



TRENDS IN AIR QUALITY AND HEALTH IN SOUTHEAST EUROPE

A STATE OF GLOBAL AIR SPECIAL REPORT



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WHAT IS THE STATE OF GLOBAL AIR?

The *State of Global Air* report and [interactive website](#) offer a comprehensive analysis of the levels and trends in air quality and health for every country in the world. They are produced annually by the [Health Effects Institute](#) and the [Institute for Health Metrics and Evaluation's \(IHME's\) Global Burden of Disease \(GBD\)](#) project and are a source of objective, high-quality, and comparable air quality data and information.

WHO IS IT FOR?

The report and website are designed to give citizens, journalists, policymakers, and scientists access to reliable, meaningful information about air pollution exposure and its health effects. These resources are free and available to the public.

ABOUT THIS REPORT

This report provides an overview of the state of air quality and its impacts on the health of populations in the following countries across Southeast Europe: Albania, Bulgaria, Bosnia and Herzegovina, Croatia, Montenegro, North Macedonia, Serbia, Romania, and Slovenia. We draw on data from the GBD Study 2019 as well as from a recent global assessment on sources of air pollution (McDuffie et al. 2021) to discuss trends in air pollution and the associated disease burden.

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STATE OF GLOBAL AIR

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INTRODUCTION

Air pollution is the leading environmental risk factor for public health globally. Exposure to air pollution is associated with substantial health, economic, and social costs with the impacts often experienced inequitably across regions and communities. Over the last few decades, researchers have continued to build an extensive body of evidence – perhaps the most extensive that exists for any environmental risk factor – on the health effects of exposure to air pollution. In addition, the pandemic of the infectious disease caused by the novel coronavirus SARS-CoV2 (COVID-19) has brought renewed attention to the effects of air pollution, offering an unprecedented opportunity to realign the economic and policy objectives to provide clean air and improved public health.

Air pollution is responsible for 1 in 10 deaths in Southeast Europe.

In 2019 alone, exposure to air pollution contributed to 6.67 million deaths (uncertainty interval [UI]: 5.90–7.49), nearly 12% of all global deaths. The disease burden associated with air pollution was surpassed only by high blood pressure, tobacco use, and poor diet (HEI 2020). Thus, understanding air pollution's health consequences is key to informing air quality interventions and saving lives.

Across Southeast Europe, air quality remains a key concern. Countries in the region experience exposures of fine particulate matter, or PM_{2.5}, well above the World Health Organization (WHO) annual guideline value of 5 µg/m³ and air pollution ranked among the top 10 leading risk factors for death in 2019 (IHME 2020; GBD 2020). Economic costs of air pollution are also high in this region. For example, the economic cost of deaths linked to ambient air pollution represents up to 10.5% of the total gross domestic product in the region, and total welfare losses from air pollution (PM_{2.5} and ozone) were estimated to cost Croatia, Bulgaria, and Romania 9%–13% of the gross domestic product of these nations, the largest cost among the 27 European Union (EU) countries (OECD 2020). At the same time, coverage of air quality monitors and availability of air quality data remain limited.

WHAT THIS REPORT ADDS

Systematic and consistent efforts to track progress toward reducing air pollution, as well as the impacts these reductions have on human health, remain essential. This report provides an overview of the state of air quality and its impacts on the health of populations in the following countries across Southeast Europe: Albania, Bulgaria, Bosnia and Herzegovina, Croatia, Montenegro, North Macedonia, Serbia, Romania, and Slovenia (Figure 1). These countries are in varying stages of EU ascendancy (i.e., candidacy, formal negotia-

FIGURE 1 Southeast European countries included in report. Six of these countries, plus Kosovo*, comprise the Western Balkan nations (Albania, Bosnia and Herzegovina, Croatia, Montenegro, North Macedonia, and Serbia). Since the GBD Study 2019 does not provide estimates for Kosovo*, data for levels of exposure and health impacts are not included in this report.



* This designation is without prejudice to position on status and is in line with the United Nations Security Council Resolution 1244 (UNSCR 1244/99) and the International Court of Justice Opinion on the Kosovo declaration of independence.

tions, and accession/members). Four of the countries (Bulgaria, Croatia, Romania, and Slovenia) are officially EU members, Bosnia and Herzegovina¹ is a potential candidate country, and Albania, Montenegro, North Macedonia, and Serbia are candidate countries (EC 2020b; World Bank 2020).

The report is designed to present the latest data on air pollution exposures and associated health impacts, including the disease burden across age groups. We draw on data from the GBD Study 2019, a unique resource where high-quality and internally consistent state-of-the-art methods have been applied to estimate current status and yearly trends in exposures and burden of disease from 87 risk factors or groups of factors in 204 countries and territories. The report also draws on a first of its kind, recent global assessment (McDuffie et al. 2021) to discuss the major air pollution sources in the region and the related source-specific disease burden.

For this report, 2019 was selected as the baseline for an “average” year instead of 2020 because the lockdowns related to COVID-19 caused abnormal changes in air pollution in countries across the globe in 2020.

We present data on ambient (outdoor) PM_{2.5} as well as PM_{2.5} emitted due to use of solid fuels for cooking (referred to as household air pollution from cooking) and ozone. Fine particles with aerodynamic diameter less than 2.5 µm (PM_{2.5}) and ground-level (tropospheric)

¹ Bosnia and Herzegovina is formed by the Federation of Bosnia and Herzegovina and the Republic of Srpska entities and the Brčko district.

ozone are both commonly measured and have been linked to a variety of health effects. These forms of air pollution are considered key indicators of air quality, and each contributes to the collective impact of air pollution on human health. The focus of this report is on long-term exposures to each of these air pollutants and on associated health effects. Long-term exposures are those that occur over multiple years and that have been shown by studies to be the strongest determinants of the heavy burden from chronic diseases, which are diseases that persist for a long time and can take several years to develop.

In addition to this regional report on air pollution and health, two country-specific reports have been published and provide an overview of the status and trends in PM_{2.5}, ozone, and household air pollution as well as of the health impacts on citizens in Bulgaria and Serbia (HEI in press a, in press b).

A larger, annually updated trove of data – with detailed statistics for every country in the world, tools for generating custom data tables and graphs, and fact sheets for countries in the region – is available at www.stateofglobalair.org.

Global Burden of Disease (GBD) Study

The approach taken by the Global Burden of Disease (GBD) comparative risk assessment provides an opportunity to understand both the absolute and relative importance of the multiple risks that contribute to burdens on public health, putting air pollution into perspective. Every year, the GBD study incorporates the latest scientific evidence and methods to refine estimates of the burden of disease – or impacts on population health – from air pollution and other risk factors. Each analysis represents a systematic, scientific effort to quantify the magnitude of mortality and disability from all major diseases, injuries, and risk factors by age, sex, and population. To learn more, please visit <http://www.healthdata.org/gbd/2019>.

The State of Global Air report and website, released annually since 2017, draw on the GBD study and provide a global report card on the status of air pollution and health worldwide, the progress that has been made, and where problems persist or are getting worse. The report and interactive website bring into one place a comprehensive analysis of the levels and trends in air quality and health. The report and website are produced by the Health Effects Institute and the Institute for Health Metrics and Evaluation (IHME). To learn more, please visit www.stateofglobalair.org. Specifically, please visit [here](#) to learn about the methods for exposure estimates and [here](#) to learn about the disease burden estimates.

GROWING MOMENTUM FOR ACTION ON AIR POLLUTION

Public engagement in the air quality discourse continues to grow, especially in urban centers across the region, driven in part by the very visible air pollution episodes during winter as well as expanding access to air quality data through government air quality monitoring networks and citizen monitoring initiatives. Media coverage on air quality has also increased over time, thereby increasing visibility of the topic in the public discourse. Taken together, this has led to greater civic engagement and a growing demand for action to improve air quality across the region.

Furthermore, in countries that currently are not EU members, accession into the EU is an important driver for national recognition and implementation of air quality regulations because member states must be in compliance with the requirements of the EU's Clean Air Programme for Europe, which sets forth air quality standards across the EU (see text box: EU Legislation and Funding Initiatives Related to Air Quality) and objectives for 2020 and 2030 (OECD 2020; EC 2020). Western Balkan countries, including North Macedonia, Serbia, Montenegro, Albania, and Bosnia and Herzegovina, have developed action programs for the implementation and enforcement of the various EU air quality and climate change directives (EC 2020b).

Air Pollution and Human Health

Air pollution is the 4th leading cause of death globally, accounting for nearly 7 million deaths. The large body of existing research has shown conclusively that both short-term (i.e., a few days to weeks) and long-term (i.e., months to years) exposures to air pollution can contribute to serious effects on health ranging from temporary to chronic, mild to debilitating, and even fatal conditions. Long-term exposure to PM_{2.5} is associated with a variety of health effects, including ischemic heart disease, lung cancer, COPD, lower respiratory infections (such as pneumonia), stroke, type 2 diabetes, and adverse birth outcomes. Household air pollution is also associated with the development of cataracts. Long-term exposure to ground-level ozone is associated with the development of COPD, a progressive and debilitating disease that makes it harder to breathe. Exposure to air pollution also reduces life expectancy around the world.

EU Legislation and Funding Initiatives Related to Air Quality

The EU has an overarching goal to protect its citizens and susceptible subpopulations from the adverse effects of major ambient air pollutants. The EU's Clean Air Programme is based on three main pillars (EC 2018): (1) the Ambient Air Quality Directives (EP 2020), which set out air quality standards and require member states to assess air quality in a harmonized and comparable manner and to implement air quality plans to improve or maintain the quality of air; (2) the National Emissions Ceiling Directive (EEA 2016), which establishes national emission reduction commitments; and (3) source-specific legislation establishing specific emission standards for key sources of air pollution, for example, the Industrial Emissions Directive and road transport regulations including emission performance standards. The directives have established EU air quality standards in the form of limit values – which are not to be exceeded – and target values, which are to be attained where possible (Table i). The air quality standards currently in place were established in two complementary Ambient Air Quality (AAQ) Directives in 2004 and 2008 (EP 2020). The EU works with member nations expected to meet the AAQ Directive. Failure to meet the directives can result in the

EC filing infringement procedures, as was the case in Bulgaria in 2017 and 2019 (EC 2019). (Please note: EU legislation pertains only to the EU member states in this report, that is, Bulgaria, Croatia, Romania, and Slovenia.)

The EU has implemented various institutional frameworks to support the region, in aligning with the numerous environmental directives and transposing EU legislation to the non-EU countries in the region, including the Energy Community Treaty, which contains legislation related to emissions of large combustion plants. Additionally, the Economic Investment Plan for the Western Balkans of 2020 commits up to €9 billion of funding for the region in general support including for human capital, competitiveness, and a digital and green transition (EC 2020a). The EC also provided guidelines (not legislation) for implementing the Green Agenda in the Western Balkans intended to support the region in improving air quality and aligning environmental policies with European requirements, including on climate action, for example, decarbonization and greening of energy, as well as combating air, soil, and water pollution (EC 2020a).

TABLE i WHO Air Quality Guidelines and EU Pollutant Limit Values for pollutants of interest

Standard	PM _{2.5}	Ozone
WHO AQ Guideline	5 µg/m ³ annual mean	60 µg/m ³ peak season (average of daily maximum 8-hour mean based on long-term exposures)
	15 µg/m ³ 24-hour mean	
EU AQ Limit Value	25 µg/m ³ annual mean	100 µg/m ³ 8-hour daily maximum
		120 µg/m ³ daily maximum 8-hour mean (based on short-term exposures)

Source: [https://www.who.int/news-room/fact-sheets/detail/ambient-\(outdoor\)-air-quality-and-health](https://www.who.int/news-room/fact-sheets/detail/ambient-(outdoor)-air-quality-and-health); <https://ec.europa.eu/environment/air/quality/standards.htm>.

EXPOSURE TO AIR POLLUTION

Up to 71% of the population in this region lives in areas that do not meet the current EU air quality limit value of annual mean $25 \mu\text{g}/\text{m}^3$.

Air pollution is a complex mixture of particles and gases, whose sources and composition vary spatially and temporally. Key pollutants of interest include pollutants such as coarse and fine particulate matter (PM_{10} and $\text{PM}_{2.5}$, respectively), nitrogen oxides (nitrogen oxide $[\text{NO}]$ and nitrogen dioxide $[\text{NO}_2]$, referred to as NO_x), ozone, carbon monoxide (CO), and sulfur dioxide (SO_2). Household air pollution, a mixture of particles and gases resulting from incomplete combustion of fuels in the home, is also of concern due to the proximity of the source to humans and the potential for high exposures. Exposure to these pollutants contributes to the disease burden of air pollution. As such, knowledge of trends of different pollutants is important to estimate the disease burden attributable to air pollution in each population and around the world.

In this section, we present an overview of current levels of key air pollutants at present, and their long-term trends across the various countries in Southeast Europe using data from the GBD 2019 study.

LEVELS AND TRENDS

Ambient $\text{PM}_{2.5}$

Ambient fine particle air pollution refers to $\text{PM}_{2.5}$ (i.e., particles measuring less than 2.5 micrometers in aerodynamic diameter, and less than a 30th of the diameter of a human hair). These particles are emitted from cars, coal-burning power plants, industrial activities, homes burning coal and wood for heating or cooking, waste burning, and other human and natural sources. Fine particles are also formed in the atmosphere from gaseous air pollutants, such as nitrogen or sulfur oxides. Although exposures to smaller and larger airborne particles can both be harmful, studies have shown that among air pollutants, high $\text{PM}_{2.5}$ exposure over several years is the most consistent and robust predictor of mortality and morbidity due to cardiovascular, respiratory, and other types of diseases. Such small particles can be suspended in the air for days and be transported with the wind over thousands of kilometers. These particles penetrate deep into the lungs.

