AIR QUALITY LIFE INDEX® | 2023

Annual Update

By Michael Greenstone and Christa Hasenkopf

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Dear Friends and Colleagues,

We are pleased to bring you the latest data from the Air Quality Life Index (AQLI). This data shows that fine particulate air pollution remains the greatest external threat to public health. Yet, throughout history countries like the United States, Europe, Japan, and, most recently, China have been able to significantly reduce air pollution thanks to a persistent, public call for change followed by strong policies. At the foundation of those actions were common elements: political will and resources, both human and financial, that reinforced each other. When the public and policymakers have these tools, action becomes much more likely.

The AQLI was built to help solve some of these challenges by providing local information on air quality and its health consequences. It is succeeding in many respects, having been used by more than 325,000 visitors from every country globally and covered by more than 300 media outlets reaching more than 1.1 billion people in at least 20 languages. Government leaders in India and elsewhere have drawn on the AQLI's data to justify new policies and pollution actions.

At the same time, the underlying satellite data on air pollution concentrations is only available periodically (e.g. annually), and it isn't currently widely used for enforcing air quality regulatory policies. Thus, more frequent (e.g. daily), locally-generated ground monitoring data is often a starting point for public engagement in a community—and is required for policy enforcement in most instances.

Unfortunately, the countries experiencing some of the worst pollution today don't have the tools they need to fill these basic air quality management holes like generating high-frequency local air quality data. Local air quality data that is accessible to citizens in a timely and reliable manner is a basic tool in the pollution arsenal that complements efforts like the AQLI. With it and local health data, researchers can deepen their knowledge on the connection between high pollution and local health impacts; local and global organizations can apply this timely knowledge and provide information to civil society; and, leaders can set strong air quality standards, build robust policies and monitor their progress to ensure policies are successful. Yet, just a small fraction of countries in Asia and Africa provide their citizens with such fully open air quality data.

Meanwhile, the philanthropic pie for air pollution is unbalanced compared to the size of its burden on both the Asian and African continents. Africa, for example, receives about as much philanthropic money to combat outdoor air pollution as what it would cost to buy an average single-family home in the United States. There is an outsized opportunity for these countries, as well as international aid organizations and private philanthropy, to strategically target funding toward the build-out of infrastructure countries need to unleash knowledge and, ultimately, action. Right now, that's not happening.

In the coming months and years, Energy Policy Institute at the University of Chicago (EPIC) will further explore the data gap and look for opportunities to work with organizations who are interested in producing the information necessary to help societies make more informed decisions about air pollution. In the meantime, this report continues the AQLI's efforts to raise awareness about fine particulate air pollution that is causing the average person on the planet to lose 2.3 years of life expectancy.

Sincerely,

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At a Glance

Air pollution is the greatest external threat to human life expectancy on the planet.

- The AQLI's latest 2021 data reveals that permanently reducing global $PM_{2.5}$ air pollution to meet the World Health Organization (WHO) guideline would add 2.3 years onto average human life expectancy—or a combined 17.8 billion life years saved.
- The impact of $PM_{2.5}$ on global life expectancy is comparable to that of smoking, more than 3 times that of alcohol use and unsafe water, more than 5 times that of transport injuries like car crashes, and more than 7 times that of HIV/AIDS.

Asia and Africa bear the greatest burden yet lack key infrastructure.

- South Asia is home to the world's four most polluted countries and nearly a quarter of the global population. In Bangladesh, India, Nepal and Pakistan, the AQLI data reveal that residents are expected to lose about 5 years of life expectancy on average, if levels of pollution persist. Since 2013, about 59 percent of the world's increase in pollution has come from India alone.
- The African countries of the Democratic Republic of the Congo, Rwanda, Burundi, and Republic of the Congo are amongst the ten most polluted countries in the world. Air pollution is now as much of a health threat in Central and West Africa as well-known killers in the region like HIV/AIDS and malaria.
- Despite the fact that Asia and Africa contribute 92.7 percent of life years lost due to pollution, they lack basic infrastructure for change. Just 6.8 and 3.7 percent of governments in Asia and Africa, respectively, provide fully open air quality data and just 35.6 and 4.9 percent of countries in Asia and Africa, respectively, have air quality standards.[1] Both are foundational ingredients for policy action.
- There is an outsized opportunity to reverse this inequality. While there is a large global fund for HIV/AIDS, malaria, and tuberculosis that annually disburses 4 billion USD toward the issues, there is no equivalent set of coordinated resources for air pollution. The entire continent of Africa receives under 300,000 USD in philanthropic funds toward air pollution. Just 1.4 million USD goes to Asia (outside of China and India). Europe, the United States, and Canada receive 34 million USD, according to the Clean Air Fund.[2]

1 OpenAQ. 2022. "Open Air Quality Data: The global landscape."

2 Clean Air Fund. 2022. "The State of Global Air Quality Funding."

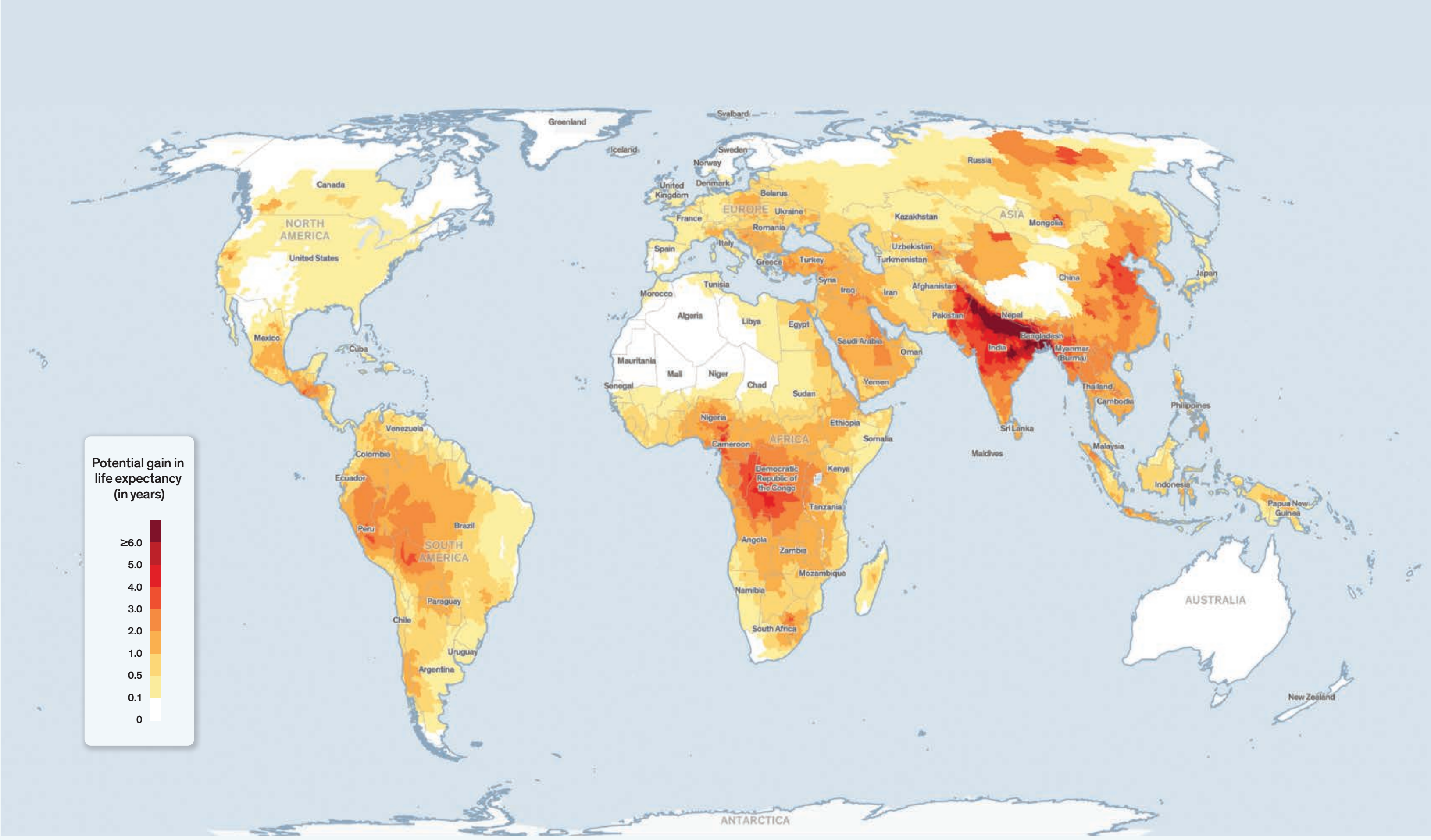
China's efforts to curb pollution remain a remarkable success—and a work in progress.

- China's pollution has declined 42.3 percent since 2013, the year before the country began a "war against pollution." Due to these improvements, the average Chinese citizen can expect to live 2.2 years longer, provided the reductions are sustained.
- The pollution in China is still six times the WHO guideline, taking 2.5 years off life expectancy.

While the United States and Europe seek tougher standards, pollution's impacts are unequal in both places.

- In 2021, 20 out of the top 30 most polluted counties in the United States were in California due to the impact from wildfires. Residents of California's Central Valley are now consistently exposed to average particulate pollution levels above the nation's $PM_{2.5}$ standard of 12 µg/m³.
- This year, the U.S. Environmental Protection Agency proposed to lower the standard from 12 to 9–10 µg/m³. If the upper limit of that proposed standard were met, people living in the 40 counties that exceeded that level in 2021 could gain a combined 3.2 million life years.
- Residents in eastern Europe are breathing dirtier air than their western neighbors and living shorter lives because of it.[3] If the east were to clean up its air to meet the levels in the western part of the continent, the average citizen in the east could live 7.2 months longer, which translates to 114 million total life years gained for the eastern European region as a whole.
- In 2022, the European Commission proposed ratcheting down the European Union's current annual $PM_{2.5}$ pollution standard of 25 µg/m³ to 10 µg/m³ by 2030. If the 15 member countries that currently exceed the proposed stricter standard were to meet it, residents would gain a combined 80.3 million life years.

3 Western Europe is defined as the following countries: Germany, Switzerland, Italy, Monaco, Luxembourg, Belgium, France, Netherlands, Andorra, Spain, United Kingdom, Portugal, Denmark, Ireland, Iceland, Austria. Eastern Europe is defined as the countries listed in the following file: https://drive.google.com/file/d/1k-7Tel92GdulJsoSl06JG2wzQdHD8qKQH/view?usp=drive_link. This definition is used only when comparing Eastern and Western Europe in this report (both in text and figure 7.4). All other types of calculations follow the original definition of Europe (which includes a couple more countries) as listed under footnote 54.



Latin America struggles with pollution hotspots and lacks fully open air quality data.

- The most polluted areas across Latin America—located within Guatemala, Bolivia, and Peru—experience air quality similar to pollution hotspots like Pune, India and Harbin, China. In these regions, the average resident would gain 3 to 4.4 years of life expectancy if their air quality met the WHO guideline.
- Only 19 percent of countries in Latin America make their government pollution data fully open to the public,[1] making research and advocacy—and subsequently policy action—around air pollution much more difficult.

METHODOLOGY

The life expectancy calculations made by the AQLI are based on a pair of peer-reviewed studies, Chen et al. (2013) and Ebenstein et al. (2017), co-authored by Michael Greenstone, that exploit a unique natural experiment in China. By comparing two subgroups of the population that experienced prolonged exposure to different levels of particulate air pollution, the studies were able to plausibly isolate the effect of particulate air pollution from other factors that affect health. Ebenstein et al. (2017) found that sustained exposure to an additional 10 µg/m³ of PM_{10} reduces life expectancy by 0.64 years. In terms of $PM_{2.5}$, this translates to the relationship that an additional 10 µg/m³ of $PM_{2.5}$ reduces life expectancy by 0.98 years. This metric is then combined with sea-salt and mineral dust removed satellite-derived $PM_{2.5}$ data. All 2021 annual average $PM_{2.5}$ values are population-weighted and AQLI's source of population data is https://landscan.ornl.gov/. We are grateful to the Atmospheric Composition Analysis Group, based at the Washington University in St. Louis for providing us with the satellite data. The original dataset can be found here: https://sites.wustl.edu/acag/datasets/surface-pm2-5/.

To learn more deeply about the methodology used by the AQLI, visit: aqli.epic.uchicago.edu/about/methodology.

Section 1

Air Pollution's Threat to Health and the Tools to Combat It Remain Unequally Distributed Worldwide

As global pollution edged upward in 2021, so did its burden on human health. The AQLI shows that reducing global pollution to meet the World Health Organization (WHO) guideline would add 2.3 years onto average life expectancy.[4] Yet, the burden of pollution is not spread evenly throughout the world—nor are the basic resources necessary to build strong policies.

PARTICULATE POLLUTION IS A GLOBAL HEALTH THREAT: 2021 GLOBAL DATA UPDATE

According to new and revised satellite-derived $PM_{2.5}$ data, the global population weighted-average $PM_{2.5}$ level increased slightly between 2020 and 2021, from 28 to 28.2 µg/m³—more than five times the World Health Organization (WHO)'s guideline of 5 µg/m³.

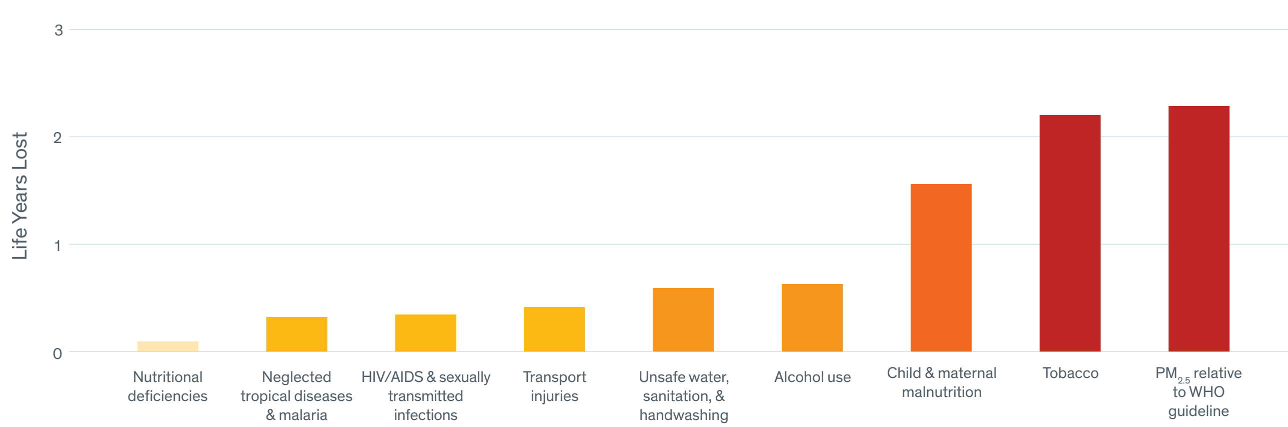
The AQLI shows that reducing global $PM_{2.5}$ pollution to meet the WHO guideline would add 2.3 years onto average life expectancy.

4 This data is based on the AQLI 2021 dataset. All annual average $PM_{2.5}$ values (measured in micrograms per cubic meter: µg/m³) are population weighted.

In other words, permanently reducing particulate pollution to the WHO guideline would mean the world's population would gain a total of 17.8 billion life years.

