AQLI Air Quality Life Index®

AIR QUALITY LIFE INDEX® | JUNE 2022

Annual Update

By Michael Greenstone, Christa Hasenkopf and Ken Lee

June 2022

Dear Friends and Colleagues

We are pleased to bring you the latest data from the Air Quality Life Index (AQLI). This report reaffirms that particulate pollution is the greatest global health threat. Yet, we also see the opportunity for progress. Air pollution is a winnable challenge. It just requires effective policies. To get there, targeted information, like what the AQLI provides, can unleash civil awareness and lead to the call for strong policies.

To help steer this work, we are thrilled to welcome Dr. Christa Hasenkopf as the new director of the AQLI. Christa brings exceptional expertise in data transparency, atmospheric science, and community building. Previously, through creating the non-profit OpenAQ, she led efforts to open up the global air quality data landscape and foster collaborative communities across various sectors and geographies to build on top of that data together. She views providing accessible, relatable air quality information as an essential ingredient for enabling communities to tackle their air pollution. This strikes at the heart of the AQLI's mission.

Under Christa's leadership, we look forward to expanding the AQLI's work and impact in communities around the world by providing people and institutions with critical information on air pollution and its health consequences. This information allows for better decision making by governments and people.

Sincerely,

Michael Greenstone
Milton Friedman Distinguished Service Professor in Economics
Director, EPIC & BFI
University of Chicago

Dear Friends and Colleagues,

Welcome to the latest edition of the Air Quality Life Index Report.

This edition of the AQLI report provides a global snapshot of the continuing severe impact of particulate (PM2.5) pollution on human lives in 2020, as the COVID-19 pandemic first emerged. The report also highlights the biggest opportunities to address particulate pollution—where in the world the largest gains in average life expectancy can be made by improving the air.

Creating this global landscape showing how the length of a life is affected by particulate pollution is foundational for efforts of all kinds to understand the consequences of air pollution for individuals, NGOs, companies, and governments. With this information, it is possible to develop strategic and cost effective approaches to achieve clean air. The importance of such efforts jumps out of the numbers. The average person on the planet currently loses 2.2 years of life expectancy because of exposure to particulate pollution. Meanwhile, funding to address air pollution does not match the scale of the problem. As just one example, globally, less than $45 million is spent by all philanthropies on air pollution each year, which is just 0.1 percent of total annual grantmaking[1] .

As the *New York Times* recently pointed out, fixing air pollution is a neglected issue, yet it is such a tractable one and this is what makes us so hopeful. Diverse technical and policy solutions to reduce pollution abound and have been tried and tested in communities of all types across the world. Given the current low level of global funding for the issue, it's also the case that a relatively small increase in support can have an outsized impact, filling basic air quality management gaps such as access to continuous, reliable air quality monitoring data. And a simple metric capturing the impact of particulate pollution on human health like the AQLI helps make this global public health crisis more visible and urgent, spurring the most impacted communities into action.

As the new director of AQLI, I am excited about how communities can use the AQLI to communicate the massive impact air pollution has on public health, as well as its ability to shine a light on the opportunities to address it. I look forward to learning and engaging with communities around the world working to clean the air they breathe.

Sincerely,

CHasenkopf

Christa Hasenkopf
Director, AQLI
Director, Air Quality Programs, EPIC

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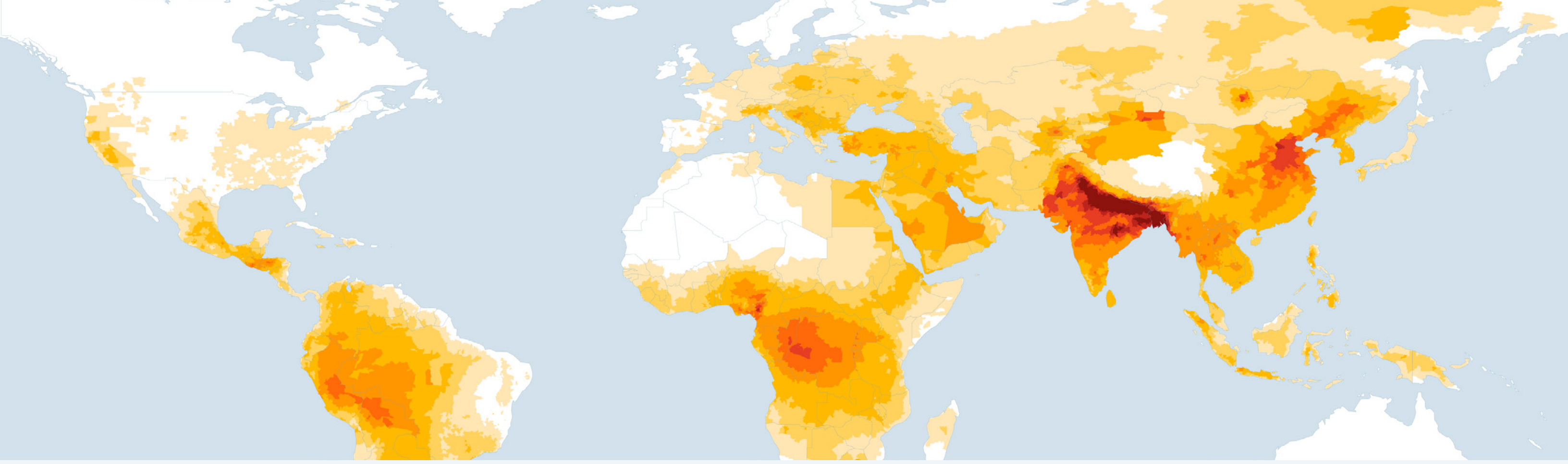
[1] 2021 State of Global Air Quality Funding, Clean Air Fund



Executive Summary

In 2020, Covid-19 lockdowns shut industries and forced vehicles off the roads, momentarily bringing blue skies to localized areas in some of the most polluted regions on Earth. But according to new and revised satellite-derived $PM_{2.5}$ data, there was little change in global particulate pollution. The global population weighted-average $PM_{2.5}$ level declined only from 27.7 to 27.5 µg/m^3 between 2019 and 2020, despite the well-documented, rapid slowdown in the global economy. In South Asia, the world's most polluted region, pollution actually rose during the first year of the pandemic.

