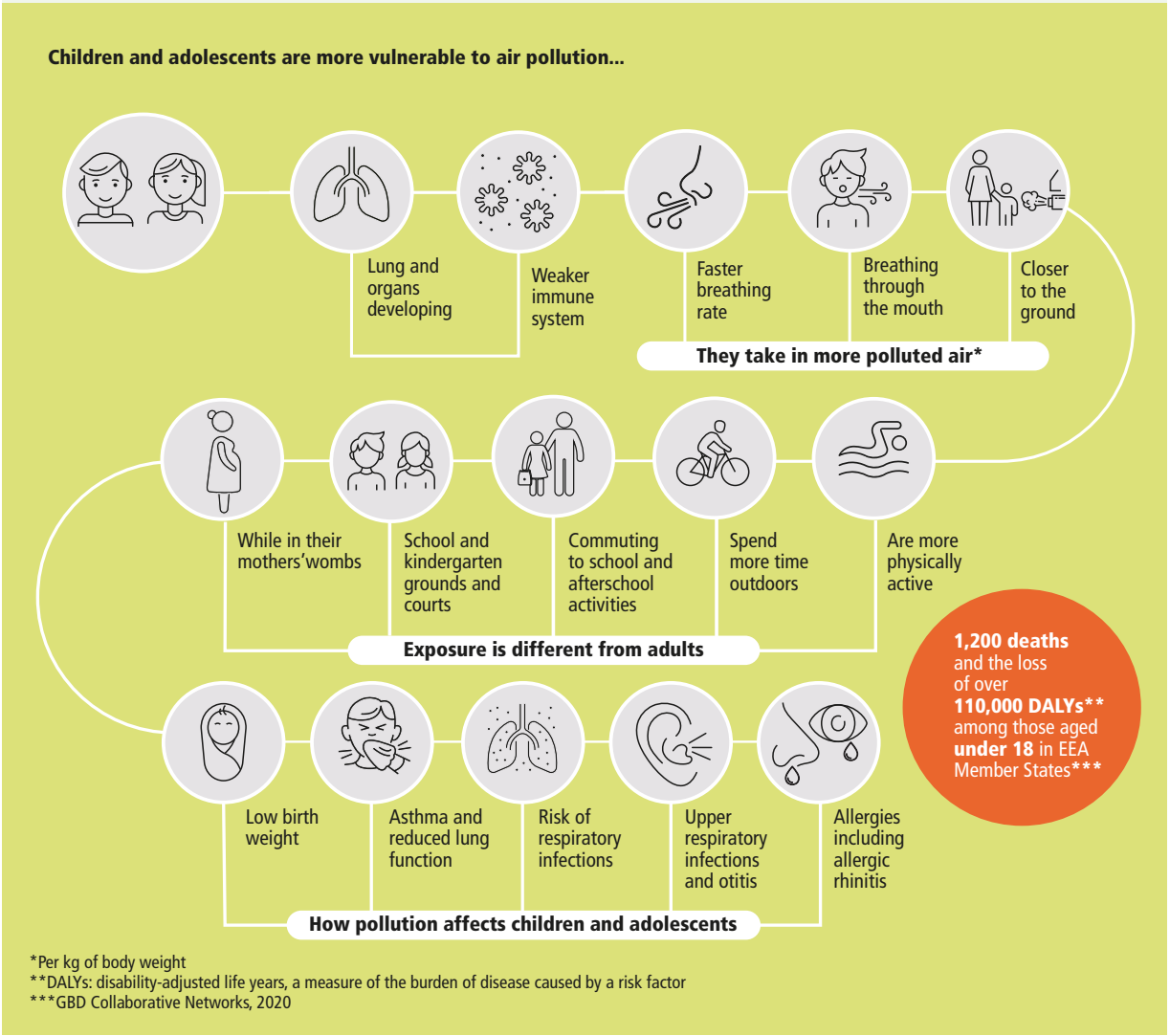
Chapter 2:
Air

Air

1. Introduction

The quality of the air we breathe is of critical importance to our health and the health of our ecosystems. As an island on the periphery of Europe with south-westerly prevailing winds, Ireland is less frequently affected by transboundary air pollution from its neighbours than other parts of Europe. However, national emissions of air pollutants contribute to poorer air quality throughout the year, be they from home heating, transport, agriculture or energy. The national emissions are added to by episodes of transboundary air pollution from continental Europe. Overall, there is an increasing understanding of the negative, pervasive impacts on our health of air pollutants, including impacts on the health of children (Figure 2.1).

Figure 2.1 Health impacts of air quality on children in the EU

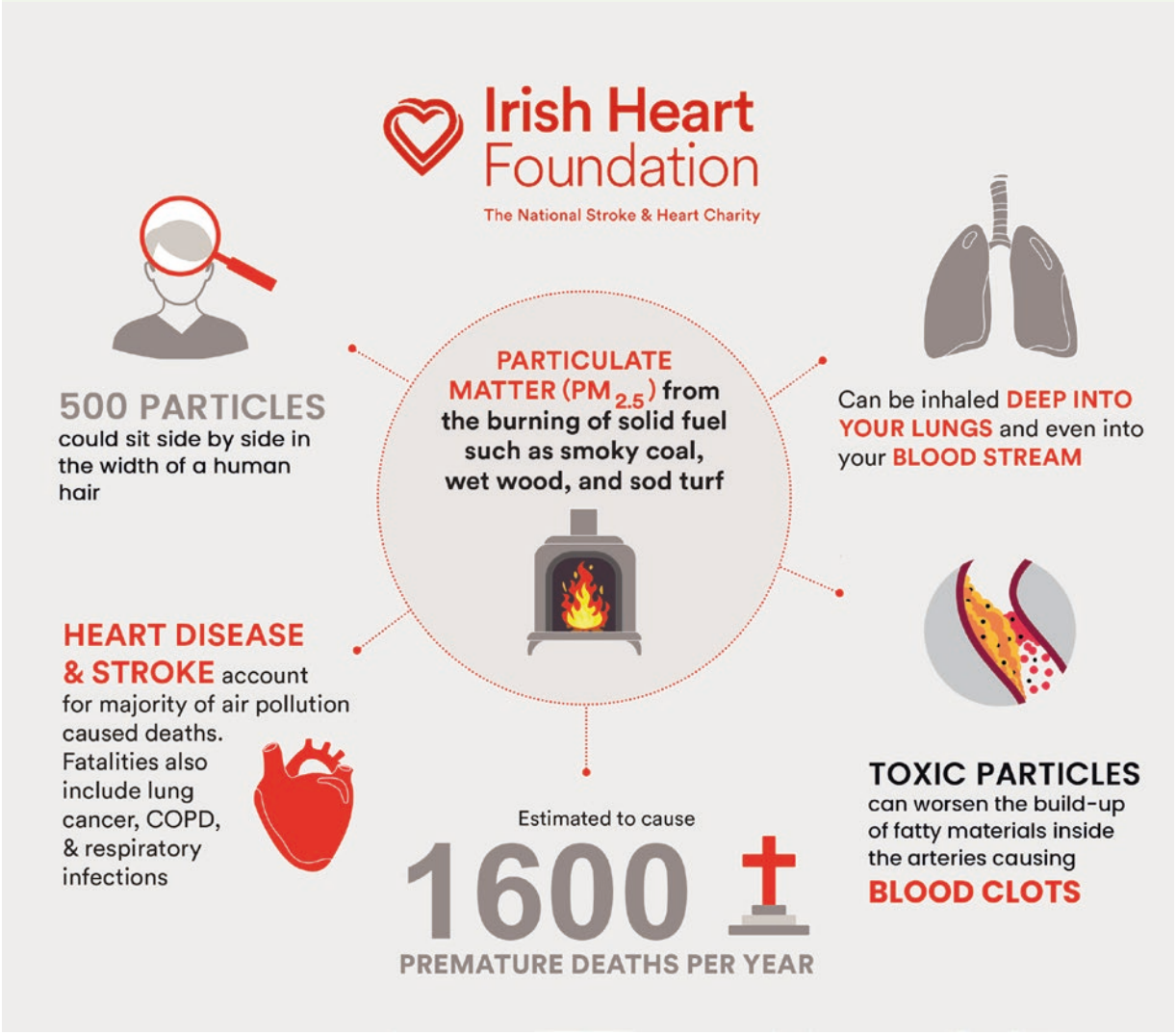


Source: Adapted from EEA, 2023a

The World Health Organization (WHO) has identified poor air quality as the single largest threat to public health (WHO, 2021). Poor air quality is linked to premature death and life-limiting conditions such as dementia (Wood *et al.*, 2022), type 2 diabetes and neonatal mortality (GBD 2019 Risk Factors Collaborators, 2020). Long-term exposure to particulate matter contributes to the risk of developing cardiovascular and respiratory diseases, as well as lung cancer (WHO, 2024).

The European Environment Agency (EEA) estimates that in excess of 1600 premature deaths in Ireland annually are due to air pollution from causes including cardiovascular disease and respiratory illnesses (EEA, 2023b). Irish research has shown the impacts of poor air quality on older citizens (Ó Domhnaill *et al.*, 2022) and the increased incidence of stroke due to air pollution (Byrne *et al.,* 2020). Recently published research also shows estimated healthcare costs of €56 million over 4 years for five conditions attributable to air pollution (ESRI, 2023). Irish research also shows that, for the older population, higher fine particulate concentrations (Figure 2.2) are associated with an increase in the prevalence of both depression and anxiety (ESRI, 2023).

Figure 2.2 Health impacts of air pollution



Source: Irish Heart Foundation

WHO stresses that even extremely low levels of air pollution can have health impacts, such that there is no safe level of air pollution. Therefore, taking action even at low levels of pollution can deliver health benefits.

