08.
Air pollution

Key messages

- Air pollutants are emitted by a large range of economic activities (and from some natural sources). They can affect air quality far away from the source, and local effects also depend on local conditions. Air pollution is the single largest environmental health risk in Europe.

- The emissions of most main air pollutants decreased in Europe between 2000 and 2017. This decrease did not happen at the same pace in all countries and regions and not in all sectors. For instance, for the 33 EEA member countries, sulphur oxides from energy production and distribution decreased by 77 % (2000-2017), while ammonia emissions from agriculture decreased much less significantly and have even increased by about 3 % from 2013 to 2017. Reductions were comparably less for fine particulate matter, the pollutant that poses the greatest threat to human health.

- The reduction in emissions has led to a general improvement in air quality. However, there are still exceedances of EU air quality health standards for key pollutants such as particulate matter, nitrogen dioxide and ozone; EU vegetation standards for ozone; World Health Organization (WHO) health guidelines; and of critical loads of nitrogen in many ecosystems. These exceedances are expected to remain in 2020.

- With the full implementation of the current emission abatement policies, air pollutant concentrations above the WHO guidelines are expected to be almost completely eliminated by 2030. The current number of more than 400 000 premature deaths attributable to air pollution in the 28 EU Member States is expected to decline by more than a half by 2030, while the reduction in the impacts on ecosystems is expected to be smaller. Therefore there is still a need to substantially reduce the impacts on human health and ecosystems.

- To further improve air quality, additional measures are needed to reduce emissions, especially from agriculture, transport and domestic heating. The continuing contribution to poor air quality by these sectors is consistent with a need for systemic changes in the food, mobility and energy systems. Because of the transboundary character of air pollution, maintaining collaboration and coordinated action at international, national and local levels will be crucial to curb air pollution, in coordination with other environmental, climate and sectoral policies.

Thematic summary assessment

Theme	Past trends and outlook		Prospects of meeting policy objectives/targets	
	Past trends (10-15 years)	Outlook to 2030	2020	2030
Emissions of air pollutants	Trends show a mixed picture	Trends show a mixed picture	☑ Largely on track	☐ Partly on track
Concentrations of air pollutants	Improving trends dominate	Trends show a mixed picture	☒ Largely not on track	☑ Largely on track
Air pollution impacts on human health and well-being	Improving trends dominate	Trends show a mixed picture		☑ Largely on track
Air pollution and impacts on ecosystems	Trends show a mixed picture	Trends show a mixed picture	☐ Partly on track	☐ Partly on track

Note: For the methodology of the summary assessment table, see the introduction to Part 2. The justification for the colour coding is explained in Section 8.3, Key trends and outlooks (Tables 8.2, 8.3, 8.4 and 8.5).

08.
Air pollution

8.1 Scope of the theme

The air we breathe and live in is a critical natural resource for humans, plants and animals. Good air quality is essential to protect not only human health and natural capital but also the built environment and therefore part of the cultural heritage.

Natural sources such as volcanic eruptions, sea salt or dust from wind erosion can contribute to air pollution. However, most pollutants are released as a result of human activities in economic sectors such as transport, agriculture, generation and use of energy, industry or waste management (Chapters 7, 9, 12, and 13).

Emitted pollutants, once released, undergo various physical and chemical processes (such as transport, reactions, absorption, and deposition on vegetation or with rain water), impacting ambient air quality, which can be analysed by measuring pollutant concentrations. Air pollution affects human health, vegetation and ecosystems, with

Air pollution is the single largest environmental risk to the health of Europeans.

particulate matter (PM), nitrogen dioxide (NO_2) and ground-level ozone (O_3) being the pollutants of greatest concern.

This assessment is primarily based on data officially provided by EU Member States and EEA member and cooperating countries under the obligations of the Convention on Long-range Transboundary Air Pollution (CLRTAP) protocols (UNECE, 2019), the National Emissions Ceilings (NEC) Directive (EU, 2016) and the Ambient Air Quality Directives (EU, 2004, 2008). In this last case, only measurement data from monitoring stations have been included (modelling data are not considered). The assessment focuses on the main, most harmful pollutants in ambient air and does not cover indoor air pollution.

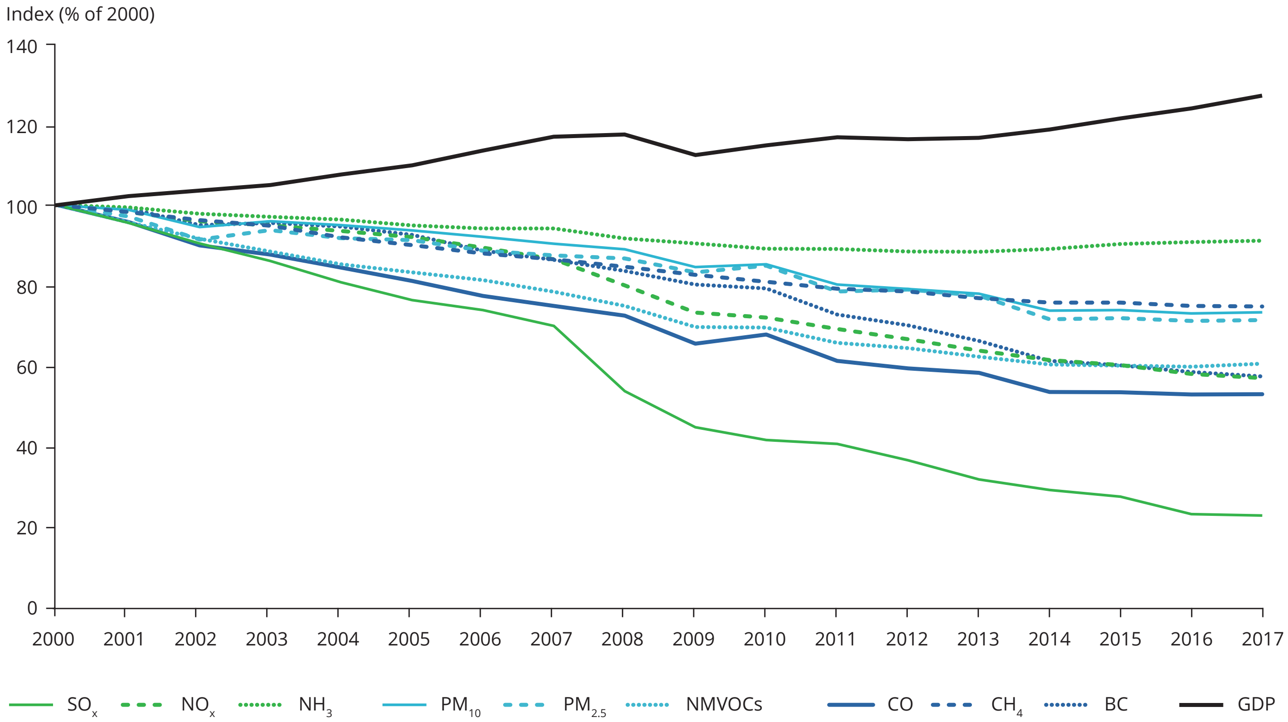
8.2 Policy landscape

Air pollution is a transboundary issue and therefore needs internationally concerted action to address it. The most significant international instrument to abate transboundary air pollution is the CLRTAP (UNECE, 1979), signed in Geneva in 1979, and its eight protocols to cut emissions of air pollutants. It has the overall objective of limiting and gradually reducing and preventing air pollution including long-range transboundary air pollution.

At the EU level, air pollution is a well-established environmental policy area, which has followed an approach based on three pillars (EC, 2018b):

1. it has implemented emission mitigation controls on national totals (via the NEC Directive (EU, 2016));

FIGURE 8.1 **Trends in the main air pollutant emissions and in gross domestic product in the EU-28**



Notes: Values for 2000-2017 are expressed as percentages of 2000 levels. Gross domestic product is expressed in chain-linked volumes (2010), as percentages of the 2000 level.
Methane (CH_4) emissions are total emissions (integrated pollution prevention and control sectors 1-7) excluding sector 5, land use, land use change and forestry. The present emission inventories include only anthropogenic non-methane volatile organic compound (NMVOC) emissions.
BC, black carbon.

Source: EEA (2019b).

2. it has set emission and energy efficiency standards for specific sources or sectors (e.g. the Industrial Emissions Directive, Euro regulations for vehicles, the Medium Combustion Plants Directive, the fuels and products directives, the Ecodesign Directive or the Nitrate Directive (EC, 2019b) (Chapters 7, 12, 13)); and

3. the two Ambient Air Quality Directives (EU, 2004, 2008) have set legal limits for ambient concentrations of air pollutants and the obligation to implement plans and measures when those limits are exceeded.

The objective of the most recent strategic policy directions such as the Seventh Environment Action Programme (7th EAP) (EC, 2013b) or the Clean Air for Europe Programme (EC, 2013a) is to achieve levels of air quality that do not give rise to significant negative impacts on, and risks to, human health and the environment.

Finally, the actions taken under other international environment and climate strategies, such as the Paris Agreement (UNFCCC, 2015) or the EU's Energy Union strategy (EC, 2015), are also expected to have a positive impact in reducing emissions of the main air pollutants. Table 8.1 presents an overview of selected policy objectives and targets on air pollution.