The fact that global pollution remained flat, or even increased, even as economies stalled across the world, underscores that pollution is a stubborn problem that can only be solved by strong policies backed by an even stronger willingness for change. The Air Quality Life Index (AQLI) demonstrates the importance of these policies by showing that clean air pays back in additional years of life for people across the world. The AQLI's latest data reveal that permanently reducing global air pollution to meet the World Health Organization's (WHO) guideline would add 2.2 years onto average life expectancy.

In no region of the world is the opportunity for improved health and life expectancy greater than in South Asia, which includes four of the five most polluted countries in the world. In Bangladesh, India, Nepal, and Pakistan, the AQLI data reveal that the average person would live 5 years longer if pollution were reduced to meet the WHO guideline. Due to South Asia's high population and pollution concentrations, the region accounts for 52 percent of total life years lost globally due to particulate pollution exceeding the WHO guideline.

Pollution is also a challenge in Central and West Africa, which continue to grow their use of fossil fuels while particulate pollution is already as much of a threat as well-known killers in the region like HIV/AIDS and malaria. At the same time, almost all of the countries in this region lack a national pollution limit and only three real-time air quality monitoring stations exist. That's in comparison to about 200 monitors in India, which has a far smaller land mass. The lack of data transparency is a major hindrance to policy action.

Although the challenge of reducing air pollution across the world may seem daunting, China is an important beacon of progress. In 2013, China experienced some of its highest pollution levels to that point, and public awareness and criticism reached new heights. The following year, Chinese Premier Li Keqiang declared a "war against pollution," allocating substantial public resources to combating pollution. China's strict policy action led to a swift reduction in pollution. Since 2013, particulate pollution in China has declined by 39.6 percent, adding about 2 years onto average life expectancy, assuming these reductions are sustained. To place China's impact into context, the reductions in pollution account for all of the global average decline since 2013. It took several decades and recessions for the United States and Europe to achieve the same pollution reductions that China was able to accomplish in 7 years, even as it continued to grow its economy. Still, pollution in China significantly exceeds the WHO guideline.

It is important to note that air pollution is also deeply intertwined with climate change. Both challenges are primarily caused by the same culprit: fossil fuel emissions from power plants, vehicles, and other industrial sources. These challenges also present a rare win-win opportunity, because policy can simultaneously reduce dependence on fossil fuels that will allow people to live longer and healthier lives and reduce the costs of climate change.

In this report, we use new and revised satellite-derived $PM_{2.5}$ data to illustrate the extraordinary benefits of clean air policy.

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 University of Chicago Professor in Economics Michael Greenstone, draw on 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 are able to plausibly isolate the effect of particulate air pollution from other factors that affect health. The more recent of the two studies found that sustained exposure to an additional 10 µg/m^3 of PM_{10} reduces life expectancy by 0.64 years. Calculated in terms of $PM_{2.5}$, we estimate that this means that each additional 10 µg/m^3 of $PM_{2.5}$ exposure reduces life expectancy by 0.98 years. The AQLI applies this relationship to global, satellite-derived $PM_{2.5}$ measurements to determine the gains in life expectancy that could be achieved from cleaner air in communities around the world.

To learn more about the AQLI and its methodology, visit: aqli.epic.uchicago.edu/about/methodology

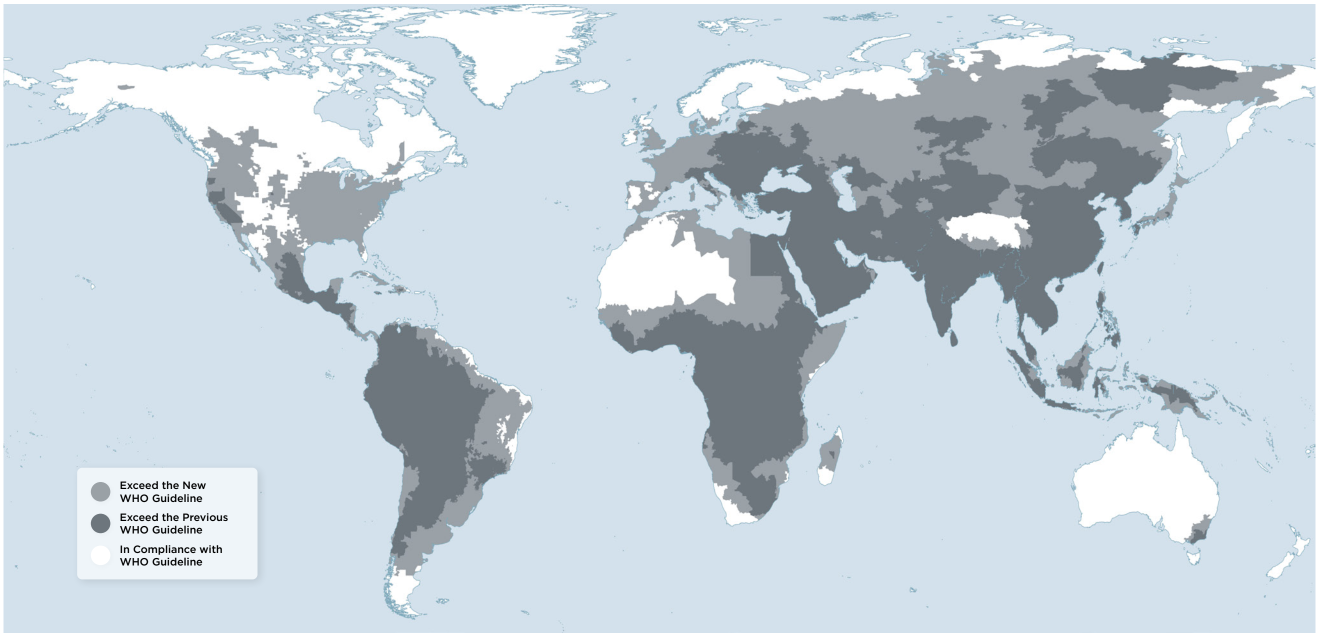
Increased Evidence of Pollution’s Impact on Health Leads to a Stronger Benchmark for Safety

