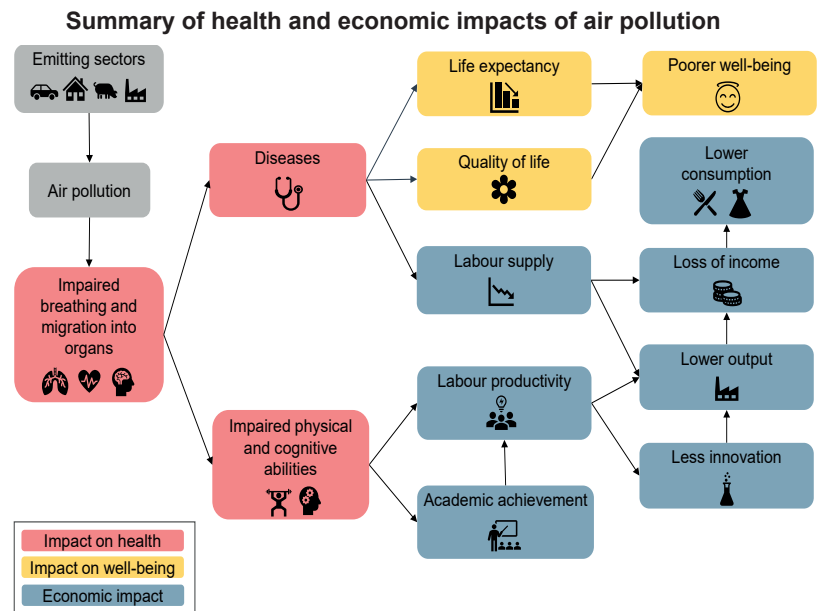


Beyond Health Impacts: the Heavy Economic Toll of Air Pollution

Laure Baratgin, Agathe Eupherte and Nicolas Taconet

- Air pollution is a major public health issue. Fine particulate matter is associated with more than 40,000 deaths each year in France. It also interacts with other pollutants to trigger or worsen many diseases affecting organs including the lungs, heart and brain. It is estimated to account for 20% of new asthma cases in children.
- These health impacts carry a high socio-economic cost, related not just to direct healthcare expenditure (e.g. hospitalisation and medicine costs) but also to impaired quality of life and lost production due to sickness absence.
- In addition to these effects on mortality and morbidity, recent research papers have shown that air pollution also affects cognitive and physical abilities, resulting in lower productivity. These impacts can be seen across a broad array of occupations not just involving physically demanding work, in agriculture and industry for example, but also involving a cognitive aspect, such as financial services, call centres, and even umpiring in sport.
- In addition to these direct short-term impacts, air pollution may also be undermining future productivity by reducing academic achievement and hampering innovation.



Source: DG Trésor.

How to read this chart: Air pollution from various business sectors affects health in many different ways, carrying a heavy economic cost and leading to poorer well-being.

1. While substantial improvements have been made, air pollution is still high in some parts of France, with knock-on effects for public health

1.1 Air pollution has multiple causes

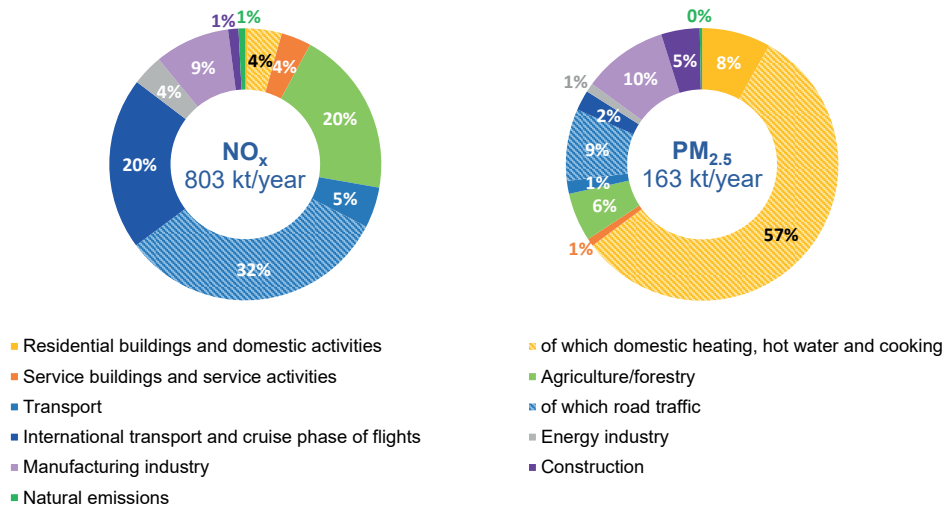
Atmospheric pollution is the contamination of air by gases and particulate matter that are harmful to human health and the environment. These substances are primarily emitted by human activities, in particular transport, agriculture, domestic heating (chiefly wood and fuel oil), and industry. They may also be caused by natural processes such as volcanic eruptions, the release of volatile organic compounds (VOCs) by plants, or chemical reactions between substances already in the air (secondary pollutants).

