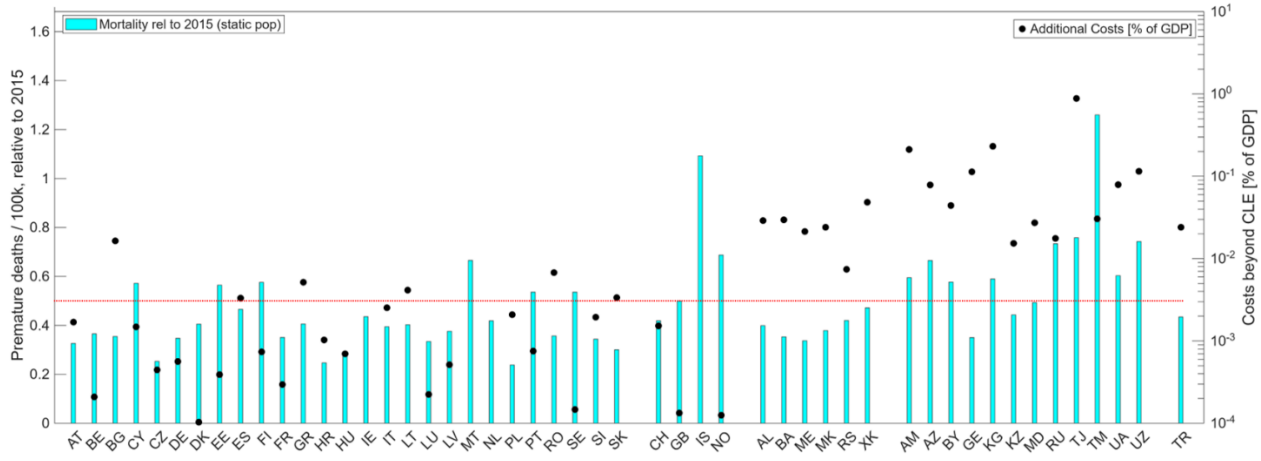
51. The least-cost optimizations show much larger differences at the country level (Figure 8 to Figure 13) than the change of total costs would imply (Figure 7). Increasing ambition for reducing health risks beyond 55% would require more efforts to reduce PM emissions from domestic heating, while lower ambitions for biodiversity would mainly require less efforts to reduce ammonia and nitrogen oxides emissions (see also Figure 15).

Figure 8: Country outcomes of least cost scenarios for 2040 for a combined 50% risk reduction for health and biodiversity. Blue bars, left axis: premature mortality relative to 2015; black dots, right axis (logarithmic): Costs beyond Baseline, expressed as % of GDP.



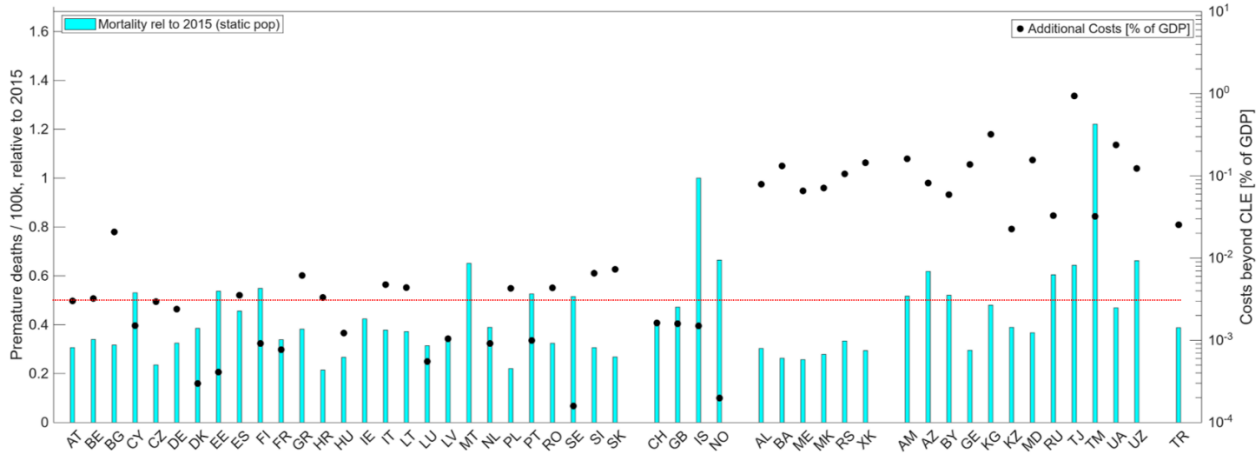
Source: GAINS model (CIAM, dataset v7a)

Figure 9: Country outcomes of least cost scenarios for 2040 for a combined 55% risk reduction for health and 45% for biodiversity



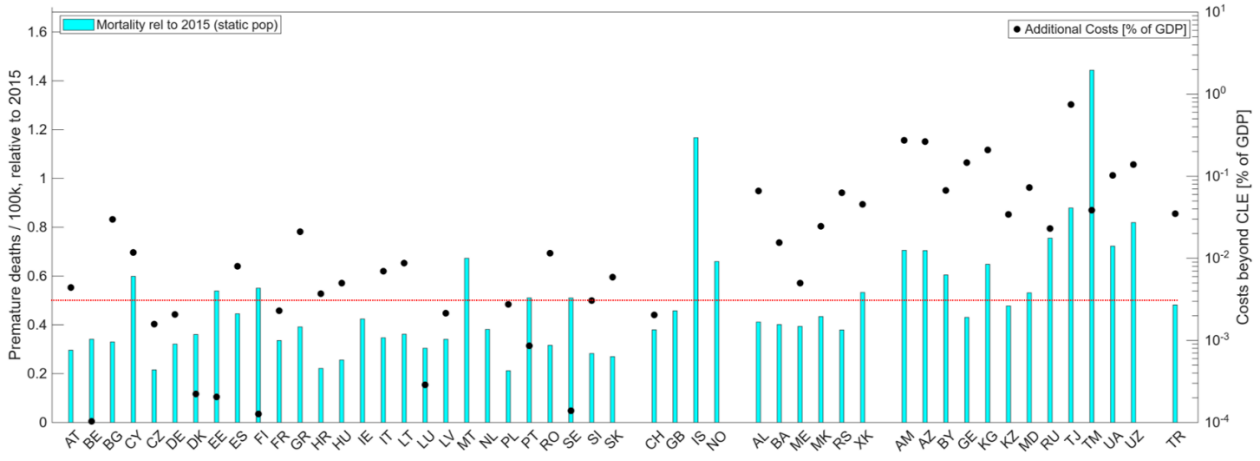
Source: GAINS model (CIAM, dataset v7a)

Figure 10: Country outcomes of least cost scenarios for 2040 for a combined 60% risk reduction for health and 45% for biodiversity



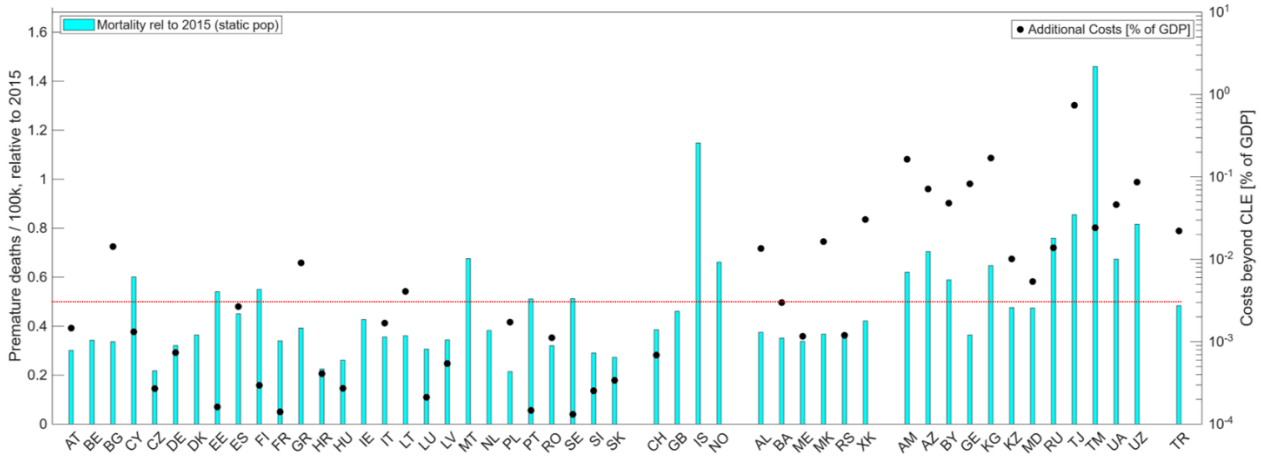
Source: GAINS model (CIAM, dataset v7a)

Figure 11: Country outcomes of least cost scenarios for 2050 for a combined 50% risk reduction for health and biodiversity



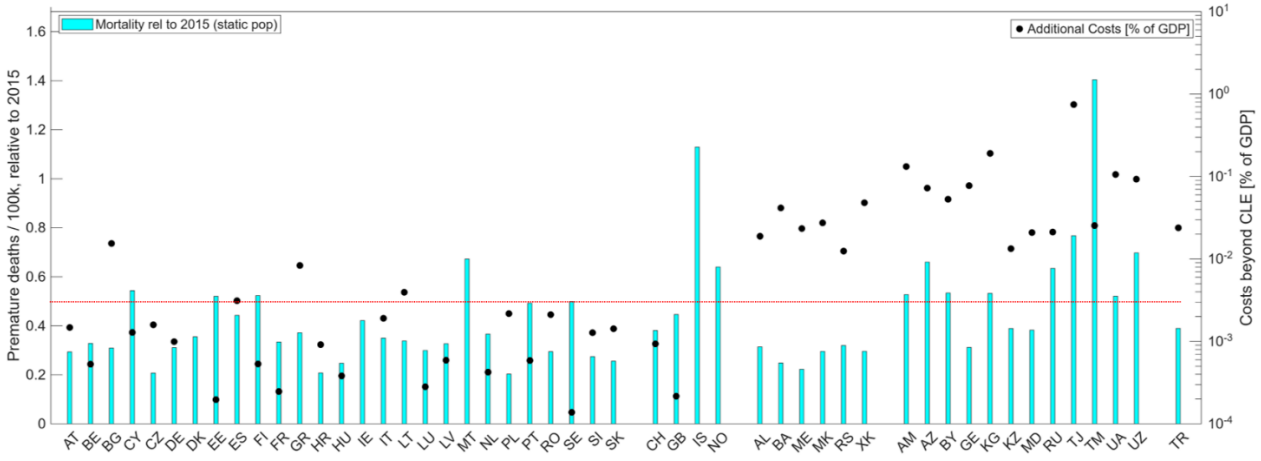
Source: GAINS model (CIAM, dataset v7a)

Figure 12: Country outcomes of least cost scenarios for 2050 for a combined 55% risk reduction for health and 45% for biodiversity



Source: GAINS model (CIAM, dataset v7a)

Figure 13: Country outcomes of least cost scenarios for 2050 for a combined 60% risk reduction for health and 45% for biodiversity

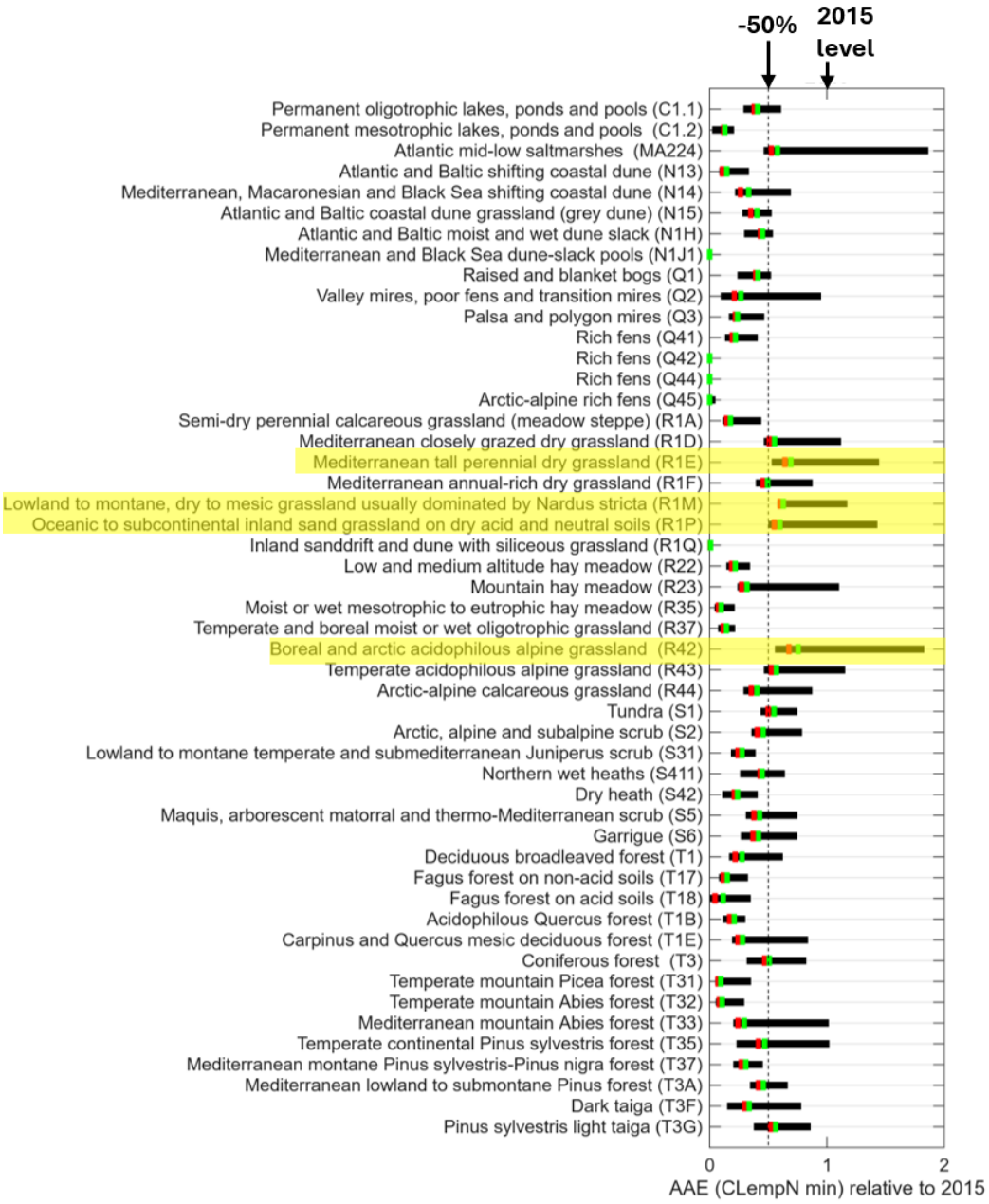


Source: GAINS model (CIAM, dataset v7a)

52. Figure 14 shows the results for biodiversity. The black bars show the relative change of biodiversity risk (expressed as changes in AAE) for individual EUNIS habitat types (2040) in a range between CLE and MTFR. The black dotted line indicates the level where biodiversity risks are reduced by 50% relative to 2015. The green and red points in the black bars indicate results for joint health and biodiversity risk reduction goals. The green points show the results of the scenario aiming at a risk reduction in 2040 of -55% for health and -45% for biodiversity, the red points indicate the same results for an ambition level of 50% for both health and biodiversity risks. A reduction of risk by 50%, compared to 2015, is not feasible for four ecosystems. These are marked in yellow in Figure 14 and they are excluded from the target setting (cost optimization). These ecosystems are mainly natural grasslands, where flora (and

subsequently butterflies and birds) are disappearing. However, also in these ecosystems the risks are reduced beyond the level in the baseline.