With an abundance of scientific evidence on the negative health impacts of particulate pollution exposure, even at relatively low concentrations, on September 22, 2021 the World Health Organization (WHO) updated its guidance on the acceptable level of particulate pollution people should breathe.[2] The update, from 10 $\mu g/m^3$ to 5 $\mu g/m^3$, was the first since establishing air quality guidance in 2005.[3] The WHO’s decision to revise its guideline by such a significant amount is a powerful signal that air pollution is more deadly than initially thought.

According to new and revised satellite-derived $PM_{2.5}$ data, 80.2 percent of the global population lived in areas where $PM_{2.5}$ concentrations exceeded 10 $\mu g/m^3$, the previous WHO guideline, based on 2020 levels. Under the revised, and more stringent guideline, 97.3 percent of the global population are now considered to live in areas where air pollution exceeds the recommended threshold (see Figure 1).

The effects of this revision are particularly stark in the United States and Europe. According to the old guideline, just 7.6 and 47.3 percent of the population in the United States and Europe, respectively, lived in areas with polluted air, based on 2020 levels. Perhaps as a result, clean air has not been a leading political issue in recent years. But according to the new guideline, 92.8 and 95.5 percent of people in the United States and Europe, respectively, are now considered to be living in polluted areas. Meanwhile, virtually all of South and Southeast Asia, and more than 93 percent of Latin America are now considered to be polluted.

Figure 1 ·Impact of the Revised WHO Guideline on Polluted Regions in the World



Note: **White** regions correspond to those places that are in compliance with the WHO guideline. **Dark Grey** regions correspond to those places that were categorized as polluted under the previous WHO guideline. **Light Grey** regions correspond to regions that are newly out of compliance with the updated WHO guideline.

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[2] See, e.g., Burnett and Aaron, 2020.

[3] WHO, 2021.

Section 1

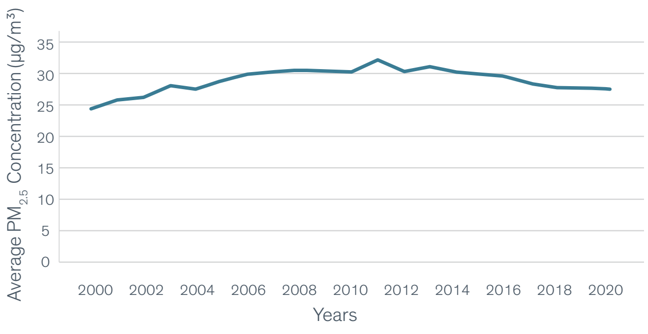
Global Pollution Remained Flat Despite Pandemic Lockdowns, Underscoring the Health Threat

Even as economies stalled across the world, global pollution remained flat during the first year of the pandemic, underscoring that pollution is a stubborn problem solved only by strong policies. The AQLI shows that reducing global pollution to meet the now more stringent World Health Organization (WHO) guideline would add 2.2 years onto average life expectancy.

In 2020, the onset of the Covid-19 pandemic was soon followed by lockdowns and travel restrictions across the globe, leading to improved environmental quality in numerous localized regions for a short period of time. Yet, at the global level, there was virtually no change in average particulate pollution levels. According to new and revised satellite-derived PM$_{2.5}$ data, the global population weighted-average PM$_{2.5}$ level declined slightly between 2019 and 2020, from 27.7 to 27.5 $\mu g/m^3$—more than five times the WHO's revised guideline of 5 $\mu g/m^3$—despite a rapid slowdown in economic activities across the globe. In fact, global particulate pollution concentrations today are roughly the same as they were in 2003 (See Figure 2).

The fact that particulate pollution remained relatively flat, even in a year when economies across the world stalled because of the pandemic, underscores the immense challenge air pollution poses and the opportunities to improve human health if strong policies are enacted. The AQLI shows that reducing global pollution to meet the now more stringent World Health Organization (WHO) guideline would add 2.2 years onto average life expectancy. In other words, permanently reducing air pollution to the WHO guideline would increase global average life expectancy from roughly 72 to 74.2 years, and in total, the world's population would gain an astounding 17 billion life-years.

Figure 2 ·Global Trends in PM$_{2.5}$ Concentrations, 2000-2020



Across the world, 7.4 billion people—97.3 percent of the global population—live in areas where PM$_{2.5}$ exceeds the WHO's new, stronger guideline. This stronger guideline reflects the fact that a decade and a half worth of scientific evidence shows air pollution has a much stronger negative impact on human health, even at low levels of exposure, than initially thought.