In Southeast Europe, annual mean $\text{PM}_{2.5}$ levels have remained high, and more than 95% of the population in the region lives in areas where the $\text{PM}_{2.5}$ exposures exceed the WHO guideline for healthy air ($5 \mu\text{g}/\text{m}^3$). In Serbia, Bosnia and Herzegovina, and North Macedonia more than 50% of the population lives in more polluted areas

Defining Pollutant Emissions, Concentration, and Exposure

Throughout this report, we use three key terms to describe air pollutant levels and trends: emissions, concentration, and exposure. It is important to understand what each term represents as they are not directly comparable.

Emission – Discharge of pollutants into the atmosphere from stationary sources (such as smokestacks and other vents as well as from surface areas of commercial or industrial facilities) and from mobile sources (e.g., motor vehicles, locomotives, and aircraft) (EEA 2020). Emission data can help us answer the question of what amount of pollutants were emitted from each anthropogenic source. Typical units for emissions are kilogram and ton.

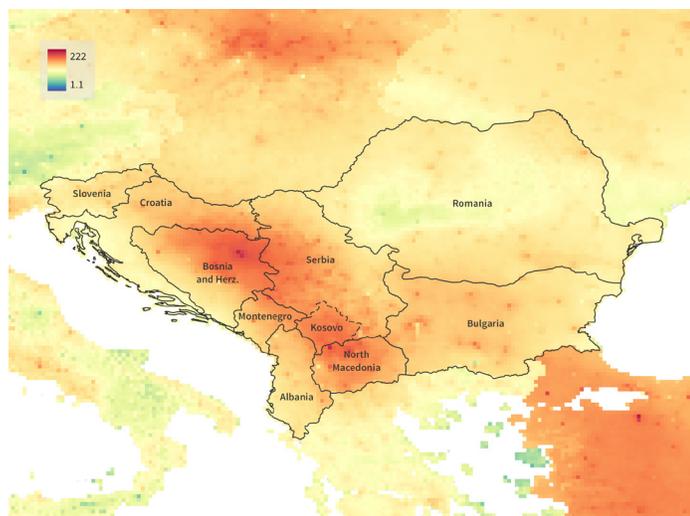
Concentration – The amount of pollutant present in a unit volume of ambient air (Sexton 1988). Pollutant concentrations can be measured using ground-level monitors directly or estimated using air quality models or satellite data, for example. Concentrations are closer proxies for air pollutant levels in our environment than emissions. Therefore, air quality standards are set using air pollutant concentrations. Typical units for concentration are $\mu\text{g}/\text{m}^3$, parts per million (ppm), and parts per billion (ppb).

Exposure – The pollutant concentration in the air at the point of contact between the external environment and human body (Sexton 1988). A person's exposure not only depends on air pollutant concentrations in the environment but also on their activities and behaviors that affect the magnitude, frequency, and duration of their contact with air pollutants. Therefore, individuals living in areas with the same air pollution concentrations do not necessarily have the same exposures.

that do not meet the current EU air quality limit value for annual $\text{PM}_{2.5}$ concentration ($25 \mu\text{g}/\text{m}^3$), whereas in Croatia, Bulgaria, and Albania less than 10% of the population lives in polluted areas where $\text{PM}_{2.5}$ levels exceed the annual EU limit value.

Within the region, in 2019, North Macedonia experienced the highest annual mean $\text{PM}_{2.5}$ exposure ($30.3 \mu\text{g}/\text{m}^3$) while Romania experienced the lowest ($15.7 \mu\text{g}/\text{m}^3$) (Figure 2 and Table 1). Notably, $\text{PM}_{2.5}$ levels in countries across the region were consistently lower than the global average for $\text{PM}_{2.5}$ exposure ($42.6 \mu\text{g}/\text{m}^3$, UI: $32.5 - 36.5 \mu\text{g}/\text{m}^3$) in 2019. Compared with the average $\text{PM}_{2.5}$ levels in the European Union (EU-28) ($11.4 \mu\text{g}/\text{m}^3$), all countries in this region have higher

FIGURE 2 Population-weighted annual average PM_{2.5} exposures (µg/m³) in 2019 across Southeast Europe.



levels of PM_{2.5}. In fact, with the exception of Poland² (22.6 µg/m³, UI: 13–35.2 µg/m³), Southeast European countries almost exclusively make up the list of top five countries with the highest ambient PM_{2.5} levels in Europe: North Macedonia has the highest PM_{2.5} exposure in all of Europe, followed by Bosnia and Herzegovina, Serbia, and Montenegro.

PM_{2.5} exposures have decreased for every country in the region over the last decade, with the largest decrease in Serbia, where levels of PM_{2.5} in 2019 were 19.1% lower compared to 2010 (Figure 3).

Seasonal and Diurnal

In addition to annual average data, insights into temporal trends of pollutant concentrations can help identify seasonal and diurnal patterns. For many cities in the region, time series data are available

² Poland is not included in the analysis of this report.

TABLE 1 Population-weighted annual average PM_{2.5} exposures and percentage of population living in areas above WHO guideline and EU limit value in countries across Southeast Europe in 2019 (µg/m³)

Rank	Country	PM _{2.5} (µg/m ³)	95% Uncertainty Intervals*	Percentage of Population Living in Areas Above Annual WHO Guideline (5 µg/m ³)	Percentage of Population Living in Areas Above EU Limit Value (25 µg/m ³)
1	North Macedonia	30.3	27.4–33.1	97	71
2	Bosnia and Herzegovina	29.5	26.7–32.7	100	69
3	Serbia	25.4	23.0–27.9	100	56
4	Montenegro	21.3	18.4–24.4	100	21
5	Bulgaria	19.4	18.3–20.5	100	6.0
6	Albania	18.6	16.5–20.7	99	2.6
7	Croatia	18.5	17.0–20.0	100	7.8
8	Slovenia	17.0	16.0–18.0	98	0
9	Romania	15.7	14.7–16.9	100	0
	EU-28	11.4	11.3–11.6	N/A	N/A

*The 95% uncertainty intervals are a measure of scientific uncertainty. They reflect a range of values, from the 2.5th to the 97.5th percentile of a possible distribution of values, within which the true exposure value is likely to fall.

for a range of pollutants. Here, we present three examples using hourly PM_{2.5} data for the year 2019 from the U.S. embassy monitors in Sarajevo (Bosnia and Herzegovina) and Pristina (Kosovo), as well as daily PM_{2.5} data from the Bulgarian Environmental Authority for Sofia, Bulgaria (Dzhambov AM, personal communication, August 2021; Figure 4). Data for all three capital cities show a distinct seasonal pattern, with higher concentrations of PM_{2.5} during winter months (i.e., November to February) and the lowest monthly average concentrations observed during summer months.

The highest PM_{2.5} concentrations are observed during the winter months.

Ozone

Ground-level, or tropospheric, ozone is a highly reactive pollutant that is not released directly into the air but is formed through complex chemical interactions between NO_x and volatile organic compounds (VOCs) in the presence of sunlight. NO_x and VOCs are both produced by a variety of human activities. NO_x are emitted from the burning of fossil fuels (oil, gas, and coal) in cars, power plants, industrial boilers, and home heating systems, while VOCs are also emitted by cars as well as through oil and gas extraction and processing and other industrial activities. Given these emitting sources, and the fact that NO₂

Progress on decreasing ozone pollution has been slow among countries in Southeast Europe in the last 10 years.

scavenges/titrates ozone especially along roadways, NO₂ is typically higher in urban areas, while ozone is found in higher concentrations in suburban and rural areas. Although not directly

comparable, the EU target value for short-term ozone (maximum daily 8 hour mean) is 120 µg/m³. The WHO ozone air quality guideline is 100 µg/m³ for the short-term daily maximum 8-hour mean and 60 µg/m³ for the long-term as the peak season (6 months) mean of daily maximum 8-hour means.

FIGURE 3 Trends in population-weighted annual average PM_{2.5} exposure (µg/m³) in Southeast Europe, 2010–2019. Visit <https://www.stateofglobalair.org/data> to explore data for your country or region.

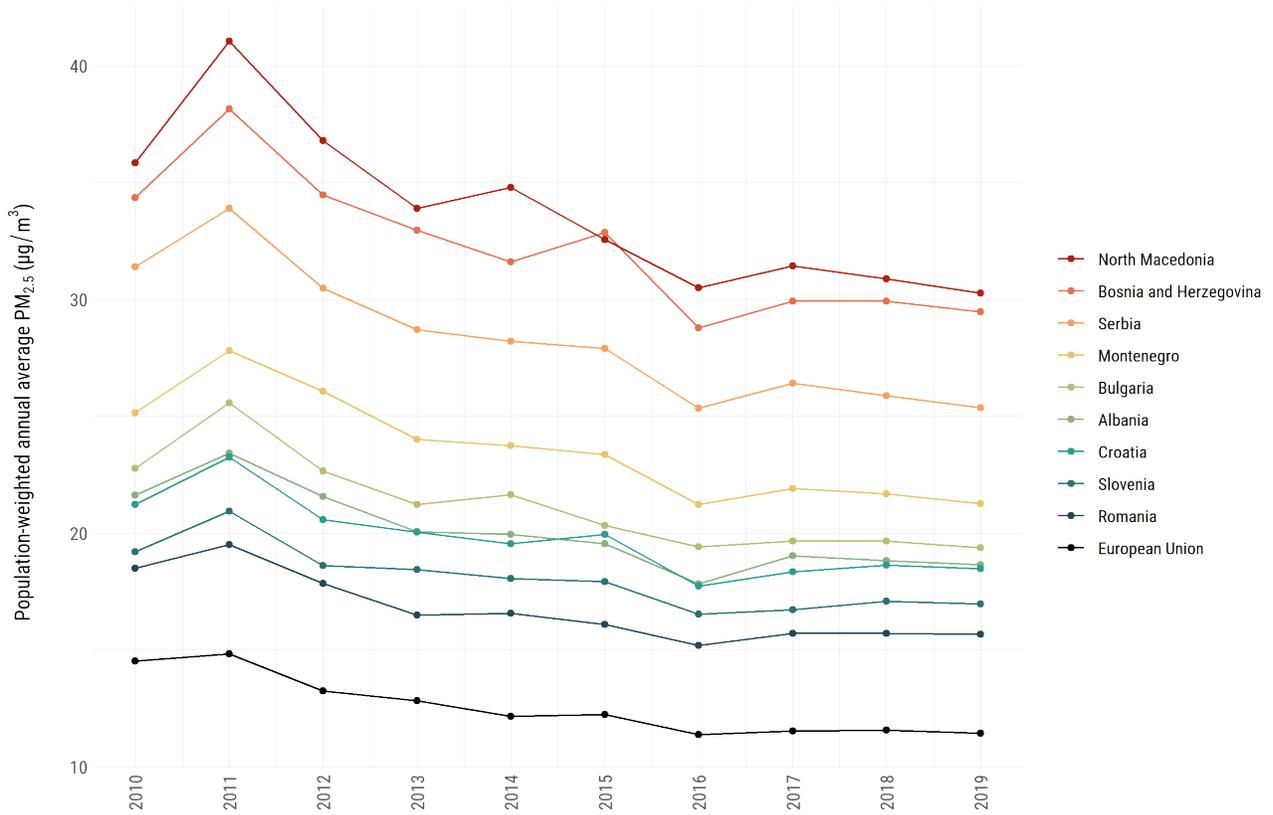


FIGURE 4 Monthly trends in PM_{2.5} concentrations (µg/m³) in Sarajevo, Pristina and Sofia (January–December 2019). (Data source: AirNow.gov; Bulgarian Environmental Authority.)

