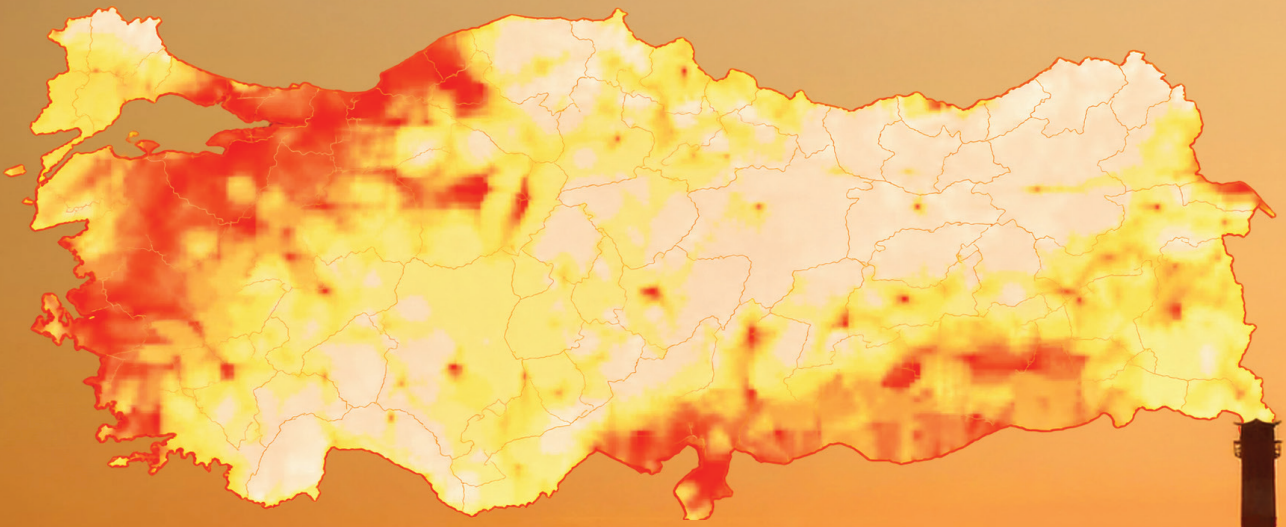




BURNING THROUGH TÜRKİYE'S GDP

The high cost of fossil fuel PM_{2.5}
pollution on public health

ABOUT CREA

The Centre for Research on Energy and Clean Air (CREA) is an independent research organisation focused on revealing the trends, causes, and health impacts, as well as the solutions to air pollution. CREA uses scientific data, research, and evidence to support the efforts of governments, companies, and campaigning organisations worldwide in their efforts to move towards clean energy and clean air, believing that effective research and communication are the keys to successful policies, investment decisions, and advocacy efforts. CREA was founded in Helsinki and has staff in several Asian and European countries.

ABOUT THHP

The Right to Clean Air Platform (THHP) is a platform that unites professional health associations and civil society organisations working on environmental issues, nature conservation, and climate change. Established in 2015, THHP aims to reduce air pollution, protect public health, and ensure the recognition of clean air as a fundamental human right. Through research, advocacy, and effective public communication, the Platform promotes environmental, energy, and climate policies that prioritise health and supports a just transition away from fossil fuels.

Burning through Türkiye's GDP:

The high cost of fossil fuel PM2.5 pollution on public health

October 2026

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| ABBREVIATIONS

BC	Black carbon
CIESIN	Center for International Earth Science Information Network
CO	Carbon monoxide
COPD	Chronic Obstructive Pulmonary Disease
CREA	Centre for Research on Energy and Clean Air
DEFRA	Department for Environment, Food and Rural Affairs
EEA	European Environment Agency
EMEP	European Monitoring and Evaluation Programme
GBD	Global Burden of Disease
GDP	Gross Domestic Product
GNi (PPP)	Gross National Income (Purchasing Power Parity)
GPWv4	Gridded Population of the World, Version 4
HEAL	Health and Environment Alliance
HRAPIE	Health Risks of Air Pollution in Europe
HRW	Human Rights Watch
IEA	International Energy Agency
IHME	Institute for Health Metrics and Evaluation
LPG	Liquefied Petroleum Gases
MSC-W	Meteorological Synthesising Centre – West
NASA	National Aeronautics and Space Administration
NMVOC(s)	Non-Methane Volatile Organic Compounds
NO ₂ / NO ₃	Nitrogen dioxide / Nitrate
NO _x	Nitrogen oxides
OECD	Organisation for Economic Cooperation and Development
PLoS	Public Library of Science
PM _{2.5} / PM ₁₀	Particulate Matter ≤2.5 µm / ≤10 µm
RR	Risk Ratio
SO ₂	Sulphur dioxide
THHP	Temiz Hava Hakkı Platformu (Right to Clean Air Platform)
TRY	Turkish Lira
TÜİK	Turkish Statistical Institute
UK	United Kingdom
UN	United Nations
UNPD	United Nations Population Division
USD	US Dollar
VOCs	Volatile Organic Compounds
WHO	World Health Organisation
WPP	World Population Prospects

| KEY FINDINGS

Türkiye's fossil fuel emissions (from domestic sources as well as international aviation and shipping departing from Türkiye) account for 52% of population exposure to PM_{2.5} nationwide.

PM_{2.5} pollution attributable to Türkiye's fossil fuel use is responsible for approximately 26,500 deaths in the country every year, including deaths from cardiovascular and respiratory diseases, lung cancer, stroke, and diabetes.

Children are among the most affected, with fossil fuel-derived PM_{2.5} pollution contributing to an estimated 8,000 preterm births, 8,200 low-birth-weight infants, 5,100 new cases of childhood asthma and 6,500 emergency room visits for asthma each year.

The cumulative health impacts of fossil fuel-derived PM_{2.5} pollution are estimated to cost the Turkish economy approximately USD 55 billion each year, equivalent to 4.1% of national GDP in 2024.

Transboundary pollution attributable to Türkiye's land-based fossil fuel emissions also leads to thousands of deaths in five neighbouring countries, with estimated economic burden per year (as of 2024) reaching USD 2.1 billion in Egypt (3,200 deaths), USD 0.2 billion in Syria (1,700 deaths), USD 0.8 billion in Iraq (800 deaths), USD 4.5 billion in Israel (500 deaths), and USD 1.5 billion in Greece (400 deaths).

Türkiye currently has no national ambient air quality standard for PM_{2.5}, despite the substantial health burden associated with exposure to the pollutant. Reducing fossil fuel use and emissions across Türkiye's energy, transport and industrial systems would deliver substantial air quality and public health benefits by reducing exposure to PM_{2.5} and preventing associated illness and deaths.

| INTRODUCTION

Fine particles (PM_{2.5}) are toxic pollutants that harm people throughout their lives. Exposure during pregnancy is associated with adverse birth outcomes, including preterm birth and low birth weight (Sapkota et al., 2012). Exposure to PM_{2.5} can worsen respiratory conditions such as asthma and increase emergency room visits (Zheng et al., 2015). Over the longer term, exposure contributes to chronic disease and premature death, including cardiovascular and respiratory diseases, lung cancer and diabetes (Burnett et al., 2022). In Türkiye, concentrations of PM_{2.5} above the World Health Organisation (WHO) 5 µg/m³ guideline are linked to 62,644 deaths each year (THHP, 2025).

The economic consequences of PM_{2.5} exposure can be substantial. The World Bank estimates that ambient PM_{2.5}-related health damages amount to trillions of dollars globally (World Bank, 2022). In Türkiye, the economic burden associated with PM_{2.5} exposure has been estimated at USD 138 billion per year (THHP, 2025). Yet, there is no legally binding ambient air quality standard for PM_{2.5} in the country, although regulations for other pollutants, such as PM₁₀, exist (THHP, 2025).

Fossil fuels are a significant source of PM_{2.5} pollution (McDuffie et al., 2021). PM_{2.5} is a mixture of particles with different chemical components. Some are emitted directly during the combustion of coal, oil and gas, including black carbon and organic carbon. Fossil fuel combustion also releases precursor gases, including nitrogen oxides (NO_x), sulphur dioxide (SO₂), ozone (O₃), polycyclic aromatic hydrocarbons (PAHs), and volatile organic compounds (VOCs), which undergo chemical reactions in the atmosphere to form secondary particulate matter. The contribution of fossil fuels to PM_{2.5} pollution therefore extends beyond particles emitted directly at the source. These emissions and the particles they form can also travel through the atmosphere, meaning that fossil fuel use can affect populations far from where the fuel is burned.

The health and economic burden associated with coal-fired power generation in Türkiye has been well-documented. The Health and Environment Alliance (HEAL) has quantified the health and economic impacts associated with emissions from Türkiye's coal-fired power plants, including mortality and economic losses (HEAL, 2022). A health impact assessment of the proposed Alpu coal-fired power plant in Eskişehir similarly estimated substantial additional premature mortality over the plant's lifetime (Etiler et al., 2024). More recent evidence from around existing coal facilities, including the Afşin-Elbistan power complex, has continued to highlight air pollution and concerns about its impacts on nearby communities (Human Rights Watch, 2025). For other fossil fuel sources, however, the available evidence is less complete.