The AQLI makes this abundant stream of scientific evidence even more poignant. Measured in terms of life expectancy, the AQLI shows that ambient particulate pollution is consistently the world's greatest risk to human health. While particulate pollution is set to reduce global average life expectancy by 2.2 years, first-hand cigarette smoke, for instance, reduces global life expectancy by about 1.9 years. Alcohol use reduces life expectancy by 8 months; unsafe water and sanitation, 7 months; HIV/AIDS, 4 months; malaria, 3 months; and conflict and terrorism, just 9 days (see Figure 4). Thus, the impact of particulate pollution on life expectancy is comparable to that of smoking, more than three times that of alcohol and unsafe

Figure 3 ·Potential Gain in Life Expectancy from Permanently Reducing $PM_{2.5}$ from 2020 Concentrations to the WHO Guideline in the 10 Most Populated Countries in the World

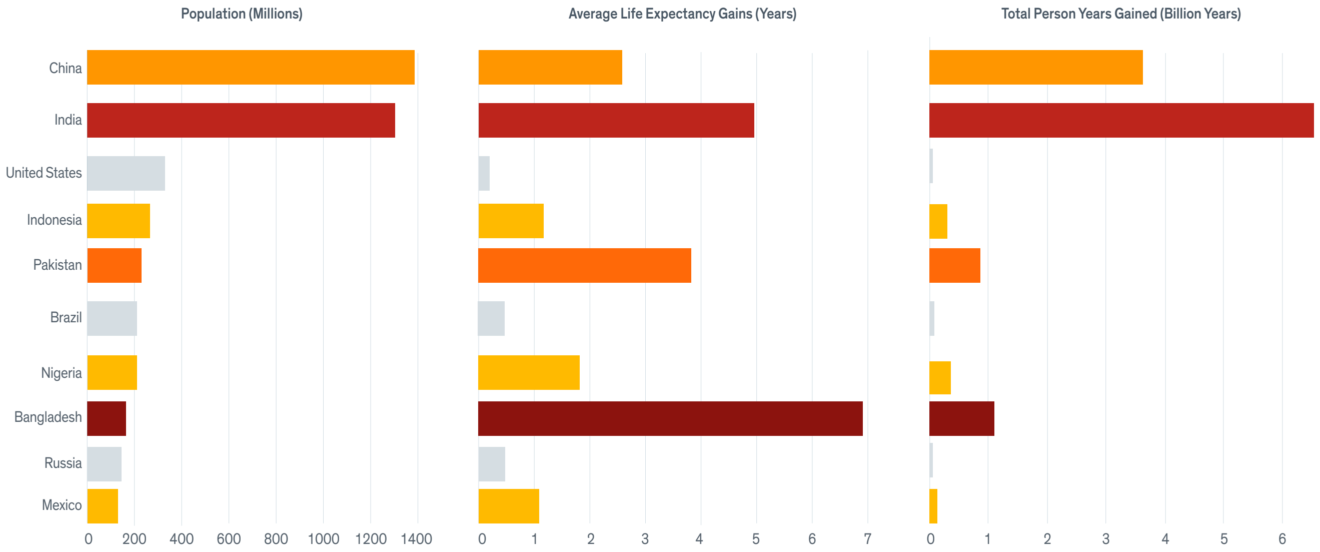
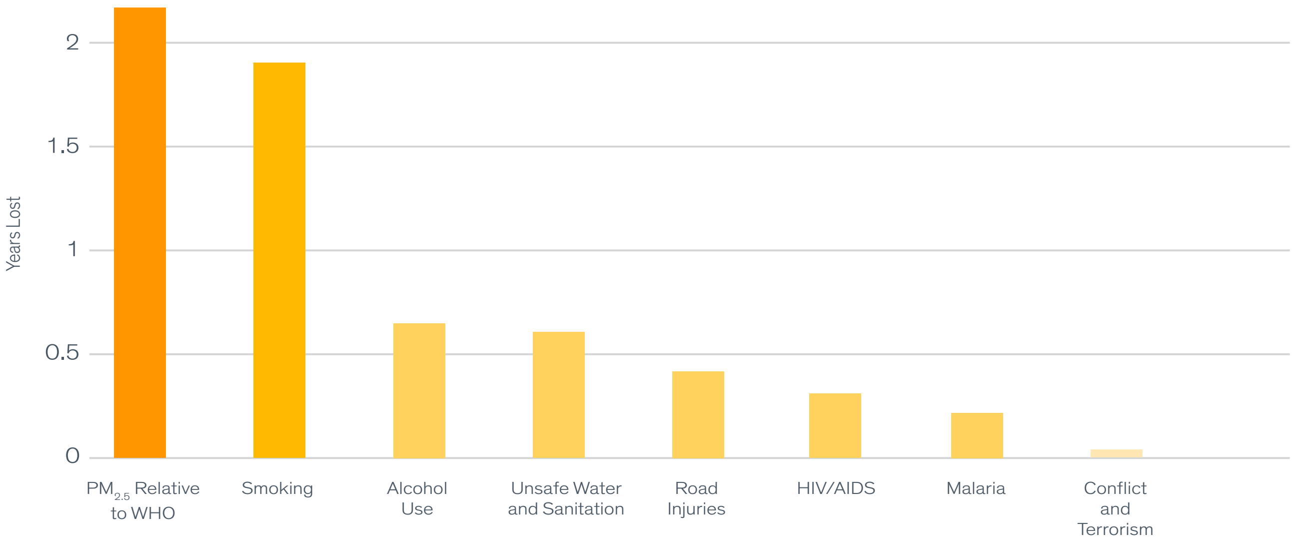