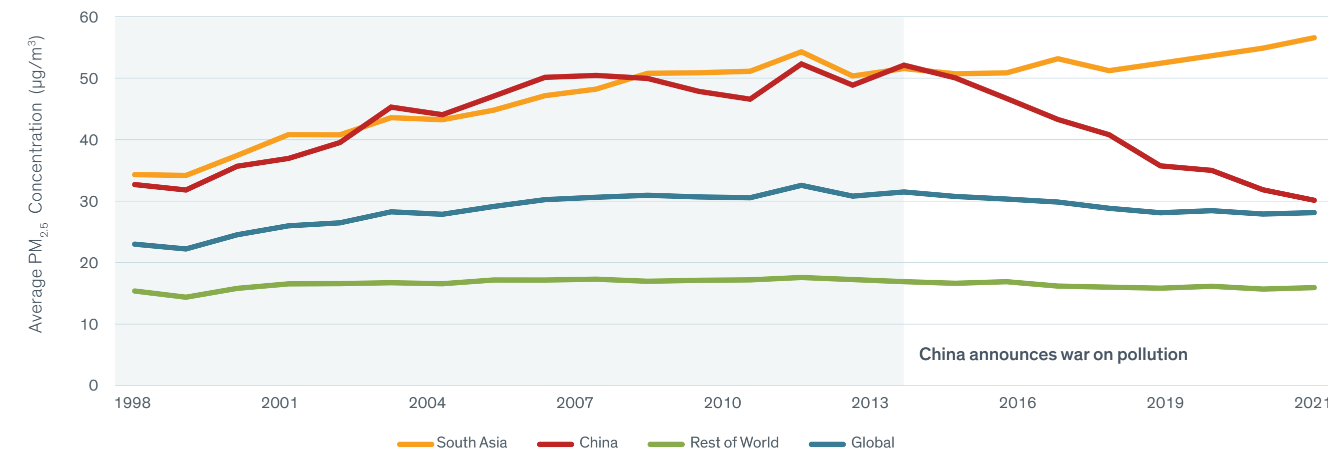
Measured in terms of life expectancy, the AQLI reveals that ambient particulate pollution is consistently the world's greatest external risk to human health. While particulate pollution is set to reduce global average life expectancy by 2.3 years, tobacco use, for instance, reduces global life expectancy by 2.2 years. Child and maternal malnutrition reduces life expectancy by 1.6 years; alcohol use by 7.2 months; unsafe water, sanitation and handwashing, 7.2 months; HIV/AIDS, 3.6 months; and nutritional deficiencies, just 1.2 months (see Figure 1.1). Thus, the impact of particulate pollution on life expectancy is comparable to that of tobacco use, 3.8 times that of alcohol use and unsafe water sanitation and handwashing, 5.8 times that of transport injuries, 7.6 times that of HIV/AIDS, and 23 times that of nutritional deficiencies.

Figure 1.1 · Select major global threats to life expectancy



Sources: Global Burden of Disease (https://vizhub.healthdata.org/gbd-results/) level-2 causes and risks data and WHO Life Tables (https://apps.who.int/gho/data/node.main.LIFECOUNTRY?lang=en) were combined with the Life table method to arrive at these results. "$PM_{2.5}$ relative to WHO Guideline" bar displays the reduction in life expectancy relative to the WHO guideline as calculated by latest AQLI (2021) data.

Figure 1.2 · Global and select regional annual average $PM_{2.5}$ concentrations, 1998-2021



Note: South Asia is defined as the following countries: Afghanistan, Bangladesh, Bhutan, India, Maldives, Nepal, Pakistan, Sri Lanka. Rest of the World refers to all regions across the globe except South Asia and China.

Global particulate pollution concentrations have remained fairly constant over the past two decades (Figure 1.2). However, since 2013, air pollution's course has been made up of two competing regional trends (Figure 1.2). In South Asia, particulate pollution has increased 9.7 percent from 2013 to 2021, which the AQLI estimates reduces life expectancy in the region by an additional 6 months. In India, $PM_{2.5}$ levels rose 9.5 percent; in Pakistan 8.8 percent; and in Bangladesh, levels rose by 12.4 percent over this same time interval.

Meanwhile, China has had staggering success in combating pollution since declaring a "war on pollution" in 2014, reducing its pollution by 42.3 percent from 2013 to 2021 and extending its population's average life expectancy by 2.2 years, if these reductions in pollution are sustained. From 2020 to 2021, pollution levels in China fell another 5.3 percent. In fact, the small decline in global pollution levels from 2013 to 2021 is entirely due to China's progress.

SOME REGIONS BEAR THE BRUNT OF THE POLLUTION BURDEN

Despite China's progress in reducing pollution, more progress is necessary to reach the air pollution concentrations that the WHO considers a safe level. Because of its large population, China experiences the second highest health burden from pollution globally, behind India, in terms of total life years lost. India and China, combined with Pakistan, Bangladesh, Nigeria, and Indonesia, together account for three-quarters of the global air pollution burden due to their high pollution levels and large populations (Figure 1.3).

The fact that six countries alone make up the majority of air pollution's global impact on life expectancy highlights the vastly unequal experience in the quality of the air one breathes across the planet—and its impact on health. In Bangladesh, the country with the highest pollution levels in 2021, a citizen stands to lose an average 6.8 years of life because pollution levels do not meet the WHO guideline. Meanwhile, in the United States, the average American loses just 3.6 months.

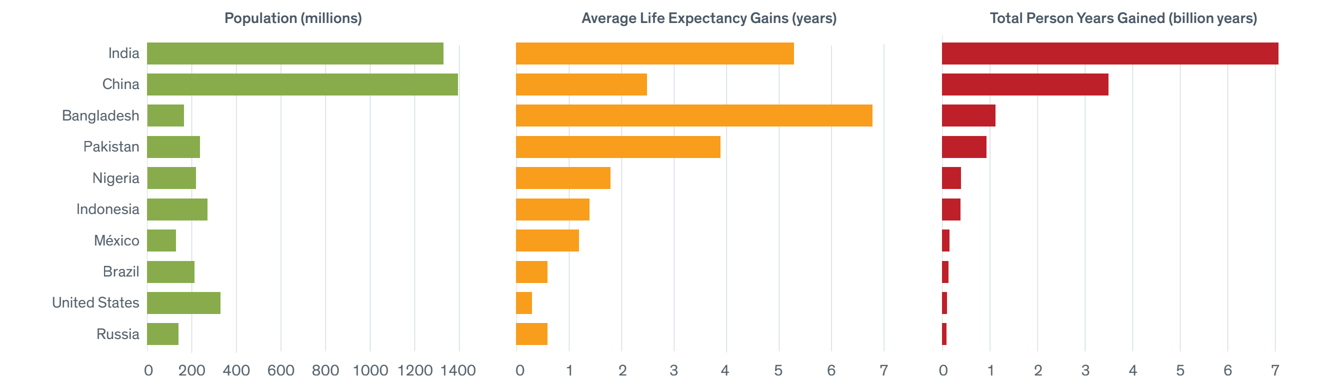
Americans breathe cleaner air largely because of strong policies, but it wasn't always this way. During periods of industrialization, countries like the United States and Europe were as polluted as many of today's pollution hotspots. Key accelerants of the change came from data showing how polluted the air was and studies showing its health impact. People began to call for change, and change came. For example, since the United States passed the Clean Air Act, pollution has decreased by 64.9 percent—extending the average American lifespan by 1.4 years (See Section 7 of this report).

FULLY OPEN DATA IS KEY FOR PROGRESS BUT MISSING IN MANY PARTS OF THE WORLD

The global community has an opportunity to help countries in the midst of their own industrialization to follow—or even leapfrog—a similar path. But in many of these areas, the basic infrastructure for change is lacking: data, research, and the subsequent call for change is too often as unequally distributed as air pollution itself (Table 1.1). For example, installing monitors to track air pollution data is a relatively cheap and easy first step to provide the foundation needed for building research, public knowledge, and, ultimately, policy. Yet, only 6.8 percent of countries in Asia, 3.7 percent in Africa, and 19 percent in Latin America, make their government data fully available. That same type of information is available in 69.2 percent of Europe, the United States, and Canada (Table 1.1).[5]

5 OpenAQ. 2022. "Open Air Quality Data: The global landscape."

Figure 1.3 · Potential gains in life expectancy from permanently reducing $PM_{2.5}$ from 2021 concentrations to the WHO guideline in the 10 most populated countries in the world



Further, of all large cohort, long-term particulate matter pollution epidemiological studies, 71.4 percent (60 studies) have occurred in Europe, the United States, or Canada.[6] Meanwhile, outside of China, only 8 studies have been conducted in all of Asia, including just one in the world's largest and second most polluted country, India. The challenge is that there is an absence of representative air pollution and health (e.g. vital statistics) data. In addition to fueling regional will to establish and revise national air quality standards, addressing these gaps in epidemiological studies in highly polluted environments could improve our scientific understanding of particulate pollution's impact on human health where the burden is greatest.[7,8]

Government air quality monitoring data, administrative health and/or vital statistics data, and epidemiological studies conducted in regionally-relevant conditions have historically been foundational for establishing national air quality standards in the first place and then ratcheting their ambition up over time.[9] Without these ingredients, the standards—and subsequent policies—are much less likely to emerge.

While Asia and Africa bear the majority of the total life years lost across the world due to air pollution that exceeds the WHO guideline, 92.7 percent, only 35.6 and 4.9 percent of countries on each of those continents have set a national air quality standard, respectively.[10] Meanwhile, Europe, the United States, and Canada make up just 4.1 percent of the global health burden from particulate pollution, yet 83.4 percent of nations from those regions have national air quality standards.

AN OUTSIZED OPPORTUNITY FOR THE GLOBAL AIR POLLUTION COMMUNITY

Air pollution is the largest external global health challenges, and the international community has an outsized opportunity to change that. Specifically, an increase and rebalancing of support that strategically targets funding towards the key components needed to confront air pollution seems poised to pay off handsomely.

The Clean Air Fund estimates that 63.8 million USD was deployed worldwide in 2021 by philanthropic foundations to combat outdoor air pollution. This amount is comparable to what Americans are estimated to lose each year in spare change.[11] Meanwhile, Europe, the United States, and Canada received 34 million USD in philanthropic foundation funding devoted to addressing air pollution in 2021, while the entire continent of Africa received less than 300,000 USD in philanthropic funds for air pollution reduction that same year (i.e. roughly the current price of a single-family home in the United States[12]).

The remainder of this report will further describe where pollution has increased and decreased over time, and consequently outline where the greatest opportunities lie for improving the most important measure that exists: longer lives.

6 This analysis captures all epidemiological research studies (>1000 people; max sample size: 1380 million), that are long term (> 1 year) with unique cohorts and measure the impact of ambient $PM_{2.5}$, PM_{10}, TSP, Ultra Fine Particulate Matter on Mortality (cause-specific, all cause, premature)/Life Expectancy published between 1993 and early 2023. The underlying dataset can be accessed here: https://docs.google.com/spreadsheets/d/1AljEJhN-PLWX_8×RbT_HJuERBpbQt_QGixgJ9jEzFyQw/edit#gid=1301709334 and analysis at: https://github.com/aqli-epic/epi.meta.analysis

7 Pozzer, A., Anenberg, S. C., Dey, S., Haines, A., Lelieveld, J., & Chowdhury, S. 2023.

8 Joshua S. Apte, Julian D. Marshall, Aaron J. Cohen, and Michael Brauer. 2015.

9 Vahlsing, C., Smith, K.R. 2012.

10 Country wise annual average $PM_{2.5}$ standards (where available) as compiled by AQLI for this report can be found here: https://docs.google.com/spreadsheets/d/1BMaCvcuK06D7KvupzwaC7queMTBECqD7ThB0mstq4Sw/edit#gid=1839504889

11 CBS News. 2016 "Americans throw away $62 million in coins each year."

12 U.S. Census Bureau and U.S. Department of Housing and Urban Development. 2023. "Median Sales Price of Houses Sold for the United States [MSPUS]."

Table 1.1 · Global air quality infrastructure landscape across regions

Region	2021 Estimated years lost due to $PM_{2.5}$[13]	Percent of countries with a national $PM_{2.5}$ air quality standard(s)[14]	Number of large cohort, long term PM epidemio-logical studies conducted[15,16]	Percent of countries with fully open public, government air quality data[17]	Total annual philanthropic funding in 2021 (millions USD)[18]
Asia	3.3	35.6	24 (China 16, India 1)	6.8	21.57 (China 5.94, India 14.21)
Africa	1.3	4.9	0	3.7	0.29
Latin America[19]	0.9	47.6	0	19	0.82[20]
Europe, US and Canada	0.6	76.4	60	69.2	34.58[21]

13 Europe in this column is defined as the 53 countries listed in the following file: https://drive.google.com/file/d/1CpDGkKu96HcK-r5×CZ3QozIdnozJMetrH/view?usp=drive_link. Refer to the Latin American section for the definition of Latin America.

14 Refer footnotes 10 and 13.

15 Refer footnote 14.

16 Refer footnote number 6.

17 OpenAQ. 2022. "Open Air Quality Data: The global landscape." By fully open government public air quality data we specifically mean "Y"'s (yes) in columns E to H of the following spreadsheet: https://docs.google.com/spreadsheets/d/1m3KfNOGQNIBBGn-jSqPoRmKH-IU0ic1AY9UNCIXQb3I/edit#gid=1038230352

18 Clean Air Fund. 2022. "The State of Global Air Quality Funding."

19 Refer footnote number 44 in the Latin America section of this report.

20 For this category, we are using data from the category "Latin America and Caribbean" from footnote number 18.

21 This category was created by combining "Europe and North America data from the reference referred to in footnote number 18, in which "North America" refers to only Canada and the United States.

Section 2

South Asia Continues as Global Epicenter for Pollution

In 2021, pollution continued to increase in South Asia, home to the world's most highly-polluted nations. Sustained exposure to particulate pollution is reducing the life spans of South Asians by 5.1 years. The toll is even greater in the most polluted areas.

No other location on the planet illustrates the stubborn nature of the pollution challenge more than South Asia,[22] where pollution continued its upward trend in 2021. Bangladesh, India, Nepal, and Pakistan—where 22.9 percent of the global population lives—are the top four most polluted countries in the world. South Asia accounts for more than half, 52.8 percent, of the total life years lost globally due to high pollution. The average South Asian would live 5.1 years longer if these four countries reduced pollution to meet the WHO guideline.

In each of these four countries, the impact of particulate pollution on life expectancy is substantially higher than that of other large health threats. Tobacco use, for instance, reduces life expectancy in these countries by as much as 2.8 years; unsafe water and sanitation by as much as 1 year; and alcohol use by half a year.

The average resident of Bangladesh, India, Nepal, and Pakistan is exposed to particulate pollution levels that are 51.3 percent higher than at the turn of the century. Had pollution levels in 2000 remained constant over time, the residents in these countries would be on track to lose 3.3 years of life expectancy—not the 5.2 years that they stand to lose in 2021.[23]

Of all the countries in the world, India faces the greatest health burden from air pollution due to the large number of people its high particulate pollution concentrations affect. Since 2013, 59.1 percent of the world's increase in pollution has come from India. According to new and revised 2021 satellite-derived $PM_{2.5}$ data, pollution in India has increased from 56.2 µg/m³ in 2020 to 58.7 µg/m³ in 2021—more than 10 times the WHO guideline. The average Indian resident is set to lose 5.3 years of life expectancy if the WHO guideline is not met.

The most polluted region of India is the Northern Plains[24], home to more than a half billion people and 38.9 percent of the country's population. In this region, the average resident is on track to lose about 8 years of life expectancy if the pollution level persists. The region contains the capital city of Delhi, the most polluted megacity in the world with annual average particulate pollution of 126.5 µg/m³—more than 25 times the WHO guideline.

However, particulate pollution is no longer just a feature of the Northern Plains of India. High levels of air pollution have expanded geographically over the last two decades. For example, in the Indian states of Maharashtra and Madhya Pradesh, home to 204.2 million people, pollution has risen by 76.8 and 78.5 percent, respectively, since 2000. Here, the average person is now losing an additional 1.8 to 2.3 years of life expectancy, relative to what they would have lost if 2000 levels had persisted.

While some Indians breathe the most polluted air in the world, the most polluted country overall is Bangladesh. Despite a 2.1 percent dip in particulate pollution compared to 2020 levels, pollution in Bangladesh has hovered around 14 to 15 times the WHO guideline for the past decade. In the most polluted part of the country—the district of Gazipur in the division of Dhaka, residents would live 8.3 years longer if the WHO guideline was permanently met.