Fossil fuel use in Türkiye extends well beyond coal-fired power generation. In 2024, coal accounted for 35% of electricity generation, while natural gas accounted for a further 19% (IEA, 2025). Road transport remains overwhelmingly dependent on fossil fuels: in 2024, 66% of energy consumed in road transport came from diesel, 17% from liquefied petroleum gas (LPG) and 16% from gasoline, compared with just 0.2% from electricity (TÜİK, 2025). Industry is also heavily reliant on fossil fuels, with 24% of final energy consumption supplied by natural gas, 23% by solid fossil fuels and 14% by petroleum products in 2024 (TÜİK, 2026). Together, these fossil fuels accounted for around 60% of industrial final

energy consumption. Basic metals, including steel production, alone accounted for 23% of industrial energy consumption (TÜİK, 2025). Indeed, across the European Monitoring and Evaluation Programme (EMEP) network and Organisation for Economic Co-operation and Development (OECD) member states, Türkiye ranks among the top three in industrial emissions of toxic pollutants (OECD, 2019; CEIP, 2026).

This means that the health and economic burden associated with fossil fuel-attributable PM_{2.5} in Türkiye extends beyond coal-fired power. While the contributions of individual fossil fuel sources to air pollution have been documented in various contexts, their combined contribution to PM_{2.5} exposure and its health and economic consequences has not been assessed at the national level. This report provides the first comprehensive assessment of this burden.



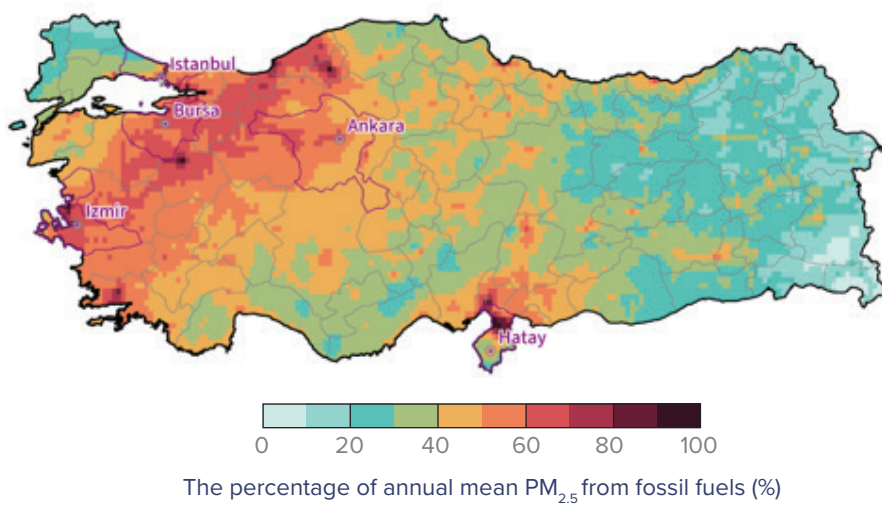
@Hakan Arslan

The pollution footprint of fossil fuels

THE POLLUTION FOOTPRINT OF FOSSIL FUELS

In this section, we explore how emissions from fossil fuels contribute to ambient PM_{2.5} concentrations across Türkiye. We use emission inventories submitted by Türkiye to EMEP together with the EMEP MSC-W (Meteorological Synthesizing Centre-West of EMEP) chemical transport model to simulate air quality under current conditions and under a counterfactual in which selected fossil fuel emissions are removed.

Figure 1. The percentage of Türkiye's fossil fuel emissions in total annual PM_{2.5} emissions, using the EMEP emission inventory and EMEP MSC-W chemical transport model

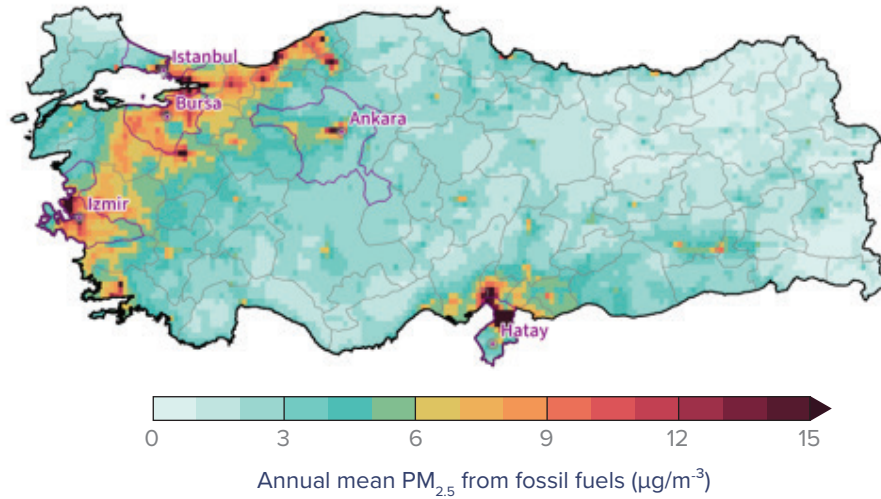


Source: CREA analysis (2026)

The fossil fuel contribution considered in our main assessments includes emissions from land-based sources within Türkiye, together with emissions from international shipping and aviation, which include shipping and aviation to and from Türkiye. Land-based sources include power generation, industry, residential and commercial buildings, on-road and off-road transport, and other energy-related activities involving the combustion of coal, oil or natural gas. The contribution of these domestic sources is shown in Appendix 1. The model also includes natural sources, such as dust, soils and lightning, and other human-made sources besides fossil fuels. The contribution of fossil fuel sources to PM_{2.5} concentrations is estimated as the difference between the baseline simulation and the simulation in which these fossil fuel emissions are removed. This captures both PM_{2.5} emitted directly from fossil fuel combustion and PM_{2.5} formed in the atmosphere from precursor pollutants.

Figure 1 demonstrates the percentage of annual PM_{2.5} emissions in Türkiye's fossil fuel emissions. Fossil fuels contribute substantially to annual mean PM_{2.5} concentrations across Türkiye, particularly in the more populated western parts of the country, including the provinces of Istanbul, Bursa and Izmir, as well as in Hatay Province in the south. Türkiye's fossil fuel emissions contribute 52% of population exposure to PM_{2.5} nationwide.

Figure 2. The absolute contribution of fossil fuel emissions to annual mean PM_{2.5} concentrations in Türkiye, simulated using the EMEP emission inventory and EMEP MSC-W chemical transport model

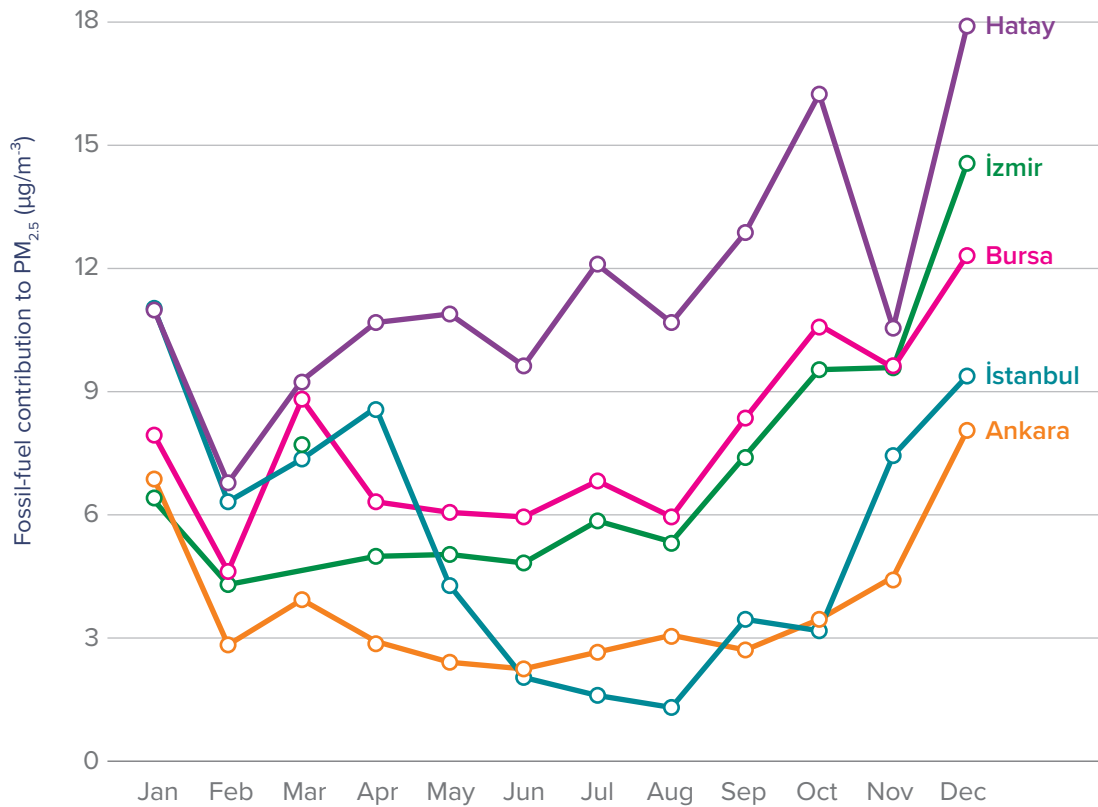


Source: CREA analysis (2026)

Figure 2 shows the total influence of fossil fuels on annual mean PM_{2.5} emissions concentrations across Türkiye. Overall, we find that emissions from fossil fuels have a substantial influence on particulate pollution across the country. The map shows particularly high fossil fuel-derived PM_{2.5} concentrations in several major population centres and industrial regions. For example, the average concentration contribution of fossil fuel sources is 5 µg/m³ in Istanbul, 8 µg/m³ in Bursa, 4 µg/m³ in Ankara, 7 µg/m³ in Izmir and 12 µg/m³ in Hatay.