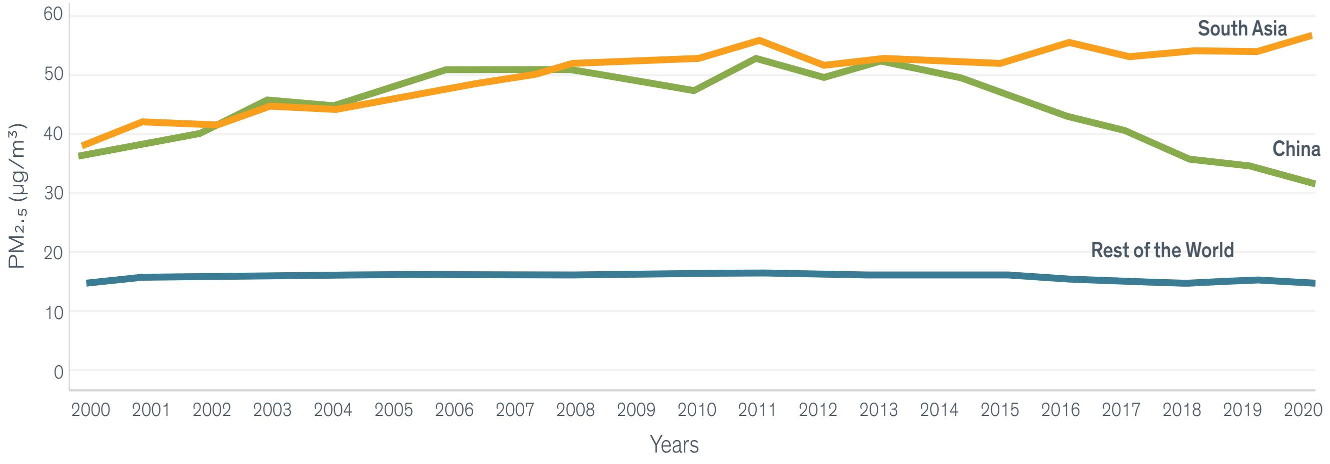
Figure 4 ·Life Expectancy Impact of $PM_{2.5}$ and Unassociated Causes/Risks of Death, Global



water and sanitation, six times that of HIV/AIDS, and 89 times that of conflict and terrorism.

Air pollution is so deadly because for the majority of people living in polluted countries, it is nearly impossible to avoid. Whereas it is possible to quit smoking or take precautions against diseases, everyone must breathe air. Thus, air pollution affects many more people than any of these other conditions. Other risk factors such as HIV/AIDS, tuberculosis, and conflict and terrorism have a larger impact among the affected, but they affect far fewer people. In 2017, for example, the people who died from HIV/AIDS died prematurely by roughly 53 years. And although 36 million people were afflicted with this disease, the number of people affected is just a small fraction of the 7.4 billion people breathing polluted air.

Figure 5 ·Global Trends in $PM_{2.5}$ Concentrations, 2000-2020



Fortunately, strong clean air policies—like those targeting fossil fuel combustion—can reduce particulate pollution concentrations and increase life expectancies, along with the co-benefit of reducing the greenhouse gas emissions that cause climate change.

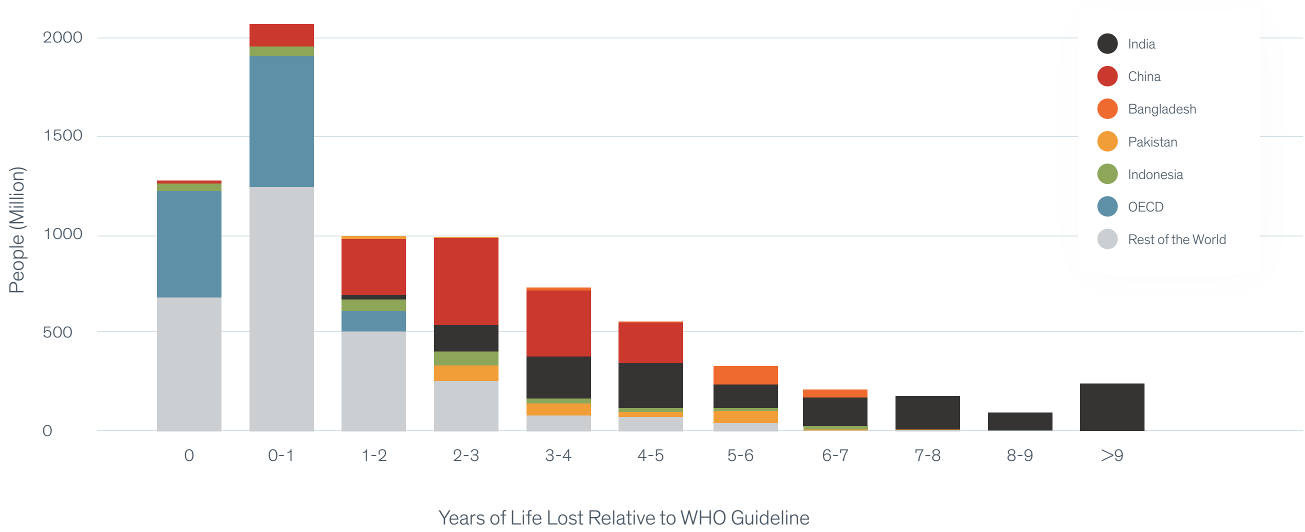
Today, the most extreme levels of pollution are found in the industrializing countries of the developing world. These countries are burning high amounts of fossil fuels without the policy safeguards that are in place in many developed countries, such as in China where strong policies have significantly reduced pollution in recent years (Figure 5).

Figure 6, which presents the distribution of person-years gained if PM2.5 is reduced to the WHO guideline across the world, shows that the greatest gains from clean air (in terms of life expectancies) are concentrated in India, China, Pakistan, Bangladesh, and Indonesia. In fact, these five countries alone account for three-quarters of the global air pollution burden, due to their high pollution levels and large populations.