The pollutants of concern in Ireland are fine particulate matter, nitrogen dioxide and ammonia (Table 2.1).

Table 2.1 Fine particulate matter ($PM_{2.5}$), nitrogen dioxide (NO_2) and ammonia (NH_3)

Pollutant	Description	Sources and solutions
Fine particulate matter	Particulate matter is a mixture of very small solid and liquid particles suspended in air. $PM_{2.5}$ particles have a diameter of < 2.5 µm. Small particles can penetrate the lungs and enter the blood system, causing damage. $PM_{2.5}$ is a strong indicator of anthropogenic (human-generated) emissions and it is responsible for significant negative impacts on human health.	Levels of $PM_{2.5}$ are particularly problematic in or near urban centres, villages, towns and cities, because of the cumulative effects of multiple sources of the pollutant, with the dominant source being solid fuels used in home heating. $PM_{2.5}$ pollution can be reduced by changing how we heat our homes, specifically by moving away from smoky fuels and choosing cleaner options.
Nitrogen dioxide	While not as impactful on health as $PM_{2.5}$, NO_2 can have negative impacts on respiratory and cardiovascular health. Nitrogen oxides (NO_x) also contribute to the acidification of soils and surface waters, and to ground level ozone (O_3) formation. They can contribute to excess nitrogen in terrestrial ecosystems.	The dominant sources of NO_2 are from transport, particularly diesel- and petrol-powered vehicles. NO_2 pollution is particularly an issue in urban areas due to transport emissions. NO_2 pollution could be decreased by reducing overall traffic volumes in towns and cities, increasing the electrification of the fleet and giving consideration to low emission zones in our largest urban centres.
Ammonia	NH_3 emissions to air are associated with nitrogen deposition, acid rain and the formation of secondary particulate matter. Excessive deposition of reactive nitrogen negatively affects terrestrial ecosystems, including biodiversity loss, through eutrophication and acidification.	Agriculture is the dominant source of NH_3 emissions in Ireland. To decrease concentrations, there is an urgent need for a significant uptake of abatement techniques such as low-emission slurry spreading, the use of inhibited fertiliser products and reduction in the crude protein concentration of livestock feeds.

2. Air quality standards in Ireland

European directives on air quality and emissions

The EU zero pollution targets for 2030 include a reduction of more than 55% in the number of premature deaths across Europe as an indicator of the overall reduced health impacts of air pollution. The EU's comprehensive Clean Air Policy (EC, 2018) is based on three pillars: ambient air quality standards, national emission reduction targets and emission standards for key sources of pollution. Collectively, these pillars combine to tackle air pollution and achieve the EU's zero pollution vision for 2050 (EC, 2021) including the 2030 target.

Emission standards are used in the regulation of industry and the power generation sector. Industrial Emissions Directive (2010/75/EU) licences, which are granted and enforced by the Environmental Protection Agency (EPA), work to curb emissions from industry and the power generation sector in Ireland. Installations with a power generation capacity of 50 MWth (thermal input) and above are covered by this directive. The Medium Combustion Plant Directive ((EU) 2015/2193), applies to installations with on-site combustion plants with a rated thermal input capacity of 1-50 MWth. To continue to ensure that industrial facilities do not affect the quality of air in the surrounding environment, industrial emissions of pollutants to air are controlled. Industry's impact on the environment is discussed in Chapter 13.

Ambient air quality directives

European ambient air quality legislation sets out concentration limits for 13 air pollutants that have impacts on human health and on vegetation.[1] These pollutants are NO_2, particulate matter (both particulate matter < 10 µm (PM_{10}) and $PM_{2.5}$), O_3, sulphur dioxide (SO_2), benzene, lead, carbon monoxide (CO), arsenic, cadmium, nickel and benzo(a)pyrene. The relevant directives include the Cleaner Air For Europe (CAFE) Directive and one current daughter directive, the fourth daughter directive. When a Member State does not meet the standards in the directives, it must prepare an air quality plan to ensure compliance in future.

The EU ambient air quality directives have been subject to a review since 2022. This review is substantially informed by the revised WHO air quality guidelines (Topic Box 2.1). At the time of writing, this review was at the end stage of the EU's approval process. The proposed CAFE Directive sets out to move Europe's air quality standards towards the health-based WHO guideline limits in a stepwise manner. Its new provisions include tighter limits on air pollutants, including new air pollutants such as ultrafine particles and black carbon, and a strengthened regime for Member States' air quality plans when new limits have not been met. Innovatively, it obliges Member States to put in place air quality roadmaps when they anticipate future issues with complying with the revised air quality standards. This means that action needs to be taken proactively rather than waiting until a standard has been breached. The roadmaps are intended to set out the steps to ensure compliance when potential breaches of standards are considered likely.

Topic Box 2.1 WHO air quality guidelines

Based on extensive scientific evidence, the WHO sets human health-based guideline limits for pollutants in ambient air. In 2021, it issued a new set of guidelines (WHO, 2021), the first global update since 2005. The guidelines reflect the growing volume of understanding and medical evidence showing the impacts of air pollutants at increasingly lower concentrations. The guidelines cover the pollutants most critical for health, i.e. for which the evidence for health effects arising from exposure has advanced in the past 15 years. Based on the evidence, they provide recommendations on air quality guideline limits for key air pollutants: $PM_{2.5}$ and PM_{10}, O_3, NO_2, SO_2 and CO. The 2021 guideline limits are significantly lower for particulate matter and NO_2. WHO also included interim targets to guide reduction efforts towards achieving the air quality guideline limits (Figure 2.3). According to WHO, meeting the interim targets could have a notable benefit for health, especially in those regions where exposure far exceeds the interim targets.

1 Directive 2008/50/EC on ambient air quality and cleaner air for Europe (CAFE Directive) and Directive 2004/107/EC relating to arsenic, cadmium, nickel and polycyclic aromatic hydrocarbons in ambient air.

Figure 2.3 Air quality guideline (AQG) limits and interim targets recommended by the WHO, by pollutant

Pollutant	Averaging time	Interim target				AQG level
		1	2	3	4	
Fine particulate matter ($PM_{2.5}$), µg/m³	Annual	35	25	15	10	5
	24-hour[a]	75	50	37.5	25	15
Particulate matter (PM_{10}), µg/m³	Annual	70	50	30	20	15
	24-hour[a]	150	100	75	50	45
Ozone (O_3), µg/m³	Peak season[b]	100	70	–	–	60
	8-hour[a]	160	120	–	–	100
Nitrogen dioxide (NO_2), µg/m³	Annual	40	30	20	–	10
	24-hour[a]	120	50	–	–	25
Sulphur dioxide (SO_2), µg/m³	24-hour[a]	125	50	–	–	40
Carbon monoxide (CO), mg/m³	24-hour[a]	7	–	–	–	4

a 99th percentile (i.e. 3-4 exceedance days per year).

b Average of daily maximum 8-hour mean O_3 concentration in the six consecutive months with the highest six-month running-average O_3 concentration.

Source: WHO, 2021

EU National Emission Reduction Commitments Directive

The National Emission Reduction Commitments (NEC) Directive ((EU) 2016/2284) set 2020 and 2030 commitments to reduce emission of five air pollutants,[2] based on 2005 levels. The directive incorporates the reduction commitments for 2020 agreed by the EU and its Member States under the 2012 revised Gothenburg Protocol (UNECE, 2016). The reduction commitments for 2030 have been designed to reduce the health impacts of air pollution by half compared with 2005. The directive also requires that Member States, including Ireland, draw up a National Air Pollution Control Programme (DECC, 2021) to help ensure that national emission reduction commitments are met. It also obliges Member States to create a network to monitor the effects of air pollution on ecosystems.

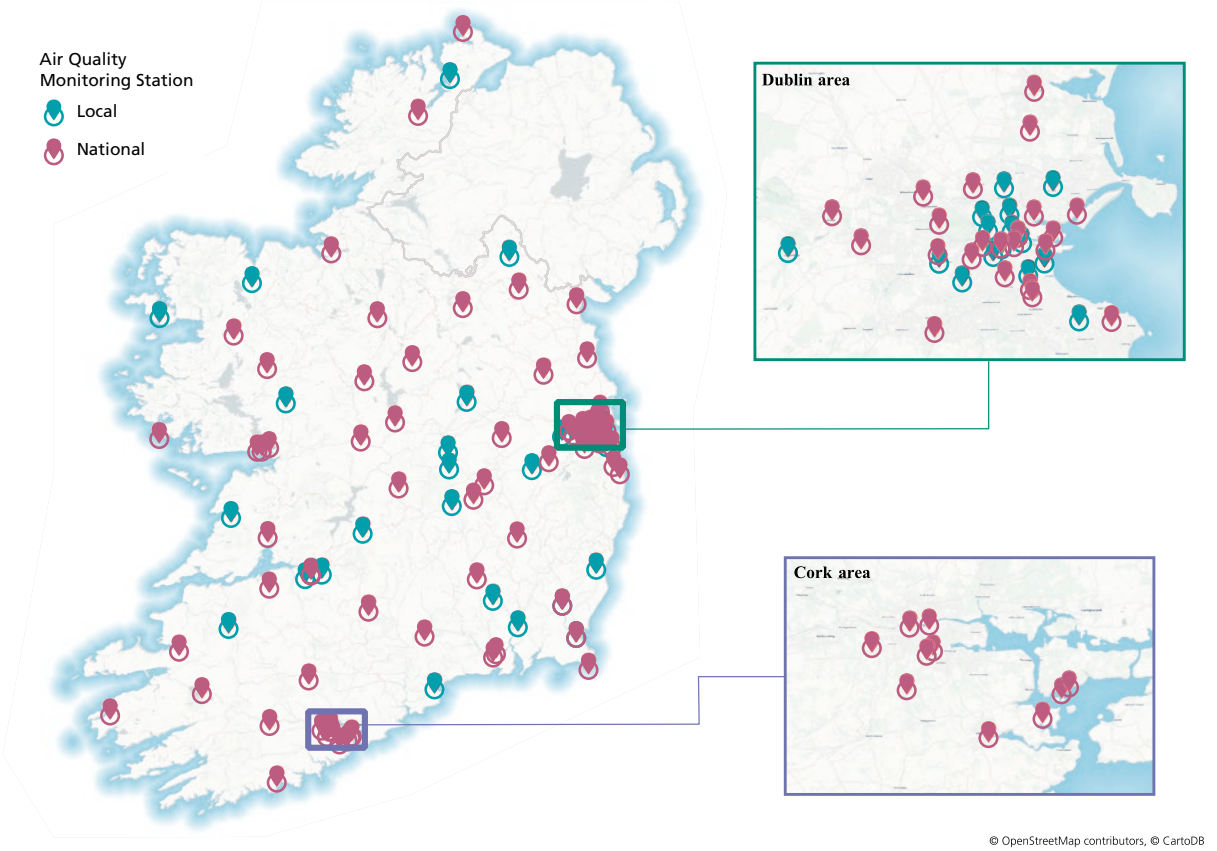
National air quality policy, monitoring and enforcement