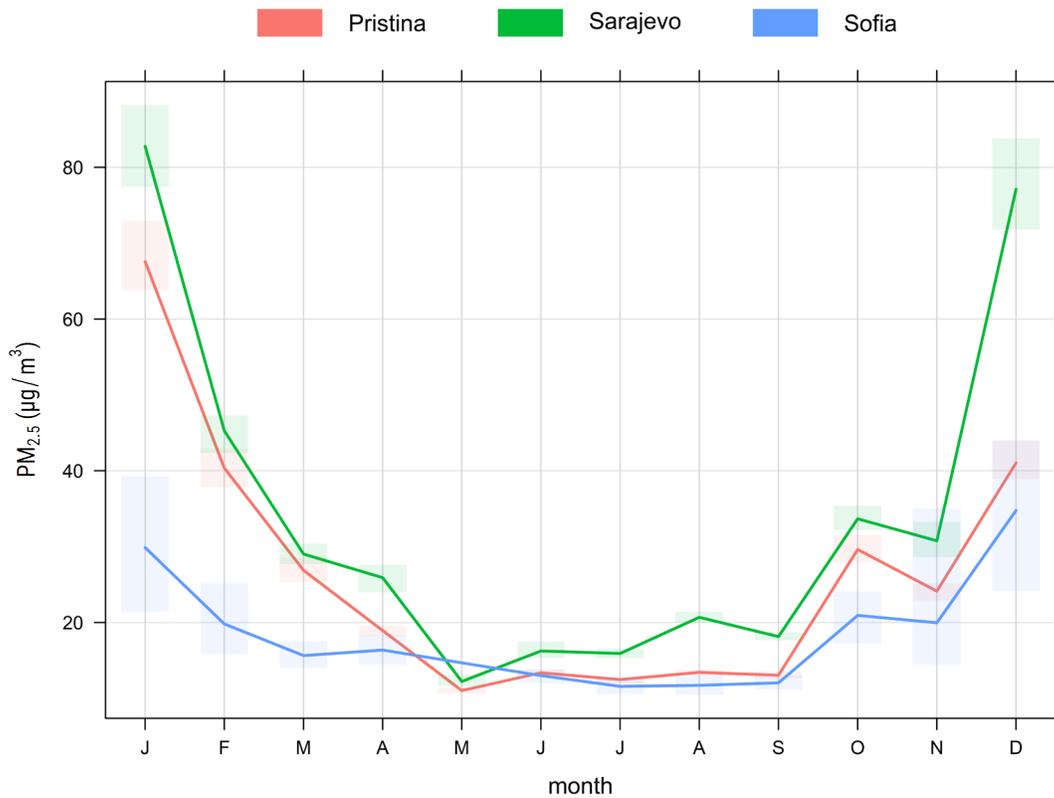
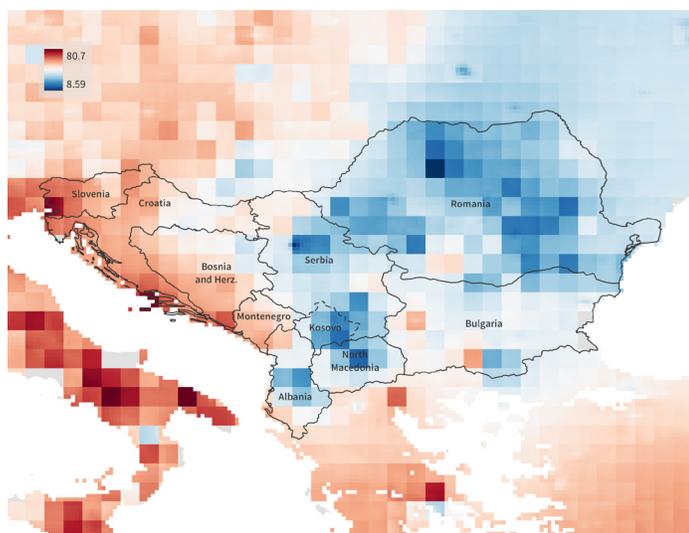


FIGURE 5 Population-weighted average seasonal 8-hour maximum ozone exposure in 2019 across Southeast Europe.



Levels and trends for ozone, a secondary pollutant, can be significantly different from those of PM_{2.5}. For example, despite having the second lowest PM_{2.5} exposures in the region, Slovenia had the highest population-weighted average seasonal 8-hour maximum ozone exposures at 100.7 µg/m³ in 2019, followed by Croatia and Montenegro (Figure 5 and Table 2). Unlike PM_{2.5}, five of the countries in this region are below the EU (EU-28) ozone average of 83.5 µg/m³.³

Over the last decade, about half of the countries in Southeast Europe experienced declines in ozone exposures, with the exceptions of Bosnia and Herzegovina, Croatia, Montenegro, and Slovenia (Figure 6). The largest decline in levels of ozone was estimated in North Macedonia, where levels went down by 20.5% to 71.1 µg/m³ in 2019.

Household Air Pollution from Use of Solid Fuels for Cooking

Household air pollution results from the combustion of solid fuels (such as coal, lignite, charcoal, wood, agricultural residue, and animal dung, as well as waste) for heating or cooking using open fires or cookstoves with limited ventilation. Burning these fuels produces an array of pollutants that may harm human health, including PM_{2.5}, black carbon, carbon monoxide, polycyclic aromatic hydrocarbons, and other carcinogenic compounds. Of note, GBD only includes the role of burning solid fuels for cooking in its estimates of exposure to household air pollution, and these exposures are estimated in terms of PM_{2.5} exposures based on the proportion of a country's population that relies on solid fuel for cooking combined with evidence from household and personal exposure measurement studies.

Between 6%–39% of the population across countries are exposed to household air pollution from solid fuel use for cooking (Table 3). Although most countries in the region are below the global average of 48.6% (UI: 47.8–49.3%), the proportions remain much higher than in countries in Western Europe where less than 1% of the population is exposed to household air pollution. It is worth noting that these

TABLE 2 Population-weighted average seasonal 8-hour maximum ozone exposure (µg/m³) for 2019

Rank	Country	Average ozone (µg/m ³)	95% Uncertainty Intervals* (µg/m ³)	Percentage of Population Living in Areas Above WHO Guideline (peak season mean) (60 µg/m ³)
1	Slovenia	100.7	98.8–102.7	98
2	Croatia	95.6	93.9–97.2	97
3	Montenegro	92.3	90.0–94.5	100
4	Bosnia and Herzegovina	89.4	87.6–90.9	100
5	Bulgaria	79.4	77.8–80.9	99
6	Albania	74.5	71.1–77.4	97
7	North Macedonia	71.1	69.2–73.1	80
8	Serbia	69.8	68.2–71.7	66
9	Romania	65.3	63.9–66.6	61
	EU-28	83.5	83.3–83.7	N/A

*The 95% uncertainty intervals are a measure of scientific uncertainty. They reflect a range of values, from the 2.5th to the 97.5th percentile of a possible distribution of values, within which the true exposure value is likely to fall.

estimates only account for pollution from solid fuel use for cooking. In the Southeast Europe region, burning polluting fuels inside the home for heating is a much bigger contributor and the true exposure is likely underestimated. The cleaner district heating systems in use across much of Southeast Europe are inefficient compared with other technologies and often have low coverage even where they do exist. This leaves people to rely primarily on individual heating, for which more affordable but often dirtier fuels and inefficient stoves emitting more pollutants are typically used.

Despite declines over the last decade, some countries still have as much as 25% or more of their populations exposed to household air pollution from use of solid fuels for cooking.

Progress has been made on household air pollution in Southeast Europe in the last decade. The percentage of population relying on solid fuels for cooking has decreased in every country in this region since 2010 (Figure 7). In particular, reliance on solid fuels for cooking in Albania was at a low of 29.2% in 2019, down from 38.1% (UI: 33%–43.3%) in 2010. More than 40% of the annual heat demand in the Western Balkans is met using firewood. Notably, Albania is the only country in the Western Balkans where electricity is the primary heating method (World Bank 2017). According to the International Energy Agency, in 2019 the percentage of heat generation from biofuels was highest in Croatia (29.7%), followed by Bosnia and Herzegovina (18.4%) and Slovenia (18.2%) (IEA 2019).

³ All GBD estimates for ozone have been converted (1 ppb = 1.96 µg/m³ for 25°C). https://uk-air.defra.gov.uk/assets/documents/reports/cat06/0502160851_Conversion_Factors_Between_ppb_and_pdf.

FIGURE 6 Trends in population-weighted annual average seasonal 8-hour daily maximum ozone exposures (ppb) in Southeast Europe, 2010–2019. Visit <https://www.stateofglobalair.org/data> to explore data for your country or region.

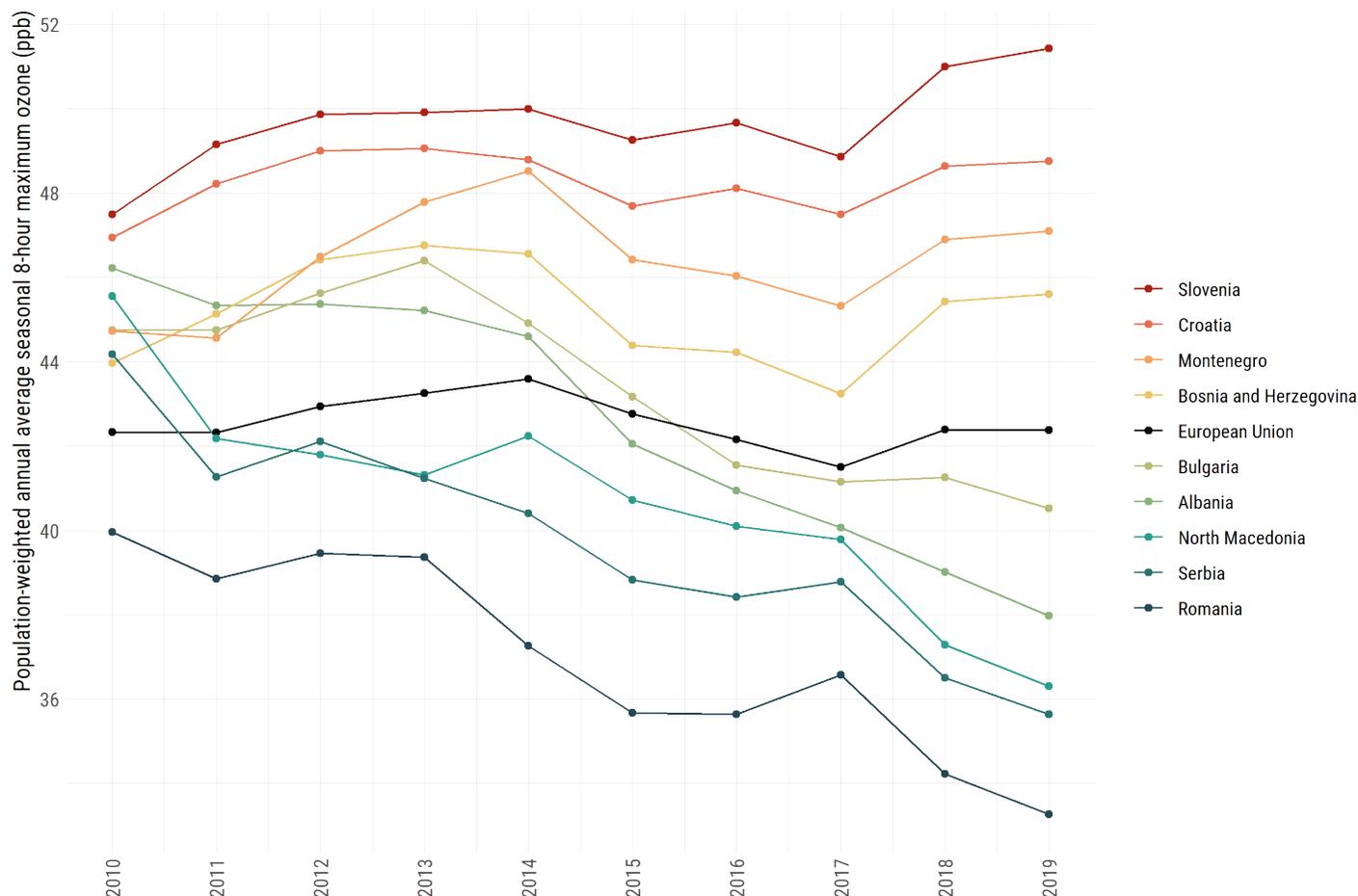
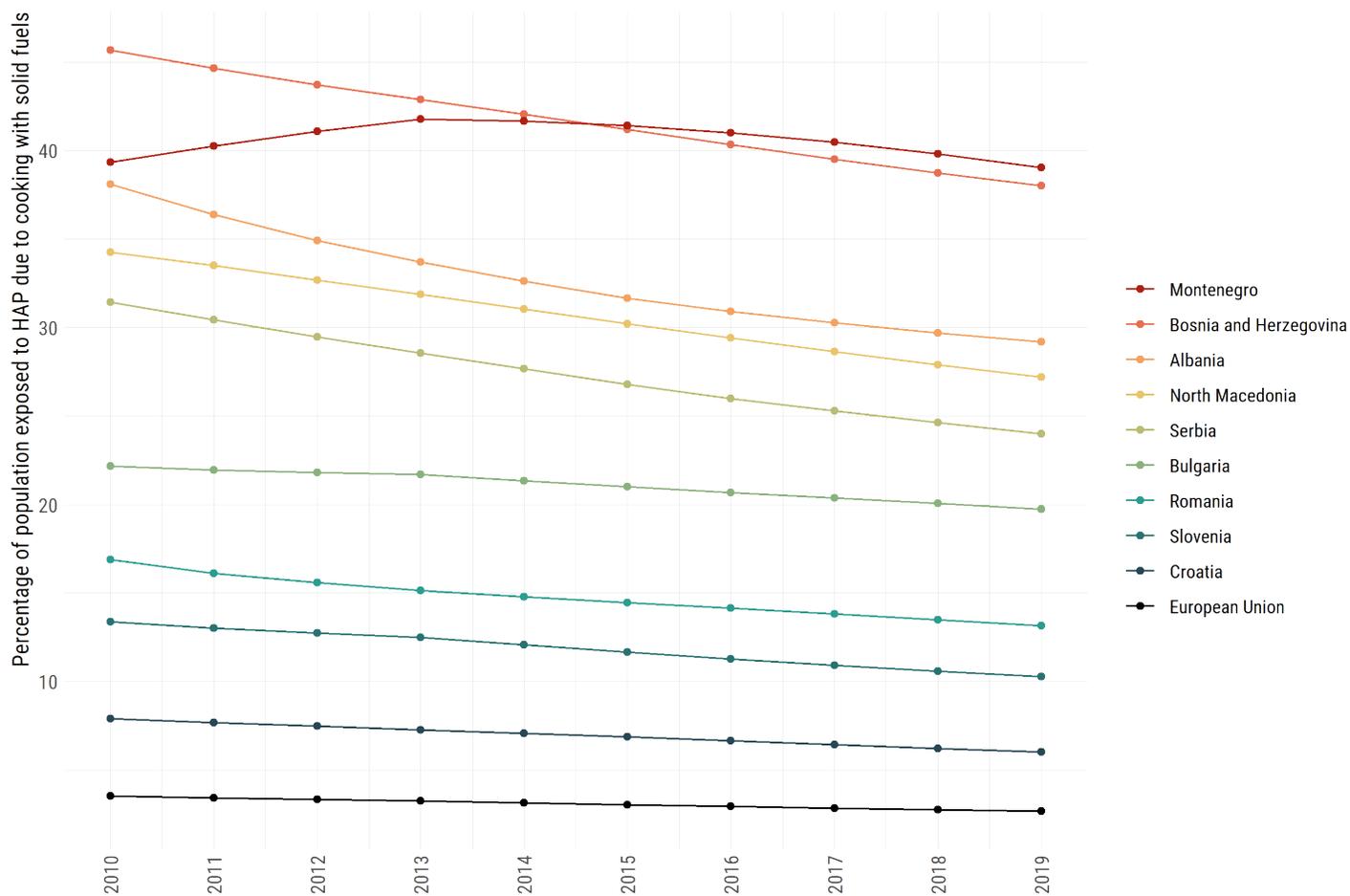