Figure 14: Relative change of biodiversity risk (expressed through AAE) for individual EUNIS habitat types (2040), range between CLE and MTFR (black bars). Results for joint health and biodiversity risk reduction goals: -55%/-45% green, -50%/-50% red. Reduction of risk by 50%, compared to 2015, is not feasible for four ecosystems (marked yellow)



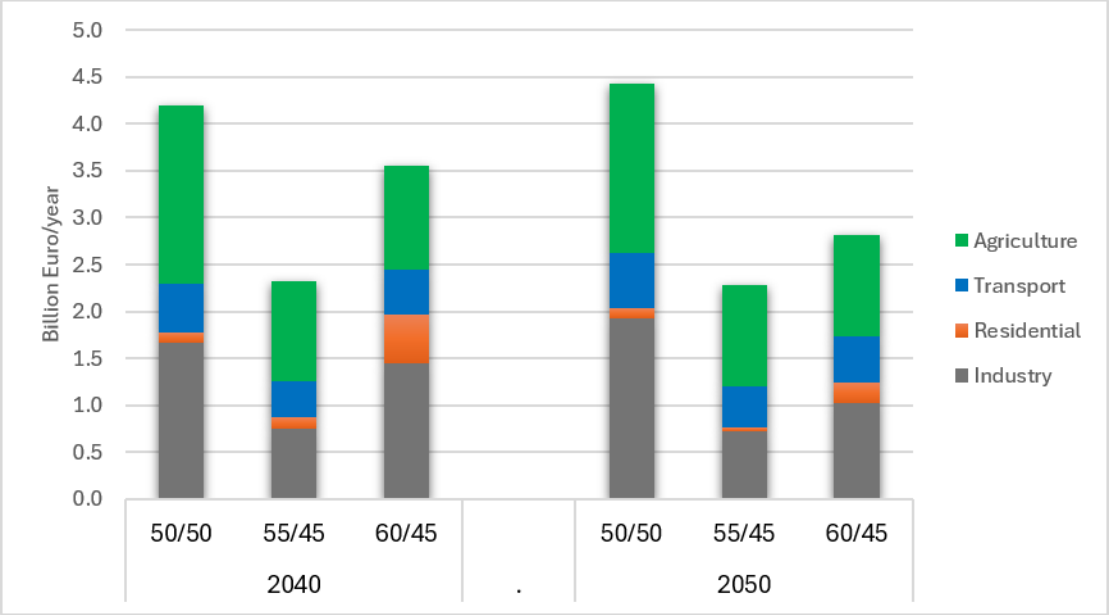
Source: GAINS model (CIAM, dataset v7a)

53. Figure 15 shows how the distribution of costs across key sectors changes between the scenario reducing risks both for health and biodiversity by 50% and for the scenarios that reduce the risk for health by 50% through 60% and for biodiversity by 45%. When moving from the 50%/50% scenario to the 55%/45% scenario, additional costs (beyond baseline) in 2040 and 2050 decrease by nearly 50%, primarily due to lesser efforts needed to reduce reactive nitrogen emissions and therefore lower costs in agriculture, industry and even transport. Since the health objectives are already overachieved in the 50%/50% case, only a moderate additional effort and increase in costs for the residential sector is needed in 2040, while for 2050 even residential sector costs are estimated to decline compared to the 50%/50% case. Increasing health ambition to 60% leads to an overall increase in costs for all sectors compared to the 50%/45% scenario, but they remain well below the cost for the 50%/50% case. The key difference is the residential sector for which costs increase significantly compared to other cases both in 2040 and 2050.

54. Annex 4 shows the results of mitigation costs for all optimised scenarios, except the three scenarios with the highest (65%) ambition level for health, which are illustrated only in Figure 7.

55. Compared to version 6 of the Policy Brief, ammonia abatement costs and mitigation potential have been updated in GAINS based on data received from TFRN. Farm size-specific data about costs, along with the change in the farm-size structure, can now be considered in the GAINS model. Additional measures (slurry acidification) and savings in fertilizer use have been included, although the spikes in fertilizer prices due to wars (Russia-Ukraine, Middle East/Hormuz) are not included.

Figure 15: Distribution of costs for key sectors in three selected optimized scenarios



Source: GAINS model (CIAM, dataset v7a)

56. Table *1* to Table 5 in the data annex (Annex 1) show which pollutants (NOx, NH_3, SO_2, $PM_{2.5}$, and NMVOC) to reduce in which country to achieve the ambition levels in the "core" scenarios for a cost-minimal combined risk reduction for human health and biodiversity. Results are given for 2040 and

2050. Table 6 indicates what these scenarios would imply for BC emissions. The tables also show the emission reductions in 2040 and 2050 that can be expected in the baseline (relative to 2015), as well as further mitigation potential in the MTFR scenario. Note that the US and Canada are not included in the optimised scenarios. For North America, results are available for the baseline and the MTFR scenarios.

57. For NOx and NH_3, the scenario with the risk reduction combination 50%/50% (for Health/Biodiversity) leads to higher emission reductions percentages than the 60%/45% and the 55%/45% scenario, both in the aggregated EU and in the aggregated non-EU country regions. This holds for 2040 and 2050. For SO_2 and $PM_{2.5}$, the scenario with the risk reduction combination 60%/45% leads to higher emission reduction percentages than the 55%/45% and the 50%/50% scenarios. This is also true for NMVOCs, but here the differences between the scenarios are less pronounced.

58. Table 7 indicates, for the same three optimized scenarios, the additional costs beyond the baseline (current legislation) in 2040 and 2050, expressed as percentage of GDP. These additional costs remain below 0.02% in 2040 for all EU27 countries. For non-EU countries, in 2040, they remain below 0.1% for most countries and do not exceed 0.3% for any country of the Convention.

59. Table 8 shows the changes in mortality risks (premature deaths due to $PM_{2.5}$ per 100.000 people) between 2015 and 2040/2050. Results differ between countries. Mortality risks relative to 2015 are reduced for all EU27 countries in all three scenarios. The minimum risk reduction of the three scenarios for EU27 countries is approximately 34%, and the maximum risk reduction is about 77%. Health risks are reduced for most non-EU countries, but for a minority, health risks increase compared to the 2015 level. The changes in risks vary from -27% to +59% in 2040 in the 50%/50% scenario, from -26% to +66% in the 55%/45% scenario and from -22% to +74% in the 60%/45% scenario.

60. Table 9 presents the changes in biodiversity risks, expressed through average accumulated exceedance for the minimum empirical critical loads for nitrogen for all ecosystems combined, by country.

61. As indicated in paragraph 43 above, the results presented so far correspond to target setting carried out for the whole UNECE Europe (excl. NA) region. This includes three members of the UNECE that are not parties to the Air Convention (Tajikistan, Turkmenistan and Uzbekistan). Annex 1 presents how the results in Table *1* to Table 9 would change for the medium ambition scenario (55%/45% risk reduction) in 2040 if these three countries were excluded from the target setting. Annex 2 provides additional information on this sensitivity case.

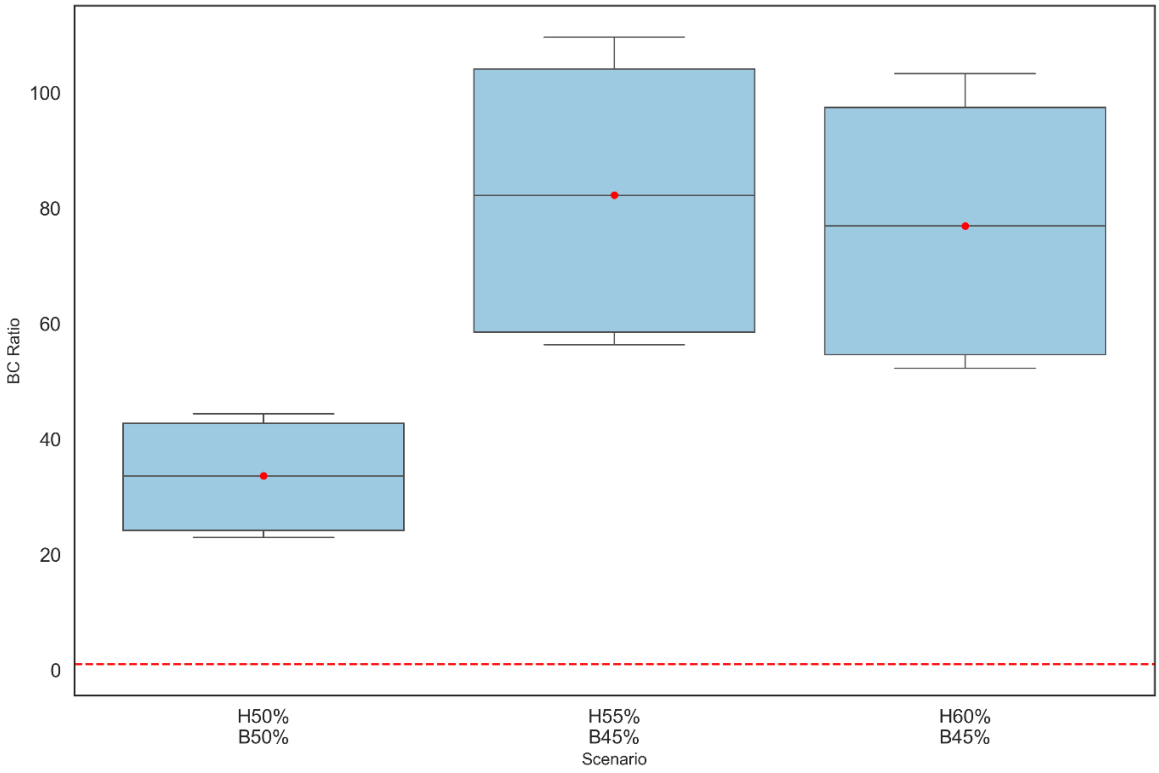
5. Benefits and costs

62. A crucial question is whether the benefits of health risk and ecosystem risk reduction will exceed the costs. As shown above, the additional costs of a combined 50% health and biodiversity risk reduction are estimated at about 4.2 billion euros per year for the whole UNECE (excluding North America) in 2040 with a cost-optimal distribution of emission reduction efforts over countries. In the scenario aiming at a 55% health risk reduction combined with a 45% biodiversity risk reduction, these costs amount to approximately 2.3 billion euros in 2040, and in the scenario combining 60% health risk reduction with 45% of biodiversity risk reduction the additional cost are approximately 3.6 billion euros. In 2050, these costs are estimated at 4.4 billion euros, 2.3 billion euros and 2.8 billion euros, respectively. Comparable studies in the past have consistently shown that the benefits of health risk reduction measures are considerably higher than the costs.

63. A cost-benefit analysis (CBA) was carried out for the v7a scenarios. With input from experts of the Working Group on Effects, socio-economic values of emission reductions were estimated including effects on human health, selected crops, carbon sequestration in living biomass, soiling of materials, and biodiversity. Potential effects of reduced fertilization from nitrogen deposition over insensitive areas is considered. The CBA is still not including all known effects but is more complete than earlier CBAs on air pollution emission control. The current economic valuation of “biodiversity” is likely low since valuation data identified up until the writing of this policy brief only allows for valuation of avoided costs needed to enforce other nitrogen biodiversity legislation. Accordingly, biodiversity benefits are only calculated for EU, EFTA+UK, Russia, Belarus, Bosnia-Herzegovina, and Ukraine. Benefits for other EECCA countries and West Balkan countries are not considered in this version. There are other monetary benefits for biodiversity. However, reliable data to express the real monetary value of biodiversity and ecosystem resilience for the stability of the economic system is not yet identified by the research community.

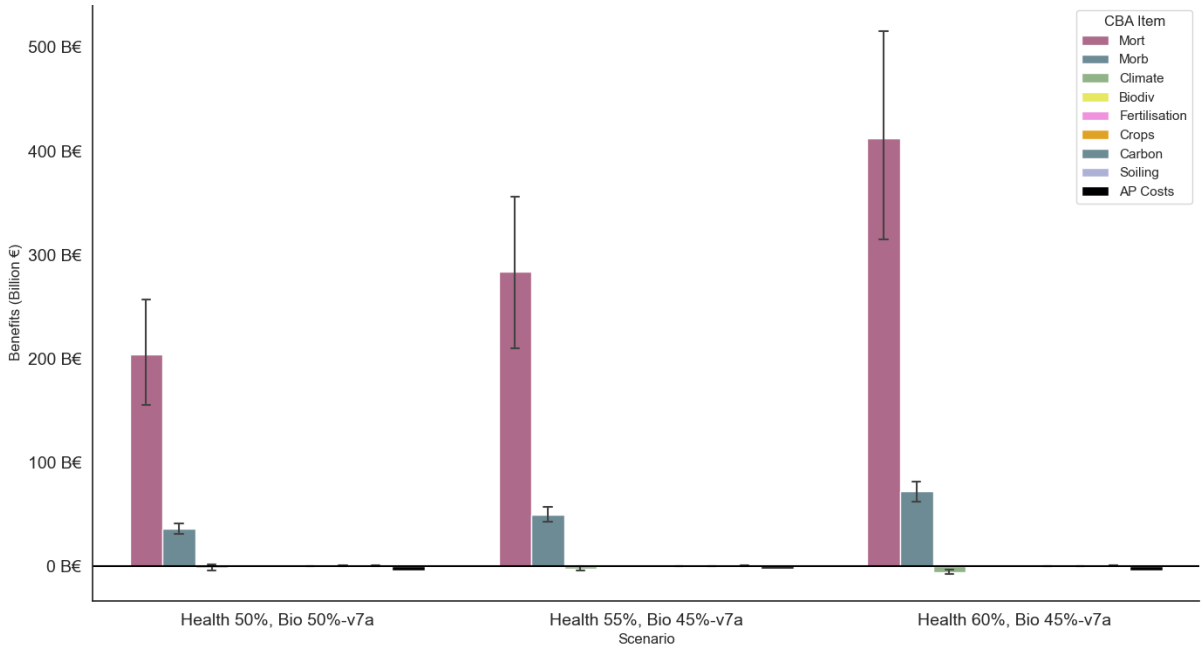
64. Figure 16 shows the benefit-cost (B-C) ratios for the three selected optimized scenarios in 2040, i.e. the ratio of benefits and costs when moving from the baseline scenario in 2040 to the respective optimized scenarios in 2040. In this figure, all benefits mentioned above are included. In these box plots, the red dot indicates the mean of the B-C ratio, the black horizontal line the median, the box the 25^{th} and 75^{th} percentiles and the whiskers the 5^{th} and 95^{th} percentiles. The horizontal red dashed line indicates a B-C ratio of 1, where the benefits equal the additional abatement costs (beyond baseline). A B-C ratio > 1 indicates that benefits exceed costs. The figure shows that the benefits exceed the additional costs by far for any of the three scenarios. The benefits are highest relative to the additional costs for the scenario aimed at 55% reductions of health risks combined with 45% reduction of biodiversity risk (55%/45%), followed by the 60%/45% scenario.

Figure 16: 2040 Benefit-cost ratios of the three selected optimized scenarios. Red dot = mean. Box = 25th-75th percentile. Whiskers = 5th – 95th percentile. Red dashed line: B/C =1



65. Figure 17 indicates the absolute values of benefits in 2040 relative to the baseline in 2040 and the additional abatement costs beyond the baseline for the three core scenarios. It shows that benefits are dominated by health benefits (avoided mortality followed by avoided morbidity).

Figure 17: 2040 Benefits and additional abatement costs by scenario relative to the baseline scenario



66. The socio-economic value of mortality stands out as much higher than all other items in the CBA. This is due to the unit costs used in the valuation of mortality that are based on willingness-to pay studies. Nevertheless, the values used in this policy brief to calculate socio-economic values of mortality are lower than currently considered state-of-the-art by the OECD. Mortality in the CBA is based on the quantification of attributable years of life lost as calculated by GAINS, Figure 17 shows that the avoided morbidity costs (health treatment costs and lost productivity) alone would already exceed the additional abatement cost by far.

67. As shown, all scenarios have benefits higher than costs compared to the baseline. In addition, changing ambition from a 50% health and 50% biodiversity into 55% & 45% or 60%& 45% would imply higher benefits and lower costs. Furthermore, detailed analysis shows that benefits are higher than costs for all countries in the UNECE region (excl. North America). Analysis for 2050 shows the same overall results.

68. In the least-cost scenario to meet 50% risk reduction for health and biodiversity loss, some countries would have to move towards expensive technological solutions to reduce ammonia and NO_x emissions. This is especially the case for countries with or situated near sensitive ecosystems, e.g., in Türkiye and Greece. However, it should be noted that the GAINS scenario only includes technical abatement measures and does not offer the possibility to apply potentially more cost-effective structural changes, such as the substitution of fertilizer use and measures to increase nitrogen efficiency. For countries with high livestock densities the costs of ammonia measures might be overestimated, as for instance nature polices and water quality policies (Habitat Directive, Framework Directive for Water) would already imply structural changes that are not included in GAINS.

69. Additional results for CBA are shown in Annex 6.

6. Conclusions

70. Scenarios to reduce health and ecosystem risks will imply monetary costs and benefits. For all least-cost scenarios assessed, benefits exceed the abatement costs, at a regional level and at the level of individual countries.

71. 10 scenarios combining different levels of ambition for risk reduction for health and biodiversity have been analysed as combined target setting options. The least ambitious health/biodiversity risk reduction scenario assessed includes 50% less risks of premature mortality and 35% less risk of biodiversity loss for the whole UNECE, excluding North America. This would cost in total € 0.8bn/year in 2040 on top of the costs of current legislation. For the EU there hardly would be additional costs in this case. Aiming at 40% reduction of biodiversity risks in 2040 would cost € 1.3bn/year (with EU costs <€ 0.1bn/year), and 45% reduction of biodiversity risks would increase these costs to € 2.2bn/year (including € 0.3bn for the EU). All combined with 50% reduction of health risks.

