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HOW MUCH DOES EUROPE PAY FOR CLEAN AIR?

JUAN MEJINO-LÓPEZ AND MIQUEL OLIU-BARTON

Despite significant progress, air pollution still causes €600 billion in losses each year in the European Union – equal to 4 percent of its annual GDP. These costs stem from productivity losses such as increased absenteeism, the reduction of in-job productivity and harm to ecosystems. Air pollution costs are disproportionately high in eastern Europe and Italy, where losses are projected to remain above 6 percent of GDP until 2030. The EU's 10 percent most-polluted regions suffer 25 percent of the burden of mortality attributable to air pollution. Measures against air pollution should be prioritised, not delayed, in these regions.

Promoting clean air boosts economic growth by €50 billion to €60 billion every year. The EU's increasing commitment to cleaner air is reflected by a threefold increase in the funds allocated to promoting clean-air policies, from €7 billion annually for the period 2014-2020 to €25 billion annually for 2021-2027, notably supported by the Recovery and Resilience Facility (RRF). EU financial support must continue beyond 2026 when the RRF terminates.

The EU Ambient Air Quality Directive sends a strong signal but leaves loopholes: exceptions and postponements may jeopardise overall progress on cleaner air. Fossil-fuel consumption is one of the main obstacles to achieving clean-air targets. Yet fossil fuels subsidies were fourteen times higher than EU clean-air funds between 2014 and 2020, and are projected to remain five times higher for the years ahead. Ammonia, an important precursor of fine particulate matter mainly stemming from agriculture, is insufficiently regulated.

Effectiveness of clean-air policies is context-dependent. Identifying concrete actions for each region and quantifying the potential gains are required to accelerate the transition to cleaner air. Phasing out coal use in residential heating is most profitable in eastern Europe, while reducing industrial and agricultural emissions would reap more benefits in the north of Italy.

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Juan Mejino-López (juan.mejino-lopez@bruegel.org) is a Research Assistant at Bruegel
Miquel Oliu-Barton (miquel.oliu-barton@bruegel.org) is a Non-resident Fellow at Bruegel

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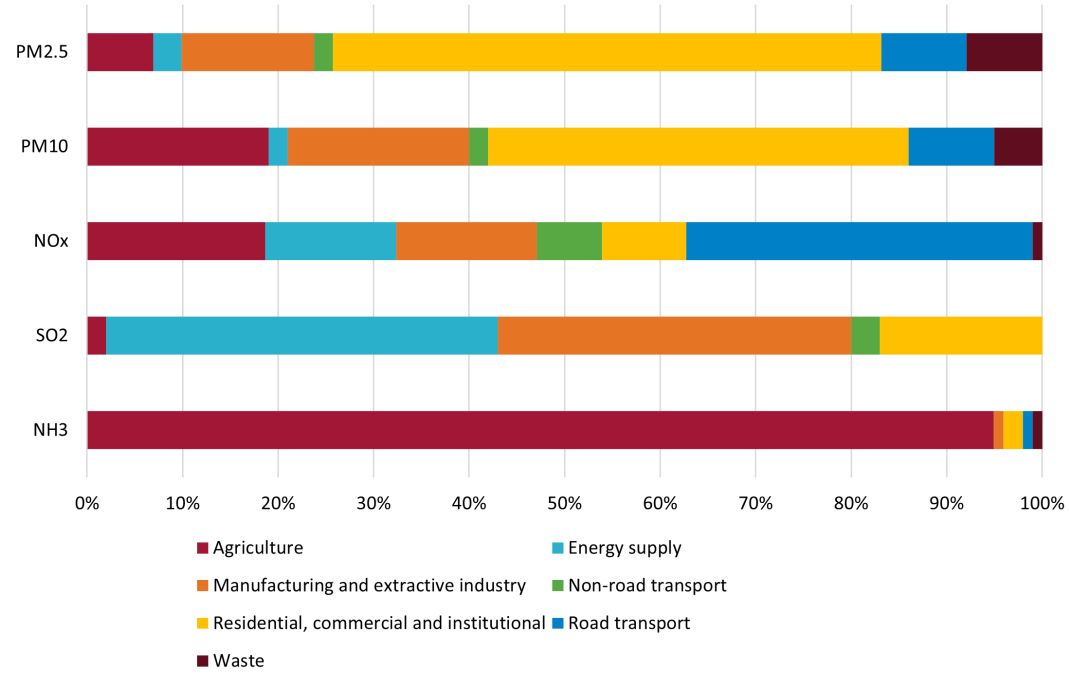
1 Introduction

1.1 What is air pollution, and why does it matter?

Air pollution refers to a large variety of substances suspended in air. Its negative impact on health is well documented (Landrigan *et al*, 2017). At the global level, it is considered, alongside climate change, as the top health threat by the World Health Organisation[1]. Air quality standards and regulation vary across the world, with Europe being among the most advanced on clean-air policies. The European Union's Air Quality Directives define limit concentration values for several pollutants, both in terms of short-term and long-term exposure. Despite major progress, the cost of air pollution is still huge for the European Union.

Figure 1: Distribution of air pollutants emissions across different sectors in the EU



Source: EEA (2023).

The most harmful air pollutants are fine particulate matter (PM2.5 and PM10) and gases including nitrogen oxides (NOx), sulphur dioxides (SO2) and ground-level ozone (O3). The main sources of pollution are road transport, energy consumption, manufacturing and the extractive industry, agriculture, waste and energy supply. The sources vary depending on the pollutant. For example, the majority of PM2.5 (58 percent) comes from the residential and commercial sector, while nitrogen oxides are mainly emitted by road transport (37 percent) and agriculture (20 percent). Similarly, each air pollutant impacts human health and the environment in a different manner. The three pollutants

[1] See WHO, 'Ten threats to global health in 2019', undated, https://www.who.int/news-room/spotlight/ten-threats-to-global-health-in-2019.

with a major impact on mortality are PM2.5, NO2 and O3, while PM10 has a significant effect in terms of causing non-fatal respiratory diseases (see Figure 1 and Table 1 for more details).

Table 1: Main impact on health and the environment for key air pollutants

Pollutant	Effects proven and included	Effects probable but not included
PM10/PM2.5	All-cause mortality	Medication use
	Acute mortality	Lower respiratory symptoms
	Infant mortality	Diabetes
	Workdays loss	
	Restricted activity days	
	Chronic bronchitis	
	Respiratory hospital admission	
	Cardiovascular hospital admissions	
Ozone	Acute mortality	Chronic mortality
	Respiratory hospital admission	Workdays loss
	Cardiac hospital admissions	
	Restricted activity days	
	Increased mortality risk	
NO2	Bronchitis in asthmatic children	Cardiovascular effects
	Respiratory hospital admissions	Acute mortality

Sources: CE Delft assessment based on WHO (2013) and other reports. Notes: Impacts are calculated using Relative Risks (WHO, 2013) and country-specific incidence rates, while others are calculated using Concentration Response Functions (CE Delft *et al*, 2019) using European incidence rates.

Health and economic impacts

The European Environment Agency (EEA, 2021) estimated that air pollution causes 300,000 deaths every year in the EU, or 6 percent of the annual mortality in the region. The health burden of air pollution also includes millions of years of life lost, and significantly increased prevalence of many chronic diseases, including asthma, chronic obstructive pulmonary disease, diabetes, heart diseases, lung cancer and stroke (see section 2.1).

The economic impact of air pollution is the subject of an emerging literature. The European Commission (2022b) estimated the cost of air pollution between at €330 billion and €940 billion each year. Using a different methodology, based on a seminal study from the Organisation for Economic Co-operation and Development (OECD) on the impact of air pollution on economic output, we estimate that air pollution causes around €600 billion in economic losses each year in the EU, or 4 percent of the GDP. Details and variations between EU countries are given in section 2.2.

Cutting air pollution is compatible with economic growth

Is reducing air pollution compatible with economic growth? Yes. In recent decades, emissions of key air pollutants have been decoupled from economic growth both globally and in the EU (Figure 2). According to Dechezleprêtre (2019) cleaner air explained 16 percent of economic growth between 2000 and 2015. The significant shift to cleaner air has resulted from policy decisions on pollution control and energy, along with structural changes in the economy and consumption patterns. The critical role of policy interventions will continue to be paramount in the future.

Air pollution and climate change

Air pollution shares several commonalities with greenhouse-gas (GHG) emissions. They both originate from human activities which alter atmospheric conditions. Also, cities are of particular concern, as they contribute approximately 70 percent of global greenhouse-gas emissions (IPCC, 2022), and are often hotspots for air pollution exposure because of the high concentration of polluting activities and their population densities. Third, some short-lived air pollutants such as black carbon (a key component in particulate matter), methane and ozone contribute to near-term warming. In this sense, air pollution and climate change are two aspects of the same problem, and policies targeting the former are often also beneficial for the latter, and vice versa. A notable example is the reduction of fossil-fuel consumption, which mitigates GHG emissions while enhances air quality.

But air pollution has three distinctive characteristics: it is local, visible and present. Air pollutants can travel several kilometres but prominently affect people living in high emissions zones, or in nearby areas situated down-wind. The dispersion of air pollutants also depends critically on local conditions such as the weather (eg wind, temperature inversions) or topographic conditions (eg air pollutants can be trapped in areas surrounded by mountains). Both short-term and long-term concentrations of air pollution are observable directly (eg smog, traces in buildings), and people can perceive directly the impact of air pollution on health (eg via irritation of the eyes or respiratory problems). Finally, though the impact of air pollutants on infrastructure and ecosystems cumulates over time, they prominently affect the current generation, who breathe polluted air.

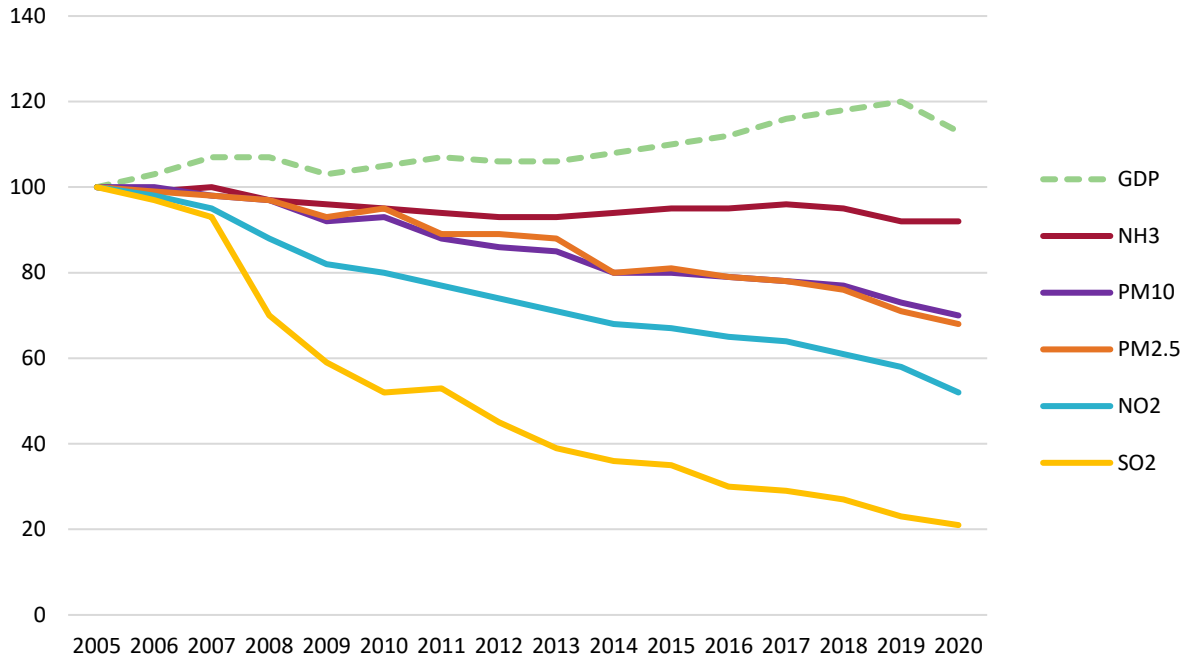
Clean air action

The 'local, visible and present' characteristics of air pollution are useful for understanding the differences in perception and policy levers between air pollution and climate change. For example, the localised nature of air pollution has an important corollary: air pollution can be addressed unilaterally. Air pollution also depends not only on the quantity of fossils fuels burned, but also on where they are burned. Hence, unlike GHG emissions, the impact of which is global, the delocalisation of air pollution can effectively reduce its overall health and economic impact – though not the environmental damage it causes. This is the case as population density, the share of vulnerable groups (eg children, the elderly, people suffering from chronic diseases, low-income households) and the weather and topographic conditions play important roles in the harms from air pollution. The visibility and

immediacy and of air pollution, on the other hand, contribute to the acceptability of action. The benefits of reducing emissions will be realised – and quickly – by the same population that puts in place pro-clean air policies.

However, the non-local, invisible aspects of air pollution cannot be neglected, especially as the most-harmful pollutants (including the five on which this paper focuses) persist in the atmosphere for extended periods, travelling hundreds or even thousands of miles before affecting the quality of air, as well as the quality of soil, rivers, lakes and food supplies. For example, between 41 percent and 53 percent of air-quality related mortality in the United States results from invisible emissions imported from another state (Dedoussi *et al*, 2020). Cooperation between EU countries is thus paramount to address air pollution in the EU.

Figure 2: Evolution of GDP in constant € and evolution of average emissions of the main air pollutants, EU, from 2005 to 2020, 2005 = 100



Source: EEA (2021).

1.2 How much are Europeans willing to pay for cleaner air?

Most Europeans favour stricter measures to tackle air pollution (European Commission, 2022a), but problems start when it comes to paying for it. The European Commission has numerous ongoing infringement cases against EU member countries for failing to hit current air pollution targets[2], with Poland, Italy, Bulgaria, Romania and Portugal among the top offenders. The only three countries to not

[2] See https://app.powerbi.com/view?r=eyJrIjoiNzZiNDEzYjktYjM2ZS00MTIxLWIzY2MtNzFlYWQ5NzJlZDVhIiwidCI6ImIyNGM4YjA2LTUyMmMtNDZmZS05MDgwLTcw0TI2ZjhkZGRiMSIsImMiOjh9.

be facing legal proceedings are the Netherlands, Slovakia and Estonia[3]. Italy – the most exposed country to PM2.5 concentrations in Western Europe – has argued that compliance with stricter air pollution standards is unrealistic in regions where intense economic activity is paired with adverse orographic conditions, for example in the Po Valley. Stricter air quality standards may be perceived as a cost rather than as an investment, excessive in the context of the cost-of-living crisis. Are these fears justified? To respond, we need to turn to the economics of air pollution.

Is enough money being spent to improve air quality?

First, we estimated how much EU funds are allocated to tackling air pollution. Second, we analyzed whether EU funds are well allocated, in the sense that member states who suffer more form air pollution receive more funds.

Are EU funds implemented effectively? What is the return on investment?

We analysed European Union funds over the last decade, with a particular focus on a group of four EU countries where air pollution is of particular concern, namely Czechia, Italy, Poland and Romania. By comparing the total funds mobilised with the observed outcomes over time, we derive insights into the cost-effectiveness of the intervention, and identify possible levers for future action.

1.3 Policy context

Differences in fuel use, topography and weather conditions have led to varied pollution levels and control policies worldwide.

EU context. In Europe, the Ambient Air Quality Directive (AAQD, 2008/50/EC) sets limits and target values for the main pollutants, based on, but less ambitious than, World Health Organisation recommendations (WHO, 2005). In 2021, based on an extensive body of scientific evidence of the various impacts of air pollution, particularly on human health and the environment, the WHO updated its air quality guidelines by considerably lowering the maximum levels for three major pollutants: PM2.5, NO2 and O3 (WHO, 2021). The European Commission followed suit by proposing a revision of the AAQD as an integral part of the EU's zero-pollution action plan in the framework of the European Green Deal. The revision was agreed by the EU institutions in February 2024, thus sending a strong signal of EU political determination to ensure cleaner air for all Europeans (Table 2). However, loopholes remain, holding back adequate implementation, especially in view of the agreed exceptions and postponements for regions that do not make sufficient progress[4].