Covid-19 lockdowns had little impact on pollution in these highly polluted countries during the first year of the pandemic. South Asia saw its pollution levels continue to rise across the board. In India, $PM_{2.5}$ levels rose 2.9 percent, year-over-year, to 55.8 µg/m^3; in Pakistan, it rose by 6.3 percent to 44.2 µg/m^3; and in Bangladesh, levels rose by 13.1 percent to 75.8 µg/m^3 (see Figure 7).

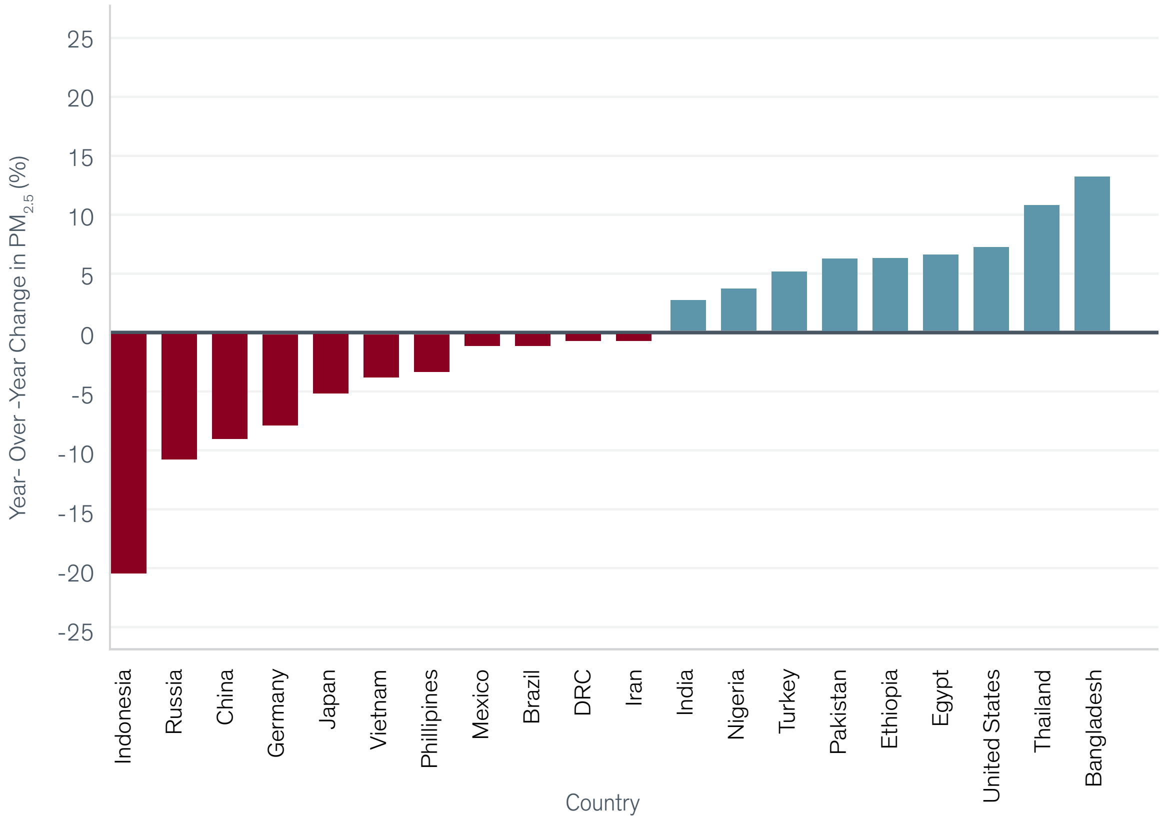
Parts of Southeast Asia also continued to see a rise in pollution. In Cambodia and Thailand, $PM_{2.5}$ increased by 25.9 and 10.8 percent, respectively. However, other parts of the region saw a decrease in pollution in 2020, driven by a lower number of fires compared to 2019—a year that was characterized by regional haze events stemming from thousands of fires, primarily set on the Indonesian islands of Sumatra and Borneo. In Singapore and Indonesia, $PM_{2.5}$ fell by 38.3 and 20.3 percent, respectively. The remainder of this report will further describe where pollution has increased and decreased over time, and what this means in terms of the most important measure that exists: longer lives.

Figure 6 ·Distribution of Person-Years Gained if $PM_{2.5}$ is Reduced to WHO Guideline Around the World



Note: India, China, Bangladesh, Indonesia, and Pakistan rank as the top five countries globally in terms of the gain in person-years from reducing $PM_{2.5}$ concentrations to the WHO guideline.

Figure 7 ·Year-Over-Year Change in $PM_{2.5}$ Levels in 2020, the First Year of the Pandemic



Section 2

South Asia Remains the World's Pollution Hotspot

Despite Covid-19 lockdowns, pollution continued to increase in South Asia during the first year of the pandemic. Home to the most polluted countries on Earth, prolonged exposure to air pollution is cutting the life expectancy of those living in South Asia short by 5 years—by even more in the most polluted areas.

In no area of the world is the stubborn nature of the pollution challenge more evident than in South Asia, where despite economic slowdowns due to the pandemic, pollution continued to rise in 2020. India, Pakistan, Bangladesh, and Nepal—where nearly a quarter of the global population lives—remain among the top five most polluted countries in the world. South Asia accounts for more than half, 52 percent, of the expected lost life years globally due to high pollution. Average life expectancy across these four countries would be 5 years higher if pollution concentrations permanently complied with the WHO guideline.

In each of these countries, the impact of air pollution on life expectancy is substantially higher than that of other large health threats. Smoking, for instance, reduces life expectancy in these countries by as much as 2.5 years; unsafe water and sanitation by roughly 1 year; and alcohol use by about half a year.