Previous research indicates that pollution peaks during winter months, and so here we explore how fossil fuels influence this phenomenon. Figure 3 shows the seasonal cycle in fossil fuel-derived particulate pollution across five of the largest cities. Across most of these cities, monthly mean fossil fuel PM_{2.5} concentrations peak in the winter, reaching around 18 µg/m³ in Hatay, 9 µg/m³ in Istanbul and 8 µg/m³ in Ankara in December. However, these wintertime pollution episodes do not remain confined to cities.

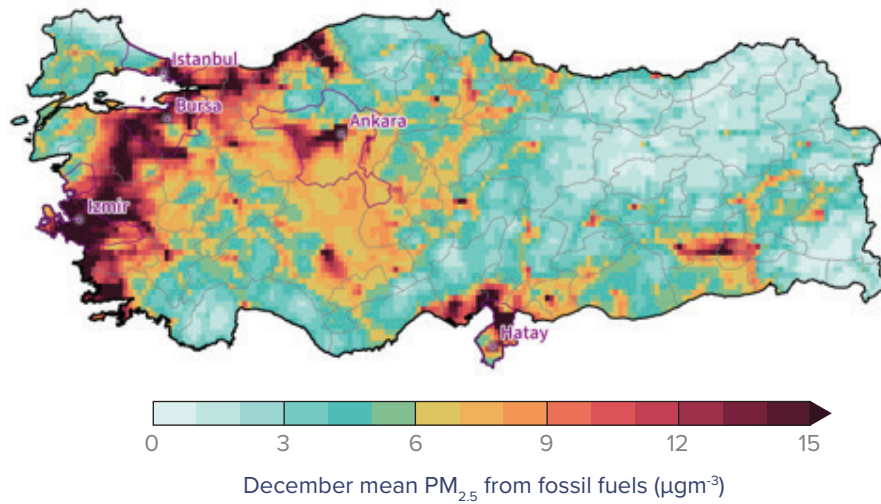
Figure 3. Contribution of fossil fuel emissions in Türkiye to monthly mean PM_{2.5} concentrations in Istanbul, Ankara, Bursa, Izmir and Hatay



Source: CREA analysis (2026)

Figure 4 shows the contribution of fossil fuels to monthly mean PM_{2.5} concentrations across the whole country. In December, fossil fuels lead to monthly mean PM_{2.5} concentrations exceeding 15 µg/m³ across much of western Türkiye, with hotspots across the west. Low temperatures can increase the conversion of gaseous nitrate (NO₃) to PM_{2.5}, and temperature inversions and low wind speeds can prevent the dispersion of pollution (Seinfeld & Pandis, 2016; Wan et al., 2026). Increased fuel burning during the cold months can also increase pollutant emissions.

Figure 4. Contribution of fossil fuel emissions to December mean PM_{2.5} concentration in Türkiye, simulated using the EMEP emission inventory and EMEP MSC-W chemical transport model



Source: CREA analysis (2026)

Overall, these simulations reveal that fossil fuels play a crucial role in both long-term exposure to PM_{2.5} throughout the year and episodes of severe wintertime haze. Their influence extends across Türkiye, affecting air quality in both urban and rural areas. This demonstrates that fossil fuel pollution is not confined to individual cities or industrial hotspots, but is a nationwide public environmental problem. In the next section, we explore how these exposures affect human health.



@Greenpeace

The health burden of fossil fuels

THE HEALTH BURDEN OF FOSSIL FUELS

Using the fossil fuel-attributable $PM_{2.5}$ concentrations described above, which include emissions from fossil fuel sources within Türkiye together with international shipping and aviation, we estimated the associated health burden for the population of the country, and the results are shown in Table 1. The methods used to calculate these impacts are described in detail in the methodology section. In general, we use $PM_{2.5}$ concentrations levels simulated by the EMEP MSC-W model, together with health incidence data and concentration-response functions. All analyses are based on emissions reported by Türkiye for the year 2024, and meteorology from the year 2015. Since fossil fuel combustion also contributes to exposure to other harmful air pollutants, including SO_2 , CO, NO_x , and VOCs, the total health and economic impacts attributed to Türkiye’s fossil fuel emissions may be even larger than our estimate.

Table 1. Annual health and economic impacts in Türkiye attributable to $PM_{2.5}$ from Türkiye’s fossil fuel emissions.*

Health outcome	Annual impacts (2024)**
Asthma emergency room visits	6,500 (4,300–8,700)
New asthma cases in children	5,100 (2,700–7,500)
Low birthweight births	8,200 (2,600–13,800)
Preterm births	8,000 (4,000–8,500)
Work absence (sick leave days)	8,463,000 (7,219,000–9,692,000)
Years lived with disability due to chronic obstructive disease	18,800 (10,000–29,400)
Years lived with disability due to diabetes	52,100 (20,900–102,900)
Years lived with disability due to stroke	11,300 (4,800–20,900)
Years of life lost	498,300 (28,800–787,300)
Deaths	26,500 (15,600–41,200)
Economic costs (billion USD) (2024)	55 (32 – 85)
Economic costs (billion TRY) (2024)	1,800 (1,100 – 2,800)

* These emissions include the domestic fossil fuel emissions within Türkiye, in addition to the fossil fuel emissions from international shipping and aviation to and from Türkiye.

**The ranges represent the 95% upper and lower confidence intervals of the pollutant dose-response functions.

Adverse birth outcomes

The impacts of air pollution on human health begin before birth. We find that fine particle pollution from fossil fuels leads to 8,200 (2,600–13,800) underweight births and 8,000 (4,000–8,500) preterm births per year (Table 1). Such outcomes not only affect the immediate health of infants but also have long-term developmental and health implications, further straining the healthcare system and the individuals affected.

| Asthma-related health impacts

PM_{2.5} pollution damages the respiratory system, particularly in children. We find that PM_{2.5} from fossil fuels contributed to 6,500 (4,300–8,700) asthma-related emergency room visits per year (Table 1). Children are especially vulnerable to air pollution due to their underdeveloped lungs. Indeed, we find that PM_{2.5} from fossil fuels leads to 5,100 (2,700–7,500) children developing asthma each year in Türkiye (Table 1).

For patients and healthcare systems, emergency room visits represent a significant strain, increasing the demand for medical resources such as hospital beds, oxygen therapy, and medications. This burden extends beyond healthcare infrastructure, as frequent asthma episodes can disrupt daily life. Children's asthma leads to school absences and to productivity losses for caretakers, who must take time off work to provide care. For working-age people, the result is work absences. Additionally, the economic strain is felt both at the individual level, such as through medical expenses and lost wages, and at the societal level, such as higher healthcare costs and reduced workforce productivity, which place pressure on public health systems and economies.

| Workforce productivity losses

The impact of air pollution extends beyond direct health outcomes, imposing a significant economic burden on workforce productivity. We estimate that PM_{2.5} pollution from Türkiye's fossil fuel emissions leads to 8.5 (7.2–9.7) million days of work absences due to PM_{2.5} emissions in the country (Table 1). These absences represent lost productivity, disrupted workflows, and reduced economic output across multiple sectors.

| Mortality

Particle pollution from fossil fuel use in Türkiye leads to an estimated 26,500 (15,600–41,200) deaths per year (Table 1). This represents one of the most severe consequences of PM_{2.5} pollution caused by fossil fuels. Deaths caused by PM_{2.5} occur due to lung cancer, chronic obstructive pulmonary disease (COPD), lower respiratory infection, ischemic heart disease, stroke, and diabetes.

Vulnerable populations, including the elderly, children, and those with preexisting health conditions, are disproportionately affected by these pollutants. Deaths carry profound personal and societal costs. While economies face reduced productivity and increased healthcare expenditures, families lose loved ones. The value of these lost lives also reflects a broader moral imperative to address air pollution comprehensively.

Additional health impacts not quantified in this study

The health impacts quantified in this report — birth outcomes, childhood asthma, cardiovascular and respiratory mortality, and diabetes-related disability — represent only part of PM_{2.5}'s documented health burden. A growing body of scientific evidence links exposure to effects across nearly every organ system (WHO, 2021), many of which were not included in the quantitative assessment above, either because the underlying evidence base is still developing or because Türkiye-specific estimates are not yet available. These findings nonetheless reinforce the case for reducing exposure to fossil fuel-derived PM_{2.5}.