8.3
Key trends and outlooks

8.3.1
Emissions of air pollutants

► *See Table 8.2*

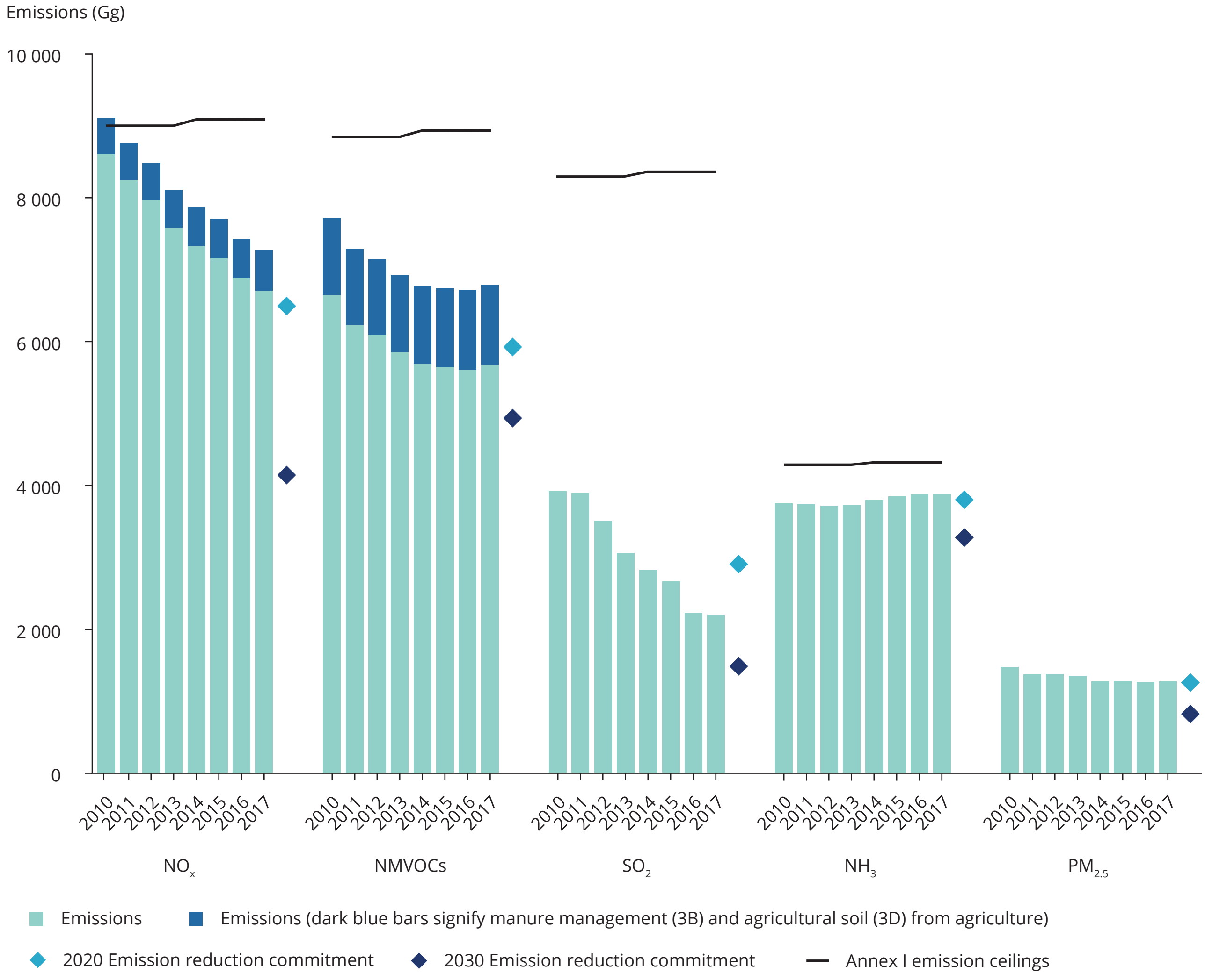
Figure 8.1 shows total emissions of the main air pollutants in the 28 EU Member States (EU-28), indexed

TABLE 8.1 Overview of selected policy objectives and targets

Policy objectives and targets	Sources	Target year	Agreement
Emissions of air pollutants			
Attain emission ceilings and reduction commitments for the main air pollutants SO_x, NO_x, NMVOCs, NH_3 and primary $PM_{2.5}$ (for the latter, only reduction commitments)	CLRTAP (UNECE, 1979) and protocols (UNECE, 2019), (particularly the 2012 amended Gothenburg Protocol)	Ceilings: 2010, remain applicable until 2019 Reduction commitments: 2020 and beyond	Legally binding to the Parties to the Gothenburg Protocol
	SDG 7 (Affordable and clean energy); SDG 13 (Climate action)	SDGs 2030	
Attain EU Member State and EU emission ceilings and reduction commitments for the main air pollutants SO_x, NO_x, NMVOCs, NH_3 and primary $PM_{2.5}$ (for the latter, reduction commitments only)	NEC Directive (EU, 2016) (transposes the reduction commitments for 2020 agreed by the EU and its Member States under the 2012 amended Gothenburg Protocol (CLRTAP); more ambitious reduction commitments agreed for 2030)	Ceilings for 2010, Annex I (and Annex II, environmental objectives for SO_x, NO_x and NMVOCs): remain applicable until 2019 Reduction commitments: 2020 and 2030	Legally binding (only Annex I ceilings)
	SDG 7 (Affordable and clean energy); SDG 13 (Climate action)	SDGs 2030	
Air quality			
Attain limit values for SO_2, NO_2, C_6H_6, CO, Pb, PM_{10} and $PM_{2.5}$; achieve target values for $PM_{2.5}$, O_3, As, Cd, Ni and BaP; the long-term objective for O_3; the national exposure reduction target and the exposure concentration obligation for $PM_{2.5}$; and critical levels for SO_2 and NO_x	Ambient Air Quality Directives (EU, 2004, 2008)	2005/2010/2013/2015/2020	Legally binding
	Clean Air Programme for Europe (EC, 2013a)	2020	
	SDG 11 (Sustainable cities)	SDG 2030	
Achieve levels of air quality that do not give rise to significant negative impacts on, and risks to, human health and the environment (in line with the WHO air quality guidelines)	7th EAP (EC, 2013b), Clean Air Programme for Europe (EC, 2013a)	N/A	Non-binding commitment
Impacts on human health and well-being			
By 2030, substantially reduce the number of deaths and illnesses from air pollution	SDG 3.9 (Ensure healthy lives and promote well-being for all at all ages)	2030	Non-binding commitment
By 2030, cut the health impacts of air pollution (in terms of premature mortality due to PM and O_3) by 52 % compared with 2005	Clean Air Programme for Europe (EC, 2013a)	2030	Non-binding commitment
Impacts on ecosystems			
No exceedances of the critical loads and levels	7th EAP (EC, 2013b)	N/A	Non-binding commitment
By 2030, reduce the ecosystem area exceeding eutrophication limits to 35 %	Clean Air Programme for Europe (EC, 2013a), NEC Directive (indirectly) (EU, 2016)	2030	Non-binding commitment

Note: As, arsenic; BaP, benzo[*a*]pyrene; C_6H_6, benzene; Cd, cadmium; CO, carbon monoxide; NH_3, ammonia; Ni, nickel; NMVOCs, non-methane volatile organic compounds; NO_2, nitrogen dioxide; NO_x, nitrogen oxides; Pb, lead; $PM_{2.5}$, fine particulate matter (≤ 2.5 µm diameter); PM_{10}, particulate matter ≤ 10 µm diameter; O_3, ozone; SDG, Sustainable Development Goal; SO_2, sulphur dioxide; SO_x, sulphur oxides; WHO, World Health Organization; N/A, non-applicable.

FIGURE 8.2 **EU progress towards meeting the 2010 emission ceilings set out in the NEC Directive and the 2020/2030 reduction commitments**



Note: Annex I lists the legally binding ceilings applicable for 2010-2019. To assess future attainment of 2020 and 2030 reduction commitments, NO_x and NMVOC emissions from two main agricultural activities — manure management (3B) and agricultural soils (3D) — are not considered. The magnitude of these emission sources is indicated by the blue bars on top of the NO_x and NMVOC columns. Only the lower part of the NO_x and NMVOC columns should be considered for comparison with the 2020 and 2030 reduction commitments.

Source: EEA (2019k).

as a percentage of their value in the reference year 2000. Emissions of all primary and precursor pollutants contributing to ambient air concentrations of the main air pollutants decreased between the years 2000 and 2017 in the EU-28. Generally, this decline was similar in the 33 EEA member countries (EEA-33), where

While sulphur dioxide emissions declined by 62 % since 2000, ammonia emissions decreased by only 4 % in the EEA member countries.

sulphur dioxide (SO_2) emissions have decreased by 62 % since the year 2000, while ammonia (NH_3) emissions have decreased only slightly by 4 % but have increased in the agriculture sector since 2013 by about 3 % (EEA, 2019e).

The substantial reduction in SO_2 emissions occurred mainly in the energy production, distribution and use sectors (Chapter 12). Reductions in nitrogen oxides (NO_x) emissions, for example, have been achieved primarily as a result of fitting three-way catalytic converters to petrol-fuelled cars, driven by the legislative European emission standards (EEA, 2019d); emissions by economic sector are also shown in Chapter 12.

In 2017, the total emissions for the EU as a whole of four important air pollutants — NO_x, non-methane volatile organic compounds (NMVOCs), SO_2 and ammonia (NH_3) — were below the respective NEC Directive 2010 ceilings, which remain applicable until 2019 (EEA, 2019k).

However, 6 Member States continued to exceed their national emission ceilings for one or more pollutants in 2017: the Netherlands for NH_3 and NMVOCs; and Austria, Croatia, Germany, Ireland and Spain for NH_3. No Member State exceeded its NO_x or SO_2 ceilings.

Norway and Switzerland have signed and ratified the Gothenburg Protocol. Only Norway still exceeded its NO_x and NH_3 ceilings in 2017 (EEA, 2019e). Liechtenstein has signed, but not ratified, the Protocol, while Iceland and Turkey have not yet signed it (UNECE, 2018a).