The Department of the Environment, Climate and Communications (DECC) has responsibility for ensuring that Ireland meets its air quality obligations under EU legislation and international agreements. In 2023, the government launched Ireland's first Clean Air Strategy (DECC, 2023), which sets out a high-level strategic policy framework to reduce air pollution and promote cleaner ambient air.

The EPA coordinates ambient air quality monitoring, modelling, assessment and reporting nationally. Its air-related activities also involve regulating industrial and waste activities, including air emissions associated with these activities; maintaining the national solid fuel register; compiling, and reporting the national inventory of air emissions; and overseeing the environmental enforcement activities undertaken by local authorities. Local authorities also regulate some activities that give rise to air pollution and some also undertake local air monitoring programmes.

2 The five pollutants are NH_3, NO_x, $PM_{2.5}$, non-methane volatile organic compounds (NMVOCs) and SO_2.

Figure 2.4 Map showing the network of 115 air quality monitoring stations



National ambient air quality monitoring and modelling

The EPA, in partnership with other national bodies, monitors air pollutants across the National Ambient Air Quality Monitoring Network. The monitoring network has almost quadrupled in size since 2017 from 29 stations to the current network of 115 stations (Figure 2.4) in 2024. Pollutants monitored include PM_{10} and $PM_{2.5}$, NO_2, ground level O_3, SO_2, CO, benzene, heavy metals and polycyclic aromatic hydrocarbons. The EPA makes real-time monitoring information available online (www.epa.ie and www.airquality.ie). It provides public information based on the Air Quality Index for Health, developed in conjunction with the Health Service Executive (HSE).

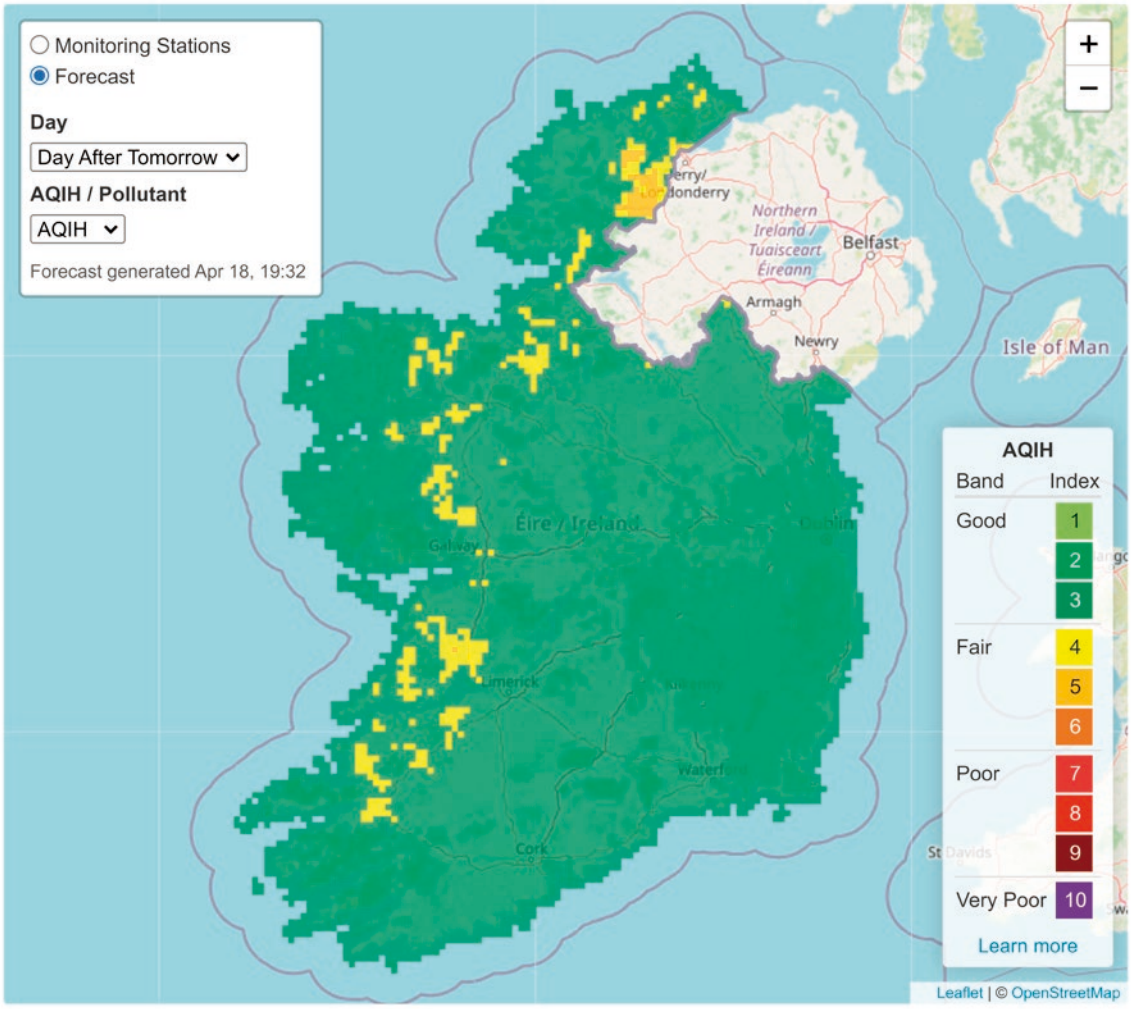
Modelling concentrations of air quality across the country improves our ability to understand and manage air pollution. High-resolution models provide maps essential to understanding air pollution and exposure across the country. These models are produced under the EPA's LIFE Emerald project (EPA, 2023a) and from previous modelling focused on Dublin (EPA, 2019). Such maps have been used as part of the LIFE Emerald project to review the effectiveness of national plans and our monitoring network, while also informing an assessment of national health impacts and improving our ability to highlight areas with high emission levels. Such models will be key to highlighting current and potential future air pollutant concentrations across Ireland, assessing strategies to reduce emissions while also maximising the co-benefits of efforts to reduce greenhouse gas emissions by targeting areas where air pollution is also an issue. The EPA's LIFE Emerald project has also developed an air quality forecast (Topic Box 2.2) and hourly updated Air Quality Index for Health maps.[3] Building on previously published modelling scenarios (EPA 2019, 2023a), new annual air quality maps will be provided to show the annual average air quality for all areas.

3 All are available on the air pages of www.epa.ie and on www.airquality.ie (both accessed 28 May 2024).

Topic Box 2.2 EPA LIFE Emerald air quality forecast

The EPA's LIFE Emerald 3-day air quality forecast, launched in November 2023, consists of maps showing the Air Quality Index for Health and concentrations of four air pollutants (PM_{10}, $PM_{2.5}$, NO_2 and O_3) for today, tomorrow and the day after tomorrow (Figure 2.5). Live data collected from the EPA's air quality monitoring network, weather forecasts, and geographical information are input to the computer model to produce the forecast, validated in line with EU standards. Users can zoom in to their local area to a scale of 3 km and can see the predicted air quality for that area. The maps are updated twice a day. The forecast enables members of the public to make informed decisions about their planned activities that can positively affect their health.

Figure 2.5 LIFE Emerald forecast as presented on www.epa.ie and www.airquality.ie



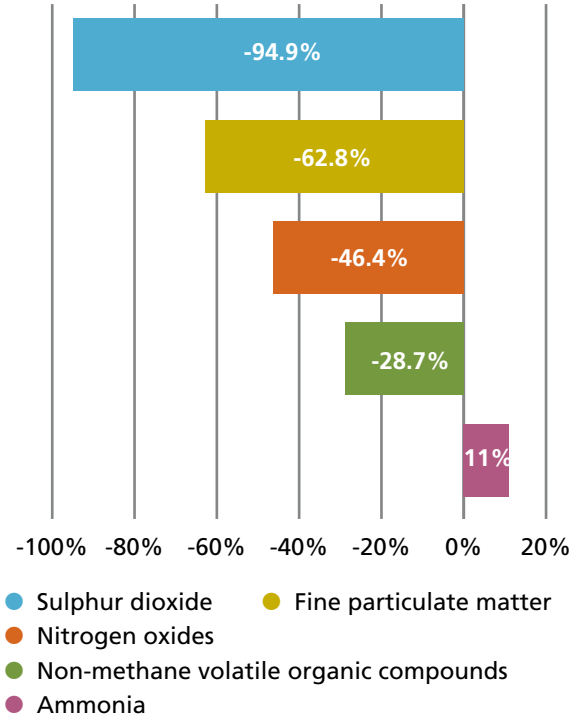
3. Emissions and national emission reduction commitments

National emissions of air pollutants

Total annual national emission levels of five air pollutants are subject to emission reduction commitments specified in the NEC Directive. The pollutants are NO_x, non-methane volatile organic compounds (NMVOCs), SO_2, NH_3 and $PM_{2.5}$.

