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The Fourth Clean Air Outlook

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1. INTRODUCTION

Air pollution in the EU has decreased over the last decades as a result of EU clean air legislation and joint action taken by the EU and national, regional and local authorities. Emissions of the five main air pollutants have fallen significantly between 2005-2024. And yet air quality remains a serious concern for the health of European citizens, especially in urban areas where pollution levels remain above WHO guideline levels[1], and for the state of ecosystems.

The EU's approach to improving air quality involves taking action in three areas (or 'pillars'). The first is on ambient air quality standards set in the **revised Ambient Air Quality Directive**[2]. The second is to set national emission reduction obligations under the National Emission reduction Commitments Directive (NEC Directive)[3] for the main transboundary air pollutants[4]. The third is to set emission standards at EU level, laid down in legislation, for key sources of pollution from vehicle and ship emissions to energy and industry, as well as ecodesign requirements for boilers and stoves. Most emissions from agricultural activities, however, are not regulated.

The EU has stepped up action under all three pillars to adapt to new policy and scientific developments. In particular, to implement the European Green Deal and the EU's ambition to reach zero pollution for a toxic-free environment, the Ambient Air Quality Directive has been revised to bring in more ambitious 2030 ambient air quality standards that will put the EU on a path to achieve zero air pollution at the latest by 2050. The standards are aligned more closely with the World Health Organization (WHO) updated air quality guidelines for key air pollutants[5]. These more ambitious ambient air quality standards mean that Member States will need to reduce their emissions of air pollutants further.

Under the second pillar, the **NEC Directive**, since 2022 the EU has carried out yearly **compliance checks** against the national emission reduction commitments for 2020-2029 for the five most harmful transboundary air pollutants. The first compliance check in 2022 using 2020 emission data revealed that **much more action is needed**, **in particular to reduce ammonia emissions**.

The third pillar is to tackle emissions at source. To this end, several revisions of legislation have been finalised since the Third Clean Air Outlook[6]. These include finalising the Euro 7 emission standard for new motor vehicles[7]; revising the Industrial

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1 https://europa.eu/eurobarometer/surveys/detail/2660

2 Directive (EU) 2024/2881 on ambient air quality and cleaner air for Europe.

3 Directive (EU) 2016/2284 on the reduction of national emissions of certain atmospheric pollutants.

4 Sulphur dioxides (SO_2), nitrogen oxides (NO_x), ammonia (NH_3), non-methane volatile organic compounds (NMVOC) and fine particulate matter ($PM_{2.5}$).

5 WHO (2021) WHO Global Air Quality Guidelines.

6 COM(2022) 673 final

7 Regulation (EU) 2024/1257 of the European Parliament and of the Council of 24 April 2024 on type-approval of motor vehicles and engines and of systems, components and separate technical units intended for such vehicles, with respect to their emissions and battery durability (Euro 7).

Emissions Directive[8], and importantly, the suite of Fit for 55 and REPowerEU initiatives. The work to revise the ecodesign criteria for solid fuel boilers and local space heaters is still ongoing.

This fourth edition of the Clean Air Outlook assesses the prospects of achieving the objectives of the NEC Directive for 2030 and beyond, in terms of reducing emissions of air pollutants and subsequent impacts on air quality, health, ecosystems and the economy. It complements the second report on implementation of the NEC Directive published in July 2024[9] by providing a forward-looking analysis. This analysis builds on the above legislative revisions and on the Communication for a 2040 climate target for the EU and its impact assessment[10].

The Fourth Clean Air Outlook directly contributes to the **Second Zero-Pollution Monitoring and Outlook report by the European Environment Agency (EEA) and the Joint Research Centre (JRC)**[11] by analysing the prospect of achieving the two clean air-related zero-pollution action plan[12] targets. The targets are:

- to reduce, by 2030 in the EU, by more than 55% the health impacts of air pollution (expressed as premature deaths); and
- to reduce by 25% the ecosystems where air pollution threatens biodiversity (compared to 2005 levels).

Finally, the Fourth Clean Air Outlook provides an updated analysis to feed into the ongoing **evaluation of the NEC Directive**, due to be finalised by the end of **2025**[13], and highlights the co-benefits for climate and air quality of reducing methane emissions.

2. STATE OF AIR POLLUTANT EMISSIONS AND AIR QUALITY

2.1. Current air pollutant emissions and air quality situation

Over the years, the EU has reduced emissions of the main air pollutants, though at very different paces depending on the type of pollutant. As seen in Figure 1, the EU has already reduced emissions of SO_2 by over 80%, NO_x by 50% and NMVOC and $PM_{2.5}$ by over 30% since 2005. However, emissions of **ammonia** (NH_3), over 90% of which are generated by the agricultural sector, **remain worryingly flat** and have even increased in recent years in some Member States.

8 Directive (EU) 2024/1785 of the European Parliament and of the Council of 24 April 2024 amending Directive 2010/75/EU of the European Parliament and of the Council on industrial emissions (integrated pollution prevention and control) and Council Directive 1999/31/EC on the landfill of waste.

9 COM(2024) 348 final.

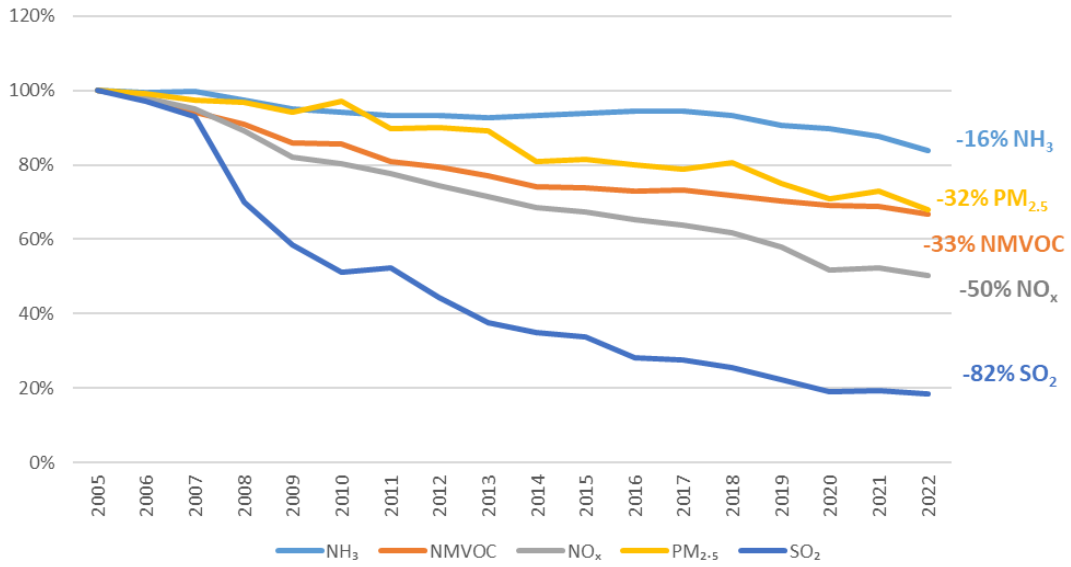
10 COM(2024) 63 final, underpinning impact assessment: SWD(2024) 63 final.