After 2019, new commitments to reduce emissions for 2020 onwards, and later for 2030 onwards, are applicable under the NEC Directive. Every second year, Member States must report their emission projections for 2020, 2025 and 2030 for SO_2, NO_x, NH_3, NMVOCs, fine particulate matter (≤ 2.5 µm, $PM_{2.5}$) and, if available, black carbon (BC). These officially reported emission projections are used to assess whether or not Member States are on track to meet their reduction commitments for 2020 and 2030 (EU, 2016). Figure 8.2 summarises the EU's progress in meeting the ceilings and reduction commitments.

Besides general mitigation of air pollutant emissions in sectors such as road transport, residential households or agriculture, emissions in certain areas and during certain periods of the year also need consideration when planning regional and local mitigation measures (Box 8.1).

More efforts are needed for all pollutants to meet the EU's 2030 emission reduction commitments.

For the EU as a whole, the projections reported by the Member States in 2019 for the year 2030 show that additional efforts are needed to achieve the 2030 emission reduction commitments for all pollutants (EEA, 2019k). This means for NO_x a reduction of almost 40 % compared with 2017 emissions, for NMVOCs and NH_3 around 15 %, and for SO_2 as well as $PM_{2.5}$ more than 30 %.

The First Clean Air Outlook (EC, 2018c) is underpinned by a detailed study (Amann et al., 2018b), which includes *inter alia* a scenario analysis considering post-2014 source-oriented regulations for emission controls for medium combustion plants, non-road mobile machinery and domestic solid fuel combustion, as well as the implementation of the 2016 NEC Directive (EU, 2016).

The resulting emission projections from this scenario indicate whether the EU Member States are on track to meet the 2030 reduction commitments set within the NEC Directive or not and to which extent additional measures will be needed to reach the reduction commitments.

The Clean Air Outlook analyses do not consider measures to comply with air quality limit (and target) values set in

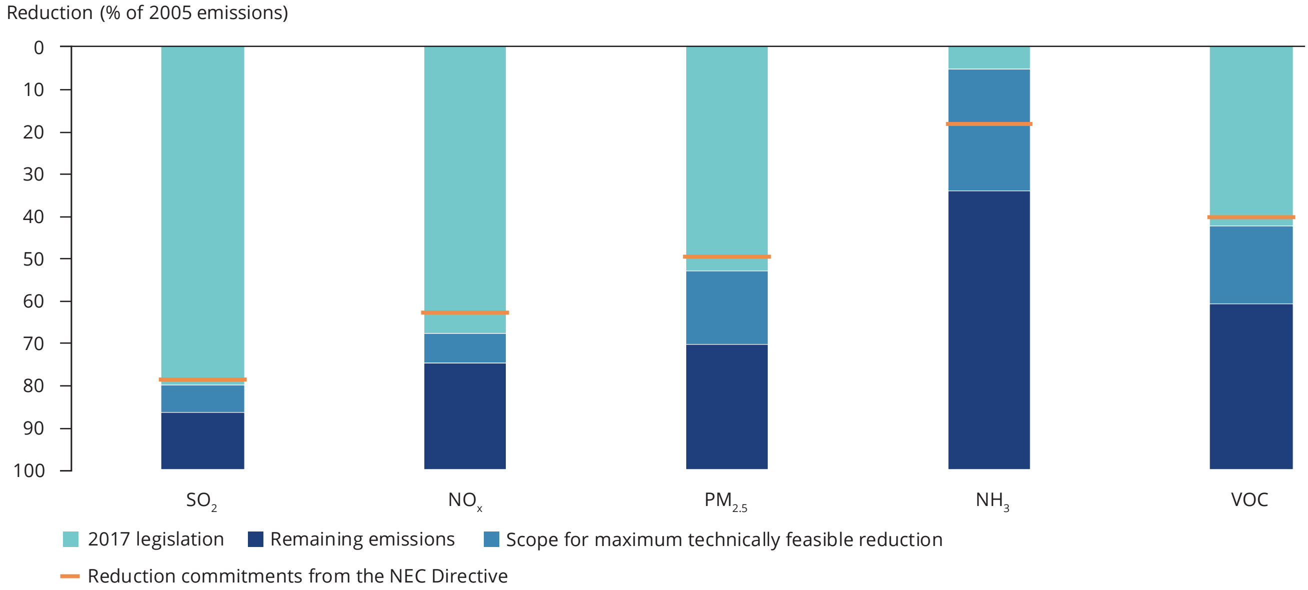
BOX 8.1
Regions, areas and periods with high air pollutant emissions

In parts of Europe (particularly eastern Europe and northern Italy) burning of wood, coal and other solid fuels in domestic stoves, especially during winter time, leads to locally or regionally high fine particulate matter ($PM_{2.5}$) emissions. The International Institute for Applied Systems Analysis estimated that solid fuel combustion in households contributes only about 2.7 % to total energy consumption in the EU-28, whereas it is responsible for more than 45 % of the total emissions of primary $PM_{2.5}$, i.e. three times more than road transport (Amann et al., 2018a).

Moreover, in street canyons with a high density of buildings and high levels of road traffic, nitrogen oxide emissions can be very high locally, leading to exceedances of air quality standards for nitrogen dioxide.

Furthermore, intensively managed agricultural areas, particularly when animal manure is spread on fields with no or little vegetation cover, can have very high ammonia emissions temporarily. This contributes to the formation of high levels of PM in the air, again contributing to exceedances of air quality standards for protecting human health (Section 8.3.2). ■

FIGURE 8.3 EU-28 emission reductions in 2030 relative to 2005



Notes: Specific developments in each country and sector might emerge differently, particularly due to the flexibility mechanisms built into the climate and energy package.
The maximum technically feasible reduction reflects full implementation of the technical emission control measures, going beyond what is required by current legislation.

Source: Amann et al. (2018b).

TABLE 8.2 Summary assessment — emissions of air pollutants

Past trends and outlook		
Past trends (10-15 years)		There were steep declines in emissions of the main air pollutants from 2000 to 2017, although improvements slowed down after 2010. The exception is ammonia, for which emissions have increased since 2013.
Outlook to 2030		Continued progress is expected as implementation of current policies to mitigate air pollutant emissions continues. However, ammonia emissions are projected to decrease only slightly. Full implementation of policies is required to deliver improvements, which will also be supported by climate change, energy and transport legislation.
Prospects of meeting policy objectives/targets		
2020	☑	The EU as a whole is on track to meet the 2020 targets for the main air pollutants, although there are still issues regarding ammonia in some countries. However, according to reported emission projections, most Member States are not expected to meet their reduction commitments in 2030. This is largely due to projected developments in ammonia emissions and local/regional issues with small-scale combustion of solid fuels. Additional measures on top of current legislation are required.
2030	☐	
Robustness		Information on air pollutant emissions is robust. It is based on officially reported inventory data under the National Emission Ceilings (NEC) Directive (in place since 2001). The European Commission and the Convention on Long-range Transboundary Air Pollution review emissions inventories regularly (including NEC Directive projections in 2019). Reported emission projections, particularly those for 2030, are more uncertain, and reporting under the 2016 revised NEC Directive only started in 2017. The emission scenarios were calculated with the GAINS model, which uses authoritative, sound input data and is regularly used by the European Commission for impact assessments and projections, and the underlying assumptions are documented.

the Air Quality Directives. An example is local air pollution abatement plans in cities, such as traffic restrictions that aim to reduce NO_x and PM emissions (Section 8.4).

Figure 8.3 shows the results of the Clean Air Outlook analyses for emissions of the five main air pollutants (Amann et al., 2018b). With legislation fully implemented, including the 2016 NEC Directive, the EU would not only meet the emission reduction commitments for SO_2 and NO_x but also attain the 2030 commitments for primary $PM_{2.5}$ and volatile organic compounds (VOCs). For NH_3, abatement measures are driven by the NEC Directive alone, which lacks ambition concerning this pollutant. However, if technically feasible reduction measures were applied, the NH_3 emission reduction commitments for the EU could be achieved (Figure 8.3). The situation in single Member States can be different, i.e. according to the scenario analyses it is envisaged that some will surpass their commitments. It is expected that other Member States will not reach their national emission reduction commitments for one or several pollutants (e.g. France, Germany, Poland and Spain for NH_3 and also several countries for $PM_{2.5}$) (Amann et al., 2018b). A number of countries will have to take additional measures, as full implementation of the legislation is not sufficient. Overachievement in some Member States reflects the synergies between different policies (air pollution, climate and energy).

The EU is on track to meet the 2020 emission reduction targets for all air pollutants except for ammonia emissions in some countries.

8.3.2 Concentrations of air pollutants

►See Table 8.3

In recent years, the air quality standards of some pollutants have only rarely been exceeded, i.e. for SO_2, carbon monoxide (CO), benzene (C_6H_6) or the toxic metals (EEA, 2019b). Nevertheless, full attainment of respective limit and target values has not yet been achieved.

Trend analyses published by the EEA (EEA, 2016) showed a significant downward trend in annual mean concentrations of PM_{10} at 75 % of the 839 monitoring stations considered. Less than 1 % of the stations registered a significant increasing trend. On average, the decreases were larger for urban traffic stations than for those measuring urban background levels. This pattern was also consistent for $PM_{2.5}$ (period 2006-2014). For O_3, trends depend on the metrics used. For those metrics reflecting the highest concentrations, the trends were decreasing. For the annual mean, the trend at rural sites was also decreasing, but it was small and frequently not significant. In contrast, at traffic stations, the annual mean showed an upward trend. Finally, the annual mean concentrations of NO_2 also showed on average downward trends at all types of the 1 261 stations considered, but the trends were stronger in absolute terms at traffic stations.

Even if these trends indicate a reduction in concentrations at most of the stations, there remain persistent exceedances of the regulated standards especially for PM, NO_2, O_3 and benzo[*a*]pyrene (BaP). Taking NO_2 as an example, Map 8.1 shows concentrations above the annual limit value in 2017 all over Europe (in 17 EU-28 Member States and four other EEA-39 countries), especially at traffic stations (EEA, 2019h). This is mainly because the anticipated reductions in emissions of NO_x have not been met in real-world driving conditions, and diesel engine emissions in particular have been bigger than expected.