The main pollutants monitored to assess air quality include nitrogen oxides (NO_x) and fine particulate matter (PM_{2.5}). Nitrogen oxides include nitrogen dioxide (NO₂), an irritant gas, and nitric oxide (NO), which is not highly toxic in itself but is a precursor to NO₂. They are mainly formed during the combustion of fossil fuels, with road transport a key contributor (see Chart 1). Fine particulate matter (PM_{2.5}) is defined as solid particles measuring 2.5 µm or less in diameter. It can be released directly (see Chart 1), in particular from wood combustion for residential heating, domestic

hot water and cooking, which together accounted for 57% of direct emissions in 2024. It can also be formed in the atmosphere from other pollutants. Agriculture is estimated to account for an average of 22% of fine particulate concentrations in France through the ammonia (NH₃) formed from the nitrogen in animal waste and mineral fertilisers, despite being responsible for just 6% of direct emissions.¹ In a similar vein, emissions from other European countries account for 18% of concentrations, and intercontinental and natural pollution² for 21%.

Pollutant concentration is a key indicator of air quality (see Box 1). Levels of nitrogen dioxide (NO₂), mainly from road transport, tend to be particularly high close to major traffic routes and in large urban areas (see Chart 2). Fine particulate matter (PM_{2.5}) concentrations are highest in the north and east of France. This geographical distribution can be explained by a variety of factors including population density, greater use of wood for heating, proximity to other European countries, and steeply sloping terrain making temperature inversions more likely to occur.³

Chart 1: Breakdown of emissions by sector in mainland France in 2024, for two main types of atmospheric pollutant (NO_x and PM_{2.5})



Source: CITEPA, SECTEN, 2025.

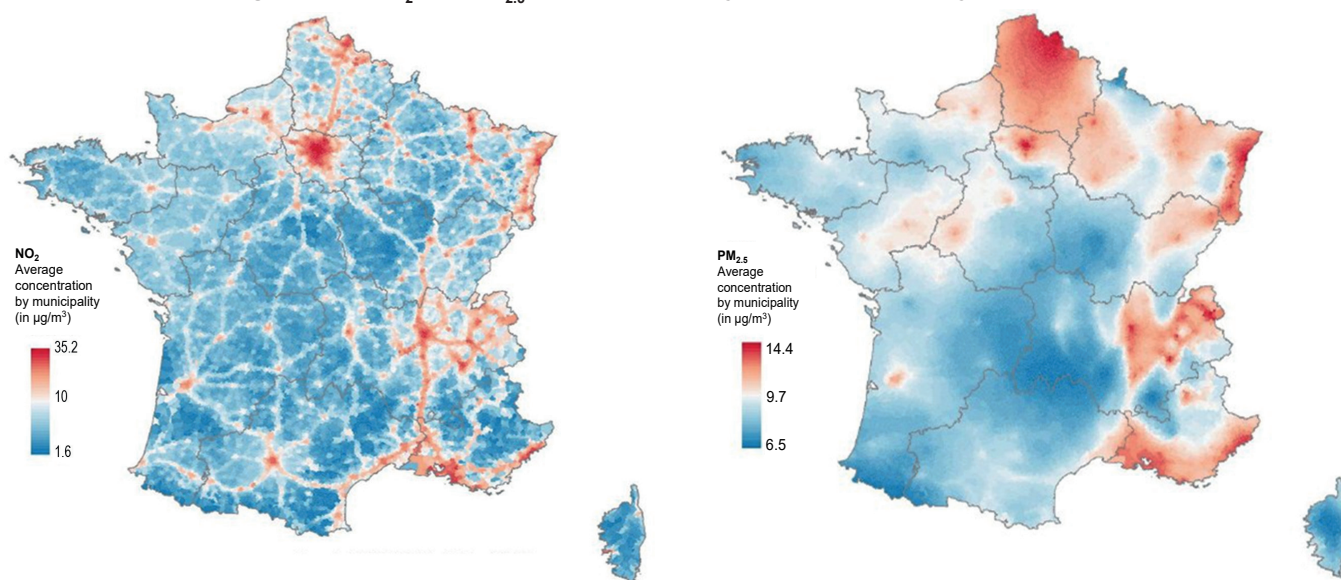
How to read this chart: In 2024, 37% of France's NO_x emissions were generated by domestic transport (excluding the cruise phase of flights), of which 32% by road transport and 20% by international and air transport. 66% of PM_{2.5} emissions stemmed from the use of buildings and from residential and service activities.

(1) Calculated by the French National Institute for Industrial Environment and Risks (INERIS), presented in the study entitled "Le bois énergie et les particules" (in French only) published by the Central Laboratory for Air Quality Monitoring (LCSQA) on 2 October 2024.
 (2) Anthropogenic pollution from outside Europe and all natural sources such as Saharan dust, sea salt, compounds from plants, etc.
 (3) During the winter, cold air sinks into valley bottoms and traps pollutants close to the ground.

Box 1: Emissions and concentration: two distinct indicators of air quality

Emissions and concentration are two indicators used to measure air quality. Emissions refer to the quantity of pollutants released into the atmosphere and are measured in tonnes per year (t/year). Concentration, measured in micrograms per cubic metre of air ($\mu\text{g}/\text{m}^3$), refers to the quantity of pollutants in the ambient air at a given place and moment in time. Concentration is hence governed not just by emissions but also by other factors such as weather conditions (e.g. wind, temperature, sunlight), geography (e.g. valley or dense urban area) and secondary chemical reactions taking place in the air. It is a key indicator of air quality and the related health risks.