11 https://environment.ec.europa.eu/strategy/zero-pollution-action-plan/zero-pollution-targets_en

12 COM(2021) 400 final.

13 Under Article 13 of the NEC Directive. More details on the evaluation including the evaluation questions identified is available on Have your say as well as on the Commission's Air website.

Figure 1: Trend in EU-27 emissions, 2005-2022 (% of 2005 levels)



Source: European Environment Agency, based on Member States' air pollutant emission inventories

Despite an overall decrease in air pollution, the impacts of pollution on health and ecosystems remain problematic. In 2022, **most people living in urban areas in the EU were exposed to air pollution at levels that damage their health**[14]. The EEA estimates that air pollution is the single largest environmental health risk in Europe and one that disproportionately affects sensitive and vulnerable social groups[15]. Therefore, tackling air pollution is also a matter of fairness and equality.

Some 239 000 premature deaths are attributable to exposure to fine particulate matter in the EU annually, 70 000 to ozone and 48 000 to nitrogen dioxide[16]. The EEA also estimated that in 2022, 73% of ecosystems in the EU were above the critical load for eutrophication. Large proportions of forests and agroecosystems were exposed to ground-level ozone concentrations above threshold values, resulting in damage to vegetation and yields[17].

2.2. Compliance with EU clean air legislation

After reviewing the 2020 emission inventories submitted by Member States in 2022[18], the Commission concluded that **14 Member States did not meet their reduction commitments for at least one pollutant**. In 11 of these Member States, ammonia is one of the pollutants emitted in excess. As a consequence, the Commission issued letters of

14 European Environment Agency (2024) Europe's air quality status 2024.

15 EEA Report No 22/2018.

16 https://www.eea.europa.eu/en/analysis/publications/harm-to-human-health-from-air-pollution-2024. This estimate is based on air pollution concentration *monitoring* and only includes premature deaths attributable to air pollution above WHO air quality guidelines level, unlike other estimates in the remainder of this report from *modelling* results in Klimont et al., 'Support to the development of the fourth Clean Air Outlook', IIASA et al., 2025 [IIASA 2025], and which reflect all impacts (including below WHO guidelines level), to remain consistent with previous Clean Air Outlook analyses.

17 https://www.eea.europa.eu/en/analysis/publications/impacts-of-air-pollution-on-ecosystems-in-europe

18 Emission inventories are reported with a two-year time lag, which means that compliance checks against the 2020-29 obligations took place for the first time in 2022.

formal notice to 14 Member States for 19 cases of non-compliance[19]. Based on the 2023 compliance assessment, the Commission followed up by issuing additional letters of formal notice and reasoned opinions in November 2023[20]. The 2024 inventories indicate slight improvements, though the compliance situation for ammonia remains difficult with eight Member States still failing to meet their reduction commitment[21].

The 2022 emission data submitted by Member States in 2024 highlight that several Member States need to take **far stronger action** to reduce emissions of several pollutants **to fulfil their more ambitious emission reduction commitments for 2030** onwards. An EEA analysis[22] shows that 8 and 5 Member States respectively need to lower their $PM_{2.5}$ and NO_x emissions by over 30% between 2022 and 2030. For NMVOC and ammonia emissions, 8 and 10 Member States respectively need to reduce their emissions by over 10% between 2022 and 2030.

Member States set out their policies and measures to tackle air pollution in national air pollution control programmes[23]. The NEC Directive requires Member States to update their programmes at least every four years, or earlier[24] if the latest inventory or projected emissions data indicate that they will not meet the reduction commitments. The second Commission implementation report on the NEC Directive[25] summarises the assessment of Member State submissions of national air pollution control programmes.

In terms of compliance with the Ambient Air Quality Directives, as of January 2025, there were **25 ongoing infringement cases** due to poor application of the Ambient Air Quality Directives by 16 Member States. Proceedings before both the Court of Justice of the EU and national courts confirm that in many cases, air quality plans were inadequate and/or insufficient measures were adopted to reduce air pollution.

3. IMPLEMENTATION OF THE NEC DIRECTIVE

3.1. Changes in legislation and policy context

Since the Third Clean Air Outlook, Council and Parliament have finalised the legislative work on all files related to the 2021 Fit for 55 package, which increase the EU's ambition to reduce greenhouse gas emissions to at least 55% below 1990 levels by 2030. The ambition level was brought up further through the REPowerEU plan[26] to end the EU's dependency on gas, oil and coal imports from Russia.

In February 2024, the European Commission presented a **Communication for a 2040 climate target** for the EU and its accompanying impact assessment and recommended reducing the EU's net greenhouse gas emissions by 90% in 2040 relative to 1990 levels. The evolution of the EU's energy system in the 'S3 scenario' of that impact assessment,

19 https://ec.europa.eu/commission/presscorner/detail/EN/inf_23_142
20 https://ec.europa.eu/commission/presscorner/detail/en/inf_23_5380.
21 The outcomes of the 2024 inventory review are summarised in the horizontal review report 2024.
22 https://www.eea.europa.eu/publications/national-emission-reduction-commitments-directive-2024; these figures are based on Member States' data as submitted, not taking in account the Commission's review of these submissions.
23 Available at https://environment.ec.europa.eu/topics/air/reducing-emissions-air-pollutants/national-air-pollution-control-programmes-and-projections_en.
24 Such earlier update includes an update of policies and measures to tackle air pollution.
25 COM(2024) 348 final.
26 COM(2022) 230.

which illustrates a pathway to meet the greenhouse gas emission reductions of the preferred target option, has been taken into account as basis for the modelling underpinning this Fourth Clean Air Outlook. More ambitious energy and climate policies generally bring co-benefits for air quality by reducing emissions of key air pollutants ($PM_{2.5}$, NO_x and SO_2)[27].

In terms of emissions from transport, the analysis of the Fourth Clean Air Outlook builds upon the adopted **Euro 7 emission standard** and incorporates **revised CO_2 targets** for cars, lorries and other heavy-duty vehicles.