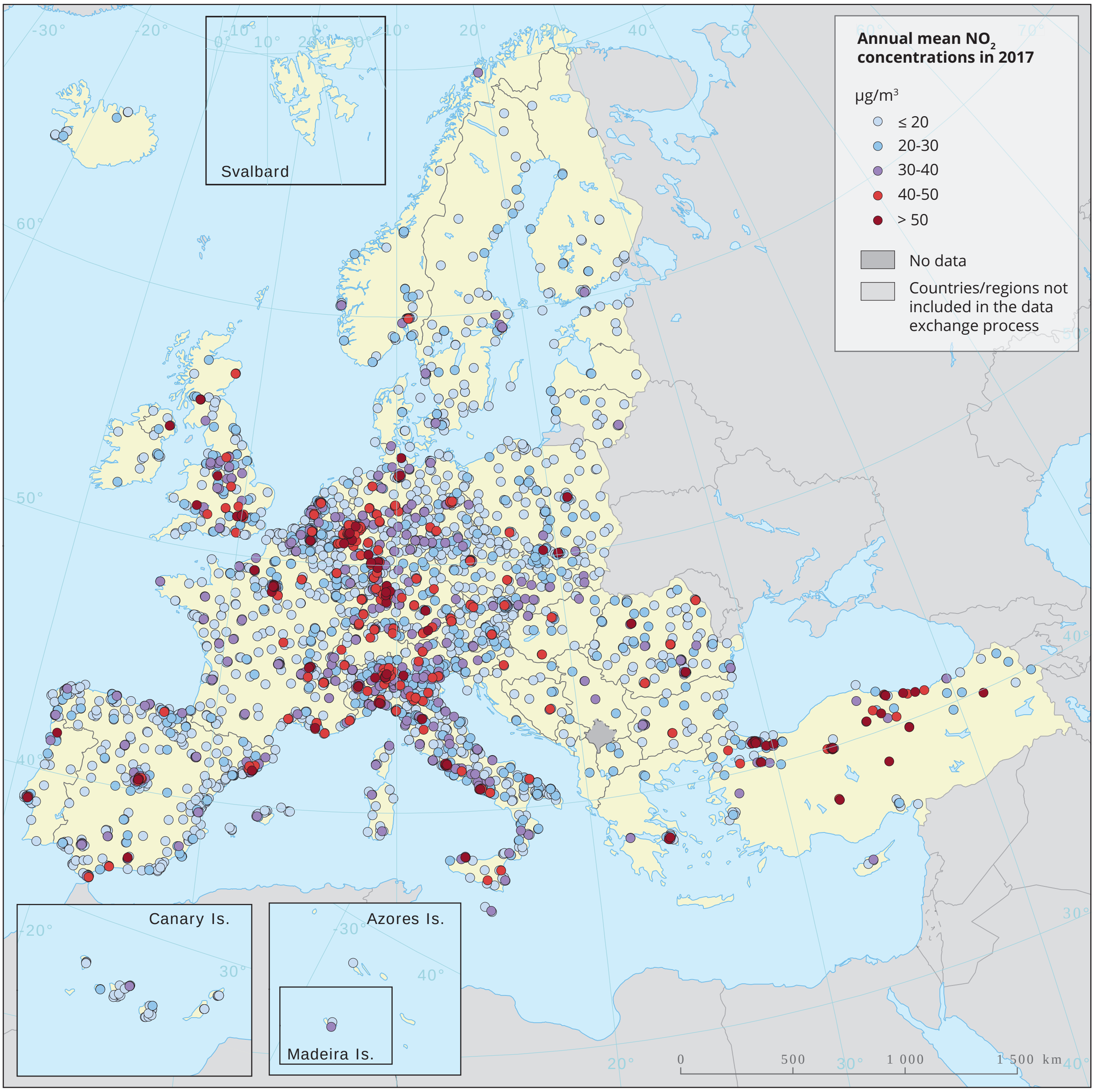
Exceedances of EU air quality standards for particulate matter, nitrogen dioxide, ground-level ozone and benzo[*a*]pyrene remain.

High pollutant concentrations are especially serious in urban areas, where most of the European population lives (Eurostat, 2018). Poor air quality in cities can be mainly attributed to the high levels of emissions from road traffic (as the case of NO_2 shows) and residential combustion in urban areas (namely for $PM_{2.5}$ and BaP). In some cases the situation is made worse by conditions unfavourable for the dispersion of emissions because of topography and meteorological conditions (Box 8.1).

If, instead of considering the EU standards, concentrations of pollutants are compared with the WHO air quality guidelines (WHO, 2006), the picture is even more negative. Figure 8.4 shows, per country, a summary of the $PM_{2.5}$ concentrations registered at all the stations in that country. While seven Member States and three other EEA-39 countries reported concentrations above the annual limit value for $PM_{2.5}$ in 2017 (plus another one in 2016), in only three countries were all the concentrations reported below the World Health Organization (WHO) air quality guidelines.

A recurrent issue in recent years is the occurrence of episodes of high PM concentrations. These episodes last for several days and can affect large parts of Europe. Residential heating, agriculture, road transport and, to a lesser extent, industry have been identified as the main sources (Tarrasón et al., 2016;

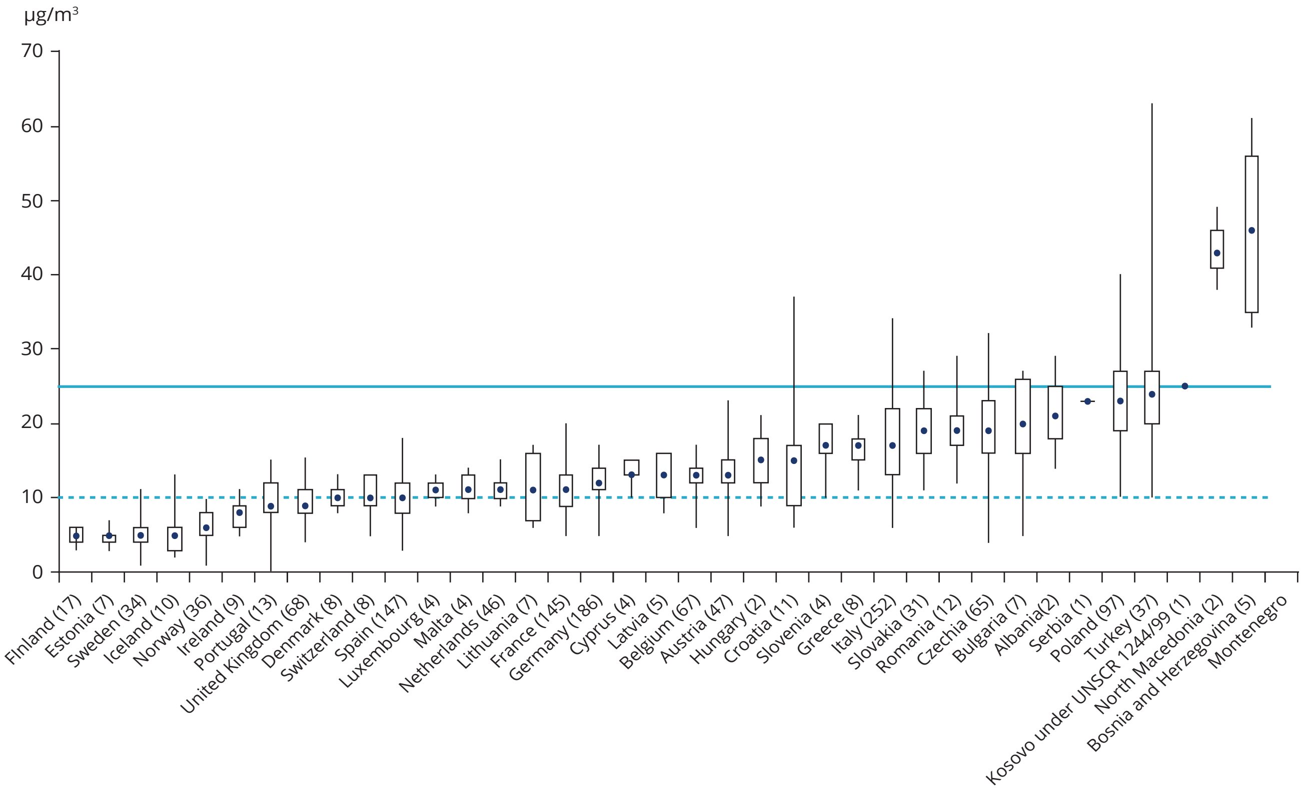
MAP 8.1 **Annual mean NO_2 concentrations in 2017**



Note: Observed concentrations of NO_2 in 2017. Dots in the last two colour categories correspond to values above the EU annual limit value and the equal WHO air quality guidelines (40 μg/m³). Only stations with > 75 % of valid data have been included in the map. The French overseas territories' stations are not shown in the map but can be found at EEA (2019j).

Source: EEA (2019a).

FIGURE 8.4 **Country comparison — $PM_{2.5}$ concentrations in 2017**



Notes: The graph is based on annual mean concentration values at the station level. For each country, the number of stations considered (in brackets), the lowest, highest and average (blue dots) concentrations and the 25th (bottom side of the box) and 75th (top side of the box) percentiles are shown. At 25 % of the stations, levels are below the 25th percentile; at 25 % of the stations, concentrations are above the 75th percentile. The limit value set by EU legislation is marked by the upper horizontal line. The WHO air quality guideline is marked by the lower dashed horizontal line. The country's situation depends on the number of operational stations. Concentrations correspond to values measured at stations, without taking into account that, for checking compliance with the Air Quality Directive (EU, 2008), there is the possibility of subtracting contributions from natural sources and winter road sanding/salting.