PM_{2.5} is small enough to cross from the lungs into the bloodstream and reach the brain, where it contributes to neuroinflammation, oxidative stress and mitochondrial damage (Nan, N., et al., 2023). An expanding body of research links long-term exposure to a higher risk of dementia and Alzheimer's disease (X Huang et al., 2025; Best Rogowski et al., 2025), alongside associations with stroke (Yuan et al., 2019; HEI, 2024) and depression (Borroni et al., 2022; Liu et al., 2021). In children, exposure during pregnancy and early life has been associated with small but measurable reductions in cognitive test performance, adding a further dimension to the developmental effects already reflected in this report's birth-outcome estimates (Alter et al., 2024).

PM_{2.5} has also been classified by the WHO's International Agency for Research on Cancer (IARC) as a Group 1 carcinogen — the agency's highest level of certainty with associations extending beyond lung cancer to bladder (Li et al., 2024), breast (Wang et al. 2025), liver (Pritchett et al., 2022) and colorectal cancers (Pritchett et al., 2022; Fu et al., 2024). Separately, PM_{2.5} weakens immune defences, increasing susceptibility to respiratory and other infections (Yang, L. et al. 2020), an effect that falls disproportionately on children (Mehta et al., 2013; Ni et al., 2025). A more recent body of evidence also links long-term exposure to chronic kidney disease (Wathanavasin et al., 2024), reflecting the kidney's role in the body's endocrine regulation.

Finally, PM_{2.5} exposure has been associated with a range of endocrine and reproductive effects, including gestational diabetes (Yang, B. Y. et al., 2020) and disruption of thyroid function (Liu et al., 2023), as well as a higher risk of stillbirth (Xue et al., 2022) and congenital heart defects (Zhang et al., 2016) when exposure occurs during pregnancy. Taken together, this wider evidence base shows that the health burden of PM_{2.5} pollution extends well beyond the outcomes this report was able to quantify for Türkiye.



@Umut Vedat

The economic cost of fossil fuels

| THE ECONOMIC COST OF FOSSIL FUELS

Many of the health impacts covered in this report have an economic cost to society. For example, work absences lead to productivity losses that affect not only individual employers but also have cascading impacts on national economies. Increased health-related absences strain businesses, reduce workforce efficiency, and drive up operational costs. In addition, the associated healthcare costs compound the financial burden, creating a dual pressure on both the private and public sectors. Finally, deaths significantly weaken the economy by reducing the labour force, lowering productivity, and increasing healthcare costs. Many of the health impacts are associated with increased medical expenses.

When considering the health costs of multiple health outcomes, Türkiye's fossil fuel use is estimated to cause economic damages of TRY 1,800 (1,100–2,800) billion, which is approximately equivalent to USD 55 (32–85) billion (Table 1). This is equivalent to 4.1% of the country's GDP in 2024 (World Bank, 2025). The scale of these damages shows that the costs of fossil fuel dependence extend well beyond the energy system itself and represent a substantial economic as well as public health burden for Türkiye.

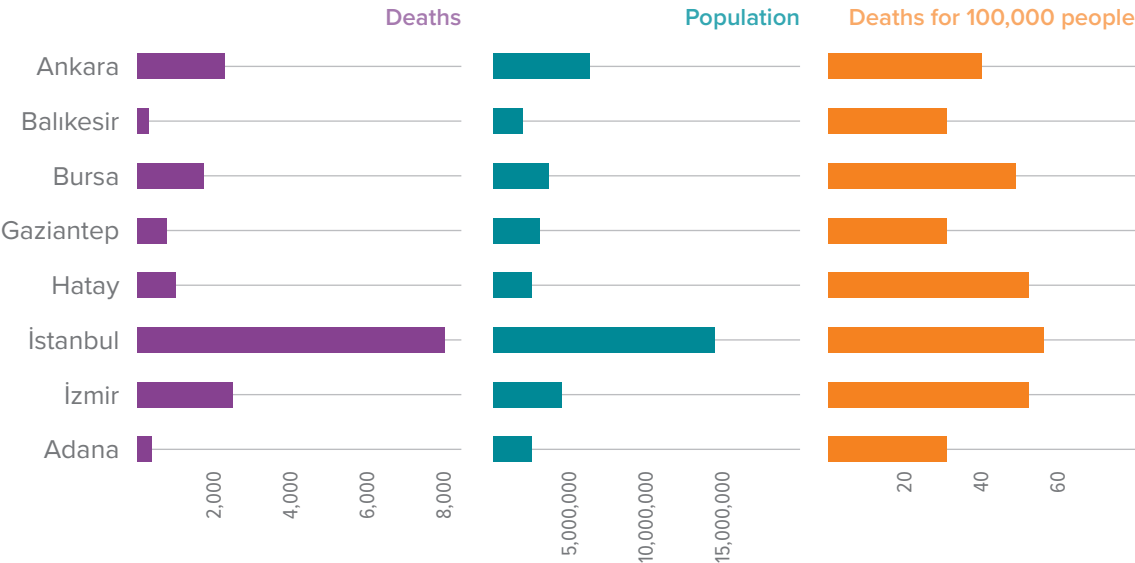
| Regional impacts

The health burden of fossil fuel pollution is not distributed evenly across Türkiye. Differences in fossil fuel-derived PM_{2.5} concentrations, population size and age, and underlying disease rates mean that the number of attributable deaths varies substantially between provinces.

Figure 5 shows the estimated annual deaths attributable to fossil fuel-derived PM_{2.5} in each province. The largest burdens occur in Istanbul, Ankara, Izmir, Bursa, and Hatay, where the combination of high population exposure and underlying health vulnerability results in approximately 8,100, 2,500, 2,400, 1,600, and 1,000 deaths per year, respectively.

However, the absolute number of deaths does not necessarily indicate where fossil fuel pollution poses the greatest risk to an individual resident. Therefore, Figure 5 also shows fossil fuel-attributable deaths per 100,000 people, allowing the health burden to be compared between provinces with very different population sizes. The highest mortality rates occur in Istanbul, where PM_{2.5} from fossil fuels leads to 56 deaths per 100,000 people annually.

Figure 5. Provinces with the highest annual deaths attributable to PM_{2.5} from fossil fuel emissions in Türkiye



Source: CREA analysis (2026)

Together, these results show that the national burden of approximately 26,500 premature deaths masks substantial geographic variation in the impacts of fossil fuel pollution across Türkiye.

Türkiye’s domestic fossil fuel pollution crosses borders

The analysis in this section focuses specifically on Türkiye’s domestic land-based fossil fuel emissions. The geographic reach of these health impacts extends beyond Türkiye’s borders. Air pollutants and their atmospheric reaction products can be transported over long distances, meaning that fossil fuel emissions originating within Türkiye also affect populations in other countries — and the country is affected by fossil fuel pollution from outside its borders.

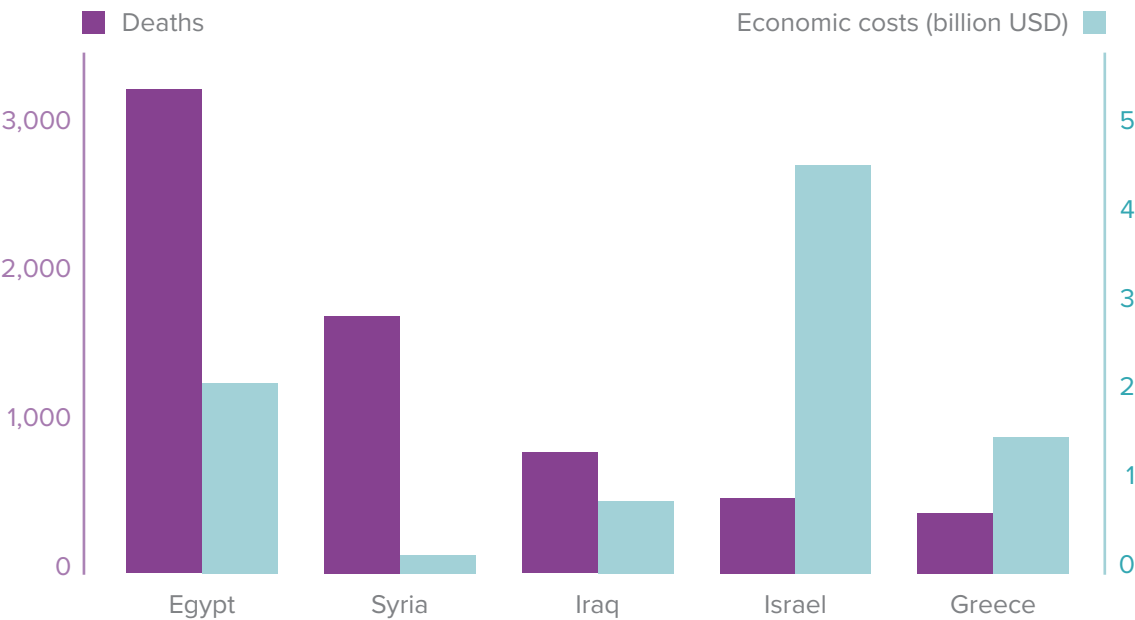
The estimates presented above capture the combined contribution of land-based fossil fuel sources within Türkiye and international shipping and aviation. In order to distinguish the pollution generated by fossil fuel use within Türkiye itself and trace its impacts both within the country and beyond Türkiye’s borders, this section focuses specifically on land-based fossil fuel emissions originating within Türkiye, excluding international shipping and aviation emissions. This allows us to distinguish the pollution generated by fossil fuel use within Türkiye itself and trace its impacts both within the country and beyond Türkiye’s borders. From the results, we see that international shipping and aviation make a rather small contribution to the results.