Finally, this Fourth Clean Air Outlook incorporates the changes brought in by the **revised Industrial Emissions Directive (IED)**. The modelling assumes, as a minimum, compliance with the upper end of the emission levels associated with the best available technique conclusions (BAT-AELs)[28]. Reflecting the outcome of the IED revision implied undoing some of the model developments carried out for the Third Clean Air Outlook, e.g. the proposal to cover large cattle farms.

3.2. Prospects for achieving the NEC Directive's emission reduction commitments

According to the results of the Fourth Clean Air Outlook, **only four Member States**[29] **are on course to achieve in 2030 all their emission reduction commitments**, under current national measures and EU legislation and in line with the above changes in the policy context (this is the 'baseline' policy scenario[30]). All other Member States must take additional measures to fulfil their obligations. Action is needed in particular to reduce **ammonia emissions**, as **21 Member States need to make reductions by 2030**. Table 1 shows the Member States projected to miss their emission reduction commitments by type of pollutant. These forward-looking modelling results confirm the trend observed in the data analysed by EEA (see section 2.2).

Looking at the modelling for emission levels in 2025 and at whether Member States are on a linear reduction trajectory[31] to reach their more ambitious reduction commitments for 2030, only eight Member States[32] are on course to reduce all five pollutants to the extent needed. Swift action must be taken by the remaining Member States, in particular to reduce ammonia emissions. Estimates indicate that 17 Member States are not on a linear reduction trajectory in 2025 for ammonia emissions. Using all available technical

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27 The scenarios in the impact assessment on the 2040 climate target (SWD(2024) 63 final) project reductions of around 60-75% for SO_2, NO_x and $PM_{2.5}$ emissions over 2015-2040.

28 The revised IED will lead to a greater emphasis on, and application of, the *lower* end of the BAT-AEL ranges. As such, the revised IED will likely lead to reductions beyond those assumed here, however, it is currently not possible to estimate the extent of that further reduction.

29 EE, EL, IT, FI.

30 For a description of all scenarios mentioned in this report, see section 3 of IIASA (2025). All results presented here stem from the GAINS model (https://gains.iiasa.ac.at/gains).

31 Under Article 4(2) of the NEC Directive, indicative levels of the 2025 emissions are calculated by a linear reduction trajectory established between the emission levels set by the emission reduction commitments for 2020 and the emission levels set by the emission reduction commitments for 2030. The assessment is hence made against a maximum allowed emission level that is the average maximum allowed level resulting from the 2020-29 and 2030 emission reduction commitments.

32 BE, CY, EE, EL, IT, MT, AT, FI.

measures[33] would enable all Member States to meet their 2030 commitments, except for one Member State as regards NH_3.

The analysis confirms the rather worrying compliance prospects for NH_3 that previous Outlook reports also highlighted. Since the Third Outlook report, there has been an increase in the number of countries expected not to meet the $PM_{2.5}$ emission reduction commitments. This can be explained by increases in estimated emissions from solid fuel combustion (biomass and coal) in the residential sector, linked to new information integrated in the GAINS model on the structure of installations, wood and coal consumption and emission factors.

Table 1: Member States projected to miss their emission reduction commitments

Scenario	Year	NH_3	NMVOC	NOx	$PM_{2.5}$	SO_2
Baseline	2025	BG, CZ, DK, DE, IE, ES, FR, HR, LV, LU, HU, NL, PL, PT, SK, SI, SE	LT	LT, RO	CZ, HU, PL, RO, SI	-
Baseline	2030	BE, BG, CZ, DK, DE, IE, ES, FR, HR, CY, LV, LU, HU, NL, AT, PL, PT, RO, SK, SI, SE	LT, HU, SI	MT, RO	CZ, DK, CY, ES, HU, PT, RO, SI	-
All technical measures	2030	NL	-	-	-	-

Source: Based on IIASA (2025) modelling results.
Note: For 2025, the assessment is carried out against the linear reduction trajectory, as explained in Footnote 31. '-' means all Member States are projected to meet the targets.

3.3. Extending the range of emissions covered under the NEC Directive

The modelling underpinning this edition of the Clean Air Outlook follows a new approach as regards including **condensable particulate matter emissions**. These are emissions initially in vapour form (inside or close to the stack) that transform into particulate matter when discharged into ambient air. It is important to include these emissions as they impair the quality of the air we breathe. Particularly in domestic heating, condensable particulate matter emissions are significant and are estimated to represent about the same level as filterable emissions. As a result of recent improvements in the official reporting of emissions with condensables[34], the baseline model set-up now includes a consistent representation of the condensable part of particulate matter emissions linked to the combustion of wood and coal in the residential sector[35].

Alternative assumptions were tested as part of the sensitivity analysis to see the effect of including filterable particulate matter only or including a set of higher emission factors that factor in bad combustion practices. The **prospects of meeting the $PM_{2.5}$ emission**

[33] Maximum technically feasible reduction scenario, referred to as 'all technical measures'.

[34] This followed the introduction of a set of emission factors including condensables in the EEA/EMEP Guidebook. According to IIASA (2025), five Member States do not include the condensable part of PM emissions from residential solid fuel combustion in their inventories (Austria, Estonia, Germany, Lithuania and Luxembourg). The GAINS model uses country-specific PM emission factors that assume that the condensable fraction is included, also for these five countries. This assumption has been communicated to Member States during consultations with them that IIASA held in early 2024.

[35] In the Third Clean Air Outlook, condensables were consistently included in the sensitivity analysis only.

reduction commitments barely change depending on these assumptions[36], but the total volume of emissions reported changes depending on the exact emission factor used.

Another improvement to the modelling of real-world emissions is to include **NO_X and NMVOC emissions from agriculture**. These emission sources are excluded from the compliance checks under the NEC Directive[37] due to the lack of sufficiently reliable data when the commitments were set. More recent data now allow this information to be incorporated into models. Indeed, if these emissions were to be included, the projected compliance status in several Member States would change.

When including **NO_X emissions** from agriculture, the prospects of compliance with 2030 reduction commitments under the baseline worsen. The level of non-compliance is expected to rise from two Member States (MT, RO) to eight (DK, FR, HU, IE, LT, MT, RO, SE). When including **NMVOC emissions** from agriculture, non-compliance prospects under the baseline for 2030 also worsen, rising from three Member States (HU, LT, SI) to six Member States (HU, IE, LT, LU, SI, ES). This demonstrates that, despite not being currently required by the NEC Directive, additional action is needed in several Member States to unlock the full potential of the sector to mitigate air pollution.