Data from Albania, Kosovo (under United Nations Security Council Resolution 1244/99) and Serbia are for 2016.

Source: EEA (2019a).

Hamer et al., 2017). The formation of secondary PM also plays an important role. For example, several episodes in spring time are mostly due to NH_3 coming from the use of fertilisers applied to agricultural fields and to NO_x emissions from urban traffic. In some cases, dust from the Sahara also contributes to the increase in PM concentrations.

The ambition to achieve the EU legal standards by 2020 as specified in the Clean Air Programme for Europe (EC, 2013a) appears pessimistic. According to the above-mentioned analysis (EEA, 2016), if the averaged trend over the period 2000-2014 is extrapolated to 2020, 1.6 % of the stations are expected to still have concentrations above the annual limit value for PM_{10} (and 3 % of stations for $PM_{2.5}$). Similarly, 7 % of stations measuring O_3 are expected to have concentrations above the European target value and 7 % of stations measuring NO_2 to have concentrations above the annual limit value.

This outlook has also been confirmed by the information reported by European countries as part of their plans to improve air quality. Some countries have indicated that they anticipate achieving compliance with PM, NO_2 and BaP legal standards beyond 2020 and in some cases as late as 2026 (EEA, 2019c).

TABLE 8.3 Summary assessment — concentrations of air pollutants

Past trends and outlook		
Past trends (10-15 years)		Since 2000 there has been a decrease in concentrations of the main air pollutants.
Outlook to 2030		Continued progress is expected and full implementation of current policies would deliver reductions in fine particulate matter ($PM_{2.5}$) concentrations to levels below the WHO air quality guidelines in almost all of the EU-28. For nitrogen dioxide, around 3 % of stations are still likely to exceed the limit value (same as the WHO guideline). For the rest of the European countries where the National Emissions Ceiling Directive is not applied, the outlook is more uncertain without efforts to implement the Gothenburg Protocol.
Prospects of meeting policy objectives/targets		
2020	☒	Europe is not on track to meet policy objectives by 2020, as there will still be exceedances for most air quality standards. If current policies are fully implemented, the objective of meeting the WHO air quality guidelines is expected to be achieved in most areas by 2030.
2030	☑	
Robustness		Information on air pollutant concentrations is robust enough, as the Ambient Air Quality Directives have been in place for more than two decades and have ensured a common and comparable monitoring methodology. The prospects to 2020 are based on trend analysis and projections of the measured air concentrations and also on the projections reported by the Member States on their implementation of air quality plans and measures. Finally, the outlook to 2030 is based on the calculations of the GAINS model, used for many years for impact assessments and projections by the European Commission, and the underlying assumptions are documented.

Looking further ahead (Section 8.3.1), modelled scenarios suggest that the significant decreases in precursor emissions are expected to reduce $PM_{2.5}$ concentrations in almost every country below the WHO guideline by 2030 (Amann et al., 2018b). The only exceptions are expected to be in northern Italy and southern Poland. Regarding NO_2, the analysis predicts that only 3 % of the almost 2 000 analysed monitoring stations are expected to be above the annual limit value and the equivalent WHO guideline by 2030.

8.3.3 Impacts on human health and well-being

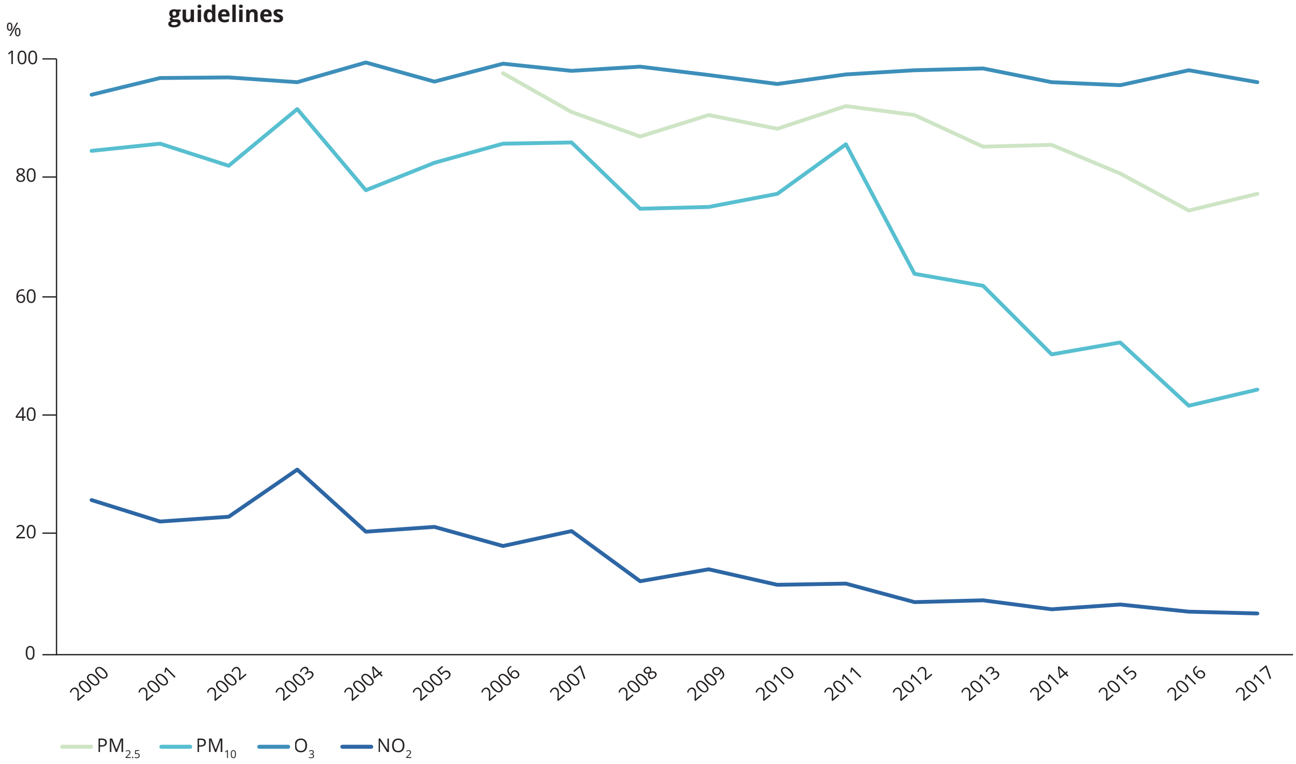
► See Table 8.4

Exposure to air pollution may lead to adverse health impacts, such as premature mortality and morbidity, mainly related to respiratory and cardiovascular diseases (WHO, 2015). Air pollution in general, and PM as a separate component of air pollution mixtures, have been classified as carcinogenic (IARC, 2013).

95 % of the EU urban population remain exposed to pollutant concentrations above WHO air quality guidelines.

The fact that in many cases air pollutant concentrations remain above the legal standards implies that the population's exposure to those pollutants is also high. Focusing on people living in urban areas, where higher population densities and high air pollution coincide, Figure 8.5 shows that a considerable percentage of the EU-28 population is still living in areas with concentrations of pollutants above the WHO air quality guidelines. Since 2000, the trend has been decreasing for all pollutants, with the exception of O_3. That is particularly evident for PM in the latest 6 years shown in the figure. Nevertheless, as the starting point was high, the ambition of having none of the population living in areas where the WHO guidelines are exceeded seems unachievable by 2020. This is especially true for O_3, for which exposure above the WHO guidelines has been stable at around 95 % of the

FIGURE 8.5 **EU urban population exposed to air pollutant concentrations above selected WHO air quality guidelines**



Source: EEA (2019g).

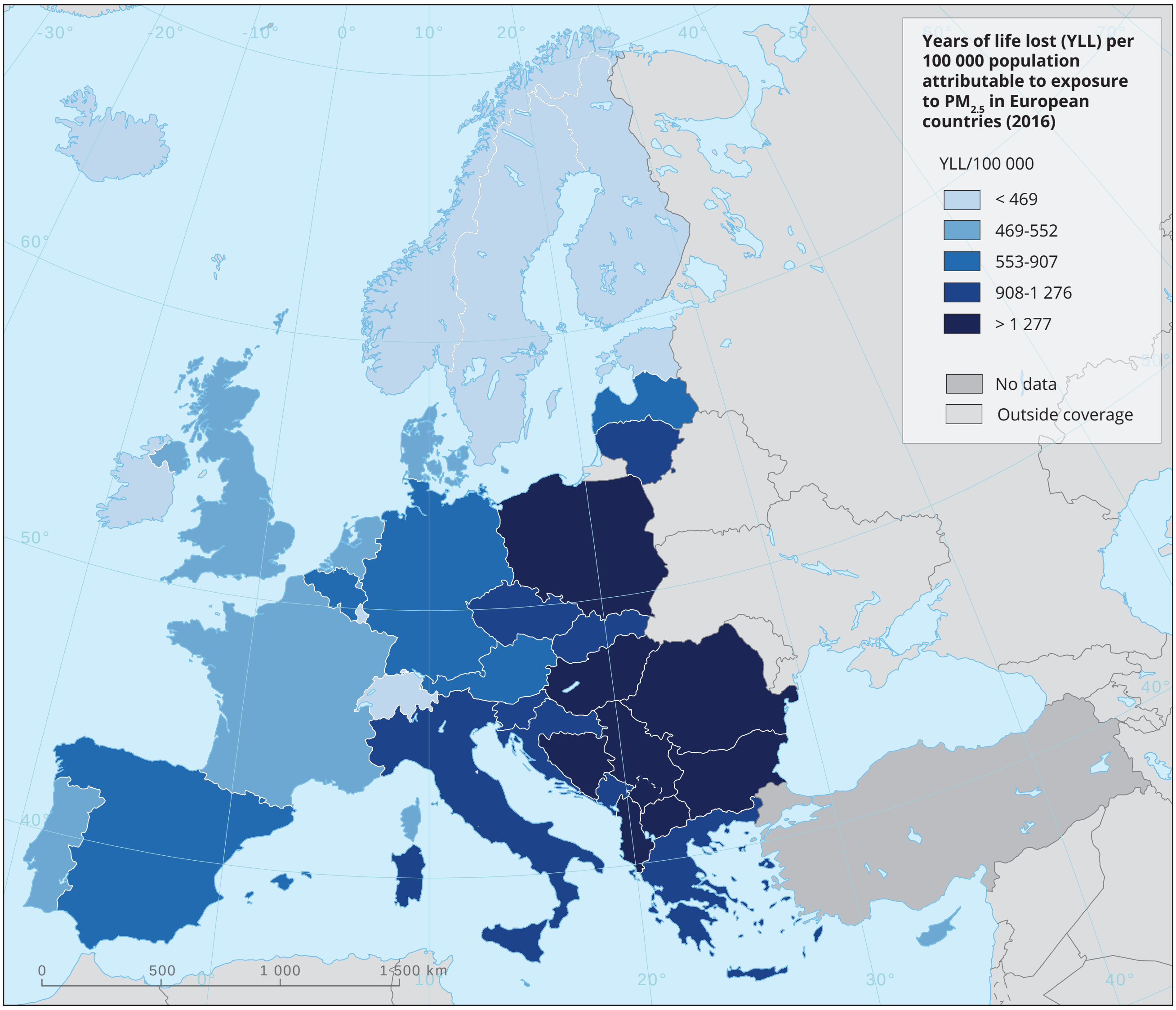
EU-28 urban population. Considering the EU legal standards, up to almost 20 % of the EU-28 urban population still lives in areas where at least one of the standards is exceeded (EEA, 2019g).