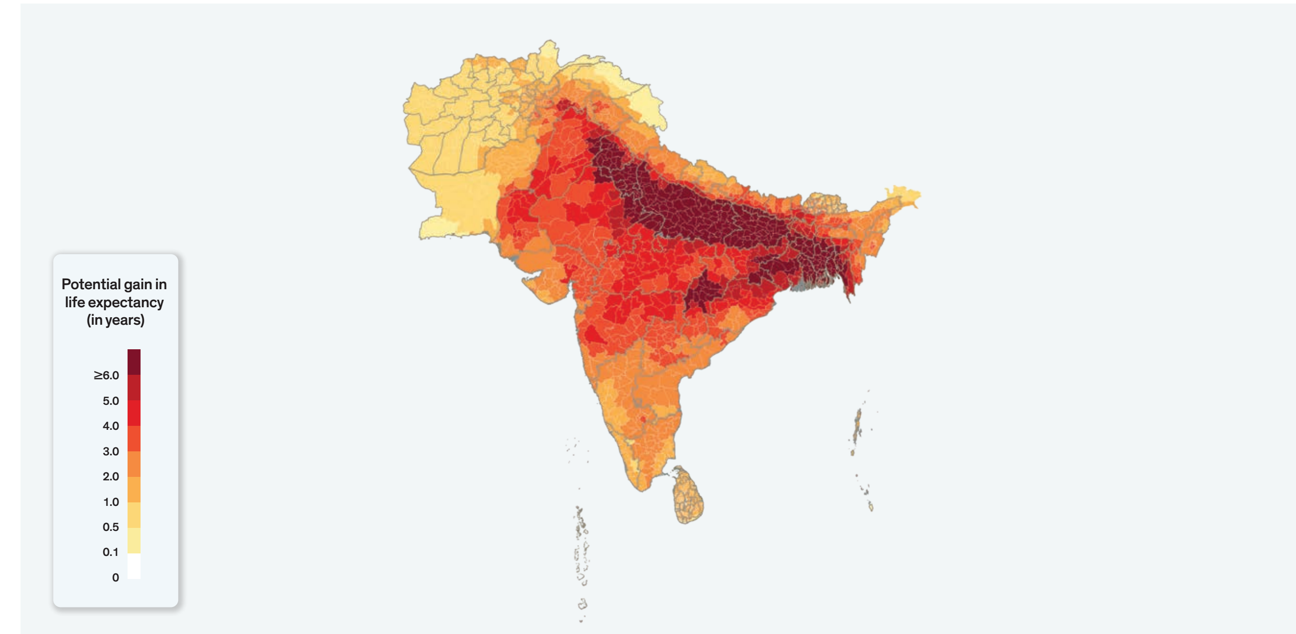
In Nepal, where the $PM_{2.5}$ concentration was 51.7 µg/m³ in 2021, the average resident would live 4.6 years longer if the country met the WHO guideline. In the most polluted parts of the country, like the district coordination committees of Mahottari and Rautahat,

22 South Asia is defined as the following 8 countries: Afghanistan, Bangladesh, Bhutan, India, Maldives, Nepal, Pakistan, Sri Lanka.

23 2021 is the latest year for which AQLI satellite derived $PM_{2.5}$ data is available.

24 We define this region as the following seven states and union territories: Bihar, Chandigarh, Delhi, Haryana, Punjab, Uttar Pradesh, and West Bengal.

Figure 2.1 · Potential gain in life expectancy from permanently reducing $PM_{2.5}$ from 2021 concentration to the WHO guideline



residents stand to gain more than 7 years onto their lives from cleaner air. In Pakistan, where the $PM_{2.5}$ concentration was 44.7 µg/m³ in 2021, the average resident would gain 3.9 years from meeting the WHO guideline. Those in Lahore, the most polluted city in the country, would gain 7.5 years.

The increase in air pollution in South Asia over time is not surprising. Over the last two decades, industrialization, economic development, and population growth have led to skyrocketing energy demand and fossil fuel use across the region. In India and Pakistan, the number of vehicles on the road has increased about four-fold since the early 2000s. The number of vehicles roughly tripled in Bangladesh from 2010 to 2020.[25] In Bangladesh, India, Nepal, and Pakistan combined, electricity generation from fossil fuels tripled from 1998 to 2017.[26] Crop burning, brick kilns, and other industrial activities have also contributed to rising particulate emissions in the region.

The increase in energy use has led to higher living standards and economic output, which have greatly enhanced well-being. Yet, the concomitant rise in particulate pollution has had serious consequences, and energy demand in non-OECD regions is only projected to continue growing. Without concerted policy action, the threat of air pollution will also grow.

Fortunately, more and more people in these countries are recognizing the severity of the problem, and governments are beginning to respond. In 2019, for example, the Government of India declared a "war on pollution" and launched its National Clean Air Programme ("NCAP") with the stated goal of reducing 2017 particulate pollution levels by 20 to 30 percent by the year 2024. In 2022, the Government of India revamped its NCAP goal, aiming to achieve a 40 percent reduction in particulate pollution levels by 2026 in 131 non-attainment cities. Achieving and sustaining such a reduction for the 131 non-attainment cities would increase India's national average life expectancy by 7.9 months, and by 4.4 years for residents of Delhi–the most polluted non-attainment city, underscoring the massive potential benefits.

Other countries across South Asia are beginning to take policy actions as well. Nepal has instituted an Air Quality Management Action Plan for Kathmandu Valley, and adopted various other policies to control emissions from vehicles and industries, and manage air quality. In Pakistan, the government began installing more pollution monitors and shutting down factories in highly polluted districts during the winter months when energy demand for heating is high. Similarly, Bangladesh has doubled its monitoring capacity and real-time air pollution measurements now cover eight of its cities.[27]

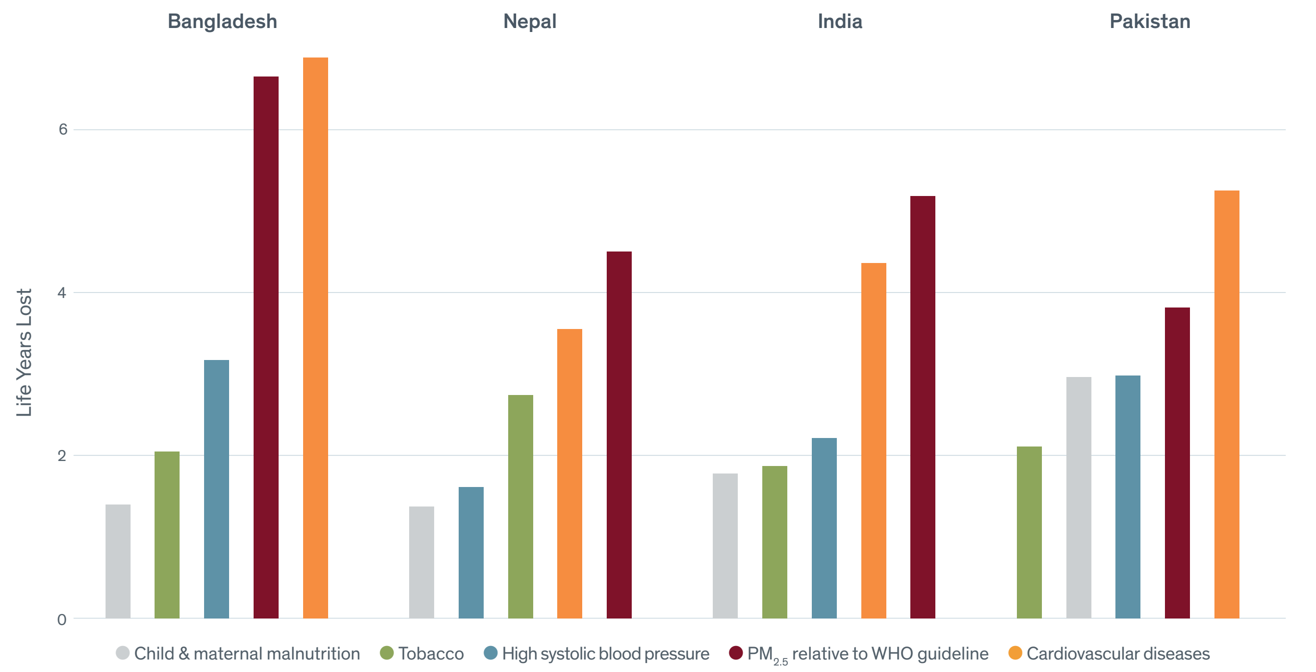
Pakistan and Bangladesh have both encouraged brick kiln owners to shift to cleaner technologies. In Bangladesh, where brick kilns are responsible for 58 percent of the particulate pollution in

25 India Ministry of Statistics and Programme Implementation. 2017. "Motor vehicles – Statistical year book India 2017. Table 20.4."; Pakistan Statistical Pocket Book. 2006. "Table 17.5." and Pakistan Today. 2019. "Registered vehicles in Pakistan increased by 9.6% in 2018."; Bangladesh Road Transport Authority. 2020. "Number of registered vehicles in the whole BD."

26 U.S. Energy Information Administration. "International: Electricity [Data set]."

27 Bangladesh Ministry of Environment, Forest and Climate Change. 2018. "Ambient Air Quality in Bangladesh." The 8 cities are as follows: Dhaka, Chittagong, Narayanganj, Gazipur, Khulna, Rajshahi, Barisal and Sylhet.

Figure 2.2 · **Comparison of selected major global threats to life expectancy in South Asian countries**

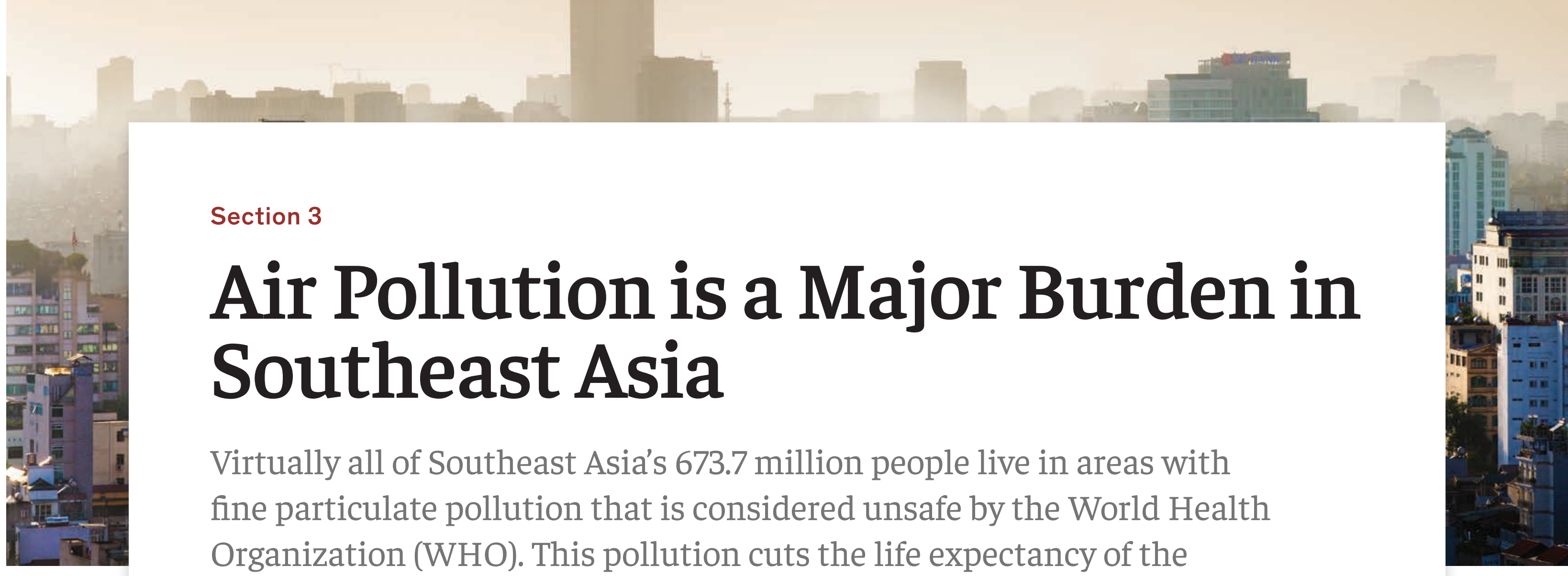


Sources: Global Burden of Disease (https://vizhub.healthdata.org/gbd-results/) level-2 causes and risks data and WHO Life Tables (https://apps.who.int/gho/data/node.main.LIFECOUNTRY?lang=en) were combined with the Life table method to arrive at these results. "$PM_{2.5}$ relative to WHO Guideline" bar displays the reduction in life expectancy relative to the WHO guideline as calculated by latest AQLI (2021) data.

Dhaka, the law governing brick kiln production was amended in 2019 to prohibit the establishment of brick kilns near residential, commercial, agricultural, and environmentally sensitive areas.[28] In addition, the government is planning to phase out the use of bricks in favor of concrete blocks by 2025 in order to lessen the damage to both the quality of the air and topsoil.[29] In the end, the real test for these policy changes in South Asia will be if they are able to make the air cleaner and lengthen average life expectancies in the region.

28 Dhaka Tribune. 2019. "Environment minister: Brick kilns responsible for 58% air pollution in Dhaka."

29 The Daily Star. 2019. "Checking Air Pollution: Bye bye brick!"



Section 3

Air Pollution is a Major Burden in Southeast Asia

Virtually all of Southeast Asia's 673.7 million people live in areas with fine particulate pollution that is considered unsafe by the World Health Organization (WHO). This pollution cuts the life expectancy of the average Southeast Asian person short by 1.6 years, relative to what it would be if the WHO guideline was met. In some of the most polluted areas, residents are losing up to 3.5 years of life expectancy.

As a whole, pollution ticked upward across Southeast Asia in 2021. In Cambodia and Thailand, for example, particulate pollution increased by 15.8 and 5.5 percent, respectively. Virtually all, 99.9 percent, of Southeast Asia's roughly 673.7 million people now live in areas where particulate pollution exceeds the revised WHO guideline of 5 µg/m³. Across the region, air pollution reduces average life expectancy by 1.6 years, relative to what it would be if the WHO guideline was met. In the 11 countries that make up this region, an estimated 1.1 billion total life years are lost due to air pollution.[30]

While average pollution increased slightly in 2021, pollution levels in Southeast Asia have remained largely unchanged for two decades, generally fluctuating between 18 and 22 µg/m³ on average (21.4 µg/m³ in 2021). However, during dry seasons, fires in Indonesia cause sudden spikes in pollution for the country and its downwind neighbors like Malaysia. The significant impact of fewer fires in the region in 2021 compared to the most recent active wildfire season in 2019, a year characterized by thousands of fires on the Indonesian islands of Sumatra and Borneo, bears out in the data. Indonesia saw a 16.3 percent decrease in 2021 compared to 2019, while Malaysia experienced a 31.4 percent decrease.

In the Indonesian island of Java, the country's population and industrial center, pollution levels dipped slightly in 2021, compared to 2019. In the region surrounding the megacity of Jakarta (including Bogor, Depok, Bekasi, and Tangerang), the average annual $PM_{2.5}$ concentration fell roughly 18.7 percent in 2021 to 30 µg/m³. Still, if the region met the WHO guideline, the roughly 30.3 million residents would gain an average of 2.5 years in life expectancy. In 2021, North Sumatra was among the most polluted regions in Indonesia, and yet also saw a decrease relative to 2019. Medan, for example, experienced pollution levels of 33.9 µg/m³, slightly up from 32.6 µg/m³ in 2020 but still significantly down from 2019 levels of 40 µg/m³. Here, residents stand to gain 2.8 years of life expectancy if pollution were to be reined in to meet the WHO guideline.

Cambodia, Thailand and Myanmar—all less impacted by Indonesia's periodic fire events—have seen increases in particulate pollution from 2019 to 2021. Myanmar was the most polluted country in Southeast Asia in 2021, a ranking it has held since 2012, with a population weighted-average particulate pollution concentration of 35 µg/m³— seven times the WHO guideline. Because pollution surpasses the guideline, residents of Myanmar are losing 2.9 years of life expectancy, which is significantly larger than other health threats in Myanmar such as child and maternal malnutrition (1.4 years) or diabetes (1.1 years) (Figure 3.3). In Yangon and Mandalay, average pollution levels were 33 and 39.9 µg/m³ in 2021, respectively, suggesting that if the WHO guideline were met, residents would gain 2.7 and 3.4 years, respectively.

In Thailand, particulate pollution was up 5.5 percent from 2019. The national average was 23.2 µg/m³ in 2021, a level that has been roughly constant since the mid-2000s. But overall, particulate concentrations varied widely in 2021, ranging from 33.4 µg/m³ in Phayao in the North, to 20.6 µg/m³ in the metropolis of Bangkok, to 13.4 µg/m³ in Phuket in the South. This variation is

30 Southeast Asia includes the following countries: Brunei, Cambodia, Indonesia, Laos, Malaysia, Myanmar, The Philippines, Singapore, Thailand, Timor-Leste, and Vietnam.