4. PROSPECTS OF MEETING ZERO-POLLUTION OBJECTIVES ON CLEAN AIR

4.1. The EU's 2030 clean air targets in the zero-pollution action plan

The zero-pollution action plan includes two EU-level targets for 2030 related to clean air:

1) reduce by more than 55% the health impacts (expressed as premature deaths) of air pollution compared to 2005 figures;
2) reduce by 25% the EU ecosystem area where air pollution threatens biodiversity, expressed as ecosystem areas that have exceeded the 'critical loads' of nitrogen deposition (compared to 2005 figures).

In line with the analysis summarised in the Third Clean Air Outlook, the EU is currently on track to meet the **zero-pollution target to reduce the health impacts** under the baseline scenario. The analysis estimates a 62% reduction in the number of premature deaths between 2005 and 2030. However, it is not on track to **meet the ecosystem target on time**, with only a 19% reduction expected in areas at risk between 2005 and 2030[38].

4.1.1. Health-related target and overall health impacts across scenarios

Background concentration of air pollutants and population exposure

Even under the baseline scenario, pollutant concentrations are expected to fall over time and, by 2030, very few areas in the EU are projected to exceed 20 µg/m^3 for $PM_{2.5}$. However, large areas are still projected to have pollution concentration levels above the currently recommended WHO air quality guideline of 5 µg/m^3 in 2030, and even in 2050.

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36 This masks some changes in the margin of compliance, which changes in different directions across Member States. This includes cases where the inclusion of high emission factors improves the margin of compliance.

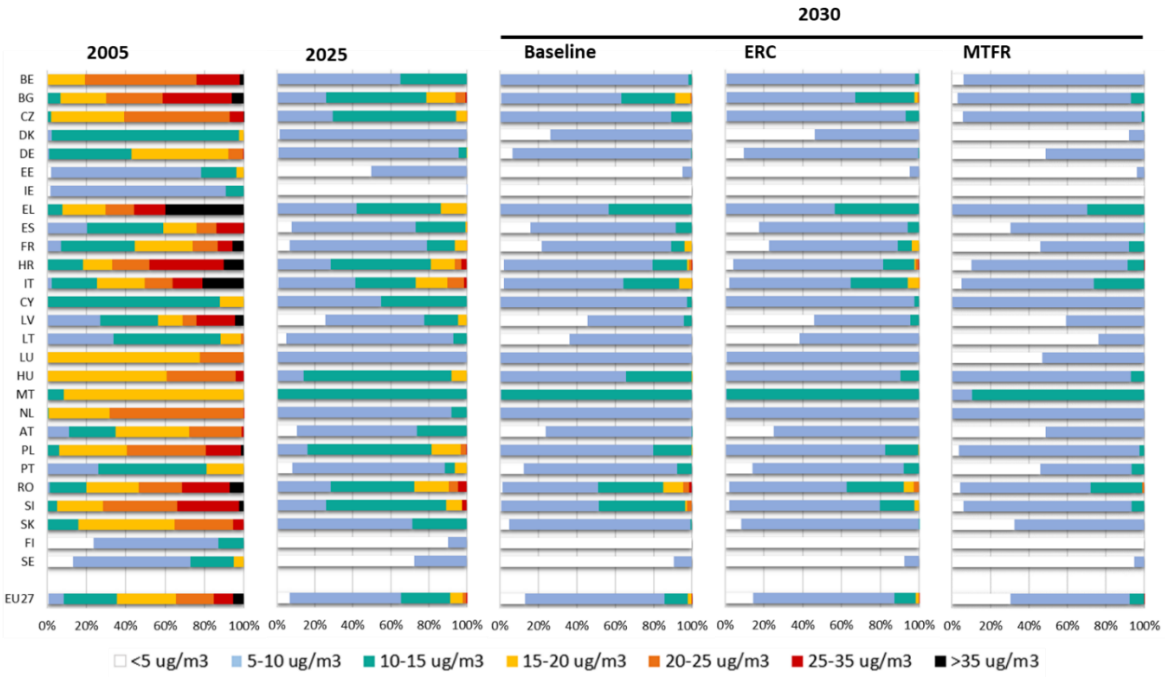
37 Article 4(3)(d) of the NEC Directive.

38 The 25% reduction target is expected to be met between 2040 and 2045.

Translating background concentration levels into impacts on the health of the EU population shows that the number of people living in areas with clean air is set to rise considerably. While this would be a significant improvement, **further policy action is needed to limit the negative health impacts also for the (roughly) remaining half of the EU population in 2050** still exposed to pollution above the 2021 WHO guidelines.

As seen from Figure 2, the results vary for individual countries, though all are projected to see a steady improvement both in background concentrations and the share of population exposed to pollution. It also shows that for some countries, under a scenario that assumes all Member States meet their emission reduction commitments, further improvements would be achieved by 2030.

Figure 2: EU-27 population exposed to different concentrations of $PM_{2.5}$



Source: IIASA (2025)
Note: 'ERC' is a scenario that assumes all Member States meet their emission reduction commitments. MTFR is the 'all technical measures' scenario.

Currently, **most of the EU population** (97%) **live in areas with NO_2 pollution levels below the current EU limit** of 40 µg/m^3, and nearly 60% live in areas below the WHO guideline limit of 10 µg/m^3 in 2025. By 2030, this is projected to increase to over 70% in all scenarios, reaching over 80% if all technical measures are implemented. By 2050, under all scenarios, well over 95% of the EU population is projected to live in areas where pollution remains below the WHO-recommended level for NO_2.

Premature deaths and achieving the zero-pollution target

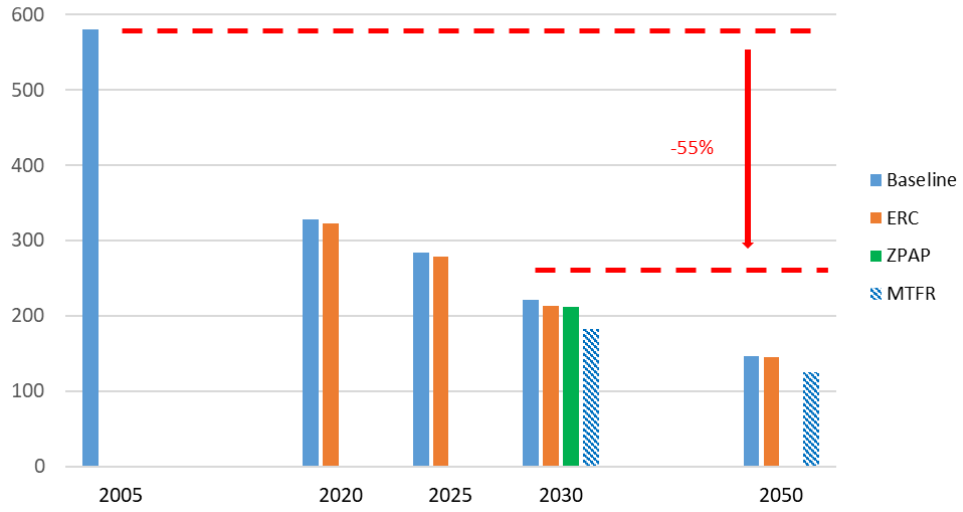
Premature deaths[39] due to **$PM_{2.5}$** exposure are projected to fall by about 62-79% compared to 2005 figures, across all scenarios (including the baseline) by 2030 and 2050.