The revised AAQD also requires better monitoring of air quality, notably in urban areas, improved access to information about the impacts of air pollution on human health, with a special focus on

[3] Louise Guillot, 'EU countries demand 10 extra years to meet air pollution targets', *Politico*, 15 February 2024, https://www.politico.eu/article/eu-countries-demand-10-extra-years-meet-air-pollution-targets/.
[4] Miquel Oliu-Barton, 'EU air quality agreement sends a positive signal but leaves loopholes', *First Glance*, Bruegel, 23 February 2024, https://www.bruegel.org/first-glance/eu-air-quality-agreement-sends-positive-signal-leaves-loopholes.

vulnerable citizens such as children, the elderly, people with comorbidities and socio-economic disadvantaged group, and improved access to justice for citizens to obtain monetary compensation the permitted levels of pollution are surpassed at local or national level.

Table 2: Evolution of the maximum concentration levels for 5 key air pollutants in the EU compared to WHO guidelines

Pollutant	WHO 2005	EU 2008	WHO 2021	EU 2024
PM2.5	10	25	5	10
PM10	20	40	15	20
Nitrogen oxides	40	40	10	20
Sulphur (8 hours)	20	125	40	50
Ozone (8 hours)	100	120	100	120

Source: Bruegel, based on the EU AAQDs (2008 and 2024) and WHO Air Quality Guidelines (2005 and 2021). Note: Concentration levels are expressed in µg/m3, averaged over one year for PM2.5, PM10, and nitrogen oxides, and over 8 hours for sulphur and ground-level ozone.

The EU pursues two other complementary routes to reduce air pollution. First, the National Emissions Ceiling Directive (Directive (EU) 2016/2284) aims at reducing at source the emissions of major air pollutants, notably those that travel across national boundaries (ie sulphur dioxide (SO2), nitrogen oxides (NOx), non-methane volatile organic compounds (NMVOC), ammonia (NH3) and fine particulate matter (PM2,5)). EU countries are required to monitor and report the emissions of these, and possibly other, pollutants. They must also determine national air pollution control programmes compatible with the 2020 and 2030 reduction commitments

Second, emission standards for key sources of pollution set emissions standards in various sectors including transport, energy and industry. These rules include directives on industrial emissions, medium combustion plants, fuel quality and sulphur content in liquid fuels, eco-design, and emissions from vehicles (eg the Euro 7 emission standards for road vehicles) and non-road mobile machinery. See Karamfilova (2021) for more details.

Beyond the EU. Many countries have set limit values for the main air pollutants. For the sake of a simpler comparison, we focus on PM2.5 annual concentrations. The annual limit values for PM2.5 concentrations vary across OECD countries, but many adhere to standards influenced by EU regulations and WHO guidelines (see Table 3). These standards reflect efforts to reduce exposure to fine particulate matter, recognising its significant health impacts. Each country's standards are tailored to their specific environmental and public health policies, but they broadly aim to align with international guidelines to protect public health. Overall, PM2.5 emissions have decreased steadily since 2000 across OECD economies.

Table 3: Comparison of air quality regulations in a selection of countries, proxied by PM2.5 annual concentrations (ranked from looser to stricter limit/target values)

Country	PM2.5 annual concentration
UK, except Scotland	20
China	15
Japan	15
Mexico	12
Singapore	12
EU – new AAQD	10
Scotland	10
US	9
Canada	8.8
Australia	8
WHO 2021 guidelines	5

Source: Bruegel, based on national policy documents.

2 Economics of air pollution

While the volume of air pollutant emissions is critical to assess the environmental damage they cause, when it comes to human health and the economy, the key variable is the average exposure of the population to these pollutants. That is, the level of air pollution the population is confronted with both over short time periods (peak concentrations) or long-term (annual concentrations). Air quality in densely populated areas is thus a central element for our analyses.

For the sake of simplicity, we focus on the most harmful pollutants for human health and the economy: particulate matter (PM2.5 and PM10) and three gases – nitrogen oxides (NOx), sulphur dioxides (SO2) and ground-level ozone (O3). In line with the literature, we will assume the mean annual concentration of PM2.5 – in a given area, with a given population – is a good proxy for air pollution exposure when it comes to assessing the economic impact.

2.1 Mortality rates and the broader health burden

The health burden of air pollution is well documented, notably by Landrigan *et al* (2017) and the WHO. The burden comprises mortality and morbidity, measured as the excess of deaths and the incidence of disease attributable to air pollution, and the number of years of life lost, adjusted for disability[5]. The European Environment Agency (EEA, 2023) estimated that PM2.5, nitrogen oxides and ground-level ozone were responsible, respectively, for 253,000, 52,000 and 23,000 deaths in 2021. Overall, this represents 6 percent of annual mortality, and half the death toll from the first year of the COVID-19

[5] Disability-adjusted years of life lost results from adding the years of life lost, obtained by comparing for each individual the age at which death occurs with their theoretical life expectancy, and by including the burden of disabling diseases. To each disabling disease is associated an index between 0 and 1 representing share of lost autonomy; this same index is used to adjust for the share of years lost due to disabilities.

pandemic. Moreover, the first two pollutants were respectively responsible for 2,500,000 and 630,000 years of life lost adjusted for disability (Table 4). So on average, each death caused by air pollution is associated with a loss of ten years of life.

Over the last few decades, however, significant progress has been made to reduce air pollution. In terms of mortality, for example, the more than 300,000 deaths of 2021 represent a 20 percent decrease compared to the average mortality over the past decade (Table 4). Note however, that while progress has been significant for PM2.5 and nitrogen oxides, the damage of ground-level ozone is increasing.

Table 4: Mortality attributed to air pollution in 2010/2019 and in 2021 by pollutant

	2010-2019 average	2021	Change
PM2.5	315 000	253 000	-20%
N02	75 000	52 000	-31%
03	22 000	23 000	5%
Total	412 000	328 000	-20%

Source: Bruegel based on EEA data.

Under the Zero Pollution Action Plan (European Commission, 2021), the EU set the objective of reducing the mortality attributed to PM2.5 by at least 55 percent by 2030 compared to 2005. The apparent success in meeting this objective (see Figure 3) hides several important obstacles. First, the annual fatality rate remains extremely high: in relative terms, it is equivalent to the death toll of the first six months of the COVID-19 pandemic. Second, it varies greatly from one region to another, with Northern Italy, Poland and Czechia being the hardest hit in terms of PM2.5 mortality, while the greatest impact from nitrogen oxides is found in large cities in western and southern Europe (Khomenko *et al*, 2021). See Figure 4 for a comparative map of air pollution mortality for the periods 2007–2013 and 2014–2021.

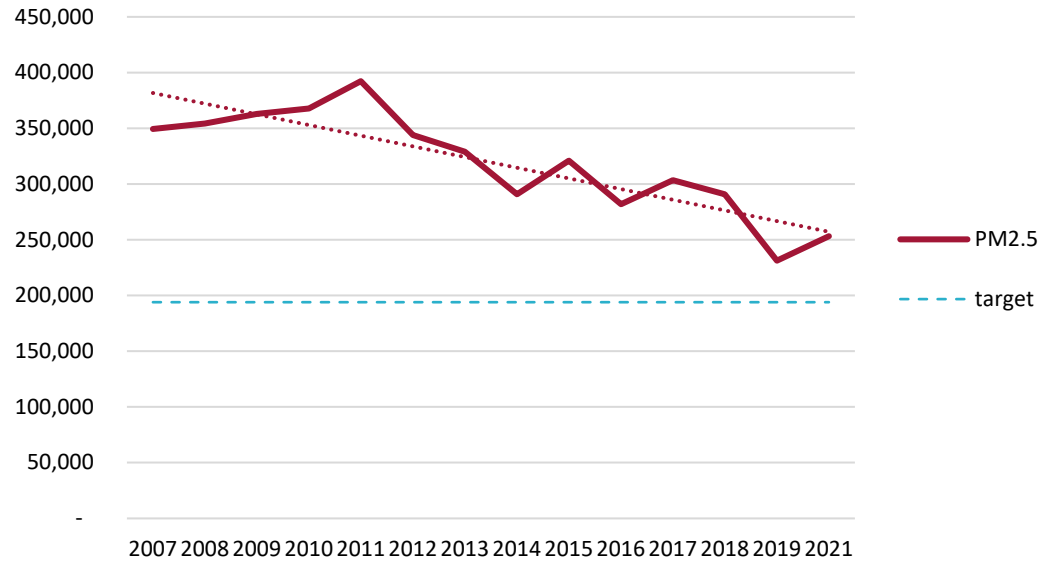
Third, a closer look at local trends reveals an unexpected fact: one region in four is not on track to halving air pollution death tolls by 2030 (Figure 5). Regions where air pollution will continue at high concentrations unless decisive action is taken include the north of Italy and Poland, Greece, Czechia and Germany. The reasons for prevalent pollution levels can be explained by a combination of factors. In Italy, it results from intensive economic activity paired with specific topographic conditions. By contrast, residential heating and old cars play key roles in maintaining air pollution in Eastern European cities.

Table 5: Burden of disease attributed to fine particulate matter (PM2.5) and nitrogen oxides (NO2) for 2021 in the EU

PM2.5	Disability-adjusted life years lost
Ischemic heart disease	760,000
Stroke	630,000
Diabetes	500,000
Chronic pulmonary disease	350,000
Lung cancer	260,000
Asthma	25,000
Total	**2,525,000**
NO2	Disability-adjusted life years lost
Diabetes	315,000
Stroke	200,000
Asthma	115,000
Total	**630,000**

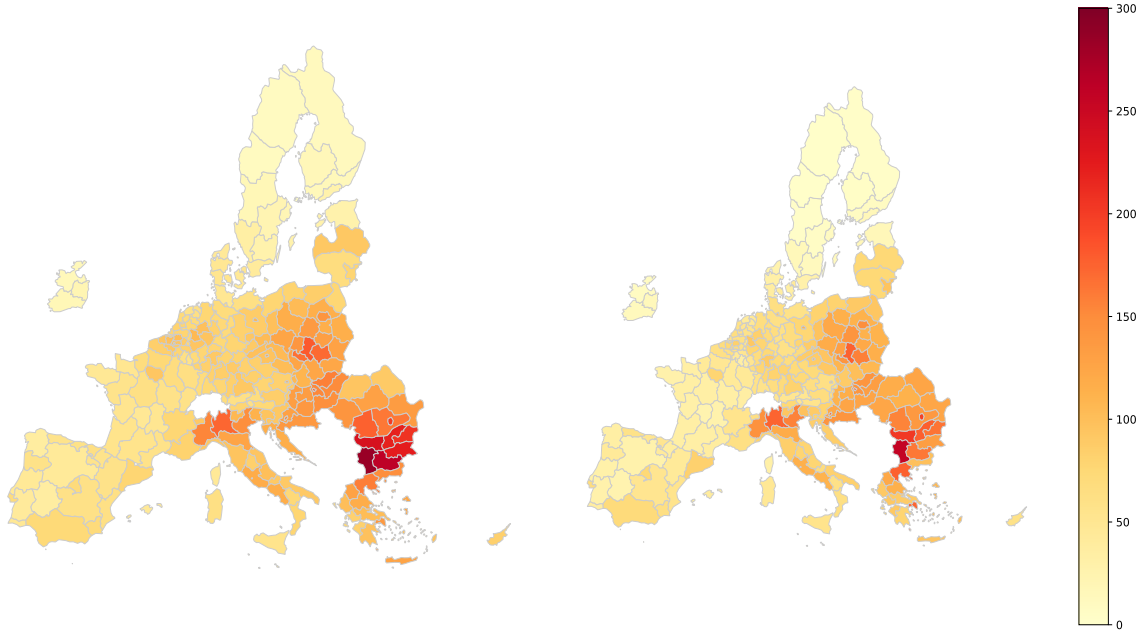
Source: Bruegel based on EEA.

Figure 3: Evolution of EU annual mortality attributable to PM2.5 compared to the EU 2030 target



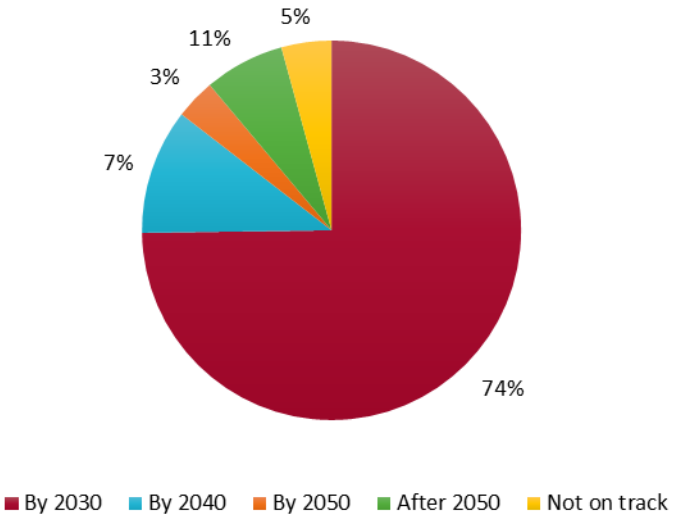
Source: Bruegel based on EEA data. Note: data from 2020 was excluded due to lockdown disruptions.

Figure 4: Air pollution mortality for the period 2007-2013 (left panel) and 2014-2020 (right panel)



Source: Bruegel based on EEA data.

Figure 5: Classification of the 234 EU regions into 5 groups, depending on the estimated year of reaching the air pollution mortality objectives (top)



By 2050	After 2050	Not on track
Střední Čechy (CZ)	Praha (CZ)	Αττική (EL)
Jihovýchod (CZ)	Severovýchod (CZ)	Wielkopolskie (PL)
Střední Morava (CZ)	Mecklenburg-Vorpommern (DE)	Zachodniopomorskie (PL)
Moravskoslezsko (CZ)	Κεντρική Μακεδοία (EL)	Lubuskie (PL)
Berlin (DE)	Grad Zagreb (HR)	Kujawsko-pomorskie (PL)
Ανατολική Μακεδονία, Θράκη (EL)	Észak-Magyarország (HU)	Warmińsko-mazurskie (PL)
Panonska Hrvatska (HR)	Veneto (IT)	Pomorskie (PL)

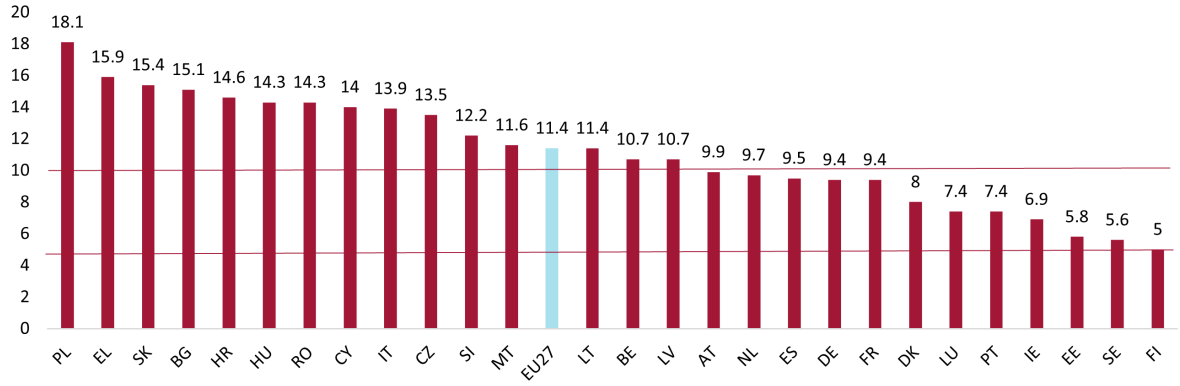
Lombardia (IT)	Małopolskie (PL)	Łódzkie (PL)
	Śląskie (PL)	Warszawski stołeczny (PL)
	Dolnośląskie (PL)	Mazowiecki regionalny (PL)
	Opolskie (PL)	
	Świętokrzyskie (PL)	
	Lubelskie (PL)	
	Podkarpackie (PL)	
	Podlaskie (PL)	
	Východné Slovensko (SK)	

Source: Bruegel based on EEA data. Note: The 'not on track' category reflects an increasing rather than decreasing trend is observed. Regions lagging behind are listed below the chart.

