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# Every breath we take

## Improving air quality in Europe

European Environment Agency

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# Editorial

**Jacqueline McGlade**

# Linking science, policy and the public

**The atmosphere, weather patterns and seasonal variations have long been an object of fascination and observation. In the 4th century B.C., Aristotle's treatise *Meteorology* compiled the great philosopher's observations not only on the weather patterns, but on earth sciences in general. Until the 17th century, air symbolised 'nothingness'. It was assumed that air had no weight until Galileo Galilei scientifically proved that it has.**

Today we have a much more comprehensive knowledge and understanding of our atmosphere. We can set up stations to monitor air quality, and within minutes we can see the chemical composition of the air at those locations and how these relate to long-term trends. We also have a much clearer overview of the sources of air pollution affecting Europe. We can estimate the amount of pollutants released to the air by individual industrial facilities. We can predict and monitor air movements and offer immediate and free access to this information. Our understanding of the atmosphere and its chemical interactions has certainly come a long way since Aristotle.

The atmosphere is complex and dynamic. Air moves around the world and so do the pollutants the air contains. Emissions from car exhausts in urban areas; forest fires; ammonia emitted by agriculture; coal-fired power plants across the planet; and even volcano eruptions affect the quality of the air we breathe. In some cases, the pollutant sources are located thousands of kilometres away from where the damage occurs.

We also know that poor air quality can have a dramatic effect on our health and well-being as well as on the environment. Air pollution can trigger and aggravate respiratory diseases; it can damage forests, acidify soils and waters, reduce crop yields and corrode buildings. We can also see that many air pollutants contribute to climate change and that climate change itself is going to affect air quality in the future.

## Policies have improved air quality but...

As a result of an ever-growing body of scientific evidence, demands by the public and a series of legislation, Europe's air quality has improved considerably in the last 60 years. The concentrations of many air pollutants, including sulphur dioxide, carbon monoxide, and benzene, have decreased significantly. Lead concentrations have dropped sharply below the limits set by legislation.

But despite such achievements, Europe has not yet attained the air quality foreseen in its legislation or desired by its citizens. Particulate matter and ozone are today the two most important pollutants in Europe, posing serious risks to human health and the environment.

Current laws and air quality measures target specific sectors, processes, fuels and pollutants. Some of these laws and measures put limits on the amount of pollutants that countries are allowed to release into the atmosphere. Other measures aim to reduce the population's exposure to unhealthy levels of pollutants by limiting high concentrations — the amount of a certain pollutant in the air at a given location at a given time.

A considerable number of EU countries fail to achieve their emission targets for one or more air pollutants (nitrogen oxides in particular) covered by legislation. Concentrations are also a challenge. Many urban areas struggle with levels of particulate matter, nitrogen dioxide and ground-level ozone higher than the thresholds set in legislation.

## Further improvements are needed

Recent opinion polls show that the European public is clearly concerned about air quality. Almost one out of five Europeans says that they suffer from respiratory problems, not all necessarily linked to poor air quality. Four out five think that the EU should propose additional measures to address air-quality problems in Europe.

And three out of five do not feel informed about air quality issues in their country. In fact, despite significant improvements in recent decades, only less than 20 % of Europeans think air quality in Europe has improved. More than half of Europeans actually think that air quality has deteriorated in the last 10 years.

Communicating air-quality issues is essential. It might not only enhance our understanding of the state of Europe's air today but also help reduce the impacts of exposure to high levels of air pollution. For some people who have family members suffering from respiratory or cardiovascular diseases, knowing the air pollution levels in their city or having access to accurate and timely information could be among their top daily priorities.

## The potential benefits of action are significant

This year, the European Union will start outlining its future air policy. This is not an easy task. On the one hand, it requires minimising the impacts of air pollution on public health and on the environment. The cost estimates of these impacts are strikingly large.

On the other hand, there is no easy and quick fix to improve Europe's air quality. It requires tackling many different pollutants from different sources over the long term. It also requires a more structural shift in our economy towards greener consumption and production patterns.

Science shows that even very small improvements in air quality — particularly in highly populated areas — result in health gains as well as economic savings. These benefits include: higher quality of life for citizens who suffer less from pollution-related diseases; higher productivity due to fewer sick days; and lower medical costs for society.

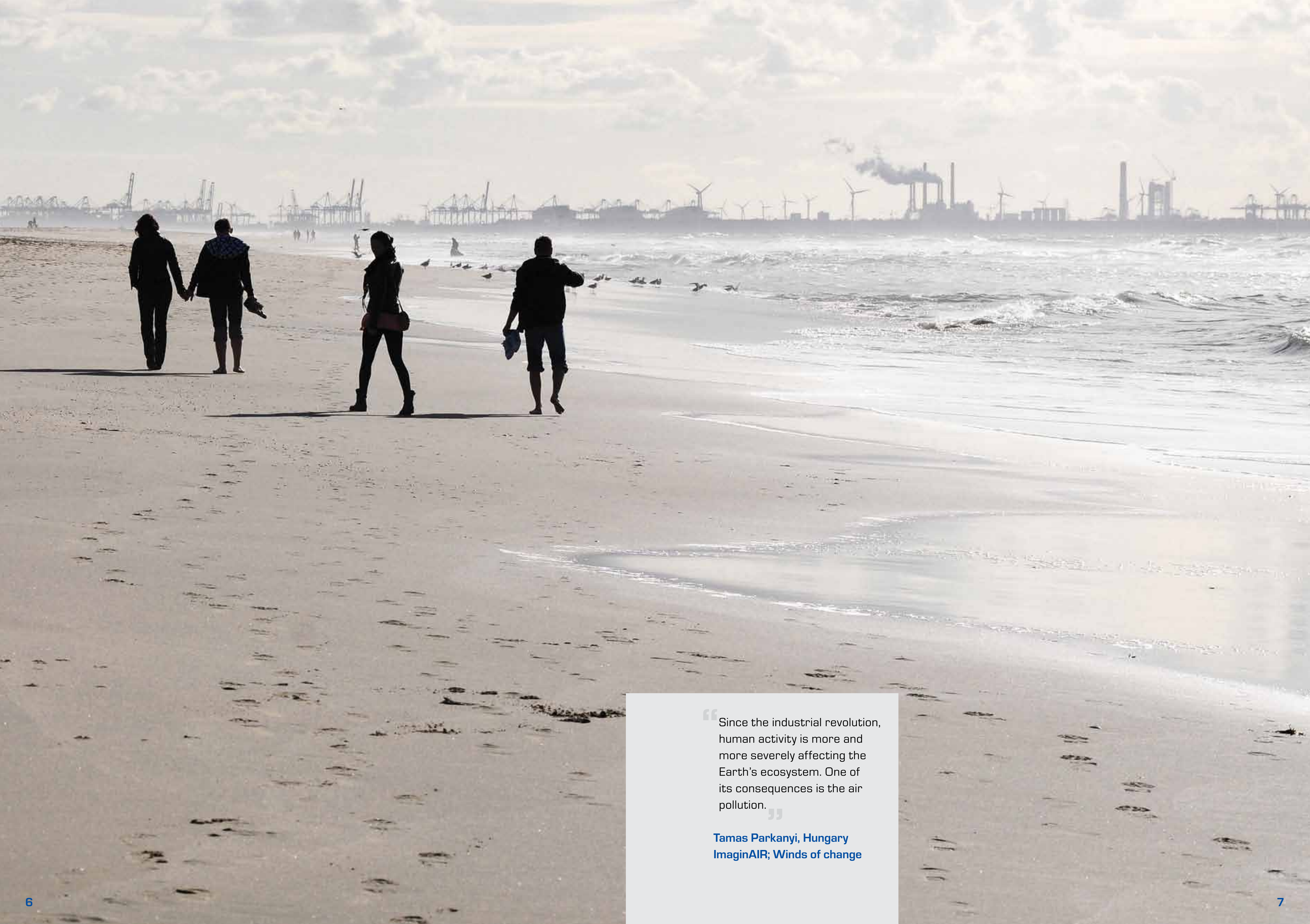
Science also tells us that taking action on air pollution can have multiple benefits. For example, some greenhouse gases are also common air pollutants. Ensuring that climate and air policies are mutually beneficial can help combat climate change and improve air quality at the same time.

Improving the implementation of air legislation presents another opportunity to improve air quality. In many cases, local and regional authorities are the ones putting policies into action and dealing with the day-to-day challenges that result from poor air quality. They are often the public authority closest to the people affected by air pollution. Among them, local authorities have a wealth of information and concrete solutions for dealing with air pollution in their area. Bringing these local authorities together to share their challenges, ideas and solutions is critically important. It will give them new tools to achieve objectives set in legislation, better inform their citizens, and ultimately reduce health impacts from air pollution.

We now face the challenge of how to continue translating our growing understanding of the air into better policy and health outcomes. What are the actions we can take to reduce air pollution's impact on our health and the environment? What are the best options available? And how do we get there?

It is exactly at moments like these that the scientist, the policymaker and the citizen need to work hand-in-hand to address these questions, so that we can continue to improve air quality in Europe.

*Prof. Jacqueline McGlade*
Executive Director



"Since the industrial revolution, human activity is more and more severely affecting the Earth's ecosystem. One of its consequences is the air pollution."

**Tamas Parkanyi, Hungary**
**ImaginAIR; Winds of change**

"I can only but wonder how the magnificence of the environment is diminishing because of pollution, especially air pollution."

**Stephen Mynhardt, Ireland**
**ImaginAIR; Ever closing**

# Every breath we take

**We breathe from the moment we are born until the moment we die. It is a vital and constant need, not only for us but for all life on Earth. Poor air quality affects us all: it harms our health and the health of the environment, which leads to economic losses. But what does the air we breathe consist of and where do the various air pollutants come from?**

The atmosphere is the gaseous mass that surrounds our planet and has been classified into layers with varying densities of gases. The smallest and lowest (ground-level) layer is known as the troposphere. This is where plants and animals live and where our weather patterns occur. Its altitude reaches about 7 kilometres high at the poles and 17 kilometres at the equator.

Like the rest of the atmosphere, the troposphere is dynamic. Depending on the altitude, the air has a different density and a different chemical composition. The air moves around the globe constantly, crossing oceans as well as vast areas of land. Winds can carry small organisms, including bacteria, viruses, seeds and invasive species to new locations.

## What we call air consists of...

Dry air is made up of about 78 % nitrogen, 21 % oxygen and 1 % argon. There is also water vapour in the air, making up between 0.1 % and 4 % of the troposphere. Warmer air usually contains more water vapour than colder air.

The air also contains very small amounts of other gases, known as trace gases, including carbon dioxide and methane. The concentrations of such minor gases in the atmosphere are generally measured in parts per million (ppm). For example, the concentrations of carbon dioxide, one of the most prominent and abundant trace gases in the atmosphere, were estimated to be around 391 ppm, or 0.0391 %, in 2011 (EEA indicator on atmospheric concentrations).

In addition, there are thousands of other gases and particles (including soot and metals) released into the atmosphere from both natural and man-made sources.

The composition of the air in the troposphere changes all the time. Some of the substances in the air are highly reactive; in other words, they have a higher propensity to interact with other substances to form new ones. When some of these substances react with others, they can form 'secondary' pollutants harmful to our health and the environment. Heat — including from the sun — is usually a catalyst facilitating or triggering chemical reaction processes.

## What we call air pollution

Not all substances in the air are considered pollutants. In general, air pollution is defined as the existence of certain pollutants in the atmosphere at levels that adversely affect human health, the environment, and our cultural heritage (buildings, monuments and materials). In the context of legislation, only the pollution from man-made sources is considered, although pollution might be defined more broadly in other contexts.

Not all air pollutants come from man-made sources. Many natural phenomena, including volcanic eruptions, forest fires, and sand storms release air pollutants into the atmosphere. Dust particles can travel quite far depending on winds and clouds. Regardless of whether they are man-made or natural, once these substances are in the atmosphere, they can take part in chemical reactions and contribute to air pollution. Clear skies and high visibility are not necessarily signs of clean air.

Despite significant improvements in recent decades, air pollution in Europe continues to harm our health and the environment. In particular, pollution from particulate matter and pollution from ozone pose serious health risks to European citizens, affecting quality of life and reducing life expectancy. But different pollutants have different sources and impacts. It is worth taking a closer look at the main pollutants.

## When tiny particles float in the air

Particulate matter (PM) is the air pollutant that causes the greatest harm to human health in Europe. Think of PM as particles so light that they can float in the air. Some of these particles are so small (one thirtieth to one fifth of the diameter of a human hair) that not only do they penetrate deep in our lungs, they also pass into our bloodstream, just like oxygen.

Some particles are emitted directly into the atmosphere. Others come about as a result of chemical reactions involving precursor gases, namely sulphur dioxide, nitrogen oxides, ammonia, and volatile organic compounds.

These particles can be composed of various chemical components, and their impact on our health and the environment depends on their composition. Some heavy metals and toxic metalloids, such as arsenic, cadmium, mercury and nickel, can also be found in particulate matter.

A recent study by the World Health Organization (WHO) shows that fine particle pollution ($PM_{2.5}$, i.e. particulate matter no greater than 2.5 microns in diameter) might be a greater health concern than previously estimated. According to the WHO's 'Review of evidence on health aspects of air pollution', long-term exposure to fine particles can trigger atherosclerosis, adverse birth outcomes, and childhood respiratory diseases. The study also suggests a possible link with neurodevelopment, cognitive function and diabetes, and strengthens the causal link between $PM_{2.5}$ and cardiovascular and respiratory deaths.

Andrzej Bochenski, Poland
ImaginAIR; Price of comfort

Depending on their chemical composition, particles can also affect global climate by either heating or cooling the planet. For example, black carbon, one of the common components of soot found mostly in fine particles (smaller than 2.5 microns in diameter), results from the incomplete combustion of fuels — both fossil fuels and wood burning. In urban areas, black carbon emissions are mostly caused by road transport, diesel engines in particular. Besides its health impacts, black carbon in particulate matter contributes to climate change by absorbing the sun's heat and warming the atmosphere.