Figure 3.1 · Potential gain in life expectancy from permanently reducing $PM_{2.5}$ from 2021 concentration to the WHO guideline

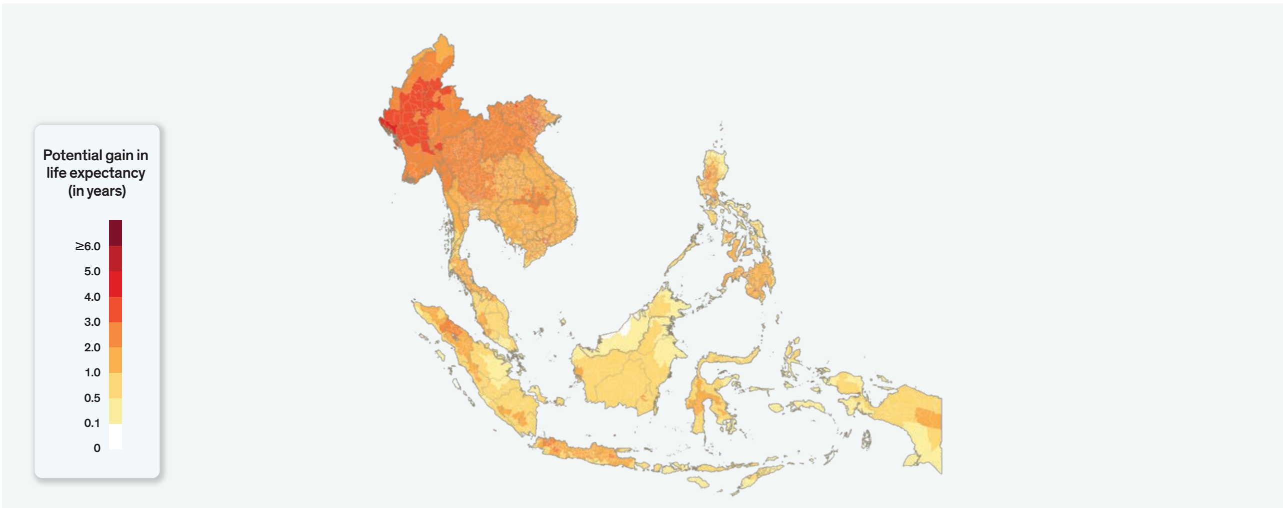


Figure 3.2 · Potential gain in life expectancy from reducing $PM_{2.5}$ from 2021 levels to the WHO guideline in 10 most populous regions of Southeast Asia

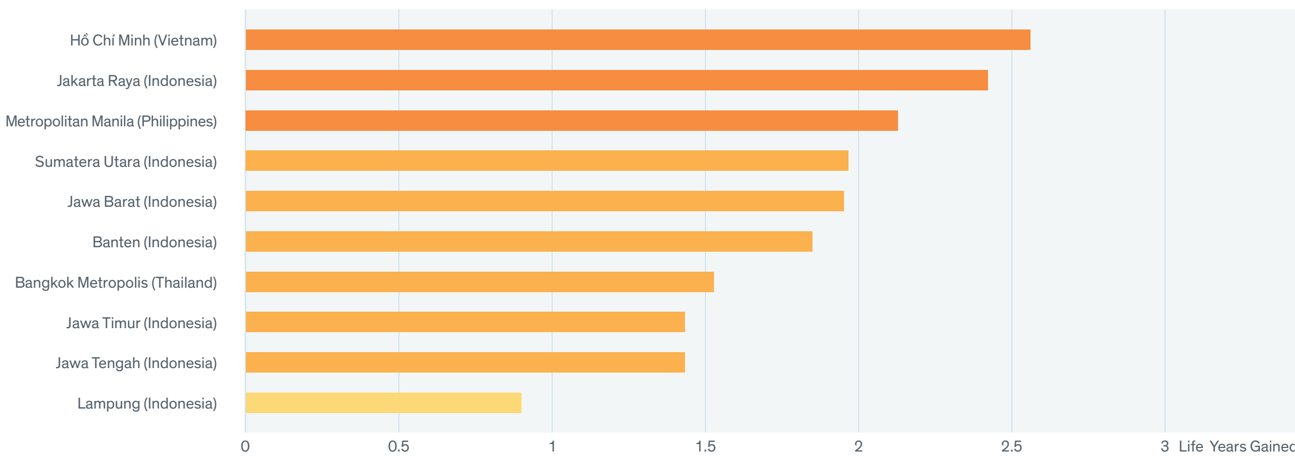
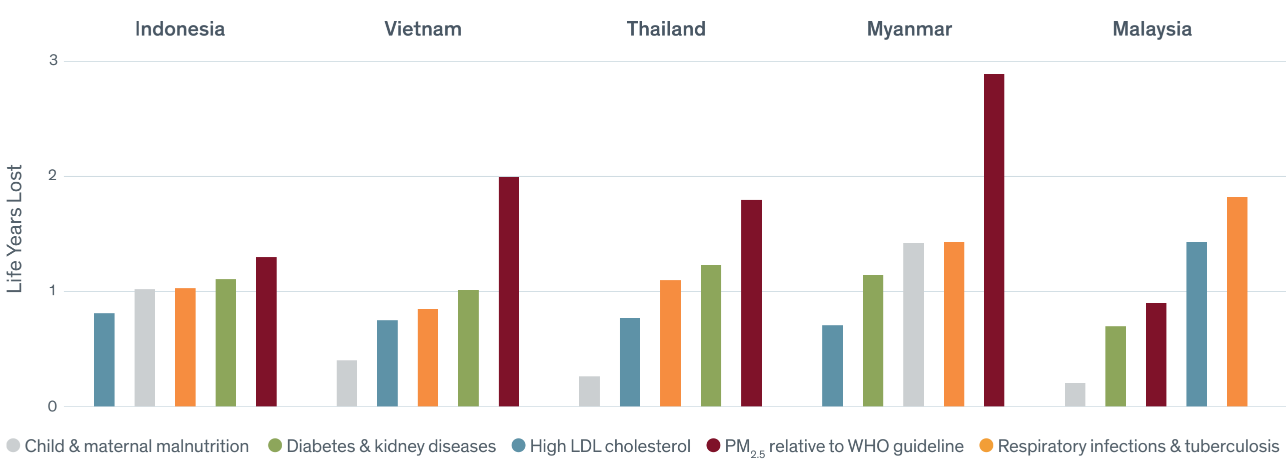


Figure 3.3 Comparison of selected major global threats to life expectancy in Southeast Asian countries



Sources: Global Burden of Disease (https://vizhub.healthdata.org/gbd-results/) level-2 causes and risks data and WHO Life Tables (https://apps.who.int/gho/data/node.main.LIFECOUNTRY?lang=en) were combined with the Life table method to arrive at these results. "$PM_{2.5}$ relative to WHO Guideline" bar displays the reduction in life expectancy relative to the WHO guideline as calculated by latest AQLI (2021) data.

partly due to fires in Thailand's northern region (including the regions surrounding Chiang Mai, Chiang Rai, Kamphaeng Phet, and Phayao, for instance) that have increased the amount of regional air pollution, reducing life expectancy by up to 2.5 years relative to life expectancy under the WHO guideline. Meanwhile, in Thailand's largest urban area, Bangkok, residents would gain 1.5 years if pollution levels met the WHO guideline.

In Vietnam, there are even sharper differences between regions. In the capital city of Hanoi, home to more than 8 million people and one of Vietnam's major industrial centers, life expectancy would increase by 3 years if air quality met the WHO guideline. The impacts are much lower in many of Vietnam's southern regions, where coastal provinces such as Binh Dinh would only see 0.9 years of added life expectancy if air quality met the WHO guideline. Overall, the average Vietnamese citizen stands to gain 2 years in life expectancy, if pollution was permanently reduced to the WHO guideline. This threat to life expectancy is significantly larger than other health threats in Vietnam such as diabetes (1 year) or respiratory infections and tuberculosis (0.9 years) (Figure 3.3.).

How can countries in this region tackle this problem? Alongside reducing biomass, forest and peatland fires—which are often set illegally to clear land for agricultural plantations—tighter fuel emissions standards offer another area of potential improvement. In contrast to China and India, where fuel standards are at least as stringent as those adopted by the European Union (Euro-6), the fuel standards are much lower in Indonesia and Thailand. Vehicles there are only required to meet Euro-4 standards, which allow for up to 3 times as much diesel NOx emissions, and 5 times as much sulfur content. The Thai government, which had plans to adopt the Euro-5 standards in 2021, has delayed the adoption of the standards to 2024 due to COVID-19 restrictions and their subsequent impact on the private sector's readiness to practically implement those standards[31]. Vietnam brought Euro-5 standards into effect on January 1, 2022.[32]

Industrial emissions make up another area of potential improvement. Indonesia's coal-fired power plants—of which there are around ten within a 100-kilometer radius of Jakarta[33]—are allowed to emit 3 to 7.5 times more particulate matter, NOx, and SO2 than China's coal plants, and 2 to 4 times more than India's plants installed between 2003 and 2016.[34] NOx and SO2, once emitted into the atmosphere, can form particulate matter.

Across the region, awareness is rising for the need for urgent clean air action, in many cases driven by community advocates. In 2021, for example, a Jakarta court ruled in favor of a citizen-led lawsuit claiming that the government had failed to deliver safe, clean air to its citizens. In 2022, the grassroots organization Thailand Clean Air Network submitted the first citizen-driven draft legislation to the Thai Parliament aiming to create a Thai Clean Air Act.

31 China Daily. 2023. "Thailand approves delay on imposing Euro 5 emission standard on new vehicles."

32 Transport Policy. 2022. "As of January 1, 2022, 4-wheeled light-duty vehicles in Vietnam are regulated under the Euro 5 standard."

33 Reuters. 2019. "Asia's coal addiction puts chokehold on its air-polluted cities."

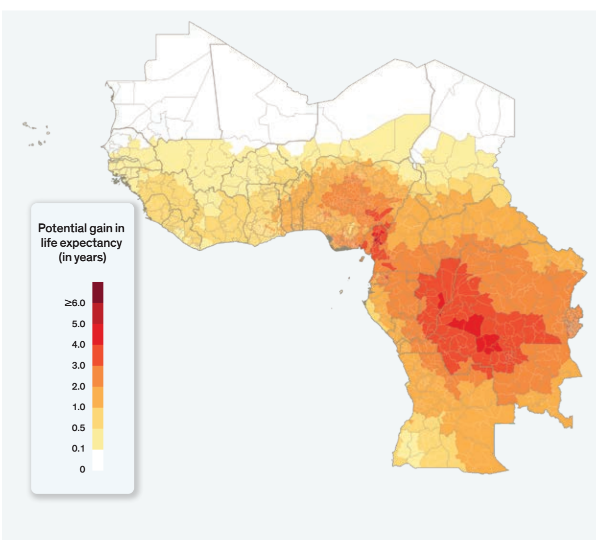
34 Zhang, Xing. 2016.

Section 4

Central and West Africa is a Growing Pollution Hotbed

As Central and West Africa continue to grow their energy use, particulate pollution is becoming a rising health threat—as much of a threat as well-known killers in the region like HIV/AIDS and malaria, cutting life expectancy by as much as 5.4 years in the most polluted regions.

Figure 4.1 · **Potential gain in life expectancy from permanently reducing $PM_{2.5}$ from 2021 concentration to the WHO guideline**



While South Asian countries rightly receive the most media coverage about extreme levels of air pollution, new and revised satellite data show that African countries like the Democratic Republic of the Congo, Rwanda, Burundi, and the Republic of the Congo are amongst the ten most polluted countries in the world.

The year 2021 did not bring substantial changes to the average quality of air in the region. The population weighted-average $PM_{2.5}$ concentration in 2021 was nearly identical to the average level in 2020, at 21.2 µg/m³—4.2 times the WHO guideline.[35] As a result, in the Central and West Africa region—home to 638.7 million people across 27 countries—the average person is set to lose 1.6 years off their lives if these levels of pollution persist. That translates to 1 billion total life years that could be saved if the region reduced pollution to meet the WHO guideline.

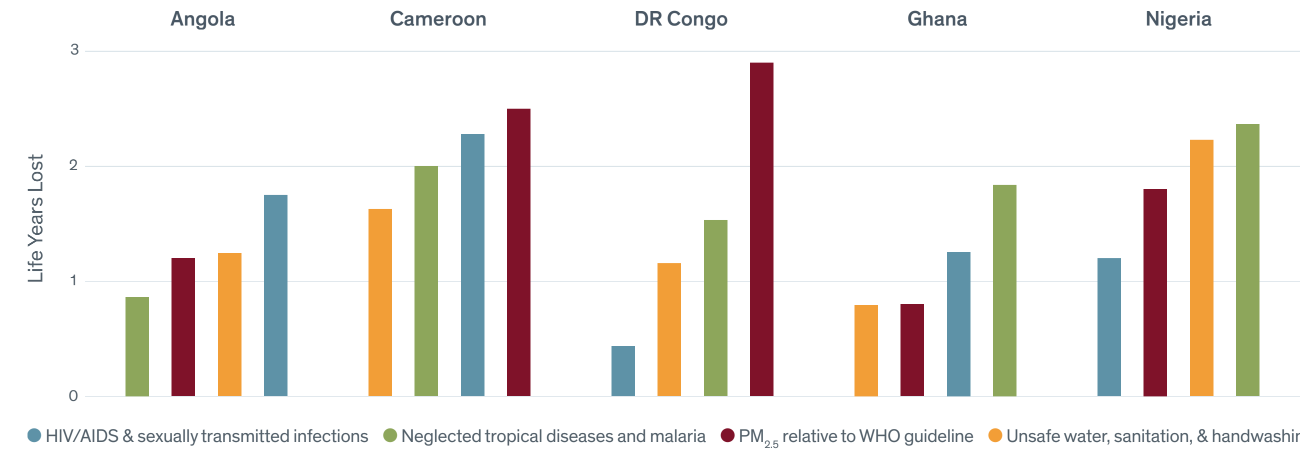
While the health discourse in Sub-Saharan Africa has centered on infectious diseases, like HIV/AIDS and malaria, the data show that the health impacts of particulate pollution exposure are no less serious. That is certainly the case in the Democratic Republic of the Congo (DRC)—home to 105 million people and the most polluted country on the African continent in 2021—where particulate pollution was 34.6 µg/m³, or nearly 7 times the WHO guideline. As a result, average life expectancy is 2.9 years lower than what it would be if the country met the WHO guideline.

In Kinshasa, the capital and largest city of the DRC with 11.9 million people, residents are losing 3.3 years of life expectancy relative to if the city met the WHO guideline. However, a cluster of regions to the east of Kinshasa—namely, Mai-Ndombe, Kwilu, and Kasaï—experience even higher levels of pollution, leading residents there to lose 3.8 to 4 years off their lives. In these regions, high air pollution levels have been largely attributed to waste burning, mining, and industrial practices such as mineral processing and cement manufacturing. Moreover, with high usage of solid fuels, residents face increasing exposure to high levels of indoor air pollution.[36]

35 Central Africa is defined as the following 11 countries: Angola, Burundi, Cameroon, Central African Republic, Chad, Republic of the Congo, Democratic Republic of the Congo, Equatorial Guinea, Gabon, São Tomé and Príncipe, Rwanda. West Africa is defined as the following 16 countries: Benin, Burkina Faso, Cabo Verde, Gambia, Ghana, Guinea, Guinea-Bissau, Côte d'Ivoire, Liberia, Mali, Mauritania, Niger, Nigeria, Senegal, Sierra Leone, Togo.

36 Interactive Country Fisches. "Democratic Republic of Congo: Pollution."

Figure 4.2 · **Comparison of selected major global threats to life expectancy in the five most populous countries in Central and West Africa**



Sources: Global Burden of Disease (https://vizhub.healthdata.org/gbd-results/) level-2 causes and risks data and WHO Life Tables (https://apps.who.int/gho/data/node.main.LIFECOUNTRY?lang=en) were combined with the Life table method to arrive at these results. "$PM_{2.5}$ relative to WHO Guideline" bar displays the reduction in life expectancy relative to the WHO guideline as calculated by latest AQLI (2021) data.

The Republic of Congo, Rwanda, Burundi, Cameroon, and Equatorial Guinea were the most polluted countries in Central and West Africa in 2021 following the DRC. Their stories are similar. In the Republic of the Congo's capital city of Brazzaville, residents are losing 3.3 years; in Musanze, Rwanda, it is 3 years; in Burundi's capital of Gitega, it is 2.4 years; in Mezam, Cameroon, residents are losing 4.6 years; and in Bata, Equatorial Guinea, it is 2.2 years.