2.2 Mean annual exposure to PM2.5

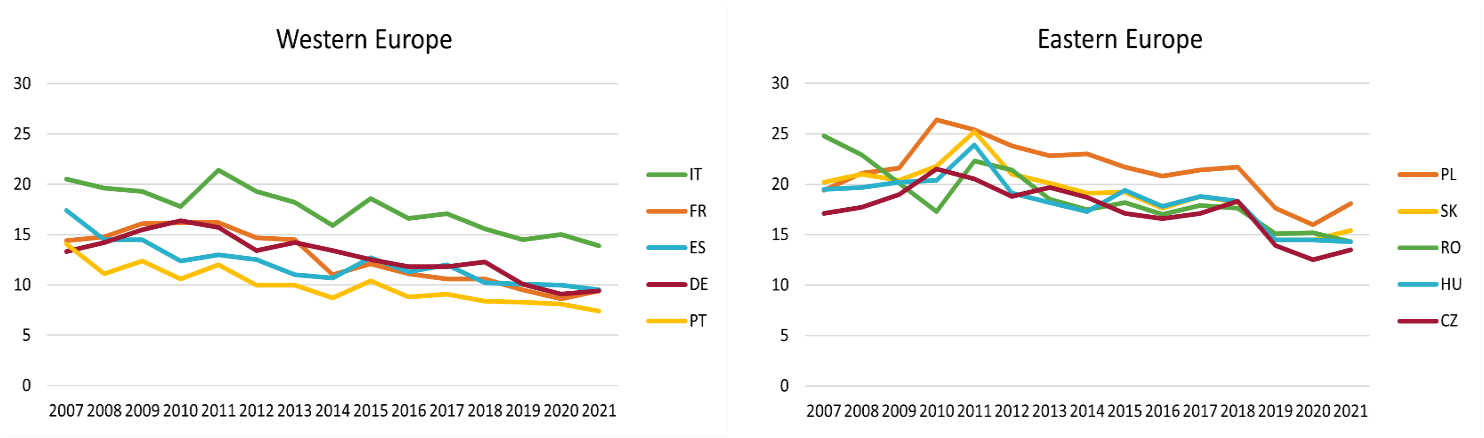
We now focus on PM2.5. These fine particles can travel deep into the respiratory tract, reaching the lungs and causing short-term health effects including irritation, coughing or shortness of breath. In 2021, the mean annual exposure to PM2.5 for the EU's population was 11.4 µg/m3, which is significantly above the limit set by the new AAQD (10 µg/m3) and more than twice the WHO recommended limit (5 µg /m3). But like for other pollutants, there are major differences across EU countries, with Poland (18.1 µg /m3), Romania (14.3), Italy (13.9) and Czechia (13.5) among the more-exposed countries (Figure 6). These four countries are analysed in greater detail in section 3. On the other hand, Spain, France and Germany are among the 12 EU countries that comply already with the new EU limits. Interestingly, while all countries have made major progress over the past few decades, the disparities between them have persisted (Figure 7).

Figure 6: Annual exposure to PM2.5 in 2021 for each EU country compared to thresholds set by WHO in 2021 and by the EU's Air Quality Directive in 2024 of, respectively, 5 µg/m3 and 10 µg/m3



Source: Bruegel based on EEA data.

Figure 7: Evolution of PM2.5 mean annual exposure (mg/m3) in a selection of EU countries from Eastern Europe (left panel), and Western Europe (right panel)



Source: Bruegel based on OECD data.

Air pollution hotspots

To identify regions where air pollution has a disproportionate impact, we classified the 234 EU regions by their air pollution mortality for the periods 2007-2013 and 2014-2021, according to EEA estimates. For the most recent period, we identified 16 hotspots where mortality rates were highest, located in Bulgaria (5), Czechia (1), Greece (1), Croatia (1), Hungary (1), Poland (4) and Romania (2). While these regions represent 7 percent of the EU's population, their air pollution mortality is 14 percent of the EU's total air pollution mortality. Between 2014 and 2021, 360,000 people died prematurely in these regions because of air pollution – more than 1 person per 1000 inhabitants.

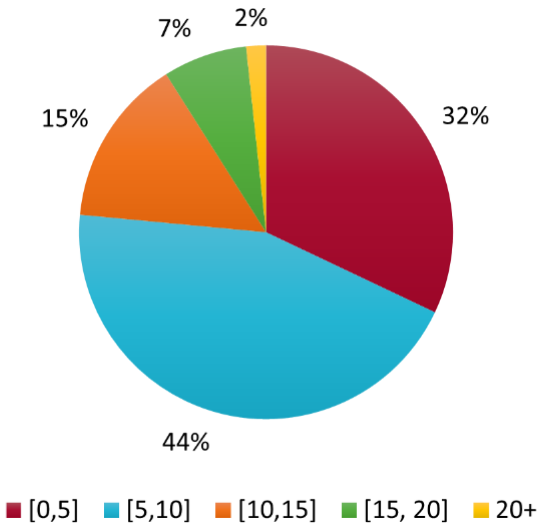
As a complementary approach, we then estimated the mean exposure to PM2.5 in all EU regions by 2030. To do so, we analysed the data between 2005 and 2021, and assumed the observed trend over this period was prolonged. We identified 21 hotspots in which the mean exposure is estimated to stay above 15 µg /m3 by 2030. While 76 percent will comply with the new AAQD by 2030, the remaining 24 percent will not, including 9 percent where the mean exposure is estimated remain above 15 µg /m3 (listed to the right of Figure 8). These regions are in Poland, Croatia, Czechia, Greece, Hungary and Italy (Figure 8). Not surprisingly, the health burden is disproportionately high in air-pollution hotspots: in these regions alone, 600,000 lives were lost prematurely over the period 2014-2021 because of air pollution, that is again more than 1 person per 1,000 inhabitants. In terms of mortality this burden represents 23 percent of the EU's total mortality associated with air pollution over the considered period, even though these regions represent less than 13 percent of the EU's population. The current trend suggests similar disproportionate losses for the years to come.

Interestingly, Bulgaria and Romania appear in the first list, which is backward-looking, but not in the second, which is forward looking. These two countries thus appear to be taking serious action to curb air pollution. Two regions in Italy, one in Greece, one in Croatia and eight in Poland are at the opposite side of the scale, as their future pollution levels are of particular concern. Last, we identified seven

regions in which air pollution is both causing enormous damage and the prospects are particularly pessimistic.

The local nature of air pollution calls for prioritised action in the identified hotspots, first to protect their populations and also to avoid increased tensions with neighbouring regions and countries, which may import significant shares of pollutants. Moreover, the vast majority of the identified regions have relatively high proportions of low-income households (see Table A1 in the online annex), which are known to be most affected by exposure to air pollution (Carson *et al*, 1997, Jbaily *et al*, 2022).

Figure 8: Classification of EU regions according to their projected mean annual exposure to PM2.5 by 2030



Between 15-20	Above 20
Moravskoslezsko (CZ)	Κεντρική Μακεδονία (EL)
Észak-Magyarország (HU)	Αττική (EL)
Grad Zagreb (HR)	Śląskie (PL)
Panonska Hrvatska (HR)	Łódzkie (PL)
Lombardia (IT)	
Veneto (IT)	
Małopolskie (PL)	
Wielkopolskie (PL)	
Dolnośląskie (PL)	
Opolskie (PL)	
Kujawsko-pomorskie (PL)	
Warmińsko-mazurskie (PL)	
Świętokrzyskie (PL)	
Lubelskie (PL)	
Podkarpackie (PL)	
Warszawski stołeczny (PL)	
Mazowiecki regionalny (PL)	

Source: Bruegel based on EEA data. Note: [0,5] = exposure levels between 0 and 5 µg/m3, and similarly for [5, 10], [10,15] and [15,20]; 20+ stands for levels above 20.

2.3 Economic losses associated with air pollution

The effect of air pollution on the economy is the object of an emerging literature. In line with this literature, we focus on PM2.5 as this pollutant stands out as having the largest estimated impacts on mortality and health outcomes. Most of the studies reviewed in this paper use PM2.5 exposure as a proxy for air pollution. The WHO also uses this indicator for general exposure to air pollution. Nevertheless, it is important to note that the estimated impact of air pollution in a given area does not correspond only to PM2.5, but to a cocktail of pollutants, which is proxied by the mean annual exposure to PM2.5 in each area. The health and economic impacts of other pollutants, such as ground-level ozone for example, are significantly lower than PM2.5, and also much more difficult to mitigate (Xie *et al*, 2019).

International studies (World bank, IMF and OECD). In 2016, a joint study by the World Bank and the Institute for Health Metrics and Evaluation estimated, based on the costs of premature deaths, that the cost of air pollution was around 6.1 percent of GDP globally in 2013, with costs being highest in low- and middle-income countries (Sander *et al*, 2016).

Using a different methodology, the International Monetary Fund (IMF, 2023) estimated the annual economic costs of air pollution from burning fossils fuels for more than a hundred countries, from 2015 to 2022, and then forecast these costs up to 2030. For 2022, for example, these costs were estimated at 1 percent of the GDP for the US, 6 percent for China, and between 1 percent and 5 percent for European countries. These results are also aligned with UNECE (2022), which concluded that in 26 of 56 countries in the Pan-European region and North America, the cost of air pollution corresponds to over 5 percent of GDP.

On the other hand, an OECD study, based on the impact of air pollution on several economic outcomes, notably productivity, estimated that a 1 µg/m3 reduction in the annual concentrations of PM2.5 resulted in a 0.8 percent increase of GDP in Europe throughout the period 2000-2015 (Dechezleprêtre *et al*, 2019). Interestingly, 95 percent of this impact was due to reductions in output per worker, which can occur through greater absenteeism at work or reduced labour productivity. In particular, the estimated impact did not rely on the value of a human life. At the European level, the average decrease of 0.2 µg/m3 every year over the considered period was thus associated with an annual increase in GDP of 0.16 percent. Compared to the average of 1 percent growth over this period (at constant prices), the authors concluded that air pollution reduction explained one sixth of the overall economic growth within the EU over the considered period.

National studies. The impact of PM2.5 concentrations on the economy is corroborated by other studies from China and the US, though the estimated effects differ in magnitude. For example, Fu *et al* (2017) estimated that a 1 µg/m3 increase in annual PM2.5 concentration caused labour productivity to decrease by 1.1 percent in Chinese manufacturing plants. On the other hand, a study focusing on the impact of PM2.5 peaks found that a 1 µg/m3 increase in PM2.5 concentration led to a 2.5 percent reduction in income. While the three estimates concluded that concentrations of particulate matter

significantly affect the economy, the differences suggest that the size of the impact may depend on other factors, such as population characteristics (ie age-structure, density, underlying health conditions), which contribute to the vulnerability to air pollution or the overall level of PM2.5, as the effect of air pollution is likely nonlinear, with higher levels leading to proportionately heavier consequences.

Conclusion. While the scope and methodology for measuring the economic costs of air pollution differ from one study to another, there is increasing evidence that the economic costs of air pollution are not only massive, but also greater than previously acknowledged. Reducing air pollution should thus be prioritised for economic reasons alone.

2.4 The economic cost of air pollution

Methodology choice and limitations

We now focus on the economic costs of air pollution within the EU, proxied by the mean annual exposure to PM2.5. We retain the OECD estimates (of 0.8 percent GDP per 1 µg/m3), as the methodology is particularly prudent and transparent, and includes both human activities and pollution from natural sources. We make two further assumptions, founded in the available evidence: first, that below the WHO's recommended level of 5 µg/m3, the economic impact of air pollution is negligible; second, that above this level the effect is constant. Together, these assumptions imply that in any area (region, country, the EU), the economic impact of air pollution is proportional to the exceedance of mean annual exposure to PM2.5 with respect to the WHO's recommendations and to that area's/country's GDP.

Our methodological choice has several caveats and should thus be interpreted cautiously. First, we rely on the PM2.5 concentrations across the EU, which may vary depending on the locations of the measurement devices used, and their distances from sources of pollution. Second, we rely on the estimates from the period 2000-2015, when air pollution levels were higher and GDP was smaller. The estimated economic impacts of air pollution from 2016 onwards may thus differ from the retained estimates. On the other hand, using the same, rigorous methodology for all countries allows us to make meaningful country comparisons, over time.

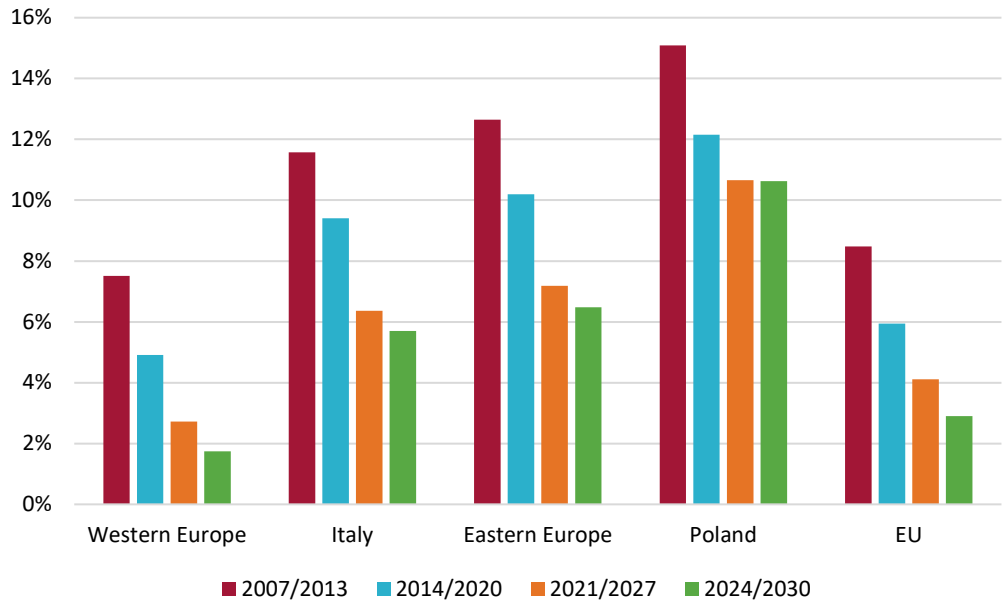
We estimated the annual cost of air pollution in every European region between 2007 and 2030, combining the available data with projections. For example, for the annual concentrations of PM2.5, we relied on data from the European Environment Agency between 2007 and 2021 and estimated the annual concentrations between 2022 and 2030 using linear regressions. On the other hand, we used annual regional GDP data between 2007 and 2024, and projections from the World Bank for the remaining years (at constant prices).

Main results

Over the period 2014-2021, the annual cost of air pollution in the EU is estimated at €770 billion, or 6 percent of GDP. This result is in line with previous estimates from the World Bank and the European Commission, who estimated the annual economic cost of air pollution in the EU to be between €330 billion and €940 billion, in an impact assessment prior to the revision of the Ambient Air Quality Directive (European Commission, 2022b).