Pollution from domestic land-based fossil fuel emissions alone results in annual mean PM_{2.5} exposure above the WHO guideline of 5 µg/m³ for 53% of Türkiye’s population, and above the new EU standard of 10 µg/m³ (set to take effect in 2030) for 16% of the population (European Commission, 2024). Türkiye is also affected by transboundary PM_{2.5} pollution from fossil fuel emissions outside the country.

Land-based fossil fuel emissions within Türkiye alone are associated with approximately 25,800 (15,200–40,100) premature deaths annually in the country. This is only modestly lower than the estimated deaths associated with the broader set of fossil fuel sources considered above.

The health burden associated with Türkiye’s land-based fossil fuel emissions is not confined to its borders. Pollutants and their atmospheric reaction products can be transported over long distances, affecting populations in other countries. This transboundary pollution results in a substantial health burden beyond Türkiye’s borders.

Figure 6. Annual deaths attributable to Türkiye’s land-based fossil fuel emissions in the five most affected countries, based on 2024 emissions



Source: CREA analysis (2026)

Figure 6 shows the estimated annual deaths attributable to Türkiye’s land-based fossil fuel emissions in the five most affected countries. Türkiye’s domestic land-based fossil fuel emissions are used in these analyses, since they can be attributed to emissions from Türkiye alone, while aviation and shipping include international emissions as well. Egypt, Syria, Iraq, Israel, and Greece suffer the most from fossil fuels burned in Türkiye, which cause thousands of deaths annually (Figure 6). In Egypt, PM_{2.5} from fossil fuels causes 3,200 (1,800–5,100) deaths, leading to an economic burden of USD 2.1 (1.1–3.3) billion per year as of 2024. For Syria, deaths climb to 1,700 (1,000–2,800), and the economic burden amounts to USD 0.2 (0.1–0.4) billion. In Iraq, there are 800 (500–1,200) deaths, causing an economic burden of USD 0.8 (0.5–1.2) billion annually as of 2024. In Israel, there are 500 (400–700) annual deaths, leading to an economic burden of USD 4.5 (3.2–5.9) billion, and in Greece, there are 400 (300–500) deaths, causing an economic burden of USD 1.5 (1.0–1.9) billion (Figure 6). The economic costs are adjusted to the GDP of 2023 in each country. The economic valuations for these countries are listed in Appendix 2.



@kerem Yücel

Conclusion

| CONCLUSION

| Fine particle (PM_{2.5}) pollution is controllable

Türkiye currently has no national standard for PM_{2.5} pollution, despite its substantial health burden. Our modelling shows that fossil fuels make a major contribution to PM_{2.5} pollution across Türkiye. These emissions are controllable: they can be eliminated by replacing fossil fuels with clean energy or substantially reduced through air pollution controls. Therefore, a significant part of Türkiye's PM_{2.5} burden is preventable.



Policy recommendation:

Establish a national PM_{2.5} standard.

| Fossil fuel phase-out protects health

Fossil fuels drive climate change while also producing toxic air pollution with immediate and long-term consequences for public health and the economy. Fossil fuel-derived PM_{2.5} contributes to approximately 26,500 deaths and USD 55 billion in health-related economic costs each year in Türkiye. Phasing out fossil fuels would therefore deliver major health and economic benefits alongside climate benefits.



Policy recommendation:

Commit to the phase-out of coal-fired power generation.

| Benefits extend beyond borders

Fossil fuel pollution does not stop at national borders. Land-based fossil fuel emissions from Türkiye contribute to thousands of deaths in other countries, with the largest impacts in Syria, Egypt and Iraq. Reducing these emissions would protect public and economic health both within Türkiye and across the wider region.



Key message:

Domestic action would deliver regional health and economic benefits.



@Ümit Bektaş

Methodology

METHODOLOGY

This study quantifies the contribution of fossil fuel emissions associated with Türkiye to ambient fine particulate matter (PM_{2.5}) concentrations and the resulting health and economic impacts. We use a source-attribution approach combining emissions data with atmospheric chemical transport modelling and health impact assessment. Fossil fuel-attributable PM_{2.5} concentrations are estimated by comparing a baseline simulation representing current emissions with counterfactual simulations in which selected fossil fuel emissions are removed. The resulting changes in PM_{2.5} concentrations are then combined with population, baseline health and epidemiological data to estimate associated health impacts and economic costs.

The main assessment considers fossil fuel emissions from land-based sources within Türkiye, together with international shipping and aviation. A separate assessment isolates emissions from land-based fossil fuel sources within Türkiye, allowing their impacts both within Türkiye and across national borders to be quantified. All simulations use anthropogenic emissions for 2024 and meteorological conditions representative of 2015.

EMEP chemical transport model

We use the latest version (v5.6) of the Open Source European Monitoring and Evaluation Programme (EMEP) MSC-W chemical transport model, which is widely used in scientific research. Meteorological conditions, such as temperature, precipitation, and air pressure, are incorporated from the Chemical Coordinating Centre of EMEP, and the model applies sulphur and nitrogen chemistry with photochemistry. We use a model grid domain covering most of Europe, extending from 0 °W to 70.1 °E and from 30 °N to 55.1 °N, at a spatial resolution of 0.1° × 0.1° (approximately 10 km × 10 km). We use the most recent publicly available meteorological data at this grid resolution, which are for the year 2015. The official model configuration used in this study is distributed with model-ready anthropogenic emissions for 2024; these emissions and their treatment in this analysis are described in the next section.

Three simulations were performed using the EMEP MSC-W model. First, a baseline simulation was run using the full anthropogenic emissions inventory. Two counterfactual simulations were then performed in which specified fossil fuel emissions were removed while other emissions remained unchanged.

In the first counterfactual simulation, fossil fuel emissions from land-based sources within Türkiye, together with international shipping and aviation, were removed. The difference in PM_{2.5} concentrations between this simulation and the baseline represents the fossil fuel contribution used for the main assessment of health and economic impacts in Türkiye.

In the second counterfactual simulation, only fossil fuel emissions from land-based sources within Türkiye were removed, while international shipping and aviation emissions remained unchanged. The difference between this simulation and the baseline isolates the contribution of Türkiye's land-based fossil fuel emissions to PM_{2.5} concentrations within Türkiye and across national borders.

This modelling approach captures changes in both directly emitted PM_{2.5} and secondary PM_{2.5} formed in the atmosphere from precursor emissions.

| Emissions

Anthropogenic emissions were taken from the official input dataset distributed for use with the EMEP MSC-W model configuration applied in this study (EMEP/CEIP, 2026). This model configuration uses emissions for 2024, including emissions reported by Türkiye to EMEP and subsequently prepared for use within the EMEP modelling system. Using the emissions supplied with the model ensures consistency between the emissions inventory, model configuration and other model inputs. The country-reported emissions and EMEP emissions are in relatively good agreement for NH₃, CO and NO_x, while larger differences are observed for SO_x, NMVOCs, PM_{2.5}, and PM₁₀. The emissions reported by Türkiye are about 2.4 times those used in the EMEP dataset for SO_x and about 46% higher for NMVOCs. In contrast, the reported PM_{2.5} and PM₁₀ emissions are approximately 40% and 48% lower, respectively. Black carbon (BC) is not available from the country-reported emissions, whereas it is included in the EMEP emission dataset as a speciated component of PM emissions.

To construct the counterfactual simulations described above, we identified the emissions within the EMEP inventory that were attributable to fossil fuel use. The EMEP emissions inventory is organised by source sector rather than by fuel type. Therefore, we classified sectors according to whether their emissions could be attributed directly to fossil fuel use or whether additional separation of fossil and non-fossil sources was required.

For sectors whose emissions are almost entirely associated with fossil fuel use, including electricity generation, road transport, international shipping and aviation, the full reported emissions were classified as fossil fuel emissions.

For sectors containing substantial contributions from both fossil and non-fossil fuels, pollutant-specific scaling factors were applied to estimate the share attributable to fossil fuels. For example, residential and commercial combustion includes emissions from fossil fuels as well as biomass and waste combustion. Scaling factors were therefore applied to distinguish emissions associated with coal, oil and natural gas from those associated with non-fossil fuels.

Industrial emissions require pollutant-specific treatment because the sector includes both fuel combustion and non-combustion industrial processes. Emissions of SO₂, NO_x, PM_{2.5}, PM₁₀, CO and black carbon were classified as fossil fuel emissions, reflecting the dominant role of fossil fuels in industrial energy use. For NMVOCs, only the estimated combustion-related fraction was classified as fossil fuel emissions, recognising that a substantial proportion of industrial NMVOC emissions originates from industrial processes, solvent use and fugitive releases rather than fuel combustion.