TABLE 3 Percentage of population relying on solid fuels for cooking in 2019

Rank	Country	Average (%)	95% Uncertainty Intervals*
1	Montenegro	39.0	30.2–48.3
2	Bosnia and Herzegovina	38.0	26.9–50.5
3	Albania	29.2	20.5–39.9
4	North Macedonia	27.2	19.9–35.9
5	Serbia	24.0	16.2–32.1
6	Bulgaria	19.7	12.1–29.1
7	Romania	13.2	8.83–18.4
8	Slovenia	10.3	6.05–16.0
9	Croatia	6.02	3.41–9.48
	EU-28	2.65	2.13–3.35

* The 95% uncertainty intervals are a measure of scientific uncertainty. They reflect a range of values, from the 2.5th to the 97.5th percentile of a possible distribution of values, within which the true value is likely to fall.

FIGURE 7 Trends in the percentage of population exposed to household air pollution due to cooking with solid fuels in Southeast Europe, 2010–2019. Visit <https://www.stateofglobalair.org/data> to explore data for your country or region.



Air Quality and COVID-19

In 2020, the COVID-19 pandemic led to unprecedented restrictions that dramatically reduced global and local travel, shut down schools, universities, public services, and businesses, and halted some industrial activity. Global satellite and ground-based air quality monitoring data have since shown reductions in concentrations of pollutants such as NO₂ and, in some cases, modest reductions for other pollutants, such as PM_{2.5}. In North Macedonia, researchers reported decreases in concentrations of PM₁₀, PM_{2.5}, NO₂, and ozone from February to May of 2020 compared with the same periods in 2017–2019 (one exception was the PM_{2.5} levels in Kumanovo). The most significant declines were for levels of NO₂, which

decreased by 5%–31% (Dimovska et al. 2020). Similarly, a study in Novi Sad, Serbia, found that average daily concentrations of PM_{2.5}, NO₂, PM₁₀, and SO₂ were reduced by 35%, 34%, 23%, and 18%, respectively, in March to May of 2020 compared to the same periods in 2018 and 2019. However, the average daily concentration of ozone increased by 8%. Overall, this decrease in short-term exposure resulted in a decrease in estimated deaths attributable to air pollution. In Novi Sad, a reduction in the average daily PM_{2.5} concentration (of 11.2 µg/m³) during the 53-day lockdown resulted in 1.36% decrease in total number of deaths (Dragic et al. 2021).

IMPACTS OF AIR QUALITY ON HEALTH

Our health is strongly influenced by the air we breathe. Air pollution affects the young and the old, the rich and the poor, and people across the globe. However, the burden of diseases associated with air pollution is not borne equally across regions and countries, as variations reflect not only exposures but other social, economic, and demographic factors that affect the underlying health and vulnerability of populations to air pollution. Because socioeconomic development can be tied to both air pollution exposures and the availability of health care, changes in a country's level of development can also influence the burden of disease over time. Thus, lower-income households and communities are generally more vulnerable to the health effects from air pollution due to potentially greater exposure and to overall increased susceptibility given possible poor baseline health (for example, exposure to other risk factors such as smoking), lack of access to health care, and limited ability to afford protective measures or improve housing quality. Additionally, the burden of disease attributable to air pollution does not fall evenly across age groups. Throughout the world, children and the elderly are those most acutely affected.

Across Southeast Europe, death rates linked to air pollution are among the highest in Europe. This section will explore the patterns and trends in the burden of disease across Southeast Europe from total air pollution as well as the individual air pollutants that compose total air pollution in GBD estimates (i.e., PM_{2.5}, ozone, and household air pollution).

Health Effects of Air Pollution

Understanding the burden of disease that air pollution places on society begins with scientific evidence for its effects on health. An extensive body of scientific evidence has been amassed over several decades, including studies from many countries of the world. Short-term exposures to air pollution can harm health; for example, pollution can trigger asthma symptoms and cause a local spike in hospitalizations or even deaths related to respiratory and cardiovascular diseases. There is broad scientific consensus that long-term exposures to air pollution contribute to increased risk of illness and death from chronic noncommunicable diseases, such as ischemic heart disease, lung cancer, chronic obstructive pulmonary disease (COPD), stroke, and type 2 diabetes as well as lower-respiratory infections (e.g., pneumonia) especially in children under 5 years of age. Exposure to PM_{2.5} also puts mothers at risk of delivering babies too early and smaller than normal, and these babies are more susceptible to dying

EVIDENCE FROM SOUTHEAST EUROPE

In Croatia, a 2018 study in Zagreb found that during winter or spring, more patients were admitted for stroke on days when ozone levels were higher (Knezovic et al. 2018).

In Serbia, two separate studies in Novi Sad found a significant positive association between hospital admissions from all cardiovascular diseases and ambient NO₂ concentrations (relative risk [RR]: 1.049, 95% confidence interval [CI]: 1.009–1.091) (Jevtić et al. 2014), whereas an earlier study found no association between ambient concentrations of SO₂ and NO₂ and COPD (Jevtić et al.

2012). Two studies also assessing short-term associations between air pollution and COPD, as well as asthma and pneumonia in Niš, found a significant association with concentrations of black smoke and emergency room visits for COPD (Milutinović et al. 2009), with concentrations of NO₂ and asthma admissions in the elderly (65+ years) (RR: 1.012, 95% CI: 1.003–1.002), males (18–64 years) (RR: 1.020, 95% CI: 1.005–1.035), females (65+ years) (RR: 1.015, 95% CI: 1.003–1.027), and COPD admissions in elderly patients (RR: 1.007, 95% CI: 1.000–1.015). Stosic and colleagues (2021) found signifi-

There are over 50 studies and risk assessments of air pollution and health in the region.

from a range of diseases or are considered to be at increased risk for diseases later in life. There is also emerging evidence on the role of air pollution in cognitive disorders, including dementia. For example, air pollution was recently acknowledged as a modifiable risk factor by the Lancet Commission on Dementia Prevention, Intervention and Care, and other effects (Livingston et al. 2020). Overall, the public disease burden from long-term exposures is much larger than that from short-term exposures. This large burden of disease reflects the substantial contribution that long-term exposures to air pollution make to chronic noncommunicable diseases and, more specifically, to some of the world's leading causes of death.

For a summary on health effects of air pollution, please refer to the factsheet and the resources listed at the end of the report. For data on health impacts of air pollution, please visit <https://www.stateofglobalair.org/health>.

cant associations between PM_{2.5} and pneumonia in males up to 18 years of age (RR: 1.006, 95% CI: 1.000–1.012).

In Bulgaria, increased exposure to SO₂ was associated with an increased number of COPD exacerbations and related hospital stays (Doneva et al. 2019). A study in the Užice region of Serbia found short-term exposure to black carbon to be associated with an increased risk of emergency department visits for asthma (odds ratio [OR] = 3.23; 95% CI: 1.05–9.95), and exposure to SO₂ (OR = 1.97; 95% CI: 1.02–3.80) and PM₁₀ (OR = 2.38; 95% CI: 1.17–4.84) with an increase in visits for asthma with coexisting allergic rhinitis (Kovačević et al. 2020). A study in Smederevo, the only town in Serbia with a steel factory, found increased concentrations of PM_{2.5} was associated with exacerbations of both asthma and COPD in female patients (Stevanović et al. 2016). Another study in Niš assessed the short-term association between urban ambient concentrations of black smoke and SO₂ and the daily values of blood pressure and heart rate in 98 healthy nonsmoking female volunteers and found no associations (Stanković et al. 2018). Another study in Novi Sad found that increased ambient concentrations of polycyclic aromatic hydrocarbons increased risk of lifetime lung cancer, especially during heating season (Radonić et al. 2017).

In Plovdiv, Bulgaria, two studies assessed nonrespiratory outcomes and found that type 2 diabetes mellitus was positively, although not significantly, associated with PM_{2.5} (OR = 1.32, 95% CI: 0.28–6.24) as well as high road traffic (OR = 1.40, 95% CI: 0.48–4.07), whereas in a later study, investigators found no association between NO₂ and mental health (Dzhambov et al. 2016, 2018).

Additional Evidence from Regional Health Impact Assessments

Health impact assessments are an approach to estimate the potential health effects of a policy, program, or project on a population. As with estimates of global disease burden, a number of factors can result in differences among estimates, obtained from health impact assessments, including the method/approach, input data, and scenarios used. A health impact study in two cities in Bosnia and Herzegovina (Matković et al. 2018) estimated possible health gains under two air pollution reduction policy scenarios. The study found that while ambient PM_{2.5} pollution accounts for 16.2% and 22.8% of all-cause mortality among adults in Tuzla and Lukavac, respectively, life expectancy could be increased by 2.1 and 2.4 years, respectively, underscoring that, with the implementation of air quality improvement plans and legislative actions to improve exposure to air pollution, considerable health gains can occur.

Across the region, a recent preliminary UN Environment Programme study assessed disease burden from ambient pollution in 18 cities across 6 countries (Albania, Bosnia and Herzegovina, North Macedonia, Montenegro, Serbia, and Kosovo⁴) and found that air pollution

⁴ This designation is without prejudice to position or status and is in line with the United Nations Security Council Resolution 1244 (UNSCR 1244/99) and the International Court of Justice Opinion on the Kosovo declaration of independence.

(PM_{2.5}, NO₂, and ozone) exposure decreased life expectancy (between 0.4 and 1.3 years) of the population (UNEP 2019). On average, 20% of years of life lost (130,000 years over a 10-year period) due to exposure to air pollution (PM_{2.5} and/or PM₁₀ and NO₂) resulted from premature deaths of persons under the age of 65 years, and exposure to PM_{2.5} accounted for 75% of these deaths (UNEP 2019). The analysis focused on 18 cities in the region with national and local air quality data (2015–2017) and health monitoring systems, and estimated annual mean concentrations of PM_{2.5}, NO₂, and ozone (SOMO35 levels⁵), as well as the disease burden. The AirQ+ software tool was used for cities where a minimum of 274 days/year of air quality data was available. Specifically, the study found that 5,000 deaths per year in the Western Balkan cities analyzed were attributable to air pollution, and the rate of mortality due to air pollution varied between 150–250 deaths/100,000 people in most cities. The highest impact, given population size, was in Pljevlja, Montenegro (350 deaths/100,000 population). Cause-specific death rates attributable to PM_{2.5} exposure ranged between 15%–20% for lung cancer and COPD across the cities, and the estimates for cardiovascular disease and ischemic heart disease ranged between 5%–10% (UNEP 2019). Importantly, this study confirms that data are available in selected countries in the region to allow for thorough burden of disease analyses from air pollution, as well as of potential exposure reduction in the selected cities.

Additionally, a 2020 World Bank analysis estimated the annual disease burden from air pollution (PM_{2.5}) for Kosovo, North Macedonia, and Bosnia and Herzegovina. It found that of the 760 PM_{2.5}-attributable deaths in Kosovo, approximately 11% of this disease burden is borne by residents of the country's capital, Pristina. Of these total deaths, 90% are from ischemic heart disease and stroke combined, and 53% from ischemic heart disease and 63% from strokes occurring in people under the age of 70. Population age groups between 50 and 69 years carry the largest share (~ 45%) of the total disease burden associated with exposure to ambient air pollution, followed by people over 70 years of age (World Bank 2020).

On a large Europe-wide scale, Barcelona Institute for Global Health assessed premature mortality due to air pollution in nearly 1,000 cities across 31 countries (EU member states) and found the following four cities in the Southeast European region were among the top 100 cities for highest premature deaths from air pollution: Ljubljana (Slovenia), Osijek and Slavonski Brod (Croatia), and Sofia (Bulgaria) (Khomenko et al. 2021).