The average resident of these four countries is exposed to particulate pollution levels that are 47 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 years that they stand to lose today.

Of all the countries in the world, India faces the highest health burden of air pollution due to its high particulate pollution concentrations and large population. Since 2013, about 44 percent of the world's increase in pollution has come from India, where the particulate pollution level has increased from 53 then, to 56 µg/m^3 today—roughly 11 times higher than the WHO guideline. The average Indian resident is set to lose 5 years of life expectancy, if the WHO guideline is not met.

The most polluted region of India is the Indo-Gangetic plains of the north[4] , home to more than half a billion people, or about 40 percent of the country's population. The annual average $PM_{2.5}$ concentration in 2020 was 76.2 µg/m^3. The region contains the capital city of Delhi, the most polluted megacity in the world with average annual $PM_{2.5}$ levels exceeding 107 µg/m^3, or more than 21 times the WHO guideline.[5]

However, particulate pollution is no longer just a feature of the Indo-Gangetic plains. 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 200 million people, pollution has risen by 68.4 and 77.2 percent, respectively, since the year 2000. Here, the average person is now losing an additional 1.5 to 2.2 years of life expectancy, relative to the life expectancy implications of pollution levels in 2000.

While India contains the most polluted air in some of its regions, the most polluted country overall in the world is Bangladesh. According to new and revised satellite-derived $PM_{2.5}$ data, Bangladesh had a pollution concentration of 75.8 µg/m^3 in 2020. That's a 13.1 percent increase in pollution during a year when Covid-19 lockdowns were

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

[5] North India/Northern India/North Indian Belt are all different terms that refer to the exact same region: specifically, the Indo-Gangetic Plain (as described in footnote 4).

in place. While this is a significant increase over the 2019 level of 67 μg/m^3, pollution in Bangladesh has remained consistently high over the past decade, fluctuating between 63 and 77 μg/m^3. That's 12 to 15 times higher than the WHO guideline.

In Nepal, where the $PM_{2.5}$ concentration was 47.1 μg/m^3 in 2020, the average resident would live 4.1 years longer from clean air. In Pakistan, where the $PM_{2.5}$ concentration was 44.2 μg/m^3 in 2020, the average resident would gain 3.8 years from clean air.

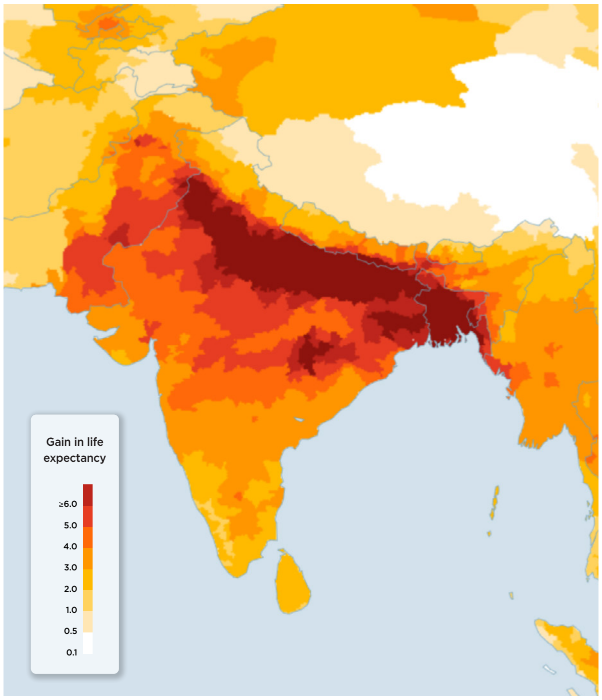
The increase in South Asian air pollution over time is not surprising. Over the last two decades, industrialization, economic development, and population growth have led to skyrocketing energy demand and fossil fuel use across the region. In India and Pakistan, the number of vehicles on the road has increased about four-fold since the early 2000s. In Bangladesh, the number of motor vehicles roughly tripled from 2010 to 2020.[6] In Bangladesh, India, Nepal, and Pakistan combined, electricity generation from fossil fuels tripled from 1998 to 2017.[7] Crop burning, brick kilns, and other industrial activities have also contributed to rising particulates in the region.

The increase in energy use has led to higher living standards and economic output, which have undoubtedly enhanced well-being. Yet, the accompanying 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. Since then, India has adopted fuel emissions standards that are on par with European Union standards. Although the NCAP targets are non-binding, achieving and sustaining such a reduction would increase India's national life expectancy by as much as 1.6 years, and by as much as 3.2 years for residents of Delhi.

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 is expanding its monitoring capacity and real-time air pollution measurements are expected to soon cover eight cities, up from the four that are covered today.[8]

Figure 8 · Potential Gain in Years of Life Expectancy Through Permanently Reducing $PM_{2.5}$ from 2020 Concentrations to the WHO Guideline, South Asia



Pakistan and Bangladesh have both encouraged brick kiln owners to shift to cleaner technologies. In Bangladesh, where brick kilns are responsible for about 60 percent of the particulate pollution in 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. 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.

Ultimately, the success of these policies will be judged by whether particulate pollution actually decreases. We will need to turn to air quality data produced in these countries in the coming years to provide a quantitative assessment.