72. The most ambitious scenario option that would not lead to excessive costs assumes 60% health risk reduction and 45% reduction of the risks of biodiversity loss in 2040. That would cost € 3.6bn/year (0.5bn/year for the EU), which is still less than the additional costs of the reference scenario with 50% reduction of both health and biodiversity risks, that would cost € 4.2bn/year (€ 1bn for the EU).

73. A mid-ambition scenario (in terms of total costs) would reduce health risks in the UNECE-region (excl. North America) by 55% and biodiversity risks by 45%. That scenario costs € 2.3bn/year (€ 0.3bn for the EU), which is only marginally more (€ 0.16bn/year) than the 50%/45% case, while providing higher health benefits.

74. The core scenarios presented in this policy brief show a modest increase in costs within the considered range of ambition levels, avoiding the cases where costs steeply increase for highest ambition levels for both health and biodiversity. While there are differences in distribution of economic burden between countries, there is a systematic difference between the EU, EFTA, UK and other countries, where the latter bear higher relative increase in policy costs, relative to the baseline scenario. Nevertheless, for none of the parties the estimated additional costs exceed 0.3% of GDP.

75. Looking at 2050, the cost differences for the higher ambition levels for reducing biodiversity risks remain the same, while the additional costs of higher ambitions to reduce health risks will become lower. One of the main uncertainties in the scenarios is whether the policies will actually be implemented. It remains uncertain which countries will ratify a protocol that includes more abatement efforts and costs than foreseen in current legislation. To increase the chance of ratification, TFIAM and CIAM had explored various options to reduce the costs for countries with relatively low incomes. This analysis was not updated here but is available in version 6 of the policy brief.

76. Policy makers should decide whether the non-Parties to the Air Convention should be excluded from the target setting.

ANNEX 1: Changes in emissions, costs and impacts 2015-2040/2050

77. Table 1 to Table 9 present:

- NOx emission changes
- NH3 emission changes
- SO2 emission changes
- PM2.5 emission changes
- NMVOC emission changes
- BC emission changes
- Additional costs beyond CLE in 2040 (as a percentage of GDP)
- Changes in mortality risks (premature deaths due to $PM_{2.5}$ per 100.000 inhabitants)
- Changes in biodiversity risks (average accumulated exceedance of CLempN(min))

78. Reduction in indicator levels in 2040 (2050) relative to 2015 are indicated with a negative sign.

79. The data shown here focuses on the core scenarios. Results for all combinations of ambition levels for risk reduction for health and biodiversity are available on the TFIAM and CIAM web pages and in the GAINS Explorer.

80. Following a request from the heads of delegation meeting in the Netherlands in October 2026, additionally to showing results for the core scenarios, a variant is introduced into Table 1 to Table 5 and Table 7 to Table 9. It indicates for the medium ambition scenario (55% risk reduction for health and 45% risk reduction for biodiversity) how changes in 2040 relative to 2015 would be affected by the exclusion of three non-parties to the Air Convention (Tajikistan, Turkmenistan and Uzbekistan) from the target setting (see grey column with the 55%/45%exNP heading in the tables below). As the difference between the two columns for the 55%/45% scenario in 2040 indicates, reductions in emissions, and health and biodiversity risks would be lower (or even change into increases) for these three countries which is due to the fact that their emissions are assumed to stay at the baseline level in 2040 when the countries are excluded from the optimization.

81. More information on this variant is provided in annex 2.

82. The aggregated emission changes over the regions in the tables always include all UNECE countries.

Table 1: NOx emission changes - *Scenarios include the core cases and the variant of 55%/45% excluding 3 non-parties in 2040*

	2040 relative to 2015						2050 relative to 2015				
	BL	50%/50%	55%/45%	55%/45% exNP	60%/45%	MTFR	BL	50%/50%	55%/45%	60%/45%	MTFR
Austria	-76%	-81%	-79%	-78%	-81%	-83%	-80%	-85%	-82%	-82%	-86%
Belgium	-72%	-74%	-73%	-73%	-76%	-79%	-74%	-75%	-75%	-75%	-81%
Bulgaria	-59%	-67%	-65%	-66%	-66%	-72%	-69%	-77%	-74%	-74%	-78%
Croatia	-66%	-70%	-69%	-69%	-70%	-81%	-71%	-74%	-74%	-74%	-84%
Cyprus	-70%	-83%	-73%	-73%	-73%	-84%	-73%	-86%	-75%	-75%	-86%
Czech Rep.	-69%	-77%	-73%	-73%	-75%	-81%	-74%	-79%	-77%	-79%	-84%
Denmark	-66%	-68%	-68%	-68%	-68%	-72%	-74%	-75%	-75%	-75%	-78%
Estonia	-69%	-71%	-71%	-72%	-71%	-76%	-73%	-74%	-74%	-74%	-79%
Finland	-61%	-63%	-63%	-66%	-63%	-71%	-67%	-69%	-69%	-69%	-76%
France	-77%	-79%	-78%	-78%	-78%	-81%	-80%	-83%	-81%	-81%	-83%
Germany	-77%	-83%	-79%	-79%	-81%	-84%	-80%	-83%	-81%	-81%	-86%
Greece	-77%	-86%	-82%	-86%	-83%	-88%	-83%	-91%	-89%	-89%	-91%
Hungary	-62%	-70%	-66%	-66%	-67%	-73%	-66%	-73%	-69%	-69%	-75%
Ireland	-59%	-59%	-59%	-59%	-59%	-66%	-63%	-63%	-63%	-63%	-69%
Italy	-66%	-74%	-69%	-69%	-71%	-77%	-74%	-81%	-76%	-76%	-83%
Latvia	-62%	-65%	-64%	-65%	-64%	-71%	-65%	-67%	-67%	-67%	-73%
Lithuania	-68%	-73%	-71%	-71%	-71%	-77%	-74%	-78%	-76%	-76%	-80%
Luxembourg	-82%	-86%	-85%	-85%	-86%	-90%	-85%	-86%	-86%	-86%	-92%
Malta	-60%	-63%	-62%	-64%	-62%	-68%	-72%	-73%	-73%	-73%	-74%
Netherlands	-67%	-70%	-70%	-70%	-70%	-74%	-73%	-76%	-76%	-76%	-79%
Poland	-69%	-76%	-73%	-72%	-73%	-81%	-75%	-77%	-77%	-77%	-84%
Portugal	-70%	-76%	-73%	-75%	-73%	-84%	-76%	-80%	-78%	-78%	-87%
Romania	-52%	-62%	-59%	-60%	-60%	-72%	-60%	-72%	-64%	-64%	-76%
Slovakia	-62%	-74%	-66%	-65%	-68%	-80%	-70%	-79%	-72%	-73%	-84%
Slovenia	-75%	-79%	-78%	-77%	-82%	-83%	-78%	-81%	-80%	-81%	-85%
Spain	-66%	-74%	-68%	-70%	-68%	-79%	-73%	-80%	-74%	-74%	-82%
Sweden	-62%	-66%	-66%	-66%	-66%	-73%	-63%	-67%	-67%	-67%	-74%
EU-27	**-70%**	**-76%**	**-73%**	**-73%**	**-74%**	**-80%**	**-75%**	**-80%**	**-77%**	**-77%**	**-83%**
Albania	-29%	-57%	-45%	-45%	-43%	-75%	-45%	-75%	-52%	-52%	-83%
Armenia	1%	-72%	-69%	-32%	-64%	-74%	14%	-74%	-67%	-64%	-76%
Azerbaijan	85%	-40%	-10%	20%	-10%	-61%	124%	-37%	-1%	-1%	-63%
Belarus	-8%	-17%	-14%	-14%	-15%	-66%	2%	-12%	-8%	-8%	-68%
Bosnia-Herzegovina	-60%	-68%	-65%	-65%	-68%	-79%	-73%	-79%	-75%	-75%	-86%
Georgia	-37%	-80%	-75%	-54%	-74%	-83%	-38%	-83%	-79%	-78%	-87%
Iceland	-29%	-36%	-36%	-36%	-36%	-57%	-26%	-34%	-34%	-34%	-67%
Kazakhstan	17%	-45%	-13%	-12%	-13%	-69%	26%	-41%	-8%	-7%	-68%
Kosovo	-71%	-80%	-77%	-77%	-77%	-86%	-80%	-88%	-84%	-84%	-91%
Kyrgyzstan	-25%	-76%	-74%	-31%	-73%	-78%	-20%	-74%	-72%	-71%	-76%
North Macedonia	-54%	-71%	-67%	-69%	-69%	-80%	-75%	-84%	-81%	-81%	-90%
Moldova	-19%	-44%	-41%	-41%	-44%	-69%	-19%	-56%	-45%	-45%	-79%
Montenegro	-64%	-71%	-70%	-70%	-70%	-83%	-83%	-87%	-86%	-86%	-94%
Norway	-58%	-61%	-60%	-63%	-60%	-72%	-62%	-64%	-64%	-64%	-75%
Russia	-7%	-34%	-32%	-34%	-31%	-68%	-11%	-38%	-32%	-32%	-73%
Serbia	-66%	-73%	-70%	-72%	-72%	-82%	-75%	-80%	-77%	-78%	-87%
Switzerland	-56%	-60%	-60%	-58%	-60%	-64%	-58%	-63%	-62%	-63%	-67%
Tajikistan	136%	-63%	-62%	137%	-62%	-64%	171%	-62%	-61%	-61%	-64%
Türkiye	-8%	-52%	-46%	-42%	-44%	-60%	-7%	-54%	-48%	-48%	-60%
Turkmenistan	86%	27%	32%	86%	32%	-78%	123%	52%	58%	58%	-77%
Ukraine	-12%	-31%	-24%	-24%	-25%	-67%	-3%	-41%	-17%	-18%	-74%
United Kingdom	-69%	-70%	-70%	-70%	-72%	-78%	-69%	-70%	-70%	-71%	-80%
Uzbekistan	46%	-38%	-26%	46%	-26%	-50%	54%	-33%	-25%	-25%	-48%
Non-EU	**-13%**	**-45%**	**-38%**	**-32%**	**-38%**	**-69%**	**-11%**	**-46%**	**-37%**	**-37%**	**-72%**
Canada	-33%					-54%	-32%				-55%
United States	-51%					-75%	-53%				-76%
North America	**-49%**					**-72%**	**-51%**				**-74%**
Total	**-46%**	**-81%**	**-79%**	**-53%**	**-79%**	**-73%**	**-47%**	**-82%**	**-79%**	**-79%**	**-76%**

Source: GAINS model (CIAM, dataset v7a); US and Canada are not included in the optimized cases

Table 2: NH_3 emission changes - Scenarios include the core cases and the variant of 55%/45% excluding 3 non-parties in 2040

	2040 relative to 2015						2050 relative to 2015				
	BL	50%/50%	55%/45%	55%/45% exNP	60%/45%	MTFR	BL	50%/50%	55%/45%	60%/45%	MTFR
Austria	-7%	-31%	-27%	-23%	-27%	-34%	-6%	-35%	-33%	-32%	-38%
Belgium	-22%	-28%	-28%	-28%	-29%	-34%	-20%	-25%	-24%	-25%	-31%
Bulgaria	-4%	-38%	-35%	-36%	-35%	-44%	-5%	-44%	-39%	-39%	-47%
Croatia	1%	-20%	-14%	-13%	-14%	-41%	-1%	-26%	-17%	-18%	-47%
Cyprus	13%	-16%	-8%	-3%	-8%	-18%	20%	-16%	-9%	-9%	-18%
Czech Rep.	-30%	-38%	-37%	-37%	-37%	-40%	-34%	-44%	-43%	-43%	-46%
Denmark	-24%	-30%	-28%	-28%	-29%	-39%	-25%	-32%	-30%	-30%	-36%
Estonia	23%	15%	15%	14%	15%	1%	24%	15%	15%	15%	-4%
Finland	-25%	-32%	-33%	-35%	-33%	-40%	-26%	-33%	-35%	-35%	-43%
France	-13%	-27%	-21%	-21%	-21%	-35%	-12%	-29%	-23%	-23%	-39%
Germany	-34%	-46%	-42%	-39%	-43%	-51%	-35%	-49%	-47%	-47%	-55%
Greece	-9%	-36%	-33%	-36%	-33%	-37%	-9%	-40%	-39%	-39%	-40%
Hungary	-11%	-27%	-21%	-21%	-21%	-33%	-13%	-32%	-25%	-25%	-37%
Ireland	1%	-3%	-2%	-2%	-3%	-24%	2%	-6%	-3%	-5%	-28%
Italy	-9%	-35%	-28%	-26%	-26%	-36%	-11%	-39%	-33%	-33%	-42%
Latvia	-8%	-22%	-18%	-18%	-18%	-28%	-6%	-24%	-20%	-20%	-28%
Lithuania	-17%	-34%	-31%	-25%	-31%	-38%	-18%	-38%	-35%	-35%	-41%
Luxembourg	13%	-2%	-2%	-2%	-2%	-11%	12%	-11%	-10%	-11%	-18%
Malta	-42%	-46%	-45%	-47%	-46%	-50%	-45%	-47%	-45%	-47%	-50%
Netherlands	-20%	-23%	-23%	-23%	-23%	-28%	-22%	-24%	-24%	-24%	-24%
Poland	-10%	-35%	-32%	-29%	-32%	-43%	-17%	-44%	-43%	-43%	-53%
Portugal	-5%	-24%	-19%	-23%	-17%	-38%	-5%	-23%	-19%	-20%	-40%
Romania	0%	-28%	-26%	-26%	-15%	-30%	3%	-29%	-16%	-16%	-32%
Slovakia	-19%	-37%	-36%	-25%	-36%	-41%	-24%	-42%	-31%	-31%	-46%
Slovenia	-3%	-25%	-21%	-16%	-21%	-35%	-2%	-28%	-19%	-20%	-39%
Spain	-12%	-35%	-32%	-33%	-32%	-46%	-14%	-38%	-35%	-35%	-48%
Sweden	-9%	-17%	-17%	-18%	-17%	-23%	-6%	-17%	-16%	-17%	-24%
EU-27	**-16%**	**-33%**	**-29%**	**-28%**	**-28%**	**-40%**	**-17%**	**-36%**	**-32%**	**-33%**	**-43%**
Albania	-5%	-22%	-20%	-22%	-20%	-30%	-5%	-23%	-20%	-20%	-29%
Armenia	-17%	-37%	-37%	-28%	-37%	-37%	-16%	-37%	-37%	-37%	-37%
Azerbaijan	-6%	-30%	-30%	-20%	-30%	-29%	-6%	-31%	-32%	-32%	-31%
Belarus	12%	-36%	-33%	-4%	-33%	-40%	15%	-35%	-32%	-32%	-39%
Bosnia-Herzegovina	8%	-17%	-11%	-11%	-15%	-23%	9%	-17%	-11%	-12%	-23%
Georgia	-36%	-52%	-52%	-40%	-52%	-52%	-43%	-57%	-57%	-57%	-57%
Iceland	-2%	-5%	-5%	-5%	-5%	-30%	-1%	-3%	-3%	-3%	-29%
Kazakhstan	56%	25%	26%	26%	26%	24%	66%	32%	33%	33%	31%
Kosovo	13%	-28%	-26%	-25%	-26%	-29%	18%	-30%	-28%	-28%	-31%
Kyrgyzstan	39%	17%	17%	32%	17%	17%	52%	28%	28%	28%	28%
North Macedonia	-11%	-29%	-27%	-26%	-27%	-29%	-8%	-28%	-27%	-27%	-28%
Moldova	45%	-10%	22%	22%	21%	-22%	46%	-13%	24%	24%	-23%
Montenegro	-5%	-16%	-12%	-11%	-12%	-18%	-9%	-20%	-16%	-16%	-22%
Norway	4%	-8%	-8%	-8%	-7%	-15%	5%	-4%	-4%	-4%	-14%
Russia	26%	-19%	-16%	-15%	-16%	-26%	31%	-16%	-13%	-13%	-24%
Serbia	19%	-37%	11%	-10%	-36%	-41%	21%	-39%	15%	15%	-42%
Switzerland	-4%	-22%	-18%	-11%	-18%	-24%	-4%	-20%	-18%	-18%	-21%
Tajikistan	46%	0%	0%	46%	0%	0%	49%	1%	1%	1%	1%
Türkiye	44%	-5%	-4%	-3%	-4%	-5%	49%	-3%	-2%	-2%	-3%
Turkmenistan	4%	-42%	-42%	4%	-42%	-43%	2%	-43%	-42%	-42%	-43%
Ukraine	35%	-28%	-24%	-24%	-25%	-37%	39%	-28%	-24%	-24%	-36%
United Kingdom	-1%	-14%	-14%	-14%	-16%	-30%	-6%	-17%	-14%	-17%	-32%
Uzbekistan	23%	-10%	-10%	23%	-10%	-9%	22%	-11%	-11%	-11%	-11%
Non-EU	**25%**	**-15%**	**-12%**	**-5%**	**-14%**	**-20%**	**28%**	**-14%**	**-11%**	**-11%**	**-18%**
Canada	28%					-42%	37%				-38%
United States	9%					-43%	11%				-43%
North America	**13%**					**-43%**	**15%**				**-42%**
Total	**7%**	**-53%**	**-51%**	**-17%**	**-51%**	**-35%**	**9%**	**-53%**	**-51%**	**-51%**	**-36%**