Nigeria also faces a high pollution burden. In 2021, the particulate pollution level in Nigeria was 23 µg/m³—4.6 times the WHO guideline. In Lagos, home to Nigeria's largest city with 21.1 million people, vehicle emissions due to long commutes and high sulfur content fuel, industrial emissions, and the use of diesel generators in the face of unreliable electricity supply contribute to high levels of urban air pollution.[37] Residents there could see their life expectancy increase by 1.4 years if particulate pollution were permanently reduced to meet the WHO guideline.

In 2021, some of the highest pollution levels in Nigeria were observed in the Niger River Delta, where oil refineries are linked to the grim daily reality of air pollution.[38] In the states of Akwa Ibom, Taraba, Cross River, and Delta, average pollution levels ranged from 26.6 to 34.3 µg/m³. According to the AQLI, residents in these states are losing 2.1 to 2.9 years of life expectancy relative to the WHO guideline. The most polluted Nigerian city in 2020 was the local government area Sardauna in Taraba state, where $PM_{2.5}$ concentrations averaged 44.6 µg/m³, a level similar to Pakistan, the fourth most polluted country on the planet. Here, residents stand to lose 3.9 years of life expectancy.

While there is a large global fund for HIV/AIDS, malaria, and tuberculosis that annually disburses 4 billion USD toward the issues, there is no equivalent set of coordinated resources for air pollution.[39] In fact, the Clean Air Fund estimates that the entire continent of Africa receives under 300,000 USD in philanthropic funds to help combat outdoor air pollution.[40] Yet, air pollution shaves off more years from the average person's life in the DRC and Cameroon than HIV/AIDS, malaria, and other health threats (see Figure 4.2).[41] In Nigeria, air pollution's impact on life expectancy is greater than that of HIV/AIDS but less than malaria.

None of the 27 Central and West African countries have set a national standard for particulate pollution. In fact, only 17 of Africa's 61 countries have adopted legislative instruments containing some air quality standards.[42] Furthermore, 96.3 percent of the African countries do not have fully open public government air quality data.[43]

37 Croitoru, L., Chang, J. C., and Kelly, A., 2020.

38 Niger river delta is defined as the following nine states: Rivers, Delta, Akwa Ibom, Imo, Edo, Ondo, Cross River, Abia, Bayelsa.

39 From the Global Fund website, accessed 9 August 2023.

40 Clean Air Fund. 2022. "The State of Global Air Quality Funding."

41 Life expectancy impacts of causes and risks of death besides ambient $PM_{2.5}$ air pollution are calculated from mortality rate data from the Global Burden of Disease 2019. For details, see https://aqli.epic.uchicago.edu/about/methodology/.

42 UN Environment Program. 2021." Regulating Air Quality: The First Global Assessment of Air Pollution Legislation." Also, please note that only a subset of these countries are a part of Central and West Africa. These 17 countries are as follows: Algeria, Benin, Burkina Faso, Côte d'Ivoire, Egypt, Eswatini, Gambia, Ghana, Kenya, Mauritius, Morocco, Mozambique, Nigeria, Rwanda, Senegal, South Africa, and the United Republic of Tanzania.

43 Open Air Quality Data. 2022. "The global landscape community summary table." Please note that in reporting numbers using this table, we have assumed this table's definition of the African continent (54 countries). The AQLI definition that is used elsewhere in the factsheet defines the African continent as containing a total of 61 countries. Some of the regions in this definition may or may not be included elsewhere in the African continent's definition.

Section 5

Most Latin Americans are Breathing Air Exceeding the WHO Guideline

The vast majority of Latin America's 641.7 million people breathe air that exceeds what the WHO considers safe. In the most polluted locations in the region, air pollution is taking off 3 to 4.4 years from life expectancy.

New and revised 2021 satellite-derived $PM_{2.5}$ data reveal that 96.3 percent of Latin America's 641.7 million people are exposed to particulate pollution levels that exceed the WHO guideline of 5 µg/m³.[44] Although the average gain in life expectancy from cleaning up the air is relatively low—at just under 11 months on average—across Latin America, the gain is substantially higher in regional hotspots. Sixty of the most polluted regions are in Guatemala, Bolivia, and Peru. In these regions, residents breathe air similar to other major pollution hotspots around the world, such as Pune, India and Harbin, China.

44 Latin America region is defined as comprised of the following 21 countries: México, Guatemala, Honduras, El Salvador, Nicaragua, Costa Rica, Panama, Colombia, Venezuela, Ecuador, Peru, Bolivia, Brazil, Paraguay, Chile, Argentina, Uruguay, Cuba, Haiti, Dominican Republic, Puerto Rico.

The most polluted region in Latin America is the city of Mixco, Guatemala, where average pollution was 50.3 µg/m³ in 2021—or 10.1 times the WHO guideline. If the region cleaned up its air to permanently meet the guideline, residents would see their life expectancy increase by 4.4 years. There is a similar story in Porto Velho, Brazil, where residents are losing 2.5 years off their life due to polluted air; Cercado (in the department of Beni), Bolivia, where residents are losing 3.1 years, and Peru's capital, Lima, where it is 2.3 years. Across this region, major sources of pollution span vehicular emissions, unleaded fuel usage, and, more recently, wildfires.

Vehicle emissions are primarily responsible for poor air quality in Latin America's major hotspot cities in Guatemala, Bolivia, and Peru among others.[45] In recent decades, several Latin American cities like Bogotá, Mexico City, Santiago de Chile, and Quito have implemented policy instruments to reduce urban air pollution and traffic congestion such as license plate–based restrictions on car use.[46] Each of those cities has seen substantial declines in particulate matter pollution over the past 15 years with the exception of Santiago de Chile.

Figure 5.1 · Potential gain in life expectancy from permanently reducing $PM_{2.5}$ from 2021 levels to the WHO guideline in 15 most populated regions of Latin America

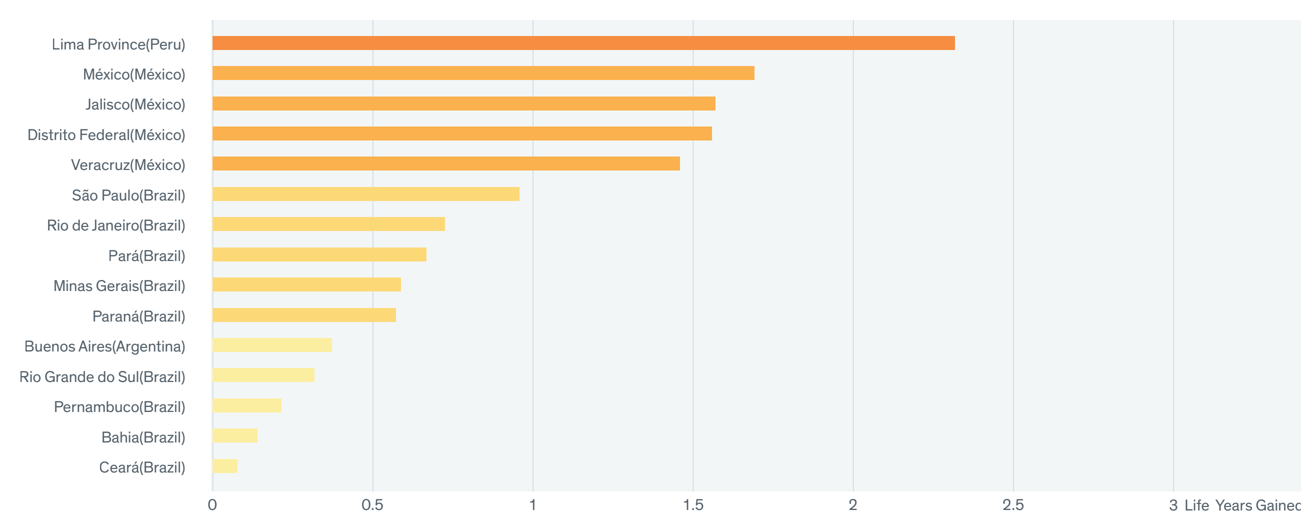


Figure 5.2 · Potential gain in life expectancy from permanently reducing $PM_{2.5}$ from 2021 concentration to the WHO guideline

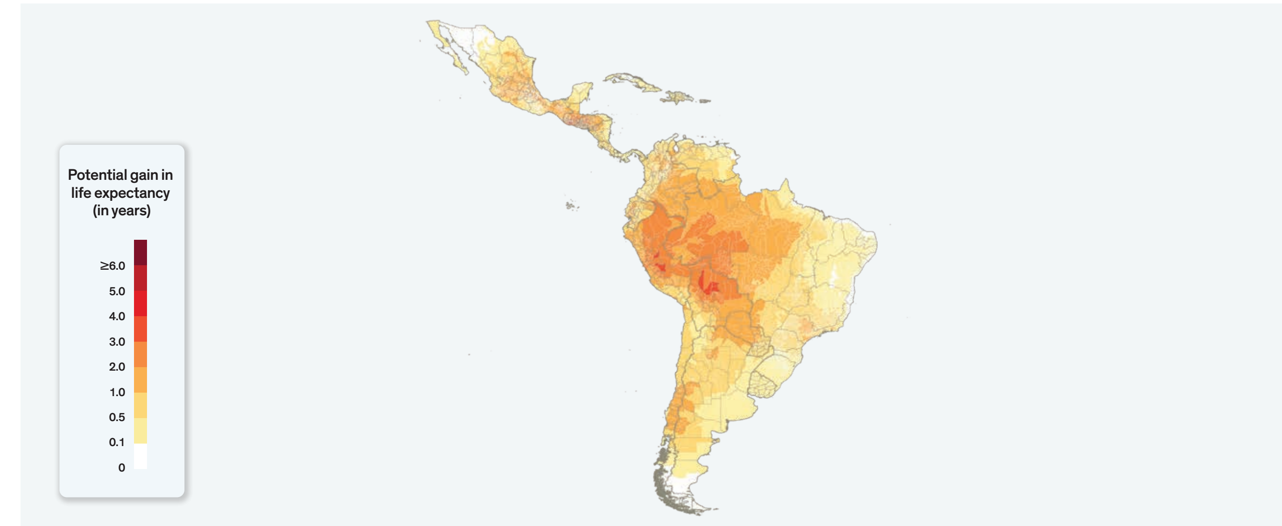
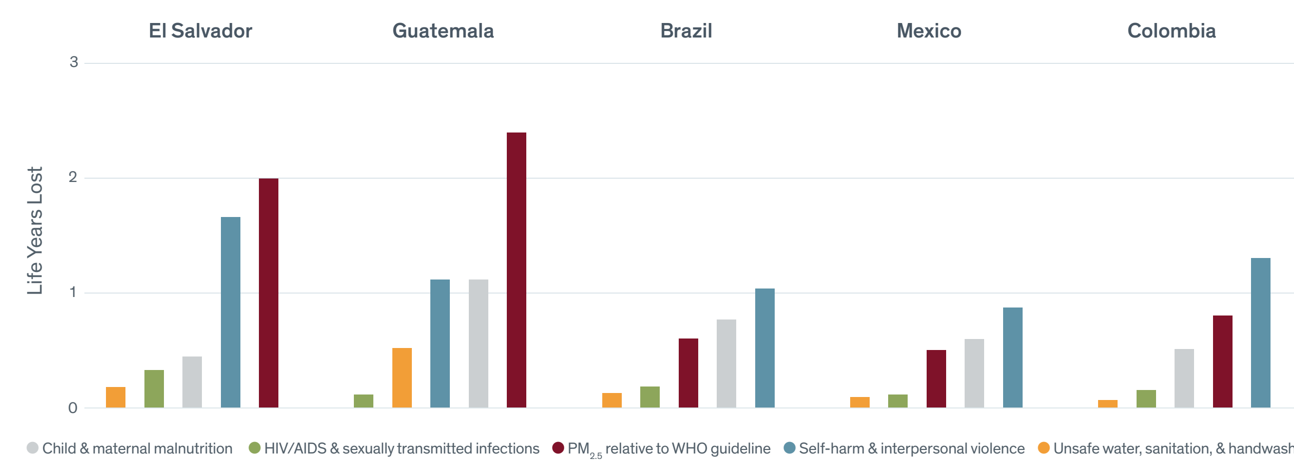


Figure 5.3 · Comparison of some major global threats to life expectancy in select countries in Latin America



Sources: Global Burden of Disease (https://vizhub.healthdata.org/gbd-results/) level-2 causes and risks data and WHO Life Tables (https://apps.who.int/gho/data/node.main.LIFECOUNTRY?lang=en) were combined with the Life table method to arrive at these results. "$PM_{2.5}$ relative to WHO Guideline" bar displays the reduction in life expectancy relative to the WHO guideline as calculated by latest AQLI (2021) data.

Latin America's air pollution is not only limited to its cities. Rural residents in Bolivia also face high levels of particulate pollution. For example, in Mamoré (Department of Beni), a rural region containing some of the country's worst air quality, the average level of particulate pollution in 2021 was 32.9 µg/m³. Residents there are losing 2.7 years of life expectancy due to this unclean air, relative to the WHO guideline.

In Brazil, particulate pollution levels are 4.4 times the WHO recommended threshold across the Amazonas, primarily due to the burning of the rainforests. The fires are a result of deforestation and illegal fires set to clear land for farming and cattle grazing. The 4.2 million residents of the area could gain 1.7 years of life expectancy if pollution was reduced to permanently meet the WHO guideline.

45 Guatemala: International Women's Media Foundation. 2018. "How Outdated Cars Live On in a Smoggy Afterlife."; Bolivia: Mardoñez, V., Uzu, G., Andrade, M., Borlaza, L. J. S., Pandolfi, M., Weber, S., Moreno, I., Jaffrezo, J.-L., Besombes, J.-L., Alastuey, A., Perez, N., Močnik, G., and Laj, P., 2022; Peru: Pinedo-Jáuregui, C., Verano-Cachay, J., Barrantes-Santos, V., 2020.

46 Boso, À., Oltra, C., Garrido, J. et al., 2023.

Section 6

China's War Against Pollution Marches On

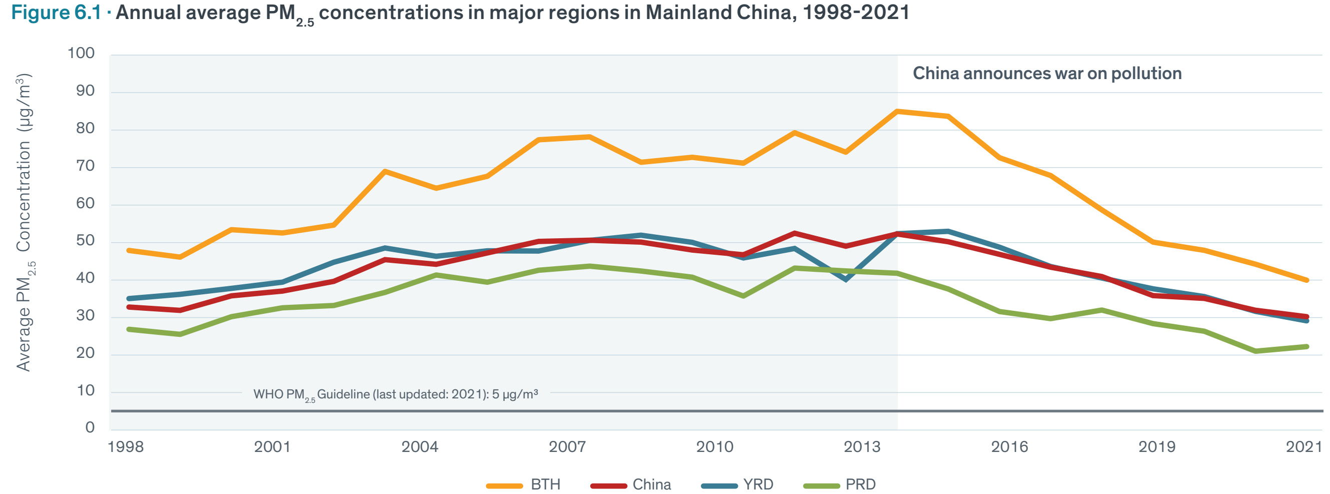
China's pollution has been declining each year since the country began a "war against pollution" in 2014. This decline continued through 2021, with pollution levels down by 42.3 percent compared to 2013. Due to these improvements, the average Chinese citizen can expect to live 2.2 years longer, provided the reductions are sustained.