[39] The health impacts of air pollution extend beyond mortality and include morbidity. The impacts have been analysed and are monetised in order to assess the economic impacts as well as the benefits of lower air pollution (see section 4.2).

Premature deaths will fall somewhat faster if countries meet their reduction commitments, with a much steeper reduction if they also take all technical measures.

Provided all policies included in the baseline scenario achieve the intended results, **the EU is set to achieve the zero-pollution health target** by a comfortable margin in 2030. This target is formulated at EU level, but it also translates into reductions in premature deaths of 55% or more at the level of most Member States individually.

Figure 3: Cases of premature deaths attributable to exposure to total $PM_{2.5}$ concentrations in the EU-27, in thousand cases per year



Source: IIASA (2025).
Note: The 55% marking indicates the zero-pollution target. Only anthropogenic sources of $PM_{2.5}$ are included, in line with the way the zero-pollution target was set.

In absolute numbers[40], while this projection shows that significant improvements should be achieved over the baseline scenario, it still means an estimated 220 000 **premature deaths due to $PM_{2.5}$** exposure in 2030. Taking all technical measures would reduce the number of premature deaths by over 37 000.

Exposure to **NO_2** is projected to cause around 68 000 premature deaths under the baseline scenario in 2030. Taking all technical measures would reduce deaths by over 11 000. Between 2030-2050, the number of premature deaths attributable to **NO_2** exposure is set to more than halve. Exposure to **ground-level ozone** is projected to cause around 65 100 premature deaths under the baseline scenario in 2030[41], varying only slightly by scenario and over time.

[40] Using the same methodological approach as in the Second Clean Air Outlook, which was the basis for setting the zero-pollution targets.

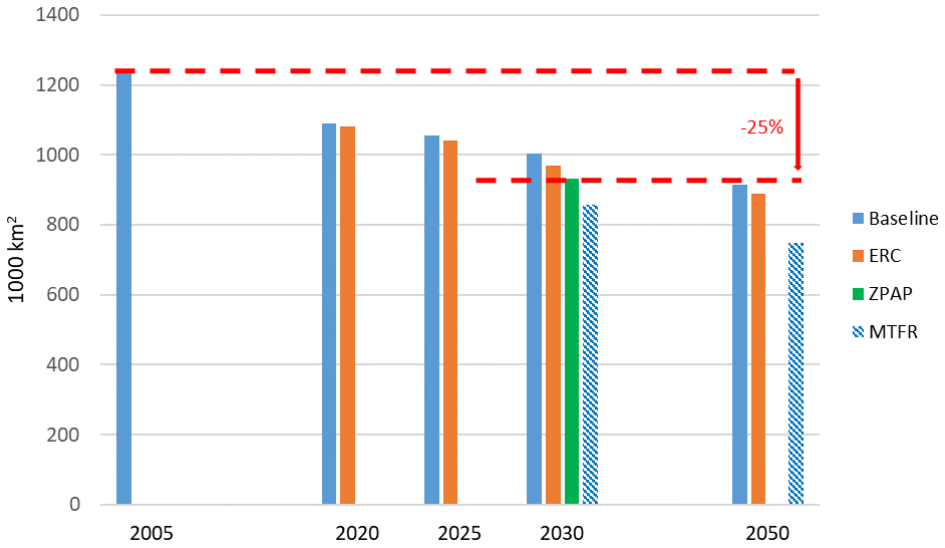
[41] This is a rather pronounced change compared with the estimated 50 000 deaths attributable to ozone exposure in CAO3. This is due to the more developed and detailed modelling approach taken here, as explained in IIASA (2025).

4.1.2. Ecosystem-related target and overall ecosystem impacts

Air pollution affects **ecosystem health** through acidification, eutrophication and ozone impacts. Modelling results[42] show a significant improvement over time as regards **acidification**: under the baseline scenario, by 2030, less than 3% of the ecosystem area in the EU would suffer from acid deposition exceeding critical loads, compared to 15% in 2005. This demonstrates the benefits of the significant reduction in SO_2 emissions already achieved over the past decades. The benefits would be even greater if all Member States meet their emission reduction commitments, or all technical measures are taken.

In line with previous Outlook reports, the situation is considerably less positive when looking at the impacts of air pollution on **eutrophication**[43]. This is linked to the current projection that the EU will not achieve the zero-pollution ecosystem target under baseline policies only. In this scenario, 69% of EU ecosystems would still suffer from eutrophication in 2030 (down from 86% in 2005). Under the baseline conditions, **protected areas would continue to be highly affected in 2030**, with 60% of Natura 2000 areas suffering from eutrophication (down from 78% in 2005). If all technical measures are taken, the share of EU ecosystems suffering from eutrophication would fall to 59% (and to 49% in Natura 2000 areas) by 2030.

Figure 4: Ecosystems in the EU-27 exceeding the critical loads for eutrophication



Source: IIASA (2025)
Note: The marked 25% line indicates the zero-pollution target.

The GAINS model was used to estimate a cost-effective set of measures needed to reach the 25% reduction target at EU level ('ZPAP' scenario in Figure 4). This is achievable by taking **additional measures to limit ammonia emissions in all Member States** (ammonia being the air pollutant with the greatest impact on ecosystems). Such measures would tackle emissions from cattle manure (in particular, spreading manure on fields),

[42] Estimation of ecosystem impacts follows the same methodology applied in the Third Clean Air Outlook, based on the same critical load database compiled through the Coordination Centre for Effects of the Working Group on Effects under the UNECE Air Convention (see IIASA, 2025).

[43] Assessed as the area of ecosystems where nitrogen deposition exceeds the critical loads.

followed by measures to mitigate emissions from using mineral fertilisers and from breeding pigs and poultry.