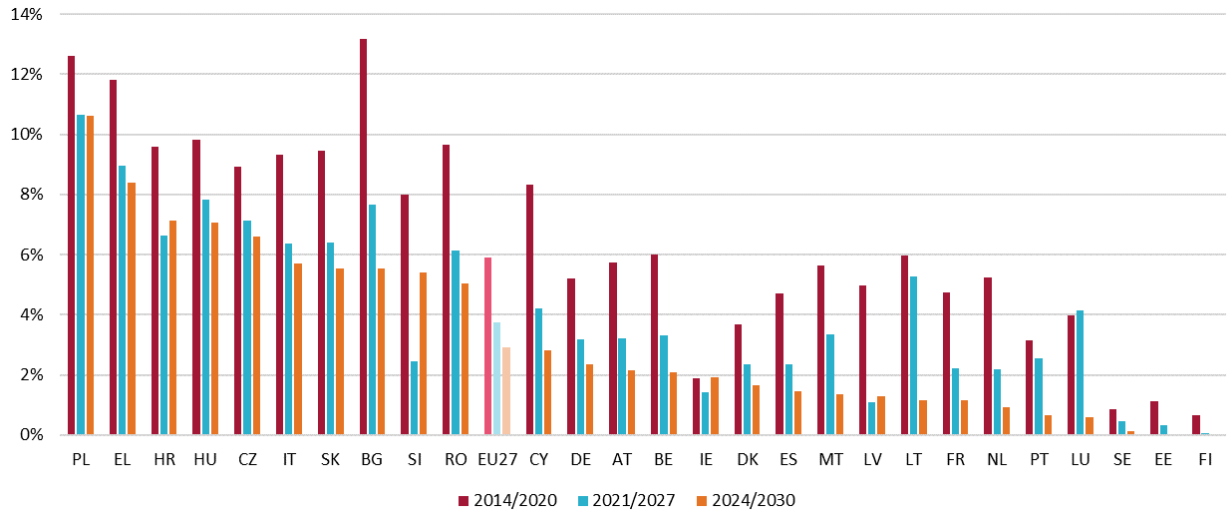
Over the period 2024-2030, the annual cost of air pollution in the EU is estimated at €490 billion, or 3 percent of GDP. While this significant decrease likely results from ambitious policy measures, including regulation and dedicated funds, the cost remains extremely high and hides significant differences between member states. Indeed, like air pollution levels themselves, the associated economic costs are not spread evenly across EU countries. They represent less than 1 percent of GDP in Sweden, Finland, Estonia and Lithuania, but more than 5 percent in Bulgaria (6 percent), Italy (6 percent), Czechia, Croatia and Hungary (all 7 percent), Greece (8 percent) and Poland (10 percent). Disparities are also important when it comes to progress towards cleaner air and the associated reduction in economic costs (Figures 9 and 10).

Figure 9: Estimated cost of air pollution, expressed as the share of the region's GDP over the period, for a selection of EU countries



Source: Bruegel. Western Europe comprises France, Germany, Spain and Portugal, while Eastern Europe comprises Bulgaria, Czechia, Greece, Hungary, Romania and Slovakia.

Figure 10: Estimated cost of air pollution for each EU member state, expressed as a share of their GDP, for different 7-year periods



Source: Bruegel.

Overall, our estimates suggest that the direct economic benefits from air pollution control policies might be much greater than previously thought. For example, the improvement in air quality during the period 2014-2021 (proxied by the reduction of annual average exposure to PM2.5) boosted the economy by €423 billion, or 0.5 percent of GDP. Similarly, the projected reduction of air pollution in the period 2021-2027 will boost the EU economy by another €328 billion, or 0.3 percent of GDP.

These economic analyses indicate that, while action for air pollution is often framed –in the media or public debate – as a cost, clean air action is a profitable investment that will yield economic benefits in multiple sectors. Changing the discourse may be key generate great coherence among different EU sectors and policies.

Why isn't more being done?

Given that the economic losses from air pollution are so massive, why is more not being done to reduce them? A possible explanation is that is spite of being local, visible and present, clean air is a public good. Everyone has access to free air, but unless regulation is in place, neither firms nor households have sufficient incentives to preserve it. Rather, they all prefer that *others* make the effort, so they can enjoy clean air for free. Clean air is thus a classic example of the tragedy of the commons, in which individual's interests clash with collective wellbeing. The preservation of natural resources, the environment and public health are other examples of this same phenomenon.

According to Nobel prize laureate Elinor Ostrom (1990), the tragedy of the commons is not inevitable. There are several ways to solve it provided that some conditions are satisfied, namely: 1) the public good needs to have a clear boundary, in particular, access to it can be controlled; 2) the rules can be changed by the people affected by them, within the framework of the regulation in place; 3) there is a

mechanism to monitor the actions of the participants, graduated penalties can be put in place, and there are inexpensive ways to resolve conflicts; 4) the situation does not change too quickly. While clean air satisfies conditions 2 to 4, controlling access to clean air is unthinkable. Solving the tragedy of the commons thus requires decisive policy intervention, and coordination among all participants.

Yet, public intervention to promote clean air is costly in economic and political terms, and also tends to be much more visible and concrete than air pollution. Furthermore, in the EU, the cost of air pollution is decreasing over time – in most places – and is paired with economic growth. Air pollution damage is thus assimilated with a secondary effect from growth, which overall is improving citizens' livelihoods.

Our results suggest a different angle. Reducing air pollution is manageable while preserving economic growth. Better still, reducing air pollution enhances productivity gains. So the question is whether the economics benefits of cleaner air outweigh the costs of the transition. The overwhelming costs of air pollution, ie over €3 trillion for the 7-year period 2024-2030 for the EU, suggest this is clearly the case.

Robustness check via an alternative methodology

The economic costs associated with air pollution vary, of course, with the method used. The following table shows a comparison of annual costs from the OECD and the IMF methodologies for 2022, expressed as share of countries' GDP (Table 6). Except for Italy, where differences required further study, we find consistent ratios between the two estimates. This suggests that the IMF methodology, based on the quantification of air pollution externalities per unit of fossil fuel burned in the economy, is a good proxy for estimating the economic costs, though falls short by a factor of two or three. A possible explanation for this gap is that fossil-fuel use is not the only contributor to air pollution. Conversely, it suggests fossil-fuel use represents around between 30 percent and 50 percent of the economic damage attributed to air pollution. Phasing out fossil-fuel use is thus key to achieving cleaner air, but not the unique path.

Table 6: Comparing our estimates, based on the OECD methodology, with the IMF estimates, for a selection of countries and for year 2022

	OECD	IMF
Poland	11.9%	4.2%
Romania	7.4%	3.4%
Czechia	8.0%	2.5%
Italy	7.7%	1.1%
Germany	3.9%	1.4%
France	3.0%	0.8%
Spain	3.0%	0.9%

Source: Bruegel.

2.5 EU funding of clean-air policies

Next, we compare the economic costs of air pollution with the amounts of money that EU countries are willing to pay to address air pollution, notably in countries where the economic losses from air pollution are highest. We thus turn to the funding of clean air.

Funding to improve air quality is usually scarce across public institutions (Clean Air Fund, 2021). We distinguish between *positive* and *negative funding*, that is, respectively, money that is dedicated to tackling air pollution, directly or indirectly, and subsidies for polluting activities, such as fossil-fuel production and consumption.

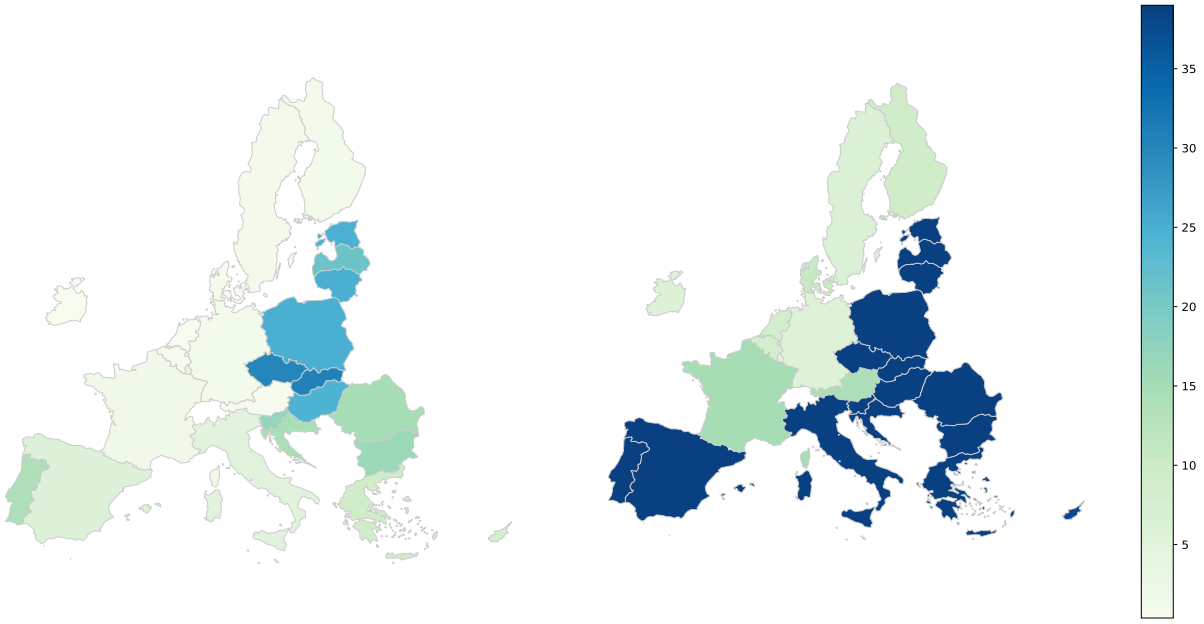
Positive funding

EU budgeting and expenditure is structured over multi-year periods – the multiannual financial framework (MFF). We restrict our attention to the last two MFFs, covering 2014-2020 and 2021-2027, and estimate the amount of money dedicated to clean air in each of these two periods.

There exist different financial instruments in both MFFs associated with clean air policies. We estimate total spending of around €50 billion for the 2014-2020 period on clean-air objectives, and €178 billion for the 2021-2027 period (see the online annex for the methodology). The fivefold increase in the second period is mainly due to the adoption of the Recovery and Resilience Facility (RRF), an exceptional instrument.

Significant differences exist between member states. Given the intrinsic regionality associated with the funds covered (Cohesion Policy and RRF), poorer countries are expected to receive more money. This is also the case for clean air funds, so in that sense the higher clean air funding rates for Eastern European and the Baltic countries comes as no surprise. On the other hand, while the RRF significantly increased the funding in these areas, it also did so in western European countries including France, Italy, Portugal and Spain, as shown in Figure 11.

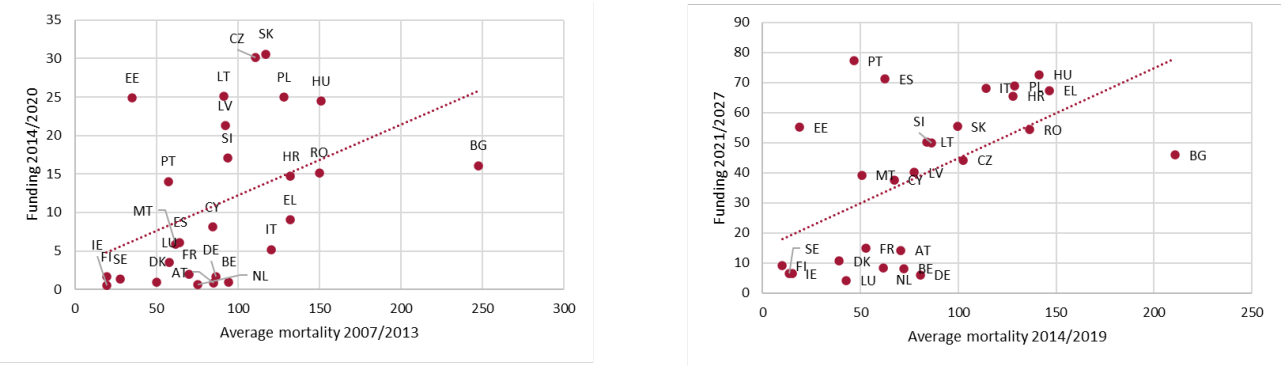
Figure 11: Clean air funding across member states in € millions per 100,000 inhabitants for the two considered periods 2014-2020 (left) and 2021-2027 (right)



Source: Bruegel. Note: the data for the 2014/2020 and the 2021/2027 periods include the funding from the cohesion fund and the RRF.

Is EU funding well allocated? Regression analysis suggests a significant correlation between the funds that were allocated in each financial period (ie 2014-2020 and 2021-2027), and the burden of air pollution in the previous years, measured in mortality rates, in economic cost, or in air pollution levels. While these relationships do not imply causality, notably because there might be confounding factors, such as GDP *per capita* or the share of low-income households, it nonetheless suggests that EU funding was indeed allocated to the countries that needed it most (Figure 12).

Figure 12: The correlation between air pollution mortality rates and allocated EU funds



Source: Bruegel. Note: Average mortality (including all deaths, all pollutants) is the average for the relative deaths (deaths per 100k inhabitants) for the period. Funding is measured in € millions per 100,000 inhabitants. We compare mortality in the period 2007/2013 versus EU funds for 2014/2020 (left), and mortality rates in 2014/2019 versus EU funds for 2021/2027 (right).

To capture the effectiveness of funding, we compare the progress made – measured in terms of economic gains from reducing air pollution – with the EU funding received (Table 7). For the first considered period, the gains exceeded the funds for all member states. In the second, however, while the overall expected gains exceed allocated funds by a factor of three, there are several member states where the EU funds are estimated to exceed the gains. We interpret this result with caution, notably as the economic gains attributed to air-pollution reduction are estimated using past trends. Therefore, the negative expected gains in Greece and Poland for the period 2021-2027 are the result of the rebound effect of 2021, and a moderate progression over the period 2007-2019. On the other hand, in countries including Italy, Romania, Spain and Slovakia, EU funds *per capita* are important, yet smaller or comparable to the expected economic benefits.

It is also noteworthy that, though EU funds are five times more in the second period, the estimated gains are similar, or even smaller. A plausible explanation is that reducing air pollution becomes more difficult as pollution diminishes. Moreover, the estimated gains remain way above the amounts of dedicated EU money, which shows that the returns on investments in clean air remain positive at the EU level.

Table 7: Gains from reducing air pollution throughout the periods 2014/2020 and 2021/2027 are compared with the EU dedicated funds in these same periods

	2014/2020		2021/2027	
	Gains AP	EU funds	Gains AP	EU funds
AT	20	0.1	13	1.3
BE	24	0.1	16	0.9
BG	6	1.2	4	3.2
CY	1	0.1	2	0.3
CZ	11	3.2	1	4.6
DE	151	1.3	68	5.0
DK	5	0.1	7	0.6
EE	0	0.3	0	0.7
EL	5	1.0	-1	7.2
ES	15	2.8	36	33.8
FI	2	0.1	1	0.5
FR	95	1.3	73	10.1
HR	1	0.6	1	2.6
HU	4	2.4	1	7.1
IE	9	0.0	6	0.3
IT	56	3.1	43	40.4
LT	1	0.7	1	1.4
LU	4	0.0	2	0.0
LV	1	0.4	1	0.8
MT	0	0.0	1	0.2
NL	32	0.1	36	1.5
PL	22	9.5	-3	26.1
PT	5	1.5	5	8.0
RO	7	3.0	11	10.4
SE	18	0.1	2	0.7
SI	2	0.4	1	1.1
SK	3	1.7	1	3.0
EU 27	**500**	**35.2**	**328**	**171.8**

Source: Bruegel. Note: This table includes EU funds from cohesion policy and the RRF.

Negative funding

The second element of our analysis is the money spent on major contributors to air pollution, notably the burning of fossil fuels. From 2007 to 2022, fossil-fuel use decreased by 23 percent in the EU, which is very significant compared to the 10 percent over all OECD countries, and the non-OECD increase by more than 40 percent. However, progress is not uniform across the EU; for example, over this period, use of fossil-fuel energy remained stable in Poland, Bulgaria and Lithuania and decreased,

though by below the EU average, in Austria, Czechia, Germany, Hungary and Slovakia (Ritchie and Rosada, 2017).