It is anticipated that the commitments to reduce air pollutant emissions by 2030 under the revised NEC Directive (Figure 8.2) will result in a reduction in the population exposed to $PM_{2.5}$ concentrations above the WHO guideline to around 13 % by 2030, and in most of those locations the exceedances will be small enough to be addressed by local measures (Amann et al., 2018b). The latest estimations indicate that exposure to $PM_{2.5}$ is responsible for around 400 000 premature deaths in Europe every year (EEA, 2019b). Exposure to NO_2 and O_3 were responsible for around 70 000 and 15 000 premature deaths in 2017, respectively. These calculations are made for individual pollutants without taking into account that pollution is a mix of all of them and concentrations are in some cases correlated. Therefore, the impacts cannot simply be aggregated, as this may result in double counting of the effects (EEA, 2019b). The impacts of air pollution may also be expressed in terms of years of life lost ([1]).

Map 8.2 shows years of life lost per 100 000 inhabitants (as a way of normalising the numbers and making countries easily comparable independently of their size and population) in 2016 for $PM_{2.5}$. The largest relative impacts are observed in the central and eastern European countries where the highest concentrations are also observed, i.e. ordered by relative impacts, Kosovo (under UNSCR 1244/99), Serbia, Bulgaria, Albania and North Macedonia. The detailed data for each country, together with the impacts of NO_2 and O_3, can be found in the EEA's report on air quality in Europe (EEA, 2019b).

([1]) Years of life lost (YLL) are defined as the years of potential life lost due to premature death. YLL is an estimate of the number of years that people in a population would have lived had there been no premature deaths. The YLL measure takes into account the age at which deaths occur and therefore the contribution to the total is greater for a death occurring at a young age than that for a death occurring at an older age (EEA, 2018a).

MAP 8.2 **Estimated years of life lost per 100 000 population attributable to exposure to $PM_{2.5}$ in European countries in 2016**



Note: YLL, years of life lost. The classification of values in map legends is quantiles, so one fifth of countries fall in each class. The calculations are made for all of Europe and they may differ for specific studies at country level.

Source: Based on EEA (2019b).

400 000

premature deaths per year in Europe are attributable to exposure to $PM_{2.5}$.

A recent study (ETC/ACM et al., 2018) assessed the long-term trends in the exposure of the European population to $PM_{2.5}$ concentrations from 1990 to 2015 and the associated premature deaths. The study points to a median decrease in premature mortality attributed to exposure to $PM_{2.5}$ of about 60 % in Europe between 1990 and 2015.

Existing scientific evidence (EEA, 2018c) shows that in Europe some groups are more affected by air pollution than others because they are also more exposed or vulnerable to

TABLE 8.4 Summary assessment — air pollution impacts on human health and well-being

Past trends and outlook		
Past trends (10-15 years)		Europe's air quality is improving and although fine particulate matter ($PM_{2.5}$) still causes serious impacts on health, there has been an estimated 60 % reduction in premature mortality attributed to exposure to $PM_{2.5}$ since 1990.
Outlook to 2030		Full implementation of current policies is expected to deliver projected reductions in premature deaths attributable to $PM_{2.5}$ of 54 % by 2030. However, 194 000 premature deaths are estimated to occur, which indicates that there is still a need to substantially reduce the number of premature deaths and illnesses from air pollution.
Prospects of meeting policy objectives/targets		
2030	☑	The 54 % reduction in premature deaths attributable to $PM_{2.5}$ anticipated by 2030 goes beyond the 52 % objective set by the 2013 Clean Air Programme for Europe.
Robustness		Analysis of past trends has used different data sets but a common methodology to estimate the number of premature deaths. Although the different data sets show a wide range of final results, the median values have been considered. The main uncertainty in the health risk assessments is the concentration-response functions used. The functions recommended by WHO have been used in all calculations. Finally, for prospects, the GAINS model has again been used and the underlying assumptions are documented.

environmental hazards. Older people, children and those with pre-existing health conditions are more vulnerable, while lower socio-economic groups tend to be more exposed (Chapter 14). For a 'business as usual' (i.e. baseline) emissions scenario, models project that the impacts of air pollution are expected to continue decreasing. Beyond 2020, and without further measures, reductions in the impacts on health are expected to continue but at a considerably slower rate (Maas and Grennfelt, 2016). According to the EEA (EEA, 2015), around 144 000 premature deaths could be avoided in the EU in 2012, compared with the real situation, if the WHO air quality guidelines had been attained. According to Amman et al. (2018b), taking into account the overachievements in reducing emissions that might result from fully implementing EU legislation, premature deaths attributable to $PM_{2.5}$ are expected to decline by 54 % from 2005 to 2030 (from 418 000 cases to 194 000), assuming a constant population between 2005 and 2030.

54 %

of premature deaths from $PM_{2.5}$ in Europe could be avoided by 2030 if current policies are implemented fully.

8.3.4 Impacts on ecosystems

► See Table 8.5

Air pollution may directly affect vegetation and fauna and the quality of water and soils as well as the ecosystem services that they support. The atmospheric deposition of nitrogen as nitrate and ammonium compounds can disrupt terrestrial and aquatic ecosystems by introducing excessive amounts of nutrient nitrogen, which can lead to changes in species diversity and to invasions of new species. When this happens, the so-called critical load for eutrophication by nitrogen is exceeded (Box 8.2). NH_3 and NO_x, together with SO_2, also contribute to the acidification of soil, lakes and rivers, causing biodiversity loss.

The cooperative programme for monitoring and evaluation of the long-range transmission of air pollutants in Europe (EMEP) shows that in 2016 critical loads for eutrophication were exceeded in virtually all European countries, in about 62 % of the ecosystem area (EMEP, 2018). This confirms that, although the magnitude of critical load exceedances decreased in most areas, deposition of atmospheric nitrogen remains a threat to ecosystem health. In 2016, the highest exceedances occurred in the Po valley (Italy), on the Dutch-German-Danish border and in north-eastern Spain. Steps taken to mitigate emissions of nitrogen compounds have to date been insufficient to provide conditions in which ecosystems can begin to recover

TABLE 8.5 **Summary assessment — air pollution and impacts on ecosystems**

Past trends and outlook		
Past trends (10-15 years)		Lower emissions of air pollutants have contributed to fewer exceedances of acidification and eutrophication limits. However, in 2016, the critical loads for eutrophication were still exceeded in over 62 % of the European ecosystem area.
Outlook to 2030		Further progress is expected regarding acidification of forest soils and freshwaters due to reductions in atmospheric sulphur and nitrogen deposition. A few acidification hot spots are expected to remain in 2030 due to regional ammonia emissions. Furthermore, there is a time lag between reducing emissions and the recovery of ecosystems. The total area where critical loads for eutrophication are exceeded is projected to be 49 % of European ecosystems, although the magnitude of exceedance is expected to be significantly less than in 2005 in most areas.
Prospects of meeting policy objectives/targets		
2020	☐	Europe is on track to meet policy targets to reduce the acidification of sensitive ecosystems. However, Europe is not on track to meet policy targets to reduce eutrophication, which aim to reduce the ecosystem area exceeding eutrophication limits to 35 % by 2030. Current projections suggest that 49 % of the area is expected to still be in exceedance of critical loads.
2030	☐	
Robustness		Critical loads exceedance modelling requires input from many different sources, and hence it is subject to uncertainty. Critical loads are based on information provided by the scientific community in the Working Group on Effects under the Convention on Long-range Transboundary Air Pollution. The critical loads concept has been applied and developed for around four decades.

from eutrophication. Thus, further reductions are necessary (Maas and Grennfelt, 2016), particularly of NH_3 emissions.