Health impact and economic analyses

For the $PM_{2.5}$ concentration associated with fossil fuels derived from the EMEP MSC-W simulations discussed above, we calculate how exposure affects public health and the economy. We select health outcomes where the exposure-response relationship is relatively well-established, indicated by their previous applications in peer-reviewed studies for the global population level. This indicates the evidence is mature enough to be applied across geographies and exposure levels.

CREA has developed a detailed globally implementable health impact assessment (HIA) framework based on the latest science (Myllyvirta, 2020). This framework includes as complete a set of health outcomes as possible without obvious overlaps. Health outcomes covered in this framework have been identified in peer-reviewed academic literature from meta-studies across multiple populations, for which incidence data are available at the national level from global datasets.

For each health outcome, we use a concentration-response relationship that has been used in peer-reviewed academic literature to quantify the global health burden from air pollution. This indicates that the evidence is mature enough to be applied across varying geographies and exposure levels. We estimate the number of cases for each health outcome following a standard epidemiological calculation:

$$\Delta cases = Pop \times \sum_{age} \left[Frac_{age} \times Incidence_{age} \times \left(\frac{RR_{c,age}}{RR_{c_{base},age}} - 1 \right) \right],$$

Where:

Pop is the total population in the grid cell;

age is the specific age group for which the epidemiological studies have established a health risk;

$Frac_{age}$ is the fraction of the population belonging to the specific age group;

$Incidence_{age}$ is the baseline rate of occurrence of the health outcome for the population belonging to the specific age group;

c is the pollutant concentration from the baseline combined with pollution from the sources that had been discussed in this work, with c_{base} referring to the baseline concentration or current ambient concentration; and,

$RR_{c,age}$ is the function giving the risk ratio of the health outcome at the given concentration for the given age group.

In the case of a log-linear, non-age-specific concentration-response function, the RR function becomes:

$$RR(c) = RR_0 \exp\left(\frac{c - c_0}{\Delta c_0}\right) \text{ when } c > c_0, 1 \text{ otherwise}$$

Where:

RR_0 is the risk ratio found in epidemiological research;

Δc_0 is the concentration change that RR_0 refers to; and,

c_0 is the assumed no-harm threshold concentration.

Table 2 presents a summary of the health outcomes included in this study, together with their associated data and sources. Incidence rates come from a variety of sources, including the Global Burden of Disease results for 2023 (GBD, 2025), which is accessed from the Institute for Health Metrics and Evaluation (IHME, 2025). We use Gridded Population of the World v4 (for the latest year, 2020) from the Centre for International Earth Science Information Network (CIESIN, 2025). We then scale this to the target year using changes in population and death rates from the World Population Prospects dataset of the United Nations Department of Economic and Social Affairs (UN DESA, 2024).

Health impact modelling projects the effects of pollutant exposure during the study year. Some health impacts are immediate, such as exacerbation of asthma symptoms and lost working days, whereas other chronic impacts may have a latency of several years. Concentration-response relationships for emergency room visits for asthma and work absences are based on studies that evaluated daily variations in pollutant concentrations and health outcomes; these relationships were applied to changes in annual average concentrations.

Table 2. Input parameters and data used in estimating physical health impacts

Age group	Effect	Pollutant	Relative risk	No-risk threshold	Reference	Incidence data
0–17	Asthma emergency room visits	PM _{2.5}	1.025 (1.013–1.037) / 10 µg/m ³	6 µg/m ³	Zheng et al. (2015)	Anenberg et al. (2018)
18–99	Asthma emergency room visits	PM _{2.5}	1.023 (1.015–1.031) / 10 µg/m ³	6 µg/m ³	Zheng et al. (2015)	Anenberg et al. (2018)
Newborn	Preterm birth	PM _{2.5}	1.15 (1.07–1.16) / 10 µg/m ³	8.8 µg/m ³	Sapkota et al. (2012)	Chawanpaiboon et al. (2019)
Newborn	Low birth weight	PM _{2.5}	1.10 (1.03–1.18) per 10 µg/m ³	4 µg/m ³	Dadvand et al. (2013)	(IHME, 2025)
20–65	Work absence	PM _{2.5}	1.046 (1.039–1.053) / 10 µg/m ³	0 µg/m ³	WHO (2013)	EEA (2014)
0–4	Deaths from lower respiratory infections	PM _{2.5}	Burnett et al. (2022)	0 µg/m ³	Burnett et al. (2022)	IHME (2025)
25–99	Deaths from non-communicable diseases, disaggregated by cause, and from lower respiratory infections	PM _{2.5}	Burnett et al. (2022)	0 µg/m ³	Burnett et al. (2022)	IHME (2025)
25–99	Disability caused by diabetes, stroke and chronic respiratory disease	PM _{2.5}	Burnett et al. (2022)	0 µg/m ³	Burnett et al. (2022)	IHME (2025)

Note: Numeric values in the column 'Relative risk' refer to the odds ratio corresponding to the increase in concentrations given in the column 'No-risk threshold'. Literature 'References' indicate the use of a non-linear concentration-response function. No-risk threshold refers to a concentration below which the health impact is not quantified, generally because the studies on which the function is based did not include people with lower exposure levels. Data on concentration-response relationships do not exist for all geographies, so a global risk model is applied to all cities. Incidence data are generally unavailable at the city level, so national averages have to be applied.

Air pollution increases the risk of developing respiratory and cardiovascular diseases, while also increasing complications from them, significantly lowering the quality of life and economic productivity of people affected and increasing healthcare costs. Economic losses as a result of air pollution were calculated using the methods outlined in Myllyvirta (2020). The valuation of deaths was updated to the values derived by Viscusi & Masterman (2017), which are based on labour market data, and pay particular attention to applicability in middle- and low-income countries.

The Global Burden of Disease project has quantified the degree of disability caused by each disease into a 'disability weight' that can be used to compare the costs of different illnesses. The economic cost of disability and reduced quality of life caused by these diseases and disabilities is assessed based on disability weights, combined with the economic valuation of disability used by the UK environmental regulator DEFRA (Birchby et al., 2019), and adjusted by GNI PPP for Türkiye. The deaths of young children are valued at twice the valuation of adult deaths, following the recommendations in OECD (2012). For the valuations used in our methodology, see Table 3.

Table 3. Input parameters and data used to estimate the economic costs of health impacts

Outcome	Valuation at current USD for year 2023*	Valuation at 2023 Turkish lira**	Reference
Work absence (sick leave days)	50	1,191	EEA, 2014
Deaths	1,964,000	46,782,480	Viscusi & Masterman, 2017
Asthma emergency room visits	152	3,620	Brandt et al., 2012
Preterm births	70,580	1,681,215	Trasande et al., 2016
Years lived with disability	19,260	458,773	Birchby et al., 2019

* Valuation is calculated for 2023 based on average GDP/GNI and income at country level because of the lack of recent-year GDP/GNI and income data for part of the region. Final economic costs are then scaled to the year 2024 based on OECD GDP projections.

** The exchange rate is USD 1: TRY 23.78 for the year average.

References

Achakulwisut, P., Brauer, M., Hystad, P. and Anenberg, S. C. (2019). Global, National, and Urban Burdens of Paediatric Asthma Incidence Attributable to Ambient NO₂ Pollution: Estimates from Global Datasets. *The Lancet*, 3 (4): E166-E178.

 doi.org/10.1016/S2542-5196(19)30046-4

Alter, N.C., Whitman, E.M., Bellinger, D.C. et al. (2024). Quantifying the association between PM_{2.5} air pollution and IQ loss in children: a systematic review and meta-analysis. *Environmental Health*, 23, 101.

 doi.org/10.1186/s12940-024-01122-x

Anenberg, S., Henze, D., Tinney, V., Kinney, P., Raich, W., et al. (2018). Estimates of the Global Burden of Ambient PM_{2.5}, Ozone, and NO₂ on Asthma Incidence and Emergency Room Visits. *Environmental Health Perspectives*, 126(10).

 doi.org/10.1289/EHP3766

Best Rogowski C, Bredell C, Shi Y et al. (2025). Long-term air pollution exposure and incident dementia: a systematic review and meta-analysis. *The Lancet Planetary Health*, Volume 9, Issue 7, 101266, July 2025.

 doi.org/10.1016/S2542-5196(25)00118-4

Birchby, D., Stedman, J., Whiting, S. and Vedrenne, M. (2019). Air Quality Damage Cost Update 2019. 2019. *Ricardo Energy & Environment*/ED59323/Issue Number 2.0.

 uk-air.defra.gov.uk/assets/documents/reports/cat09/1902271109_Damage_cost_update_2018_FINAL_Issue_2_publication.pdf

Borroni, E., et al. (2022). Air pollution exposure and depression: A comprehensive updated systematic review and meta-analysis. *Environmental Pollution*, 292, 118245.

 doi.org/10.1016/j.envpol.2021.118245

Brandt, S.J., Perez, L., Künzli, N., Lurmann, F. and McConnell, R. (2012). Costs of childhood asthma due to traffic-related pollution in two California communities. *European Respiratory Journal*, August 2012, 40(2): 363-370.

 doi.org/10.1183/09031936.00157811

Burnett, R., Chen, H., Szyszkowicz, M., Fann, N., Hubbell, B., et al. (2018). Global Estimates of Mortality Associated with Long-Term Exposure to Outdoor Fine Particulate Matter. *Proceedings of the National Academy of Sciences*, 115 (38): 9592-9597.

 doi.org/10.1073/pnas.1803222115

Burnett, R. T., Spadaro, J. V., Garcia, G. R., & Pope, C. A. (2022). Designing health impact functions to assess marginal changes in outdoor fine particulate matter. *Environmental Research*, 204, 112245.