Ireland has seen substantial reductions in the emissions of all pollutants except NH_3, which have increased over the last 30 years (see Figure 2.6). Despite this progress, challenges remain in maintaining a decreasing trend in the face of increasing economic activity, particularly in relation to emissions from the transport and agriculture sectors.

Figure 2.6 Percentage change in the five air pollutants covered by the NEC Directive, 1990-2022



Source: EPA, 2024a

The reduction commitment for each pollutant is a proportional reduction in emissions relative to the reported national emissions in 2005. These emission reduction commitments are in force for the period 2020-2029 and then from 2030 onwards (Table 2.2).

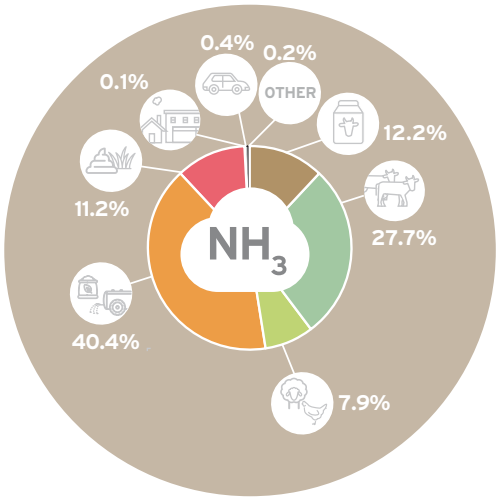
Table 2.2 National emission reduction commitments for 2020-2029 and 2030 onwards

Pollutant	2020	2030
Sulphur dioxide (SO_2)	-65%	-85%
Nitrogen oxides (NO_x)	-49%	-69%
Ammonia (NH_3)	-1%	-5%
Non-methane volatile organic compounds (NMVOCs)	-25%	-32%
Particulate matter < 2.5µm ($PM_{2.5}$)	-18%	-41%

Source: EPA, 2024a

Ammonia. NH_3 emissions are associated with nitrogen deposition, acid rain and the formation of secondary particulate matter. The agriculture sector accounts for virtually all (99.4%) NH_3 emissions in Ireland (Figure 2.7).

Figure 2.7 Sources of ammonia emissions in Ireland



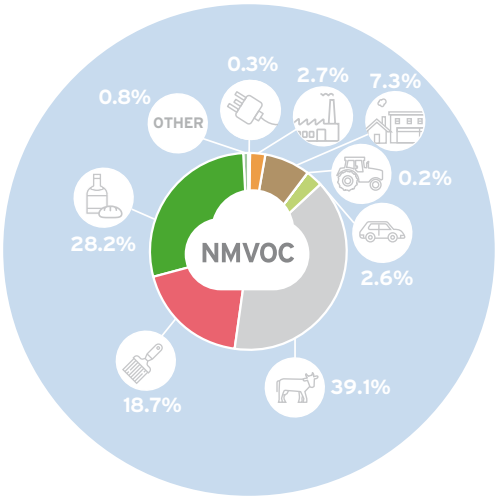
Source: EPA, 2024a

Ireland's national emission reduction commitment for NH_3 for 2020-2029 under the NEC Directive is a 1% reduction compared with the 2005 baseline level. As emissions in 2020, 2021 and 2022 were, respectively, 3.2%, 4.2% and 3.0% higher than in 2005, Ireland is currently one of eight Member States that is not compliant with its emission reduction commitment for 2020-2029 (EEA, 2024). Ireland was served with an infringement notice in January 2023 and a reasoned opinion in November 2023 by the European Commission for failing to meet its emission reduction commitments under the NEC Directive. Polices and measures contained in national plans indicate that compliance can be achieved over the coming years (Department of Agriculture, Food and the

Marine Ag Climatise,[4] Teagasc marginal abatement cost curve[5] and the Climate Action Plan (DECC, 2024) for example) should the uptake of abatement techniques be substantial. Techniques include low-emission slurry spreading, use of inhibited fertiliser products, and reductions in the crude protein concentration of livestock feeds. Ammonia is further discussed in Chapter 10.

Non-methane volatile organic compounds. NMVOCs are emitted as gases from a wide array of products including paints, paint strippers, glues, cleaning agents and adhesives. They also arise as a product of incomplete combustion of fuels, from the storage and handling of animal manure and fertilisers in agriculture, and from the food and beverage industry (Figure 2.8).

Figure 2.8 Sources of non-methane volatile organic compounds emissions in Ireland



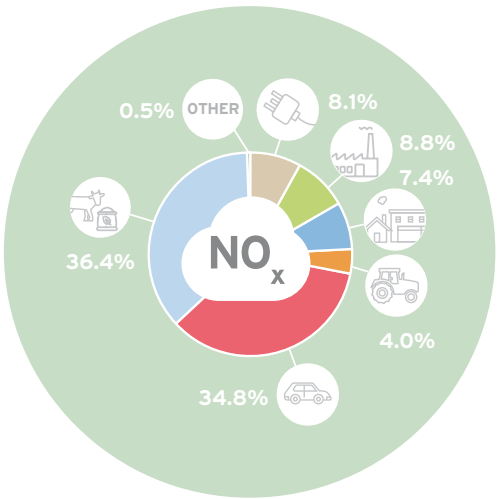
Source: EPA, 2024a

In terms of Ireland's national emission reduction commitment for NMVOCs, the NEC Directive has a flexibility mechanism that allows Member States to make an adjustment to their national inventory estimates for compliance purposes (Article 5(1)). This is allowed when non-compliance with national emission reduction commitments would result from applying improved emission inventory methods that have been updated in accordance with scientific knowledge. This flexibility ensures that countries are not penalised for updating estimates with information that could not have been envisaged when the emission reduction commitments were agreed in 2012. Ireland was non-compliant with national emission reduction commitments for NMVOCs for 2022 as a result of applying improved emission inventory methods that consist of using more up-to-date emission factors and recognising new sources of emissions. When the flexibility mechanism adjustment is made, Ireland will be compliant with the emission reduction commitment for NMVOCs for 2020, 2021 and 2022.

There has been significant expansion in whiskey production over recent years. With respect to the 2030 emission reduction commitment, it is projected that Ireland will be non-compliant. However, under the scenario in which emissions from spirit production are not included in the 2030 emission reduction commitment, as is currently the case for 2020-2029, compliance is expected. The adjustment to exclude spirit production is subject to annual review and approval by the European Commission.

Nitrogen oxides. NO_x contribute to the acidification of soils and surface waters, ground-level O_3 formation and excess nitrogen or saturation in terrestrial ecosystems. The principal sources of NO_x come from agriculture (as a result of using both organic and synthetic nitrogen-containing fertilisers) and fossil fuel combustion in the power generation and transport sectors (Figure 2.9). For the purposes of assessing compliance with the emission reduction commitments for this pollutant, emissions from agriculture are not included. Ireland is currently compliant with the emission reduction commitment for NO_x for the period 2020-2029 and is also projected to be compliant with the 2030 reduction commitment.

Figure 2.9 Sources of emissions of nitrogen oxides in Ireland



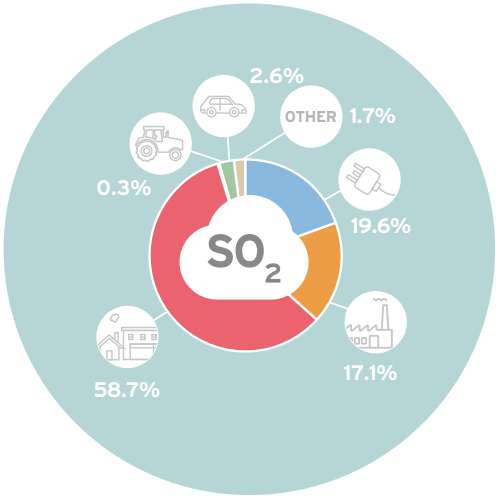
Source: EPA, 2024a

4 www.gov.ie/en/publication/07fbe-ag-climatise-a-roadmap-towards-climate-neutrality/ (accessed 28 May 2024).

5 www.teagasc.ie/media/website/publications/2020/NH3-Ammonia-MACC.pdf (accessed 28 May 2024).

Sulphur dioxide. SO_2 is the major contributor to acid deposition, which is associated with the acidification of soils and surface waters and the accelerated corrosion of buildings and monuments (Figure 2.10). Emissions of SO_2 are derived from the sulphur in fossil fuels such as the coal and oil used in combustion activities. Ireland is currently compliant with the emission reduction commitment for SO_2 for the period 2020-2029 and is also projected to be compliant with the 2030 reduction commitment.

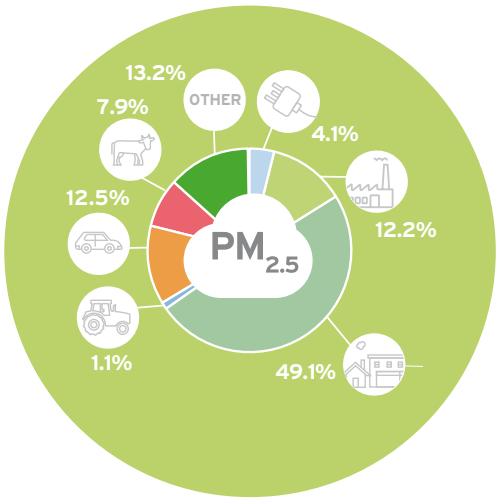
Figure 2.10 Sources of sulphur dioxide emissions in Ireland



Source: EPA, 2024a

Fine particulate matter. Ireland is currently compliant with the emission reduction commitment for $PM_{2.5}$ for the period 2020-2029 and is projected to also be compliant with the 2030 reduction commitment. However, the narrow margin between compliance and non-compliance in 2030 is of concern and further abatement above and beyond that currently proposed may be required. Figure 2.11 sets out the sources of $PM_{2.5}$ emissions in Ireland.