We rely on IMF data to obtain the amount of money that each member state spends on fossil fuels, both explicitly (ie subsidising consumption or undercharging for the supply costs of fossil fuels) and implicitly (ie undercharging for environmental costs and forgone consumption tax revenues). We consider both explicit and implicit funding.

The available data covers the period between 2015 and 2030, and all current EU countries. Interestingly, negative funding is again disproportionately located in Central and Eastern Europe for both considered periods. Moreover, negative funding is estimated to increase between 2014-2020 and 2021-2027, partly reflecting in particular the response to the energy crisis following Russia's invasion of Ukraine.

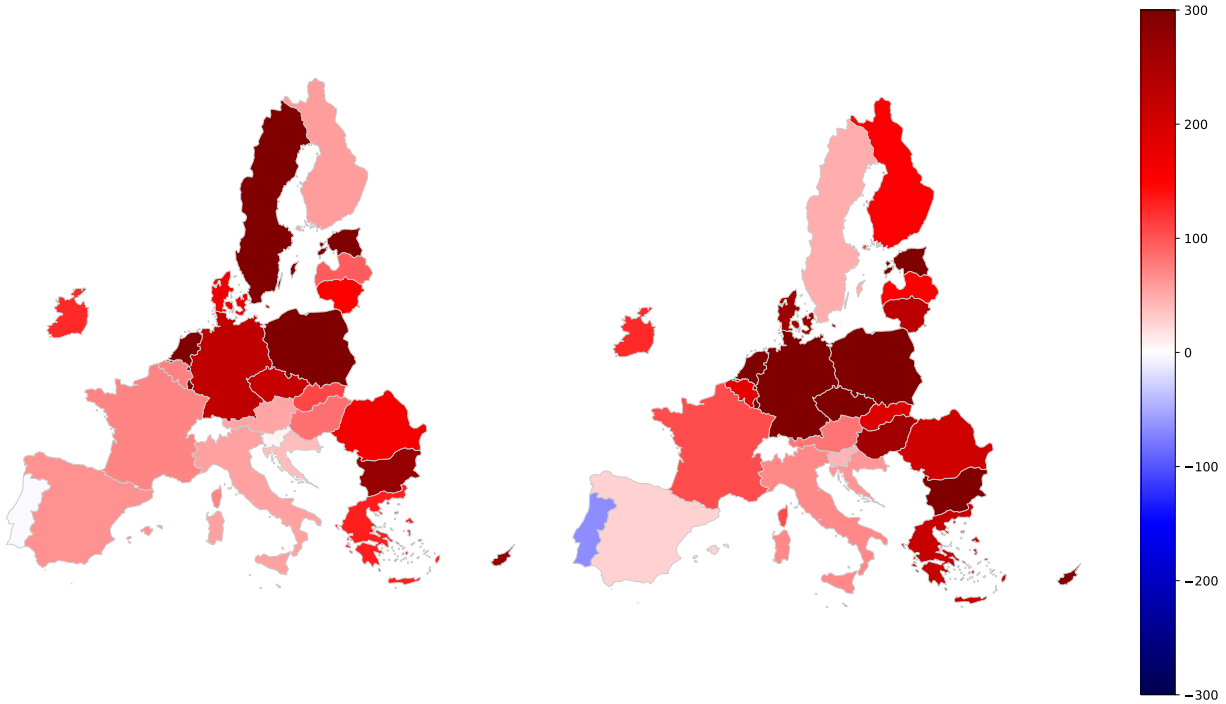
Balance between positive and negative funding

Unfortunately, we do not have access to data on national expenditure on clean-air policies, and we are left with a rather unfair comparison: on the one hand, the total EU funds dedicated to promote clean air, which are also intended to foster cohesion between member states; on the other hand, subsidies to fossil fuels, which can be interpreted as promoting air pollution, but are also a means for governments to sustain people's purchase power. Though questionable and imperfect, the difference between the two types of funding, positive and negative, is an indicator of the overall effort countries are making on clean air. It represents the amount of money they should dedicate to clean air to achieve an air-pollution neutral expenditure.

Overall, the negative funding far exceeds the positive funding for clean air in every member state except Portugal in the period 2021-2027 (Figure 14). Our indicator suggests that countries including Germany, Poland and Romania should be spending more national money to tackle air pollution than, for example, Spain, Portugal or Italy.

At the EU level, for the period 2021-2027 we estimated that €178 billion was dedicated to direct or indirect action against air pollution, that is nearly 10 percent of the MMF and NextGenerationEU budgets. While this represents a threefold increase over the previous MMF, it still falls short of the subsidies to fossil fuels, estimated at €1,020 billion (Table 8). The ratio of negative and positive funding is striking, although there has been significant progress between the first and the second periods, falling from a ratio of fourteen times to five times. Though these ratios are worrisome, the evolution leaves room for some hope.

Figure 14: Balance between negative and positive funding for the periods 2014-2020 (left) and 2021-2027 (right) in € millions per 100,000 inhabitants



Source: Bruegel.

Table 8: Positive funding (left) vs negative funding (right) in € billions of 2021

Positive funding		
Instrument/Type	2014-2020	2021-2027
Cohesion Policy	35	48
Horizon 2020 / Horizon Europe	4	4
EFSI	1	-
CEF	9	3
EAFRD	1	-
LIFE	0	0
RRF	-	123
Total	**50**	**178**

Negative funding		
Type of subsidy	2014-2020	2021-2027
Implicit	526	625
Explicit	200	403
Total	**726**	**1029**

Source: Bruegel.

3 Case studies: implementation

3.1 General considerations

Human-induced PM2.5 concentrations arise from all sectors, yet the proportion varies across the EU (Figure 15). For example, domestic fuel burning is a predominant contributor in Northern and South Eastern Europe, while traffic is a leading contributor in South Western Europe.

Figure 15: Contributions to human-induced PM2.5 concentrations by sector, four different EU regions

	Northern EU	Western EU	SW EU	SE EU
Domestic fuel burning	28%	16%	15%	38%
Industry	16%	12%	14%	20%
Traffic	27%	26%	44%	23%
Unspecified	29%	46%	28%	19%

Source: Bruegel based on Kalagulian *et al* (2015).

A variety of interventions, both at local and wider levels, can be implemented to reduce the concentration of air pollutants. In urban areas, where most air pollution hotspots are concentrated, these include policies to retrofit vehicles to reduce their emissions, enforcing stricter regulations on the emission factors of new vehicles, using vegetation to absorb pollutants, introducing pedestrianised areas, modifying the built environment to improve air circulation and replacement of polluting heating devices by clean alternatives (eg heat pumps).

Low-emission zones and electric vehicles

Urban Vehicle Access Regulations (UVAR) are one strategy under active consideration across the European Union. They improve air quality by changing the car fleet, as the scheme bans the most polluting vehicles. This approach can be highly cost-effective as it also leverages existing infrastructure, encourages public transportation and promotes active travel, such as walking and cycling.

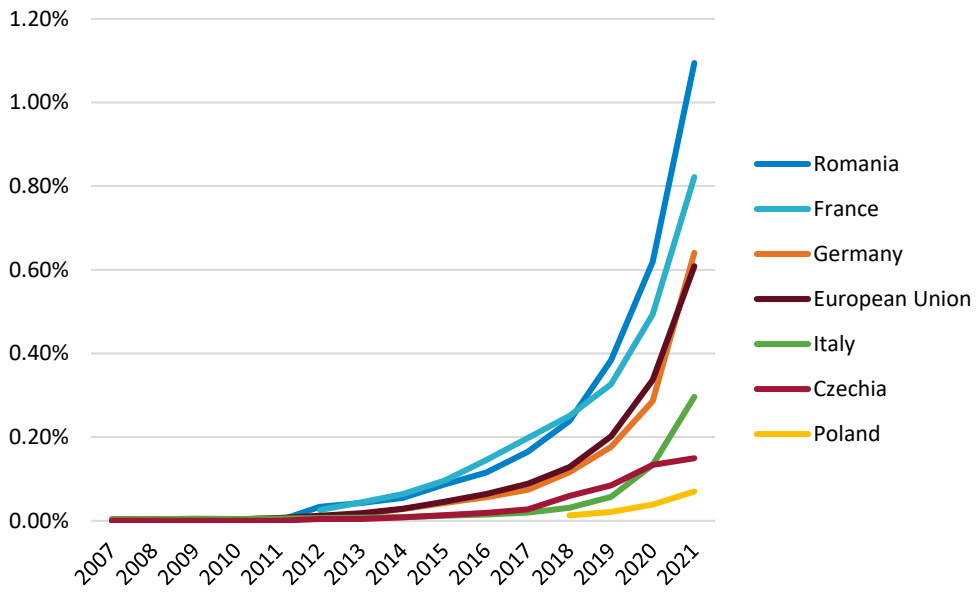
A specific type of UVAR, known as Low Emission Zones (LEZs) or Clean Air Zones, is currently being explored in 15 EU countries and in the UK. From 2019 to 2022, the number of LEZs implemented in Europe jumped from 228 to 320, a 40 percent increase. More than 500 are expected by 2050 according to Transport & Environment. LEZs typically discourage certain vehicles from operating within designated areas through bans or by levying charges during specified times, to reduce sources of emissions.

European LEZs helped reduce PM2.5 and nitrogen oxide emissions by, respectively, 26 percent and 21 percent on average between 2018 and 2021, according to Transport and Environment (2022). More specifically, in London, Brussels and Paris, the reduction in nitrogen oxides was estimated at 40 percent, 16-33 percent and 24 percent respectively.

But implementing policies that may restrict citizens' mobility is often contentious (Christiansen, 2018), driven by concerns over personal freedom and distributional impacts. Public and political resistance has halted or reversed the introduction of UVARs in several cities worldwide over the past two decades (see Morton *et al*, 2021, for references). Understanding public acceptance of LEZs,

guided by the perceived policy efficacy, distributional equity and the policy risk due to their newness, can assist their development and facilitate implementation.

Figure 16: Share of electric vehicles in a selection of EU countries; Czechia, Poland and Italy lagging behind



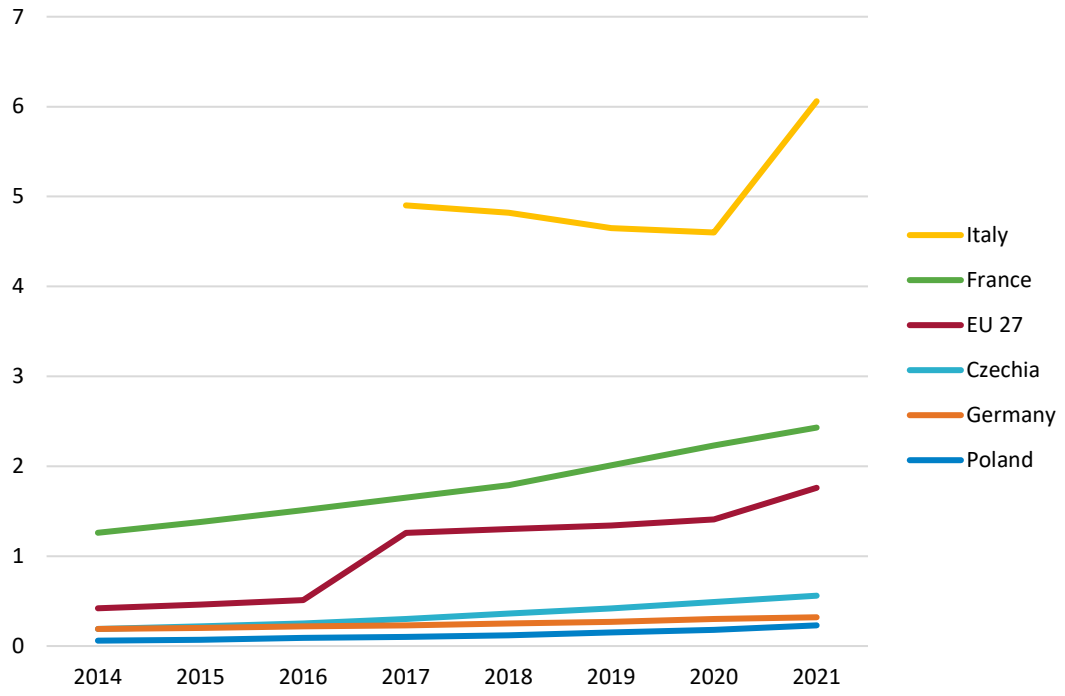
Source: Bruegel based on Odyssée Mure database.

Residential heating

Another significant clean-air policy involves heat pumps, electric heating devices that convert energy from external sources (air or water) into heat for space heating and hot water in buildings. The replacement of polluting heating devices (ie using fossil fuels) by heat pumps can be pivotal in reducing air pollution in urban areas. This is the case because the heating sector is the most energy and carbon-intensive, accounting for nearly 50 percent of the total energy demand, 75 percent of which comes from fossil fuels (Gaut *et al*, 2021).

Heat pumps have been popular for decades, but they have gained significant importance in recent years for their potential to reduce both CO2 emissions and air pollutants. Policymakers recognise the crucial role this technology can play in the transition to a sustainable energy future, as shown by incentives promoting adoption and diffusion of heat pumps. In the EU, heat-pump installation capacity increased fourfold between 2014 and 2022 (see Figure17). As stakeholders too have shown renewed interest in this technology, a strong increase in heat-pump installations is expected in the coming years, particularly in countries where the majority of heat demand is still met by fossil fuels. Adoption of heat pumps is increasing, though from a low penetration level.

Figure 17: Comparison of heat pumps progression in EU countries, measured as installed thermal capacity in KW per one thousand households, where heat pump sizes range from roughly 6kW to 15kW



Source: Bruegel based on Eurostat.

Global action

Reducing air pollution can be paired with decarbonisation. Phasing out fossil-fuel devices from all sectors of the economy can be achieved with a combination of non-binding instruments (eg education campaigns, for example providing information on the benefits of clean air for health, ecosystems and the economy), monetary incentives (eg taxes and subsidies) and regulation (eg progressively banning the most polluting vehicles or devices, notably from city centres). Though many measures require substantial upfront investment in research, development and infrastructure, they can be cost-effective in the long term by substantially reducing the losses associated with air pollution, estimated in section 2.

Incentivising innovation and providing subsidies for renewable energy and electric vehicles can offset these initial costs, making global actions a strategic investment for a sustainable future. Balancing financial incentives and public infrastructure funding with regulatory measures creates a comprehensive approach: regulation sets the framework with clear targets and a route for compliance, while funding supports the necessary steps for the transition.

A selection of EU countries

The economic cost of air pollution for each EU country was estimated in section 2. We now focus on four EU countries for which air pollution is of particular concern: Poland, Italy, Czechia and Romania. In 2022, the economic costs of air pollution represented, respectively, 8 percent of GDP in Poland, 7.4 percent in Italy, 11.9 percent in Czechia and 7.7 percent in Romania. We use International Monetary Fund data to estimate the contribution of each polluting activity to the cost of air pollution in each country (Table 9). The sectoral distribution of air pollution costs is informative of the countries' specificities. The IMF distinguishes a dozen categories including the consumption of diesel and gasoline, the residential use of coal, and other uses of coal (eg for industrial activities or power generation).

Table 9: Distribution of air pollution costs by use in a selection of EU members for 2022, as estimated by the IMF

	Diesel	Gasoline	Residential coal	Other coal use	Other
Czechia	68.2%	5.5%	15.2%	9.7%	1.4%
Italy	83.3%	5.0%	0.0%	0.7%	11.0%
Poland	21.8%	1.0%	27.6%	47.9%	1.6%
Romania	80.8%	7.0%	0.9%	7.8%	3.6%
France	90.7%	2.2%	0.9%	1.8%	4.3%
Germany	80.8%	3.1%	1.3%	9.7%	5.2%
Spain	81.2%	2.0%	0.9%	4.4%	11.4%

Source: Bruegel based on IMF (2023).