Chart 2: Average annual NO_2 and $\text{PM}_{2.5}$ concentrations by French municipality over the 2016-2019 period



Source: Data from INERIS, CHIMERE, 2023 – Maps: The French Public Health Agency 2024.

How to read this chart: NO_2 concentrations are particularly high in urban areas and close to road traffic. $\text{PM}_{2.5}$ concentrations are higher in urban areas and in the east and north of France.

1.2 France and the EU have set ambitious air quality targets backed up by policies to achieve them

At EU level, the revised Air Quality Directive,⁴ which came into force in December 2024, sets concentration limits for the main atmospheric pollutants (see Table 1 for the targets relating to NO_2 and $\text{PM}_{2.5}$). These standards will become more stringent in 2030, but will remain less stringent than the recommendations laid down by the World Health Organization (WHO) in its air quality guidelines.⁵ Another EU directive, the National Emission Ceilings (NEC) Directive,⁶ sets annual

limits on total emissions of various pollutants for each Member State and requires that each country draw up a national air pollution control programme including measures applicable to each sector.

In France, these EU directives form the framework for air pollution control. The National Plan for the Reduction of Air Pollutant Emissions (PREPA), revised every four years, is the main monitoring instrument. Its latest edition⁷ (2022-2025) includes several measures spanning all emitting sectors: transport (Low-Emission Zones,⁸ grants for the purchase of electric vehicles, railway network upgrades), agriculture (regulation



- (4) Directive (EU) 2024/2881 of the European Parliament and of the Council of 23 October 2024 on ambient air quality and cleaner air for Europe (recast).
- (5) WHO global air quality guidelines.
- (6) Directive (EU) 2016/2284 of the European Parliament and of the Council of 14 December 2016 on the reduction of national emissions of certain atmospheric pollutants.
- (7) Official Journal of the French Republic – No. 291 of 16 December 2022 (in French only).
- (8) Low-Emission Zones (LEZs) were introduced by the Mobility Reform Act (2019) and strengthened by the Climate and Resilience Act (2021), requiring urban areas with more than 150,000 inhabitants to restrict access for the most polluting vehicles. In 2025, 25 metropolitan areas had set up an LEZ.

of landspreading to reduce ammonia emissions), residential heating (grants to help fund the cost of replacing wood-burning and fuel oil-fired boilers) and industry (tighter regulations to reduce emissions across the sector, and stricter monitoring of certain classified installations).⁹ These national policies are complemented by various local plans. In regions that exceed quality thresholds or include an urban area with more than 250,000 inhabitants, an Atmosphere Protection Plan (PPA) is implemented under the prefect's authority. This plan sets emission reduction targets for each pollutant and sector, along with the key measures required to achieve them. At municipal or intermunicipal level, a Regional Climate, Air and Energy Plan (PCAET) is mandatory for government-funded intermunicipal cooperation institutions (EPCIs) with tax-levying powers and more than 20,000 inhabitants. The PCAET includes an air quality action plan which must

be consistent with the Atmosphere Protection Plan (if one exists), while also reviewing air quality across the region and proposing measures to improve it. Such measures might include not just reducing emissions, but also reducing the population's exposure to air pollution.

The measures implemented to combat air pollution are often also low-carbon solutions implemented as part of the transition to net zero. As a result, many of France's climate change mitigation policies also deliver significant co-benefits in terms of curbing air pollution. According to the European Commission's "Fit-for-55" scenarios,¹⁰ decarbonising the energy, domestic heating and transport sectors, combined with ongoing technological developments, would reduce fine particulate emissions by around 40% between 2015 and 2030 in France.

Table 1: Targets set for France for nitrogen dioxide (NO₂) and fine particulate matter (PM_{2.5})

	Emission reduction targets (relative to 2005)		Target concentrations (µg/m ³)				
			Annual average		Daily average ^a		
	NEC Directive 	Environmental Code 	Air Quality Directive 		WHO guidelines 	Air Quality Directive 	WHO guidelines 
			2020	2030		2025	
NO _x /NO ₂ ^b	-50%	-69%	-60%	40	20	10	50
PM _{2.5}	-27%	-57%	-42%	25	10	5	25

a. The WHO guidelines and the EU directive also set limits on the number of days these daily values can be exceeded: WHO specifies three days per year, and the EU 18 days.

b. The air quality targets are defined in terms of NO₂, as this is the gas that poses a direct threat to human health. However, the emission targets are defined in terms of NO_x, which includes both nitric oxide (NO) and nitrogen dioxide (NO₂), because emitted NO is then partially converted into NO₂ in the atmosphere.

Source: DG Trésor based on regulatory provisions: NEC Directive (EU) 2016/2284, Air Quality Directive (EU) 2024/2881, Environmental Code (Article D222-38), WHO air quality guidelines.

How to read this chart: The European Union sets emission reduction targets for pollutants and air quality (pollutant concentrations in the air). NO_x emissions, for example, must be reduced by 69% by 2030 relative to 2005.

(9) Installations classified on environmental protection grounds (ICPEs).