Figure 2.11 Sources of fine particulate matter emissions in Ireland



Source: EPA, 2024a

4. National ambient air quality monitoring network

The EPA's ambient air monitoring network of 115 stations provides data for the assessment of Ireland's air quality and supports reporting required under EU legislation. In this context, Ireland is divided into four zones for ambient air quality monitoring and management under the EU directives: zone A, Dublin city; zone B, Cork city; zone C, large towns with a population over 15,000; and zone D, the remainder of the country. The following section summarises the assessment of monitoring results for particulate matter, NO_2, O_3 and other pollutants in these zones.

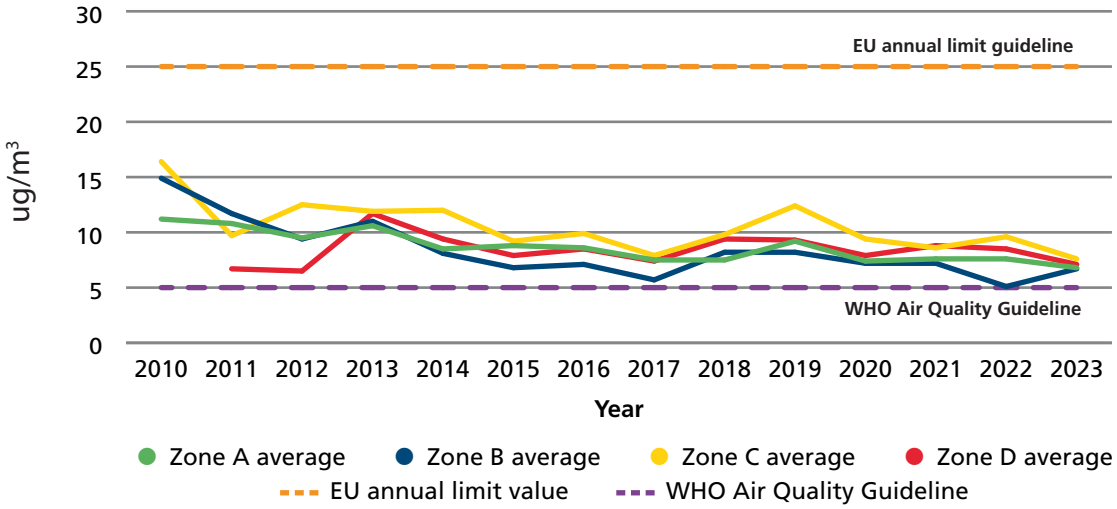
Particulate matter

Particulate matter in air consists of very small particles that have a significant negative impact on health. Primary particulate matter is emitted into the atmosphere from human activities (e.g. burning solid fuel, vehicle exhaust discharges, tyre and road surface wear and construction works) and natural events (e.g. sea salt from sea spray). Secondary particulate matter is formed in the atmosphere from precursor compounds (e.g. NH_3 emissions arising from agricultural activities).

In Ireland, research has shown that the dominant sources of particulate matter from human activities are solid fuels used in home heating, transport and agricultural activities that lead to the formation of secondary particulate matter (Ovadnevaite *et al.*, 2021). Peat is a significant contributor to particulate matter in our air (Ovadnevaite *et al.*, 2021). Moreover, EPA-funded research estimates that around 90% of sod turf comes from non-traded sources (informal markets, gifted or harvested from own land) as opposed to formal traded sources (supermarkets, garages or other companies that specialise in supplying fuel), meaning that significant air pollution will remain in some areas of the country, affecting householders and those in the locality (Eakins *et al.*, 2022). A range of policy measures is needed to encourage the transition away from using peat and other solid fuels towards more sustainable alternatives. An examination of the implementation of policy measures in other countries suggests that measures to tackle solid fuel use are most effective when implemented as a suite of supportive interventions (Eakins *et al.*, 2022).

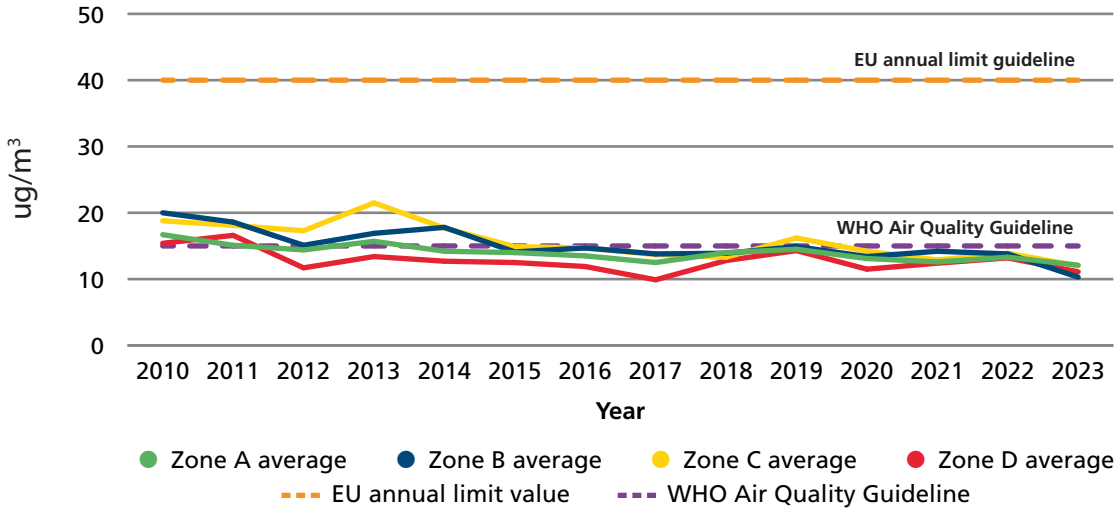
The annual average levels of $PM_{2.5}$ from 2010 to 2023 are displayed in Figure 2.12. Annual average levels in Ireland have remained below the EU annual limit value since 2010. However, they did not meet the 2021 WHO air quality guideline limits (5 µg/m^3 in all zones). During winter, spikes of short duration occur across the monitoring network, particularly on still, cold evenings. These spikes can move the Air Quality Index for Health[6] at monitoring stations to a poor or very poor status, indicating the localised impacts of air pollution levels.

Figure 2.12 Annual mean levels of fine particulate matter ($PM_{2.5}$) 2010-2023 (µg/m^3). Annual average levels across monitoring stations in zones A, B, C and D



6 The EPA's Air Quality Index for Health indicates the level of air quality being recorded at each monitoring station and what effect it might have on human health. The index provides a sliding scale from 1 to 10, where 10 indicates very poor air quality and 1-3 indicates good air quality.

Figure 2.13 Annual mean levels of particulate matter (PM_{10}), 2010-2023 (µg/m³). Annual average levels across monitoring stations in zones A, B, C and D

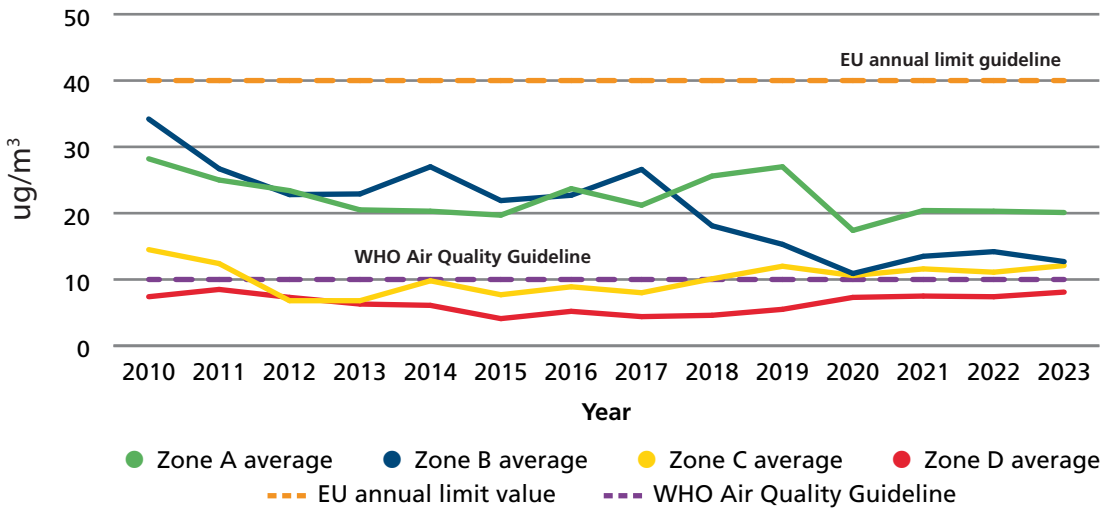


The annual average levels of PM_{10} in Ireland from 2010 to 2023 are illustrated in Figure 2.13. Annual averages are well within the EU annual limit value (40 µg/m³). There is an overall downwards trend in all zones. Since 2020, the annual averages for all zones have been below the 2021 WHO air quality guideline for PM_{10} (15 µg/m³).

Nitrogen dioxide

Measured annual average concentrations of NO_2 have decreased overall in zones A, B and C, while in zone D they have remained generally constant. During the COVID-19 pandemic, traffic volumes drastically reduced, with commensurate falls in the levels of NO_2 concentrations measured at traffic monitoring stations (EPA, 2021). Levels of NO_2 in our larger urban centres, zone A (Dublin) and zone B (Cork) have increased since COVID-19 restrictions were lifted. However, annual average levels of NO_2 in these zones have not moved back to their full pre-COVID levels. Figure 2.14 details the annual average concentrations of NO_2 across the country from 2010 to 2023.