## Ozone: when three atoms of oxygen bind together

Ozone is a special and highly reactive form of oxygen, consisting of three atoms of oxygen. In the stratosphere — one of the upper layers of the atmosphere — ozone protects us from the Sun's dangerous ultra-violet radiation. But in the lowest layer of the atmosphere — the troposphere — ozone is in fact an important pollutant affecting public health and nature.

Ground-level ozone is formed as a result of complex chemical reactions between precursor gases such as nitrogen oxides and non-methane volatile organic compounds. Methane and carbon monoxide also play a role in its formation.

Ozone is powerful and aggressive. High levels of ozone corrode materials, buildings and living tissue. It reduces plants' ability to conduct photosynthesis, and hinders their uptake of carbon dioxide. It also impairs plant reproduction and growth, resulting in lower crop yields and reduced forest growth. In the human body, it causes inflammation in the lungs and the bronchia.

Once exposed to ozone, our bodies try to prevent it from entering our lungs. This reflex reduces the amount of oxygen we inhale. Inhaling less oxygen makes our hearts work harder. So for people already suffering from cardiovascular diseases or respiratory diseases like asthma, high-ozone episodes can be debilitating and even fatal.

## What else is in the mix?

Ozone and PM are not the only air pollutants of concern in Europe. Our cars, lorries, energy plants and other industrial facilities all need energy. Almost all vehicles and facilities use some form of fuel and burn it to obtain energy.

Fuel combustion usually changes the form of many substances, including nitrogen — the most abundant gas in our atmosphere. When nitrogen reacts with oxygen, nitrogen oxides form in the air (including nitrogen dioxide — $NO_2$). When nitrogen reacts with hydrogen atoms, it creates ammonia ($NH_3$), which is another air pollutant with severe adverse effects on human health and nature.

In fact, combustion processes release a variety of other air pollutants, ranging from sulphur dioxide and benzene to carbon monoxide and heavy metals. Some of these pollutants have short-term effects on human health. Others, including some heavy metals and persistent organic pollutants, accumulate in the environment. This allows them to get into our food chain and ultimately end up on our plates.

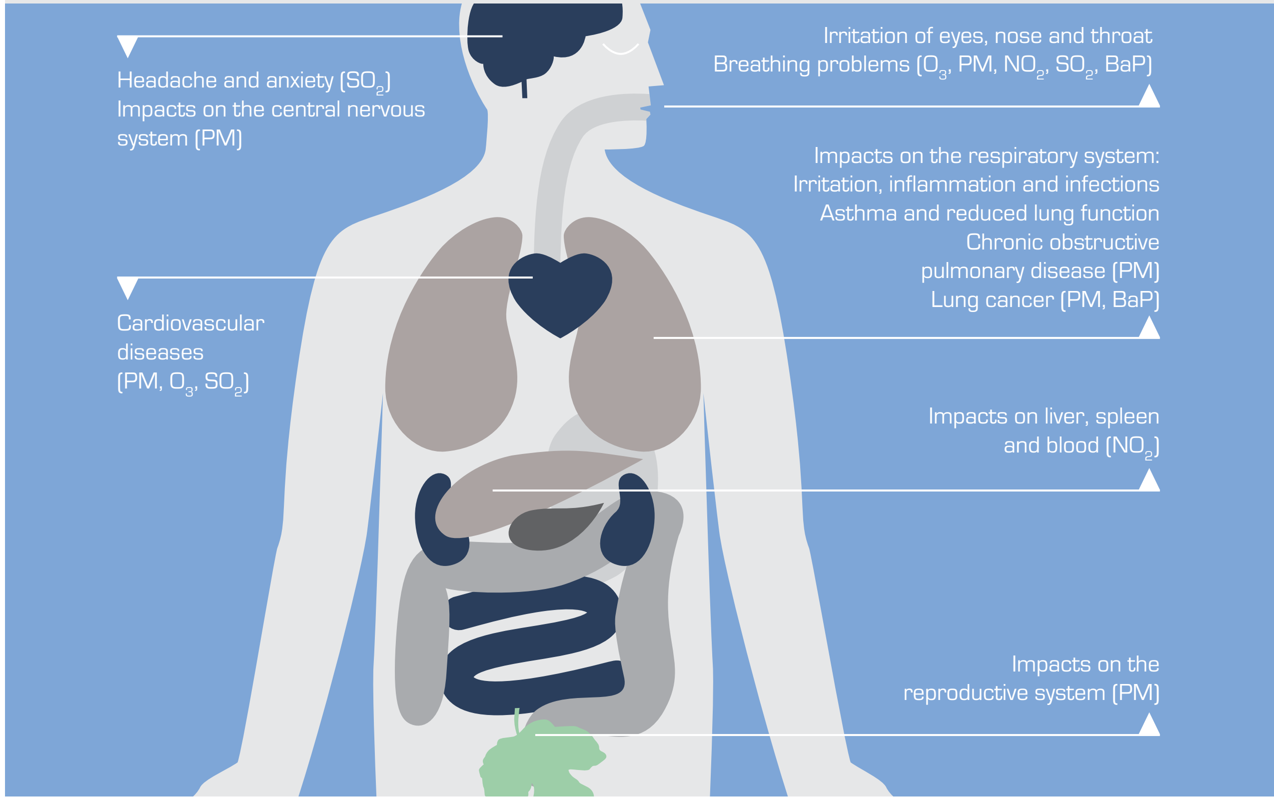
Other pollutants, such as benzene, can damage cells' genetic material and cause cancer in the event of long-term exposure. As benzene is used as an additive to petrol, around 80 % of benzene released into the atmosphere in Europe comes from the combustion of fuels used by vehicles.

Another known cancer-causing pollutant, benzo(a)pyrene (BaP), is released mainly from the burning of wood or coal in residential stoves. Car exhaust fumes, especially from diesel vehicles, is another source of BaP. In addition to causing cancer, BaP can also irritate the eyes, nose, throat and bronchial tubes. BaP is usually found in fine particles.



### Health impacts of air pollution

Air pollutants can have a serious impact on human health. Children and the elderly are especially vulnerable.




**Particulate matter (PM)** are particles that are suspended in the air. Sea salt, black carbon, dust and condensed particles from certain chemicals can be classed as a PM pollutant.

**Nitrogen dioxide ($NO_2$)** is formed mainly by combustion processes such as those occurring in car engines and power plants.

**Ground-level ozone ($O_3$)** is formed by chemical reactions (triggered by sunlight) involving pollutants emitted into the air, including those by transport, natural gas extraction, landfills and household chemicals.

**Sulphur dioxide ($SO_2$)** is emitted when sulphur containing fuels are burned for heating, power generation and transport. Volcanoes also emit $SO_2$ into the atmosphere.

**Benzo(a)pyrene (BaP)** originates from incomplete combustion of fuels. Main sources include wood and waste burning, coke and steel production and motor vehicles' engines.

**97 %**
of Europeans are exposed to $O_3$ concentrations above the World Health Organization recommendations.

**EUR 220–300**
is how much air pollution from the 10 000 largest polluting facilities in Europe cost each EU citizen in 2009.

**63 %**
of Europeans say they reduced their car use in the last two years in order to improve air quality.

Sources: EEA, WHO, Eurobarometer

Stella Carbone, Italy
ImaginAIR; BADAIR

## Measuring the impacts on human health

Although air pollution affects everyone, it does not affect everyone to the same extent and in the same way. More people are exposed to air pollution in urban areas because of the higher population densities there. Some groups are more vulnerable, including those suffering from cardiovascular and respiratory diseases, people with reactive airways and airway allergies, the elderly, and infants.

'Air pollution affects everyone in developed and developing countries alike,' says Marie-Eve Héroux from the World Health Organization's Regional Office for Europe. 'Even in Europe, there is still a high proportion of the population that is exposed to levels exceeding our recommendations on air quality guidelines.'

It is not easy to estimate the full extent of the damage to our health and the environment caused by air pollution. However, there are many studies based on various sectors or pollution sources.

According to the Aphekom project co-funded by the European Commission, air pollution in Europe leads to a reduction in life expectancy of around 8.6 months per person.

Some economic models can be used to estimate the costs of air pollution. These models typically contain the health costs caused by air pollution (loss of productivity, additional medical costs, etc.), as well as costs arising from lower crop yields and damage to certain materials. However, such models do not include all the costs to society caused by air pollution.

But even with their limitations, such cost estimates give an indication of the magnitude of the damage. Nearly 10 000 industrial facilities across Europe report the amounts of various pollutants they emit to the atmosphere to the European Pollutant Release and Transfer Register (E-PRTR). Based on these publicly available data, the EEA estimated that air pollution from the 10 000 largest polluting facilities in Europe cost Europeans between EUR 102 and EUR 169 billion in 2009. Importantly, just 191 facilities were found to be responsible for half of the total damage cost.

There are also studies estimating the possible gains that could be obtained by improving air quality. For example, the Aphekom study predicts that reducing annual average levels of $PM_{2.5}$ to World Health Organization guideline levels would result in concrete gains in life expectancy. Achieving just this target is expected to result in possible gains ranging from 22 months on average per person in Bucharest, and 19 months in Budapest, to 2 months in Malaga, and less than half a month in Dublin.

## Nitrogen's impacts on nature

It is not only human health that is affected by air pollution. Different air pollutants have different impacts on a wide range of ecosystems. Excess nitrogen, however, poses particular risks.

Nitrogen is one of the key nutrients found in the environment that plants need for healthy growth and survival. It can dissolve in water and is then absorbed by plants through their root systems. Because plants use large amounts of nitrogen and deplete the existing amounts in the soil, farmers and gardeners usually use fertilisers to add nutrients, including nitrogen, to the soil to boost production.

Airborne nitrogen has a similar effect. When deposited to water bodies or soils, extra nitrogen can work to the advantage of certain species in ecosystems where limited amounts of nutrients exist, such as the so-called 'sensitive ecosystems', with their unique flora and fauna. Excess nutrient supply in these ecosystems can completely alter the balance between species, and can lead to biodiversity loss in the affected area. In freshwater and coastal ecosystems, it can also contribute to algal blooms.

The ecosystems' response to excess nitrogen deposition is known as eutrophication. In the last two decades, the sensitive ecosystem area affected by eutrophication in the EU has declined only slightly. And today, almost half of the total area defined as sensitive ecosystems is estimated to be at risk of eutrophication.

Nitrogen compounds also contribute to the acidification of freshwaters or forest soils, affecting the species that are dependent on those ecosystems. Similar to the impacts of eutrophication, the new living conditions can favour some species to the detriment of others.

The EU has succeeded in significantly reducing the area of sensitive ecosystems affected by acidification, mainly thanks to strong reductions in sulphur dioxide emissions. Only a few hot-spot areas in the EU, in the Netherlands and Germany in particular, face acidification problems.

## Pollution without borders

Although some areas and countries might experience its impacts on public health or the environment more severely than others, air pollution is a global problem.

Global winds mean that air pollutants move around the world. A part of the air pollutants and their precursors found in Europe are emitted in Asia and North America. Similarly, a part of the pollutants released into the air in Europe are transported to other regions and continents.

The same is also true on a smaller scale. The air quality in urban areas is generally affected by the air quality in the surrounding rural areas and vice versa.

'We breathe all the time and are exposed to air pollution — whether indoors or outdoors,' says Erik Lebret from the National Institute for Public Health and the Environment (RIVM) in the Netherlands. 'Everywhere we go we are breathing air, which is contaminated with a whole range of pollutants at levels where you can sometimes expect adverse health effects. Unfortunately, there is no place where we can breathe only clean air.'

"The Jizerske hory Mts. Protected Landscape Area situated in the northern part of the Czech Republic belongs to the region which in the past was known infamously as 'the Black Triangle' due to its severe air pollution."

**Leona Matoušková, Czech Republic ImaginAIR; Forests in the Czech Republic still affected by air pollution**

### More information

- EEA Technical report No 15/2011: **Revealing the costs of air pollution from industrial facilities in Europe.**
- World Health Organization — Air pollution & health impacts: **http://www.who.int/topics/air_pollution/en** and the Aphekom study **www.aphekom.org**