Source: GAINS model (CIAM, dataset v7a); US and Canada are not included in the optimized cases

Table 3: SO_2 emission changes - Scenarios include the core cases and the variant of 55%/45% excluding 3 non-parties in 2040

	2040 relative to 2015						2050 relative to 2015				
	BL	50%/50%	55%/45%	55%/45% exNP	60%/45%	MTFR	BL	50%/50%	55%/45%	60%/45%	MTFR
Austria	-45%	-45%	-45%	-45%	-50%	-59%	-49%	-49%	-49%	-49%	-62%
Belgium	-49%	-49%	-53%	-53%	-73%	-78%	-52%	-52%	-52%	-62%	-82%
Bulgaria	-87%	-87%	-88%	-88%	-91%	-97%	-89%	-89%	-89%	-91%	-98%
Croatia	-77%	-77%	-77%	-77%	-84%	-91%	-78%	-78%	-78%	-80%	-92%
Cyprus	-89%	-89%	-89%	-89%	-89%	-98%	-90%	-90%	-90%	-90%	-98%
Czech Rep.	-88%	-88%	-88%	-88%	-92%	-94%	-89%	-89%	-89%	-91%	-94%
Denmark	-38%	-38%	-38%	-39%	-38%	-50%	-49%	-49%	-49%	-49%	-59%
Estonia	-96%	-96%	-96%	-96%	-96%	-98%	-96%	-96%	-96%	-96%	-98%
Finland	-72%	-72%	-74%	-74%	-74%	-83%	-76%	-76%	-76%	-78%	-85%
France	-65%	-65%	-66%	-66%	-72%	-77%	-69%	-69%	-69%	-71%	-79%
Germany	-69%	-69%	-74%	-74%	-82%	-85%	-72%	-72%	-75%	-77%	-86%
Greece	-85%	-86%	-86%	-86%	-86%	-95%	-88%	-88%	-88%	-88%	-96%
Hungary	-73%	-73%	-73%	-74%	-75%	-79%	-74%	-75%	-75%	-75%	-79%
Ireland	-78%	-78%	-78%	-79%	-78%	-86%	-82%	-82%	-82%	-82%	-90%
Italy	-60%	-61%	-62%	-62%	-75%	-83%	-68%	-69%	-69%	-70%	-86%
Latvia	-39%	-39%	-39%	-38%	-39%	-46%	-42%	-42%	-42%	-42%	-48%
Lithuania	-76%	-76%	-76%	-76%	-77%	-88%	-86%	-86%	-86%	-86%	-92%
Luxembourg	-38%	-38%	-38%	-38%	-38%	-70%	-35%	-35%	-35%	-35%	-68%
Malta	-93%	-93%	-93%	-95%	-93%	-96%	-94%	-94%	-94%	-94%	-97%
Netherlands	-47%	-47%	-47%	-47%	-69%	-71%	-59%	-59%	-59%	-73%	-76%
Poland	-90%	-90%	-90%	-90%	-92%	-96%	-91%	-91%	-91%	-92%	-97%
Portugal	-68%	-69%	-69%	-69%	-70%	-87%	-73%	-73%	-73%	-73%	-89%
Romania	-83%	-84%	-84%	-84%	-89%	-94%	-84%	-85%	-85%	-87%	-95%
Slovakia	-87%	-87%	-87%	-87%	-92%	-96%	-89%	-89%	-89%	-91%	-96%
Slovenia	-69%	-69%	-69%	-69%	-79%	-88%	-70%	-70%	-70%	-72%	-88%
Spain	-76%	-76%	-76%	-77%	-79%	-89%	-79%	-79%	-79%	-80%	-90%
Sweden	-22%	-22%	-22%	-23%	-23%	-31%	-20%	-20%	-20%	-20%	-27%
EU-27	**-78%**	**-78%**	**-79%**	**-79%**	**-84%**	**-89%**	**-80%**	**-81%**	**-81%**	**-83%**	**-90%**
Albania	49%	47%	47%	47%	-9%	-78%	58%	58%	58%	56%	-75%
Armenia	-94%	-94%	-94%	-94%	-94%	-98%	-93%	-94%	-94%	-94%	-98%
Azerbaijan	-43%	-44%	-45%	-45%	-49%	-91%	-40%	-42%	-42%	-45%	-90%
Belarus	-35%	-38%	-45%	-45%	-80%	-87%	-36%	-38%	-38%	-57%	-87%
Bosnia-Herzegovina	-96%	-96%	-96%	-96%	-99%	-99%	-96%	-96%	-96%	-97%	-99%
Georgia	7%	5%	4%	0%	-9%	-68%	24%	22%	22%	14%	-64%
Iceland	18%	18%	14%	14%	2%	-7%	24%	24%	20%	20%	-5%
Kazakhstan	-7%	-24%	-26%	-26%	-48%	-82%	-6%	-24%	-24%	-35%	-84%
Kosovo	-94%	-94%	-94%	-94%	-98%	-99%	-94%	-94%	-94%	-94%	-99%
Kyrgyzstan	5%	4%	-5%	-5%	-71%	-90%	14%	13%	13%	-42%	-90%
North Macedonia	-96%	-96%	-96%	-96%	-97%	-98%	-96%	-96%	-96%	-97%	-98%
Moldova	-25%	-26%	-26%	-24%	-35%	-65%	-26%	-27%	-27%	-34%	-71%
Montenegro	-99%	-99%	-99%	-99%	-99%	-100%	-99%	-99%	-99%	-99%	-100%
Norway	-37%	-42%	-42%	-42%	-42%	-62%	-39%	-46%	-46%	-46%	-65%
Russia	-24%	-24%	-29%	-41%	-67%	-87%	-33%	-33%	-33%	-61%	-91%
Serbia	-94%	-95%	-95%	-95%	-98%	-98%	-94%	-95%	-95%	-95%	-98%
Switzerland	-48%	-48%	-48%	-48%	-51%	-54%	-46%	-46%	-46%	-47%	-53%
Tajikistan	179%	175%	73%	73%	-28%	-73%	187%	183%	183%	73%	-76%
Türkiye	-70%	-70%	-77%	-79%	-85%	-92%	-69%	-70%	-70%	-82%	-93%
Turkmenistan	103%	102%	102%	102%	84%	-62%	129%	127%	127%	127%	-56%
Ukraine	-57%	-57%	-60%	-60%	-90%	-93%	-56%	-57%	-57%	-76%	-95%
United Kingdom	-71%	-71%	-71%	-72%	-80%	-88%	-74%	-74%	-74%	-75%	-89%
Uzbekistan	62%	60%	29%	25%	-27%	-69%	64%	63%	63%	-26%	-71%
Non-EU	**-49%**	**-52%**	**-56%**	**-59%**	**-76%**	**-89%**	**-50%**	**-53%**	**-53%**	**-68%**	**-91%**
Canada	-41%					-53%	-40%				-51%
United States	-74%					-86%	-76%				-86%
North America	**-67%**					**-79%**	**-68%**				**-79%**
Total	**-61%**	**-74%**	**-76%**	**-64%**	**-86%**	**-86%**	**-62%**	**-75%**	**-75%**	**-82%**	**-86%**

Source: GAINS model (CIAM, dataset v7a); US and Canada are not included in the optimized cases

Table 4: $PM_{2.5}$ emission changes - Scenarios include the core cases and the variant of 55%/45% excluding 3 non-parties in 2040

	2040 relative to 2015						2050 relative to 2015				
	BL	50%/50%	55%/45%	55%/45% exNP	60%/45%	MTFR	BL	50%/50%	55%/45%	60%/45%	MTFR
Austria	-70%	-71%	-72%	-72%	-73%	-78%	-73%	-73%	-73%	-74%	-79%
Belgium	-52%	-54%	-56%	-56%	-57%	-63%	-53%	-54%	-55%	-58%	-64%
Bulgaria	-69%	-74%	-78%	-78%	-79%	-84%	-75%	-80%	-81%	-82%	-87%
Croatia	-85%	-88%	-90%	-90%	-92%	-94%	-87%	-89%	-89%	-93%	-94%
Cyprus	-47%	-52%	-53%	-50%	-54%	-65%	-48%	-53%	-53%	-55%	-66%
Czech Rep.	-79%	-79%	-80%	-80%	-81%	-85%	-84%	-85%	-85%	-86%	-90%
Denmark	-62%	-62%	-63%	-63%	-65%	-70%	-68%	-68%	-68%	-69%	-75%
Estonia	-66%	-67%	-68%	-67%	-68%	-75%	-72%	-72%	-72%	-72%	-79%
Finland	-47%	-49%	-51%	-50%	-54%	-62%	-55%	-57%	-57%	-61%	-70%
France	-73%	-74%	-74%	-74%	-75%	-78%	-73%	-74%	-74%	-75%	-79%
Germany	-57%	-58%	-60%	-60%	-61%	-64%	-58%	-59%	-59%	-61%	-64%
Greece	-67%	-73%	-75%	-75%	-77%	-80%	-73%	-78%	-79%	-80%	-84%
Hungary	-70%	-71%	-78%	-78%	-78%	-82%	-80%	-80%	-81%	-81%	-86%
Ireland	-73%	-73%	-75%	-75%	-75%	-82%	-74%	-75%	-75%	-75%	-83%
Italy	-55%	-61%	-66%	-66%	-68%	-72%	-65%	-70%	-71%	-72%	-76%
Latvia	-68%	-69%	-70%	-70%	-71%	-79%	-75%	-75%	-75%	-76%	-84%
Lithuania	-66%	-67%	-69%	-69%	-70%	-78%	-76%	-77%	-78%	-78%	-85%
Luxembourg	-50%	-51%	-52%	-50%	-52%	-54%	-55%	-56%	-56%	-56%	-60%
Malta	-35%	-46%	-46%	-50%	-46%	-50%	-33%	-43%	-36%	-44%	-48%
Netherlands	-32%	-36%	-37%	-37%	-39%	-43%	-36%	-41%	-41%	-43%	-47%
Poland	-81%	-82%	-82%	-82%	-83%	-87%	-84%	-84%	-85%	-85%	-89%
Portugal	-54%	-57%	-65%	-60%	-69%	-78%	-60%	-62%	-62%	-73%	-81%
Romania	-57%	-67%	-77%	-77%	-77%	-84%	-72%	-80%	-81%	-83%	-88%
Slovakia	-67%	-69%	-75%	-75%	-78%	-80%	-76%	-77%	-79%	-80%	-83%
Slovenia	-60%	-60%	-67%	-68%	-71%	-78%	-74%	-74%	-74%	-78%	-84%
Spain	-51%	-52%	-54%	-53%	-56%	-61%	-54%	-55%	-55%	-58%	-63%
Sweden	-32%	-33%	-33%	-34%	-35%	-43%	-34%	-35%	-35%	-36%	-44%
EU-27	**-66%**	**-68%**	**-71%**	**-71%**	**-72%**	**-76%**	**-71%**	**-73%**	**-73%**	**-75%**	**-79%**
Albania	-24%	-31%	-46%	-45%	-60%	-74%	-31%	-36%	-44%	-58%	-80%
Armenia	29%	-5%	-41%	-41%	-58%	-67%	29%	-12%	-42%	-62%	-79%
Azerbaijan	55%	-22%	-27%	-21%	-37%	-68%	86%	-15%	-17%	-32%	-67%
Belarus	-3%	-29%	-56%	-56%	-59%	-74%	-1%	-26%	-33%	-58%	-77%
Bosnia-Herzegovina	-50%	-53%	-70%	-69%	-81%	-85%	-58%	-60%	-68%	-82%	-91%
Georgia	-34%	-43%	-66%	-66%	-78%	-82%	-30%	-38%	-62%	-72%	-87%
Iceland	-3%	-4%	-4%	-7%	-26%	-35%	7%	6%	6%	5%	-29%
Kazakhstan	-13%	-27%	-33%	-32%	-47%	-80%	-8%	-25%	-25%	-33%	-84%
Kosovo	-58%	-59%	-74%	-73%	-85%	-87%	-65%	-66%	-75%	-85%	-92%
Kyrgyzstan	-21%	-45%	-48%	-47%	-54%	-74%	-21%	-45%	-46%	-53%	-76%
North Macedonia	-57%	-61%	-76%	-75%	-84%	-85%	-61%	-65%	-73%	-83%	-89%
Moldova	-35%	-41%	-61%	-52%	-76%	-78%	-45%	-50%	-63%	-76%	-88%
Montenegro	-36%	-37%	-65%	-65%	-76%	-80%	-48%	-50%	-57%	-81%	-88%
Norway	-20%	-24%	-27%	-24%	-32%	-53%	-30%	-33%	-33%	-41%	-65%
Russia	-11%	-48%	-55%	-55%	-63%	-78%	-15%	-51%	-55%	-63%	-80%
Serbia	-20%	-39%	-54%	-54%	-66%	-75%	-37%	-53%	-59%	-68%	-83%
Switzerland	-36%	-40%	-41%	-40%	-42%	-47%	-39%	-43%	-43%	-45%	-52%
Tajikistan	63%	-15%	-50%	64%	-56%	-65%	81%	-7%	-42%	-54%	-66%
Türkiye	-17%	-26%	-56%	-56%	-72%	-83%	-7%	-16%	-17%	-70%	-84%
Turkmenistan	91%	17%	15%	90%	11%	-75%	131%	40%	41%	35%	-71%
Ukraine	-9%	-29%	-63%	-62%	-71%	-80%	-8%	-29%	-42%	-68%	-83%
United Kingdom	-37%	-39%	-41%	-41%	-45%	-50%	-45%	-46%	-47%	-51%	-58%
Uzbekistan	16%	-34%	-44%	16%	-58%	-65%	23%	-30%	-33%	-42%	-64%
Non-EU	**-13%**	**-35%**	**-52%**	**-48%**	**-62%**	**-77%**	**-12%**	**-34%**	**-39%**	**-59%**	**-80%**
Canada	-21%					-69%	-22%				-70%
United States	-43%					-70%	-42%				-71%
North America	**-39%**					**-70%**	**-39%**				**-71%**
Total	**-39%**	**-66%**	**-73%**	**-59%**	**-77%**	**-75%**	**-40%**	**-67%**	**-69%**	**-77%**	**-77%**

Source: GAINS model (CIAM, dataset v7a); US and Canada are not included in the optimized cases

Table 5: NMVOC emission changes - Scenarios include the core cases and the variant of 55%/45% excluding 3 non-parties in 2040