Figure 2.14 Annual mean nitrogen dioxide (NO_2) concentrations, 2010-2023 (µg/m³). Annual average levels across monitoring stations in zones A, B, C and D



Recorded levels of NO_2 have generally been below the EU annual limit value of 40 µg/m³. However, Ireland exceeded the annual limit for NO_2 in 2019 at the St. Johns Road West monitoring station in Dublin when the station measured an annual average concentration of 43 µg/m3 (EPA, 2020). Measures to combat this were set out in an air quality plan (DCC *et al.*, 2021) submitted to the European Commission in December 2021. There were no further exceedances in 2020, 2021, 2022 or 2023.

As transport emissions are one of the most significant elements that affects air quality in Ireland, the Urban Transport Related Air Pollution Working Group acts as a subgroup of the new Clean Air Strategic Implementation Group. It is a joint working group of DECC and the Department of Transport providing a forum for ongoing engagement among the key transport stakeholders. Actions such as the roll-out of no idling campaigns at schools, whereby drivers of all parked vehicles are requested to turn off their engines, should be progressed.

Annual NO_2 levels recorded at individual stations show that heavily trafficked cities and towns, i.e. Dublin (zone A), Cork (zone B) and large towns (zone C), would not meet the more stringent WHO air quality guideline limits for NO_2 (10 µg/m³). Studies, including modelling conducted by the EPA (EPA, 2019, 2023a), have shown high indicative concentrations in locations in Dublin where the requirements of the directives on air quality do not apply, such as on the carriageway of the M50 and at major junctions, and also in areas not directly covered by the monitoring network. In partnership with Dublin City Council, the EPA is conducting further NO_2 tube studies in areas with the highest indicative concentrations.

Ozone

Ground-level O_3 is formed as a secondary pollutant when other air pollutants chemically react in the presence of strong sunlight. Elevated concentrations of ground-level O_3 can decrease lung function and also aggravate respiratory ailments in sensitive individuals such as those with asthma or a lung disease.

O_3 is readily transported to Ireland from Atlantic and European regions by the natural movement of air masses. O_3 concentrations tend to be highest in spring and summer and are a combination of transboundary O_3 and locally produced O_3. Concentrations of ground-level O_3 are reduced through its reaction with traffic-emitted pollutants; therefore, levels of O_3 are higher in rural areas than in urban areas.

O_3 concentrations in Ireland for the period 2008-2023, measured as 8-hour averages, show levels generally well below the maximum allowed number of exceedances per year (25 occurrences). In recent years, there have been short periods of time when O_3 levels were high. This has occurred after periods of hot and sunny weather, which facilitates the build-up and formation of O_3. Ground-level O_3 could become a problematic pollutant in Ireland during sustained hot and sunny weather conditions in the future. Of concern from a transboundary point of view are continental O_3 and particulate matter events, which occur most often during summer and spring, respectively.

Other air pollutants

The EPA monitors a range of other air pollutants. These include SO_2, CO, volatile organic compounds (benzene, toluene, ethylbenezene, m- and p-xylene and o-xylene), heavy metals (lead, arsenic, cadmium and nickel) and polycyclic aromatic hydrocarbons. Ireland meets the current EU limit values for these pollutants but is above the WHO air quality guideline limits for SO_2 and the EEA reference level for polycyclic aromatic hydrocarbons.

Impact of revision of ambient air quality directives

The updated WHO guideline limits (see Topic Box 2.1) are tighter than current EU legislation (EC, 2022). In particular, the annual average guideline limits for $PM_{2.5}$ have been halved (from 10 µg/m³ to 5 µg/m³) and for NO_2 have been reduced to a quarter of the previous level (from 40 µg/m³ to 10 µg/m³) (WHO, 2021). Table 2.3 identifies the number of national ambient air monitoring stations that, while meeting current EU levels, were above the WHO air quality guideline limits based on the data collected in 2023. Specifically, 80 out of the 101 stations monitored in 2023 for $PM_{2.5}$, the pollutant with the greatest impact on health, did not meet the WHO air quality guidelines. For NO_2 a similar picture was found, with 29 of the 36 stations monitored for this pollutant not meeting the WHO air quality guidelines. Similarly, WHO air quality guidelines were not met for PM_{10}, SO_2 and O_3. The revision of the ambient air quality directives moves EU limit values towards the tighter WHO air quality guidelines.

Table 2.3 Number of national ambient air monitoring stations recording levels above WHO air quality guideline limits in 2023

Pollutant	Number of stations where parameter was monitored in 2023	WHO Air Quality Guideline (AQG) level or EEA reference level[a]
Particulate matter (PM_{10})	106	Above annual WHO AQG value at 5 stations. Above daily WHO AQG value at 10 stations
Fine particulate matter ($PM_{2.5}$)	101	Above annual WHO AQG value at 79 stations. Above daily WHO AQG value at 80 stations
Nitrogen dioxide (NO_2)	36	Above annual WHO AQG value at 24 stations. Above daily WHO AQG value at 29 stations
Ozone (O_3)	23	Above Peak Season WHO AQG level at 6 stations. Above 8hr av. daily WHO AQG value at 18 stations
Sulphur dioxide (SO_2)	15	Above WHO 24 hour AQG level at 1 station

[a] stations with at least 50% data capture

Source: EPA, 2024b

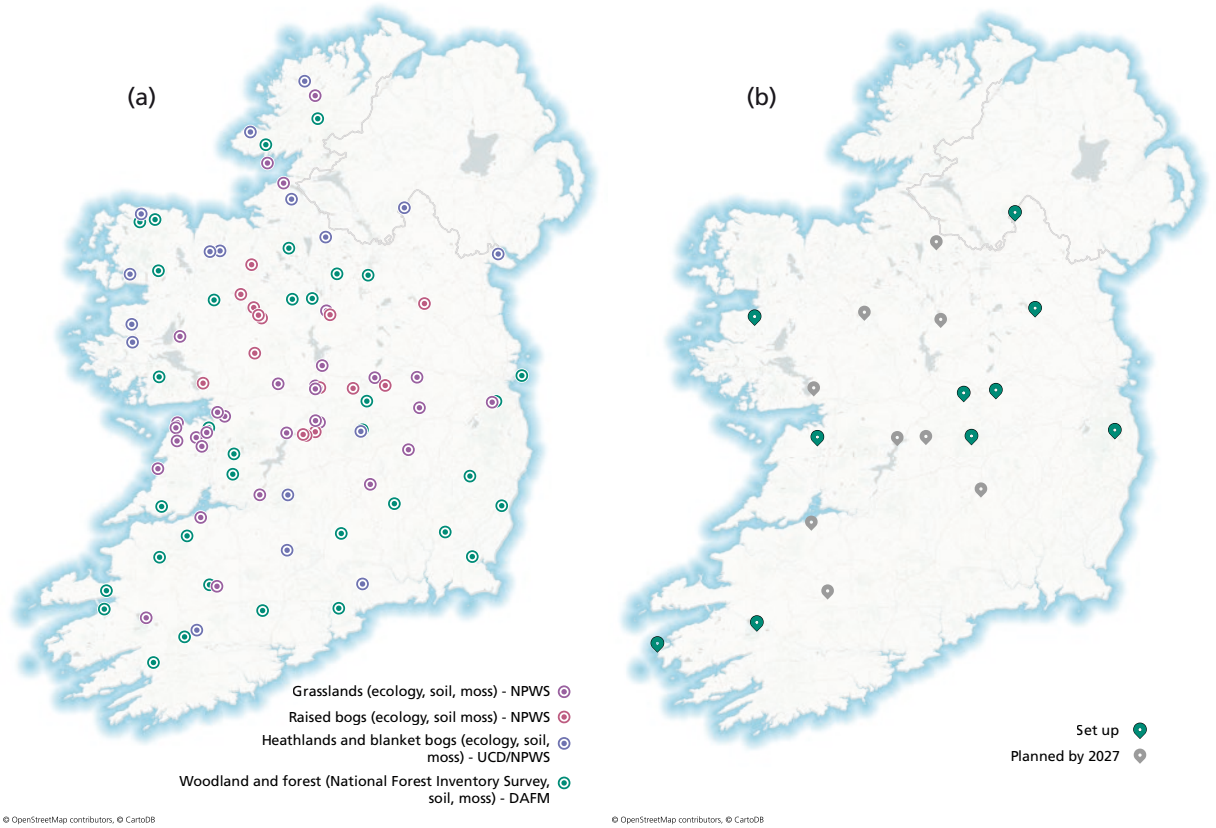
National Ecosystems Monitoring Network

Excessive deposition of reactive nitrogen can have negative impacts on terrestrial ecosystems, including biodiversity loss, through eutrophication and acidification (Maskell *et al.*, 2010; Payne *et al.*, 2017). While deposited reactive nitrogen is principally composed of NH_3 and ammonium from agriculture, it also includes NO_x. Even if Ireland succeeds in meeting its emission reduction commitments for NH_3 at a national level, high ambient NH_3 concentrations and deposited nitrogen are still likely to occur in certain locations.

A goal of the European Commission's Zero Pollution Action Plan is to reduce the size of the area of ecosystems at risk from nitrogen deposition by 25% by 2030. A recent report from the EEA highlighted that, while the size of the potentially affected area fell by 10% across Europe, it increased by 1% in Ireland in 2021 relative to 2005 (EEA, 2023c). This EEA report, modelling carried out on behalf of the EPA (Aherne *et al.*, 2021; Bealey *et al.*, 2024) and recent work measuring NH_3 at Natura 2000 sites (Kelleghan *et al.*, 2021) highlight that nitrogen deposition exceeds the level considered safe for many important sensitive habitats and species across Ireland.