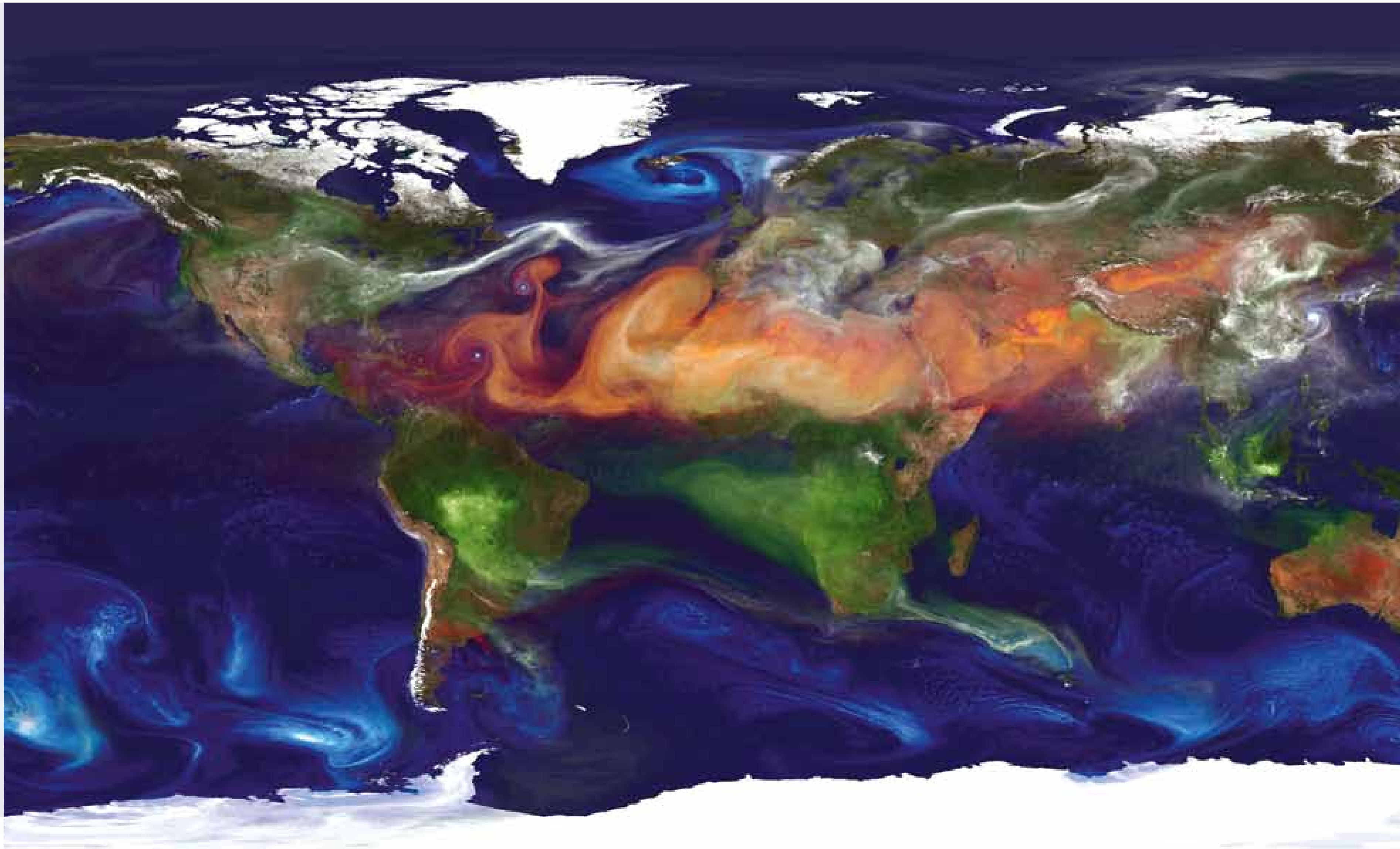
# A portrait of global aerosols

'African dust' from the Sahara is one of the natural sources of particulate matter in the air. Extremely dry and hot conditions in the Sahara create turbulence, which can propel dust upwards to a height of 4–5 km. Particles can stay at these heights for weeks or months, and are often blown across Europe.

Sea spray is also a source of particulate matter, and can contribute up to 80 % of particle levels in the air in certain coastal areas. It is comprised mostly of salt, whipped into the air by strong winds.

Volcanic eruptions, for example in Iceland or in the Mediterranean, might also produce temporary peaks of airborne particulate matter in Europe.

Forest and grassland fires in Europe burn an average of almost 600 000 hectares (roughly 2.5 times the size of Luxembourg) per year and are a significant source of air pollution. Unfortunately, nine out of ten fires are believed to be caused directly or indirectly by humans, for example by arson, discarded cigarettes, campfires, or farmers burning crop residues after the harvest.



A simulation of atmospheric particles and their movements by NASA

Dust (red) is lifted from the surface; sea salt (blue) swirls inside cyclones; smoke (green) rises from fires; and sulphate particles (white) stream from volcanoes and fossil fuel emissions.

This **portrait of global aerosols** was produced by a GEOS-5 simulation at a 10-kilometer resolution. Image credit: William Putman, NASA/Goddard; **www.nasa.gov/multimedia/imagegallery**




# Europe's air today

**Europe has improved its air quality in recent decades. Emissions of many pollutants were curbed successfully, but particulate matter and ozone pollution in particular continue to pose serious risks to the health of Europeans.**

London, 4 December 1952: A dense fog started settling over the city; the breeze stopped. In the following days, the air over the city stood still; coal burning released high levels of sulphur oxides and added a yellowish hue to the fog. Hospitals were soon filled with people suffering from respiratory diseases. At its worst moment, visibility was so poor at various locations that people could not see their own feet. During the Great Smog of London, between 4 000 and 8 000 additional people — mostly infants and elderly people — are estimated to have died on top of the average death rate.

Serious air pollution in Europe's large industrial cities was quite common in the 20th century. Solid fuels, coal in particular, were often used to fuel factories and heat homes. Combined with winter conditions and meteorological factors, there were many days when very high levels of air pollution would hover over urban areas for days, weeks, and months at a time. In fact, London was known for its air pollution episodes since the 17th century. By the 20th century, London's smog was considered one of the characteristics of the city, and had even earned its place in literature.

## Taking action led to real improvements in air quality

Much has changed since then. In the years following the Great Smog, increased public and political awareness led to legislation aimed at reducing air pollution from stationary sources such as homes, commerce and industry. In the late 1960s, many countries, not just the United Kingdom, had started to pass laws to tackle air pollution.

In the 60 years since the Great Smog, Europe's air quality has improved substantially, largely due to effective national, European and international legislation.

In some cases, it became clear that the air pollution problem could be solved only through international cooperation. In the 1960s, studies showed that the acid rain that was causing the acidification of Scandinavian rivers and lakes was caused by pollutants released into the air in continental Europe. The outcome was the first international legally binding instrument to deal with problems of air pollution on a broad regional basis, namely the United Nations Economic Commission for Europe's Convention on Long-range Transboundary Air Pollution (LRTAP) of 1979.

Technological developments, some of which were prompted by legislation, have also contributed to improving Europe's air. For example, car engines have become more efficient in using fuels; new diesel cars have particle filters installed; and industrial facilities have started using increasingly more effective pollution-abatement equipment. Measures such as congestion charges or tax incentives for cleaner cars have also been quite successful.

Emissions of some air pollutants, such as sulphur dioxide, carbon monoxide and benzene have been greatly reduced. This has led to clear improvements in air quality and thus also public health. For example, the switch from coal to natural gas was instrumental in reducing sulphur dioxide concentrations: in the period 2001–2010, sulphur dioxide concentrations were halved in the EU.

Lead is another pollutant that has been successfully tackled by legislation. In the 1920s, most vehicles started using leaded petrol to avoid damage to the internal combustion engines. The health impacts of lead released into the air became known only decades later. Lead affects the organs and the nervous system, hampering intellectual development in children in particular. Starting in the 1970s, a series of actions both at European and international level led to the phasing out of leaded additives in petrol used in vehicles. Today, almost all stations monitoring lead in the air report concentration levels well below the limits set in EU legislation.

## Where do we stand now?

For other pollutants, the results are less clear. Chemical reactions in our atmosphere and our dependence on certain economic activities make it more difficult to tackle these pollutants.

Another difficulty stems from the way the legislation is implemented and enforced across EU countries. The air legislation in the EU typically sets targets or limits on specific substances, but leaves it to the countries to determine how they will attain those targets.

Some countries have taken many effective measures to tackle air pollution. Other countries have taken fewer measures, or the measures they took proved to be less effective. This can be partly due to different levels of monitoring and different enforcement capacities in the countries.

Another problem in controlling air pollution comes from the difference between laboratory tests and real world conditions. In cases where legislation targets specific sectors such as transport or industry, technologies tested in ideal laboratory settings might appear cleaner and more effective than in real-world uses and situations.

We must also bear in mind that new consumption trends or policy measures not related to air might also have unintended effects on Europe's air quality.

"The ancient practice of burning the stubble in the rural areas is still followed in Romania. It is a way of clearing the area for new, rich crops. In addition to its negative impact on nature, I also consider this activity harmful to the local community's health. As the burning involves a certain number of people to control the fire, the impact is very specific."

**Cristina Sînziana Buliga, Romania**
**ImaginAIR; Agricultural traditions that harm**

"In many cities now, the pollution is so substantial that it's almost impossible to see the stars at night."

**Justine Lepaulard, France**
**ImaginAIR; The human being, or a destroyer species**

## PM exposure is still high in cities

Current EU and international legislation aimed at tackling PM classifies particles in two sizes — 10 microns in diameter or less and 2.5 microns in diameter or less ($PM_{10}$ and $PM_{2.5}$) — and targets direct emissions as well as emissions of precursor gases.

There are substantial achievements on PM emissions in Europe. Between 2001 and 2010, direct emissions of $PM_{10}$ and $PM_{2.5}$ decreased by 14 % in the European Union and by 15 % in the 32 EEA countries.

Emissions of PM precursors have also decreased in the EU: sulphur oxides by 54 % (44 % in EEA-32); nitrogen oxides by 26 % (23 % in EEA-32); ammonia by 10 % (8 % in EEA-32).

But these emission reductions have not always resulted in lower exposure to PM. The share of the European urban population exposed to concentration levels of $PM_{10}$ above the values set by EU legislation remained high (18–41 % for EU-15 and 23–41 % for EEA-32) and showed only a minor decline in the last decade. When taking into account the World Health Organization's (WHO) stricter guidelines, more than 80 % of the urban population in the EU is exposed to excessive $PM_{10}$ concentrations.

So if emissions decreased substantially, why do we still have high levels of exposure to PM in Europe? Reducing emissions in a specific area or from specific sources does not automatically result in lower concentrations.

Some pollutants can stay in the atmosphere long enough to be transported from one country to another, from one continent to another, or in some cases around the globe. Intercontinental transport of particles and their precursors can go some way to explaining why Europe's air has not improved by as much as PM emissions and PM precursor emissions have fallen.

Another reason for the continued high concentrations of PM can be found in our consumption patterns. For example, in recent years, coal and wood burning in small stoves for home heating has constituted a major source of $PM_{10}$ pollution in some urban areas, in particular in Poland, Slovakia and Bulgaria. This is partly caused by high-energy prices, which induced low-income households in particular to opt for cheaper alternatives.

## Ozone: a nightmare on hot summer days?

Europe also succeeded in reducing emissions of ozone precursors between 2001 and 2010. In the EU, emissions of nitrogen oxides decreased by 26 % (23 % in EEA-32), non-methane volatile organic compounds decreased by 27 % (28 % in EEA-32), and carbon monoxide emissions decreased by 33 % (35 % in EEA-32).

Just as with PM, the amounts of ozone precursors emitted into the atmosphere have dropped, but there has not been a corresponding decrease in the high concentration levels of ozone. This is partly due to intercontinental transport of ozone and its precursors. Topography and year-to-year variations in meteorological conditions such as in winds and temperatures also play a role.

Despite a decrease in the number and frequency of peak ozone concentrations in the summer months, the exposure of urban populations to ozone still remains high. In the period 2001–2010, between 15 and 61 % of the EU urban population was exposed to ozone levels above EU target values, mostly in southern Europe due to warmer summers. By the World Health Organization's stricter guidelines, nearly all of the urban residents in the EU were exposed to excessive levels. Overall, ozone episodes are more common in the Mediterranean region than in northern Europe.

But high ozone concentrations are not only an urban phenomenon seen during summer months. Surprisingly, ozone levels tend to be generally higher in rural areas, although fewer people are exposed. Urban areas usually have higher levels of traffic than rural areas. However, one of the pollutants released by road transport destroys ozone molecules through a chemical reaction, and may thus result in lower ozone levels in urban areas. However, the higher traffic levels result in higher PM levels in cities.

## Legislation to reduce emissions

Given that they may originate partly in other countries, the emissions of some of the PM and ozone precursors are covered by the Gothenburg Protocol to the Convention on Long-range Transboundary Air Pollution (LRTAP Convention).

In 2010, 12 EU countries, and the EU itself, exceeded one or more emission ceilings (the allowed amount of emissions) for one or more pollutants covered by the convention (nitrogen oxides, ammonia, sulphur dioxide and non-methane volatile organic compounds). Ceilings for nitrogen oxides were exceeded by 11 of the 12 countries.

A similar picture emerges from EU legislation. The National Emission Ceilings (NEC) Directive regulates emissions of the same four pollutants as the Gothenburg Protocol but with slightly more stringent ceilings for some countries. Final official data for the NEC Directive indicate that 12 EU countries failed to meet their legally binding emission ceilings for nitrogen oxides in 2010. Several of these countries also failed to meet their ceilings for one or more of the other three pollutants.

## Where do air pollutants come from?

The contribution of human activities to the creation of air pollutants is generally easier to measure and monitor than natural sources, but this human contribution varies greatly depending on the pollutant. Fuel combustion is clearly one key contributor and is spread across various economic sectors, from road transport and households to energy use and energy production.

Agriculture is another important contributor to specific pollutants. Around 90 % of the ammonia emissions and 80 % of the methane emissions come from agricultural activities. Other methane sources include waste (landfills), coal mining and long-distance gas transmission.

More than 40 % of emissions of nitrogen oxides come from road transport, while around 60 % of the sulphur oxides come from energy production and distribution in the EEA member and cooperating countries. Commercial, government and public buildings, and households contribute to around half of the $PM_{2.5}$ and carbon monoxide emissions.

### Sources of air pollution in Europe

Air pollution is not the same everywhere. Different pollutants are released into the atmosphere from a wide range of sources, including industry, transport, agriculture, waste management and households. Certain air pollutants are also released from natural sources.


1 / Around 90 % of ammonia emissions and 80 % of methane emissions come from **agricultural activities**.

2 / Some 60 % of sulphur oxides come from **energy production and distribution**.

3 / Many **natural phenomena,** including volcanic eruptions and sand storms, release air pollutants into the atmosphere.

4 / **Waste (landfills), coal mining and long-distance gas transmission** are sources of methane.

5 / More than 40 % of emissions of nitrogen oxides come from **road transport**.

Almost 40 % of primary $PM_{2.5}$ emissions come from transport.

6 / **Fuel combustion** is a key contributor to air pollution — from road transport, households to energy use and production.

**Businesses, public buildings and households** contribute to around half of the $PM_{2.5}$ and carbon monoxide emissions.

Source: EEA

It is clear that many different economic sectors contribute to air pollution. Bringing in air quality concerns into the decision-making processes for these sectors might not make the newspaper headlines, but it would certainly help improve Europe's air quality.