On a country level, a health impact study assessing excess mortality from coal-fired power plant emissions in Europe noted that Bulgaria and Croatia are located downwind from strong coal emissions and found significant resulting excess death rates (>100 deaths per 100,000 inhabitants per year) in Bulgaria (142.3 deaths per 100,000 people; 95% CI: 126.2–157.9) (Kushta et al. 2021).

⁵ An indicator for health impact assessment recommended by WHO and defined as the yearly sum of the daily maximum of 8-hour running average over 35 ppb.

BURDEN OF DISEASE FROM AIR POLLUTION IN SOUTHEAST EUROPE

In 2019, 11.8% of total deaths in Southeast Europe (56,300 deaths, 95% UI: 42,974–72,725) were attributable to air pollution, with outdoor PM_{2.5} representing the largest fraction (46,600 deaths and 9.7% of total deaths) of air pollution-related deaths (Figure 8). The largest number of deaths attributable to air pollution in 2019 were in Romania (17,100 deaths, 95% UI: 12,849–22,522) and Serbia (12,700 deaths, UI: 9,946–16,139), whereas Montenegro (700 deaths, 95% UI: 557–933) and Slovenia (900 deaths, UI: 685–1,279) recorded the lowest number of deaths linked to air pollution in the region (Figure 9).

Broadly, the total number of air pollution-attributable deaths declined by 16.5% between 2010 and 2019, with the exception of Albania, where the total estimated deaths increased by 7%. The

Air pollution accounts for nearly 12% of total deaths in Southeast Europe. The average rate of death attributable to air pollution was nearly four times higher in the region than the related rate across Western Europe.

largest percentage decreases in number of deaths were estimated in Romania (by 4,700 deaths, representing a decrease of 21.6% from 2010) and Serbia (by 3,200 deaths, a 20.1% decrease from 2010), with the smallest percentage decrease of total deaths in Slovenia (4.4%, or ~40 deaths).

The countries in Southeast Europe with the highest death rates attributable to total air pollution are Bulgaria and North Macedonia (Table 4). Similar to the number of deaths, the average age-standardized death rate attributable to total air pollution decreased by an average of 7.5% across the Southeast Europe region (from 124 to 113 deaths/100,000 population). The largest decreases in death rates were estimated in Serbia (18.1%), Romania (15.3%), and Croatia (13.2%). On the contrary, in two countries – Albania and Bosnia and Herzegovina – the death rates attributed to air pollution increased by 13.4% and 7.4%, respectively (HEI 2020). In terms of the overall disease burden in the region, the total number of deaths as well as the age-standardized death rates increased slightly between 2010 and 2019.

Reducing the burden of disease from air pollution poses an increasing challenge even where exposures are leveling off or declining. Populations that are growing, and especially populations with an increasing number of older individuals (due to low birth rates or higher emigration versus immigration rates) may see a rising number of people affected by air pollution even with the same exposure levels because many of the chronic conditions associated with air pollution take years to develop and thus have a greater impact on health as populations age. Such is the case in much of Southeast Europe, where four countries (Bulgaria, Serbia, Croatia, and Romania) are among the top 10 countries globally with the highest prospective old-age dependency ratio in 2019. This ratio indicates that the working age population size is insufficient to support the de-

pendent/aging population, which can negatively influence various factors, including quality and accessibility of health care (UN 2019).

Fine Particulate Matter (PM_{2.5})

Across Southeast Europe, a total of 46,600 (95% UI: 35,790–59,122) deaths⁶ were attributable to ambient PM_{2.5} in 2019, with the highest related death toll in Romania (14,600 deaths, UI: 11,298–18,501) and Serbia (10,600 deaths, UI: 8,234–13,315) (Figure 9). Although the overall number of deaths attributable to PM_{2.5} in Southeast Europe decreased by approximately 12.7% between 2010 and 2019 (from 53,500 to 46,600 deaths⁷), this improvement was not borne equally among countries. The largest decreases in PM_{2.5}-attributable deaths were estimated in Romania (17%) and Serbia (15.9%) with marginal decreases in Slovenia (4.6%) and North Macedonia (1.1%), whereas a considerable increase in deaths of 21.4% was estimated in Albania (from 1,300 to 1,500 deaths). This increase in deaths could be due to high time-varying mobility patterns, with younger population migrating and leaving a larger number of elderly citizens (Leitner 2021). Estimates from the European Environmental Agency (EEA) are higher (76,600 deaths in 2018), but differences in the absolute numbers are related to differences in estimation methods, including underlying data on health effects, use of different reference pollution level (counterfactual), and the inclusion of Kosovo (see text box: Different Methodologies for Estimating Disease Burden from Exposure to Air Pollution).

Despite slow progress, the disease burden of ambient PM_{2.5} remains high.

Using Deaths Vis-A-Vis Death Rate to Compare Air Pollution's Disease Burden Among Countries

Although total numbers of deaths are useful for identifying where most people are affected, age-standardized death rates are important for comparing the disease burden among countries. Age standardization refers to a statistical technique used to make it possible to compare death or disease rates between populations with different age profiles. Without this statistical adjustment, a population that has a larger proportion of people in older age groups would appear to have a higher rate of people dying from diseases that occur in later life (e.g., heart disease) than another population with greater numbers of younger people.

⁶ This represents the sum of the attributable deaths for all countries covered in this report, with the exception of Kosovo (for which there are currently no IHME data available).

⁷ Health estimates from Kosovo are not available from the Global Burden of Disease Study 2019.

FIGURE 8 Percentage of total deaths, including those linked to individual pollutants (PM_{2.5}, ozone, and household air pollution), in Southeast Europe in 2019.

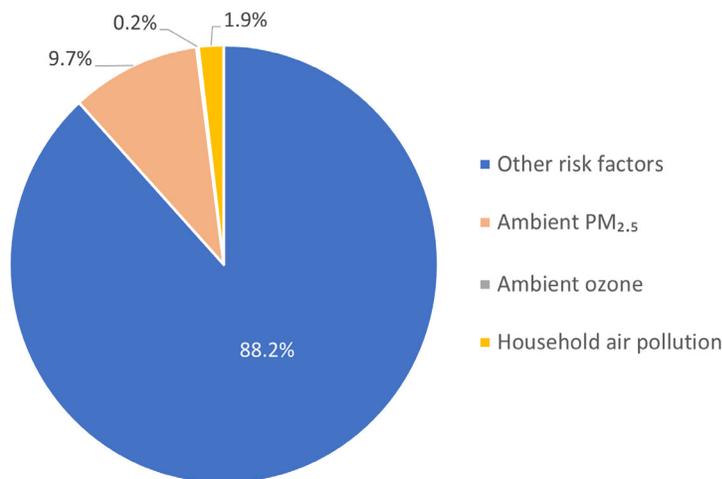


FIGURE 9 Total number of deaths linked to air pollution (ozone, PM_{2.5}, and household air pollution) in Southeast Europe in 2019.

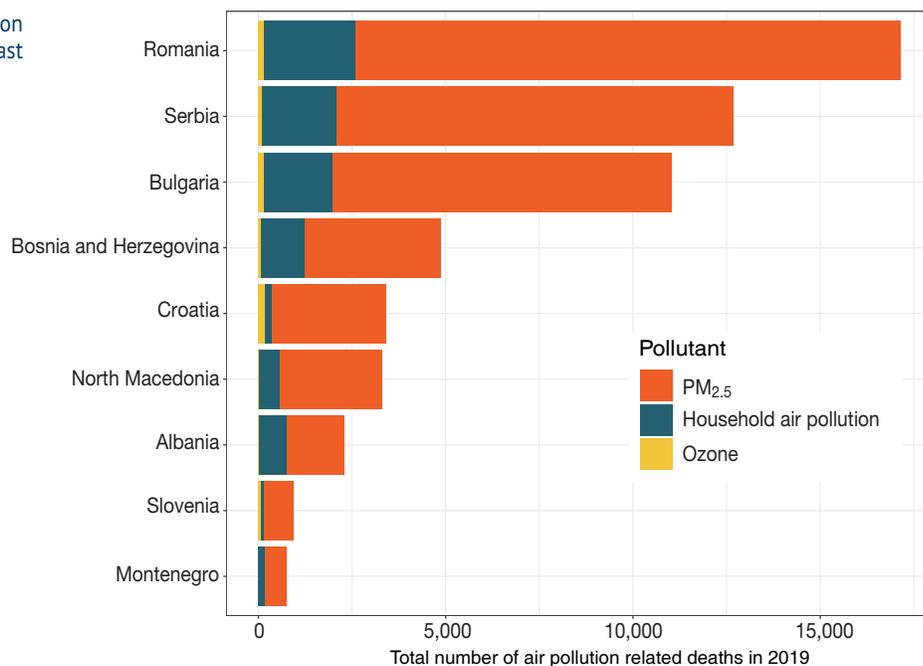


TABLE 4 The death rate (age-standardized* with 95% UI**) linked to total air pollution, PM_{2.5}, ozone, and household air pollution from solid fuels in 2019

Country	Total Air Pollution	Ambient PM _{2.5}	Ozone	Household Air Pollution
Bulgaria	159 (121–203)	131 (102–164)	2.22 (0.93–3.82)	26.1 (7.92–60.3)
North Macedonia	153(120–193)	128 (98.3–162)	0.93 (0.35–1.71)	24.8 (8.61–51.1)
Bosnia and Herzegovina	147 (114–189)	110 (81.0–140)	2.67 (1.15–4.47)	34.8 (13.7–70.9)
Serbia	145 (114–185)	121 (94.1–152)	1.28 (0.49–2.26)	22.5 (7.36–51.6)
Montenegro	119 (89.8–151)	91.0 (69.2–114)	1.08 (0.47–1.78)	27.1 (8.75–58.2)
Romania	89.1 (66.8–117)	75.8 (58.7–96.2)	0.76 (0.27–1.46)	12.7 (3.91–31.2)
Albania	83.7 (60.3–113)	56.3 (40.0–77.3)	0.88 (0.33–1.63)	26.6 (10.8–49.6)
Croatia	79.8 (60.0–102)	72.3 (54.4–92.4)	4.04 (1.78–6.73)	3.98 (1.07–10.5)
Slovenia	45.3 (33.0–61.7)	39.7 (28.9–53.1)	3.05 (1.35–5.19)	2.98 (0.71–8.05)
Global	86.2 (76.3–96.8)	53.5 (44.6–62.0)	4.72 (2.26–7.29)	29.9 (21.1–40.3)

* The total number of deaths per 100,000 people, calculated based on a standard distribution of population across age categories adjusted to match the UN 2015 Population Prospectus and obtained from the *Gridded Population of The World database* for each country.

**The 95% uncertainty intervals are a measure of scientific uncertainty. They reflect a range of values, from the 2.5th to the 97.5th percentile of a possible distribution of values, within which the true value is likely to fall.

Although the PM_{2.5}-attributable death rates exceed the global rate of 53.5 (44.6–62.0) deaths/100,000 population in eight out of nine countries (Table 4), the average age-standardized death rates attributable to PM_{2.5} have seen a slight decrease between 2010 and 2019 (by an average of ~2%) across the region (Figure 10). The two exceptions are Albania and Bosnia and Herzegovina, where PM_{2.5} death rates increased by 28.9% and 14.5%, respectively. Although most of the region's countries with the highest death rates associated with PM_{2.5} (i.e., Bosnia and Herzegovina, North Macedonia, and Serbia) also experienced some of the highest PM_{2.5} exposures (Table 1), Bulgaria experienced the highest PM_{2.5}-related death rate even though the annual exposure was not among the highest in the region. This difference could be due to a number of factors, including the aging – and therefore more susceptible – population demographic in Bulgaria, where 21% of the population was 65 years of age or older in 2019 and is projected to increase by 2% in 2030 (UN 2019).