Chawanpaiboon, S., Vogel, J., Moller, A., Lumbiganon, P., Petzold, M., et al. (2018). Global, Regional, and National Estimates of Levels of Preterm Birth in 2014: A Systematic Review and Modelling Analysis. *The Lancet Global Health*, 2018.

 doi.org/10.1016/S2214-109X(18)30451-0

EMEP Centre on Emission Inventories and Projections (CEIP). (2026). Officially reported emission data.

 www.ceip.at/webdab-emission-database/reported-emissiondata?utm_source=chatgpt.com

The Center for Integrated Earth System Information (CIESIN). (2025). Gridded Population of the World, Version 4 (GPWv4): Population Density, Revision 11 | NASA *Earthdata* [Dataset]. Earth Science Data Systems, NASA.

 www.earthdata.nasa.gov/data/catalog/sedac-ciesin-sedac-gpww4-popdens-r11-4.11

Dadvand, P., Parker, J., Bell, M., Bonzini, M., Brauer, M., et al. (2013). Exposure to Particulate Air Pollution and Term Birth Weight: A Multi-Country Evaluation of Effect and Heterogeneity. *Environmental Health Perspectives*, 1 March 2013; 121 (3): 267–373.

 doi.org/10.1289/ehp.1205575

EMEP/CEIP (2026), Emissions as used in EMEP models, accessed: October, 2026.

 www.ceip.at/webdab-emission-database/emissions-as-used-in-emep-models

Etiler, N., Yikici, A., Akgul, O., Myllyvirta, L., & Uz, D. (2024). Health impact assessment of a proposed coal-fired power plant in Türkiye. *Impact Assessment and Project Appraisal*, 42(1), 56–69.

 doi.org/10.1080/14615517.2023.2300914

- European Commission. (2024). Zero Pollution: New EU rules enter into force for cleaner air by 2030.
 environment.ec.europa.eu/news/new-pollution-rules-come-effect-cleaner-air-2030-2024-12-10_en
- European Environment Agency (EEA). (2014). *Costs of air pollution from European industrial facilities 2008–2012 — an updated assessment*. EEA Technical report No 20/2014.
 www.eea.europa.eu/publications/costs-of-air-pollution-2008-2012
- European Environment Agency (EEA). (2023). *Fugitive emissions from solid fuels: coal mining and handling*. Guidebook, 2023.
 www.eea.europa.eu/en/analysis/publications/emep-eea-guidebook-2023/part-b-sectoral-guidance-chapters/1-energy/1-b-fugitive-emissions-from-fuels/1-b-1-a-fugitive/@download/file
- Fu, P., Li, R., Sze, S. C. W., & Yung, K. K. L. (2024). Associations between fine particulate matter and colorectal cancer: a systematic review and meta-analysis. *Reviews on Environmental Health*, 39(3), 447–457.
 pubmed.ncbi.nlm.nih.gov/36810202/
- Global Burden of Disease Collaborative Network (GBD). (2025). *Global Burden of Disease Study 2023 (GBD 2023) Cause-Specific Mortality 1990–2023*. Seattle, United States of America. Institute for Health Metrics and Evaluation (IHME).
 ghdx.healthdata.org/record/ihme-data/gbd-2023-cause-specific-mortality-1990-2023
- Health and Environment Alliance. (HEAL). (2022). *Chronic coal pollution Turkey: Cumulative health effects*.
 www.env-health.org/wp-content/uploads/2022/01/HEAL-Chronic-Coal-Turkey-infographic_EN.pdf
- Health Effects Institute (HEI) (2024). *State of Global Air 2024*. Special Report. Boston, MA: Health Effects Institute. Erişim tarihi: 06.10.2025 Erişim adresi:
 www.stateofglobalair.org/resources/report/state-global-air-report-2024
- Human Rights Watch. (HRW). (2025). *Türkiye: Amicus Brief in Coal Plant Expansion Case*. July 3, 2025.
 www.hrw.org/news/2025/07/03/turkiye-amicus-brief-in-coal-plant-expansion-case
- Institute for Health Metrics and Evaluation (IHME). (2025). *GBD Results*. Website
 ghdx.healthdata.org/gbd-results-tool
- International Energy Agency (IEA). (2025). *Türkiye – Electricity*.
 www.iea.org/countries/turkiye/electricity
- ISTock. (2020). Thehakanarslan. *Istanbul Skyline Smog*.
 www.istockphoto.com/photo/istanbul-skyline-in-smog-air-pollution-gm1224429928-360014447
- Li, J., Deng, Z., Soerensen, S. J. C., Kachuri, L., Cardenas, A., Graff, R. E., Leppert, J. T., Langston, M. E., & Chung, B. I. (2024). Ambient air pollution and urological cancer risk: A systematic review and meta-analysis of epidemiological evidence. *Nature Communications*, 15, 5116.
 doi.org/10.1038/s41467-024-48857-2
- Liu, Q., Wang, W., Gu, X. et al. (2021). Association between particulate matter air pollution and risk of depression and suicide: a systematic review and meta-analysis. *Environmental Science and Pollution Research*, 28, 9029–9049 (2021).
 doi.org/10.1007/s11356-021-12357-3
- McDuffie, E. E., Martin, R. V., Spadaro, J. V., Burnett, R., Smith, S. J., Hammer, M. S., Van Donkelaar, A., Bindle, L., Shah, V., Jaeglé, L., Luo, G., Yu, F., Adeniran, J. A., Lin, J., & Brauer, M. (2021). Source sector and fuel contributions to ambient PM_{2.5} and attributable mortality across multiple spatial scales. *Nature Communications*, 12(1), 1–12.
 doi.org/10.1038/s41467-021-23853-y
- Mehta, S., Shin, H., Burnett, R., North, T., & Cohen, A.J. (2013). Ambient particulate air pollution and acute lower respiratory infections: a systematic review and implications for estimating the global burden of disease. *Air Quality, Atmosphere & Health*, 6, 69–83.
 doi.org/10.1007/s11869-011-0146-3
- Myllyvirta, L. (2020). *Quantifying the Economic Costs of Air Pollution from Fossil Fuels*. Centre for Research on Energy and Clean Air. 2020.
 xenergyandcleanair.org/publications/costs-of-air-pollution-from-fossil-fuels/
- Nan, N., Yan, Z., Zhang, Y., Chen, R., Qin, G., & Sang, N. (2023). Overview of PM_{2.5} and health outcomes: focusing on components, sources, and pollutant mixture co-exposure. *Chemosphere*, 323, 138181.
 pubmed.ncbi.nlm.nih.gov/36806809/

Ni, X., et al. (2025). The global burden of pediatric respiratory infections attributable to long-term exposure to fine particulate matters. *Environmental Pollution*, 378, 126419.

 doi.org/10.1016/j.envpol.2025.126419

Organisation for Economic Co-operation and Development (OECD). (2012). *Mortality Risk Valuation in Environment, Health and Transport Policies*.

 doi.org/10.1787/9789264130807-en

OECD. (2012). *Mortality Risk Valuation in Environment, Health and Transport Policies*.

 doi.org/10.1787/9789264130807-en.

OECD. (2019). *OECD Environmental Performance Reviews: Turkey 2019*, OECD Environmental Performance Reviews, OECD Publishing, Paris,

 doi.org/10.1787/9789264309753-en.