## Air quality under public scrutiny

What has actually made the international headlines and attracted public attention in recent years was the air quality in large urban areas, especially for the cities hosting the Olympic Games.

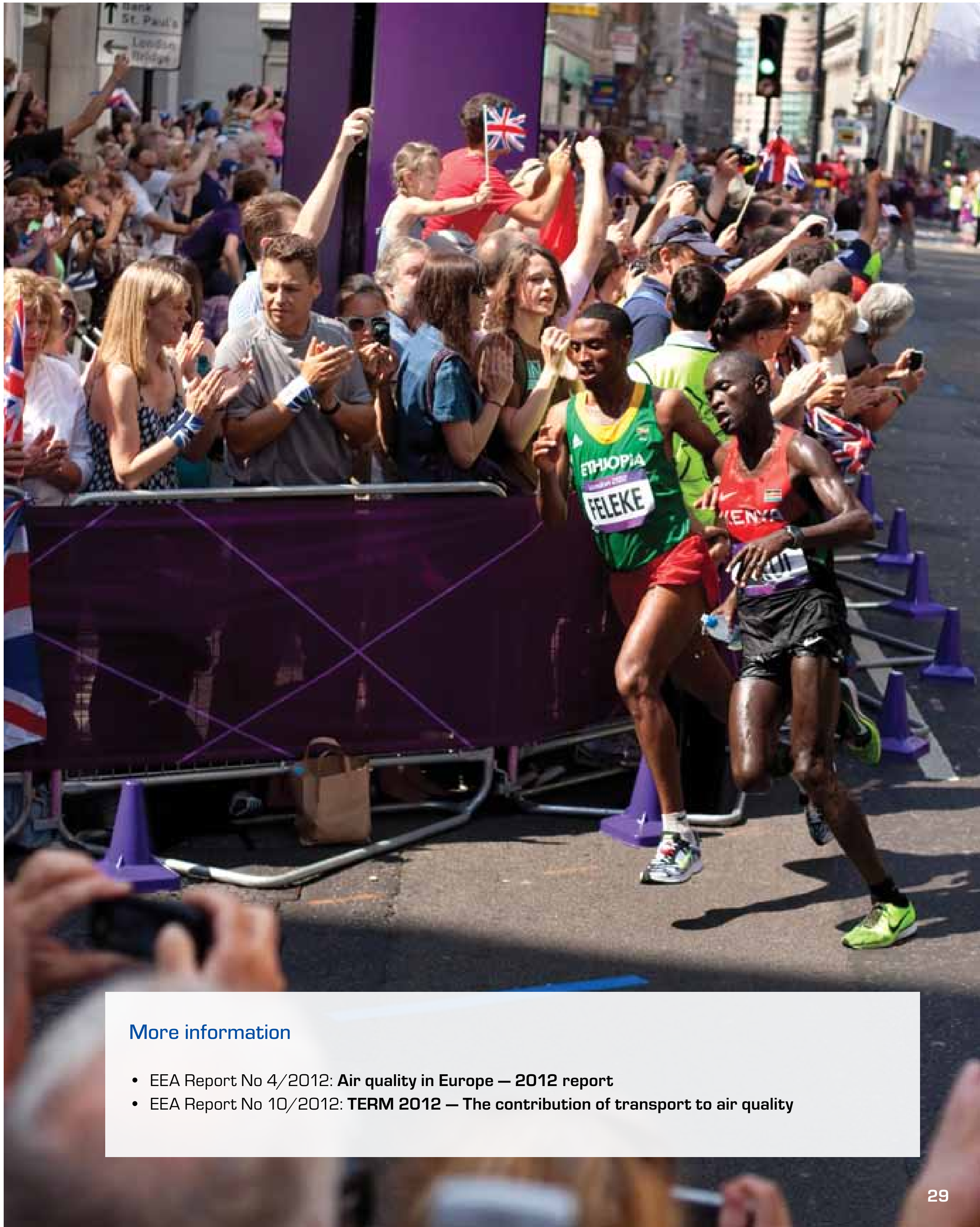
Take Beijing. The city is known for its fast-rising skyscrapers as well as its air pollution. Beijing started systematic air pollution control in 1998 — three years before being officially selected to host the Olympic Games. The authorities took concrete measures to improve air quality ahead of the Games. Old taxis and buses were replaced and dirty industries were relocated or closed. In the weeks prior to the Games, construction work was put on hold and car use was restricted.

Professor C.S. Kiang, one of the leading Chinese climate scientists, talks about air quality during the Beijing games: 'During the first two days of the Games, the concentration of $PM_{2.5}$, the fine particles that penetrate deep into the lungs, were around 150 µg/m$^3$. On the second day, it started to rain, the winds turned up and $PM_{2.5}$ levels dropped sharply and then hovered around 50 µg/m$^3$, which is double the WHO guideline value of 25 µg/m$^3$.'

A similar discussion took place in the United Kingdom ahead of the London Olympics in 2012. Would the air quality be good enough for Olympic athletes, especially the marathon runners or the cyclists? According to the University of Manchester, the London Olympics were not pollution-free, but may still have been the least polluted games in recent years. Favourable weather and good planning seem to have helped; a rather big achievement compared to London in 1952.

Unfortunately the air pollution problem does not disappear after the Olympic spotlights are turned off. In the first days of 2013, Beijing was once again immersed in severe air pollution. On 12 January, official measurements indicated $PM_{2.5}$ concentrations of over 400 µg/m$^3$, whereas unofficial readings at various locations reached 800 µg/m$^3$.






### More information

- EEA Report No 4/2012: **Air quality in Europe — 2012 report**
- EEA Report No 10/2012: **TERM 2012 — The contribution of transport to air quality**

Interview

David Fowler

Greta De Metsenaere, Belgium
ImaginAIR; S-cars in the sky

# A matter of chemistry

**The chemistry of our atmosphere is complex. The atmosphere contains layers with different densities and different chemical compositions. We asked Professor David Fowler from the Centre for Ecology & Hydrology of the Natural Environment Research Council in the United Kingdom, about the air pollutants and chemical processes in our atmosphere that impact our health and the environment.**

## Do all gases matter for the environment?

Many of the gases in the air are not especially important in terms of chemistry. Some trace gases like carbon dioxide and nitrous oxide don't react readily in the air, and for this reason they are categorised as long-lived gases. The main component of air, nitrogen, is also largely inert in the atmosphere. Long-lived trace gases are present at roughly the same concentrations all over the world. If you took a sample in the northern hemisphere and the southern hemisphere, there would not be much difference in terms of the amount of these gases in the air.

However, concentrations of other gases like sulphur dioxide, ammonia and the sunlight-sensitive oxidants such as ozone, are much more variable. These gases represent a threat to the environment and human health, and because they react so quickly in the atmosphere they don't last long in their original form. They react quickly to form other compounds or are removed by deposition to the ground, and are referred to as short-lived gases. They are therefore present close to the places they were emitted or formed by reaction. Remote sensing satellite imagery shows hotspots of these short-lived gases in certain parts of the world, typically in industrialised areas.

## How can these short-lived gases create problems for air quality and the environment?

Many of these short-lived gases are toxic to human health and vegetation. They are also readily transformed in the atmosphere to other pollutants, some by the action of sunlight. The sun's energy is capable of splitting many of these reactive short-lived gases into new chemical compounds. Nitrogen dioxide is a good example. Nitrogen dioxide is produced mainly by burning fuel, whether in cars burning petrol, or electricity plants burning gas and coal. When nitrogen dioxide is exposed to sunlight, it is split into two new chemical compounds: nitric oxide and what chemists call atomic oxygen.

Atomic oxygen is simply a single atom of oxygen. The atomic oxygen reacts with molecular oxygen (two oxygen atoms combined as molecules $O_2$) to form ozone ($O_3$), which is toxic to ecosystems and human health, and is one of the most important pollutants in all industrialised countries.

### But in the 1980s, did we not need ozone to protect us from too much radiation from the sun?

That's correct. But the ozone in the ozone layer is in the stratosphere at altitudes between 10 km and 50 km above the surface, where it provides protection from UV radiation. However, the ozone at lower levels — commonly referred to as ground-level ozone — is a threat to human health, crops, and other sensitive vegetation.

Ozone is a powerful oxidant. It enters plants through small pores in the leaves. It is absorbed by the plant and generates free radicals — unstable molecules that damage membranes and proteins. Plants have sophisticated mechanisms to deal with free radicals. But if a plant has to devote some of the energy it harvests from sunlight and photosynthesis to repairing the cell damage caused by free radicals, it will have less energy to grow. So when crops are exposed to ozone, they are less productive. Across Europe, North America, and Asia, agricultural yields are reduced by ozone.

The chemistry of ozone in humans is quite similar to the chemistry of ozone in plants. But instead of entering through pores in the plant's surface, ozone is absorbed through the lining of the lung. It creates free radicals in the lining of the lung and damages lung function. So the people most at risk from ozone are those with impaired breathing. If you look at the statistics, periods of high ozone show an increase in the daily death rate for humans.

### Given that these gases are short lived, shouldn't a drastic cut in nitrogen dioxide emissions lead to a quick decline in ozone levels?

In principle, yes. We could cut emissions and ozone levels would begin to fall. But ozone is created from very close to the earth's surface all the way up to a height of about 10 km. So there is quite a lot of background ozone still up there. If we stopped emitting it all, it would take a month or so to be back down at natural levels of ozone.

But even if Europe took that action on emissions, it would not really reduce our exposure to ozone. Part of the ozone entering Europe comes from the ozone generated from European emissions. But Europe is also exposed to ozone transported from China, India, and North America. Nitrogen dioxide itself is a short-lived gas, but the ozone it creates can last longer and therefore has time to be carried by wind around the world. A unilateral EU decision would reduce some of the peaks of ozone production over Europe, but it would make only a small contribution to the global background, because Europe is just one contributor among many.

Europe, North America, China, India, and Japan all have an ozone problem. Even the rapidly developing countries such as Brazil (where biomass burning and vehicles release ozone precursor gases) have an ozone problem. The cleanest parts of the world in terms of ozone production are the remote ocean areas.

### Is ozone the only source of concern?

Aerosols are the other main pollutant and are more important than ozone. Aerosols in this sense aren't what consumers typically think of as being aerosols, such as deodorants and furniture spray that can be bought in the supermarket. For chemists, aerosols are small particles in the atmosphere, also referred to as particulate matter (PM). They can be solid or liquid, and some of the particles become droplets in moist air and then return to solid particles as the air dries. Aerosols are associated with higher human mortality, and the people most at risk are those with respiratory problems. Particulate matter in the atmosphere causes larger health effects than ozone.

Many of the pollutants created by human activities are emitted as gases. For example, sulphur is usually emitted as sulphur dioxide ($SO_2$) while nitrogen is emitted as nitrogen dioxide ($NO_2$) and/or ammonia ($NH_3$). But once they're in the atmosphere, these gases are transformed into particles. This process turns sulphur dioxide into sulphate particles, which are no bigger than a fraction of a micron.

If there's enough ammonia in the air, then that sulphate reacts to become ammonium sulphate. If you looked at the air over Europe 50 years ago, ammonium sulphate was a really dominant component. But we've greatly reduced sulphur emissions over Europe — by about 90 % since the 1970s.

Cesarino Leoni, Italy
ImaginAIR; Air and health

But although we have reduced sulphur emissions, we haven't reduced ammonia emissions by anywhere near as much. This means that the ammonia in the atmosphere reacts with other substances. For example, $NO_2$ in the atmosphere transforms to nitric acid, and this nitric acid reacts with the ammonia to produce ammonium nitrate.

Ammonium nitrate is very volatile. Higher in the atmosphere, ammonium nitrate is a particle or a droplet, but on a warm day and close to the surface, ammonium nitrate splits up into nitric acid and ammonia, both of which deposit on the earth's surface very rapidly.

### What happens if nitric acid is deposited on the earth's surface?

Nitric acid provides an addition of nitrogen to the earth's surface and effectively acts as a fertiliser on our plants. In this way, we are fertilising the natural environment of Europe from the atmosphere in the same way that farmers fertilise cropland. The additional nitrogen fertilising the natural landscape results in acidification and leads to enhanced nitrous oxide emission, but it also increases the growth of forests and so is both a threat and a benefit. The largest effect of the nitrogen deposited on the natural landscape is in providing additional nutrients to natural ecosystems. As a result, the nitrogen-hungry plants grow very quickly and flourish and out-compete the slow-growing species. This leads to the loss of more specialist species, which have adapted to flourish in a low-nitrogen climate. We can already see a change in the biodiversity of flora across Europe as a result of our fertilising the continent from the atmosphere.