Ozone

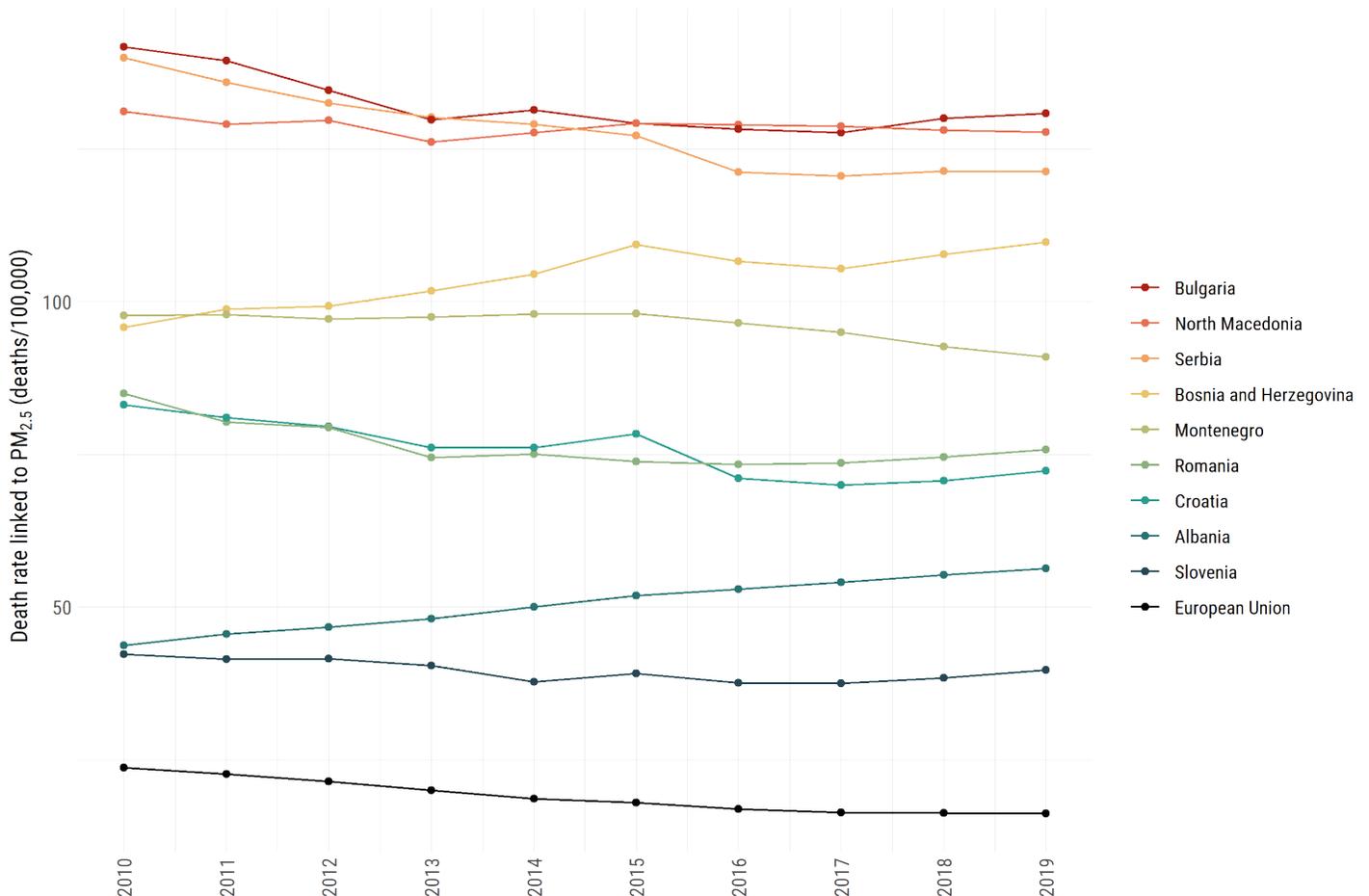
In 2019, the highest age-standardized death rates attributable to ozone in the region occurred in Croatia and Slovenia (Table 4), where ozone exposures were above the European average and the other countries in this report, but well below the EU limit values (see Air Quality Overview section above). The ozone-attributable death rates in these two countries are higher compared with the average death

rate attributed to ozone in Western Europe (3.04 deaths/100,000; 95% UI: 1.33–5.02), though lower than the average global death rate attributable to ozone (4.7 deaths/100,000; 95% UI: 2.26–7.29). The lowest death rate attributed to ozone in the region occurred in Romania and Albania (Table 4).

Although the overall disease burden from ozone improved in Southeast Europe from 2010 to 2019, a number of countries saw increased impact.

The overall average number of ozone-related deaths in Southeast Europe decreased by 31% between 2010 to 2019 (from 1,100 to 800; UI: 319–1376 total deaths). The largest improvements in the past decade in the burden of health estimate in terms of number of deaths attributable to ozone were in Romania, North Macedonia, and Serbia, where the number of deaths decreased by more than 50%. Conversely, Slovenia experienced the largest increase in number of deaths (by 47%) followed by Montenegro (29%), Croatia (24%), and Bosnia and Herzegovina (14% increase in deaths, even though the death rate did not increase). The highest numbers of ozone-attributable deaths were estimated to be in Croatia and Bulgaria (Figure 9). The EEA estimated a higher disease burden in terms of total deaths attributable to ozone in Southeast Europe, that is, 2,200 deaths in 2018, compared with the 2019 GBD estimate due to differences in

FIGURE 10 Trends in death rate linked to PM_{2.5} in Southeast Europe 2010–2019.



estimation methods and the inclusion of Kosovo data in the EEA estimate (see text box: Different Methodologies for Estimating Disease Burden from Exposure to Air Pollution).

Similarly, the average age-standardized death rate attributable to ozone across Southeast Europe decreased by ~8% between 2010 and 2019. This decreasing trend, however, was not consistent across countries as Slovenia, Montenegro, Bosnia and Herzegovina, and Croatia experienced an increase in ozone-attributable death rate while Romania, Serbia, North Macedonia, and Serbia saw declines of more than 50%.

Household Air Pollution – Cooking

Overall, less than 2% of all deaths were attributed to household air pollution across Southeast Europe. In line with global trends, the burden of disease from household air pollution has decreased steadily over the past decade in Southeast Europe. From 2010 to 2019, total number of deaths attributable to household air pollution in Southeast Europe decreased by ~30% (from 13,000 to 9,000 deaths). The countries in Southeast Europe with the highest number of deaths attributable to household air pollution are Romania (2,400; 95% UI: 752–6,008) and Serbia (2,000; 95% UI: 643–4,516), while Croatia (200; 95% UI: 46–447) and Montenegro (200; 95% UI: 54–361) had the lowest number of household air pollution-related deaths (Figure 9).

Good news: The burden of disease from household air pollution has decreased steadily over the past decade.

Similarly, household air pollution-attributable death rates decreased across Southeast Europe by between 35.5% in Croatia to 8.7% in Albania. The 2019 death rates linked to household air pollution across Southeast Europe are all above the Western Europe average (0.11 deaths/100,000 population; 95% UI: 0.03–0.27), while all, except Bosnia and Herzegovina, are below the global household air pollution-related death rate (29.9 deaths/100,000 population; 95% UI: 21.1–40.3) (Table 4). Household air pollution-related death rates in Southeast Europe are highest in Bosnia and Herzegovina and Montenegro and lowest in Slovenia and Croatia (Table 4).

GREATEST IMPACT ON THE YOUNGEST AND THE OLDEST

The burden of disease attributable to air pollution does not fall evenly across age groups. Throughout the world, children and the elderly are most acutely affected. Additionally, the three types of air pollution affect different age groups. Overall, ambient PM_{2.5} and household air pollution are the largest contributors to mortality across age groups. The effects of ozone are seen only in adults in this analysis because COPD is the only health outcome included in the analysis for ozone and it takes years to develop.

Across Southeast Europe, the peak in pollution-related deaths occurs in the older age group (ages 70 or older) (Figure 11). This peak reflects the contribution of air pollution to major noncommunicable diseases that develop over time: ischemic heart disease, stroke, COPD, lung cancer, and type 2 diabetes. In terms of deaths related to the youngest among us, exposure to air pollution accounted for 7.7% of deaths among infants, with most deaths attributed to ambient PM_{2.5}. Air pollution also accounted for 100 deaths among children under 5 years of age. The percentage of neonatal deaths attributable to air pollution (PM_{2.5} and household air pollution) in 2019 was largest in Bosnia and Herzegovina (11%) and North Macedonia (10%) (Figure 12).

68% of all deaths related to air pollution occur in people ages 70 or older.

In Southeast Europe, noncommunicable diseases rank among the most frequent causes of death, with cardiovascular (heart) diseases, diabetes, and chronic respiratory (lung) diseases, and infections ranking among the top 10 causes of death (GBD 2020); many of the same diseases are also linked with exposure to air pollution.

On average, nearly 23% of all COPD-related deaths were attributed to air pollution (Figure 13). The largest impacts were seen in Bosnia and Herzegovina (30%), North Macedonia, and Montenegro (each 26%), while the lowest such burden was estimated for Romania (14%). Other health outcomes for which air pollution remains a key risk factor in the region are type 2 diabetes, tracheal/bronchus/lung cancer, ischemic stroke, and heart disease (Figure 13).

Although global death rates from COPD attributable to ozone have declined by nearly 13% over the past decade, the overall number of associated deaths increased by 16.1%. Across Southeast Europe in 2019, ozone contributed an average of 6.1% of COPD deaths, with the largest fraction of ozone-attributable deaths from COPD in Slovenia (11%) and Croatia (10%), and the lowest percentage of total COPD deaths attributable to ozone was estimated in Romania (2%), and Serbia and North Macedonia (3% in each). The ranking of the disease burden tracks directly with the ozone exposures in these countries (i.e., Slovenia and Croatia experienced the highest ozone exposures, while North Macedonia, Serbia, and Romania have the lowest ozone levels (Table 4). *Explore a detailed breakdown of cause-specific deaths related to each pollutant for your country [here](#).*

Air pollution makes a significant contribution to the noncommunicable disease burden, including from heart and chronic lung disease and diabetes, and it has the greatest impact on the youngest and the oldest.

FIGURE 11 Distribution of deaths in 2019 in Southeast Europe linked to air pollution by age (in years, except early neonatal, 0 to 6 days, and late neonatal, 7 to 27 days).

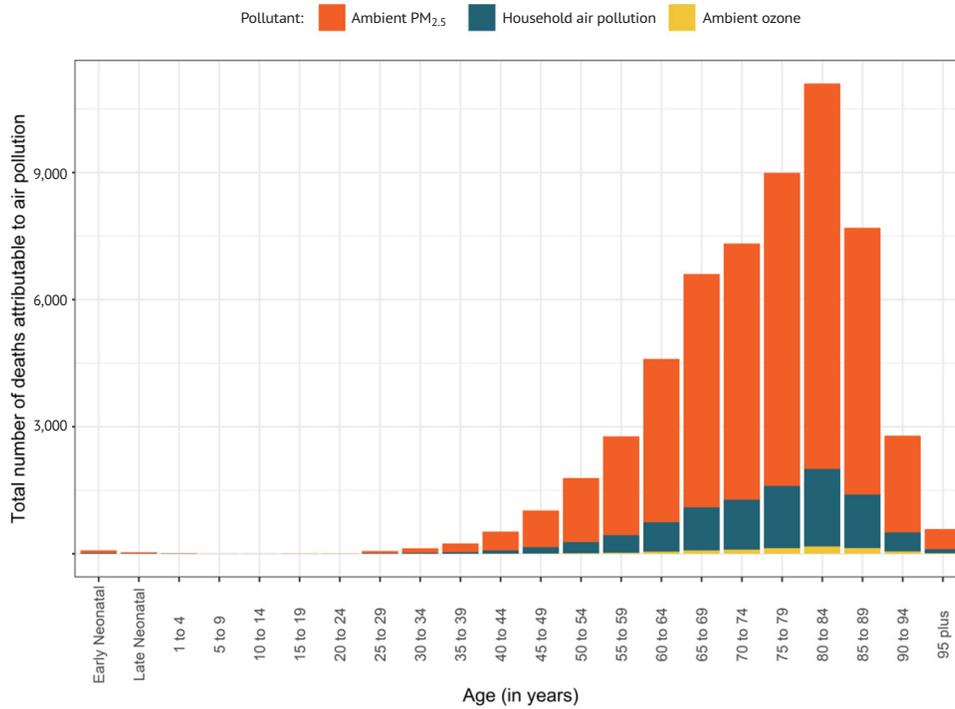


FIGURE 12 Percentage of neonatal deaths linked to air pollution (PM_{2.5} and household air pollution) in 2019 (HEI 2020).

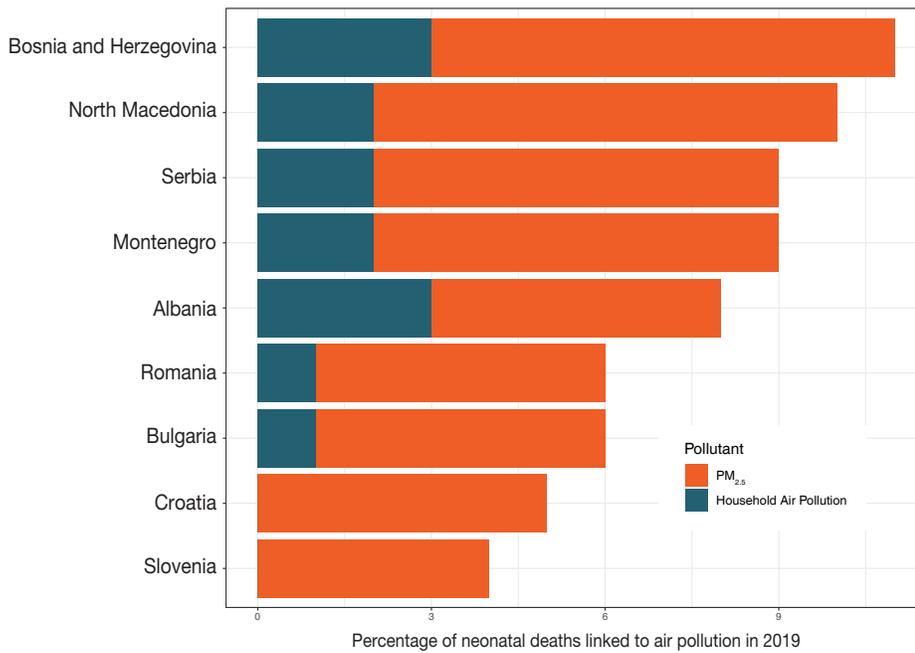
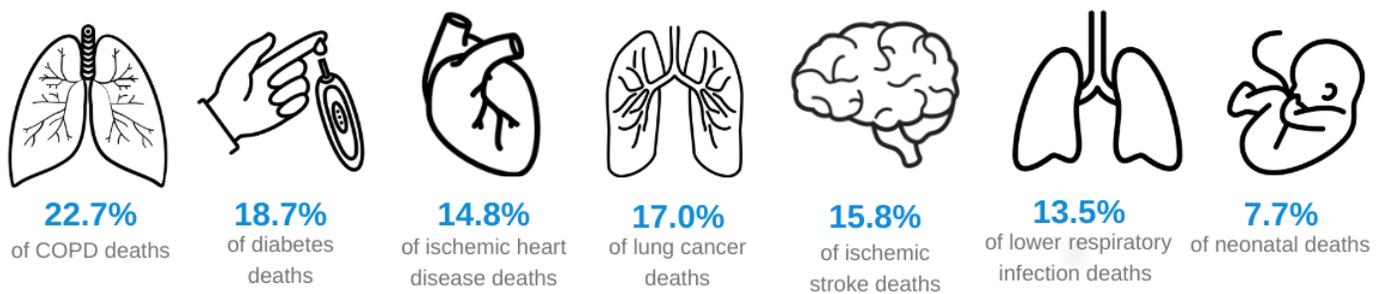


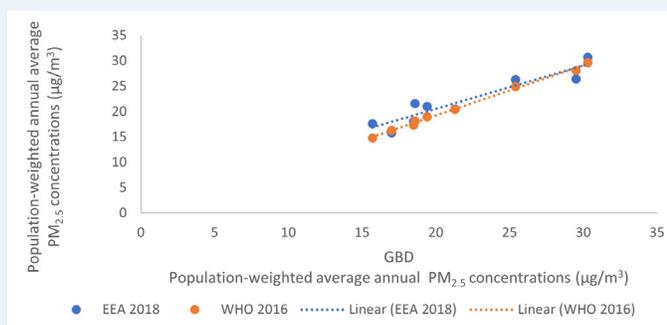
FIGURE 13 Percentage of deaths (by cause) linked to air pollution in 2019.