Altogether, these measures would reduce ammonia emissions at EU-27 level by 14% in 2030 compared to the baseline scenario, while meeting the zero-pollution target on eutrophication. Adopting these measures would also **significantly increase the prospects of meeting the NEC Directive's ammonia emission reduction commitments**, and fewer Member States would fail to achieve the commitments in 2030 (from 21 to 7).

The NEC Directive refers to these measures either as compulsory or voluntary measures[44]. During the process of the ongoing evaluation of the NEC Directive, the Commission will assess whether this list of measures and their compulsory or voluntary status are still fit for purpose. It will also take into account relevant findings from the ongoing process to revise the UNECE Air Convention guidance document on preventing and abating ammonia emissions from agricultural sources[45]. In the meantime, Member States, in particular countries facing challenges in meeting current or future emission reduction commitments for ammonia, are strongly encouraged to step up action to implement the mitigation measures by:

– adopting national legislation to make certain agricultural practices binding;
– promoting these practices through communication and awareness-raising campaigns, including by providing farm advice under the common agricultural policy.

These efforts should form part of an integrated approach to nitrogen, notably from agriculture, including measures to tackle the eutrophication of aquatic ecosystems caused by nitrates leaching and running off from agricultural fields and by pollution of freshwater resources, including groundwaters. The Commission is currently evaluating the Nitrates Directive and will assess the need for further steps in light of this evaluation, currently planned for publication in the second half of 2025.

The implementation of the Nature Restoration Regulation[46] is expected to result in additional efforts to reduce pollution pressures on ecosystems, as well as to increase overall ecosystem resilience. Urban ecosystem restoration may also provide nature-based solutions to mitigating urban air pollution's impacts on human health.

4.2. Economic impacts

The economic impacts of air pollution are numerous. Most impacts are not reflected in market prices, in particular **direct health effects** of pollution. Damage to ecosystems (including agricultural areas and forests) and to materials from air pollution also generates costs. Air pollution also generates indirect impacts, including some macroeconomic consequences that are reflected in market prices. The costs of air

[44] Annex III, part 2.

[45] The 2014 version of the document is available here: https://unece.org/DAM/env/documents/2012/EB/ECE_EB.AIR_120_ENG.pdf while a new version is expected to be available in 2025.

[46] Regulation (EU) 2024/1991 of the European Parliament and of the Council of 24 June 2024 on nature restoration and amending Regulation (EU) 2022/869.

pollution abatement measures should therefore be weighed against the benefits these measures bring to society, by attributing a monetary value to these benefits[47].

Under the baseline scenario, the **health damages** caused by air pollution are estimated at between EUR 290-950 billion per year by 2030. They are estimated to fall to between EUR 191-745 billion by 2050[48], as population exposure to air pollution decreases. When considering only the **impacts to exposure to levels of air pollution above WHO (2021) guidelines**, the health damages are estimated at between **EUR 105-347 billion per year by 2030**. They are estimated to fall to EUR 35-124 billion by 2050. Under the scenario with all technical measures taken, health damages from exposure to above-WHO guideline levels are projected to fall by over a third compared to the baseline by 2030.

The economic cost of **ecosystem damages** due to air pollution[49] ranges from EUR 3.7-11.0 billion in 2030. This is projected to fall only marginally to EUR 3.3-9.9 billion by 2050, reflecting the only modest reduction in Natura 2000 areas subject to eutrophication under the baseline. The cost of **damages to crops and to forests** are estimated at EUR 13.0-18.0 billion in 2030 respectively under the baseline, only marginally decreasing if all technical measures are adopted. The reason for this is that, factoring in only EU mitigation action, there will be a limited improvement in ozone levels, which drive damage to agriculture and forests (see the next section). The economic cost of **damages to materials** due to air pollution is estimated to reach EUR 742 million in 2030, before falling to EUR 384 million in 2050 under the baseline scenario.

Compared to current policies, the different scenarios are projected to generate different levels of non-market benefits and different levels of additional costs for the pollution abatement measures needed. Across the scenarios assessed here, the analysis of benefits to costs reveals **net direct benefits** (benefits minus costs) compared to the baseline scenario.

Measures to reduce air pollution and their positive effects on air quality also have wider **macroeconomic effects**[50] reflected in the market. Pollution abatement measures generate both a cost for some sectors and a business opportunity for others, while air quality has impacts on both labour and crop productivity and therefore on the economy as a whole. Based on recent assumptions on labour productivity effects[51], **all scenarios leading to cleaner air would increase EU GDP in 2030** compared to the baseline scenario (the same holds for 2040 and 2050, Figure 5).

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47 For a description of the methodology underpinning the results in this section, see IIASA (2025).

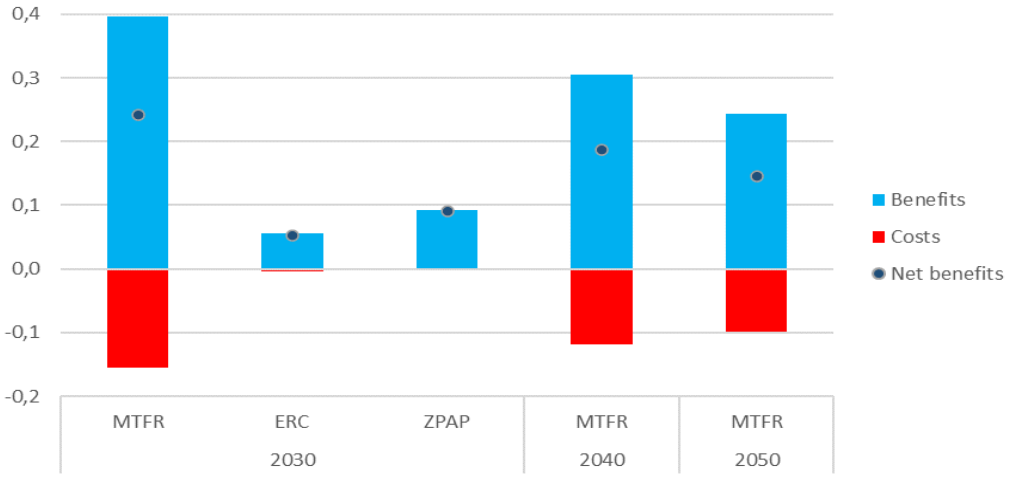
48 The ranges reflect whether mortality is valued using the value of a life-year or the value of statistical life; values are expressed per year, in 2015 prices. A conservative approach has been taken that excludes NO_2 impacts where there is potential for the effects to be double counted against the quantification of $PM_{2.5}$ effects.

49 Those impacts are estimated through the loss of ecosystem services only in Natura 2000 areas due to eutrophication. They therefore underestimate the total loss in ecosystem services.