	2040 relative to 2015						2050 relative to 2015				
	BL	50%/50%	55%/45%	55%/45% exNP	60%/45%	MTFR	BL	50%/50%	55%/45%	60%/45%	MTFR
Austria	-32%	-33%	-33%	-33%	-34%	-42%	-35%	-36%	-36%	-36%	-45%
Belgium	-24%	-26%	-26%	-26%	-26%	-34%	-25%	-27%	-27%	-27%	-38%
Bulgaria	-42%	-46%	-46%	-47%	-47%	-57%	-49%	-52%	-52%	-52%	-64%
Croatia	-52%	-57%	-58%	-58%	-58%	-72%	-56%	-62%	-62%	-62%	-75%
Cyprus	-43%	-45%	-45%	-45%	-46%	-54%	-47%	-49%	-49%	-49%	-58%
Czech Rep.	-69%	-70%	-71%	-71%	-72%	-77%	-74%	-76%	-76%	-76%	-81%
Denmark	-35%	-38%	-38%	-38%	-38%	-49%	-37%	-41%	-41%	-41%	-51%
Estonia	-19%	-22%	-22%	-23%	-23%	-39%	-22%	-25%	-25%	-25%	-44%
Finland	-34%	-36%	-38%	-36%	-38%	-47%	-42%	-43%	-43%	-45%	-54%
France	-40%	-41%	-41%	-41%	-41%	-47%	-41%	-42%	-42%	-42%	-49%
Germany	-28%	-32%	-32%	-32%	-32%	-45%	-30%	-34%	-34%	-34%	-47%
Greece	-50%	-55%	-56%	-56%	-56%	-66%	-56%	-61%	-61%	-61%	-71%
Hungary	-41%	-43%	-45%	-45%	-45%	-53%	-48%	-50%	-50%	-50%	-59%
Ireland	-1%	-3%	-3%	-3%	-3%	-19%	2%	1%	1%	1%	-18%
Italy	-31%	-35%	-38%	-38%	-38%	-50%	-38%	-42%	-42%	-44%	-56%
Latvia	-31%	-34%	-35%	-35%	-35%	-53%	-36%	-39%	-39%	-39%	-59%
Lithuania	-38%	-40%	-41%	-41%	-42%	-50%	-46%	-48%	-48%	-48%	-57%
Luxembourg	-12%	-13%	-13%	-13%	-13%	-21%	-15%	-16%	-16%	-16%	-26%
Malta	-24%	-27%	-27%	-25%	-27%	-41%	-31%	-34%	-33%	-34%	-49%
Netherlands	-23%	-24%	-24%	-24%	-24%	-30%	-27%	-29%	-29%	-29%	-37%
Poland	-48%	-51%	-51%	-51%	-52%	-60%	-53%	-55%	-55%	-56%	-64%
Portugal	-23%	-30%	-30%	-30%	-31%	-43%	-28%	-35%	-35%	-35%	-49%
Romania	-40%	-48%	-53%	-53%	-53%	-60%	-48%	-55%	-55%	-55%	-63%
Slovakia	-42%	-47%	-49%	-49%	-50%	-64%	-51%	-55%	-55%	-55%	-71%
Slovenia	-31%	-36%	-38%	-38%	-39%	-49%	-37%	-42%	-42%	-43%	-54%
Spain	-22%	-24%	-24%	-24%	-24%	-36%	-24%	-26%	-26%	-26%	-40%
Sweden	-29%	-31%	-31%	-31%	-31%	-42%	-31%	-34%	-34%	-34%	-45%
EU-27	**-35%**	**-39%**	**-39%**	**-39%**	**-40%**	**-49%**	**-39%**	**-42%**	**-42%**	**-43%**	**-53%**
Albania	-26%	-30%	-36%	-36%	-42%	-53%	-32%	-36%	-40%	-44%	-62%
Armenia	-1%	-51%	-57%	-56%	-61%	-65%	11%	-48%	-54%	-59%	-65%
Azerbaijan	40%	2%	3%	4%	3%	-3%	57%	8%	9%	9%	1%
Belarus	-25%	-39%	-41%	-41%	-41%	-52%	-25%	-39%	-41%	-42%	-55%
Bosnia-Herzegovina	-23%	-26%	-45%	-45%	-53%	-63%	-34%	-37%	-45%	-61%	-72%
Georgia	-41%	-61%	-68%	-68%	-72%	-77%	-40%	-61%	-67%	-71%	-78%
Iceland	-4%	-4%	-4%	-4%	-4%	-20%	-4%	-4%	-4%	-4%	-20%
Kazakhstan	18%	0%	0%	0%	-1%	-5%	25%	5%	5%	4%	-1%
Kosovo	-12%	-15%	-31%	-31%	-45%	-55%	-23%	-25%	-36%	-47%	-64%
Kyrgyzstan	-26%	-43%	-43%	-43%	-44%	-49%	-20%	-38%	-38%	-39%	-44%
North Macedonia	-25%	-32%	-41%	-41%	-47%	-60%	-27%	-32%	-39%	-44%	-63%
Moldova	-9%	-21%	-29%	-25%	-37%	-65%	-11%	-21%	-28%	-33%	-66%
Montenegro	-32%	-33%	-48%	-47%	-53%	-61%	-42%	-43%	-49%	-61%	-69%
Norway	-21%	-25%	-25%	-25%	-26%	-39%	-28%	-33%	-33%	-34%	-48%
Russia	-22%	-38%	-38%	-38%	-39%	-56%	-23%	-40%	-38%	-41%	-59%
Serbia	-23%	-33%	-42%	-42%	-47%	-59%	-38%	-47%	-51%	-58%	-69%
Switzerland	-14%	-20%	-20%	-20%	-20%	-28%	-16%	-21%	-20%	-21%	-30%
Tajikistan	42%	-20%	-20%	42%	-20%	-21%	60%	-14%	-14%	-15%	-16%
Türkiye	-5%	-16%	-15%	-15%	-15%	-32%	-7%	-16%	-16%	-16%	-33%
Turkmenistan	74%	52%	52%	74%	52%	-46%	113%	84%	84%	84%	-43%
Ukraine	-6%	-24%	-34%	-34%	-40%	-52%	0%	-20%	-29%	-37%	-55%
United Kingdom	-21%	-26%	-26%	-26%	-26%	-41%	-21%	-26%	-26%	-27%	-45%
Uzbekistan	-1%	-30%	-29%	-1%	-29%	-34%	4%	-28%	-28%	-28%	-32%
Non-EU	**-7%**	**-23%**	**-24%**	**-22%**	**-26%**	**-40%**	**-5%**	**-22%**	**-23%**	**-25%**	**-42%**
Canada	-20%					-50%	-28%				-55%
United States	-29%					-52%	-32%				-55%
North America	**-27%**					**-52%**	**-31%**				**-55%**
Total	**-24%**	**-65%**	**-66%**	**-31%**	**-66%**	**-48%**	**-27%**	**-66%**	**-66%**	**-67%**	**-51%**

Source: GAINS model (CIAM, dataset v7a); US and Canada are not included in the optimized cases

Table 6: BC emission changes - Scenarios include the core cases

	2040 relative to 2015					2050 relative to 2015				
	BL	50%/50%	55%/45%	60%/45%	MTFR	BL	50%/50%	55%/45%	60%/45%	MTFR
Austria	-83%	-84%	-84%	-85%	-88%	-86%	-86%	-86%	-87%	-89%
Belgium	-78%	-79%	-79%	-79%	-83%	-81%	-81%	-81%	-82%	-84%
Bulgaria	-70%	-76%	-78%	-79%	-87%	-80%	-85%	-85%	-86%	-91%
Croatia	-89%	-92%	-91%	-93%	-95%	-93%	-94%	-94%	-95%	-96%
Cyprus	-73%	-80%	-80%	-80%	-81%	-77%	-81%	-81%	-82%	-83%
Czech Rep.	-72%	-74%	-74%	-75%	-83%	-83%	-84%	-84%	-85%	-91%
Denmark	-75%	-76%	-76%	-76%	-82%	-80%	-81%	-81%	-81%	-86%
Estonia	-74%	-76%	-76%	-76%	-85%	-85%	-86%	-86%	-86%	-91%
Finland	-61%	-63%	-65%	-68%	-76%	-72%	-74%	-74%	-78%	-86%
France	-87%	-88%	-88%	-89%	-91%	-89%	-90%	-90%	-90%	-92%
Germany	-75%	-76%	-77%	-78%	-79%	-77%	-78%	-78%	-79%	-80%
Greece	-74%	-80%	-80%	-80%	-83%	-81%	-85%	-86%	-86%	-89%
Hungary	-78%	-80%	-81%	-81%	-87%	-87%	-88%	-88%	-88%	-92%
Ireland	-88%	-89%	-89%	-89%	-91%	-89%	-90%	-90%	-90%	-92%
Italy	-62%	-66%	-67%	-67%	-72%	-71%	-75%	-75%	-75%	-78%
Latvia	-67%	-68%	-68%	-69%	-80%	-79%	-80%	-80%	-80%	-89%
Lithuania	-68%	-70%	-71%	-71%	-81%	-83%	-84%	-84%	-84%	-90%
Luxembourg	-77%	-78%	-78%	-78%	-79%	-80%	-80%	-80%	-80%	-82%
Malta	-66%	-74%	-73%	-73%	-75%	-68%	-72%	-70%	-72%	-74%
Netherlands	-56%	-58%	-58%	-58%	-60%	-61%	-63%	-63%	-63%	-65%
Poland	-86%	-87%	-87%	-87%	-92%	-90%	-91%	-91%	-91%	-94%
Portugal	-78%	-80%	-81%	-81%	-83%	-84%	-86%	-86%	-86%	-88%
Romania	-55%	-67%	-68%	-68%	-80%	-74%	-83%	-83%	-83%	-89%
Slovakia	-71%	-74%	-77%	-79%	-84%	-81%	-83%	-83%	-83%	-88%
Slovenia	-64%	-65%	-69%	-75%	-84%	-80%	-80%	-80%	-83%	-91%
Spain	-72%	-74%	-75%	-75%	-84%	-81%	-82%	-82%	-82%	-88%
Sweden	-67%	-68%	-68%	-68%	-77%	-72%	-72%	-72%	-72%	-80%
EU-27	**-76%**	**-78%**	**-79%**	**-79%**	**-84%**	**-82%**	**-84%**	**-84%**	**-84%**	**-88%**
Albania	-47%	-56%	-61%	-71%	-79%	-55%	-61%	-60%	-66%	-90%
Armenia	33%	-28%	-41%	-55%	-58%	43%	-33%	-34%	-56%	-77%
Azerbaijan	76%	-32%	-33%	-35%	-73%	114%	-27%	-27%	-28%	-73%
Belarus	-1%	-30%	-31%	-33%	-74%	1%	-29%	-29%	-31%	-82%
Bosnia-H	-24%	-28%	-50%	-61%	-69%	-38%	-41%	-42%	-69%	-88%
Georgia	-52%	-65%	-70%	-78%	-81%	-53%	-63%	-64%	-70%	-90%
Iceland	-43%	-43%	-43%	-44%	-43%	-44%	-44%	-44%	-44%	-42%
Kazakhstan	-31%	-53%	-59%	-63%	-69%	-38%	-64%	-64%	-73%	-83%
Kosovo	-8%	-11%	-27%	-52%	-57%	-22%	-25%	-26%	-52%	-85%
Kyrgyzstan	-48%	-65%	-69%	-70%	-76%	-51%	-68%	-68%	-75%	-81%
North Macedonia	-38%	-45%	-54%	-67%	-68%	-43%	-48%	-49%	-66%	-85%
R Moldova	-35%	-44%	-53%	-67%	-70%	-42%	-52%	-52%	-60%	-89%
Montenegro	-38%	-41%	-61%	-68%	-76%	-54%	-56%	-57%	-78%	-91%
Norway	-30%	-35%	-35%	-36%	-60%	-43%	-49%	-49%	-50%	-75%
Russia	1%	-62%	-63%	-67%	-80%	-5%	-67%	-66%	-70%	-86%
Serbia	-17%	-34%	-47%	-55%	-71%	-40%	-54%	-54%	-71%	-87%
Switzerland	-70%	-72%	-72%	-72%	-75%	-74%	-76%	-76%	-76%	-79%
Tajikistan	61%	-54%	-57%	-63%	-64%	66%	-67%	-67%	-74%	-76%
Turkey	-64%	-78%	-80%	-82%	-86%	-66%	-80%	-79%	-84%	-89%
Turkmenistan	116%	28%	28%	27%	-80%	167%	53%	56%	52%	-76%
Ukraine	-12%	-43%	-56%	-66%	-71%	-6%	-41%	-40%	-63%	-85%
United Kingdom	-45%	-47%	-49%	-54%	-60%	-56%	-57%	-57%	-61%	-70%
Uzbekistan	-10%	-66%	-67%	-68%	-71%	-6%	-66%	-67%	-70%	-72%
Non-EU	**-19%**	**-53%**	**-58%**	**-63%**	**-75%**	**-22%**	**-58%**	**-58%**	**-66%**	**-84%**
Canada	-46%				-83%	-48%				-85%
United States	-50%				-79%	-50%				-80%
North America	**-49%**				**-79%**	**-49%**				**-81%**
Total	**-50%**	**-79%**	**-80%**	**-82%**	**-80%**	**-53%**	**-82%**	**-82%**	**-85%**	**-84%**

Source: GAINS model (CIAM, dataset v7a); US and Canada are not included in the optimized cases

Table 7: Additional costs beyond CLE in 2040 (as a percentage of GDP in the target year, rounded to 3 digits (hence 0 means <0.0005%)) - Scenarios include the core cases and the variant of 55%/45% excluding 3 non-parties in 2040

	2040 relative to 2015				2050 relative to 2015		
	50%/50%	55%/45%	55%/45% exNP	60%/45%	50%/50%	55%/45%	60%/45%
Austria	0.007%	0.002%	0.000%	0.003%	0.004%	0.001%	0.001%
Belgium	0.000%	0.000%	0.000%	0.003%	0.000%	0.000%	0.001%
Bulgaria	0.023%	0.016%	0.019%	0.021%	0.030%	0.014%	0.015%
Croatia	0.004%	0.001%	0.001%	0.003%	0.004%	0.000%	0.001%
Cyprus	0.015%	0.001%	0.001%	0.002%	0.012%	0.001%	0.001%
Czech Rep.	0.004%	0.000%	0.000%	0.003%	0.002%	0.000%	0.002%
Denmark	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%
Estonia	0.000%	0.000%	0.001%	0.000%	0.000%	0.000%	0.000%
Finland	0.000%	0.001%	0.004%	0.001%	0.000%	0.000%	0.001%
France	0.003%	0.000%	0.000%	0.001%	0.002%	0.000%	0.000%
Germany	0.004%	0.001%	0.000%	0.002%	0.002%	0.001%	0.001%
Greece	0.017%	0.005%	0.017%	0.006%	0.021%	0.009%	0.008%
Hungary	0.006%	0.001%	0.001%	0.001%	0.005%	0.000%	0.000%
Ireland	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%
Italy	0.010%	0.003%	0.002%	0.005%	0.007%	0.002%	0.002%
Latvia	0.003%	0.001%	0.001%	0.001%	0.002%	0.001%	0.001%
Lithuania	0.011%	0.004%	0.001%	0.004%	0.009%	0.004%	0.004%
Luxembourg	0.001%	0.000%	0.000%	0.001%	0.000%	0.000%	0.000%
Malta	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%
Netherlands	0.000%	0.000%	0.000%	0.001%	0.000%	0.000%	0.000%
Poland	0.008%	0.002%	0.001%	0.004%	0.003%	0.002%	0.002%
Portugal	0.002%	0.001%	0.002%	0.001%	0.001%	0.000%	0.001%
Romania	0.010%	0.007%	0.007%	0.004%	0.012%	0.001%	0.002%
Slovakia	0.008%	0.003%	0.001%	0.007%	0.006%	0.000%	0.001%
Slovenia	0.004%	0.002%	0.001%	0.007%	0.003%	0.000%	0.001%
Spain	0.009%	0.003%	0.004%	0.004%	0.008%	0.003%	0.003%
Sweden	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%
Total EU27	0.005%	0.001%	0.001%	0.003%	0.004%	0.001%	0.001%
Albania	0.047%	0.029%	0.033%	0.079%	0.066%	0.014%	0.019%
Armenia	0.292%	0.212%	0.013%	0.161%	0.274%	0.164%	0.132%
Azerbaijan	0.272%	0.079%	0.012%	0.082%	0.265%	0.071%	0.073%
Belarus	0.060%	0.044%	0.009%	0.059%	0.067%	0.048%	0.053%
Bosnia-Herzegovina	0.018%	0.030%	0.029%	0.133%	0.016%	0.003%	0.042%
Georgia	0.213%	0.113%	0.010%	0.137%	0.147%	0.083%	0.078%
Iceland	0.000%	0.000%	0.000%	0.001%	0.000%	0.000%	0.000%
Kazakhstan	0.045%	0.015%	0.012%	0.023%	0.034%	0.010%	0.013%
Kosovo	0.053%	0.048%	0.046%	0.145%	0.045%	0.030%	0.048%
Kyrgyzstan	0.286%	0.231%	0.009%	0.321%	0.209%	0.170%	0.191%
North Macedonia	0.007%	0.021%	0.020%	0.066%	0.005%	0.001%	0.023%
Moldova	0.000%	0.000%	0.001%	0.000%	0.000%	0.000%	0.000%
Montenegro	0.067%	0.027%	0.010%	0.156%	0.073%	0.005%	0.021%
Norway	0.024%	0.018%	0.018%	0.033%	0.023%	0.014%	0.021%
Russia	0.073%	0.007%	0.038%	0.106%	0.063%	0.001%	0.012%
Serbia	0.004%	0.002%	0.000%	0.002%	0.002%	0.001%	0.001%
Switzerland	0.031%	0.024%	0.021%	0.071%	0.025%	0.016%	0.027%
Tajikistan	0.880%	0.880%	0.000%	0.938%	0.745%	0.740%	0.746%
Türkiye	0.034%	0.024%	0.021%	0.025%	0.035%	0.022%	0.024%
Turkmenistan	0.048%	0.030%	0.000%	0.032%	0.038%	0.024%	0.025%
Ukraine	0.086%	0.079%	0.071%	0.238%	0.102%	0.046%	0.106%
United Kingdom	0.000%	0.000%	0.000%	0.002%	0.000%	0.000%	0.000%
Uzbekistan	0.216%	0.115%	0.000%	0.123%	0.139%	0.087%	0.093%
Total non-EU	0.028%	0.018%	0.000%	0.027%	0.027%	0.015%	0.019%