The NEC Directive requires every Member State to monitor the impacts of air pollution on sensitive ecosystems within its territory. Ireland's response to this requirement has been to develop the National Ecosystems Monitoring Network (NEMN), which focuses on atmospheric NH_3 and other nitrogen-containing pollutants. The network is coordinated by the EPA and is reliant on input from various partners including the National Parks and Wildlife Service, Department of Agriculture, Food and the Marine and Met Éireann. The network consists of adapted botanical and forest surveys carried out by the National Parks and Wildlife Service and the Department of Agriculture, Food and the Marine across a variety of habitats including bogs, grasslands and woodlands (level 1 sites – see Figure 2.15a). These surveys are intended to determine any changes in the diversity of the plant communities in those habitats due to variations in atmospheric nitrogen deposition or NH_3 concentrations. The surveys are supplemented by atmospheric monitoring managed by the EPA on a smaller network of sites (level 2 sites – see Figure 2.15b), which are a subset of the level 1 network. Air quality monitoring for NH_3 is currently carried out at ten of these sites and it is anticipated that this will increase to approximately 19 sites by 2027.

Figure 2.15 National Ecosystems Monitoring Network, 2021-2022. (a) Level 1 sites: ecological, moss and soil monitoring (b) Level 2 sites: atmospheric and lake monitoring



There are plans to install wet deposition monitoring samplers at selected sites on a phased basis. Figure 2.16 shows a typical planned site set-up. The NEMN also utilises water quality monitoring carried out on upland lakes by the EPA, which is also reported under the United Nations Economic Commission for Europe International Cooperative Programme[7] on the assessment and monitoring of the effects of air pollution on rivers and lakes.

Figure 2.16 Example of a National Ecosystems Monitoring Network atmospheric level 2 site

7 www.unece.org/modelling-and-mapping (accessed 28 May 2024).

Every 4 years, Member States submit data collected from their respective networks to the European Commission. Ireland's first submission in 2019 was heavily reliant on historical data collected on the International Cooperative Programme's forest sites. Since 2020, the NEMN has undergone substantial development, with effects monitoring carried out through ecological surveys at raised bogs, heathlands and grasslands. The network has grown from 44 predominantly forestry sites to a network of 130 sites encompassing a number of sensitive habitats. The data collected feed into reporting at a European level through the EEA. Ireland's latest data submission, made in 2023, is available on the EEA website.[8]

All data collected from the NEMN will provide evidence on atmospheric nitrogen and NH_3 emissions and their impacts on sensitive habitats, while also contributing to an improved understanding of effects at a European scale through links with the International Cooperative Programme (ICP) on Modelling and Mapping[9]. While some of the NEMN sites are located on previous ICP Forests[10] sites, many terrestrial sites have not previously been monitored for species variety and abundance and air quality. Consequently, the data from the surveys undertaken since 2021 will serve as a baseline for future surveys against which impacts and recovery of habitats can be monitored. Ireland's NEMN will also contribute to developing the wider EU monitoring network, improving our understanding of air pollution impacts on ecosystems across Europe.

5. National air quality policy

Clean Air Strategy

The government launched Ireland's first Clean Air Strategy in 2023 (DECC, 2023). It includes an ambition to achieve full alignment with WHO air quality guideline limits by 2040 and its interim targets by 2026 and 2030 (interim targets 3 and 4, respectively; see Topic Box 2.1).

The strategy sets out measures and actions to support continuous improvements in air quality. These relate, for example, to parameters such as SO_2, particulate matter (e.g. actions on solid fuel regulations, enforcement, communication), NO_2 (e.g. transport actions) and NH_3 (e.g. agriculture actions). The strategy has a focus on improving enforcement, particularly of the Solid Fuels Regulations (S.I. No. 529/2022). It also seeks to increase the evidence around how to address air quality issues and to ensure the integration of clean air considerations into policy development across government. To provide the necessary governance to support and monitor implementation of the strategy, DECC set out that it would establish and lead the Clean Air Strategic Implementation Group and the Strategic Clean Air Communications Group.

The Clean Air Strategy also proposes additional citizen engagement that builds on the successful GLOBE and Clean Air Together[11] projects, developed by the EPA and the Environmental Education Unit of An Taisce in recent years.

Ireland is not currently meeting the WHO air quality guideline limits at a national level. A roadmap of concrete actions is required to achieve the targets and deliver on the ambition of the Clean Air Strategy, including achieving the interim targets. Full and timely implementation of the framework measures will be of substantial benefit to the overall achievement of cleaner air.

Dublin Air Quality Plan

In 2019, the St. John's Road West monitoring station in Dublin measured an annual average concentration of 43 µg/m^3 for NO_2 (EPA, 2020). The four Dublin local authorities prepared an air quality plan, submitted to the European Commission in December 2021, to address the exceedance of the EU annual limit value (DCC *et al.*, 2021). To achieve compliance with the limit value for NO_2, 14 measures were included in the air quality plan. While there have been no exceedances in the intervening years, full implementation of the plan by the local authorities is necessary to maintain compliance with the air limit value for NO_2. Updates on the 14 measures are reported each year to the European Commission.

Solid Fuels Regulations

In 2022, the new Solid Fuels Regulations for Ireland (S.I. No. 529/2022) set out additional restrictions on the retail, online and commercial sale of smoky fuels, including smoky coal, turf and wet wood, to protect and improve air quality. The sale and distribution of solid fuels that are not approved under the regulations was prohibited. The regulations set national minimum technical standards

8 www.cdr.eionet.europa.eu/ie/eu/nec_revised/monitoring/envzj3asw/ (accessed 28 May 2024).

9 International Cooperative Programme on Modelling and Mapping of Critical Levels and Loads and Air Pollution Effects, Risks and Trends: www.unece.org/modelling-and-mapping

10 International Co-operative Programme on Assessment and Monitoring of Air Pollution Effects on Forests: www.unece.org/environmental-policy/air/forests

11 www.epa.ie/take-action/in-the-community/citizen-science/clean-air-projects/#d.en.84492

for residential solid fuels to allow only products with low smoke emissions to be sold. These changes limit the smoke emission rate and the permitted moisture and sulphur content of fuels, leading to lower particulate matter and SO_2 emissions when burned. Overall, these measures reduce emissions and positively influence air quality. Ten local authorities participated in a pilot project, funded by DECC, on implementing the Solid Fuels Regulations. This funding allowed the local authorities to raise awareness, monitor local air quality and test solid fuels offered for sale in the marketplace. Inspections by local authorities following the introduction of the new regulations showed that the overall compliance rates among the fuel merchants and retailers inspected was high (EPA, 2023b). Concerningly, however, sulphur sampling results from the fuels tested confirmed that a small percentage of non-compliant coal products was sold on the Irish market. The *Focus on Local Authority Environmental Enforcement – Performance Report 2022* (EPA, 2023b) highlighted areas where further action is required by local authorities to ensure that only approved solid fuels are available for sale to reduce air pollution from the combustion of solid fuels for home heating.

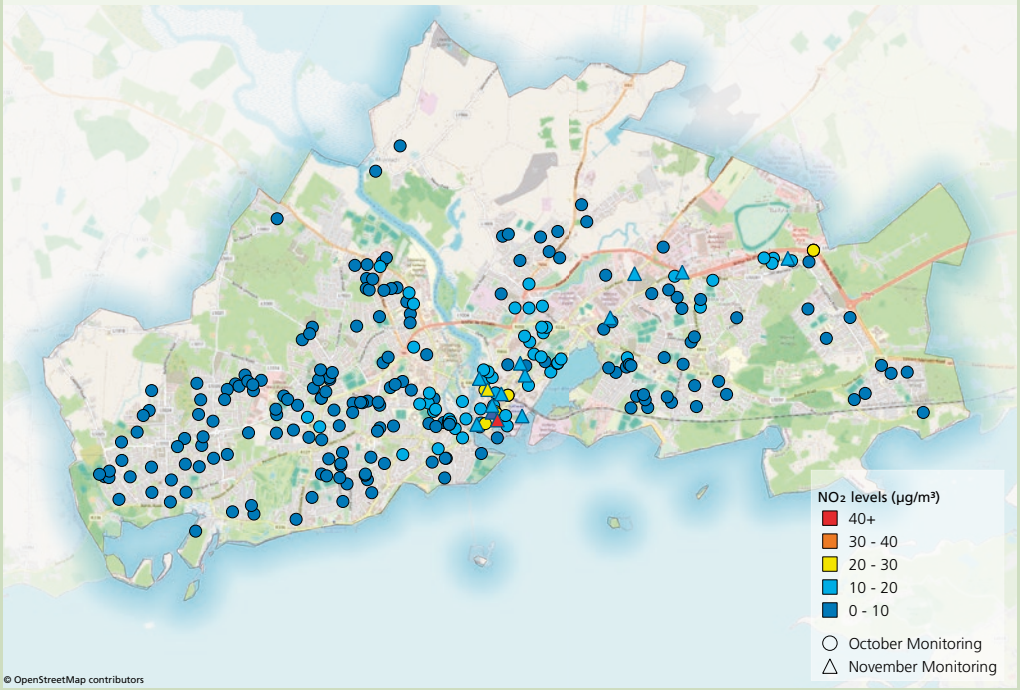
Topic Box 2.3 Clean Air Together – Dublin, Cork and Galway

Clean Air Together is a citizen science project led by the EPA in partnership with the Environmental Education Unit of An Taisce and local authorities. Participants measure levels of the traffic pollutant NO_2 near their home, business or school. The project has four main objectives:

1. increase public knowledge and engagement with the topic of air pollution
2. provide data that will help validate EPA air quality models
3. assess the impacts of citizen-based air quality monitoring on awareness, attitudes and the potential to lead to behaviour change
4. inform policy by working in partnership with stakeholders.