50 The effects have been calculated by the European Commission Joint Research Centre using the JRC-GEM-E3 model (https://joint-research-centre.ec.europa.eu/gem-e3_en). For more details, see section 5.5 of IIASA (2025).

51 Dechezleprêtre, A., Rivers, N., & Stadler, B. The economic cost of air pollution: Evidence from Europe. *OECD Economics Department Working Papers*, 2019 [OECD, 2019].

Figure 5: Macroeconomic market effects of clean air policy scenarios, in % change in EU GDP compared to the baseline scenario



Source: IIASA (2025) based on JRC modelling with OECD (2019) assumptions on labour productivity.

This shows the overriding positive economic effects of pollution abatement measures. The net effect is greatest under the scenario when all technical measures are taken (+0.24%), with more limited effects in the 2030 scenarios where the emission reduction commitments and zero-pollution targets are met. The sectoral distribution of the effects shows that only the livestock sector would see a small reduction (below 2%) in output compared to the baseline scenario.

5. CLEAN AIR AND CLIMATE ACTION CO-BENEFITS OF REDUCING METHANE AND BLACK CARBON EMISSIONS

The NEC Directive recognises the link between air pollution on the one hand and methane and black carbon, two key short-lived climate forcers, on the other. Member States must report national emissions of black carbon where data are available; currently all but two Member States do so. The Commission is looking at methane emissions in the ongoing evaluation of the NEC Directive and is analysing whether the co-legislators' decision, at the time of its adoption, not to include methane amongst the regulated air pollutants has hampered stronger synergies with climate and other policies.

Methane is both a potent climate forcer and a precursor to ground-level ozone pollution. Anthropogenic emissions of methane in the EU come mainly from agriculture (56%), waste (24%) and energy (16%)[52]. In 2024, the EU Regulation on the reduction of methane emissions in the energy sector entered into force[53]. Its scope extends to crude oil, natural gas and coal. The Regulation contains a number of measures which taken together will contribute to improving measurement and reporting of methane emissions in the EU; reducing methane emissions in the EU via mandatory abatement measures; increasing transparency on methane emissions in the EU and globally; and incentivising the EU's international partners to measure, report and reduce their methane emissions.

52 Data from 2022 based on EEA greenhouse gases – data viewer (including the land-use sector).

53 Regulation (EU) 2024/1787 of the European Parliament and of the Council of 13 June 2024 on the reduction of methane emissions in the energy sector and amending Regulation (EU) 2019/942.

However, the high share of methane emissions from agriculture remains largely unaddressed in the EU. Tackling methane as a precursor to ozone will help Member States meet the more stringent ozone target values under the revised Ambient Air Quality Directive[54].

Black carbon[55], or soot, forms fine particulate matter and generates negative impacts on health and on the environment. It is formed from the incomplete combustion of fossil fuel and wood. By absorbing light and heat in the air, black carbon also contributes to climate change. When deposited on ice and snow, black carbon reduces surface albedo[56], contributing to heating, particularly in Arctic regions.

Reducing emissions of methane and black carbon can therefore produce benefits, both in terms of clean air and in terms of climate change mitigation, increasing the benefit-to-cost ratio of their abatement measure. The modelling carried out for this report shows that baseline **EU black carbon emissions are expected to fall significantly (by 45%) between 2020 and 2030**, mostly due to the gradual roll-out of the ecodesign requirements for domestic heating appliances and less coal use in this sector. A quarter of the achieved reduction comes from the transport sector, primarily as a result of advanced Euro emission standards for motor vehicles, requiring the installation of efficient particulate filters. Even greater reductions could be achieved (66% below the 2020 baseline level) if all technical measures are taken.

Likewise, under this report's baseline scenario, **EU methane emissions are projected to fall by 21% between 2020-2030** reaching a 31% reduction by 2040, driven by further action to decarbonise the economy and reduce emissions from waste management.

However, as methane is transported on a hemispheric scale, it is vital to complement action at EU level with global action. In November 2021, the EU co-convened together with the United States the **Global Methane Pledge**[57], which built momentum to accelerate action. It puts forward a voluntary commitment to reduce global methane emissions by at least 30% from 2020 levels by 2030.

In parallel, the UNECE Air Convention is a forum to explore synergies between international rules on clean air and climate. In particular, the process to revise the Gothenburg Protocol (see next section) has opened discussions on the role of methane as an ozone precursor and therefore a pollutant of relevance to clean air policies.

The modelling carried out here confirms that there is great potential globally to reduce methane and other ozone precursors (NO_x, NMVOCs and carbon monoxide). Joint action at global level reduces ozone concentrations in Europe, bringing many additional stations in compliance with the ozone target set in the Ambient Air Quality Directive, to a greater degree than if the EU alone took action or if global action is taken to reduce only methane, not the other precursors. The impact of additional mitigation is particularly pronounced in 2040[58].

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54 The revised Directive maintains the target value of 120 μg/m^3, but it reduces the number of calendar days that this value may be exceeded to 18 (down from 25) days averaged over three years.

55 Elements from this description are sourced from the Climate and Clean Air Coalition.

56 The ability to reflect sunlight.

57 https://www.globalmethanepledge.org/. In January 2025, there were over 150 participating countries.

58 There is more limited scope for additional mitigation by 2030, given the short time left to implement mitigation measures.

6. TRANSBOUNDARY POLLUTION AND INTERNATIONAL ACTION

Air pollution in any given country comes from multiple sources: domestic emissions, emissions generated in neighbouring countries and natural sources. In most Member States, domestic sources are the main sources of pollution, and therefore the priority is to **cut domestic emissions** to reduce the background levels of air pollutants. However, the analysis confirms that in most Member States, a significant share of $PM_{2.5}$ background concentration is generated in other Member States[59]. This reflects the **transboundary nature of air pollution**, which justifies taking action at EU level as air pollution generated in one Member State may have negative impacts beyond national borders[60]. In addition, the analysis shows that a share of air pollutant background concentration also comes from non-EU countries, at varying levels depending on the geography of the Member State[61]. Over time and with increasing stringency of EU air pollution abatement scenarios, the share of pollution from within the EU is projected to fall (due to additional action in the EU), increasing the relative share of non-EU sources (in particular where non-EU countries do not reduce air pollution at a similar level of ambition). This underlines the need for the EU to **take stronger action bilaterally** (notably in the context of accession and neighbourhood policies, but also by building stronger international partnerships) **and in multilateral fora** such as the UNECE Air Convention.