The Clean Air Outlook analysis suggests that achieving compliance with the commitments to reduce emissions (Section 8.3.1) will not achieve the improvements suggested in the 2013 European Commission proposal for the NEC Directive by 2030 (Amann et al., 2018b). In 2005, 67 % of European ecosystems were exposed to nitrogen deposition exceeding the critical loads (78 % of the protected Natura 2000 areas). According to the scenario that assumes that Member States meet the commitments to reduce emissions, this area would be 49 % in 2030, although the magnitude of exceedance is expected to be significantly less than in 2005 in most areas. The Clean Air for Europe Programme calls for the area in exceedance to be reduced to 35 % (Table 8.1). The outlook suggests that biodiversity in 58 % of all Natura 2000 areas is expected to still be at risk in 2030 due to excessive atmospheric nitrogen deposition (Amann et al., 2018b).

The percentage of agricultural areas in the EEA-33 exposed to O_3 levels above the EU legal concentration standards has fluctuated between 15 and 69 % over the period 2000-2017, with some interannual variations due to meteorological conditions (EEA, 2019i). How this exposure affects crops is uncertain. According to current scientific knowledge, the so-called O_3 flux-approach is a better indicator of O_3 damage to vegetation. This methodology estimates the amount of O_3 that actually enters the plant via small pores (stomata) on the leaf surface. The amount depends on the opening and closing of the stomata under, for example, different conditions of temperature, humidity and light intensity (Mills et al., 2017).

8.4 Responses and prospects of meeting agreed targets and objectives

Europe is moving towards the air pollutant emissions and concentration objectives and targets framed in the EU legislation. Effects-based abatement measures under the 1979 CLRTAP and its protocols, mirrored in EU legislation, have led to a sharp decline in emissions, especially of SO_2. Economic growth and trends in air pollution have been progressively decoupled.

Maas and Grennfelt (2016) estimated that, if economic growth and air pollution trends were not decoupled, exceedance of critical loads for acidification in Europe would be 30 times higher than currently and three times higher for eutrophication caused by airborne nitrogen. Average $PM_{2.5}$ levels would be similar to levels in current European hot spots, with health impacts three times higher, and around 600 000 more European citizens would have died prematurely. Health impacts from O_3 would be 70 % higher and O_3 damage to crops 30 % higher. Overall, average life expectancy is 12 months more than in the hypothetical unabated world.

Efficient implementation of EU air quality standards includes effective action at various governance levels, i.e. at national, regional and local levels, and across administrative boundaries between public authorities as well as across different sectors (EC, 2018c). However, achieving policy coherence across administrative and governance levels is challenging, as are efforts to generate political and public support for improving air quality beyond the minimum EU standards (EEA, 2019f). A coherent planning approach to reducing air pollution includes local air quality plans and urban planning in general, national air pollution control programmes for reducing sectoral emissions and national energy and climate plans. The European Commission will continue to support countries to achieve clean air goals, for example through clean air dialogue with EU Member States, the EU urban agenda and the European Structural and Investment Funds or by facilitating domestic funding schemes that allow investment in low- and zero-emission mobility (EC, 2018b).

However, for most of the main air pollutants, EU Member States and EEA member countries still fail to achieve some national emission ceilings, some of the EU air quality standards and, especially, the WHO air quality guidelines. This makes it difficult to

Economic growth and trends in air pollution have been progressively decoupled.

reach the long-term objectives of achieving levels of air quality that do not give rise to significant negative impacts on, and risks to, human health and the environment.

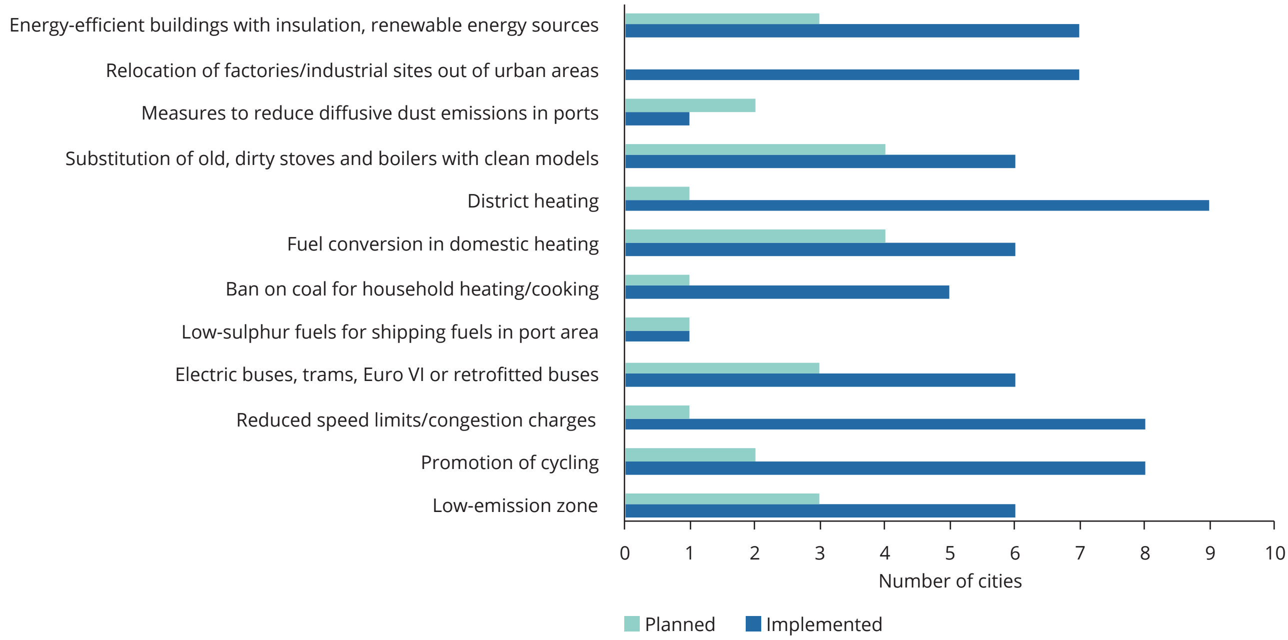
The reasons are, first, that not all sectors reduced their emissions at the same pace (e.g. agriculture). Second, integration of air policy with other policies such as those on climate has also resulted in trade-offs. The European Court of Auditors recommends that the Commission takes action to better align policies that contain elements that can be detrimental to clean air (e.g. climate and energy, transport, industry and agriculture policies) with the air quality objectives (ECA, 2018). Third, the various levels of implementation of measures require coordination of the international, national, regional and local governance levels (see, for example, the implementation of the Ambient Air Quality Directives). Finally, there are some sectors or mechanisms that may be underestimated in emissions inventories. Examples are resuspension of PM, the condensable fraction of primary PM or international shipping and aviation. As the relationship between emitted pollutants and measured concentrations is not linear, the use of models, which include processes assessing chemistry, dispersion and (changes in) meteorology, is essential to help understand the relation between emission sources and concentrations in ambient air.

BOX 8.2
The critical loads concept

A critical load is a 'quantitative estimate of an exposure to one or more pollutants below which significant harmful effects on specified sensitive elements of the environment do not occur according to present knowledge' (UNECE, 2018b). It represents the upper limit of one or more pollutants deposited on the Earth's surface that an ecosystem, such as a lake or a forest, can tolerate without its function (e.g. the nutrient nitrogen cycle) or its structure (e.g. with respect to plant species' richness) being damaged.

A positive difference between the deposition loads of acidifying and/or eutrophying airborne pollutants and the critical loads is termed an 'exceedance'. Areas and magnitude of exceedance are visualised in a map in the EEA indicator 'Exposure of ecosystems to acidification, eutrophication and ozone (EEA, 2019i). ■

FIGURE 8.6 **Examples of the main air pollution mitigation measures in place and planned in the pilot cities**



Source: EEA (2019f).

8.4.1
Synergies and trade-offs between air pollution and climate policies

Greenhouse gases (GHG) and air pollutants have mostly common emission sources. The 2020 climate and energy package (Chapter 7) implies reduced use of fuel and energy, reduced GHG and air pollutant emissions and thus co-benefits in the form of improved air quality. The European Commission has proposed a strategy for achieving a climate-neutral economy by 2050. The EU has implemented many legislative acts aimed at reducing the emissions of the most important GHGs, and several of those also result in reductions in emissions of air pollutants (Chapter 7). One example is the goal to decarbonise European transport by 2050 through mobility and energy transitions (Chapter 13). Tackling climate change requires global mitigation efforts.

> Reducing greenhouse gas emissions, as well as fuel and energy use, not only benefits energy efficiency and climate change but also improves air quality.

Achieving a net-zero GHG emissions economy on top of existing air pollution measures is expected to reduce premature deaths caused by $PM_{2.5}$ by more than 40 % and reduce the cost of damage to health by around EUR 200 billion per year (EC, 2018a). A recent study suggests that worldwide air quality benefits on morbidity, mortality and agriculture could globally offset the costs of implementing climate policies (Vandyck et al., 2018).

Nevertheless, some trade-offs between policies are obvious, for instance in transport, promoting the uptake of diesel vehicles because of their lower CO_2 emissions entailed higher real-world emissions of NO_2, worsening the air quality situation in cities (see below). Promoting biomass as a carbon-neutral fuel for domestic heating contributes to a local increase in $PM_{2.5}$, BaP and black carbon concentrations (EEA, 2016).

8.4.2
Air quality management in cities

In 2018, the EEA undertook a follow-up of the 2013 air implementation pilot organised by the EEA in cooperation with the European Commission (EEA, 2013). The follow-up project re-assessed the challenges of implementing EU air quality legislation in 10 European cities. All urban authorities stated that the air quality in their cities had improved since

2013, mainly due to implementing EU policies (EEA, 2019f).

Although most abatement measures address emissions from road traffic, mainly of NO_x and PM (EEA, 2019f), other pollutant sources are now being tackled, for example fuel combustion in residential stoves, inland shipping or construction and demolition activities, including emissions from non-road mobile machinery (Figure 8.6).