(10) Policy Scenarios for Delivering the European Green Deal; modelled using the GAINS model.

1.3 Air quality has improved significantly but still exceeds the thresholds set by WHO in some areas, especially large cities, at certain times of the year

Air quality in France has improved substantially over the last two decades. Between 2005 and 2024, NO_x emissions fell by 60% and PM_{2.5} emissions by 54% (see Chart 3), thereby meeting the targets set by the NEC Directive and the PREPA. Average air concentrations of these pollutants have also fallen across the country, and the regulatory air quality standards are now exceeded in far fewer urban areas than in the past. Only 1.2% of urban areas exceeded these standards for NO₂ in 2024, compared with 19% in 2005.¹¹ As for fine particulate matter, no urban areas have exceeded the long-term air quality standard since 2015.¹²

However, the progress made still falls short of the thresholds recommended by WHO guidelines, which are much stricter than the limit values set by the EU. In 2024, daily PM_{2.5} concentrations exceeded the WHO guidelines for more than 30 days at almost half

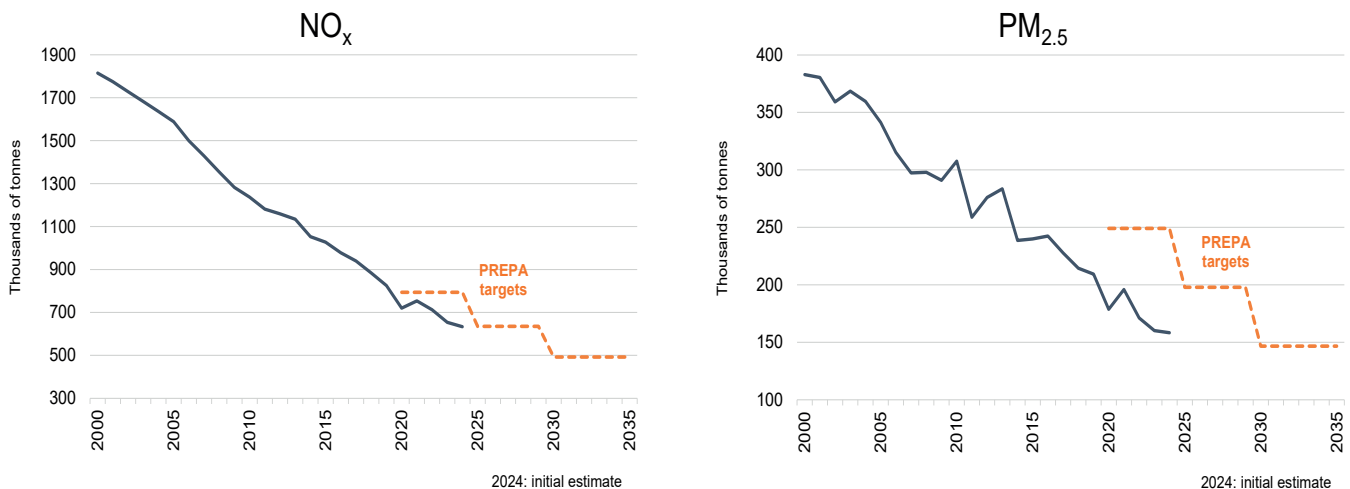
of France's monitoring stations.¹³ These exceedances mainly affect large urban areas and occur at certain times of the year, particularly in winter due to domestic heating and in summer during ozone episodes.¹⁴

1.4 The impacts of air pollution on health are well known

Exposure to air pollution has well-documented harmful effects on the respiratory system and the human body in general. Nitrogen dioxide irritates the airways and contributes to asthma and lung infections.¹⁵ Fine particulate matter can enter the bloodstream via the lungs and spread throughout the body, damaging organs¹⁶ such as the heart, brain,¹⁷ liver, pancreas and reproductive system.

Air pollution causes both short-term (acute) health effects resulting from brief exposure to high pollution episodes, and long-term (chronic) health effects linked to prolonged exposure, generally occurring after a latency period that can range from several months to several decades.

Chart 3: Change in annual emissions over the 2000-2024 period and targets set for France



Source: CITEPA 2025.

How to read this chart: Between 2000 and 2024, annual NO_x emissions decreased by 65% and PM_{2.5} emissions by 59%. Since 2020, emissions of these two pollutants have complied with the limit values set by the NEC Directive and reflected in the PREPA.

(11) SDES (2025), "Bilan de la qualité de l'air extérieur en France en 2024" (in French only). The regulatory air quality standards considered here are the limit values defined by the EU Air Quality Directive.

(12) Ibid.

(13) DG Trésor calculation based on 2024 Geod'air data (in French only) on 260 air pollution monitoring stations in France.

(14) During ozone peaks, high concentrations of ozone – a highly reactive oxidising agent – speed up the conversion of certain atmospheric gases into secondary fine particulates matter. These photochemical reactions, triggered by sunlight and heat, are why high ozone levels often coincide with an increase in fine particulate concentrations.

(15) Ministry for Health (2025), "Dualité de l'air : Sources de pollution et effets sur la santé" (in French only).

(16) WHO (2018), "First Global Conference on Air Pollution and Health".