The NEC Directive obligations are, to a large degree, reflected at international level via the UNECE Air Convention and its amended Gothenburg Protocol. In recent years, more countries have ratified this Protocol, but there are **still very few non-EU neighbouring countries that have ratified it**. In the EU, two Member States[62] are not yet Party to it but are close to finalising the ratification process. The Parties decided in December 2023 that further revision is required in order to meet the objectives of the Protocol by stepping up action to reduce air pollution in Europe and North America. A priority in revising the Gothenburg Protocol will be to consider how to achieve further ratifications by countries that are currently not Party to it. The modelling underpinning this report will also be used as the basis for the analysis done in the process of revision, to identify possible emission reduction commitments for the region. The revision process is expected to finish by December 2026, but the group regularly adjusts the work programme and projected end date. As noted in the previous section, the Air Convention Parties continue to examine the potential for synergies between the international clean air and climate frameworks, how to attain further ratifications within the UNECE region, and how the Air Convention can do more to inspire similar international treaties. UNEA Resolution 6/10[63] 'Promoting regional cooperation on air pollution to improve air quality globally', as agreed in March 2024, also pursues this ambition. The Resolution has resulted in the creation of a new Air Quality Management Exchange Platform[64] by the Climate and Clean Air Coalition. The aim of this new platform is to facilitate regional and sub-regional exchange of information and knowledge on best practices and to help meet the WHO Air Quality Guidelines and interim targets.

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59 Detailed results on the origins of $PM_{2.5}$ concentrations in EU Member States are available in IIASA (2025). While other air pollutants are also transported across borders, the report analysed $PM_{2.5}$ in more detail given it is responsible for the highest impacts on health.

60 The efficiency of transboundary pollutant monitoring can be improved considerably by using EU space data and services, such as the Copernicus Atmosphere Monitoring Service (CAMS).

61 Smaller and more isolated Member States would benefit most from reductions in pollution in non-EU neighbouring countries, and from lower emissions from international shipping (especially islands).

62 Italy and Poland.

63 https://documents.un.org/doc/undoc/gen/k24/008/31/pdf/k2400831.pdf

64 https://aqmx.org/

7. CONCLUSION

The Fourth Clean Air Outlook confirms that **air pollutant emissions in the EU continue to fall**. This is good news for EU citizens, for the economy and for society. Over the past 20 years, the EU has achieved substantial reductions in the emissions of most of the five main pollutants regulated under the NEC Directive. Ammonia remains an exception, as emissions have fallen by much less, with eight Member States still failing to meet their emission reduction commitments in 2022. The ongoing **evaluation of the NEC Directive** will shed light on what has worked well in implementing the Directive and what the challenges are, including in meeting the emission reduction commitments.

The outlook for ammonia emissions remains worrying. The projections presented here indicate that 21 Member States could miss their (more ambitious) 2030 emission reduction commitments. These Member States must take **significant additional action to reduce ammonia emissions at source** by promoting good agricultural practices, including as part of Member States' implementation of the common agricultural policy. Additional action is also needed to limit emissions of $PM_{2.5}$, for which eight Member States are currently projected to miss their 2030 reduction commitments.

Overall, the **EU is on track to meet the health-related target of the zero-pollution action plan**. However, it is still not on track to meet the ecosystem-related target in 2030. This emphasises the need to do more to reduce ammonia emissions. All in all, the results from this analysis show that, while collectively the EU and its Member States have made clear progress, more action is needed to reduce the negative health and environmental impacts of air pollution, in line with the EU's zero-pollution ambition and in full synergy with the new Commission's commitment to achieve sustainable prosperity. It is also in line with the process to revise the Gothenburg Protocol. Applying a One Health approach to tackling air pollution, which recognises that human, animal, and environmental health are interconnected, is a promising way forward to achieving cleaner air.

For the expected reductions presented here to materialise, it is important to **implement existing legislation in full** and to draw on the support available to the Member States from the Commission to this end[65]. This includes Member State action to meet the more ambitious air quality standards that have just been adopted under the revised Ambient Air Quality Directive. Additional action would further reduce the health and ecosystem impacts of air pollution and generate macroeconomic gains. An ambitious climate target for 2040 will not only consolidate and strengthen the EU's climate ambition but also generate co-benefits of clean air to both improve public health and boost the economy[66].

[65] Including through EU support, such as the Technical Support Instrument (https://ec.europa.eu/info/funding-tenders/find-funding/eu-funding-programmes/technical-support-instrument/technical-support-instrument-tsi_en) and EU-funded research and innovation initiatives related to the prevention and remediation of air pollution (https://research-and-innovation.ec.europa.eu/document/c9d4c0b5-f85e-4599-986d-e6b2438229fc_en).

[66] See SWD(2024) 63 final, Part 1, section 6.3.

ANNEX: METHODOLOGICAL DIFFERENCES WITH THE THIRD CLEAN AIR OUTLOOK

Key updates since the Third Clean Air Outlook

– The baseline scenario reflects more recent adopted and proposed EU policies. In particular, it builds on the modelling carried out for the impact assessment accompanying the 2040 climate target Communication ('S3 scenario', which illustrates a pathway to meet the greenhouse gas emission reductions of the preferred target option in that impact assessment), notably regarding the evolution of the EU's energy system. It now integrates the revised IED, whereas CAO3 was based on the Commission's legislative proposal, which was more ambitious, in particular in including large cattle farms in the regulated activities.

– The GAINS model was used to calculate emissions of air pollutants as well as concentrations of $PM_{2.5}$ and NO_2, following the same approach and model version used for CAO3. Ozone concentrations, however, were calculated using the EMEP model[67], which is different from CAO3 where these were calculated also using GAINS.

– The baseline scenario was updated to reflect as far as possible Member States' latest emission inventories, projections and policies and measures by taking into account the input received from Member States during baseline consultations.

– The baseline scenario now includes a consistent representation of the condensable part of particulate matter emissions, whereas in CAO3 this was only used for the sensitivity analysis.

– An updated methodology was used to assess health impacts. While the methodology remains largely in line with CAO3, the morbidity impacts for $PM_{2.5}$ and NO_2 are estimated based on new work under the EMAPEC ('Estimating the Morbidity from Air Pollution and its Economic Consequences') study coordinated by the WHO[68].

A more comprehensive description of the updates made to the modelling framework is available in IIASA (2025).

[67] The chemical transport model developed and maintained by the Meteorological Synthesizing Centre-West (MSC-W) of the European Monitoring and Evaluation Programme (EMEP), see Simpson et al. (2012) https://doi.org/10.5194/acp-12-7825-2012 for a general description.

[68] https://doi.org/10.1097/EE9.0000000000000314