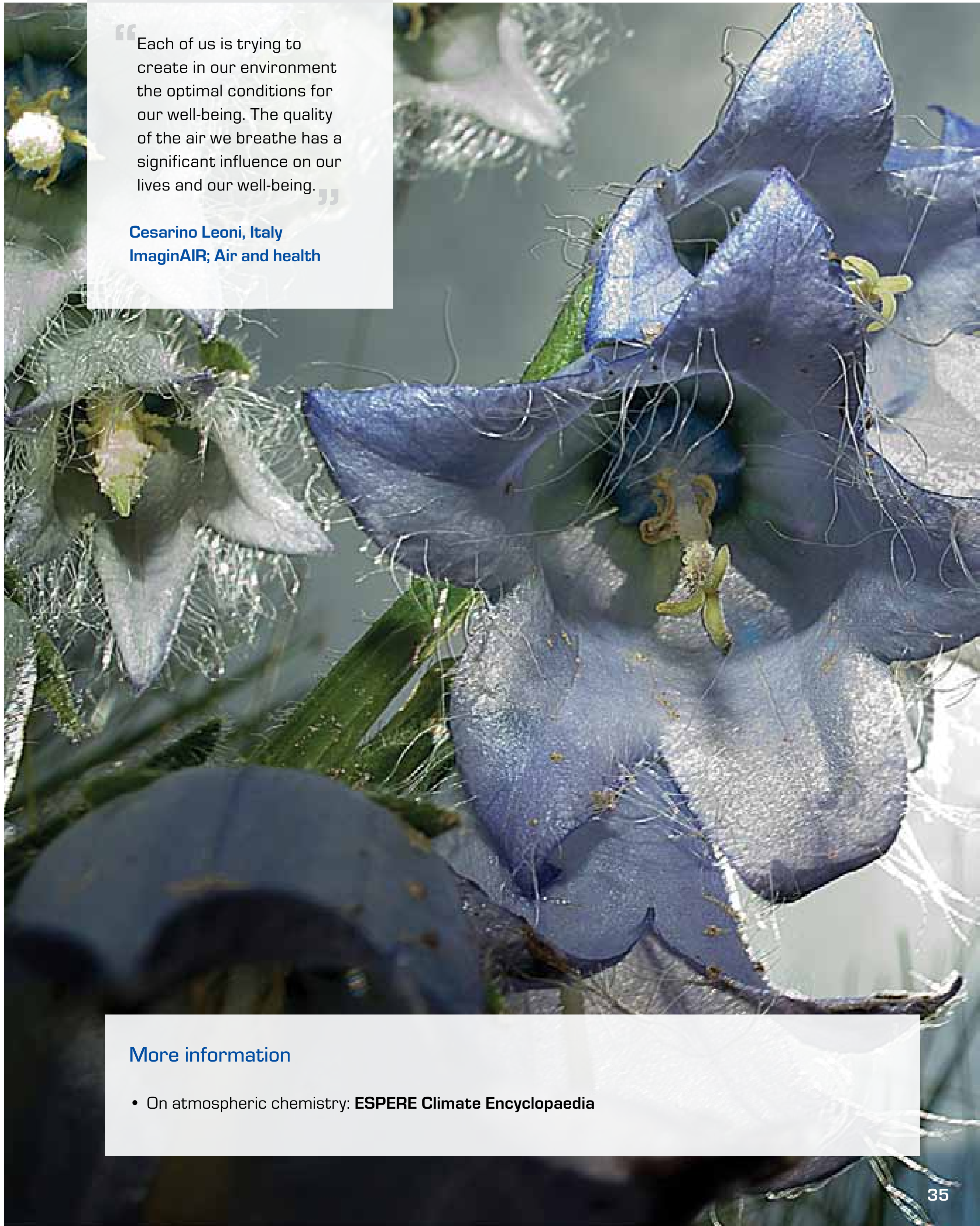
### We dealt with sulphur emissions and the ozone layer. Why haven't we dealt with the ammonium problem?

Ammonia emissions come from the agricultural sector and especially the intensive dairy sector. Urine and manure from cows and sheep on the fields lead to emissions of ammonia to the atmosphere. It is very reactive and readily deposits on the landscape. It also forms ammonium nitrate and is an important contributor to particulate matter in the atmosphere, and to associated human health problems. Most of the ammonia we emit in Europe deposits in Europe. There has to be a stronger political will to introduce control measures to reduce ammonia emissions.

Interestingly, in the case of sulphur, the political will was absolutely there. I think this was partly due to a sense of moral obligation by the large emitter countries of Europe relative to the net receiver countries of Scandinavia, where the bulk of the acid deposition problems occurred.

Reducing ammonia emissions would mean targeting the agricultural sector, and agriculture lobbies are rather influential in political circles. It's no different in North America. There's also a large problem with ammonia emissions in North America and there is also no action to control it there either.





"Each of us is trying to create in our environment the optimal conditions for our well-being. The quality of the air we breathe has a significant influence on our lives and our well-being."

**Cesarino Leoni, Italy**
**ImaginAIR; Air and health**

### More information

- On atmospheric chemistry: **ESPERE Climate Encyclopaedia**

# Climate change and air

**Our climate is changing. Many climate-changing gases are also common air pollutants that affect our health and the environment. In many ways, improving air quality can also give a boost to climate change mitigation efforts and vice versa, but not always. The challenge ahead is to ensure that climate and air policies focus on win-win scenarios.**

In 2009, a joint British and German team of researchers conducted research off the coast of Norway with a type of sonar normally used to search for shoals of fish. The team was not there to look for fish but to observe one of the most powerful greenhouse gases, methane, being released from the 'melting' seabed. Their findings were only one among many in the long timeline of warnings about the potential impacts of climate change.

In regions close to the poles, a part of the land mass or the seabed is permanently frozen. According to some estimates, this layer — known as permafrost — contains twice the amount of carbon that is currently in the atmosphere. Under warmer conditions, this carbon can be released from rotting biomass as either carbon dioxide or methane.

'Methane is a greenhouse gas more than 20 times more powerful than carbon dioxide,' warns Professor Peter Wadhams of Cambridge University. 'So now we risk facing further global warming and even faster melting in the Arctic'.

Methane emissions come from human activities (mainly agriculture, energy and waste management) and natural sources. Once released into the atmosphere, methane has a lifespan of around 12 years. Although it is considered to be a relatively short-lived gas, its lifespan is still long enough for it to be transported to other regions. In addition to being a greenhouse gas, methane is also a contributor to the formation of ground-level ozone, which itself is a major pollutant affecting human health and the environment in Europe.

## Particulate matter can have a warming or cooling effect

Carbon dioxide may be the largest driver of global warming and climate change but it is not the only one. Many other gaseous or particulate compounds, known as 'climate forcers', have an influence on the amount of solar energy (including heat) the Earth retains and the amount it reflects back into space. These climate forcers include main air pollutants such as ozone, methane, particulate matter and nitrous oxide.

Particulate matter is a complex pollutant. Depending upon its composition, it may have a cooling or warming effect on the local and the global climate. For example, black carbon, one of the constituents of fine PM and a result of incomplete burning of fuels, absorbs solar and infrared radiation in the atmosphere and thus has a warming effect.

Other types of PM containing sulphur or nitrogen compounds have the opposite effect. They tend to act as small mirrors, reflecting the sun's energy and thus leading to cooling. In simple terms, it depends on the colour of the particle. 'White' particles tend to reflect sunlight, while 'black' and 'brown' particles to absorb it.

A similar phenomenon occurs on land. Some of the particles deposit with rain and snow or simply land on the Earth's surface. But black carbon can travel quite far from its place of origin and land on the snow and ice cover. In recent years, black carbon depositions in the Arctic have increasingly darkened the white surfaces and reduced their reflectivity, which means that our planet retains more heat. With this additional heat, the size of white surfaces is shrinking ever more quickly in the Arctic.

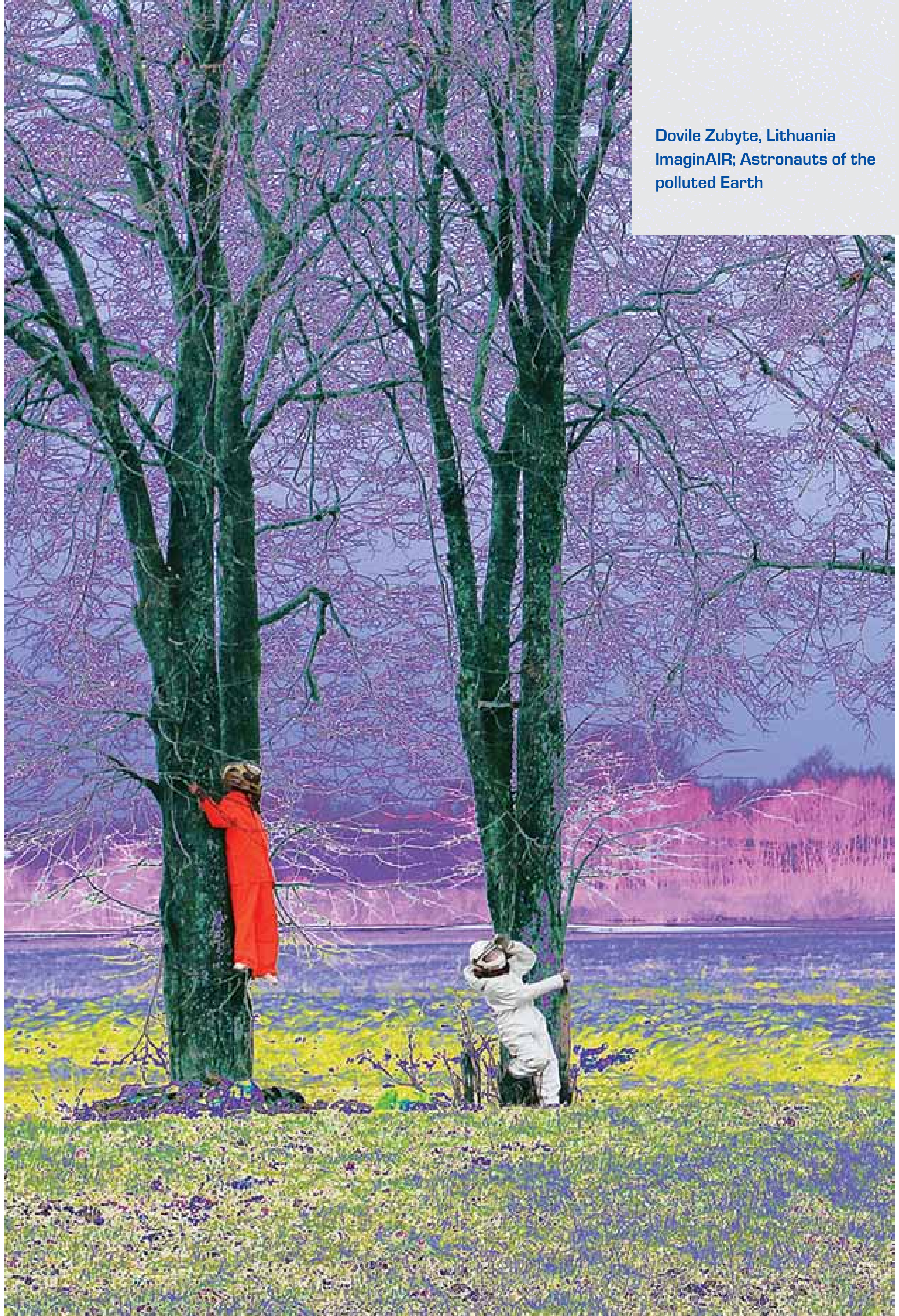
Interestingly, many climate processes are controlled not by major constituents of our atmosphere but by some gases that are only found in very small amounts. The most common of these so-called trace gases, carbon dioxide, constitutes only 0.0391 % of the air. Any variation in these very small amounts has the power to affect and alter our climate.

## More or less rain?

Their 'colour' is not the only way that particles suspended in the air or deposited on the ground can affect the climate. Part of our air consists of water vapour — tiny molecules of water suspended in the air. In their more condensed form, we all know them as clouds. And particles play an important role in how clouds come about; how long they last; how much solar radiation they can reflect; what kind of precipitation they generate and where; and so on. Clouds are obviously essential for our climate; the concentrations and composition of particulate matter might actually change the timing and location of traditional rainfall patterns.

Changes in precipitation amounts and patterns have real economic and social costs, as they tend to affect global food production and consequently food prices.

The EEA's report 'Climate change, impacts and vulnerability in Europe 2012' shows that all regions in Europe are affected by climate change, causing a wide range of impacts on society, ecosystems and human health. According to the report, higher average temperatures have been observed across Europe, combined with decreasing precipitation in southern regions and increasing precipitation in northern Europe. Furthermore, ice sheets and glaciers are melting and sea levels are rising. All of these trends are expected to continue.



**Dovile Zubyte, Lithuania
ImaginAIR; Astronauts of the polluted Earth**

## The relationship between climate change and air quality

Although we do not have a complete understanding of how climate change might affect air quality and vice versa, recent research indicates that this mutual relationship might be stronger than estimated previously. In its assessments from 2007, the Intergovernmental Panel on Climate Change — the international body set up to assess climate change — predicts a decline in air quality in cities in the future due to climate change.

In many regions across the world, climate change is expected to affect local weather, including the frequency of heat waves and stagnant air episodes. More sunlight and warmer temperatures might not only prolong the periods of time in which ozone levels are elevated, it may also exacerbate peak ozone concentrations further. This is certainly not good news for southern Europe, which is already struggling with episodes of excessive ground-level ozone.

International discussions on mitigating climate change have agreed to limit the global mean temperature increase to 2° Celsius above pre-industrial era levels. It is not yet certain if the world will succeed in curbing greenhouse gas emissions sufficiently to attain the 2-degree target. Based on several different emissions trajectories, the United Nations Environment Programme identified the gaps between the current pledges to cut emissions and the cuts we need to attain the target. It is clear that more efforts are needed to reduce emissions further in order to increase our chances of limiting the temperature increase to 2 degrees.

Some regions — like the Arctic — are projected to warm much more. Warmer temperatures above both land and oceans are expected to affect humidity levels in the atmosphere, and this could in turn affect precipitation patterns. It is not yet fully clear the extent to which higher or lower concentrations of water vapour in the atmosphere might affect precipitation patterns or the global and local climate.

However, the extent of the climate change impacts will partly depend on how different regions adapt to climate change. Adaptation actions — from improved urban planning to adaption of infrastructure such as buildings and transport — are already taking place across Europe, but more such actions will be needed in future. A wide spectrum of measures can be used to adapt to climate change. For example, planting trees and increasing green spaces (parks) in urban areas alleviates the effects of heat waves, while also improving air quality.

## Win-win scenarios possible

Many climate-forcers are common air pollutants. Measures to cut emissions of black carbon, ozone or ozone precursors benefit both human health and the climate. Greenhouse gases and air pollutants share the same emission sources. Therefore there are potential benefits that can be obtained by limiting emissions of one or the other.

The European Union aims to have a more competitive economy with lower dependence on fossil fuels and less impact on the environment by 2050. In concrete terms, the European Commission aims at reducing the EU's domestic greenhouse gas emissions by 80–95 % compared to their 1990 levels by that date.