Cities express the need for a more comprehensive approach across Europe to allow an improved and more regular exchange of knowledge and experience of, for example, good practice and capacity building. They stress that implementing air quality legislation on the local scale would be beneficial if initiatives at the national and/or EU level were implemented and took effect. Examples are the enforcement of type approval procedures for vehicles (e.g. mandatory compliance testing of vehicles during use), national-/EU-level labelling schemes based on real-world driving emissions or product-specific regulations (ecodesign, energy labelling).

Local transport authorities need to decide on the implementation of low-emission zones, urban road tolling systems, charging schemes to reduce congestion in the city centres or a general reduction in congestion by fostering the development of alternative modes of transport and the use of cleaner, more energy-efficient vehicles. With improved EU guidance, urban vehicle access regulation schemes can be a basis for such planning (Ricci et al., 2017).

Under the NEC Directive (EU, 2016), Member States are required to draw up national air pollution control programmes, which should contribute to the successful implementation of air quality plans established under the EU's Ambient Air Quality Directives. The European Court of Auditors recommends making air quality plans results oriented and reporting to the European Commission on a yearly basis on their implementation (ECA, 2018). Overall, achieving coherence between control programmes and air quality plans, addressing air pollutants as well as GHG emissions, is essential for improving the air pollution situation in Europe.

Due to the transboundary nature of air pollution, action and cooperation at global, national and local levels are required.

8.4.3 Timely information and involving citizens

The Ambient Air Quality Directives have proved to be very efficient in establishing a strong European Monitoring Network ([2]) with around 4 000 monitoring stations managed by countries' competent authorities and reporting data annually to the EEA. These stations measure air pollutant concentrations following common rules, methodologies and agreed quality controls. Countries officially report concentrations of air pollutants to the EEA to comply with the requirements of the Directives. First, these measurements are validated values, reported on a yearly basis and used by the European Commission to check compliance with standards and enforce implementation of measures to improve air quality. The European Court of Auditors has recommended advancing the deadline for reporting these data from 30 September of the following year to at least 30 June (ECA, 2018). Countries also report up-to-date data on an hourly basis to keep citizens informed about the air quality situation in 'near-real time'. This allows the EEA to inform citizens about the air quality situation in the whole of Europe via its up-to-date viewer ([3]). Based on these timely data, the EEA in cooperation with the European Commission has developed a tool to provide more easily understood information for European citizens: the European air quality index ([4]). This index fulfils the Court of Auditors' recommendation to seek agreement on harmonising air quality indices (ECA, 2018).

Assessment of air quality depends not only on measurements taken at monitoring points but also on results obtained from air quality models. Several countries report modelling results, mainly as a supplementary assessment method. The European Commission aims to streamline environmental reporting, and one suggestion is to make 'better use of data generated through the Copernicus programme' (EC, 2017). The Copernicus Atmosphere Monitoring Service (CAMS, 2018) uses an ensemble of leading European chemical dispersion models, considering changes in meteorology, to forecast air pollution and to analyse past pollution episodes (e.g. Tarrasón et al., 2018). The CAMS approach includes the use of up-to-date and validated measurement data reported to the EEA under the Ambient Air Quality Directives.

A key new element of the Copernicus space component is based on the

([2]) https://www.eea.europa.eu/data-and-maps/dashboards/air-quality-statistics
([3]) https://www.eea.europa.eu/data-and-maps/explore-interactive-maps/up-to-date-air-quality-data
([4]) https://www.eea.europa.eu/themes/air/air-quality-index/index

'Sentinel missions'. The latest constitutes a sentinel (5P) with the tropospheric monitoring instrument (Tropomi) on board, a state-of-the-art instrument that can map pollutants such as NO_2, methane (CH_4), CO, SO_2 and PM (ESA, 2019). Currently, the main use of such satellite data is mapping, monitoring and detecting trends. The potential use of such data for improving emission inventories or information on air quality, for example within CAMS, still needs evaluation.

Another suggestion from the European Commission (EC, 2017) is to 'promote the wider use of citizen science to complement environmental reporting'. More and more European citizens wish to measure air quality in their surroundings themselves using simple diffusion tubes or so-called low-cost sensors. This raises peoples' awareness regarding air quality problems and can contribute to changes in behaviour. Cooperation with city, regional or national authorities is an opportunity to re-establish trust in the work of these institutions and their official measurements. A recent example of a well-planned and coordinated citizen science initiative is the 'curious noses' project in Flanders, Belgium, in which 20 000 people measured the air quality (NO_2) near their own houses and near schools during May 2018. The results are also being used to improve a regional air quality model (CurieuzeNeuzen Vlaanderen, 2018).

8.4.4
Europe's transport sectors have great potential for positive change

The increasing demand for domestic and international road transport, aviation and shipping services, key components of Europe's mobility system, also leads to increased pressures on human health, the environment and climate (EEA, 2017). These sectors are important sources of NO_x, primary and secondary PM, and SO_x (the latter in particular for shipping).

Citizens are better informed about air pollution through real time air quality information.

They contribute significantly not only to local and regional, but also global air (and climate) pollution. Each sector has great potential for change, not only through technical innovations for effectiveness such as design or changes in practices, but also with respect to the potential introduction of new or different fiscal measures to promote the uptake of cleaner transport technologies and/or changes in societal behaviour. At present for example, many different types of subsidies are extended to existing manufacturers, infrastructure providers and operators, all of which can inhibit shifting to a more sustainable mobility system. Across the different modes, unequal forms of fuel taxation can similarly potentially prevent investment and shifting to more environmentally friendly types of passenger and freight transport.

With regard to passenger road transport, and especially in cities, electric vehicles are expected to be a key future component of Europe's mobility

To further improve air quality, additional efforts focused on the food, mobility and energy systems are needed to reduce emissions.

system, helping to reduce impacts on climate change and air quality. By 2030, battery electric vehicles (BEVs) could be between 3.9 % and 13.0 % of new car registrations, depending on the EU-wide fleet average CO_2 target levels set for passenger cars in the future (EEA, 2018b). As the new Regulation on CO_2 emission performance standards (EU, 2019) requires a reduction of 37.5 % by 2030 compared with 2021, it seems likely that the share will be at the higher end of this range. However, the environmental impacts of BEVs, and their advantages or disadvantages relative to vehicles with an internal combustion engine, are influenced by a range of key variables associated with vehicle design, vehicle choice and use patterns, reuse and recycling and the electricity generation mix. There is, therefore, an increasing need to understand BEVs from a systems perspective. This involves an in-depth consideration of the environmental impact of the product using life cycle assessment approaches (EEA, 2018b).

International rather than local factors are largely responsible for the significant demand for transport from the aviation and shipping sectors, driven, for example, by the globalisation of trade and often led by consumers through tourism and the global supply chains of certain types of food and manufactured goods. This requires implementing international abatement measures, which is challenging because agreements are only slowly reached (EEA, 2017; Engleryd and Grennfelt, 2018). Examples of measures in place are global ship fuel sulphur limits or sulphur and NO_x emission control areas, so far only established in Europe in the Baltic and North Seas. Airports have a similar infrastructure to that of cities: emissions from the numerous ground support services, such as vehicles operating at or around runways, airport heating, and transport to and from airports by passengers and freight services all significantly contribute to the emissions of air pollutants. Changing local mobility systems is challenging, but it offers many opportunities to improve local air quality (Section 8.4.2).

8.4.5 Technical and non-technical abatement measures can reduce nitrogen emissions

Agriculture is the economic sector in which air pollutant emissions have been reduced the least. NH_3 emissions are still high and have even increased in recent years, favouring the formation of secondary PM in the air, which contributes to episodes of high PM concentrations and exceedances of air quality standards (Section 8.3.2).

High NH_3 emissions are the main reason why atmospheric nitrogen deposition is still, and is expected to remain, a major threat to sensitive ecosystems such as nutrient-poor grasslands (Chapter 3). NH_3 is also the main reason why a few hot spots in Europe still exceed the critical loads for ecosystem acidification. According to Amman et al. (2018b) several EU Member States will need to introduce additional measures to reach the NEC Directive commitments to reduce $PM_{2.5}$ and especially NH_3. Regarding primary $PM_{2.5}$ emissions from agriculture, one low-cost measure is to ban the open-air burning of agricultural waste.

Technical solutions for sustainable reductions in NH_3 emissions in the agriculture sector are available. They include low-emission techniques for spreading manures and mineral fertilisers, the measure with the greatest potential to reduce NH_3 emissions, and animal feeding strategies (EC, 2019a). According to a study by the International Institute for Applied Systems Analysis (IIASA), based on Eurostat data, disposing of manure from livestock farming causes about 78 % of all NH_3 emissions in the EU-28. A total of 80 % of manures originate from 4 % of farms housing more than 50 livestock units (LSU). The largest farms (with more than 500 LSU), represent about 0.3 % of all farms, and IIASA estimates that they produce manure that releases about 22 % of all NH_3 emissions. Variations across the Member States are large, reflecting the different structures of the agricultural systems in the EU (Amann et al., 2017). There are no farm size thresholds in place, and the current tendency is increasingly to establish big industrial-scale farms, particularly in some countries. While the Industrial Emissions Directive (EU, 2010) covers big pig and poultry farms, cattle farms are not regulated.

Indirectly, reducing food waste or increasing overall efficiency in the food chain will also reduce air pollutant emissions from agriculture. In a Nordic Council of Ministers report, Engleryd and Grennfelt (2018) raise the possibility of linking agricultural subsidies to obligations to reduce emissions as well as producing healthy food. Furthermore, the editors of the report suggest including the environment in national and international dietary guidance. Such measures, which particularly aim to reduce the consumption of (red) meat would also reduce CO_2 emissions from agriculture. In conclusion, Engleryd and Grennfelt recommend joining up approaches across the nitrogen cycle and state that an overarching EU nitrogen policy, which aims to improve nitrogen resource efficiency and reduce nitrogen waste, would have considerable co-benefits for air, climate, water and the economy (Chapter 14).