Despite significant increases in particulate pollution in many regions of the world, global pollution has declined since 2013. That decline is due entirely to China's success in steeply reducing pollution—pollution dropped 42.3 percent between 2013 and 2021 and by 5.3 percent from 2020 to 2021 alone. Beijing province experienced the largest decline in pollution, dropping 56.2 percent in just eight years (Figure 6.1). Without China's steep decline in pollution, global average pollution would have slightly increased from 2013 to 2021.

Because of these air quality improvements, the average Chinese citizen can expect to live 2.2 years longer, provided the reductions are sustained. In Beijing, the average person could expect to live 4.2 years longer. In Shanghai, where $PM_{2.5}$ fell from 46.4 to 25.5 µg/m³, the average person could expect to live 2 years longer (Figure 6.2).

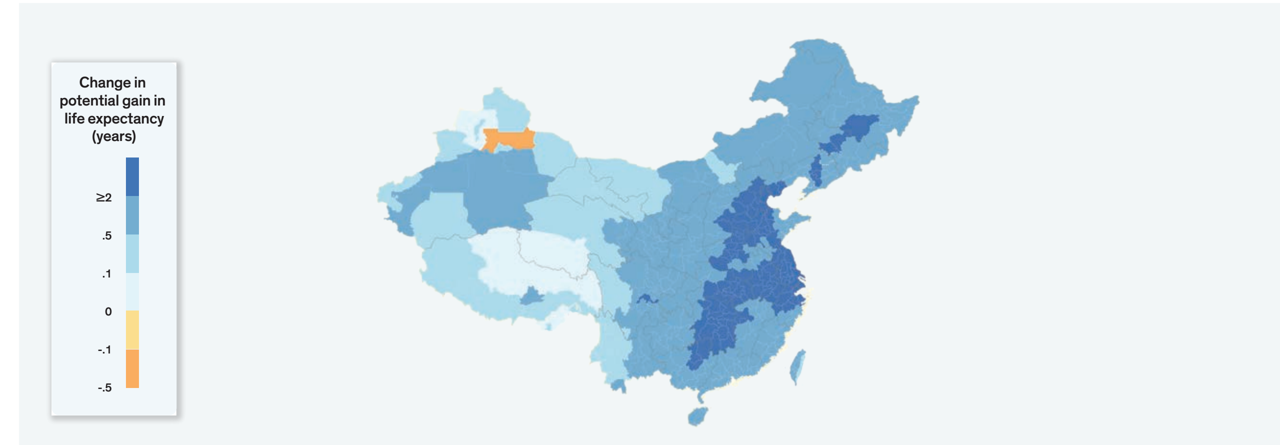
China has had such success in reducing pollution because of strict public policies. After China reached its highest pollution levels in 2013, the public began to call for change. China responded with a National Air Quality Action Plan in the fall of 2013, laying out specific targets to improve air quality by the end of 2017, including a 270 billion USD initiative to reduce pollution in the densely populated regions.

Figure 6.1 · Annual average $PM_{2.5}$ concentrations in major regions in Mainland China, 1998-2021



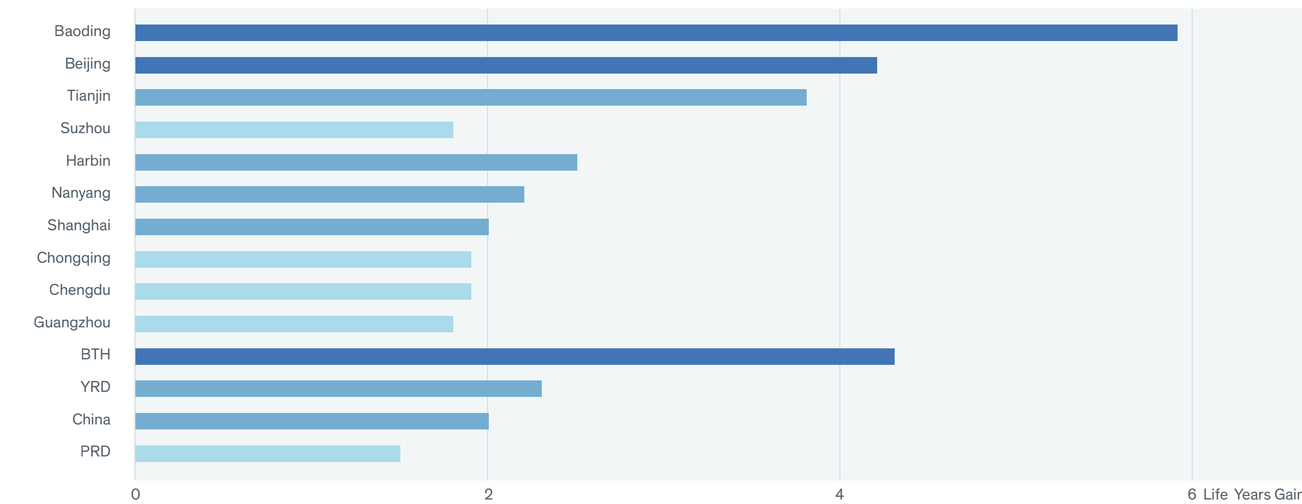
Note: PRD stands for Pearl River Delta and it includes the dense network of cities that covers nine prefectures of the province of Guangdong, namely Dongguan, Foshan, Guangzhou, Huizhou, Jiangmen, Shenzhen, Zhaoqing, Zhongshan and Zhuhai and the Special Administrative Regions of Hong Kong and Macau. YRD stands for Yangtze River Delta and it includes Shanghai, Jiangsu and Zhejiang. BTH stands for Beijing-Tianjin-Hebei. It is important to note that our definition of the YRD region includes all regions in the Jiangsu and Zhejiang provinces. Others may define the YRD region differently than how we have defined it in this report.

Figure 6.2 · Improvements in life expectancy due to reduced pollution between 2014 and 2021 in China



Note: Virtually all Chinese residents are projected to see their life expectancy improve (blue) due to recent reductions in particulate pollution since 2014, if those reductions persist.

Figure 6.3 · Change in life expectancy due to change in $PM_{2.5}$ concentration in Mainland China between 2014 and 2021



Note: This figure shows the increase in life expectancy due to a decrease in pollution between 2014 and 2021 in Mainland China. Amongst the 2 Suzhou prefectures present in China, the one shown in this figure lies in the Anhui province. Note that this figure compares regions from different administrative levels (e.g. China, BTH region, Suzhou prefecture, etc.). For more details, refer to Figure 6.1 Note.

At the 2014 annual meeting of the People's Congress, Premier Li Keqiang declared a "war against pollution."[47] The timing of this declaration marked an important shift in the country's long-standing policy of prioritizing economic growth over concerns about environmental protection.[48]

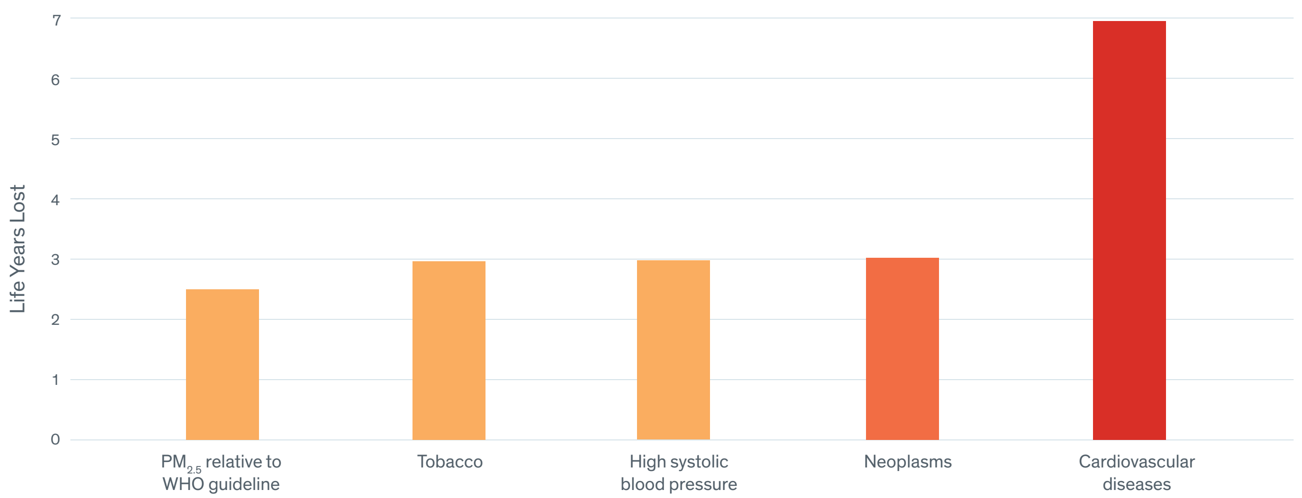
To meet the goals laid out in its National Air Quality Action Plan, the government began to restrict the number of cars on the road in large cities such as Beijing, Shanghai, and Guangzhou. In the industrial sector, iron- and steel-making capacity was reduced. New coal plants were banned in the Beijing-Tianjin-Hebei, Pearl River Delta and Yangtze River Delta regions, existing plants were mandated to reduce their emissions or switch to natural gas and renewable energy sources, while others were closed or relocated. In addition, coal-fired boilers used for heating homes in the north were replaced with gas or electric heaters.

Thanks to these, and other, strict pollution policies, the annual average pollution level in China is below the national standard. However, the pollution in China is still six times the WHO guideline and remains one of the top threats to life expectancy in the country. If China were able to reduce its pollution from 2021 levels to the WHO guideline, and those reductions were permanently sustained, the average person in China would see their life expectancy increase by 2.5 years. This threat falls just behind the threat from tobacco and high blood pressure in the country, which takes 3 years off of life expectancy (Figure 6.4). The health threat is even larger in the more heavily polluted provinces

47 Michael Greenstone, Guojun He, Shanjun Li, and Eric Yongchen Zou, 2021.

48 Greenstone, Michael, Guojun He, Ruixue Jia, and Tong Liu, 2022.

Figure 6.4 · Top 5 threats to life expectancy in China



Sources: Global Burden of Disease (https://vizhub.healthdata.org/gbd-results/) level-2 causes and risks data and WHO Life Tables (https://apps.who.int/gho/data/node.main.LIFECOUNTRY?lang=en) were combined with the Life table method to arrive at these results. "$PM_{2.5}$ relative to WHO Guideline" bar displays the reduction in life expectancy relative to the WHO guideline as calculated by latest AQLI (2021) data.

of Hebei, Tianjin, Henan, and Shandong where residents stand to gain between 3.3 and 3.5 additional years of life expectancy from clean air. Residents of Beijing stand to gain 3.2 years. Using an international lens, Beijing is still almost 3 times more polluted than Los Angeles, the most polluted major city in the United States.

Can China make further pollution reductions? To date, the country has relied on command-and-control measures to swiftly reduce pollution. While the measures have worked, they have come with significant economic and social costs (See AQLI Update 2022).[49]

As China enters the next phase of its "war against pollution," the country has an opportunity to place more emphasis on market-based approaches in order to more sustainably reduce pollution at a lower cost. Such approaches of reducing pollution have been successful in other parts of the world. One of the largest programs in history, the U.S. sulfur dioxide emissions trading scheme, reduced pollution by 40 percent between 1980 and 2003. Analysts have shown that the program's benefits exceeded its costs by a 40:1 ratio. Meanwhile, the government of Gujarat, India, implemented the world's first emissions trading market for particulate pollution in 2019 in the industrial city of Surat. Evidence suggests that participating factories have reduced pollution by about 24 percent without any measured increase in their operating costs.[50] Meanwhile, in 2021, China launched its carbon emissions trading system (ETS), which has already become the world's largest carbon market, three times bigger than the European Union's and is forecasted to grow 70 percent under plans to add heavy industry and manufacturing.[51] The market's scale could position the country well for the potential adoption of a market for conventional air pollution.

49 Air Quality Life Index (AQLI). 2022. "Annual Update."

50 Hindustan Times. 2022. "Gujarat to launch India's first carbon trading market among large polluters."

51 Forbes. 2022. "China's Emissions Trading System Will Be The World's Biggest Climate Policy. Here's What Comes Next."

Section 7

Despite Broad Improvements, Air Pollution Inequality Is Pervasive in the United States and Europe

In spite of major advancements in reducing pollution over several decades, fresh data reveal inequalities persist in the amount of pollution residents breathe in regions within the United States and Europe. Those in some of the most polluted areas would gain 2.5 years onto their lives if pollution were reduced to meet the WHO guideline, underlining the importance of continuing to strengthen and innovate air quality policy.

After periods of industrialization led to pollution that choked Europe and the United States decades ago, the two regions have largely been successfully creating and enforcing strong pollution laws. In the United States, legislative measures like the Clean Air Act have helped to reduce pollution by 64.9 percent since 1970, extending the average lifespan by 1.4 years[52]. In Europe, policies such as the European Union's Air Quality Framework Directive have helped to reduce pollution by 23.5 percent since 1998, allowing residents to gain 4.5 months.[53] Primarily due to these pollution reductions, the United States and Europe—which make up 15.4 percent of the world's population—account for only about 4.1 percent of the health burden from particulate pollution.[54]

Yet, the latest scientific evidence suggests that pollution is harmful to human health at even the low levels that exist in much of the United States and Europe today. With this new evidence now built into the WHO's guideline, the 2021 data reveal that 96 and 98.4 percent of people in the United States and Europe, respectively, are now considered to be living in polluted areas.

In the United States, average pollution was 7.8 $\mu g/m^3$ in 2021, slightly above the WHO guideline of 5 $\mu g/m^3$. At this level, residents could expect to gain roughly 3.6 months if the air they breathed permanently met the WHO guideline, equivalent to 99.2 million total life years. The average European in 2021 was exposed to a particulate pollution concentration of 12.4 $\mu g/m^3$, meeting the European Union's air pollution standard of 25 $\mu g/m^3$ but falling short of the revised WHO guideline.[55] If particulate pollution were to meet this standard, average life expectancy across Europe would improve by 8.4 months, equivalent to 602.4 million total life years.

If the United States and Europe were to further reduce pollution to meet the WHO's latest guideline, the largest benefits would be concentrated in specific areas. For example, in recent years, rising wildfires in the Western United States have caused air pollution levels to rise in the region. Residents of California's Central Valley are now consistently exposed to average particulate pollution levels above both the WHO guideline and the nation's own air quality standard. In 2021—a year in which California experienced

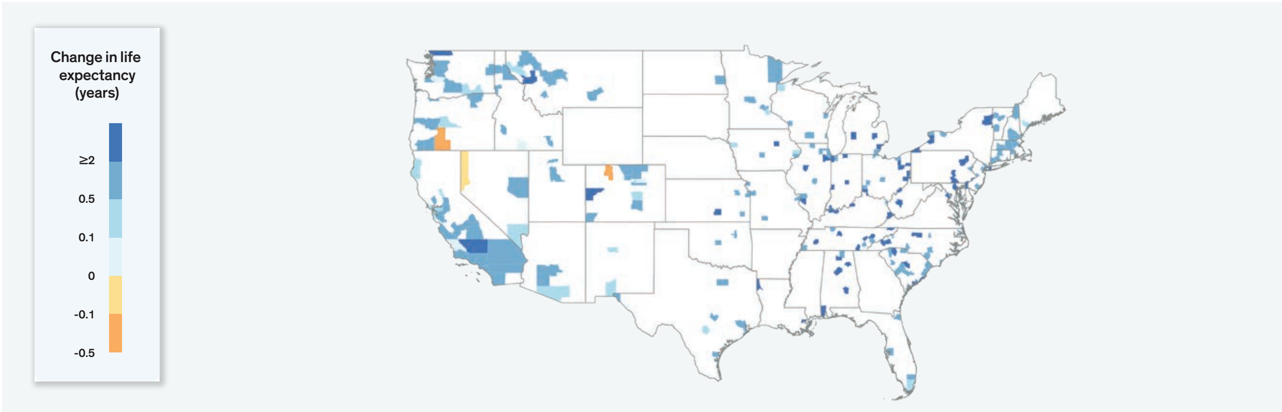
52 Our 1970 US estimates are based on only 237 US counties for which 1970 $PM_{2.5}$ concentrations could be approximated. It should be noted that not all states include counties with data available from 1970. Here we are comparing 1970s imputed $PM_{2.5}$ data for those 237 counties with 2021 $PM_{2.5}$ data, which are available for all 3,136 US counties. For further information, see the Technical Appendix available at https://aqli.epic.uchicago.edu/policy-impacts/united-states-clean-air-act/.

53 European Commission. 2008. "DIRECTIVE 2008/50/EC OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL on ambient air quality and cleaner air for Europe."