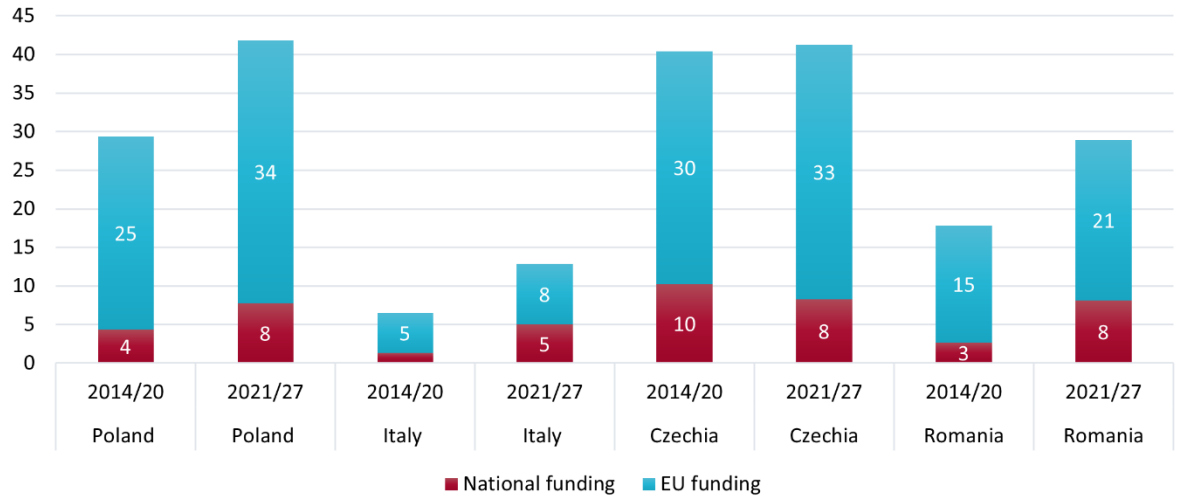
The table shows clearly the predominant role of diesel vehicles and coal in the cost of air pollution, though with remarkable differences across the selected countries.

We analysed the money spent via cohesion policy projects. As most EU funded projects are co-funded by member states, we considered both the EU funds, as described in section 2, and the money that was allocated at national level. Importantly, due to data availability, we restricted our attention to the Cohesion Fund. As previously argued, this instrument represents an important part of overall EU funds.

First, we focused on the countries' national contributions to the considered clean-air projects, interpreted as a proxy for their commitment to promoting clean air. Amounts are expressed *per capita* to facilitate country comparisons, and we distinguished two periods, 2014-2020 and 2021-2027. The evolution of this indicator is particularly informative.

Remarkably, Italy and Romania have nearly doubled their contributions to clean-air projects, from 20 percent and 15 percent respectively in 2014-2020 to 39 percent and 28 percent in 2021-2027. A positive, milder shift is observed in Poland, from 15 percent to 19 percent, while Czechia's contribution has decreased from 25 percent to 20 percent. In absolute terms, national contributions have progressed the most in Italy (3.8x), followed by Romania (3.1x), Poland (1.8x) and Czechia (0.8x). On the other hand, the four countries have benefited from increased EU funds.

Figure 18: National and EU funds allocated to clean air projects via the Cohesion Fund, expressed in € millions per 100,000 inhabitants



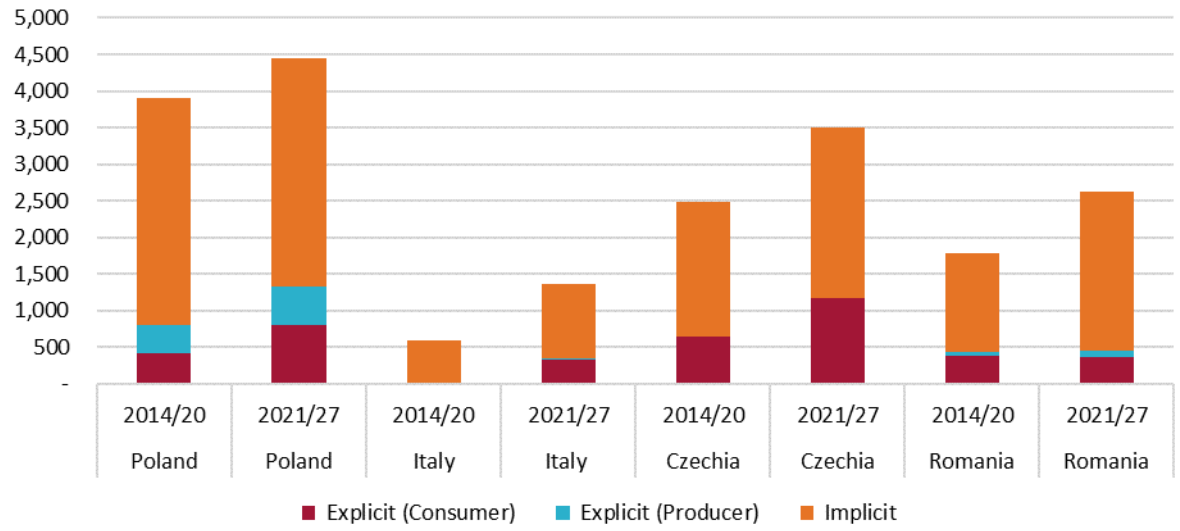
Source: Bruegel based on European Commission data.

Second, we focused on negative funding in the four countries. As in section 2.4 we followed the estimates and projections from the IMF and distinguished between explicit subsidies for consumers and for producers, and implicit subsidies resulting from undercharging for the externalities of local air pollution (Figure 18). While subsidies to producers are marginal in Italy, Czechia and Romania, all countries significantly support the consumption of fossil fuels and undercharge for air-pollution costs.

Worse, subsidies to fossil fuels are expected to increase for the four countries, and for the three considered categories. More specifically, the total subsidies will increase by 14 percent in Poland, 129 percent in Italy, 41 percent in Czechia and 47 percent in Romania. The ranking between the four countries, however, remains unchanged: in both periods, total subsidies were highest in Poland, followed by Czechia, Romania and Italy. For 2021-2027, subsidies to fossil fuels amount to €4,400 per person in Poland, €3,500 in Czechia, €2,600 in Romania and €1,400 in Italy.

Of particular concern is the comparison between funds allocated to address clean air and subsidies to fossil fuels. In section 2.4 we argued the ratio between the two was worrisome but left place for some hope given the decreasing trend from 14x to 5x. However, a closer look at the considered countries reveals important differences. In Italy and Czechia, for example, the ratio has increased in favour of subsidies to fossil fuels, while in Poland and Romania it has decreased mildly. Within the selected four countries, the ratio between subsidies to fossil fuels and funds allocated to clean air has increased between the two periods (Figure 19).

Figure 19: Negative funding for the selected countries in € *per capita* for the two periods, 2014-2020 and 2021-2027



Source: Bruegel based on IMF data.

3.2 Poland

Poland grapples with some of the most alarming air pollution levels among EU countries.

With over 50,000 premature deaths from air pollution in 2021, it was the country in the EU with second highest mortality rate. The average annual concentration of PM2.5 ranged from 12 to 34 µg/m3 in Polish regions, with an average exposure of 18.1 µg/m3, nearly twice the limit in the revised AAQD. Furthermore, 36 of the 50 most polluted cities in the European Union are in Poland, according to WHO (2018). Despite the persistently high burden from air pollution, measures taken in Poland have reduced air pollution exposure over the last years, from 33 µg/m3 in the 1990s to 27 µg/m3 in the 2000s.

Over the period 2014-2020, 9.1 people in every 100,000 died because of air pollution. Economic losses during this seven-year period are estimated at €60 billion/year, or 13 percent of the country's GDP. This figure exceeds the World Bank welfare-based approach of €30 billion to €40 billion per year (World Bank, 2019).

For the upcoming seven-year period 2024-2030, the cost is estimated at €80 billion/year, so one third higher than a decade ago, and represents 11 percent of projected GDP. The cost of air pollution is highest in the regions we identified in section 2.1 (Figure 9), where air pollution is projected to be highest. In Śląskie (PL22) and Łódzkie (PL71), for example, PM2.5 mean annual exposure is projected to remain above 20 µg/m3 by 2030, and the cost of air pollution is 14 percent of their regional GDP.

Most of the air pollution across Poland is the result of the country's dependence on coal to power its homes and economy. Despite a gradual shift towards natural gas since the 1980s, coal continues to play a significant role in the country's energy mix. As the second largest coal-mining nation in Europe (behind Germany), Poland's coal industry remains vital to its local economy.

Allocation of funding

We observed a significant increase in funding for clean-air policies between the two considered periods. However, the sectorial distribution of funds is indicative of the countries' priorities. For example, both in relative and absolute terms, the amount of funds that were allocated to clean air specific and cycling policies has decreased between 2014-2020 and 2021-2027.

In the 2014-2020 MFF, the majority of EU funds for clean air were allocated to transport infrastructure, such as railways and urban transport (56 percent). Around 17 percent of the funds was spent on energy-efficiency measures related to renovation of public infrastructure and housing, or energy efficiency in general. Renewable energy projects received around 7 percent of the funding. Finally, air-quality measures and cycling infrastructure each received only 5 percent of the funding each.

The funding priorities remained unchanged for 2021-2027 MFF. However, we observe a significant shift from railways and transport to housing renovation and energy-efficiency measures, respectively decreasing by 33 percent (ie from 56 percent to 38 percent) and more than doubling (ie from 17 percent to 39 percent). This relative change illustrates the above-mentioned determination of the Polish government to improve air quality by replacing polluting heating devices in buildings. Remarkably, while EU funds have increased in absolute terms in all categories, the increase has been spectacular in housing renovation, at the expense of a reduction in railways and transport.

Table 10: Allocation of EU clean air funds by sector in Poland

Poland	2014-2020	2021-2027
Railways/Transport	56%	38%
Clean air specific	5%	3%
Cycling	5%	3%
Housing renovation/energy efficiency	17%	39%
Renewable energy	7%	6%
Other	10%	11%

Source: Bruegel.

The way forward

The main sources of air pollution in Poland are related to coal use, which can be differentiated between residential heating, industrial use and energy generation. While the improvement of air quality requires a progressive phasing-out of coal everywhere, the shift should be prioritised in cities where air pollution harm is highest. For this reason, we focus on residential combustion, which includes heaters, stoves, fireplaces and boilers that use fossil fuels including coal, wood and natural gas. The next major

polluters are the buildings and transport sectors, largely unregulated until recent years (Zgłobicki and Baran-Zgłobicka, 2024). To improve air quality a national Clean Air Programme has been in place since 2019, with the main goal of reducing or avoiding air-pollutant emissions – mainly from single-family dwellings – by improving the energy efficiency of buildings.

With more than €20 billion allocated, the programme has a lifetime of 10 years and aims to overhaul polluting setups like coal-fired heating in favour of cleaner alternatives such as heat pumps. Regardless of their income, residents of Poland can already count on subsidies for up to 50 percent of the investment costs for renewable energy sources for their homes, up to a maximum of €13,400, of which €6,500 can go towards a heat pump. The anticipated final effect is a significant reduction in residential emissions of PM10 and PM2.5, and other pollutants.

While the subsidies appear remarkably high, we argue they are below the expected benefits these devices can bring to the economy. According to the World Bank, up to 66 percent of PM2.5 emissions in Poland comes from the 4.4 million households (that is, 35 percent of households) that are still using coal-fired heating systems (World Bank, 2019). Weighing the current level of PM2.5, as well as the corresponding economic costs, we can infer that replacing 1 percent of the polluting heating systems by clean ones would lead to about €550 million in savings. In other words, every replaced heat-pump brings €12,500 in savings, so more than the average cost of €11,000 per heat pump in Poland (see the online annex for the detailed calculation).

Heat pump sales have thus surged in recent years, with quicker growth than anticipated – more than 200,000 heat pumps were sold in 2022, that is double the number in Germany *per capita*. However, this pace is insufficient, since even assuming that all new heat pumps are used to replace coal heating devices, it would take more than 20 years to replace them all. Furthermore, to be efficient heat pumps require a properly isolated home, which comes at a significantly higher price.

Poland's air pollution challenge remains notable, and the heat-pump example suggests that estimating the economic costs of air pollution and home insulation may be key to building the case for stronger, affordable clean air action. Subsidising heat pumps massively in urban centres, and other local initiatives such as enhanced monitoring and public awareness campaigns, offer hope for improved air quality and health outcomes in the years ahead.

3.3 Italy

Among Western European countries, Italy has the most worrying air quality conditions. In 2021, there were more than 60,000 deaths attributable to air pollution in the country, that is 1 in 1000 people. We estimated the cost of air pollution at 9 percent of the country's GDP in 2014-2020, and 6 percent in 2024-2030. That is, respectively, €160 billion and €120 billion every year.

Air pollution is of greatest concern in the north – the most polluted and also the wealthiest part of the country. This part of the country, known as the Po Valley, comprises the regions of Piemonte,

Lombardy, Veneto and Emilia-Romagna. Together, they total 23.6 million inhabitants, nearly 40 percent of Italy's total population and 56 percent of GDP.

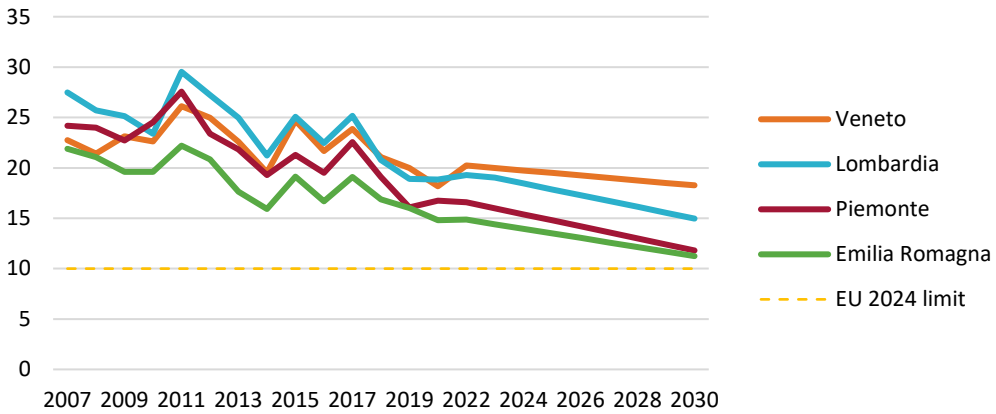
The specific orographic conditions of the Po Valley create a situation in which pollution stagnates in the air. Manufacturing and farming industries in the area, together with other sectors including buildings (specifically their heating systems), emit significant amounts of air pollutants including PM2.5 and PM10, which remain in the air for prolonged periods, causing considerable health, economic and environmental impacts. Ammonia, for example, an important precursor of PM2.5 stemming from agriculture (Figure 1) is insufficiently regulated.

In the Po Valley, the economic costs of air pollution during 2014-2021 are estimated above 10 percent of the region's GDP, that is more than €100 billion every year. Over this period, air pollution mortality in this area represented 54 percent of total air-pollution mortality in Italy, thus disproportionately high. Projections for the 2024/2030 period are only slightly better, still costing € 85 billion per year. Compared to the entire country, the Po Valley represented 62 percent of Italy's total cost of air pollution one decade ago and is projected to represent 75 percent in the years to come.

Air pollution is decreasing very slowly in the four considered regions: none of them is on track to reducing the mortality to the level of EU's ambitions (ie by 55% by 2030 compared to 2005). We forecast this objective will only be met by 2040 in Piemonte and Emilia-Romagna, and even later in Lombardy and Veneto (Figure 20). The economic gains from air pollution also stagnates in these regions, representing only round 0.1 percent of GDP (Table 3.2-b).