Source: GAINS model (CIAM, dataset v7a); US and Canada are not included in the optimized cases

Table 8: Changes of mortality risks (premature deaths due to $PM_{2.5}$/100.000) in % of 2015 numbers - Scenarios include the core cases and the variant of 55%/45% excluding 3 non-parties in 2040

	2040 relative to 2015				2050 relative to 2015		
	50%/50%	55%/45%	55%/45% exNP	60%/45%	50%/50%	55%/45%	60%/45%
Austria	-68%	-67%	-67%	-69%	-70%	-70%	-71%
Belgium	-63%	-64%	-63%	-66%	-66%	-66%	-67%
Bulgaria	-62%	-65%	-63%	-68%	-67%	-66%	-69%
Croatia	-74%	-75%	-74%	-79%	-78%	-78%	-79%
Cyprus	-40%	-43%	-40%	-47%	-40%	-40%	-46%
Czech Rep.	-75%	-75%	-74%	-77%	-79%	-78%	-79%
Denmark	-60%	-60%	-59%	-62%	-64%	-64%	-65%
Estonia	-43%	-44%	-43%	-46%	-46%	-46%	-48%
Finland	-41%	-42%	-42%	-45%	-45%	-45%	-48%
France	-65%	-65%	-65%	-66%	-66%	-66%	-67%
Germany	-65%	-65%	-64%	-68%	-68%	-68%	-69%
Greece	-58%	-59%	-58%	-62%	-61%	-61%	-63%
Hungary	-68%	-71%	-68%	-73%	-74%	-74%	-75%
Ireland	-56%	-56%	-56%	-58%	-58%	-57%	-58%
Italy	-60%	-61%	-59%	-62%	-65%	-64%	-65%
Latvia	-62%	-62%	-61%	-65%	-66%	-66%	-67%
Lithuania	-59%	-60%	-58%	-63%	-64%	-64%	-66%
Luxembourg	-67%	-67%	-66%	-69%	-70%	-69%	-70%
Malta	-34%	-34%	-34%	-35%	-33%	-32%	-33%
Netherlands	-58%	-58%	-57%	-61%	-62%	-62%	-63%
Poland	-76%	-76%	-76%	-78%	-79%	-79%	-80%
Portugal	-45%	-46%	-45%	-47%	-49%	-49%	-51%
Romania	-59%	-64%	-58%	-68%	-68%	-68%	-71%
Slovakia	-68%	-70%	-67%	-73%	-73%	-73%	-74%
Slovenia	-63%	-66%	-63%	-69%	-72%	-71%	-73%
Spain	-54%	-53%	-54%	-54%	-56%	-55%	-56%
Sweden	-46%	-46%	-46%	-48%	-49%	-49%	-50%
Total EU27	-64%	-64%	-63%	-67%	-68%	-67%	-68%
Albania	-53%	-60%	-53%	-70%	-59%	-63%	-69%
Armenia	-29%	-41%	-25%	-48%	-29%	-38%	-47%
Azerbaijan	-32%	-34%	-27%	-38%	-30%	-30%	-34%
Belarus	-38%	-42%	-38%	-48%	-40%	-41%	-47%
Bosnia-Herzegovina	-52%	-65%	-52%	-74%	-60%	-65%	-75%
Georgia	-58%	-65%	-52%	-71%	-57%	-64%	-69%
Iceland	11%	9%	11%	0%	17%	15%	13%
Kazakhstan	-50%	-56%	-49%	-61%	-52%	-53%	-61%
Kosovo	-34%	-53%	-34%	-71%	-47%	-58%	-70%
Kyrgyzstan	-37%	-41%	-26%	-52%	-35%	-35%	-47%
North Macedonia	-53%	-62%	-52%	-72%	-57%	-63%	-71%
Moldova	-40%	-51%	-40%	-63%	-47%	-53%	-62%
Montenegro	-50%	-66%	-49%	-74%	-61%	-66%	-78%
Norway	-31%	-31%	-31%	-34%	-34%	-34%	-36%
Russia	-22%	-27%	-22%	-40%	-25%	-24%	-37%
Serbia	-52%	-58%	-52%	-67%	-62%	-63%	-68%
Switzerland	-59%	-58%	-58%	-59%	-62%	-61%	-62%
Tajikistan	-16%	-24%	72%	-36%	-12%	-15%	-23%
Türkiye	-51%	-57%	-51%	-61%	-52%	-52%	-61%
Turkmenistan	27%	26%	60%	22%	44%	46%	40%
Ukraine	-28%	-40%	-27%	-53%	-28%	-33%	-48%
United Kingdom	-50%	-50%	-49%	-53%	-54%	-54%	-55%
Uzbekistan	-20%	-26%	5%	-34%	-18%	-18%	-30%
Total non-EU	-38%	-43%	-35%	-52%	-40%	-41%	-50%

Source: GAINS model (CIAM, dataset v7a); US and Canada are not included in the optimized cases

Table 9: Changes in biodiversity risks (average accumulated exceedance min CLempN) in % of 2015- Scenarios include the core cases and the variant of 55%/45% excluding 3 non-parties in 2040

	Ecosystem area [km2]	2040 relative to 2015				2050 relative to 2015		
		50%/50%	55%/45%	55%/45% exNP	60%/45%	50%/50%	55%/45%	60%/45%
Austria	54375	-82%	-78%	-75%	-79%	-85%	-82%	-83%
Belgium	14455	-74%	-72%	-71%	-73%	-75%	-73%	-73%
Bulgaria	47399	-91%	-88%	-89%	-89%	-93%	-90%	-90%
Croatia	34210	-90%	-83%	-83%	-86%	-93%	-86%	-87%
Cyprus	3358	-44%	-32%	-28%	-32%	-41%	-29%	-29%
Czech Republic	34871	-84%	-82%	-81%	-82%	-87%	-86%	-86%
Denmark	7600	-78%	-75%	-75%	-77%	-82%	-80%	-80%
Estonia	32188	-64%	-61%	-59%	-61%	-69%	-66%	-66%
Finland	268395	-90%	-89%	-89%	-89%	-93%	-93%	-93%
France	234567	-79%	-74%	-74%	-75%	-82%	-77%	-77%
Germany	158800	-78%	-75%	-73%	-76%	-81%	-79%	-79%
Greece	66817	-82%	-78%	-80%	-78%	-83%	-80%	-80%
Hungary	26238	-91%	-85%	-85%	-88%	-93%	-88%	-88%
Ireland	17283	-31%	-30%	-30%	-31%	-37%	-32%	-36%
Italy	139015	-69%	-62%	-61%	-62%	-74%	-68%	-68%
Latvia	44707	-69%	-65%	-61%	-65%	-73%	-69%	-70%
Lithuania	28720	-74%	-71%	-66%	-71%	-76%	-74%	-74%
Luxembourg	1541	-73%	-70%	-69%	-71%	-78%	-76%	-76%
Malta	9	-9%	-6%	-7%	-7%	1%	5%	4%
Netherlands	11366	-53%	-51%	-51%	-52%	-55%	-54%	-55%
Poland	117322	-84%	-81%	-79%	-81%	-88%	-86%	-87%
Portugal	44976	-70%	-65%	-68%	-63%	-69%	-64%	-65%
Romania	96882	-83%	-79%	-79%	-76%	-85%	-76%	-76%
Slovakia	24117	-94%	-92%	-91%	-93%	-95%	-93%	-93%
Slovenia	13383	-85%	-80%	-78%	-82%	-88%	-83%	-83%
Spain	235122	-66%	-62%	-63%	-61%	-69%	-65%	-65%
Sweden	357424	-79%	-78%	-77%	-78%	-83%	-82%	-82%
Total EU27	2115140	-77%	-73%	-72%	-73%	-80%	-77%	-77%
Albania	17353	-69%	-62%	-64%	-63%	-74%	-64%	-64%
Armenia	11065	-48%	-45%	-32%	-45%	-48%	-45%	-44%
Azerbaijan	28073	-53%	-46%	-25%	-46%	-53%	-45%	-45%
Belarus	117179	-68%	-65%	-46%	-65%	-69%	-65%	-65%
Bosnia and Herzegovina	33596	-92%	-84%	-85%	-90%	-95%	-87%	-87%
Georgia	49175	-80%	-77%	-65%	-77%	-82%	-79%	-79%
Iceland	58620	-65%	-65%	-65%	-65%	-61%	-61%	-61%
Kazakhstan	812522	-21%	-6%	35%	-6%	-14%	2%	2%
Kosovo	5937	-91%	-88%	-89%	-90%	-92%	-89%	-89%
Kyrgyzstan	53814	-23%	-18%	55%	-18%	-17%	-13%	-13%
North Macedonia	15525	-94%	-57%	-92%	-61%	-96%	-61%	-62%
Republic of Moldova	4266	-98%	-93%	-92%	-94%	-98%	-95%	-95%
Montenegro	10650	-75%	-89%	-70%	-89%	-79%	-91%	-91%
Norway	209371	-82%	-87%	-81%	-88%	-86%	-86%	-86%
Russian Federation	3323795	-54%	-50%	-48%	-50%	-55%	-49%	-49%
Serbia	33237	-91%	-56%	-73%	-89%	-94%	-57%	-58%
Switzerland	22305	-63%	-58%	-52%	-58%	-63%	-60%	-60%
Tajikistan	32941	-19%	-17%	76%	-17%	-17%	-15%	-15%
Turkmenistan	113793	-35%	-30%	73%	-30%	-24%	-19%	-19%
Türkiye	309969	-29%	-26%	-24%	-25%	-28%	-24%	-24%
Ukraine	147651	-69%	-66%	-64%	-66%	-72%	-65%	-66%
United Kingdom	63632	-67%	-66%	-66%	-68%	-70%	-68%	-70%
Uzbekistan	104865	-28%	-24%	58%	-24%	-26%	-23%	-23%
Non-EU	5579336	-52%	-48%	-38%	-48%	-53%	-47%	-47%

ANNEX 2: Impacts of excluding non-parties to the Convention from target setting

83. Tajikistan, Turkmenistan and Uzbekistan are included in the EMEP modelling domain. However, they are not part of the Air Convention. It is unclear whether and when they will enter the Convention and when they would be able to validate the experts' emission projections and critical loads data. Instead of assuming these non-parties would deliver a cost-effective contribution to reaching the common risk reduction targets for health and biodiversity losses, an alternative analysis was made where only the current parties to the Convention would contribute to these common targets.

84. Assuming that Tajikistan, Turkmenistan and Uzbekistan will not reduce emissions beyond Current Legislation, this will raise the costs for Convention parties to meet 55-60% health targets. Moreover, in this case for 6 ecoystems (mainly grasslands) the 45-50% targets to reduce the AAE cannot be met even with MTFR measures. These 6 ecosystems had to be excluded from target setting. Biodiversity risk reduction in these 6 ecosystems will be the result of measures needed to meet the 45-50% targets for other ecosystems, and less than 45%.

85. Comparing the 55%/45% 'mid-ambition' scenario for 2040, where all UNECE countries are included (excl. NA) with the case with the same ambitions, but 3 non-parties excluded (exNP), would for many EECCA countries lead to less emission reduction obligations (mainly for ammonia), due to the exclusion of the 45% target for the most sensitive ecosystem. For meeting the domain wide 55% health target and the 45% biodiversity target, GAINS selects the most cost-effective available in the whole domain. This involves additional measures for NOx in Western Europe, additional ammonia reduction in a few countries with larger change for Serbia, additional SO_2-reduction in several EECCA countries with largest change for Russia, while for $PM_{2.5}$ and NMVOC estimated reduction ambition would be slightly lower for several countries.

86. Table 10 compares the 55%/45% 'mid-ambition' scenario for 2040, where all UNECE countries are included (excl. NA) with the case with the same ambition, but 3 non-parties excluded (***exNP***); Green indicates increase in emissions in the ***exNP*** case (less demanding ERC by >5%). Red indicates lower emissions in the ***exNP*** case (more demanding ERC by >5%).

87. The mid-ambition scenario without the 3 non-parties will reduce the total costs beyond Baseline in 2040 from € 2.3 bn to € 1.5 bn. The price for this is a lower reduction of health risks and reduction of biodiversity loss in grassland ecosystems in EECCA countries (Table 11).

88. Detailed country results for the mid-ambition 55%/45% scenario, with and without non-parties, can be found in the GAINS-Explorer (see scenario group "UNECE_LRTAP_v7a-sensitivity").

89. How emission reductions in 2040 relative to 2015 would change between the core scenario with 55%/45% ambition including all UNECE countries and the same scenario from a sensitivity analysis excluding the three non-Parties to the Air Convention (Tajikistan, Turkmenistan and Uzbekistan) is indicated in Table *1* to Table 5 and Table 7 to Table 9.

90. In Table 10 shading indicates that change in emission reduction is larger than 5% - green shading when emissions in 2040 are larger when 3 non-parties are excluded and red shading when they are smaller, i.e., in the latter case more ambitious reduction targets would be necessary.

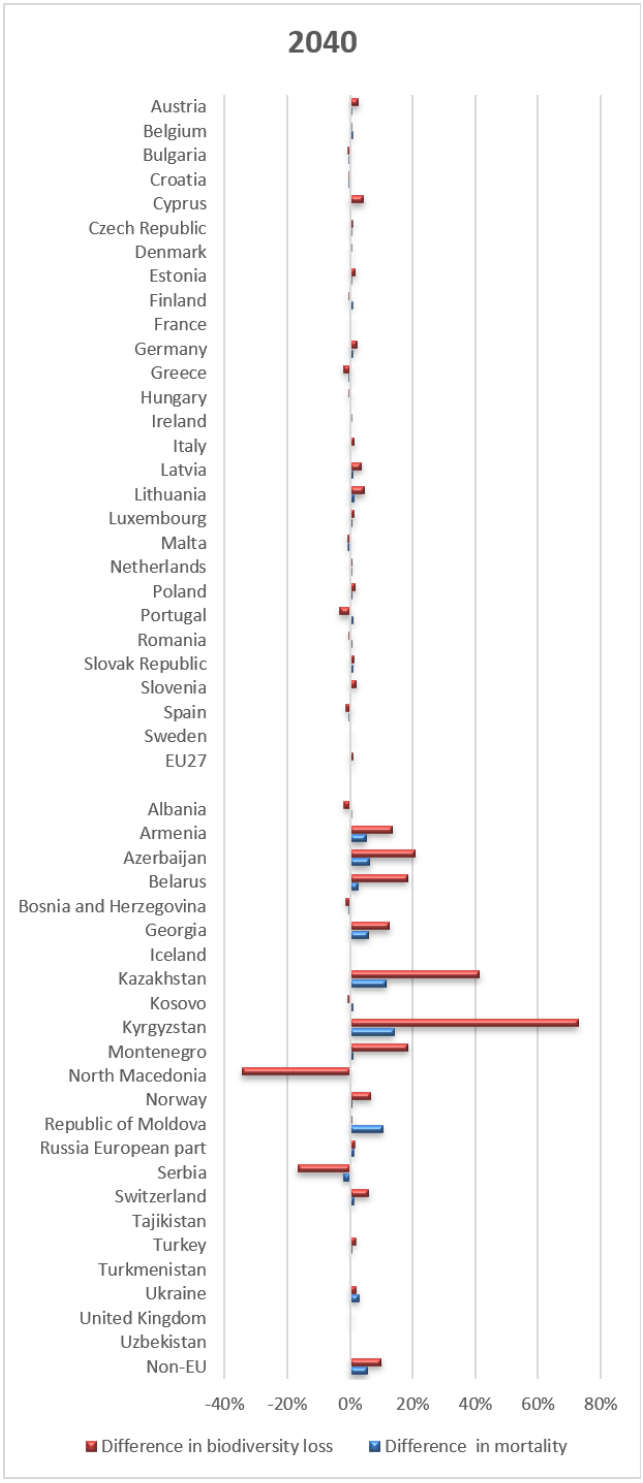
Table 10: Changes in emissions reduction between 2015 and 2040 for the mid-ambition 55%/45% scenario when excluding 3 non-parties, compared to the mid-ambition scenario involving all UNECE-countries without NA