OECD. (2026). *Real GDP long-term forecast*, Organisation for Economic Co-operation and Development.

 www.oecd.org/en/data/indicators/real-gdp-long-term-forecast.html

Pritchett, N. et al. (2022). Exposure to outdoor particulate matter air pollution and risk of gastrointestinal cancers in adults: a systematic review and meta-analysis. *Environmental Health Perspectives*, 130(3), 036001.

 pubmed.ncbi.nlm.nih.gov/35234536/

Resmi Gazete. (2025). *İklim Kanunu*. Kanun No. 7552.

 www.resmigazete.gov.tr/eskiler/2025/07/20250709-1.htm

Right to Clean Air Platform (THHP). (2025). *Kara Rapor 2025*.

 temizhavahakki.org/kara-rapor-2025/

Sapkota, A., Chelikowsky, A., Nachman, K., Cohen, A. and Ritz, B. (2012). Exposure to Particulate Matter and Adverse Birth Outcomes: A Comprehensive Review and Meta-Analysis. *Air Quality, Atmosphere & Health*, 5: 369-381.

 doi.org/10.1007/s11869-010-0106-3

Seinfeld, J. H., & Pandis, S. N. (2016). *Atmospheric Chemistry and Physics: From Air Pollution to Climate Change (3rd ed.)*. John Wiley & Sons.

 www.wiley.com/en-gb/shop/general-chemistry/atmospheric-chemistry-and-physics-from-air-pollution-to-climate-change-3rd-edition-p-9781118947401

Trasande, L., Malecha, P. and Attina, T. (2016). Particulate Matter Exposure and Preterm Birth: Estimates of U.S. Attributable Burden and Economic Costs. *Environmental Health Perspectives*, 124 (12).

 doi.org/10.1289/ehp.1510810

Turkish Statistical Institute (TÜİK). (2026). *Statistics on Final Energy Consumption in Transport, 2024*. March 27, 2026.

 veriportali.tuik.gov.tr/en/press/58141

Turkish Statistical Institute (TÜİK). (2025). *Statistics on Final Energy Consumption in Industry*. October 30, 2025.

 veriportali.tuik.gov.tr/en/press/54137/metadata

United Nations Department of Economic and Social Affairs, Population Division (UN DESA). (2024). *World Population Prospects 2024*. Online Edition.

 population.un.org/wpp/downloads?folder=Standard%20Projections&group=Population

Viscusi, W. K. and Masterman, C. J. (2017). Income Elasticities and Global Values of a Statistical Life. *Journal of Benefit-Cost Analysis*, 8(2): 226-250.

 doi.org/10.1017/bca.201712

Wan, R., Zheng, G., Li, Y., Duan, X., Jiang, J., and He, K. (2026). Driving factors for the activity coefficient of atmospheric ammonium nitrate: discrepancies among thermodynamic models and impact on nitrate pollutions. *Atmospheric Chemistry and Physics*, 26, 1795–1807.

 doi.org/10.5194/acp-26-1795-2026.

Wang, R., Wang, P., Zhou, Y., Wang, Y., Xu, C., Wang, Z., & Wang, W. (2025). Association between long-term ambient air pollution exposure and the incidence of breast cancer: A meta-analysis based on updated evidence. *Ecotoxicology and Environmental Safety*, 289, 117472.

 doi.org/10.1016/j.ecoenv.2024.117472

Wathanavasin, W., Banjongjit, A., Phannajit, J., Eiam-Ong, S., & Susantitaphong, P. (2024). Association of fine particulate matter (PM_{2.5}) exposure and chronic kidney disease outcomes: A systematic review and meta-analysis. *Scientific Reports*, 14(1), 1048.

 doi.org/10.1038/s41598-024-51554-1

World Bank Group. (2021). Awe, Y.; Larsen, B. & Sanchez-Triana, E. *The Global Health Cost of PM 2.5 Air Pollution: A Case for Action Beyond 2021 (English)*. International Development in Focus, Washington, D.C.: World Bank Group.

 documents.worldbank.org/curated/en/455211643691938459

World Bank. (2025). *Türkiye Overview*.

 www.worldbank.org/en/country/turkey/overview

World Health Organization (WHO). (2013). *WHO: Health Risks of Air Pollution in Europe-HRAPIE Project*.

 www.euro.who.int/__data/assets/pdf_file/0006/238956/Health_risks_air_pollution_HRAPIE_project.pdf?ua=1

World Health Organization (WHO). (2021). *WHO global air quality guidelines: particulate matter (PM_{2.5} and PM₁₀), ozone, nitrogen dioxide, sulfur dioxide and carbon monoxide. Executive summary*. Geneva: World Health Organization.

 iris.who.int/bitstream/handle/10665/345334/9789240034433-eng.pdf

Xue, T., Tong, M., Li, J. ve ark. (2022). Estimation of stillbirths attributable to ambient fine particles in 137 countries. *Nature Communications*. 13, 6950.

 doi.org/10.1038/s41467-022-34250-4

Yang, B. Y., Fan, S., Thiering, E., Seissler, J., Nowak, D., Dong, G. H., & Heinrich, J. (2020). Ambient air pollution and diabetes: A systematic review and meta-analysis. *Environmental Research*, 180, 108817.

 doi.org/10.1016/j.envres.2019.108817

Yang, L., Li, C., & Tang, X. (2020). The impact of PM_{2.5} on the host defense of respiratory system. *Frontiers in cell and developmental biology*, 8, 91.

 www.frontiersin.org/journals/cell-and-developmental-biology/articles/10.3389/fcell.2020.00091/full

Yuan S, Wang J, Jiang Q, He Z, Huang Y, Li Z, Cai L, Cao S. (2019). Long-term exposure to PM_{2.5} and stroke: A systematic review and meta-analysis of cohort studies. *Environmental Research*, October 2019;177:108587.

 doi: 10.1016/j.envres.2019.108587. Epub 2019 Jul 15. PMID: 31326714

Zhang, B., Liang, S., Zhao, J. et al. (2016). Maternal exposure to air pollutant PM_{2.5} and PM₁₀ during pregnancy and risk of congenital heart defects. *Journal of Exposure Science & Environmental Epidemiology*, 26, 422–427 (2016).

 doi.org/10.1038/jes.2016.1

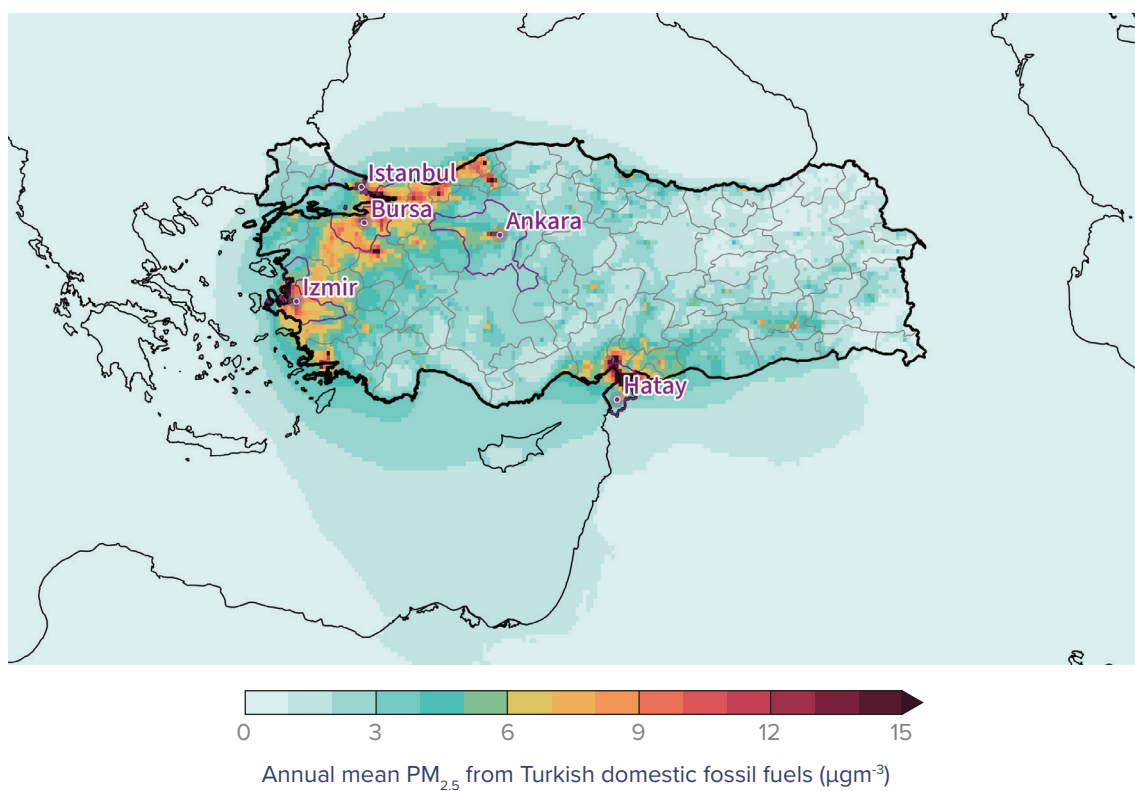
Zheng, X., Ding, H., Jiang, L., Chen, S., Zheng, J., et al. (2015). Association between air pollutants and asthma emergency room visits and hospital admissions in time series studies: a systematic review and meta-analysis. *PLoS One*, 10(9): e0138146.

 doi.org/10.1371/journal.pone.0138146.

Appendixes

Appendix 1

Figure A.1. Geographic footprint of Türkiye's domestic land-based fossil fuel emissions, showing their contribution to annual mean PM_{2.5} within the country and across neighbouring countries.



Source: CREA analysis (2026)

| **Appendix 2**

Figure A.2. Annual premature deaths and associated economic costs attributable to Türkiye’s land-based fossil fuel emissions in the five most affected countries

Country	Deaths	Economic costs of deaths (billion USD) (2024)
Egypt	3,200 (1,800–5,100)	2.1 (1.1–3.3)
Syria	1,700 (1,000–2,800)	0.2 (0.1–0.4)
Iraq	800 (500–1,200)	0.8 (0.5–1.2)
Israel	500 (400–700)	4.5 (3.2–5.9)
Greece	400 (300–500)	1.5 (1.0–1.9)