This situation has led the public authorities to implement different plans to tackle air pollution. In 2017, the Italian Ministry of Environment and regional authorities adopted an air quality plan for the Po Valley, aiming at reducing emissions from the road transport, buildings and agricultural sectors.

Figure 20: Mean annual exposure to PM2.5 in the four regions of the Po Valley, from 2007 to 2021, prolonged to 2030, compared to the limit value set by the new AAQD



Source: Bruegel based on EEA data.

Table 11: Estimated total cost of air pollution and regional GDP for the 7-year period 2024/2030 expressed in absolute terms in € billions of 2021

	AP costs	GDP	AP cost/GDP
Piemonte	72	1,055	7%
Lombardia	292	3,180	9%
Veneto	146	1,302	11%
Emilia Romagna	78	1,278	6%
Total	588	6,815	9%

Source: Bruegel.

Allocation of funding

As already mentioned, Italy will receive significantly more EU funds for the current MMF, compared to the previous one, 2014/2020, more precisely 52 percent more. Digging into a sectorial analysis is important to reveal the country's priorities.

In the 2014-2020 period, around 42 percent of the EU funds were allocated to railways and transport-related infrastructure, while 32 percent was spent on energy-efficiency measures and renovation of housing stock. These two sectors thus clearly appear as Italy's main focus in fighting air pollution. On the other hand, 11 percent of the total allocated funding was spent on environmentally friendly production processes in SMEs, over 6 percent of the funding was spent on cycling infrastructure, and 1 percent was allocated to renewable energy projects. Surprisingly, specific air-quality measures had no funding allocated for this period in Italy.

The main priorities have changed little in 2021-2027, with railway and transport-related and energy-efficiency and renovation projects still representing the large majority of EU funds, at 40 percent and 30 percent respectively. Cycling policies, by contrast were drastically reduced to 2 percent, and similarly industrial pro-clean air policies funds decreased to 8 percent. The most spectacular change, however, is the increase of EU funds for renewable energy projects, representing 8 percent of the total funds; in absolute terms, renewable energy projects will receive 12x more money in the current MMF compared to the previous one. Last, the allocation to specific clean-air projects remains marginal, barely exceeding 0.2 percent of the total funds.

Overall, it is worth noting the vast majority of clean-air funds are allocated to (polluting) sectors, such as transport and heating. Conversely, projects that specifically promote clean air have received a very small, almost negligible part of the funds. This choice raises the important question of which projects – those targeting clean air as their primary or secondary objective are more effective in tackling air pollution.

Table 12: Allocation of EU clean air funds by sector in Italy

Italy	2014-2020	2021-2027
Railways/Transport	42%	40%
Clean air specific	0%	0.2%
Cycling	6%	2%
Housing renovation/energy efficiency	32%	31%
Renewable energy	1%	8%
Industry	11%	8%
Other	7%	9%

Source: Bruegel.

The way forward

The population density, together with industrial activity in the Po Valley region, make the task of reducing air pollution difficult, with the intrinsic topographic characteristics of the area adding an extra layer of complexity. Colombo *et al* (2023) showed that with current technological levels, compliance with WHO recommended levels in the Po Valley is not possible unless economic activity is substantially reduced.

Despite the intractability of the problem, certain aspects, such as building modernisation and decarbonisation of road transport, deserve more attention. While Italy is well placed in heat-pump installations compared to major EU countries, which is a result of enormous public incentives during the last decade (Figure 17), the country remains behind in terms of electric-vehicle adoption (Figure 16). Emissions of ammonia, an important precursor of PM2.5, also deserve particular attention, notably as there has been little progress regarding its reduction. Alongside the above-mentioned efficiency changes, the Po Valley should also consider fostering more sustainable consumption patterns, notably dietary habits, to reduce concentrations of PM2.5 (Springman *et al*, 2023). The benefits associated with cleaner air outweigh the costs, and the externalities caused by industrial and agricultural activities should be considered in the regulations affecting such sectors.

3.4 Czechia

Czechia ranked seventh in air pollution mortality over the period 2024-2020, with over 7 deaths per 1000 inhabitants over this period. Furthermore, only one out of the country's eight regions is on track to meet the EU 2030 target, and just two more regions would satisfy it by 2040. Air pollution cost €18 billion annually a decade ago (ie for the period 2014-2020) and is currently projected to cost €20 billion annually. Respectively, these figures account for 11 percent and 7 percent of the country's GDP. On the other hand, air pollution reduction is projected to boost Czechia's economy by €700 million annually from 2024 to 2030.

The country is however making progress towards cleaner air. The mean annual exposure to PM2.5 has been declining almost continuously since the 1990s; similarly, the main air pollutants except for ozone observe declined over 2012-2022 according to the Czech National Institute of Meteorology.

Air pollution is worst in the north-east, where the majority of exceedances of air pollution limits have been recorded. Despite the progress in recent years, the energy crisis following Russia's invasion of Ukraine has shifted some households towards cheaper, more polluting heating systems which is having a negative impact on air quality. The contribution of residential heating to PM2.5 concentrations has been estimated at around 40 percent for the region (Seibert *et al*, 2020).

The north-eastern area also suffers from transboundary air pollution burden originating in Poland. Fine particulate matter and other pollutants are transported by meteorological conditions to Czechia, creating a negative externality affecting this part of the country (Volná *et al*, 2022). Quantifying this effect – and possibly designing compensation mechanisms – is paramount to avoid tensions between Poland and Czechia, notably in view of overwhelming health and economic costs of air pollution and the agreed update of the AAQD setting stricter air pollution limit values.

Allocation of funding

To tackle air pollution, Czechia received €3.2 billion in EU funds in 2014-2020 and €4.6 billion in 2021-2027, or 46 percent more. The sectoral distribution of these funds can inform us of the country's priorities.

In the 2014-2020 funding period, most clean air funding in Czechia was allocated to railways and transport infrastructure (45 percent), while the renovation of the housing stock and energy-efficient projects accounted for around 23 percent of total funding. Another 23 percent of the funding was spent in projects directly aimed at improving air quality, the highest share spent on specific air-quality projects among the countries covered in these case studies. Finally, around 1 percent was spent on renewable energy projects.

For the second period, 2021-2027, the share allocated to railways and clean-transportation projects decreased to 36 percent though in absolute terms this sector was allocated more funds. On the other hand, only 4 percent of the funding was allocated to specific air-quality measures, which is absolute terms represents a threefold reduction of this type of funding. However, this reduction was compensated for by a significant increase in funds for cycling infrastructure and renewable energy. The share of funds allocated to the renovation of the housing stock and energy-efficient projects remained stable, which in absolute terms represents a 40 percent increase.

Table 13: Allocation of EU clean air funds by sector in Czechia

Czechia	2014-2020	2021-2027
Railways/Transport	45%	36%
Clean air specific	23%	4%
Cycling	0%	9%
Housing renovation/energy efficiency	23%	22%
Renewable energy	1%	12%
Other	8%	17%

Source: Bruegel.

The way forward

Like in Poland, the main sources of air pollution in Czechia are related to coal use. While a key to improve air quality is phasing out of coal, this shift should be prioritized in cities. Replacing coal heating devices by cleaner ones is profitable for the same reasons outlined for Poland, and thus offers a clear way forward. This is the case as the penetration rate of heat pumps is still low in the country, as shown in Figure 17.

3.5 Romania

Around 132 people per 100,000 inhabitants lost their lives in Romania for reasons attributable to air pollution in 2021, meaning that a total of 25,000 lives were lost due to poor air quality. The country ranks seventh in the EU in terms of absolute deaths, and fifth in relative terms. Air pollution cost €18 billion annually a decade ago (ie for the period 2014-2020) and is currently projected to cost €16 billion annually. Respectively, these figures account for 10 percent and 5 percent of the country's GDP. On the other hand, air pollution reduction is projected to boost Romania's economy by €1.7 billion annually from 2024 to 2030.

The main sectors associated with air pollution in Romania are heating and road transport, with the peaks of air pollutants (particulate matter specifically) happening during heating seasons and the start/end of working days due to higher flows of traffic. Nitrogen oxides are also of major concern as their emissions have remained stable over the past 20 years, causing around 5,000 deaths every year. Nitrogen oxides are mainly related to the combustion of fossil fuels, in particular fossil fuels used by cars (eg diesel). Recall from Table 9 that, unlike Poland or Czechia, Romania's coal use is relatively moderate (ie 8 percent) compared to diesel use (ie 80 percent). It is thus natural to focus on the transport sector.

The influx of used cars in Romania significantly contributes to air pollution, notably because Romania has become a major destination for older, higher-emission vehicles from Western Europe, largely due to the affordability and availability of these cars. This trend has intensified air quality issues, especially in urban areas, where vehicle emissions are a major source of pollution. According to the

European Automobile Manufacturers' Association, in 2023 more than 85 percent of cars in Romania were more than 10 years old, and the average car age is 15 years – which is among the highest in the EU.

A key factor contributing to air pollution from these used vehicles is the outdated Euro standards. Many imported used cars adhere to older Euro 3 or Euro 4 standards, which are significantly less stringent compared to the latest Euro 6 or proposed Euro 7 standards. These older vehicles emit higher levels of nitrogen oxides and particulate matter. Another important factor is the progressive motorisation of the population, as cars *per capita* have increased by 25 percent from 2017 to 2021, which is significantly more than the other considered countries, ie Czechia (11 percent), Poland (15 percent) and Italy (6 percent).

Allocation of funding

Romania received €3 billion in EU funds for clean air in 2014-2021, and €10.4 billion in 2021-2027. This spectacular more than threefold increase shows the country's commitment to tackle clean air, and possibly rewards the progress made over the past decade.

As per the funding allocation in the 2014-2020 MFF, railways and transport projects perceived the highest share of clean-air funding with around 42 percent of the total. Energy efficiency and housing renovation each took about 23 percent of the total funding. Air-quality measures received 15 percent of the clean-air funding, and cycling infrastructure about 7 percent, shares higher than in Italy and Poland for these two specific fields. Over 8 percent of the funding was spent on renewable energy.

In the second MFF period, 2021-2027, the share of funds allocated to railways and transport projects remained stable, as well as energy-efficiency and housing renovation projects. On the other hand, clean-air specific projects were no longer supported. The share of funds allocated to cycling infrastructure and to renewable energies has been nearly halved, though financial support has increased in absolute terms.

Table 14: Allocation of EU clean air funds by sector in Romania

Romania	**2014-2020**	**2021-2027**
Railways/Transport	42%	42%
Clean air specific	15%	0%
Cycling	7%	4%
Housing renovation/energy efficiency	23%	28%
Renewable energy	8%	5%
Other	6%	21%

Source: Bruegel.

The way forward

In Romania, where the average age of cars is around 15 years, transitioning to newer vehicles is particularly important for combating air pollution. Older cars often lack the advanced emission control technologies found in more recent models, resulting in higher levels of pollutants (eg nitrogen oxides and particulate matter). To combat the negative impacts of old cars, Romania must strengthen regulatory measures in the transport sector, improve public transport infrastructure, and promote the adoption of newer cars, including electric vehicles where the penetration rate is particularly promising (Figure 16). Newer cars not only enhance air quality but also align with broader goals of environmental sustainability and public health improvement.

4 Conclusions and recommendations

Air pollution remains a great challenge for the EU, costing millions of years of life lost and billions of euros in economic losses every year. Analysing the annual exposure to particulate matter, PM2.5 – a consolidated proxy for air pollution – at the regional level, we identified hotspots, that is regions that are impacted disproportionately by air pollution. We also quantified the economic losses that each region, member state, and the EU, incurred from air pollution from 2005 to 2021. Using a similar methodology, we quantified the economic gains stemming from the reduction in air pollution over the same period. Based on the observed trends, we extrapolated our analysis to 2030, and compared the estimated gains and losses with the observed and projected GDP. Our analysis, based on the methodology developed in Dechezleprêtre *et al* (2019), highlights the potential economic benefits of cleaning up the air.

We then compared our economic analysis to the EU funds that were allocated to clean-air policies in the 2014-2021 and 2021-2027 periods, and to member state subsidies for fossil fuels from 2015 to 2023, and the projections until 2027.

Third, we assessed clean-air policies in more detail, such as phasing out diesel vehicles, progressively banning polluting cars from densely populated cities, or the replacement of polluting heating devices by cleaner ones. We focused on four EU countries – Poland, Italy, Czechia and Romania – where concentrations of particulate matter are particularly high. For each of these countries, we examined where the air pollution comes from and how EU funds spent on clean-air related items are allocated. Our sectoral analysis showed significant differences between these countries, which suggest different ways forward to promote clean air.

Our ten main conclusions and recommendations can be summarised as follows.

1. The health cost of air pollution remains extremely high. Air pollution is among the greatest global health threats, alongside pandemics and cancer. Despite significant progress in recent decades, air pollution causes over 300,000 deaths in the EU every year, that is 6 percent of annual mortality, or half the death toll from the first year of the COVID-19 pandemic. Furthermore, air

pollution causes more than 3 million years of life lost, adjusted for disability. On average, therefore, each death caused by air pollution is associated with 10 lost years of life.

2. The economic cost of air pollution is greater than previously acknowledged. Air pollution causes €600 billion in economic losses every year, or 4 percent of annual GDP. The economic costs of air pollution stem from productivity losses, such as increased absenteeism, reductions in productivity and harm to ecosystems (eg water, crops and forests). The economic impact of air pollution is highest in Eastern Europe and Italy, where losses are projected to remain above 6 percent of annual GDP in the years to come (ie until 2030). On the positive side, the costs of air pollution have decreased by 40 percent compared to the previous decade at the EU level, suggesting the efficacy of national emission reduction obligations and limit values set in the previous air quality directives.
3. Clean air action is profitable. Promoting clean air is not only compatible with, but can boost, economic growth. Air-pollution reduction has boosted the EU economy by €50 billion to €60 billion each year since 2014. These gains stem from a variety of policy tools (eg regulation, incentives) and dedicated funds, both at national and EU level. Our economic analyses indicate that, while action on air pollution is often framed in the media and in the public debate as a cost, clean-air action is a profitable investment that will yield economic benefits in multiple sectors. Changing the discourse may be key to generate greater coherence among different EU sectors and policies.
4. Air pollution hotspots. Overall, the EU is on track to achieve a 55 percent reduction in air-pollution mortality by 2030 compared to 2005. However, overall progress hides worrying disparities, with more than one region in four not on track to meet this objective. Worse, at the current pace, more than 30 percent of EU regions will not meet current air quality standards by 2030. In the 10 percent most-polluted regions, air pollution will remain in 2030 three times higher than the WHO's latest recommendations. The health and economic burden associated with air pollution is disproportionately high in Eastern Europe (eg Poland, Czechia, Greece, Croatia, Hungary, Bulgaria), and in the north of Italy (ie the Po Valley), where the EU's 20 most polluted regions are located. While these regions have 13 percent of the EU's population, nearly one person in four who dies prematurely because of air pollution lives in one of these regions. Action against air pollution, and the corresponding funds, should be prioritised, not delayed, in these regions.
5. Northern Italy and Poland deserve particular attention, as air quality is poor and is hardly improving.
    a. In Western Europe, the Po Valley is disproportionately impacted by air pollution. While it has 40 percent of Italy's population, it had 54 percent of total air pollution mortality in 2014-2021. The economic costs of air pollution are projected to be around € 85 billion per year until 2030, that is 9 percent of the regional GDP. The slow progress in the Po Valley stems from the combination of a high industrial and agricultural activity, important population density, and specific topographic conditions.
    b. In Eastern Europe, Poland is disproportionately impacted by air pollution. While it represents 8 percent of the EU's population, air pollution mortality was more than 13 percent in 2014-2021. The economic costs of air pollution are projected to be around € 80

billion per year until 2030, that is 11 percent of the country's GDP. The slow progress in Poland results from a high dependence on fossil fuels, including coal.