(17) S. A. Meo, N. Shaikh, M. Alotaibi et al. (2024), "Effect of Air Pollutants Particulate Matter (PM_{2.5}, PM₁₀), Sulfur Dioxide (SO₂) and Ozone (O₃) on Cognitive Health", *Scientific Reports* 14, 19616.

Epidemiological studies have highlighted the significant health impacts of prolonged exposure to pollution (over several years). According to the French Public Health Agency, 40,000 deaths per year are attributable to prolonged exposure to fine particulate matter in France, and a further 7,000 to NO₂.¹⁸ The European Environment Agency, for its part, estimated¹⁹ that 21,000 and 5,000 premature deaths in 2022 in France

may be attributable to long-term exposure to these two pollutants at levels above WHO guidelines.

Prolonged exposure to air pollution is also associated with chronic respiratory, cardiovascular and metabolic diseases (e.g. diabetes). In children, 20% of new asthma cases may also be linked to exposure to fine particulate matter, and 15% of new cases in urban areas may be due to NO₂ exposure.²⁰

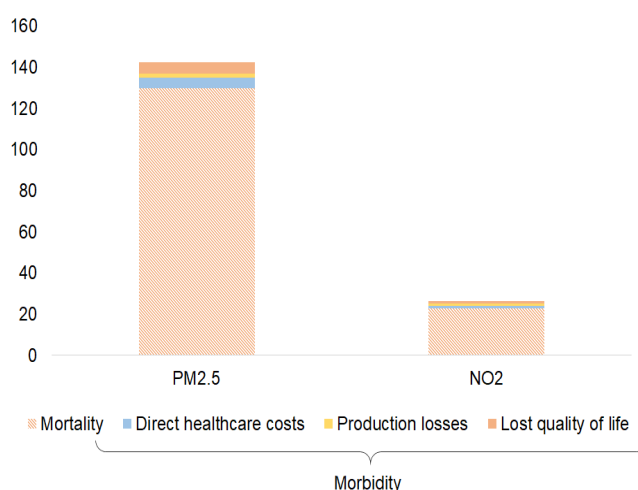
2. The effects of air pollution on individuals have multiple economic impacts that recent literature calls for reassessing

2.1 Socio-economic assessments have examined the health impact of air pollution

The effects of air pollution go far beyond human health alone and represent a significant economic cost. Drawing on methods to monetise health impacts (see Box 2), the French Public Health Agency²¹ estimates that, between 2016 and 2019, the effect of air pollution on morbidity represented an annual economic cost of around €12.9bn₂₀₁₈ for anthropogenic PM_{2.5} emissions and €3.8bn₂₀₁₈ for anthropogenic NO₂ emissions (see Chart 4).

A previous study²² published in 2020 estimated the monetary value of premature deaths avoided in a scenario without anthropogenic fine particulate pollution in 2008 at €145bn₂₀₀₈. Applying this study methodology to French Public Health Agency data, the impact of air pollution on mortality between 2016 and 2019 would represent an annual economic cost of €130bn₂₀₁₈ for fine particulate matter and €23bn₂₀₁₈ for NO₂ (see Chart 4). In a scenario in which PM_{2.5} concentrations did not exceed WHO guidelines in any French city, the study estimated a gain of €53bn₂₀₀₈ in terms of avoided premature deaths.

Chart 4: Estimated annual health impacts of anthropogenic PM_{2.5} and NO₂ pollution in France between 2016 and 2019 based on French Public Health Agency data²³ – in €bn₂₀₁₈



Source: The French Public Health Agency. DG Trésor calculation of mortality-related harm using the method developed by Chanel et al. (2020).²⁴

How to read this chart: The estimated economic cost of the health impacts of anthropogenic PM_{2.5} pollution is €143bn, of which €130bn due to premature deaths. Of the €12.9bn linked to the impact of anthropogenic PM_{2.5} pollution on morbidity, €5.3bn relate to direct healthcare costs, €1.9bn to production losses, and €5.7bn to intangible costs associated with loss of quality of life.

(18) S. Medina et al. (2021), "Impact of Ambient Air Pollution on Mortality in Metropolitan France: Reduction Related to Spring 2020 Lockdown and New Data for Total Burden of Impact for the Period 2016-2019", Saint Maurice: French Public Health Agency, 12 p.

(19) European Environment Agency (EEA) (2024), "Country Population Data and Estimated Attributable Deaths from Air Pollution, 2022".

(20) S. Medina (2025a), "Estimation de la morbidité attribuable à l'exposition à long terme à la pollution de l'air ambiant et de ses impacts économiques en France hexagonale, 2016-2019. Volume 1 : Évaluation quantitative d'impact sur la santé (EQIS-PA)", French Public Health Agency, 158 p. (in French only).

(21) S. Medina et al. (2025b), "Estimation de la morbidité attribuable à l'exposition à long terme à la pollution de l'air ambiant et de ses impacts économiques en France hexagonale, 2016-2019. Volume 2 : Évaluation des impacts économiques" (in French only), French Public Health Agency, 94 p. Estimate produced for a defined scope of diseases. Other diseases are also being considered within the EMAPEC project ("Estimating the morbidity from air pollution and its economic costs"), supervised by WHO and involving the French Public Health Agency. As this Trésor-Economics went to press, the results had yet to be published.