Following the success of Clean Air Together in Dublin and Cork cities, the large-scale citizen-based air pollution monitoring project moved to Galway city in 2023. Figure 2.17 shows monitoring results for Galway. In 2024, Clean Air Together moves to Limerick city – more information is available on www.cleanairtogether.ie.

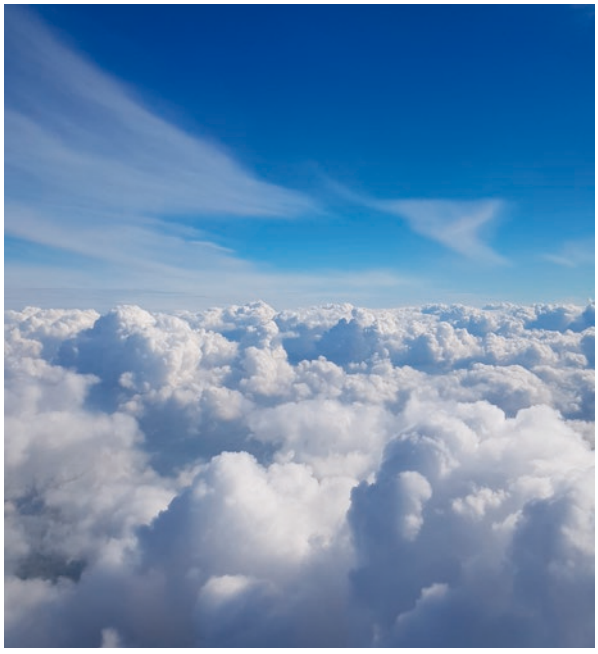
Figure 2.17 Map of results for Clean Air Together, Galway



Research

Ireland has a vibrant environmental research community, including internationally recognised centres for atmospheric research. Significant funders of such research include the EPA, Sustainable Energy Authority of Ireland, Science Foundation Ireland, the Irish Research Council, the Department of Transport, and the Department of Agriculture, Food and the Marine. Communicating the findings and recommendations of such research to as wide an audience as possible, and to the relevant policymakers, is one of its most important outcomes, as it ensures that policy development is based on the most up-to-date evidence. To achieve this, the Air Quality Unit of DECC has established a Clean Air Research Forum, which brings together researchers, policymakers and other key stakeholders to share information and results and to discuss knowledge gaps and future research priorities. There is a broad range of published and ongoing air quality research. Ongoing research includes EPA-funded projects on the sources of air pollutants including ports (the PortAIR project), railways (the STATION-AIR project) and agriculture (the IMAGE project).

Recently published projects include Irish research on the knowledge, attitudes and perception of air pollution in Ireland (Kelly and Quintyne, 2023) and sources of air pollution in Ireland (Ovadnevaite *et al.*, 2021). There is also a growing volume of Irish research on the assessment of the health impacts of air pollution (Byrne *et al.*, 2020; Ó Domhnaill *et al.*, 2022; ESRI, 2023, 2024; Lyons *et al.*, 2024). The health impacts of air pollution are further discussed in Chapter 14.



6. Conclusions

Health and air quality

There is no safe level of air pollution, as reflected in the 2021 revision of the WHO air quality guidelines, which substantially tightened guideline limits for $PM_{2.5}$ and NO_2. Ireland's Clean Air Strategy ambition is to move towards meeting these air quality guideline limits by 2040. The review of the Cleaner Air for Europe Directive will set a similar trajectory towards compliance with WHO guidelines at EU level.

While the positive impact on health would be significant, achieving the WHO interim and final guideline limits will be challenging, and the scale of the challenge has been highlighted in recent EPA air quality reports. Key to achieving this ambition will be implementing the Clean Air Strategy, the Dublin Air Quality Plan and related actions from the Climate Action Plan (DECC, 2024).

Action on air quality

Air quality can be improved by changing our behaviour, individually and collectively, so that we burn fewer fossil fuels to heat our homes and businesses and fuel our vehicles. Protecting health will require the engagement of the public to support and implement actions that achieve this reduction in fossil fuel use.

Ammonia emissions

NH_3 emissions from agriculture have a negative impact on sensitive plant and animal species. NH_3 is also responsible for the formation of secondary $PM_{2.5}$ during the atmospheric transport of NH_3. National emissions are currently breaching Ireland's emission targets. Implementing all currently planned actions will be needed to reduce the emissions of this pollutant to meet Ireland's international commitments.

Expanding the evidence base

There has been an extensive expansion in the monitoring of air pollutants in Ireland. The number of stations has increased from 29 in 2017 to the current 115 station network. Air quality information from the expanded network, supplemented by hourly modelled maps, is updated hourly and available on www.epa.ie and www.airquality.ie. A forecast, predicting air quality for today, tomorrow and the day after tomorrow, has also been available on www.epa.ie and www.airquality.ie since November 2023. The forecast enables members of the public to make informed decisions about their planned activities. $PM_{2.5}$, NO_2 and NH_3 continue to be our pollutants of concern.

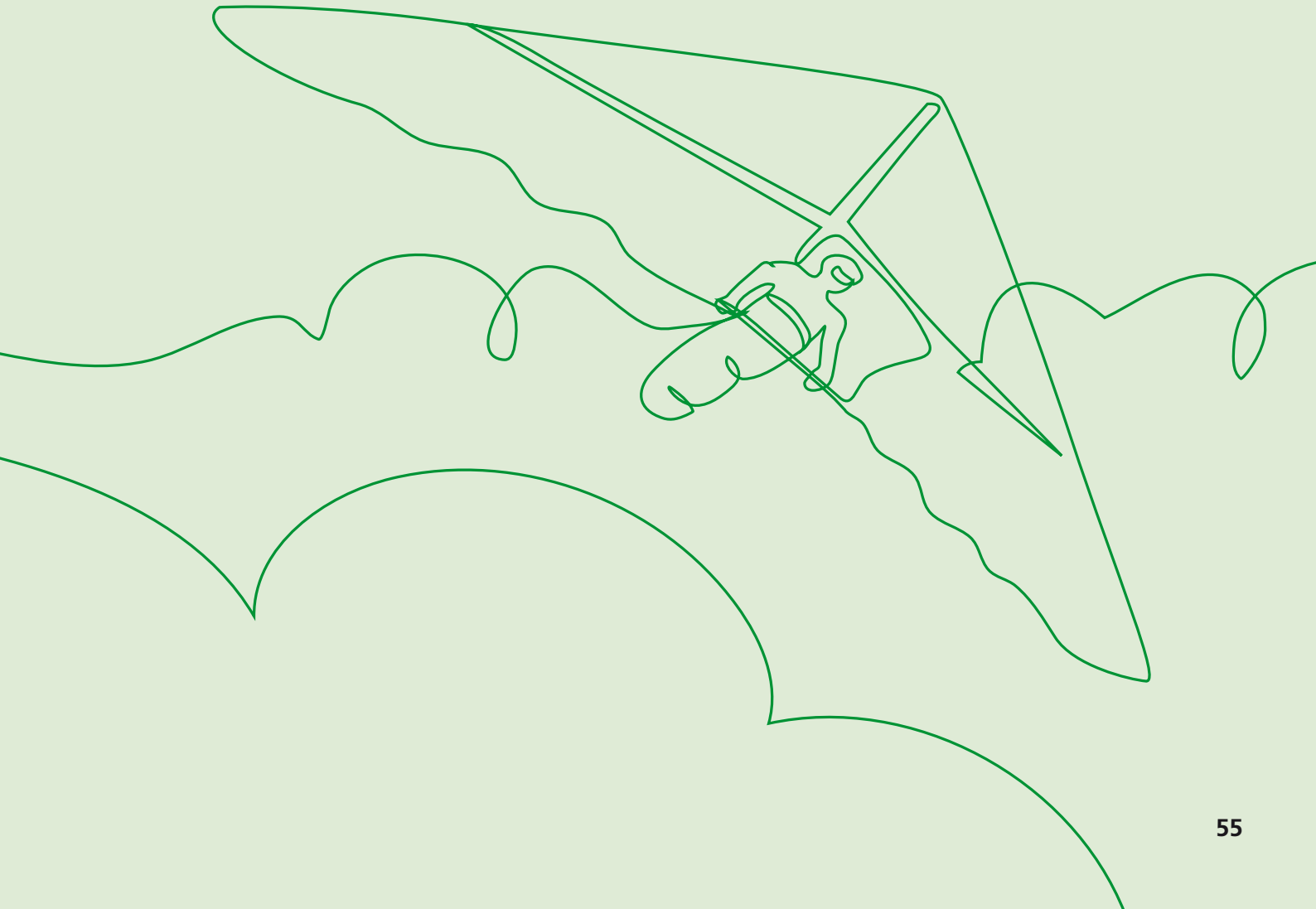
Key chapter messages

1. While air pollution has reduced over recent decades, our understanding of the level at which it impacts health has grown. The World Health Organization (WHO) says that there is no safe level of air pollution.

2. Currently, Ireland is not meeting the guidelines set by WHO for multiple pollutants including fine particulate matter and nitrogen dioxide. We can actively improve our local air quality by changing to more sustainable forms of transport and heating.

3. Achieving Ireland's ambition, set out in the Clean Air Strategy, to move towards meeting the health-based WHO air quality guideline limits will be challenging but will have a significant and positive impact on health. A road map of actions is required to deliver on the overall ambition and the 2026 and 2030 interim targets.

4. Ireland is non-compliant with the EU reduction target for ammonia and will remain so in the short term. Meeting the 2030 emission reduction commitment is dependent on fully executing all known ammonia abatement measures at the farm level.



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