54 Europe is defined as the 53 countries listed in the following file: https://drive.google.com/file/d/1CpDGkKu96HcKr5×CZ3QozldnozJMetrH/view?usp=drive_link

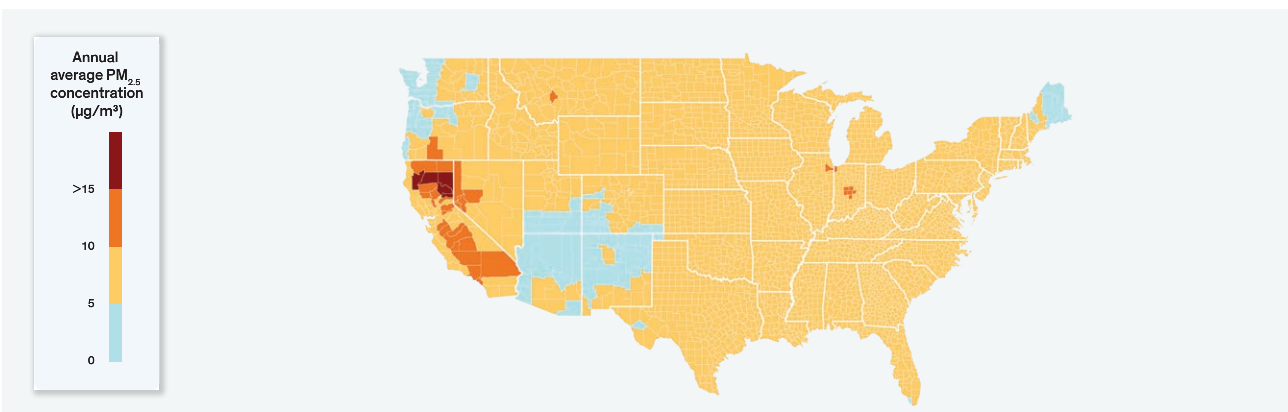
55 Although the EU $PM_{2.5}$ standard only applies to a subset of the countries in Europe that are in the EU, we use it as a reference point for all of Europe's 53 countries in this report.

Figure 7.1 · Change in life expectancy due to change in $PM_{2.5}$ concentration in 235 counties in the United States between 1970 and 2021



Note: Only three counties (in orange) are losing life years due to particulate pollution increasing in 2021 compared to 1970—Routt (Colorado), Washoe (Nevada), and Klamath (Oregon). This comparison can only be made for the 237 US counties for which 1970 PM2.5 concentrations could be estimated from available data. The 3 counties referred to in the title are: Routt (Colorado), Washoe (Nevada), Klamath (Oregon). The two counties of Anchorage (Alaska) and Honolulu (Hawaii) were excluded in this figure due to limited space; however they also experienced declines in particulate pollution in 2021 relative to 1970 resulting in gains of 7.4 months and 3.6 months respectively. For further information, see the Technical Appendix available at https://aqli.epic.uchicago.edu/policy-impacts/united-states-clean-air-act/.

Figure 7.2 · Wildfire ravaged California is home to 20 of the 30 most polluted counties in the US



its second worst wildfire season, in terms of acreage burned and its largest single wildfire[56, 57]—20 out of the top 30 most polluted counties were in California (Figure 7.2), where average pollution concentrations ranged from 5.5 µg/m³ in Monterey County to 26.6 µg/m³ in Plumas County. In Plumas, the most polluted area of the United States, residents stand to gain 2.1 years of life expectancy if air quality were kept below the WHO guideline permanently, rather than at the 2021 level. In three counties in the United States as a whole, pollution levels in 2021 were higher than their estimated levels in 1970.

The story is broadly similar in Europe, where most European residents have seen their life expectancy improve due to reductions in particulate pollution from 1998 to 2021 (Figure 7.3). Only some residents living in Bulgaria, Ireland, Spain, Serbia and the United Kingdom are losing years off their life expectancy due to increases in particulate pollution in 2021 relative to 1998.

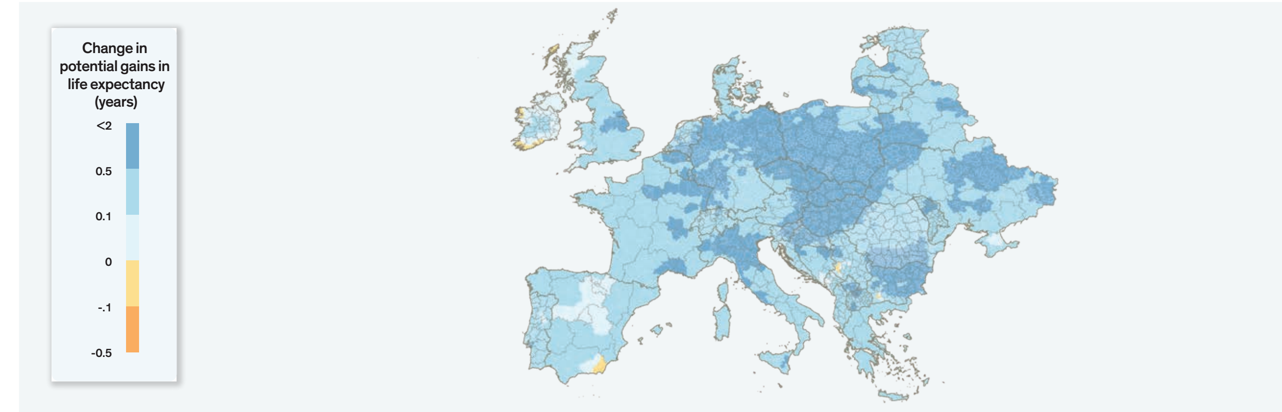
There remains a stark contrast in current pollution levels and consequent health burdens between eastern and western portions of the continent (Figure 7.4). The eastern portion of Europe could gain 6.3 more months of life expectancy than the western portion, if both regions were to meet the WHO guideline. Virtually all of the populations of Poland, Belarus, Slovakia, Hungary, Lithuania, Armenia, and Bosnia and Herzegovina do not meet the WHO's guideline.

Bosnia and Herzegovina is the most polluted country in Europe. If pollution were improved to meet the WHO guideline, an average resident would gain 1.8 years of life expectancy. The cities of Tuzla and Zenica-Doboj and their surrounding areas see particularly high levels of particulate pollution. If pollution

56 National Interagency Coordination Centre. 2021. "Wildland Fire Summary and Statistics Annual Report."

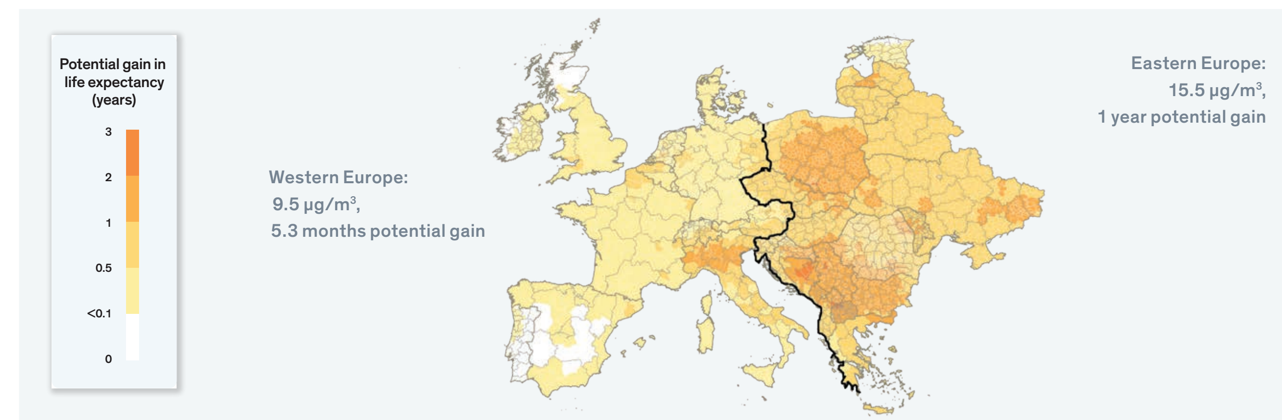
57 California State Portal. 2022. "Fire Season Incident Archive."

Figure 7.3 · Change in life expectancy due to change in $PM_{2.5}$ concentration in Europe between 1998 and 2021.



Note: Virtually all European residents will see their life expectancy improve (blue) due to reductions in particulate pollution, if those reductions persist. Refer footnotes 3, 54, and Figure 7.4 Note.

Figure 7.4 · Potential gain in life expectancy from permanently reducing $PM_{2.5}$ from 2021 concentration to the WHO guideline, comparing Eastern Europe versus Western Europe (demarcated by heavy black line)



Note: This map excludes the regions of Islas Canarias (in Spain) and Azores (in Portugal) due to space limitations. But, all underlying calculations include these regions. See footnote 3 for the definition of Eastern v/s Western Europe.

were to improve to meet the WHO guideline, residents in Tuzla, the most polluted region in the country, would add 2.5 years onto their lives. Outside of Eastern Europe, high pollution remains in areas such as Italy's Po Valley. In Milan, the city with the highest pollution in Western Europe, residents would gain 1.6 years if particulate pollution levels were reduced to meet the WHO guideline.

In the wake of the revised WHO guideline in 2021, both the United States and European Union have been taking steps to strengthen their $PM_{2.5}$ standards. This year, in the United States, the Environmental Protection Agency has proposed a new annual $PM_{2.5}$ standard of 9–10 µg/m³ to replace its current standard of 12 µg/m³.[58] If the upper limit of that proposed revision were adopted, the average citizen in these 40 counties that exceeded particulate pollution levels of 10 µg/m³ in 2021 could gain an additional 1.6 months of life expectancy relative to the current standard or 3.2 million total life years.

Meanwhile, in late 2022, the European Commission proposed ratcheting down the European Union's current $PM_{2.5}$ standard of 25 µg/m³ to 10 µg/m³ by 2030.[59] Fifteen of the 28 member countries of the EU are exceeding the proposed stricter limit, given the latest AQLI 2021 data. If these 15 countries were to reduce their pollution levels to meet the proposed stricter limit, the average citizen living in these countries would gain 4.9 months of life expectancy on average, which is equivalent to gaining 80.3 million total life years for the population of those 15 countries as a whole.[60]

58 Environmental Protection Agency. 2023. "Reconsideration of the National Ambient Air Quality Standards for Particulate Matter."

59 European Commission. 2022. "DIRECTIVE OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL on ambient air quality and cleaner air for Europe (recast)."

60 Fifteen countries exceeding the proposed stricter standard: Austria, Belgium, Bulgaria, Croatia, Cyprus, Czechia, Greece, Hungary, Italy, Latvia, Lithuania, Poland, Romania, Slovakia, Slovenia.

Conclusion

Air pollution continues to pose a significant threat to global health. The AQLI indicates that 2021 pollution levels take 2.3 years off the average global life expectancy compared to if air quality were to meet the WHO guideline, on par with the impact on life expectancy from tobacco use and more severe than HIV/AIDS or nutritional deficiencies.

Despite the global concentration of particulate pollution remaining relatively constant over the last two decades, trends have diverged in different regions since 2013. South Asia, particularly India, Pakistan, and Bangladesh, has seen pollution levels rise significantly, with residents of that region now on track to lose 5.1 years of life expectancy relative to if the pollution levels were to meet the WHO guideline. Conversely, China has achieved remarkable success in battling pollution since declaring a "war on pollution" in 2014, reducing pollution levels by 42.3 percent from 2013 to 2021, and potentially extending average life expectancy by 2.2 years.

Our analysis also highlights the unequal distribution of the pollution burden and the necessary tools to combat it. In Bangladesh, the country with the highest pollution levels, residents stand to lose an average of 6.8 years of life due to pollution levels not meeting the WHO guideline. In contrast, in the United States, residents only lose an average of 3.6 months.

Americans breathe much cleaner air because of strong policies built on a foundation of data, information, and advocacy. Many of the most polluted countries today do not have that foundation in place. For example, only 6.8 and 3.7 percent of governments in Asia and Africa, respectively,[61] generate fully open air quality data, able to be utilized by the public, compared to 69.2 percent in Europe, the United States, and Canada. As a result of this weak foundation, a significant disparity exists between the regions with the greatest burden from particulate pollution (Asia and Africa) and the existence of national air quality standards. While Asia and Africa contribute to 92.7 percent of global life years lost due to pollution, only 35.6 percent and 4.9 percent of countries in these regions have established national air quality standards, respectively.

Our report of particulate pollution levels and their impact on life expectancy reveals a striking opportunity for policy, philanthropy, and development around the world to enhance the allow people to live longer and healthier lives.

61 OpenAQ. 2022. "Open Air Quality Data: The global landscape."

Appendix: The Evolution of Satellite-Derived $PM_{2.5}$ Data

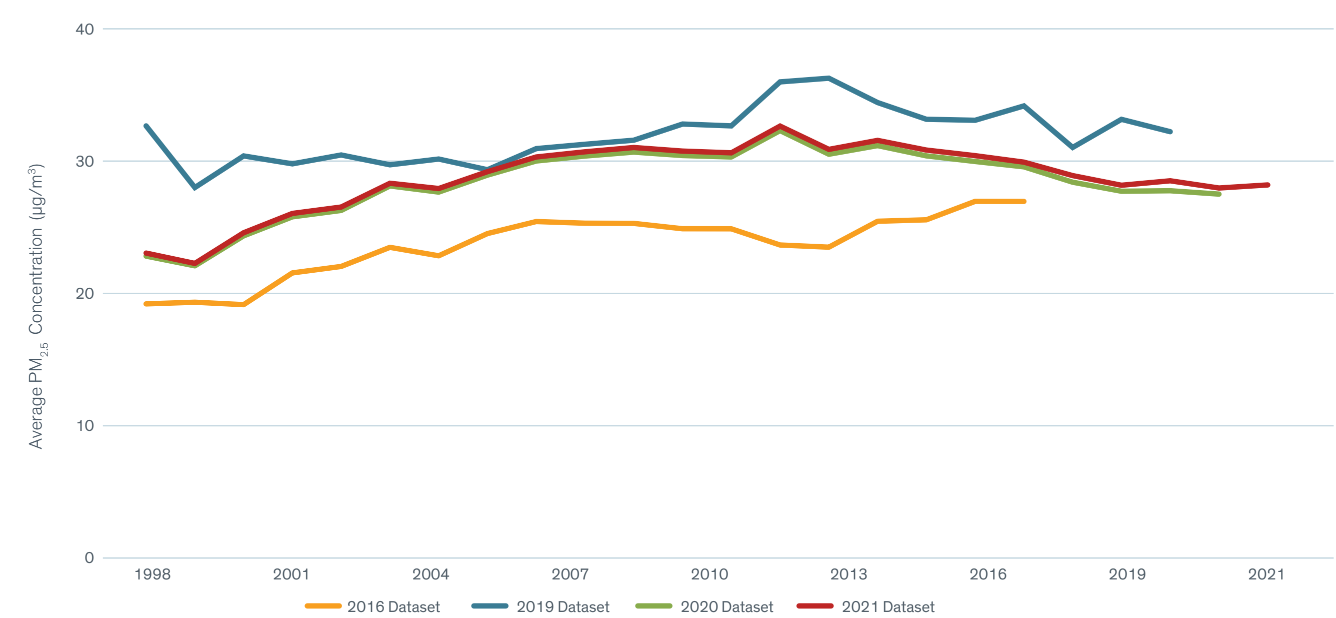
Reliable, geographically extensive pollution measurements are critical to understanding the extent of air pollution and its health impacts. Unfortunately, many areas around the world either lack extensive pollution monitoring systems or did not begin monitoring $PM_{2.5}$ until recently, making it impossible to track long-term global trends. To construct a single dataset of particulate pollution and its health impacts that is global in coverage, local in resolution, consistent in methodology, and that spans many years to reveal pollution trends over time, the latest AQLI data incorporates satellite-derived annual ambient $PM_{2.5}$ concentration estimates spanning 24 years from 1998-2021 by the Atmospheric Composition Analysis Group at the University of Washington (methodology described in van Donkelaar et al. (2021). The latest raw dataset (version: V5.GL.03) is publicly accessible at: https://sites.wustl.edu/acag/datasets/surface-pm2-5/. The AQLI uses a version of this data that excludes sea salt and dust.