Bojan Bonifacic, Croatia
ImaginAIR; Windmills

The transition to a low-carbon economy, and substantial reductions to greenhouse gas emissions, cannot be achieved without reshaping the Union's energy consumption. These policy objectives target a reduction in final energy demand; a more efficient use of energy; more renewable energy (e.g. solar, wind, geothermal and hydro); and less use of fossil fuels. They also foresee a wider application of new technologies, such as carbon capture and storage, where carbon dioxide emissions from an industrial facility are captured and stored underground, mostly in geological formations from where it cannot escape into the atmosphere.

Some of these technologies — carbon capture and storage in particular — may not always be the best solution in the long-term. However, by preventing large amounts of carbon from being released into the atmosphere in the short- and the medium term, they may help us mitigate climate change until the moment that long-term structural changes start being effective.

Many studies confirm that effective climate and air policies can benefit each other. Policies aimed at reducing air pollutants might help keep the global mean temperature increase below two degrees. And climate policies aimed at reducing black carbon and methane emissions might reduce the damage to our health and the environment.

But it is not the case that all climate and air quality policies are necessarily mutually beneficial. The technology used plays an important role. For example, some of the carbon capture storage technologies used might help improve Europe's air quality, but others might not. Equally, the replacement of fossil fuels with biofuels might reduce greenhouse gas emissions and help meet climate targets. But at the same time, it could increase the emissions of particulate matter and other carcinogenic air pollutants, hence deteriorating Europe's air quality.

A challenge for Europe is to ensure that air and climate policies for the next decade promote and invest in 'win-win' scenarios and technologies that are mutually reinforcing.



"Global warming induces long periods of drought. Drought favours increasing numbers of forest fires."

**Ivan Beshev, Bulgaria**
**ImaginAIR; Vicious circle**

## More information

- EEA core set of indicators: **CSI 013 on Atmospheric greenhouse gas concentrations**
- EEA Report No 12/2012: **Climate change, impacts and vulnerability in Europe 2012**
- **Climate-ADAPT:** Web portal on climate change adaptation information
- The EU Climate and Energy Package: **http://ec.europa.eu/clima/policies/package/index_en.htm**
- UNEP: **Integrated Assessment of Black Carbon and Tropospheric Ozone**

Interview

Martin Fitzpatrick

# Dublin tackles the health impacts of air pollution

**Martin Fitzpatrick is a Principal Environmental Health Officer in the air quality monitoring and noise unit of Dublin City Council, Ireland. He is also the Dublin contact point for a pilot project run by the European Commission DG Environment and the EEA aimed at improving the implementation of air legislation. We asked him how Dublin tackles the health problems linked to poor air quality.**

## What do you do to improve air quality in Dublin and in Ireland?

We feel that we have been very good on tackling air quality issues in larger towns and cities. One example illustrates this perfectly: the ban on the marketing and sale of bituminous (or smoky) fuel in Dublin in 1990. Medical research colleagues looked at the effects of this decision, and noted that 360 preventable deaths have been avoided in Dublin each year since 1990.

However, medium-sized towns still have poor air quality, and the authorities are now looking at new legislation to tackle this by broadening the ban on the sale of bituminous fuel to small towns as well.

In Ireland, the Department of the Environment, Community and Local Government is the official body that deals with air quality and related areas. Meanwhile the (Irish) Environmental Protection Agency acts as the operational wing of that Department. There are clearly defined responsibilities between the Department and the Agency as to how guidance on relevant policy areas will be passed down to local authority level.

## When it comes to health, what kind of challenges does Dublin City Council face? How do you tackle them?

Dublin is a microcosm of other big cities across the European Union. A lot of commonalities exist in terms of the issues needing to be dealt with. Obesity, cancer, and cardiovascular problems are the main public health issues across the EU, including in Ireland.

The Council has recognised that a lot of the work it does is relevant to public health. One example I think worth raising is a project where we brought air quality and public participation together. The project was carried out several years ago in conjunction with the EU's Joint Research Centre. Called the 'People Project', it ran across six European cities and looked at the carcinogenic air pollutant benzene. Following an oversubscribed response for volunteers on a national radio show, we turned people into walking and talking air quality monitors. They wore benzene badges so they could monitor their exposure to benzene in one given day. We then looked at air quality levels and how their daily behaviour had an impact on their health.

All volunteers got feedback on their results. One funny anecdote from this project was the sobering news that if you want to reduce your exposure to the cancer-causing agent polycyclic aromatic carbon, do not fry bacon! One volunteer working on the bacon grill in a local café had really high levels of exposure.

The serious point from this anecdote is that we have to look at the interaction of both indoor and outdoor pollutants in combination.

### Can you provide an example of an Irish initiative that worked to improve indoor air quality?

One example clearly stands out — the smoking ban in 2004. Ireland was the first country in the world to ban smoking in workplaces. This ban allowed us to focus on the occupational exposure issue whilst improving air quality.

As an interesting aside to this, one industry that suffered from this ban, which would perhaps have been difficult to predict, was the dry cleaning industry. Their business has contracted since 2004 purely because of the smoking ban. So sometimes you can have impacts you did not foresee.

### How does your organisation inform citizens?

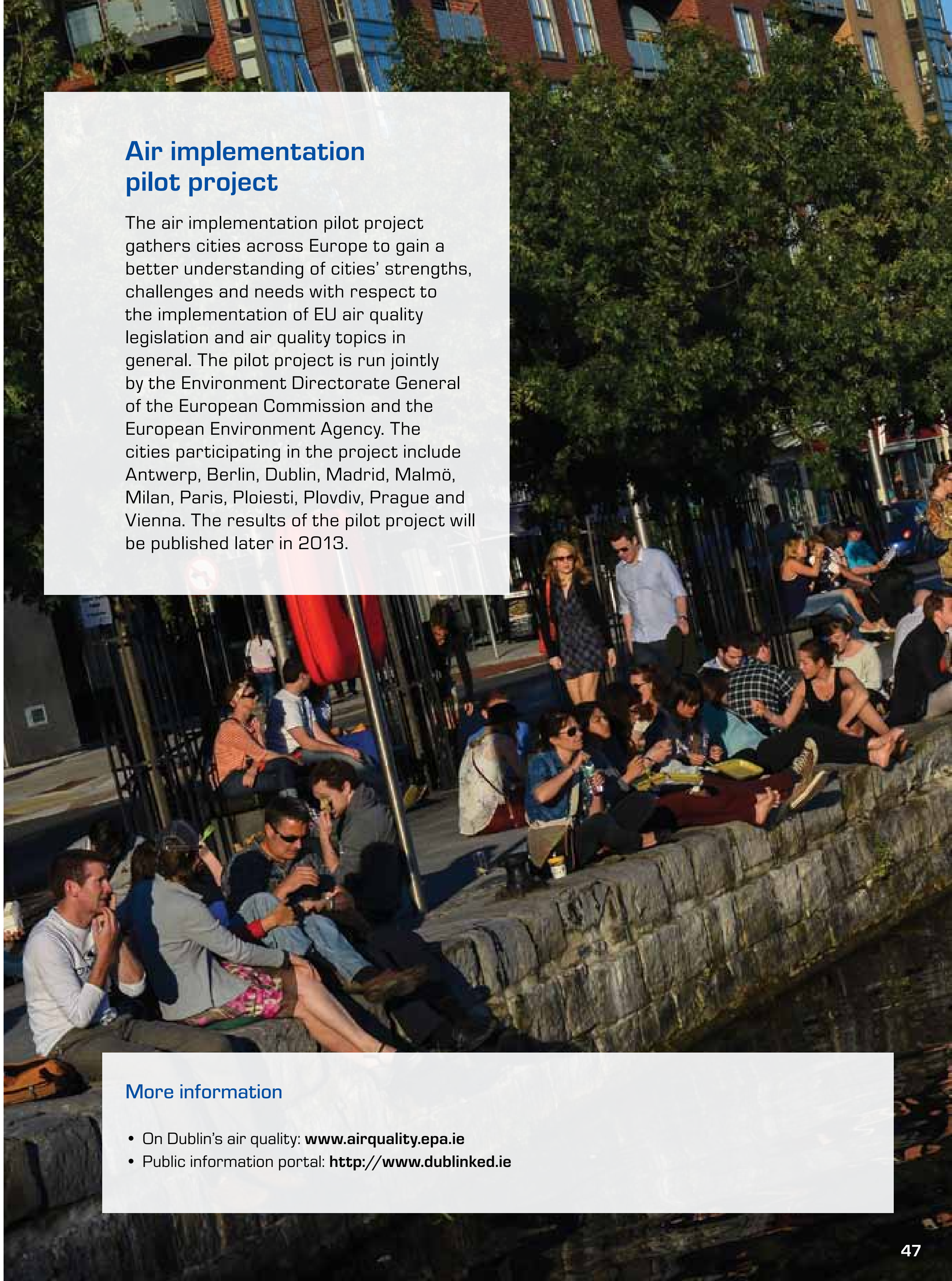
Informing citizens is an essential part of our initiatives and day-to-day work. Dublin City Council produces annual reports that provide a summary of air quality for the previous year. These reports are all placed online. Moreover, the (Irish) EPA has an air-monitoring network, which shares information with local authorities and citizens.

Another example, which is unique to Dublin, is a project launched this year called Dublinked, which gathers information held by the Council and puts it into the public domain. This can be data generated by the local authorities, by private companies delivering services in the city, and by residents. In its Communication from 2009, the European Commission notes that the re-use of public sector information has an estimated worth of EUR 27 billion. This is one of the City Council's initiatives to getting the economy started again.

### Along with other European cities, Dublin is involved in a pilot project on air quality. How did Dublin get involved?

Dublin City Council got involved following an invitation from the EEA and the European Commission. We saw the project as an opportunity to share models of good practice and to learn from sharing relevant experiences.

Through the project, we noticed how advanced other cities were in developing emissions inventories, and in having an air quality model for their city. So it has been a spur for Dublin City Council to make progress on those tasks. We then felt that it was not good value for money if just the Council alone looked at an emissions inventory and creating an air quality model. So we sat down with the Irish Environment Protection Agency to look at developing a national model, which could also be used at a regional level. Then we set out to work on that.



## Air implementation pilot project

The air implementation pilot project gathers cities across Europe to gain a better understanding of cities' strengths, challenges and needs with respect to the implementation of EU air quality legislation and air quality topics in general. The pilot project is run jointly by the Environment Directorate General of the European Commission and the European Environment Agency. The cities participating in the project include Antwerp, Berlin, Dublin, Madrid, Malmö, Milan, Paris, Ploiesti, Plovdiv, Prague and Vienna. The results of the pilot project will be published later in 2013.

### More information

- On Dublin's air quality: **www.airquality.epa.ie**
- Public information portal: **http://www.dublinked.ie**

# Indoor air quality

**Many of us might spend up to 90 % of our day indoors — at home, work or school. The quality of the air we breathe indoors also has a direct impact on our health. What determines indoor air quality? Is there any difference between outdoor and indoor air pollutants? How can we improve indoor air quality?**

It may come as a surprise to many of us that the air in an urban street with average traffic might actually be cleaner than the air in your living room. Recent studies indicate that some harmful air pollutants can exist in higher concentrations in indoor spaces than outdoors. In the past, indoor air pollution received significantly less attention than outdoor air pollution, especially outdoor air pollution from industrial and transport emissions. However, in recent years the threats posed by exposure to indoor air pollution have become more apparent.

Imagine a newly painted house, decorated with new furniture… Or a workplace filled with a heavy smell of cleaning products… The quality of air in our homes, work places or other public spaces varies considerably, depending on the material used to build it, to clean it, and the purpose of the room, as well as the way we use and ventilate it.

Poor air quality indoors can be especially harmful to vulnerable groups such as children, the elderly, and those with cardiovascular and chronic respiratory diseases such as asthma.

Some of the main indoor air pollutants include radon (a radioactive gas formed in the soil), tobacco smoke, gases or particles from burning fuels, chemicals, and allergens. Carbon monoxide, nitrogen dioxides, particles, and volatile organic compounds can be found both outdoors and indoors.

## Policy measures can help

Some indoor air pollutants and their health impacts are better known and receive more public attention than others. Smoking bans in public spaces is one of them.

In many countries, smoking bans in various public places were quite controversial before relevant legislation was introduced. For example, within days of the entry into force of the smoking ban in Spain in January 2006, there was a growing movement to assert what many considered their right to smoke in indoor public places. But the ban has also led to greater public awareness. In the days following its entry into force, 25 000 Spaniards per day sought medical advice on how to quit smoking.

Much has changed in public perception when it comes to smoking in public places and on public transport. Many airlines started to ban smoking on short-haul flights in the 1980s, followed by long-haul ones in the 1990s. It is now unthinkable in Europe to allow non-smokers to be exposed to second-hand smoke on public transport.

Today many countries, including all the EEA countries, have some legislation to limit or ban indoor smoking in public places. After a series of non-binding resolutions and recommendations, the European Union also adopted in 2009 a resolution calling on EU Member States to enact and implement laws to fully protect their citizens from exposure to environmental tobacco smoke.

Smoking bans appear to have improved indoor air quality. Environmental tobacco smoke pollutants are declining in public places. In the Republic of Ireland, for example, measurements of air pollutants in public places in Dublin before and after the introduction of a smoking ban showed decreases of up to 88 % for some air pollutants found in environmental tobacco smoke.

As in the case of outdoor pollutants, the impacts of indoor air pollutants are not limited to our health only. They also come with high economic costs. Exposure to environmental tobacco smoke in EU workplaces alone is estimated at over EUR 1.3 billion in direct medical costs, and over EUR 1.1 billion in indirect costs linked to productivity losses in 2008.