Different Methodologies for Estimating Disease Burden from Exposure to Air Pollution (*most estimates find significant burdens*)

In addition to those of GBD, several other estimates of air quality are available for Southeast Europe from various organizations, including the WHO and the EEA. Each of these data sources are updated at different time intervals, and as such, at any given time, data available from each source may be for a different year. For example, currently, the latest GBD estimates are for the year 2019, EEA data and estimates are for the years 2018 and 2019, and WHO estimates are for the year 2016. Although slight differences may exist between the data from GBD and from other sources, all-in-all they give a cohesive idea of what air quality is like in the region (see example of PM_{2.5} in Figure i).

FIGURE i. Comparison of region-specific PM_{2.5} estimates (µg/m³) for year 2019 with WHO estimates for year 2016 and EEA estimates for year 2018. EEA reports population-weighted annual average PM_{2.5} concentration (µg/m³), while WHO reports the population-weighted annual median PM_{2.5} concentration (µg/m³).



Although epidemiological research investigates the relationship between exposure to air pollutants and specific health outcomes in populations (e.g., association between long-term exposure to PM_{2.5} and lung cancer deaths), burden of disease analysis is used to describe the total disease burden at the population level. There are four major building blocks for estimating the burden of disease associated with air pollution:



Globally, two major burden of disease studies – the WHO and GBD studies – are used most widely, whereas in Europe the EEA produces burden of disease estimates for all EEA countries. Across the different analyses, a number of factors can result in differences among the estimates:

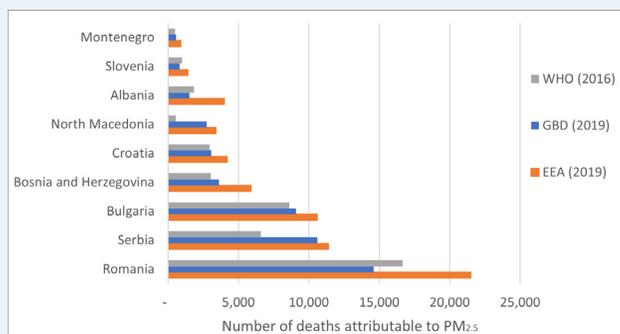
1. **Exposure data** – EEA estimates are based on more granular, location-based air pollution exposure data as well as population-weighted averages as an exposure indicator,

whereas both the IHME and WHO estimates are based on average country-level exposure to PM_{2.5}.

2. **Minimum exposure level** – EEA assumes that the counterfactual minimum exposure level for PM_{2.5} equals zero, which is lower than in the IHME and WHO estimates.
3. **Causes of air pollution-attributable deaths** – EEA takes a broader approach in estimating the excess mortality due to PM_{2.5} by considering all nonaccidental causes of death, while GBD estimates consider mortality from five main causes (cardiovascular diseases, diabetes, chronic respiratory diseases, respiratory infections, and lung cancers) and the WHO estimates focus on mortality from three main causes (ischemic heart disease, stroke, and respiratory diseases).

Generally, the EEA estimates of the number of premature deaths attributable to the effect of outdoor air pollution from PM_{2.5} are higher (76,600 in 2018 across the Southeast European countries covered in this report) compared with estimates from IHME (41,200 in 2019) and WHO (41,200 in 2016), while the WHO estimates are generally lower than those estimated by IHME, with the exception of Romania, Albania, and Slovenia (Figure ii). Furthermore, the impacts are estimated for mortality alone in the case of WHO and EEA, whereas GBD estimates both mortality and morbidity impacts. Note that morbidity data are not presented in this report but are available on www.stateofglobalair.org/data. Finally, and importantly, all the available estimation approaches are subject to considerable uncertainty caused by various factors, including incomplete data on population demographics as well as the precision of the concentration-response functions.

FIGURE ii. Number of deaths* attributable to ambient PM_{2.5} exposure (HEI 2020; Ortiz 2020; EEA 2020; WHO 2021).



*WHO 2016 estimate for North Macedonia is available for “the former Yugoslav Republic of Macedonia.”

KEY SOURCES OF PM_{2.5} AND RELATED HEALTH IMPACTS

PM_{2.5} is generated from both natural and anthropogenic sources. Common natural sources include windblown dust, sea spray, and wildfires, while anthropogenic (or man-made) sources include fossil fuel and biofuel combustion, industrial processes, agriculture, and waste management. To identify priority actions and most cost-effective solutions, it is critical to understand the major sources, especially anthropogenic sources, of air pollution. In this report, we evaluate two sources of PM_{2.5}. The first is PM_{2.5} generated from burning different types of fuels (e.g., coal, solid biofuel), and the second is PM_{2.5} generated by different sectors (e.g., residential, energy, industry). Globally, residential, industrial, and energy sectors that often involve fuel combustion contribute to nearly 40% of the PM_{2.5} exposure (McDuffie et al. 2021). However, there remain large variations in major sources of air pollution across and within countries.

MAJOR SOURCES OF PM_{2.5} IN SOUTHEAST EUROPE

When looking at fuel types, burning fossil fuels (including both coal and liquid fuel and natural gas) is the largest single contributor to PM_{2.5} in this region (Figure 14) with coal use contributing to 19% of all PM_{2.5}-related deaths in the region. In Serbia, the highest burden is 26%; in Bosnia and Herzegovina, it is 24%; and in North Macedonia, it is 23%. Coal has been widely used in power plants, industries,

Fossil fuel (coal and liquid fuel and natural gas) combustion contributes between 29.1% to 35.8% of PM_{2.5} exposures in Southeast European countries.

and to a lesser degree in household settings in southeast Europe. The PM_{2.5} shares from burning coal in almost all Southeast European countries (except for Slovenia) are higher than average shares in Western Europe (6.0%) and Eastern Europe (11.2%). It is also noteworthy that burning of solid biofuel, mostly used in households for cooking and heating, also contribute to a large share of PM_{2.5} and related disease burden, particularly in Slovenia (27%), Croatia (27%), and Romania (25%).

When looking at PM_{2.5} and its disease burden from different sectors, residential combustion, energy production, agriculture, windblown dust, transport, and industry (Figure 15) are important common sources of PM_{2.5} in the region. Across the region, the residential sector (from heating) accounted for the 20% of total PM_{2.5}-attributable deaths (9,700 deaths) (Figure 15). Other sources with large contributions to deaths related to air pollution include energy (18%; 8,700 deaths), agriculture (13%; 6,200 deaths), windblown dust (13%; 6,030 deaths), and transportation (7%; 3,300 deaths) (Figure 15).

For Serbia, North Macedonia, and Bosnia and Herzegovina, the energy sector was the leading source for PM_{2.5}-attributable deaths. The remaining 22% includes anthropogenic fugitive, combustion, and industrial dust; other combustion; waste; international shipping; agricultural waste burning; and other fires.

Data presented here represent the contribution of various sources to PM_{2.5} at the national level, but the relevance of the sources can vary at different spatial scales. For example, while transportation does not show up as the largest source at the national level, it most often contributes significantly to pollutant levels at the city or urban scale. In this context, it is noteworthy that energy production is the

leading source of PM_{2.5} in many Southeast European cities and contributes between 15%–50% across the region (Belis et al. 2019).

Energy production contributes over 20% of PM_{2.5} exposure in some countries in Southeast Europe where reliance on polluting and inefficient power plants is high.

Share of PM_{2.5} exposures and related disease burden from energy production are highest in Serbia (22.8%), Bosnia and Herzegovina (22.0%), and North Macedonia (20.8%). Shares of PM_{2.5} from energy production in southeast region are also higher than the averages reported in Western (10.0%) and Eastern Europe (16.2%) (Figure 16). As Southeast European countries rely heavily on coal-fired power plants, most of which operate at low efficiencies, the three countries with highest PM_{2.5} shares and associated disease burdens from energy production also reported highest shares from use of coal (23.3%–25.8%) (Figure 14).

Noncombustion agricultural activities, including soil cultivation, livestock production, and fertilizer application, contribute between 10.5% and 17.4% of PM_{2.5} exposures across Southeast Europe (Figure 16); this is lower than the contribution to PM_{2.5} in Western Europe (21.7%). It is useful to note that PM_{2.5} from areas with high agricultural activity in Western Europe (such as Northern Italy, Switzerland, and Southern Germany) has also been reported to contribute to the secondary PM_{2.5} exposures in Southeast Europe (Belis et al. 2019).

Agriculture, transport, and industry are also important contributors to the PM_{2.5} disease burden in many Southeast European countries.

Residential combustion and energy production are the largest contributors to deaths related to air pollution in Southeast Europe, resulting in 18,400 deaths in 2019.

FIGURE 14 Contribution of key fuel types to PM_{2.5} exposures in 2019 (Data source: McDuffie et al. 2021).

*Other refers to the PM_{2.5} generated during processes that could not be cleanly allocated to combustion of one of the fuel categories, including windblown dust, industry sources that use multiple fuels, etc.

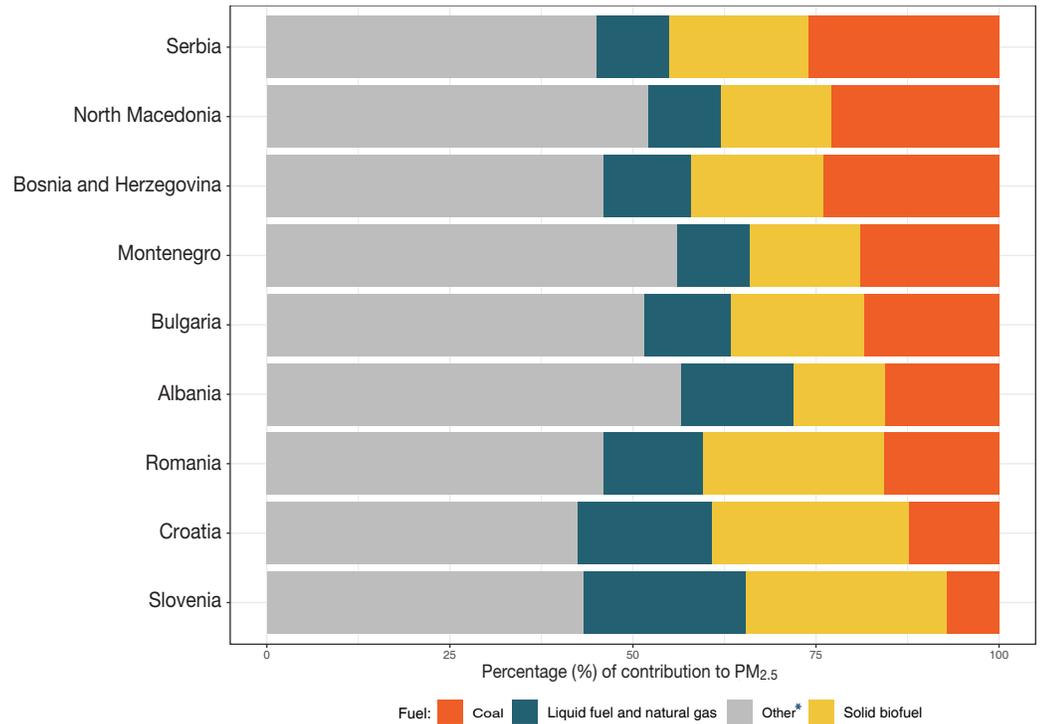


FIGURE 15 Percentage of PM_{2.5} from six major sources in nine Southeast European countries in 2019 (Data source: McDuffie et al. 2021)*

*Kosovo data are not available in the GBD MAPS Global study.