(22) O. Chanel, S. Medina & M. Pascal (2020), "Évaluation économique de la mortalité liée à la pollution atmosphérique en France" (in French only).

(23) S. Medina et al. (2021), op. cit., for the mortality data and S. Medina et al. (2025a and 2025b), op. cit., for the morbidity data.

(24) O. Chanel et al. (2020), op. cit.

Box 2: Monetising health impacts in socio-economic studies

Health impacts can be monetised to quantify their cost to society.

A. The monetary valuation of mortality

Mortality is valued in monetary terms by valuing either premature deaths or years of life lost. The former is based on the value of a statistical life (VSL), which estimates how much society is willing to pay to reduce risks of premature death, and the latter on the value of a life year (VOLY). In France, an official VSL has been defined and is updated regularly. The Quinet report^a recommends a single reference VSL of €3m₂₀₁₀ for all fields of application, causes of death and ages of individuals, and an official VOLY of €115,000₂₀₁₀.

B. The monetary valuation of morbidity

Health impacts on morbidity are monetised on the basis of three components:

1. **Direct healthcare costs.** These costs include medical expenses related to illness, such as hospitalisation, consultations and medicines. They are estimated using hospital databases and health insurance statistics, in order to identify the additional costs associated with a specific factor such as exposure to pollution.
2. **The cost of production losses.** These costs correspond to resources lost by patients or their carers due to illness, such as lost workdays or impaired ability to work due to poor health. The calculation is based on the average value of per capita production (GDP per capita or average salary).
3. **The cost of lost quality of life.** The impact of morbidity on quality of life can be valued on the basis of willingness to pay to avoid hospitalisation or illness, or by combining disability-adjusted life years (DALYs) with the monetary value of a DALY. DALYs can be estimated based on expected duration and disability weights for each disease. The French Public Health Agency study^b adopts a reference value of €45,000₂₀₁₈ per DALY.

a. General Commission for Strategy and Planning (2013), "Cost Benefit Assessments of Public Investments" (summary and recommendations available in English).

b. S. Medina et al. (2025b), op. cit.

2.2 Air pollution impairs physical and cognitive abilities

Exposure to air pollution affects not only people's health and physical abilities (see section 1.4), but also their cognitive abilities.²⁵ This means that pollution can impair workers' performance both in physically demanding jobs and in roles with a more cognitive focus.

In terms of physical abilities, air pollution can lead to increased fatigue and a loss of endurance. Empirical literature (see Box 3) has shown that

these mechanisms make workers less productive, with particularly visible effects in sectors such as agriculture²⁶ and industrial production,²⁷ where pollution directly affects individuals' performance. However, the magnitude of these effects appears to depend on the level of exposure: one study²⁸ of workers in industrial towns in China, chronically exposed to high levels of pollution, did not detect any immediate impacts on their productivity, suggesting that adaptation mechanisms may mitigate short-term effects in polluted environments.

(25) S. Aguilar-Gomez et al. (2022), "This Is Air: The "Nonhealth" Effects of Air Pollution", *Annual Review of Resource Economics*, Vol. 14:403-425

(26) J. G. Zivin & M. Neidell (2012), "The Impact of Pollution on Worker Productivity", *American Economic Review*, 102(7), pp. 3652-3673.

(27) T. Chang et al. (2016), "Particulate Pollution and the Productivity of Pear Packers", *American Economic Journal: Economic Policy*, Vol. 8, No. 3 and A. Adhvaryu et al. (2022), "Management and Shocks to Worker Productivity", *Journal of Political Economy*, 130(1), 1-47.

(28) J. He et al. (2019), "Severe Air Pollution and Labor Productivity: Evidence from Industrial Towns in China", *American Economic Journal: Applied Economics*, 11(1), 173-201.

Air pollution also impairs cognitive abilities, potentially leading to lower concentration, memory disorders and increased fatigue. Empirical studies have found declines in performance in the financial sector,²⁹ in call centres³⁰ and even in sports officiating.³¹ Workers whose productivity is impaired in this way become less accurate, take longer breaks, and need more time to complete certain complex tasks.

A recent study³² focusing on the construction sector also highlights a significant impact on workplace safety, with the likelihood of accidents increasing as NO₂ levels rise. The results were similar with particulate pollution.³³

Box 3: Establishing the causal impact of pollution

Estimating the economic impacts of air pollution requires establishing causal relationships and not merely relying on correlation: a coincidence between a drop in productivity and a deterioration in air quality is not sufficient to demonstrate a causal effect, as other factors (e.g. economic activity or weather conditions) may also play a role.

Recent studies have used econometric methods to isolate exogenous variations in air quality in order to establish the causal impact of pollution. “Difference-in-differences” approaches, for instance, compare variations in economic indicators between areas or periods with different levels of pollution exposure, while controlling for other determinants. Other studies use so-called instrumental variable strategies, leveraging external factors that influence pollutant concentrations but are independent of local economic activity.

Weather conditions are a primary cause of exogenous variations. Wind direction can carry pollutants from one region to another, while temperature inversions trap particulate matter close to the ground. Environmental policies that roll out regulatory changes, such as introducing Low-Emission Zones (LEZs, see Box 4), also create geographical or temporal discontinuities in pollution exposure.^a These “natural experiments” provide researchers with a rigorous framework for identifying the economic impacts of air pollution.