There are differences between the satellite-derived $PM_{2.5}$ dataset used in this report and those used in previous AQLI reports. For example, in the new and revised 2021 dataset used this year, the estimated global population-weighted average $PM_{2.5}$ concentration for the year 2019 has been revised upwards relative to the 2020 dataset used in our 2022 AQLI update, from 27.7 to 28.5 µg/m³ (Figure A.1).

According to van Donkelaar et al. (2021), satellite-derived $PM_{2.5}$ data were constructed by converting measurements of aerosol optical depth (AOD) over each grid cell into $PM_{2.5}$ measurements using a chemical transport model called GEOS-Chem. These estimates were then subsequently calibrated to regional ground-based observations of both total and compositional mass using a Geographically Weighted Regression (GWR). Over time, improvements in the model and calibration inputs, alongside growing ground level monitoring coverage necessitate periodic updates to the historical $PM_{2.5}$ dataset.

In Figure A.1, we plot and compare the global population-weighted $PM_{2.5}$-time trends using various years' versions of the annual average $PM_{2.5}$ dataset. Although the new and revised $PM_{2.5}$ dataset yields global average concentration levels that are higher on average than those estimated using the 2020 and 2016 reference datasets and lower on average than the 2019 reference dataset, the overall picture remains the same. The global annual average $PM_{2.5}$ level has shifted between 3.8 to 7.2 times the WHO guideline, making air pollution the greatest external threat to human health globally.

Figure A.1 · Comparing latest (2021 reference dataset) global annual average $PM_{2.5}$ concentration time series with various historical reference datasets



Note: The "2021 dataset" line plots the global population-weighted annual average $PM_{2.5}$ trend using data accessible from https://sites.wustl.edu/acag/datasets/surface-pm2-5/ (V5.GL.03) and methodology described in van Donkelaar et al. (2021). The "2020 dataset" line plots the global population-weighted average PM2.5 trend using data from van Donkelaar et al. (2021). The "2019 dataset" line plots the analogous trend using data from Hammer et al. (2020). The "2016 dataset" plots the trend using data from van Donkelaar et al. (2016). Note that the AQLI uses a version of all datasets that excludes sea salt and dust. To learn more about these versions, visit: https://sites.wustl.edu/acag/datasets/surface-pm2-5/.

Appendix Table • 2021 Annual Average $PM_{2.5}$ Pollution Concentrations by Country and Corresponding Potential Life Expectancy Gains, if WHO Guideline or National Standard Were Met

Country or Territory	Average $PM_{2.5}$ (μg/m³)	National Standard (μg/m³)	Life Expectancy Gains (in years) from reducing $PM_{2.5}$ from 2021 Concentrations to the WHO Guideline of 5 μg/m³	Life Expectancy Gains (in years) from reducing $PM_{2.5}$ from 2021 Concentrations to the country's National Standard
Afghanistan	16.9	35	1.2	0
Akrotiri and Dhekelia	11.2	*	0.6	*
Albania	13.5	25	0.8	0
Algeria	6.2	*	0.1	*
American Samoa	1	12	0	0
Andorra	7.6	25	0.2	0
Angola	16.9	*	1.2	*
Anguilla	2.2	*	0	*
Antigua and Barbuda	2.4	*	0	*
Argentina	11.2	15	0.6	0
Armenia	19.5	*	1.4	*
Aruba	3.3	*	0	*
Australia	3.6	8	0	0
Austria	10.7	25	0.6	0
Azerbaijan	12.4	*	0.7	*
Bahamas	3.8	*	0	*
Bahrain	17.9	*	1.3	*
Bangladesh	74	15	6.8	5.8
Barbados	2.5	10	0	0
Belarus	12.8	*	0.8	*
Belgium	10.1	25	0.5	0
Belize	10.4	*	0.5	*
Benin	17.4	*	1.2	*
Bermuda	3.3	*	0	*
Bhutan	30.6	*	2.5	*
Bolivia	25.2	*	2	*
Bonaire, Sint Eustatius and Saba	3.3	*	0	*
Bosnia and Herzegovina	23.7	25	1.8	0
Botswana	12.8	*	0.8	*
Bouvet Island	*	*	*	*
Brazil	11.1	*	0.6	*
British Indian Ocean Territory	*	*	*	*
British Virgin Islands	2.1	*	0	*
Brunei	6.2	*	0.1	*
Bulgaria	19	25	1.4	0
Burkina Faso	8.5	*	0.3	*
Burundi	31.9	*	2.6	*
Cabo Verde	2.6	*	0	*
Cambodia	19.8	*	1.4	*
Cameroon	31	*	2.5	*
Canada	8	8.8	0.3	0
Cayman Islands	7.4	*	0.2	*
Central African Republic	25.6	*	2	*
Chad	11.1	*	0.6	*
Chile	18.9	20	1.4	0
China	30.2	35	2.5	0
Christmas Island	2.2	*	0	*
Clipperton Island	*	*	*	*
Cocos Islands	1.8	*	0	*
Colombia	13.6	20	0.8	0
Comoros	6.4	*	0.1	*
Cook Islands	1	*	0	*
Costa Rica	12.5	*	0.7	*
Croatia	14.9	25	1	0
Cuba	6.8	*	0.2	*
Curaçao	3.6	*	0	*
Cyprus	12.3	25	0.7	0
Czechia	13.2	25	0.8	0
Côte d'Ivoire	10.8	*	0.6	*
Democratic Republic of the Congo	34.6	*	2.9	*
Denmark	8.1	25	0.3	0
Djibouti	17.4	*	1.2	*
Dominica	2.5	*	0	*
Dominican Republic	7.9	15	0.3	0
Ecuador	16	15	1.1	0.1
Egypt	18.2	50	1.3	0
El Salvador	25.8	15	2	1.1
Equatorial Guinea	29.1	*	2.4	*
Eritrea	12.9	*	0.8	*
Estonia	6.7	25	0.2	0
Ethiopia	17	*	1.2	*
Falkland Islands	2	*	0	*
Faroe Islands	2.5	*	0	*
Fiji	2.4	*	0	*
Finland	5.1	25	0	0
France	9.2	25	0.4	0
French Guiana	5.8	*	0.1	*
French Polynesia	1.4	*	0	*
French Southern Territories	*	*	*	*
Gabon	23.6	*	1.8	*
Gambia	7.1	*	0.2	*
Georgia	14.5	20	0.9	0
Germany	9.3	25	0.4	0
Ghana	13.1	*	0.8	*
Gibraltar	9.7	*	0.5	*
Greece	11.8	25	0.7	0
Greenland	1.2	*	0	*
Grenada	2.6	*	0	*
Guadeloupe	2.8	*	0	*
Guam	1.3	12	0	0
Guatemala	29	*	2.4	*
Guernsey	8	*	0.3	*
Guinea	11.2	*	0.6	*
Guinea-Bissau	8.6	*	0.3	*
Guyana	7.1	*	0.2	*
Haiti	10.1	*	0.5	*
Heard Island and McDonald Island	*	*	*	*
Honduras	25.1	*	2	*
Hungary	14.1	25	0.9	0
Iceland	4.1	25	0	0
India	58.7	40	5.3	1.8
Indonesia	18.8	15	1.4	0.4
Iran	16.6	*	1.1	*
Iraq	24.6	*	1.9	*
Ireland	6.4	25	0.1	0
Isle of Man	6.5	*	0.1	*
Israel	12.6	25	0.7	0
Italy	13	25	0.8	0
Jamaica	13	15	0.8	0
Japan	10.7	15	0.6	0
Jersey	8.4	*	0.3	*
Jordan	18.6	*	1.3	*
Kazakhstan	13.3	*	0.8	*
Kenya	17.4	35	1.2	0
Kiribati	1	*	0	*
Kosovo	20.8	*	1.6	*
Kuwait	17.2	*	1.2	*
Kyrgyzstan	14.7	5	0.9	0.9
Laos	27.2	*	2.2	*
Latvia	14.1	25	0.9	0
Lebanon	16.8	*	1.2	*
Lesotho	23.1	*	1.8	*
Liberia	10.5	*	0.5	*
Libya	6.8	*	0.2	*
Liechtenstein	11.1	*	0.6	*
Lithuania	12.2	25	0.7	0
Luxembourg	8.6	25	0.3	0
Macedonia	22.9	*	1.8	*
Madagascar	9.9	*	0.5	*
Malawi	16.2	*	1.1	*
Malaysia	13.7	*	0.9	*
Maldives	8.8	*	0.4	*
Mali	6.8	*	0.2	*
Malta	6.3	25	0.1	0
Marshall Islands	1	*	0	*
Martinique	3.2	*	0	*
Mauritania	3.8	*	0	*
Mauritius	6.1	*	0.1	*
Mayotte	8	*	0.3	*
Micronesia	1	*	0	*
Moldova	14.7	25	0.9	0
Monaco	10.1	*	0.5	*
Mongolia	36	25	3	1.1
Montenegro	17	25	1.2	0
Montserrat	2.9	*	0	*
Morocco	8.8	*	0.4	*
Mozambique	12.4	*	0.7	*
Myanmar	35	*	2.9	*
México	17.3	12	1.2	0.5
Namibia	12	*	0.7	*
Nauru	1.3	*	0	*
Nepal	51.7	*	4.6	*
Netherlands	9.7	25	0.5	0
New Caledonia	3.4	*	0	*
New Zealand	3.5	*	0	*
Nicaragua	13.6	*	0.8	*
Niger	8.9	*	0.4	*
Nigeria	23	*	1.8	*
Niue	0.9	*	0	*
Norfolk Island	1.8	*	0	*
North Korea	20	*	1.5	*
Northern Cyprus	12.2	*	0.7	*
Northern Mariana Islands	1	12	0	0
Norway	5.6	12	0.1	0
Oman	12.1	*	0.7	*
Pakistan	44.7	15	3.9	2.9
Palau	2.9	12	0	0
Palestine	12.6	*	0.8	*
Panama	9.1	20	0.4	0
Papua New Guinea	12.9	*	0.8	*
Paracel Islands	6.7	*	0.2	*
Paraguay	13.7	15	0.8	0
Peru	24.2	25	1.9	0
Philippines	18.3	25	1.3	0
Pitcairn Islands	2	*	0	*
Poland	18	25	1.3	0
Portugal	6.3	25	0.1	0
Puerto Rico	2.9	12	0	0

* No national standard specified and/or data not available.

* No national standard specified and/or data not available.

Country or Territory	Average $PM_{2.5}$ (µg/m³)	National Standard (µg/m³)	Life Expectancy Gains (in years) from reducing $PM_{2.5}$ from 2021 Concentrations to the WHO Guideline of 5 µg/m³	Life Expectancy Gains (in years) from reducing $PM_{2.5}$ from 2021 Concentrations to the country's National Standard
Qatar	30	*	2.5	*
Republic of the Congo	32.4	*	2.7	*
Romania	15	25	1	0
Russia	11.3	25	0.6	0
Rwanda	32.4	*	2.7	*
Réunion	3	*	0	*
Saint Helena, Ascension and Tris	2.8	*	0	*
Saint Kitts and Nevis	3.1	*	0	*
Saint Lucia	2.4	*	0	*
Saint Pierre and Miquelon	3.9	*	0	*
Saint Vincent and the Grenadines	2.6	*	0	*
Saint-Barthélemy	2.4	*	0	*
Saint-Martin	2.2	*	0	*
Samoa	1.2	*	0	*
San Marino	10.9	*	0.6	*
Saudi Arabia	25	15	2	1
Senegal	5.7	*	0.1	*
Serbia	20.2	25	1.5	0
Seychelles	5	*	0	*
Sierra Leone	11.6	*	0.7	*
Singapore	13	*	0.8	*
Sint Maarten	2.5	*	0	*
Slovakia	14.5	25	0.9	0
Slovenia	13.4	25	0.8	0
Solomon Islands	5.8	*	0.1	*
Somalia	9.2	*	0.4	*
South Africa	21.1	20	1.6	0.1
South Georgia and the South Sand	*	*	*	*
South Korea	20.4	15	1.5	0.5
South Sudan	16	*	1.1	*
Spain	7.5	25	0.2	0
Spratly Islands	0	*	0	*
Sri Lanka	18.8	15	1.4	0.4
Sudan	11.4	*	0.6	*
Suriname	6.4	*	0.1	*
Svalbard and Jan Mayen	*	*	*	*
Swaziland	15.9	*	1.1	*
Sweden	5.5	25	0	0
Switzerland	9.4	10	0.4	0
Syria	19.7	*	1.4	*
São Tomé and Príncipe	11.1	*	0.6	*
Taiwan	16.2	*	1.1	*
Tajikistan	16.7	*	1.1	*
Tanzania	16.4	*	1.1	*
Thailand	23.2	15	1.8	0.8
Timor-Leste	10.5	*	0.5	*
Togo	15.4	*	1	*
Tokelau	1.4	*	0	*
Tonga	1.8	*	0	*
Trinidad and Tobago	4	15	0	0
Tunisia	8.6	*	0.3	*
Turkey	21.8	*	1.6	*
Turkmenistan	10.4	*	0.5	*
Turks and Caicos Islands	3.4	*	0	*
Tuvalu	1.3	*	0	*
Uganda	26.7	*	2.1	*
Ukraine	14.6	25	0.9	0
United Arab Emirates	16.8	*	1.2	*
United Kingdom	8.7	25	0.4	0
United States	7.8	12	0.3	0
United States Minor Outlying Islands	3	*	0	*
Uruguay	8.4	*	0.3	*
Uzbekistan	20	*	1.5	*
Vanuatu	4.4	*	0	*
Vatican City	11.3	*	0.6	*
Venezuela	10.8	*	0.6	*
Vietnam	25.8	25	2	0.1
Virgin Islands, U.S.	2.2	12	0	0
Wallis and Futuna	1.3	*	0	*
Western Sahara	4.8	*	0	*
Yemen	14.8	*	1	*
Zambia	18.5	*	1.3	*
Zimbabwe	14.4	*	0.9	*
Åland	4.8	*	0	*

* No national standard specified and/or data not available.

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About the Authors

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Michael Greenstone is the Milton Friedman Distinguished Service Professor in Economics, the College, and the Harris School, as well as the Director of the Becker Friedman Institute and the interdisciplinary Energy Policy Institute at the University of Chicago. Greenstone's research, which has influenced policy globally, is largely focused on uncovering the benefits and costs of environmental quality and society's energy choices. As the Chief Economist for President Obama's Council of Economic Advisers, he co-led the development of the United States Government's social cost of carbon. Additionally, he has been researching the impacts of particulate pollution on human well-being for more than two decades, including work that plausibly quantified the causal relationship between long-term human exposure to particulate pollution and life expectancy. This work is the basis of the Air Quality Life Index.

Christa Hasenkopf

Christa Hasenkopf is the Director of Air Quality Life Index (AQLI) and Air Quality Programs at EPIC. Her career focuses on efforts that open up information, resources, and networks so that more people in more places can help make the air they breathe healthier. Previously, she co-founded and was the CEO of OpenAQ, an environmental tech non-profit, which fosters a global community around the world's largest open database of air quality information. She has also served as the Chief Air Pollution Advisor to the Office of Medical Services at the US Department of State and in multiple positions at the US Agency for International Development. Hasenkopf received a PhD in Atmospheric & Oceanic Sciences from the University of Colorado and a BS in Astronomy & Astrophysics from The Pennsylvania State University.

ABOUT THE AIR QUALITY LIFE INDEX

The AQLI is a pollution index that translates particulate air pollution into perhaps the most important metric that exists: its impact on life expectancy. Developed by the University of Chicago's Milton Friedman Distinguished Service Professor in Economics Michael Greenstone and his team at the Energy Policy Institute at the University of Chicago (EPIC), the AQLI is rooted in recent research that quantifies the causal relationship between long-term human exposure to air pollution and life expectancy. The Index then combines this research with hyper-localized, global particulate measurements, yielding unprecedented insight into the true cost of particulate pollution in communities around the world. The Index also illustrates how air pollution policies can increase life expectancy when they meet the World Health Organization's guideline for what is considered a safe level of exposure, existing national air quality standards, or user-defined air quality levels. This information can help to inform local communities and policymakers about the importance of air pollution policies in concrete terms.

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ABOUT EPIC

The Energy Policy Institute at the University of Chicago (EPIC) is confronting the global energy challenge by working to ensure that energy markets provide access to reliable, affordable energy, while limiting environmental and social damages. We do this using a unique interdisciplinary approach that translates robust, data-driven research into real-world impacts through strategic outreach and training for the next generation of global energy leaders.

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