6. The updated Ambient Air Quality Directive sends a strong signal but leaves loopholes. Ensuring its adequate implementation (eg compliance with limit values for key pollutants), will be a long battle, especially in view of the agreed exceptions and postponements for regions that do not make sufficient progress. Of particular importance are urban centres, which account for 70 percent of air-pollution hotspots.
7. The EU has the means to support clean-air action. While the EU allocated €7 billion annually to promote clean-air policies between 2014 and 2020, a 3.5 times increase is projected for the 2021-2027 period, with nearly 70 percent of these funds stemming from the Resilience and Recovery Facility. Our estimate is in line with, but significantly above, the European Commission's impact assessment for the Ambient Air Quality Directive revision in 2022. This increased funding reflects the EU's commitment to promote cleaner air both politically and financially. Furthermore, our analysis revealed that EU funding is allocated to member states that need it the most.
8. Support for fossil fuels must be phased out. Fossil-fuel consumption is one of the main obstacles to achieving clean air. Yet subsidies to fossil fuels were 14 times higher than EU clean-air funds between 2014 and 2020 and are projected to remain five times higher for the years to come. Member states should progressively reduce subsidies to fossil fuels, going hand in hand with the decarbonisation of the economy over the next few years.
9. What are the most efficient policies? The effectiveness of clean-air policies is context-dependent. Identifying concrete actions for each region and quantifying their potential gains is paramount to accelerate the transition to cleaner air. In Eastern Europe, for example, it is most profitable to replace coal heaters by clean devices, while in the north of Italy, where population density is highest and topographical conditions hinder air-pollution dispersion, reducing industrial and agricultural emissions, or accelerating transition to cleaner transport would reap more benefits. In particular, more clean-air specific projects are needed. Indeed, in EU's most affected countries, less than 5 percent of the total funds allocated to clean air have targeted this objective as their primary goal.
10. Clean-air action needs to be sustained in the years to come. The economic costs of air pollution – and thus the potential gains associated with its reduction – are estimated at more than €3 trillion for the period 2024-2030 – that is 2.9 percent of projected GDP over this period. Supporting clean-air action beyond the Recovery and Resilience Facility, which covers the majority of the current EU funds, is thus paramount. Clean-air funds should be maintained – if not increased – in the next multiannual financial framework, on the basis of the substantial health and economic benefits of reducing air pollution. A possible route is, of course, the progressive phase out of fossil-fuel subsidies.

Outlook and future work

Many aspects of air pollution deserve further attention, including the link between air pollution and climate and the transboundary aspects of air pollution, or the policy challenges that the EU will face in the upcoming years including curbing the emissions of ammonia via regulation of behavioural changes. More details are given below.

How much does climate policy solve air pollution and vice versa? As argued, climate change and air pollution are two aspects of the same problem, as they both result from human activities. Understanding to which extent they are intertwined requires further research. For example, what levels of air pollution will remain once a net-zero economy is reached? Our analysis suggested that fossil fuels explain between 30 percent and 50 percent of air pollution costs, but a regional analysis is required as the concept of net zero is global, as opposed to air pollution's localised impacts. Conversely, quantifying the implications of clean-air policy in terms of air-pollution reduction deserves more attention.

Revising the NEC Directive, namely in terms of ammonia. Following on from EU members agreeing to revise the air quality directives, next steps point towards setting more ambitious regulation for national emissions. Of particular importance is ammonia, an important precursor of PM2.5, the predominant emitter of which is the agricultural sector. Despite the existence of technically and economically viable measures to reduce ammonia – such as agronomic, livestock, or energy measures – they have yet to be adopted at the scale and intensity necessary to deliver significant emission reductions. This may be particularly relevant in areas where dispersion of pollutants is particularly difficult, such as the Po Valley in northern Italy.

Behavioural change. Another important route for improving air quality is a demand reduction for activities and products that pollute air. Two important examples are mobility and food. By reducing the number of cars or, equivalently, by increasing the mean occupancy of each car, emissions of nitrogen oxides can be significantly reduced too. On the other hand, ammonia reduction could be achieved not only by efficiency measures, but by a progressive shift to less-polluting dietary habits. The extent to which such behavioural change could help member states reduce air pollution deserves further study.

The role of pollution peaks to raise awareness of clean air policies. While air pollution can be proxied by mean annual exposure to PM2.5, air pollution peaks deserve more attention. Not only are they an important explanatory variable for assessing the cost of air pollution, but they also give more visibility to air pollution. To what extent air pollution peaks can raise awareness among the population, and more importantly adherence to stricter clean-air measures, is key for policymakers.

More transparency in national and EU funds. The economics of clean air offers another crucial element which we were not able to address: how much EU countries are spending – in their national or regional budgets together – to tackle air pollution. Together with EU funds, this information would allow for more precise cost-benefit analyses of the implemented measures, and more fair comparison with (national)

fossil-fuel subsidies. We lack a common, accessible and interoperable database comprising all EU funded projects with a project description for each. Transparency is key to guide policymakers and assess the effectiveness of the funds allocated to fight air pollution.

Transboundary air pollution should be levered to foster cooperation. While air pollution is highest near source emissions, air pollutants can also travel hundreds or even thousands of kilometres. Quantifying the import-export balance of air pollution between EU regions and countries would not only allow to define fair compensation mechanisms, but also acknowledge that achieving clean air in Europe requires all countries to cooperate, without exceptions.

References

Amann, M., G. Kiesewetter, W. Schöpp, Z. Klimont, W. Winiwarter, J. Cofala … C. Pavarini (2020) 'Reducing global air pollution: the scope for further policy interventions', *Philosophical Transactions of the Royal Society* 378(2183); 20190331

Aragón, F.M., J.J. Miranda and P. Oliva (2017) 'Particulate matter and labor supply: The role of caregiving and non-linearities', *Journal of Environmental Economics and Management* 86: 295-309

Black, M.S., A.A. Liu, I.W. Parry and N. Vernon (2023) 'IMF fossil fuel subsidies data: 2023 update', *Working Paper* No. 2023/169, International Monetary Fund

Carson, R.T., Y. Jeon and D.R. McCubbin (1997) 'The relationship between air pollution emissions and income: US data', *Environment and Development Economics* 2(4): 433-450

CE Delft Assessment (2021) *Health costs of air pollution in European cities and the linkage with transport*, available at https://cedelft.eu/wp-content/uploads/sites/2/2021/03/CE_Delft_190272_Health_costs_of_air_pollution_in_European_cities_and_the_linkage_with_transport_Def.pdf

Chang, K.H., C.C. Hsu, C.H. Muo, C.Y. Hsu, H.C. Liu, C.H. Kao and Y.C. Hsu (2016) 'Air pollution exposure increases the risk of rheumatoid arthritis: a longitudinal and nationwide study', *Environment International* 94: 495-499

Chen, S., P. Oliva and P. Zhang (2022) 'The effect of air pollution on migration: Evidence from China', *Journal of Development Economics* 156: 102833

Clean Air Fund (2021) *The State of Global Air Quality Funding*, available at https://www.cleanairfund.org/resource/state-of-global-air-quality-funding-2023/

Christiansen, P. (2020) 'The effects of transportation priority congruence for political legitimacy', *Transportation Research Part A: Policy and Practice* 132: 61-76

Colombo, L., A. Marongiu, G. Malvestiti, G. Fossati, E. Angelino, M. Lazzarini and G.G. Lanzani (2023) 'Assessing the impacts and feasibility of emissions reduction scenarios in the Po Valley', *Frontiers in Environmental Science* 11

Dechezleprêtre, A., N. Rivers and B. Stadler (2019) 'The economic cost of air pollution: Evidence from Europe', *OECD Economics Department Working Papers* 1584, Organisation for Economic Co-operation and Development, available at https://doi.org/10.1787/56119490-en

Dedoussi, I.C., S.D. Eastham, E. Monier and S. Barrett (2020) 'Premature mortality related to United States cross-state air pollution', *Nature* 578: 261–265

Ebenstein, A., V. Lavy and S. Roth (2016) 'The long-run economic consequences of high-stakes examinations: Evidence from transitory variation in pollution', *American Economic Journal: Applied Economics* 8(4): 36-65

EEA (2021) 'Air Quality Health Risk Assessments', dataset, European Environment Agency, available at https://www.eea.europa.eu/en/datahub/datahubitem-view/49930245-dc33-4c47-93b8-9512f0622ebc

EEA (2023) 'Contributions to EU-27 emissions of BC, CO, NH_3, NMVOCs, NOx, primary PM_{10}, primary $PM_{2.5}$, SO_2 and CH_4 from the main source sectors in 2020', Data Visualisation, European Environment Agency, available at https://www.eea.europa.eu/data-and-maps/daviz/contribution-to-eu-27-emissions/

European Commission (2021) 'EU Action Plan: "Towards Zero Pollution for Air, Water and Soil"', COM(2021) 400 final, available at https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A52021DC0400&qid=1623311742827

European Commission (2022a) 'Attitudes of Europeans towards Air Quality', *Special Eurobarometer* 524, available at https://europa.eu/eurobarometer/surveys/detail/2660

European Commission (2022b) 'The Third Clean Air Outlook', COM(2022) 673 final, available at https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=comnat:COM_2022_0673_FIN2

Fu, Q., D. Lyu, L. Zhang, Z. Qin, Q. Tang, H. Yin and K. Yao (2017) 'Airborne particulate matter (PM2. 5) triggers autophagy in human corneal epithelial cell line', *Environmental Pollution* 227: 314-322

Gaut A.S., D.Z. Fitiwi and J. Curtis (2021) 'Heat pumps and our low-carbon future: A comprehensive review', *Energy Research & Social Science* 71: 101764

Gu, B., L. Zhang, R. Van Dingenen, M. Vieno, X. Zhang, S. Zhang … M.A. Sutton (2021) 'Abating ammonia is more cost-effective than nitrogen oxides for mitigating PM2. 5 air pollution', *Science* 374(6568): 758-762

Heyes, A., M. Neidell and S. Saberian (2016) 'The effect of air pollution on investor behavior: Evidence from the S&P 500', *NBER Working Paper* 22753, National Bureau of Economic Research

Holub, F., L. Hospido and U.J. Wagner (2020) 'Urban air pollution and sick leaves: Evidence from social security data', *Working Paper* 2041, Banco de Espana

IPCC (2022) *Sixth Assessment Report*, Intergovernmental Panel on Climate Change

Jbaily, A., X. Zhou, J. Liu, T.H. Lee, L. Kamareddine, S. Verguet and F. Dominici (2022) 'Air pollution exposure disparities across US population and income groups', *Nature* 601(7892): 228-233

Karagulian, F., C.A. Belis, C.F.C. Dora, A.M. Prüss-Ustün, S. Bonjour, H. Adair-Rohani and M. Amann (2015) 'Contributions to cities' ambient particulate matter (PM): A systematic review of local source contributions at global level', *Atmospheric Environment* 120: 475-483

Karamfilova, E. (2021) *EU policy on air quality : Implementation of selected EU legislation, European Implementation Assessment*, European Parliamentary Research Service, available at https://www.europarl.europa.eu/thinktank/en/document/EPRS_STU(2021)654216

Khomenko, S., M. Cirach, E. Pereira-Barboza, N. Mueller, J. Barrera-Gómez, D, Rojas-Rueda, K. de Hoogh, G. Hoek and M. Nieuwenhuijsen (2021) 'Premature mortality due to air pollution in European cities: a health impact assessment', *The Lancet Planetary Health* 5(3): e121-e134

Landrigan, P.J., R. Fuller, N.J.R Acosta, O. Adeyi, R. Arnold, N. Basu … M. Zhong (2018) 'The Lancet Commission on pollution and health', *The Lancet* 391(10119): 462-512

Lelieveld, J., J.S. Evans, M. Fnais, D. Giannadaki and A. Pozzer (2015) 'The contribution of outdoor air pollution sources to premature mortality on a global scale', *Nature* 525: 367–371

Morton, C., G. Mattioli and J. Anable (2021) 'Public acceptability towards Low Emission Zones: The role of attitudes, norms, emotions, and trust', *Transportation Research Part A: Policy and Practice* 150: 256-270

OECD (2016) *The economic consequences of outdoor air pollution*, Organisation for Economic Co-operation and Development, available at https://www.oecd.org/environment/indicators-modelling-outlooks/the-economic-consequences-of-outdoor-air-pollution-9789264257474-en.htm

OECD (2017) 'The rising cost of ambient air pollution thus far in the 21st century', *OECD Working Papers* 124, Organisation for Economic Co-operation and Development, available at https://doi.org/10.1787/d1b2b844-en

Ostrom, E. (1990) *Governing the commons: The evolution of institutions for collective action*, Cambridge University Press

Pinault, L., M. Tjepkema, D.L. Crouse, S. Weichenthal, A. van Donkelaar, R.V. Martin, M. Brauer, H. Chen and R.T. Burnett (2016) 'Risk estimates of mortality attributed to low concentrations of ambient fine particulate matter in the Canadian community health survey cohort', *Environmental Health* 15: 1-15

Ritchie, H. and P. Rosado (2017) 'Fossil fuels', OurWorldInData.org, last revised in January 2024, available at https://ourworldindata.org/fossil-fuels#article-citation

Sander, K., D. Mira-Salama and A. Feuerbacher (2015) *The Cost of Air Pollution*, World Bank, available at https://doi.org/10.1596/25013

Seibert, R., I. Nikolova, V. Volná, B. Krejčí and D. Hladký (2020) 'Air pollution sources' contribution to PM2.5 concentration in the northeastern part of the Czech Republic', *Atmosphere* 11(5): 522

Springmann, M., R. Van Dingenen, T. Vandyck, C.Latka, P. Witzke and A. Leip (2023) 'The global and regional air quality impacts of dietary change', *Nature Communications* 14(1): 6227

Transport & Environment (2022) 'Quantifying the impact of low- and zero- emission zones: Evidence Review for the Clean Cities Campaign', Logika for the Clean Cities Campaign

UNECE (2022) 'Cost of inaction', United Nations Economic Commission for Europe, available at https://unece.org/sites/default/files/2022-10/ECE_EB.AIR_2022_7-2215043E_0.pdf

Volná, V., D. Hladký, R. Seibert and B. Krejčí (2022) 'Transboundary Air Pollution Transport of PM10 and Benzo [a] pyrene in the Czech–Polish Border Region', *Atmosphere* 13(2): 341

WHO (2005) *Air quality guidelines update 2005*, World Health Organisation, available at https://www.who.int/publications/i/item/WHO-SDE-PHE-OEH-06.02

WHO (2013) *Health risks of air pollution in Europe: HRAPIE project: new emerging risks to health from air pollution: results from the survey of experts*, World Health Organisation, available at https://www.who.int/europe/publications/i/item/WHO-EURO-2013-6696-46462-67326

WHO (2018) *Air quality database: Update 2018*, World Health Organisation, available at https://www.who.int/data/gho/data/themes/air-pollution/who-air-quality-database/2018

WHO (2021) *Air quality guidelines update 2021*, World Health Organisation

World Bank (2019) *Poland, Air Quality Management – Poland Final Report*, available at https://documents1.worldbank.org/curated/en/574171554178748054/pdf/Air-Quality-Management-in-Poland.pdf

World Bank (2022) *The global health cost of PM2. 5 air pollution: a case for action beyond 2021*, available at https://doi.org/10.1596/978-1-4648-1816-5

Xie, Y., H. Dai, Y. Zhang, Y. Wu, T. Hanaoka and T. Masui (2019) 'Comparison of health and economic impacts of PM2. 5 and ozone pollution in China', *Environment International* 130: 104881

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Bruegel, Rue de la Charité 33, B-1210 Brussels
(+32) 2 227 4210
info@bruegel.org
www.bruegel.org