Uncertainties remain in these assessments, however, and provide interesting possibilities for future research. For one thing, it is difficult to assess the long-term effects of pollution,^b due mainly to a lack of data: there would need to be a way to monitor individuals’ exposure over a long period. Furthermore, these methods do not provide a means of identifying the precise physiological processes through which pollution affects the brain (causing damage thereto, for example). Such questions fall within the scope of other specialist research fields.

a. These discontinuities are correlated with economic activity, however, which can make it more difficult to identify the causal effect of environmental policies.

b. Although some studies do exist, including: M. Lubczyk & M. Waldinger (2025), “The Long-Term Effects of Air Pollution on Health and Labor Market Outcomes: Evidence from Socialist East Germany”, *CESifo Working Paper* No. 12197.

(29) J. Huang et al. (2020), “Pollution and Performance: Do Investors Make Worse Trades on Hazy Days?”, *Management Science*, 66(10), pp. 4455-4476 and R. Dong et al. (2021), “Air Pollution, Affect, and Forecasting Bias: Evidence from Chinese Financial Analysts”, *Journal of Financial Economics*, Vol. 139, Issue 3.

(30) T. Chang et al. (2019), “The Effect of Pollution on Worker Productivity: Evidence from Call Center Workers in China”, *American Economic Journal: Economic Policy*, Vol. 11, No. 1.

(31) J. Archsmith et al. (2018), “Air Quality and Error Quantity: Pollution and Performance in a High-Skilled, Quality-Focused Occupation”, *Journal of the Association of Environmental and Resource Economists*, University of Chicago Press, Vol. 5(4), pp. 827-863.

(32) V. Lavy et al. (2025), “Heads up: Does Air Pollution Cause Workplace Accidents?”, *Journal of Public Economics*, Vol. 251.

(33) I. Moreno-Martinez & B. Hattamer (2025), “Dust to Dust: Tracing Air Pollution’s Impact on Work Accidents”, *Journal of the Association of Environmental and Resource Economists*.

2.3 Pollution may have a significant short-term impact on economic activity, notably through reduced worker productivity

In the short term, air pollution affects economic activity through three main channels: absenteeism among affected individuals or caregivers (sick leave or missed school classes – see Box 2), lower productivity among non-absent workers, and lower consumer demand.

The available empirical studies³⁴ suggest that the short-term impacts on activity may be substantial. One study exploiting exogenous variations in wind direction in France shows that a 10% increase in monthly exposure to PM_{2.5} leads to a 0.4% drop in sales for businesses over the following two months, with no subsequent recovery. While pollution increases absenteeism (in the form of sick leave – see Box 2), it only accounts for a small fraction of the estimated losses. Its main adverse impacts are reduced productivity among non-absent workers coupled with falling demand, potentially due to consumers exposed to pollution adapting their spending behaviour (by either postponing or avoiding non-essential purchases) and facing higher healthcare expenses.³⁵ The authors estimate that reducing monthly average exposure to PM_{2.5} by 25% between 2009 and 2015, thus meeting the daily thresholds recommended by WHO, would have generated annual GDP gains of approximately €7bn per year in France, in addition to the expected health benefits in terms of mortality and morbidity avoided (see section 2.1).

Two Europe-wide studies estimate that a 1 µg/m³ increase in PM_{2.5} concentration reduces GDP by 0.8%³⁶ and value added per worker by 0.55%³⁷ in the same year. The impacts are greatest in firms with a large proportion of highly skilled workers, consistent with evidence that pollution affects cognitive ability. This suggests that, between 2000 and 2022, the substantial improvement in air quality in France boosted labour productivity by 1.6%.

2.4 Some studies indicate long-term economic impacts due to reduced human capital accumulation and innovation

In addition to its short-term impacts on the economy, air pollution reduces short- and long-term academic performance, thereby affecting future productivity. Several studies find that pollution exposure is associated with poorer academic outcomes and lower long-term educational attainment. Taking an exam on a day with high PM_{2.5} pollution levels (11 µg/m³ above a baseline level of 21 µg/m³) is estimated to reduce students' grades by 0.9 points out of 100.³⁸ Exposure to pollution during pregnancy or infancy may also have lasting impacts on cognitive development and educational attainment,³⁹ which may even be passed on to the next generation.⁴⁰ Cutting pollution exposure during pregnancy by 10 µg/m³ is estimated to increase the likelihood of the next generation reaching higher education by 1.7 to 1.8 percentage points.

(34) The literature discussing the economic impacts of air pollution is still fairly recent. This is no reason to question the relevance of the mechanisms identified, but does mean that the outcomes should be interpreted with caution.

(35) M. Leroutier and H. Ollivier (2025), "The Cost of Air Pollution for Workers and Firms", CREST, *Working Paper series*.

(36) A. Dechezleprêtre et al. (2019), "The Economic Cost of Air Pollution. Evidence from Europe", *OECD Economics Department Working Papers* No. 1584.