## Indoor pollution is much more than tobacco smoke

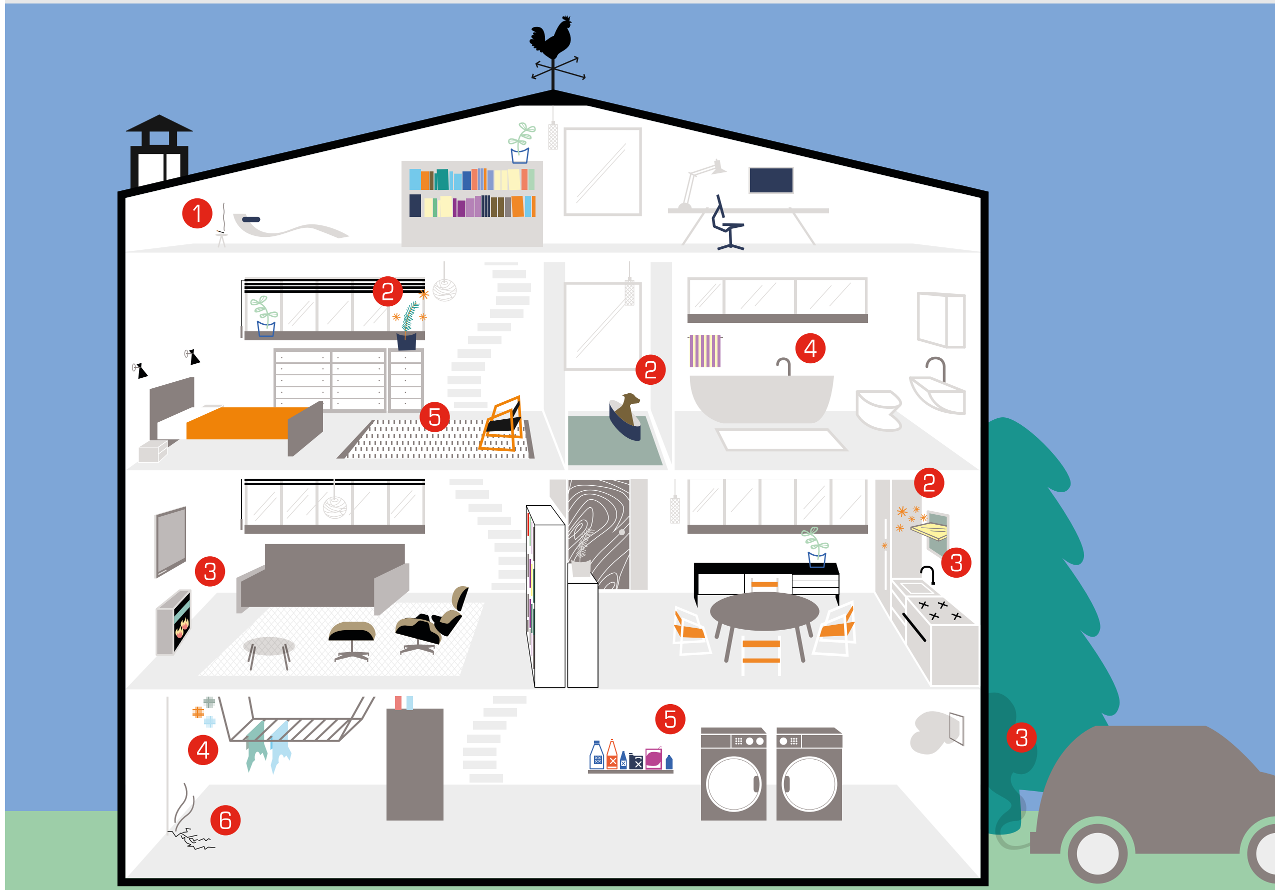
Smoking is not the only source of indoor air pollution. According to Erik Lebret from the National Institute for Public Health and the Environment (RIVM) in the Netherlands, 'Air pollution does not stop at our doorsteps. Most outdoor pollutants penetrate into our homes, where we spend most of our time. The quality of indoor air is affected by many other factors, including cooking, wood stoves, burning candles or incense, the use of consumer products like waxes and polishes for cleaning surfaces, building materials like formaldehyde in plywood, and flame retardants in many materials. Then there is also radon coming from soils and building materials.'

European countries are trying to tackle some of these sources of indoor air pollution. According to Lebret, 'we are trying to substitute more toxic substances with less toxic substances or to find processes that reduce emissions, as in the case of formaldehyde emissions from plywood. Another example can be seen with the reduction of certain radon-emitting materials used in wall construction. These materials were used in the past but their use has since been restricted.'

Passing laws is not the only way to improve the quality of the air we breathe; we can all take steps to control and reduce airborne particles and chemicals in indoor spaces.

### Indoor air pollution

We spend a large part of our time indoors — in our homes, workplaces, schools or shops. Certain air pollutants can exist in high concentrations in indoor spaces and can trigger health problems.




**1 / Tobacco smoke**
Exposure can exacerbate respiratory problems (e.g. asthma), irritate eyes and cause lung cancer, headaches, coughs and sore throats.

**2 / Allergens (including pollens)**
Can exacerbate respiratory problems and cause coughing, chest tightness, breathing problems, eye irritation and skin rashes.

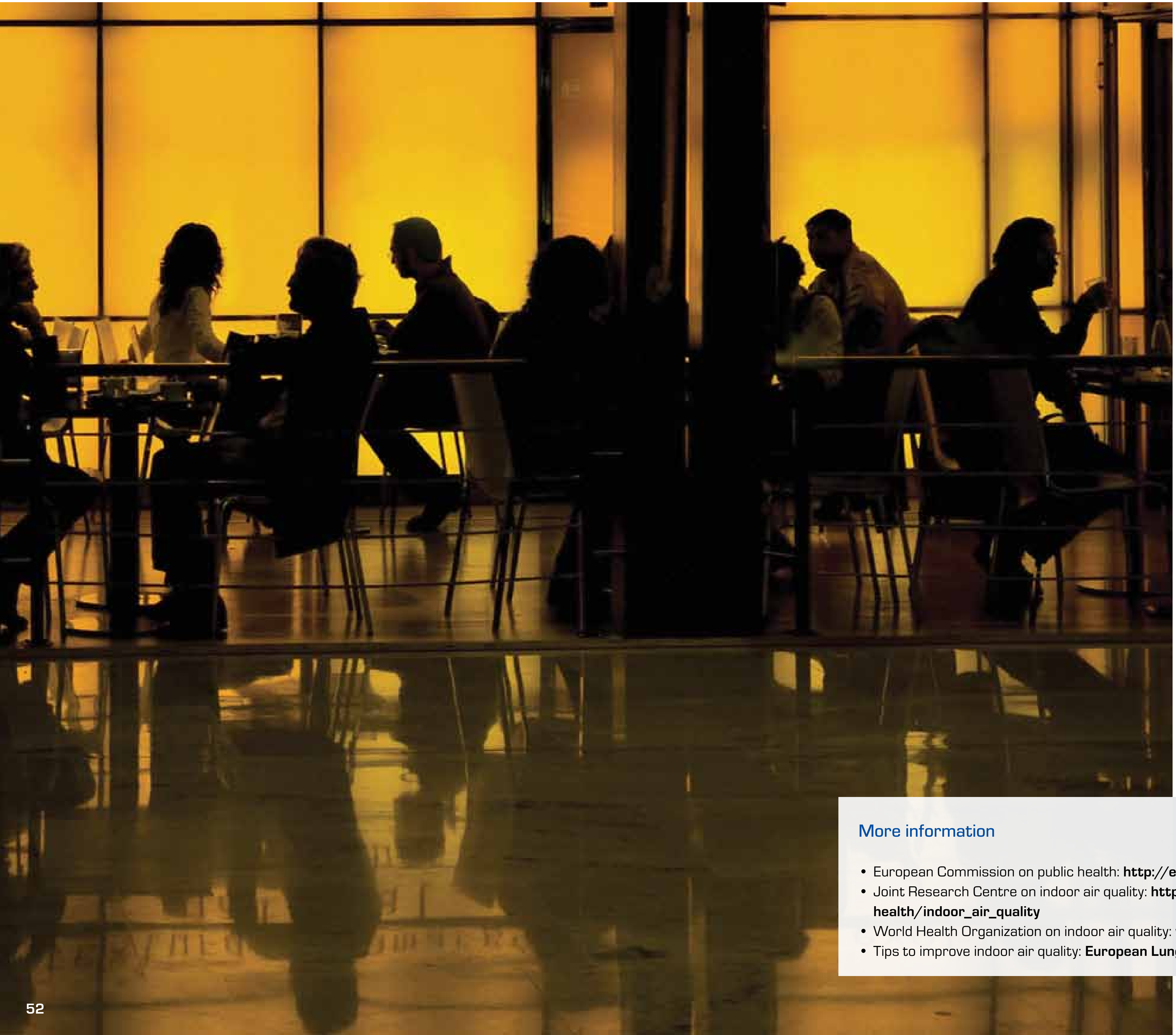
**3 / Carbon monoxide (CO) and nitrogen dioxide ($NO_2$)**
CO can be fatal in high doses and cause headaches, dizziness and nausea. $NO_2$ can cause eye and throat irritation, shortness of breath and respiratory infection.

**4 / Moisture**
Hundreds of species of bacteria, fungi and moulds can grow indoors when sufficient moisture is available. Exposure can cause respiratory problems, allergies and asthma, and affect the immune system.

**5 / Chemicals**
Some harmful and synthetic chemicals used in cleaning products, carpets and furnishings, can damage the liver, kidneys and nervous system, cause cancer, headaches and nausea, and irritate the eyes, nose and throat.

**6 / Radon**
Inhalation of this radioactive gas can damage the lungs and cause lung cancer.

Sources: The European Commission, Joint Research Centre



Small actions such as ventilating enclosed spaces can help improve the quality of the air around us. But some of our well-intended actions might actually have adverse effects. Lebret suggests: 'We should ventilate, but we should not over ventilate as this is a substantial loss of energy. It leads to more heating and use of fossil fuels, and consequently means more air pollution. We should think of it as making more sensible use of our resources in general.'

## More information

- European Commission on public health: **http://ec.europa.eu/health/index_en.htm**
- Joint Research Centre on indoor air quality: **http://ihcp.jrc.ec.europa.eu/our_activities/public-health/indoor_air_quality**
- World Health Organization on indoor air quality: **www.who.int/indoorair**
- Tips to improve indoor air quality: **European Lung Foundation**



# Building our knowledge about air

**Our knowledge and understanding of air pollution is growing every year. We have an expanding network of monitoring stations reporting data on a wide range of air pollutants, complemented with results from air quality models. We now have to make sure that scientific knowledge and policy continue to develop hand in hand.**

Mostly placed near busy roads in urban areas, or in public parks, air monitoring stations often go unnoticed. But these dull-looking boxes contain equipment that regularly samples the air at their location, measures exact concentration levels of key air pollutants such as ozone and particulate matter, and reports the data automatically to a database. In many cases, this information can be accessed online within minutes of the sampling.

## Monitoring Europe's air

Key air pollutants are addressed by European and national laws. For these pollutants, extensive monitoring networks have been set up across Europe to verify if the air quality at different locations complies with the different legal standards and health guidelines. These stations record and transmit measurements at various frequencies for a wide range of air pollutants, including sulphur dioxide, nitrogen dioxide, lead, ozone, particulate matter, carbon monoxide, benzene, volatile organic compounds, and polycyclic aromatic hydrocarbon.

The European Environment Agency brings together air quality measurements from more than 7 500 monitoring stations across Europe in the air-quality database AirBase. AirBase stores air quality data from previous years (historical data).

Some monitoring stations measure and report the latest data with a short delay (near real-time data). For example, in 2010, up to 2 000 stations were measuring ground-level ozone concentrations continuously and reported the data every hour. Such near real-time measurements can be used for warning and alert systems in the event of significant pollution incidents.

The number of monitoring stations across Europe grew considerably in the last decade, especially those that monitor certain key pollutants. In 2001, slightly more than 200 stations reported nitrogen dioxide measurements, whereas in 2010, close to 3 300 stations were reporting across 37 European countries. In the same period, the number of stations reporting $PM_{10}$ almost tripled to reach more than 3 000 stations in 38 countries.

The growth of the monitoring network contributes to our knowledge and understanding of Europe's air quality. Because setting up a new monitoring station with its high-tech equipment is quite costly, a part of our knowledge comes from other sources, such as satellite imagery; emission-estimates of large industrial facilities; air quality models; and in-depth studies on specific regions, sectors or pollutants.

Some 28 000 industrial facilities in 32 European countries report to E-PRTR — a Europe-wide pollutant registry — how much of various pollutants they release to water, land and air. All this information is online, and available to the public and policymakers alike.

## Compiling and accessing air-quality information

Putting together the information we gather from these various sources is challenging. The measurements by monitoring stations are location- and time-specific. Weather patterns, landscape characteristics, the time of the day or year, and the distance to emission sources all play a role in the pollutant measurements. In some cases such as road-side monitoring stations, a distance of even a few meters can have an impact on the readings.

Moreover, different methods are used to monitor and measure the same pollutant. Other factors also play a role. An increase in traffic circulation or traffic diversion schemes, for example, will result in different measurements than those recorded for the same street a year earlier.

Assessing the air quality of an area beyond the monitoring stations relies on modelling or a combination of modelling and measurements, including satellite observations. Air quality modelling often comes with some uncertainty, as models cannot reproduce all the complex factors linked to formation, dispersion and deposition of pollutants.

The uncertainty is much higher when it comes to assessing the health impacts of exposure to the pollutants at a given location. Monitoring stations usually measure the particulate matter mass per volume of air, but not necessarily the chemical composition of the particles. The emissions from car exhausts, for example, release black carbon containing particles directly into the air as well as gases such as nitrogen dioxide. But to be able to determine how public health might be affected, we need to know what the exact mixture in the air is.

Technology is instrumental in furthering our knowledge of the air we breathe. It is an essential element of the monitoring and reporting process. Recent developments in the information technology sector have enabled researchers and policymakers to process massive amounts of data in a matter of seconds. Many public authorities make this information accessible to the public, either through their websites, such as the municipality of Madrid, or through independent associations, such as Airparif for Paris and the broader Ile-de-France region.