	PM2.5	NH3	NOX	VOC	SO2
Albania	0%	-1%	0%	0%	0%
Armenia	1%	9%	37%	1%	0%
Austria	0%	4%	1%	0%	0%
Azerbaijan	6%	10%	30%	1%	0%
Belarus	0%	29%	0%	0%	0%
Belgium	0%	0%	0%	0%	0%
Bosnia-Herzegovina	1%	0%	0%	0%	0%
Bulgaria	0%	-1%	-1%	-1%	0%
Croatia	0%	1%	0%	0%	0%
Cyprus	0%	4%	0%	0%	0%
Czech Rep.	0%	0%	0%	0%	0%
Denmark	0%	0%	0%	0%	0%
Estonia	0%	0%	-1%	0%	0%
Finland	1%	-2%	-3%	2%	0%
France	1%	0%	0%	0%	0%
Georgia	1%	12%	21%	0%	-4%
Germany	0%	3%	0%	0%	0%
Greece	0%	-3%	-3%	0%	0%
Hungary	0%	0%	0%	0%	0%
Iceland	0%	0%	0%	0%	0%
Ireland	0%	0%	0%	0%	0%
Italy	0%	2%	0%	0%	0%
Kazakhstan	1%	0%	1%	0%	0%
Kosovo	1%	1%	0%	0%	0%
Kyrgyzstan	1%	15%	44%	0%	0%
Latvia	0%	0%	0%	0%	0%
Lithuania	0%	6%	0%	0%	0%
Luxembourg	0%	2%	0%	0%	0%
North Macedonia	1%	2%	-2%	0%	0%
Malta	0%	0%	-2%	0%	0%
Moldova	9%	-1%	0%	5%	0%
Montenegro	0%	0%	0%	1%	0%
Netherlands	0%	0%	0%	0%	-1%
Norway	3%	-1%	-3%	0%	0%
Poland	0%	3%	0%	0%	0%
Portugal	5%	-3%	-2%	0%	0%
Romania	0%	0%	-1%	0%	0%
Russia	0%	1%	-3%	0%	-12%
Serbia	0%	-21%	-2%	0%	0%
Slovakia	0%	11%	0%	0%	0%
Slovenia	0%	5%	1%	0%	0%
Spain	0%	-1%	-2%	0%	0%
Sweden	0%	-1%	0%	0%	0%
Switzerland	1%	7%	1%	0%	0%
Tajikistan					
Turkmenistan					
Türkiye	0%	0%	4%	0%	-1%
Ukraine	0%	0%	0%	0%	0%
United Kingdom	0%	0%	0%	0%	0%
Uzbekistan					
Total	2%	4%	3%	1%	-2%

Source: GAINS model (CIAM, dataset v7a); US and Canada are not included in the optimized cases

Table 11: Changes in premature mortality and biodiversity loss in 2040 in the mid-ambition scenario excluding 3 non-parties compared to the 55%/45% scenario including all UNECE countries (without NA) - Red cells in the table indicate an increase in premature deaths and risk of biodiversity loss by more than 5%, green cells indicate decline of indicators by more than 5%.

	Difference in:	
Country/region	Premature mortality	Biodiversity loss
Austria	1%	3%
Belgium	1%	1%
Bulgaria	0%	-1%
Croatia	0%	0%
Cyprus	0%	4%
Czech Republic	1%	1%
Denmark	0%	1%
Estonia	1%	2%
Finland	1%	0%
France	0%	0%
Germany	1%	2%
Greece	0%	-2%
Hungary	0%	0%
Ireland	0%	1%
Italy	0%	1%
Latvia	1%	4%
Lithuania	1%	4%
Luxembourg	1%	1%
Malta	-1%	-1%
Netherlands	1%	1%
Poland	1%	2%
Portugal	1%	-3%
Romania	1%	0%
Slovak Republic	1%	1%
Slovenia	0%	2%
Spain	0%	-1%
Sweden	0%	0%
EU27	0%	1%
Albania	0%	-2%
Armenia	5%	14%
Azerbaijan	6%	21%
Belarus	3%	18%
Bosnia and Herzegovina	0%	-1%
Georgia	6%	13%
Iceland	0%	0%
Kazakhstan	12%	41%
Kosovo	1%	-1%
Kyrgyzstan	14%	73%
North Macedonia	0%	-34%
Republic of Moldova	10%	1%
Montenegro	1%	18%
Norway	1%	7%
Russia European part	1%	2%
Serbia	-2%	-17%
Switzerland	1%	6%
Tajikistan		
Turkmenistan		
Turkey	1%	2%
Ukraine	3%	2%
United Kingdom	0%	0%
Uzbekistan		
Non-EU	6%	10%



Source: GAINS model (CIAM, dataset v7a); US and Canada are not included in the optimized cases

ANNEX 3: Sensitivity analyses

91. For the core scenarios four additional sensitivity analyses have been calculated:

A. Excluding from health target setting countries where no population is exposed to concentration levels above the WHO Air quality guideline level of 5 µg/m^3

B. Assuming that livestock numbers and fertilizer use will remain at the level of 2025 until 2050

C. Assuming that fuelwood use in the residential sector will remain at the level of 2025 until 2050

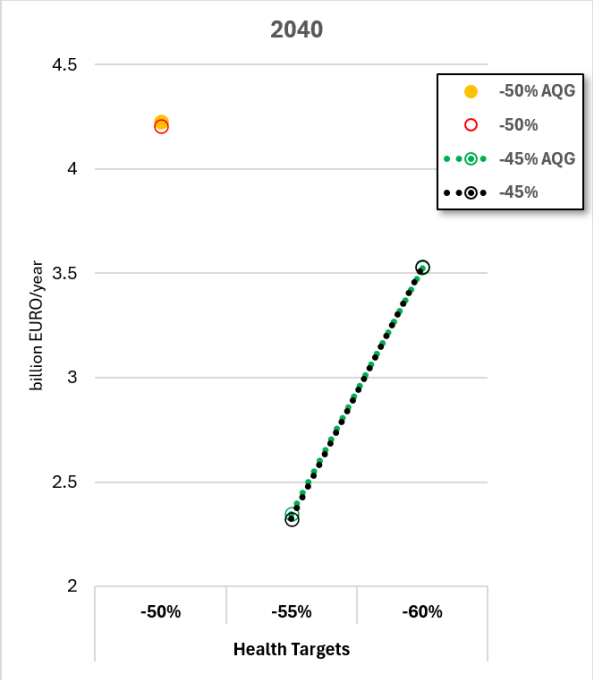
D. Assuming no further increase of electric passenger and light duty vehicles takes place after 2025

92. This analysis was done for 2040 and the three 'core' scenarios (50%/50%; 55%/45%; 60%/45%) for the whole UNECE Europe regions (excluding only NA).

A. Excluding from health target setting countries where no population is exposed to concentration levels above *the WHO Air quality guideline level of 5 µg/m^3*

93. This will exclude countries where in the baseline 2040 no population is exposed to levels above 5 µg/m^3 from health risk target setting and further mitigation: *Finland, Estonia, Sweden, Norway, Iceland and Ireland*. The differences in total costs in 2040 for UNECE (excl. NA) are less than 1%, compared to the solution where all countries are included in the health target setting. Excluding countries with no exceedance of WHO air quality guidelines will not change the overall cost-effectiveness to meet biodiversity targets in 2040.

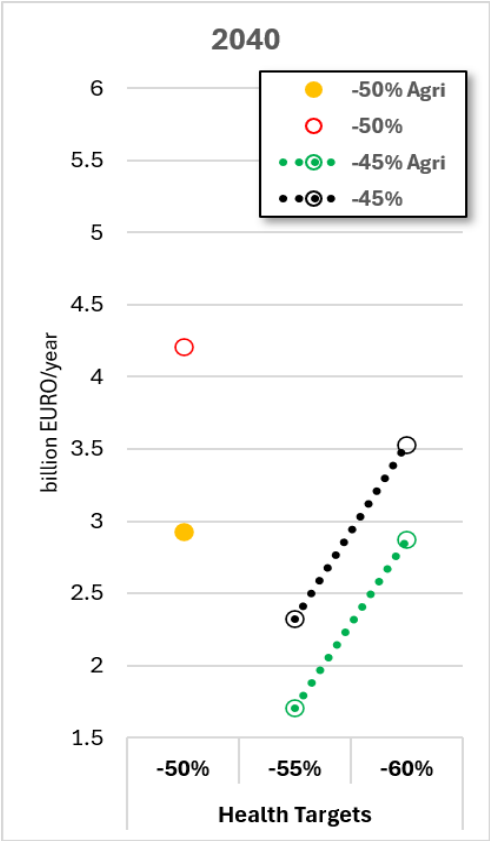
Figure 18: Cost-effectiveness for the UNECE (excl. NA) with and without countries where air quality will meet the WHO AQG levels in 2040 for the 50%/50% case (red and yellow dots respectively), and the 55%/45% and 60%/45% cases (black and green lines respectively)



B. Freezing livestock numbers and fertilizer use after 2025

94. The baseline scenario has varying trends for agricultural activities, i.e., with some reductions of livestock numbers (except poultry) and nitrogen fertilizer use in the EU and often strong increase in livestock and fertilizer use for several non-EU countries, especially EECCA. A freeze in livestock numbers and fertilizer use will strongly reduce the total costs of all core scenarios in 2040 by up to 30%, i.e., between € 0.7 bn and € 1.3 bn.

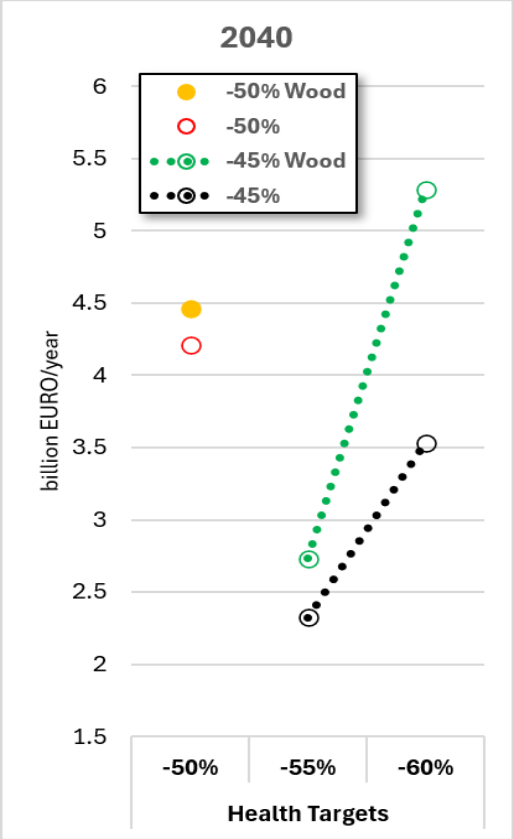
Figure 19: Cost-effectiveness for the UNECE (excl. NA) with and without an increase in livestock numbers and fertilizer use for the 50%/50% case (red and yellow dots respectively), and the 55%/45% and 60%/45% cases (black and green lines respectively)



C. Freezing fuelwood use in the residential sector after 2025

95. The baseline scenario assumes a decline in the use of fuelwood for residential heating, because of investments in energy savings, heat pumps and district heating. If use of fuelwood were to remain at the 2025 level, the total costs of all core scenarios would significantly increase. For the 55% health target, costs in 2040 would be 5% higher (€ 0.25 bn), but for the 60% target, the costs would become 50% higher (€ 1.7 bn for the whole UNECE excl. NA).

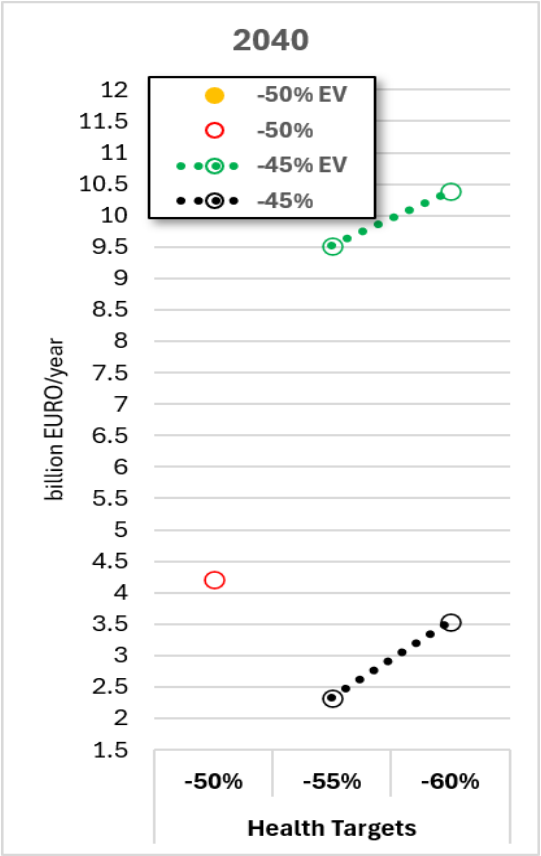
Figure 20: Cost-effectiveness for the UNECE (excl. NA) without and with a decrease in fuelwood use for the 50%/50% case (red and yellow dots respectively), and the 55%/45% and 60%/45% cases (black and green lines respectively)



D. No further penetration of electrical passenger cars after 2025

96. The baseline scenario assumes a strong increase in the number of electric vehicles and rapid decline of internal combustion engines in cars and light duty vehicles. In a sensitivity scenario it is assumed that the number of electric passenger cars and light vehicles would remain constant at the 2025 level, while the increase in EVs (as projected in the Baseline) would be instead represented by new gasoline vehicles which would follow the current legislation standards. This would make achieving the 50% biodiversity target infeasible (therefore, Figure 21 is missing the orange dot), while the costs in 2040 for the 55%/45% and 60%/45% cases would become about 3 times higher.

Figure 21: Cost-effectiveness for the UNECE (excl. NA) with and without an increase in the share of electric vehicles for the 55%/45% and 60%/45% cases (black and green lines respectively). The 50%/50% target is only feasible in the case of increasing EVs (red circle)



Detailed country results of the sensitivity cases can be found in the GAINS-Explorer.

ANNEX 4: Overview of mitigation costs for all optimized scenarios

97. Figure 22 and Figure 24 provide an overview of the distribution of additional abatement costs (beyond baseline) by optimized scenario and key sector in 2040 and 2050, respectively. The four numbers after the letter "J" in the scenario names indicate the ambition level for health (first two numbers) and for biodiversity (third and fourth number) modelled in each scenario.

98. The first four bars present the results for an ambition level of 50% risk reduction for health and for decreasing ambition levels in the risk reduction for biodiversity (in 5% steps from 50% to 35%). With decreasing ambition for biodiversity protection, costs for agriculture, industry, and also costs for transport, decrease. The reason is decreasing demand for reduction of emissions of reactive nitrogen species, mostly NH_3 from agriculture and NOx from industry and transport.

99. The following three bars indicate a 55% reduction in health risks combined with a reduction in biodiversity risk from 50% to 40%. The additional costs are higher than in the previous block of scenarios due to the higher ambition level for health protection. However, with decreasing ambition for biodiversity (45% and 40%) costs become lower than in the 50%/50% ambition scenario. As a difference to the scenarios with 50% health risk reduction ambition, the 55% ambition increases pressure also on the residential sector and transport.

100. The last three bars indicate a 60% reduction in health risks combined with a reduction in biodiversity risk from 50% to 40%. With this ambition level, additional costs are significantly higher for all sectors, and particularly for the residential sector and industry.

101. These changes in additional costs show a similar pattern in 2040 and 2050 but cost increases between the three scenario groups are clearly less pronounced in 2050 owing to continuing decline of some key emission sources like residential wood burning.