(37) A. Dechezleprêtre and V. Vienne (2025), "The Impact of Air Pollution on Labour Productivity: Large-scale Micro Evidence from Europe", *OECD Science, Technology and Industry Working Papers*, 2025/14.

(38) For an average grade of 71 points. A. Ebenstein et al. (2016), "The Long-Run Economic Consequences of High-Stakes Examinations: Evidence from Transitory Variation in Pollution", *American Economic Journal: Applied Economics*, Vol. 8, No. 4 and quoted references in section 5.2 of S. Aguilar-Gomez et al. (2022), *op. cit.*

(39) S. Von Hinke and E. N. Sørensen (2023), "The Long-Term Effects of Early-Life Pollution Exposure: Evidence from the London Smog", *Journal of Health Economics*, Volume 92, 102827, and A. Isen, M. Rossin-Slater & W. R. Walker (2017), "Every Breath You Take – Every Dollar You'll Make: The Long-Term Consequences of the Clean Air Act of 1970", *Journal of Political Economy*, 125(3), 848-902.

(40) J. Colmer and J. Voorheis (2024), "The Intergenerational Effects of Early-Life Pollution Exposure", (Accepted) *Journal of Political Economy: Microeconomics*.

Lastly, a Europe-wide study estimates that 7.2% fewer patents are filed over the year following a 1 µg/m³ increase in PM_{2.5} pollution, affecting innovation – and therefore, potentially, future productivity.⁴¹

Taken together, these findings suggest that the economic impacts of air pollution reach far beyond the health consequences usually taken into account.

Identifying these additional impacts reinforces the economic case for tackling air pollution through targeted public policies. Furthermore, in addition to the health impacts set out in this report, air pollution causes environmental harm in the form of lower agricultural yields,⁴² damage to buildings, loss of biodiversity and the associated ecosystem services, and more – all of which drive its overall economic cost upwards.

Box 4: Assessing the impact of LEZs in Germany

In 2008, Germany began rolling out Low-Emission Zones (LEZs) restricting access to the least polluting vehicles, with the aim of improving air quality.^a Their effects can now be assessed by comparing areas that have been designated as LEZs with those that have not. Pollution levels were higher in 2008 than they are today, so the gains associated with reducing pollution are also higher. The impact of LEZs hence appears to be all the greater in areas with higher initial pollution levels.

These studies suggest that implementing an LEZ reduces concentrations of air pollutants, by around 2% on average for PM_{2.5}, 2% to 9% for PM₁₀ and 3% to 8% for NO₂. These effects are more pronounced in areas close to major traffic routes.^b

Furthermore, a study on the impact of early-life exposure to air pollution estimates that the German LEZs have brought down healthcare costs, notably for treating childhood asthma.^c Another study on the introduction of LEZs in Germany estimates that pollution has a negative causal effect on education, by increasing absenteeism and impairing long-term academic attainment. In North Rhine-Westphalia, the introduction of LEZs since 2008 is estimated to have increased the number of pupils moving into the academic track (*Gymnasium*) in secondary education by about one percentage point.^d

- a. In France, the first LEZs were introduced in 2015, before being rolled out in all urban areas with more than 150,000 inhabitants, as stipulated by the 2021 Climate and Resilience Act.
- b. M. Gehrsitz (2017), “The Effect of Low Emission Zones on Air Pollution and Infant Health”, *Journal of Environmental Economics and Management*, 83, pp. 121-144 and H. Wolff (2014), “Keep Your Clunker in the Suburb: Low-Emission Zones and Adoption of Green Vehicles”, *The Economic Journal*, Volume 124, Issue 578, Pages F481-F512.
- c. A. Klauber et al. (2024), “Killing Prescriptions Softly: Low Emission Zones and Child Health from Birth to School”, *American Economic Journal: Economic Policy*, 16(2), 220-248.
- d. J. Brehm et al. (2025), “From Low Emission Zone to Academic Track: Environmental Policy Effects on Educational Achievement in Elementary School”, *Journal of Environmental Economics and Management*, Vol. 132.

(41) F. Bracht and D. Verhoeven (2025), “Air Pollution and Innovation”, *Journal of Environmental Economics and Management*, Vol. 130.

(42) The ADEME and INERIS study performed in collaboration with APCA and published in 2019 (“Coût économique pour l’agriculture des impacts de la pollution de l’air par l’ozone” – in French only) provides some initial results regarding ozone-related yield losses for several crops, forest species and pastures in France. Drawing on the APollO research project, this study confirms that ozone reduces output and affects the quality of agricultural produce. Taking the example of common wheat, the yield loss in 2010 in France may have been as high as 15%, or up to six million tonnes of unproduced grain. Studies in other countries such as the US and India also show that air pollution has a measurable effect on agricultural yields. See in particular D. A. Westenberg & G. B. Frisvold (1995), “Air Pollution and Farm-Level Crop Yields: An Empirical Analysis of Corn and Soybeans”, *Agricultural and Resource Economics Review*, 24(2), 156-165 and J. Burney & V. Ramanathan (2014), “Recent Climate and Air Pollution Impacts on Indian Agriculture”, *Proceedings of the National Academy of Sciences*, 111(46), 16319-16324.

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Publication manager:

Dorothée Rouzet
tresor-eco@dgtresor.gouv.fr

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