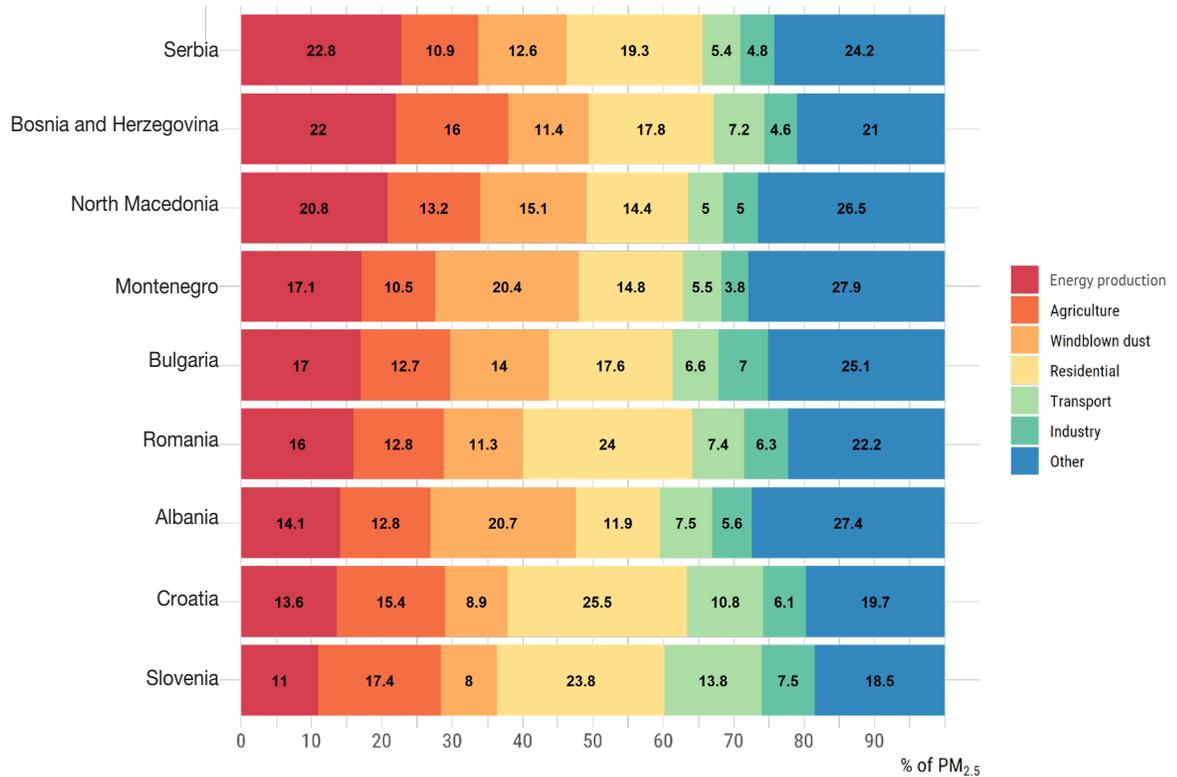
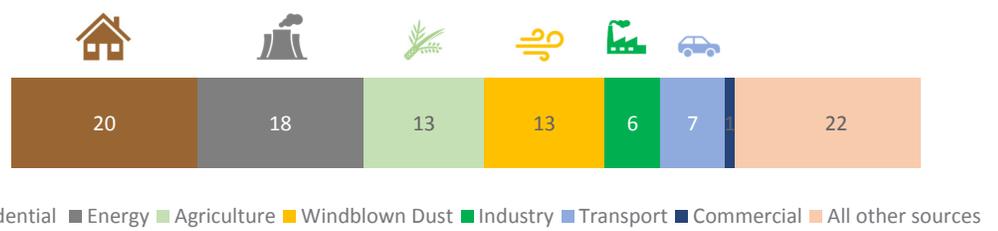


FIGURE 16 Source-specific deaths (cases as %) attributable to PM_{2.5} in Southeast Europe in 2019.



Magnitude of Contribution from Key Sources Varies Across Regional, National, and Local Scales

Transport and industry make relatively smaller contributions to national PM_{2.5} disease burden than other leading sectors in Southeast European countries but there are significant regional variations (Figure 16). Transport contributed to 5.0% to 13.8% of PM_{2.5} exposures and the disease burden across Southeast Europe, with the highest contribution in Slovenia and lowest in North Macedonia. Shares of PM_{2.5} exposure from industrial sources were highest in Slovenia (7.5%) and lowest in Montenegro (3.8%). Although these shares were still substantial, PM_{2.5} disease burden from transport and industry were generally lower than the ones observed in Western Europe (transport: 11.9%, industry: 8.2%). However, the PM_{2.5}-related disease burden from these two sources in Southeast European cities may be much higher than the national averages. Compared with rural areas, industry and transportation play a more prominent role in producing PM_{2.5} in cities, especially during warmer seasons. A study in Sofia, Bulgaria, showed that more than 80% of PM_{2.5} concentrations were from road transport in the central city area during the warm season, but this share dropped drastically in the city's outskirts and satellite villages (Dimitrova and Velizarova 2021). Another study in Zagreb, Croatia, attributed more than 10% of PM_{2.5} concentrations to the metal production industry in summer (July to September) and fall (October to December) (Perrone et al. 2018).

Seasonal Contributions from Windblown Dust

In some countries, such as Montenegro and Albania, windblown dust can also make significant contributions to the PM_{2.5} disease burden, albeit seasonally, where 20.4% and 20.7% of the annual PM_{2.5} exposures were from windblown dust, respectively (Figure 16). It also contributed to more than 10% of PM_{2.5} exposures in Romania, Bulgaria, Serbia, and North Macedonia. This was mainly due to the large amount of desert dust that is transported to the region from the Saharan and Karakum deserts, predominantly in spring and summer.

How did we identify major sources of air pollution?

We identified major sources of air pollution at national levels for countries in Southeast Europe based on the data from the GBD MAPS Global study (McDuffie et al. 2021). As sources of air pollution often differ between rural and urban areas, we also included some studies conducted in major cities in the region to provide additional insights on local sources of air pollution. The GBD MAPS Global study provided the first contemporary and comprehensive global evaluation of major sources of PM_{2.5} by fuel type and by sector in more than 200 countries using a consistent methodology and global emissions inventories. It utilized updated Community Emissions Data System emissions inventories, satellite data, ground-monitoring data, and advanced air quality modeling (GEOS-Chem model) to estimate the PM_{2.5} exposures from 16 sectors and 4 different fuel types (McDuffie et al. 2021). Unlike regulatory emission data, the GBD MAPS Global study considered both anthropogenic sources (e.g., residential use, industry, and transportation) and natural sources (e.g., windblown dust, open fires, and volcanoes). It also estimated deaths linked to different sources of PM_{2.5} using GBD methodologies. *More details about this study can be found [here](#).*



Fog over Sofia, Bulgaria on a rainy day

CONCLUSIONS

Air pollution is the leading environmental threat to public health in Southeast Europe. In 2019 alone, 56,300 deaths, nearly 12% of total deaths in the region, were attributed to air pollution, with most of the deaths (~10% of total deaths) attributed to exposure to ambient PM_{2.5}. Evidence in many countries shows that the estimated health benefits of air quality mitigation actions outweigh by far their implementation costs. Thus, an understanding of long-term air quality trends and the associated disease burden, as presented here, can help to inform decision makers as to where policy action to reduce population exposure at the national or regional levels can bring the most benefit.

Although many countries in the region have made air quality improvements over the last decade, exposures have remained higher than those seen broadly across Europe; and in some countries, up to 71% of the population lives in areas that do not meet the current EU air quality limit value of 25 µg/m³ for annual PM_{2.5} concentration.

In Southeast Europe, combustion of fossil fuels (including coal, oil, and natural gas) and wood is the dominant source of particulate matter. Energy poverty and access to clean energy remain key issues; a significant proportion of the region's population is unable to afford to heat their homes or lacks access to the centralized energy systems that rely on energy-intensive and polluting lignite coal power plants. Household heating (and cooking) using biomass and coal plays a more dominant role in air quality compared with the rest of Europe. Energy production that relies on old, inefficient coal-fired power plants means that energy production and use results in poor air quality and higher disease burden. Overall, bold air quality actions are needed at all levels (regional, national, and local) and across sectors (e.g., energy, transportation, and agriculture) and development plans for the region must account for health implications of energy choices made today and in the future.

Just as the COVID-19 crisis has demonstrated the need for multiple strategies to manage the pandemic, solutions to air pollution will require multifaceted ongoing efforts to bring attention to its health threats, to identify the policy changes necessary to control it, and to monitor progress over time. To achieve clean air across this region, local, national, and regional collaborations are necessary. It is important to not only expand and improve access to air quality data and support health studies, but to also support collaborations among researchers, physicians, and civil society experts.

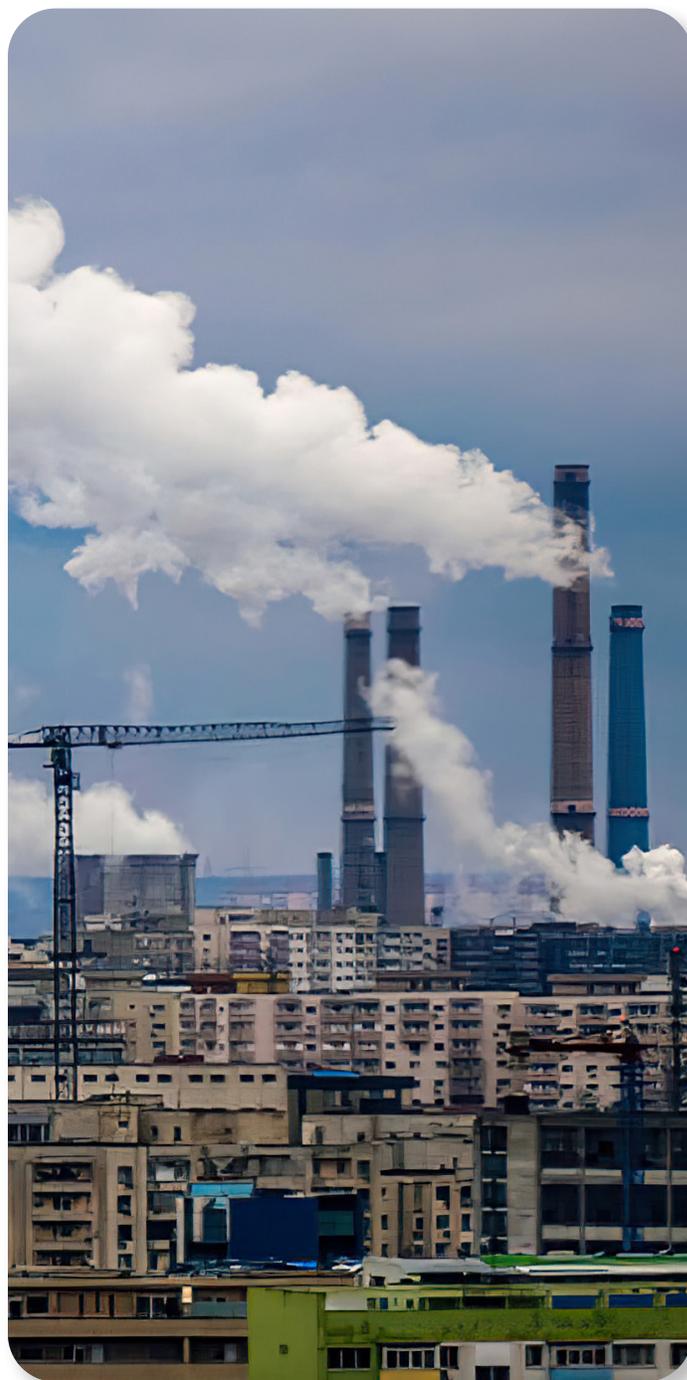


Obilic power plant in Pristina, Kosovo

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ABBREVIATIONS

CI	confidence interval
COPD	chronic obstructive pulmonary disease
COVID-19	infectious disease caused by the novel coronavirus SARS-CoV2
EC	European Commission
EEA	European Environmental Agency
EU	European Union
GBD	Global Burden of Disease
GEOS-Chem	Global 3-D model of atmospheric chemistry driven by meteorological input from the Goddard Earth Observing System (GEOS)
IHME	Institute for Health Metrics and Evaluation
OR	odds ratio
OECD	Organisation for Economic Co-operation and Development
NO	nitrogen oxide
NO ₂	nitrogen dioxide
NO _x	nitrogen oxides
PM _{2.5}	particulate matter ≤2.5 µm in aerodynamic diameter
PM ₁₀	particulate matter ≤10 µm in aerodynamic diameter
ppb	parts per billion
ppm	parts per million
RR	relative risk
SEE	Southeast Europe
SO ₂	sulfur dioxide
SoGA	State of Global Air
UI	uncertainty interval
VOCs	volatile organic compounds
WHO	World Health Organization



Chimneys of the CET Sud power plant in Bucharest, Romania

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KEY RESOURCES

Global Burden of Disease 2019 Methods

These resources provide background details on the latest GBD methods used to estimate PM_{2.5}, ozone, and household air pollution exposures and the deaths reported here.

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Explore and download additional information and data on mortality and disease burden for air pollution, as well as other risk factors, at the IHME GBD Compare site at <https://vizhub.healthdata.org/gbd-compare/>.

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A small town in Bosnia and Herzegovina

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