The EEA maintains public information portals on air quality and air pollution. The historical air quality data stored in AirBase can be viewed on a map, filtered by pollutant and year, and can be downloaded.

Near real-time data (where available) on key pollutants such as $PM_{10}$, ozone, nitrogen dioxide and sulphur dioxide can be accessed through the Eye on Earth AirWatch portal. Users can also add their personal ratings and observations to the viewing tool.

## Higher quality analysis

Technology has not only enabled us to process larger amounts of data, it has also helped improve the quality and the accuracy of our analysis. We can now analyse at the same time weather information; road transport infrastructure; population density; and pollutant emissions from specific industrial facilities, along with measurements from monitoring stations, and outcomes from air quality models. For some regions, it is possible to compare premature deaths from cardiovascular and respiratory diseases to air pollution levels. We can plot most of these variables on a map of Europe and build more accurate models.

Air research is not only limited to the factors mentioned above. Marie-Eve Héroux from the World Health Organization's Regional Office for Europe says, 'The research community also looks into how various measures impact air pollution. There are very broad types of interventions from regulatory measures to changes in energy consumption patterns and sources, or changes in modes of transportation and the behaviour of people.'

Héroux adds, 'All of this has been studied and the conclusions are clear: there are measures that can decrease pollution levels, particularly that of PM. It gives us an indication of how we can actually reduce death rates due to air pollution.'

A better understanding of health and the environmental impacts of air pollutants then feeds into the policy process. New pollutants, pollution sources and possible measures to combat pollution are identified and included in legislation. This might require the monitoring of new pollutants. The data collected as a result helps improve our knowledge further.

For example, in 2004, although there were measurements at the local and national levels, there was no monitoring station reporting directly to AirBase the concentrations of volatile organic compounds, heavy metals or polycyclic aromatic hydrocarbons in Europe. In 2010, there were more than 450, 750 and 550 such stations respectively.

## A clearer picture emerges

Air legislation usually sets targets to be achieved in a given time frame. It also foresees ways to monitor progress and verify if the targets have been met within the expected timeframe.

For policy targets that were set a decade ago, two different pictures might emerge depending on the tools we use. The EEA looked at the National Emissions Ceilings Directive adopted in 2001, aimed at limiting emissions of four air pollutants by 2010, and assessed whether the eutrophication and acidification objectives stated in the directive were met.

Based on what we knew at the time the directive was adopted, the eutrophication objective appeared to have been met and the acidification risk appeared to have been reduced significantly. However, based on current knowledge using more up-to-date tools, the picture is not as rosy. Eutrophication caused by air pollution is still a major environmental problem and there are many more areas that did not meet the acidification objective.

This year, the European Union is set to review its air policy, which will address new targets and a time frame that extends until 2020 and beyond. Along with its evolving policy on air, Europe will also continue to invest in its knowledge base.



"It is important to know what is happening in the city, the country and the world in which we live..."

**Bianca Tabacaru, Romania**
**ImaginAIR; Pollution in my city**

### More information

- AirBase: **http://www.eea.europa.eu/themes/air/air-quality/map/airbase**
- EEA Technical report No 14/2012: **Evaluation of progress under the EU National Emission Ceilings Directive**
- UNECE's LRTAP European Monitoring and Evaluation Programme (EMEP): **http://www.emep.int**

"The photographs are taken from the top of the Montparnasse tower during an air pollution episode of $NO_2$ above threshold values recorded in the winter of 1997–1998."

**Jean-Jacques Poirault, France**
**ImaginAIR; Atmospheric pollution by $NO_2$**

# Air legislation in Europe

**Air pollution is not the same everywhere. Different pollutants are released into the atmosphere from a wide range of sources. Once in the atmosphere, they can transform into new pollutants and spread around the world. Designing and implementing policies to address this complexity are not easy tasks. Below is an overview of air legislation in the European Union.**

The amount of pollutants emitted into the air we breathe has been greatly reduced since the EU introduced policies and measures concerning air quality in the 1970s. Air pollution emissions from many of the major sources including transport, industry, and power generation are now regulated and are generally declining, albeit not always to the extent envisaged.

## Targeting pollutants

One way that the EU has achieved this improvement is by setting legally binding and non-binding limits for the whole Union for certain pollutants dispersed in the air. The EU has set standards for particulate matter (PM) of certain sizes, ozone, sulphur dioxide, nitrogen oxides, lead, and other pollutants that may have a detrimental effect on human health or ecosystems. Key pieces of legislation that set pollutant limits across Europe include the 2008 Directive on ambient air quality and cleaner air for Europe (2008/50/EC), and the 1996 Framework Directive on ambient air quality assessment and management (96/62/EC).

Another approach to legislating for improvements to air quality is through the setting of national annual emission limits for specific pollutants. In these cases, countries are responsible for introducing the measures needed to ensure that their emission levels are below the ceiling set for the relevant pollutant.

The Gothenburg Protocol to the United Nations Economic Commission for Europe's Convention on Long-range Transboundary Air Pollution (LRTAP), and the EU National Emission Ceilings Directive (2001/81/EC) both set annual emissions limits for European countries on air pollutants, including those pollutants responsible for acidification, eutrophication, and ground-level ozone pollution. The Gothenburg Protocol was revised in 2012. And the National Emissions Ceilings Directive is up for review and revision in 2013.

## Targeting sectors

In addition to setting air quality standards for specific pollutants and annual country-level ceilings, European legislation is also designed to target particular sectors that act as sources of air pollution.

Emissions of air pollutants from the industrial sector are regulated, by among others, the 2010 Industrial Emissions Directive (2010/75/EU) and the 2001 Directive on the limitation of emissions of certain pollutants into the air from Large Combustion Plants (2001/80/EC).

Vehicle emissions have been regulated through a series of performance and fuel standards, including the 1998 Directive relating to the quality of petrol and diesel fuels (98/70/EC) and vehicle emission standards, known as the Euro standards.

The Euro 5 and 6 standards cover emissions from light vehicles including passenger cars, vans, and commercial vehicles. The Euro 5 standard came into force on 1 January 2011, and requires all new cars covered by the legislation to emit less particulates and nitrogen oxides than the limits set. Euro 6, which will enter into force in 2015, will impose stricter limits on nitrogen oxides emitted by diesel engines.

There are also international agreements concerning the emissions of air pollutants in other areas of transportation, such as the International Maritime Organization's 1973 Convention for the Prevention of Pollution from Ships (MARPOL), with its additional protocols, which regulate sulphur dioxide emissions from shipping.

## Putting the pieces together

A pollutant is usually regulated by more than one piece of legislation. Particulate matter, for example, is directly addressed by three European legal measures (Directives on ambient air quality and emissions of air pollutants, and the Euro limits on road vehicle emissions) and two international conventions (LRTAP and MARPOL). Some of the PM precursors are tackled by other legal measures.

The implementation of these laws are also spread over a period of time and achieved in stages. For fine particles, the air quality directive sets 25 µg/m$^3$ as a 'target value' to be met by 1 January 2010. The same threshold is set to become a 'limit value' by 2015, entailing additional obligations.

For some sectors, air policies might first cover certain pollutants in limited parts of Europe. In September 2012, the European Parliament adopted the revisions that brought the EU's standards on sulphur emissions by ships in line with the International Maritime Organization's standards from 2008. By 2020, the sulphur limit will be 0.5 % in all the seas around the EU.

For the Baltic Sea, the North Sea and the English Channel in so-called 'Sulphur Emission Control Areas', the European Parliament set an even stricter sulphur limit of 0.1 % by 2015. Considering that standard marine fuel contains 2 700 times more sulphur than conventional diesel for cars, it is clear that this legislation gives strong reasons to the shipping sector to develop and use cleaner fuels.




"Although fortunately there are still places in Romania almost wild and spectacular, where nature is unstained by the hand of man, in more urbanized areas there is an obvious ecological problem."

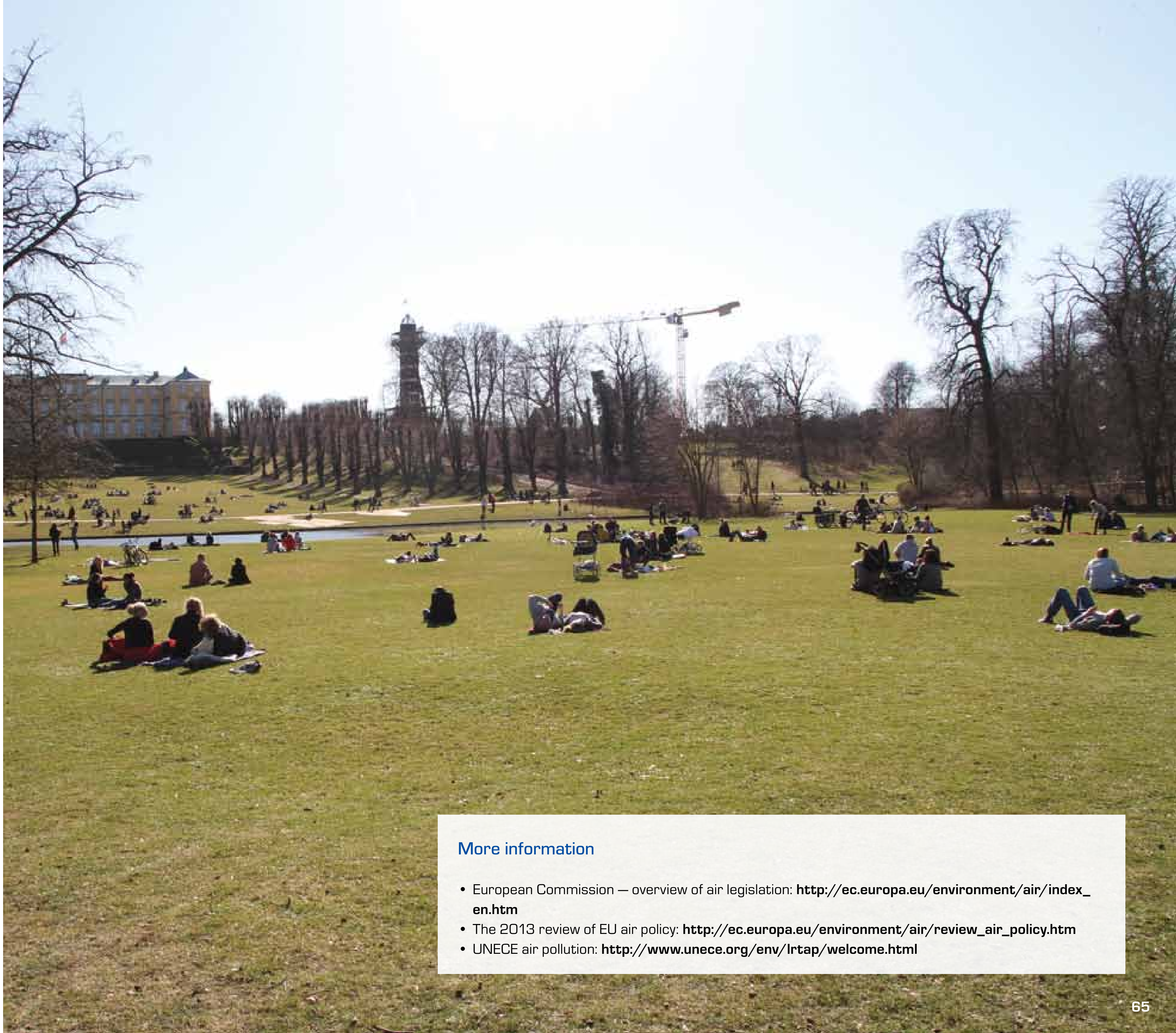
**Javier Arcenillas, Spain**
**ImaginAIR; Contamination**

## Implementation on the ground

Current European air-quality legislation is based on the principle that EU Member States divide their territories into a number of management zones in which countries are required to assess air quality using measurement or modelling approaches. Most big cities are declared to be such zones. If air-quality standards are exceeded in a zone, the Member State has to report to the European Commission and explain the reasons.

The countries are then required to develop local or regional plans describing how they intend to improve the air quality. They could for example establish so-called low-emission zones that restrict access for more polluting vehicles. Cities can also encourage a shift in transport to less polluting modes including walking, cycling, and public transport. They can also ensure that industrial and commercial combustion sources are fitted with emission-control equipment, according to the latest, best-available technology.

Research is also critical. Not only does research offer us new technologies, it also improves our knowledge of air pollutants and their negative effects on our health and ecosystems. Integrating the latest knowledge into our laws and actions will help us to continue to improve Europe's air.



### More information

- European Commission — overview of air legislation: **http://ec.europa.eu/environment/air/index_en.htm**
- The 2013 review of EU air policy: **http://ec.europa.eu/environment/air/review_air_policy.htm**
- UNECE air pollution: **http://www.unece.org/env/lrtap/welcome.html**

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# ImaginAIR

## Capturing the invisible: Europe's air story told in pictures

To raise awareness about the impacts of poor air quality on human health and the environment, the European Environment Agency organised a competition, inviting Europeans to tell their stories of Europe's air through three photographs and a short text.

The ImaginAIR photo story competition called for submissions in four thematic categories: air and health; air and nature; air and cities; and air and technology. We used parts of the ImaginAIR stories throughout Signals 2013 to highlight some of the issues and concerns raised by Europeans.

More information on ImaginAIR is available on our website: **www.eea.europa.eu/imaginair**

To see all the ImaginAIR finalists, please visit our Flick'r account: **http://www.flickr.com/photos/europeanenvironmentagency**

ImaginAIR
European Environment Agency

## Signals 2013

The European Environment Agency (EEA) publishes Signals annually, providing a snapshot of issues of interest to the environmental debate and the wider public. Signals 2013 focuses on Europe's air. This year's edition tries to explain the current state of air quality in Europe, where they come from, how air pollutants form, and how they affect our health and the environment. It also gives an overview of the way we build our knowledge on air, and how we tackle air pollution through a wide range of policies and measures.

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