Figure 22: Overview of cost for key sources in optimized scenarios – results for 2040

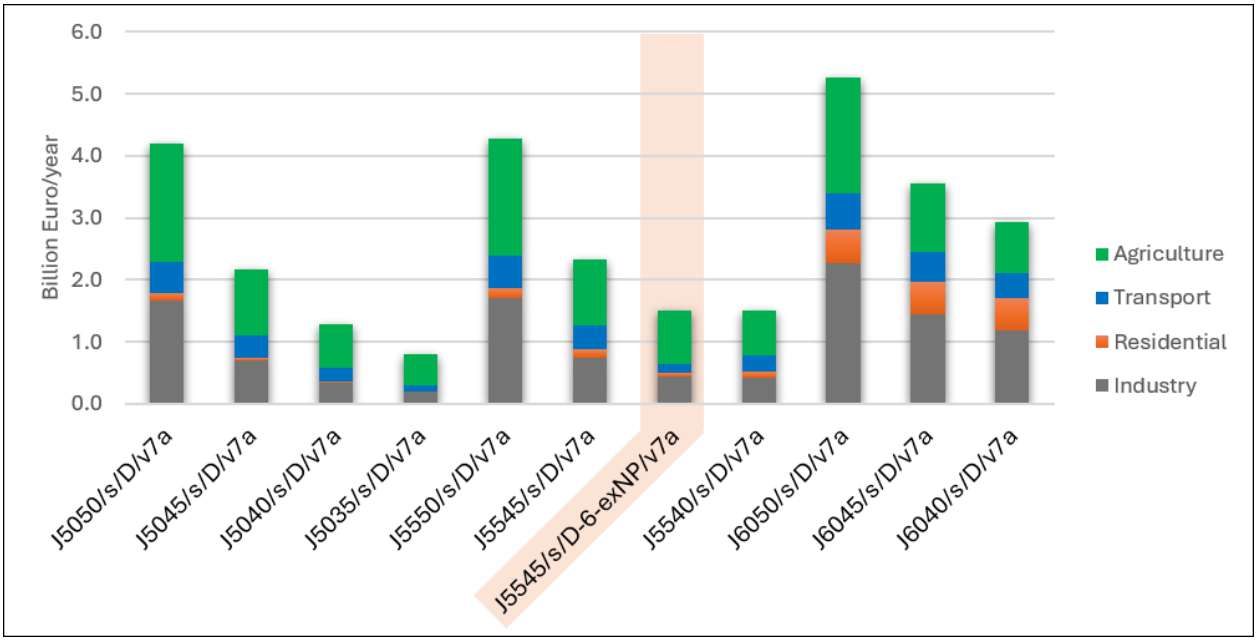
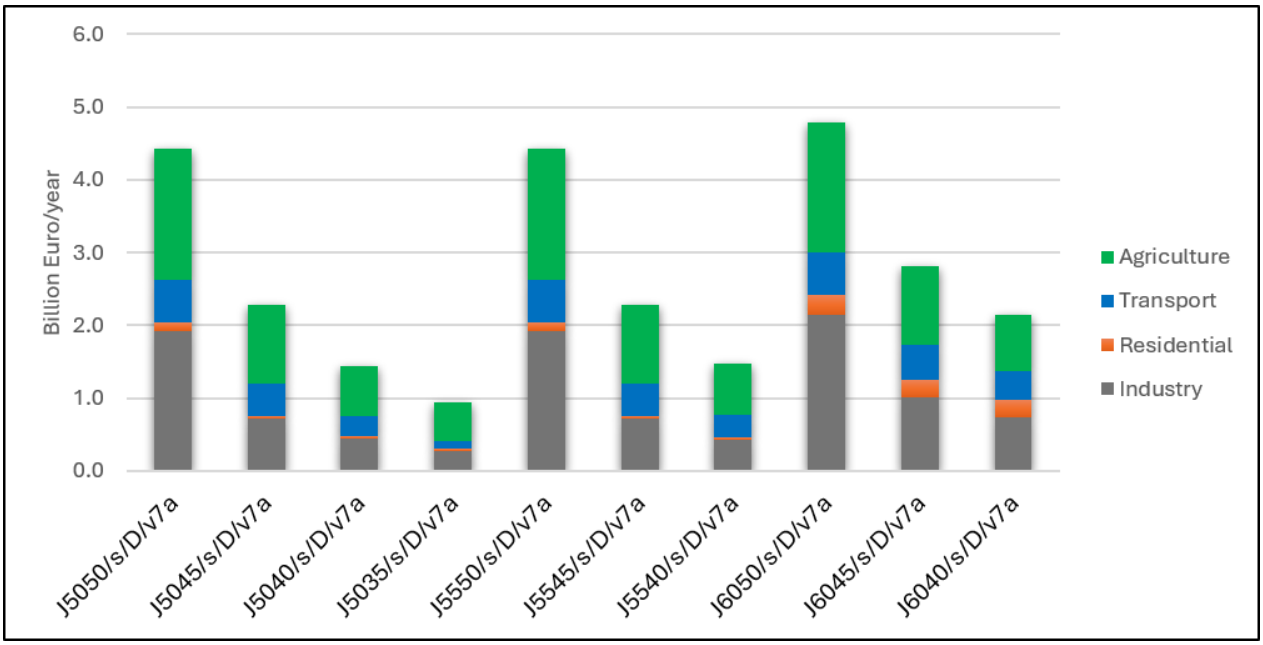


Figure 23: Overview of cost for key sources in optimized scenarios – results for 2050



ANNEX 5: Assessing health effects from ozone

102. There are also known health effects from ozone. Exposure-response functions recommended in the initial WHO HRAPIE assessment (WHO, 2013) and have been used in the GAINS model and more generally in health impact assessment and cost-benefit analysis under the air convention for many years. The recent HRAPIE 2 systematic reviews (WHO, 2025) found strong evidence for short term exposure to ozone and all-cause natural mortality. The related response function from Vicedo-Cabrera et al. (2024) received the highest confidence rating (class A) in HRAPIE 2. Furthermore, HRAPIE 2 suggests ranges of exposure for which the epidemiological evidence of the function is strongest. This range starts at 30ppb, therefore the use of the functions with SOMO30 is recommended. An alternative function for long-term exposure to ozone and respiratory mortality (Kasdagli et al., 2024) that would be used with MDA8[10] only received a lower confidence rating (B+) and is not used here.

103. A 50% target for the reduction of premature deaths due to ground level ozone between 2015 and 2050 is challenging. Current air pollution policies are largely offset by the global increase in methane emissions. Contrary to $PM_{2.5}$, the feasibility of the ozone target is more dependent on global cooperation to reduce ozone precursors, including methane. Global action on methane would be a key part of the solution and further NOx and NMVOC emission mitigation would still be important to reduce ground level ozone within the UNECE region.

104. CIAM has updated ozone modelling in GAINS in collaboration with MSC-W. Inclusion of O_3 in joint optimization is amongst the tasks that will be addressed in 2027.

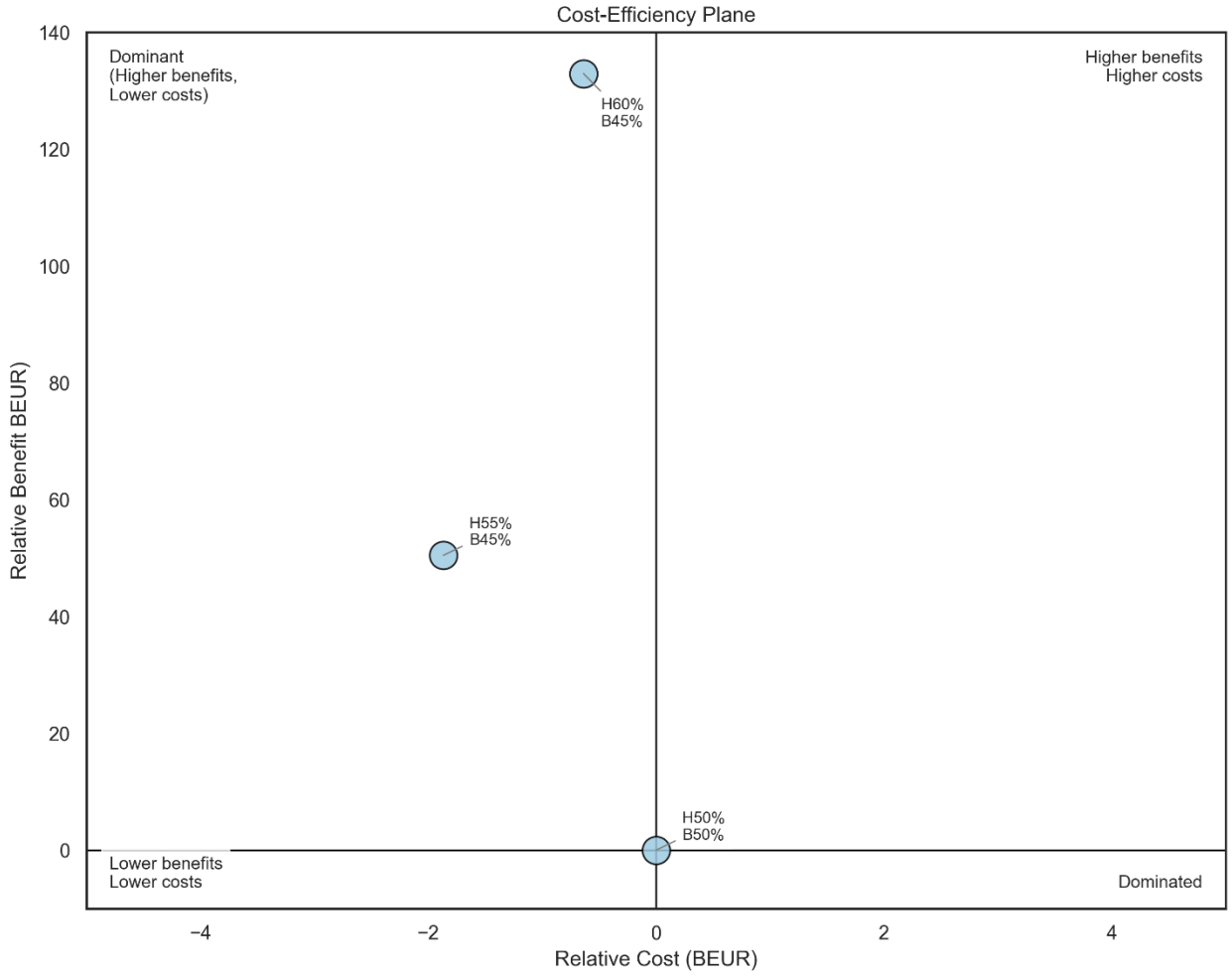
105. Further information is available in the policy brief version 6.

[10] MDA8 refers to the annual average of daily maximum 8-hour running mean O_3 concentrations.

ANNEX 6: Additional CBA results

106. The CBA figures shown thus far show benefits and costs compared to the baseline scenario. It is however interesting to also compare the policy scenarios to each other. But some scenarios cannot be easily compared between each other due to non-linear differences in the costs and benefits. When comparing incremental benefits and costs of some scenarios, the B/C ratio can become negative, which is hard to interpret. Therefore, a 'cost-efficiency plot' is used to show how incremental costs and benefits relate to any specific scenario. In Figure 24, costs and benefits relative to the 50%/50% scenario are shown as circles. Relative abatement costs are shown on the x-axis and range from -5 billion € up to +5 billion €. Relative benefits are shown on the y-axis, ranging from ~-10 billion € to +140 billion €. The position of the circle relative to the 50%/50% scenario circle is what is interesting. The scenarios that are most socio-economically favorable to the 50%/50% scenario are in the upper left field of the graph (dominant). Whilst the lower right quadrant is clearly unfavorable. As can be seen, both the other main scenarios are clearly socio-economically favorable over the 50%/50% scenario. As shown in Figure 16, the benefits of reducing emissions from baseline levels to levels corresponding to a risk reduction of 50% both for health and biodiversity are 20-40 times higher than the costs.

Figure 24: 2040 Cost-efficiency plot of the v7a scenarios compared to the 50%/50% scenario



107. Country-specific results have also been calculated for the three core scenarios. As can be seen in Figure 25 to Figure 27, compared to the baseline, all three core scenarios imply benefits higher than costs for all countries in the UNECE region (excl. North America).

Figure 25: 2040 B/C ratio per country for the 50% / 50% scenario compared to baseline

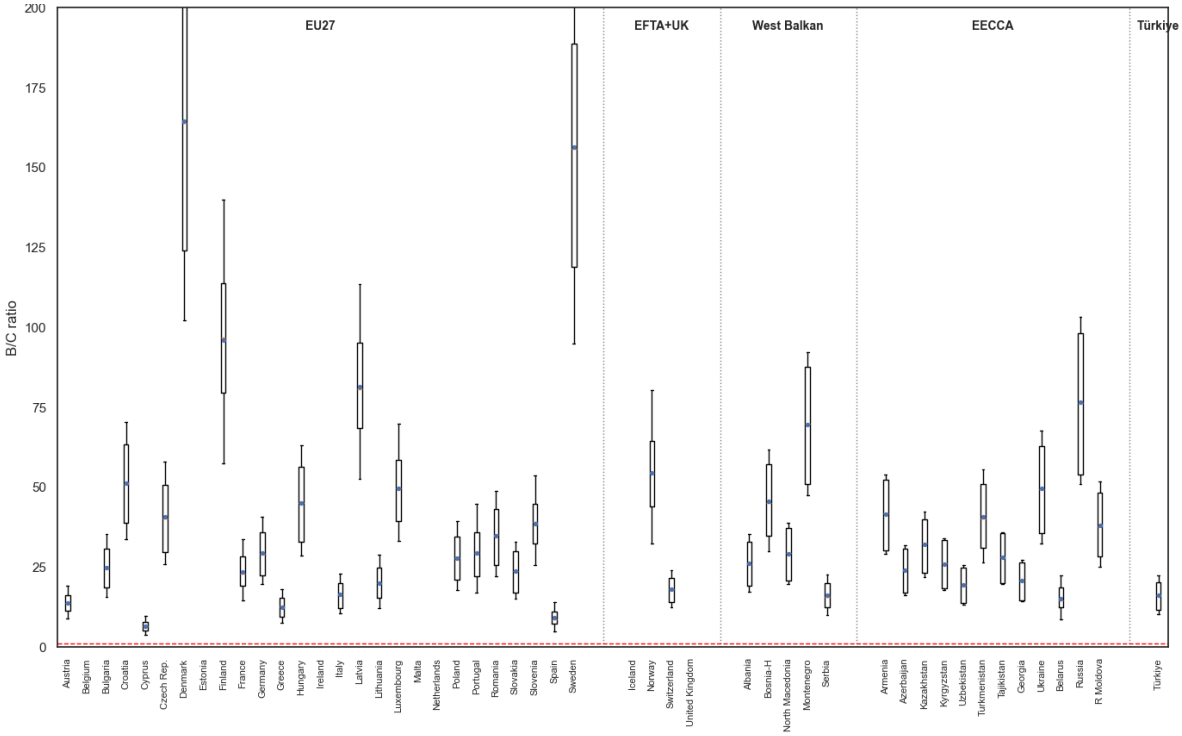


Figure 26: 2040 B/C ratio per country for the 55% / 45% scenario compared to baseline

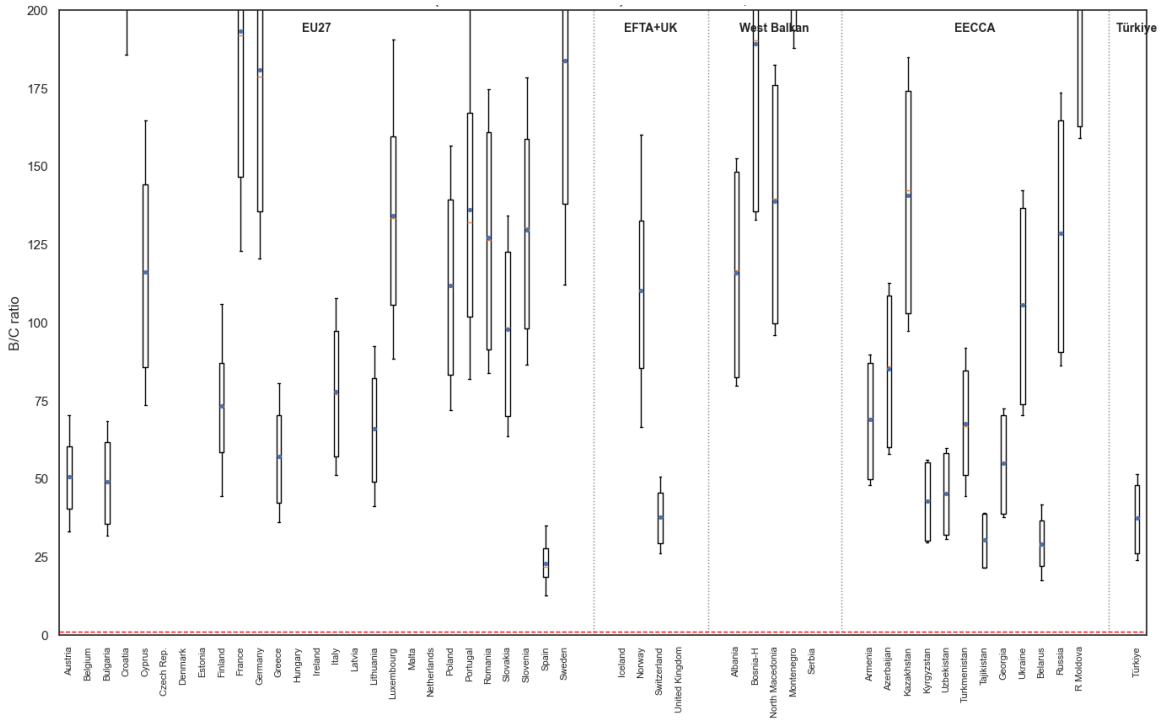


Figure 27: 2040 B/C ratio per country for the 60% / 45% scenario compared to baseline