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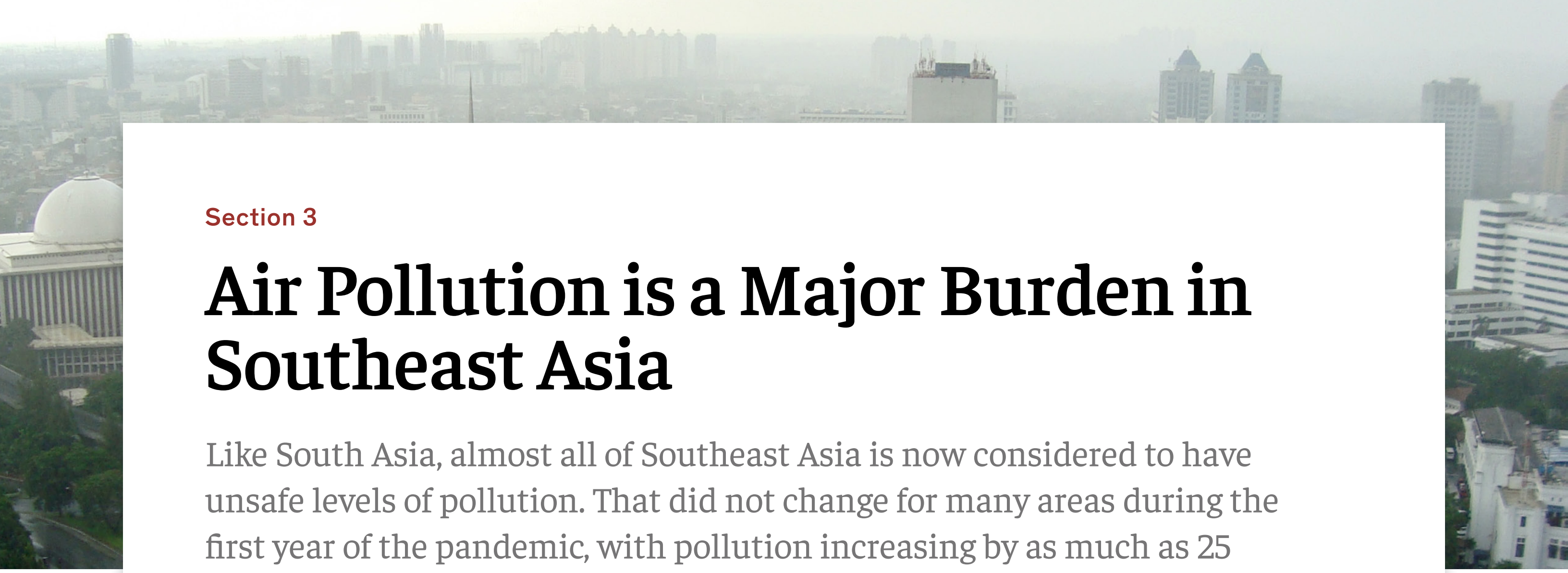
[6] Statistical Year Book of India, 2017, Table 20.4; Pakistan Statistical Pocket Book, 2006, Table 17.5 and Pakistan Today, 2019; Bangladesh Road Transport Authority, 2020.

[7] US Energy Information Administration (EIA).

[8] Ministry of Environment and Forests, Government of People's Republic of Bangladesh.



Section 3

Air Pollution is a Major Burden in Southeast Asia

Like South Asia, almost all of Southeast Asia is now considered to have unsafe levels of pollution. That did not change for many areas during the first year of the pandemic, with pollution increasing by as much as 25 percent in some regions. Some of the most polluted areas in 2020 were in the regions surrounding the cities of Mandalay, Hanoi, and Jakarta, where residents are losing 3 to 4 years of life expectancy.

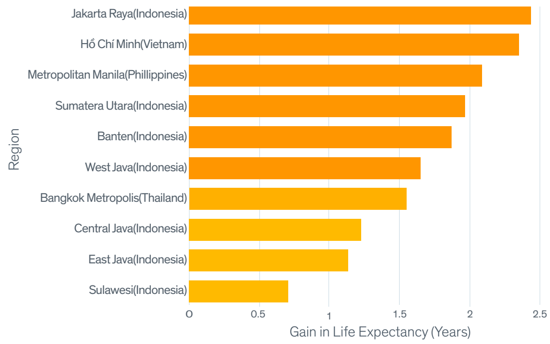
Despite the lockdowns of the pandemic, pollution continued to rise in much of Southeast Asia in 2020. In Cambodia and Thailand, for example, particulate pollution increased by 25.8 and 10.8 percent, respectively. Virtually all, 99.9 percent, of Southeast Asia's roughly 650 million people now live in areas where particulate pollution exceeds the revised WHO guideline of 5 µg/m^3. Across the region, air pollution reduces average life expectancy by 1.5 years, relative to what it would be if the WHO guideline was met. In the 11 countries that make up this region, an estimated 959.8 million person-years are lost due to air pollution.[9]

For two decades, pollution levels in Southeast Asia have remained largely unchanged, generally fluctuating between 19 and 22 µg/m^3 on average. However, during dry seasons, fires in Indonesia cause sudden spikes in pollution for the country and its downwind neighbors like Malaysia. During the first year of the pandemic, the population weighted-average pollution level across Southeast Asia declined, most likely because of a smaller number of fires compared to 2019, a year characterized by thousands of fires on the Indonesian islands of Sumatra and Borneo.

The significant impact of fewer fires in the region in 2020 bears out in the data. Indonesia saw a 20 percent decline in pollution from 2019 to 2020, and Malaysia likewise saw its pollution decline by 34 percent. On the Indonesian island of Java, the country's population and industrial center, pollution levels fell in 2020, compared to 2019. In the region surrounding the megacity of Jakarta (including Bogor, Depok, Bekasi, and Tangerang), that average annual $PM_{2.5}$ concentrations fell roughly 16 percent in 2020 to 30.1 µg/m^3. Still, if the region met the WHO guideline, the roughly 29 million residents would gain an average of 2.5 years in life expectancy. In 2020, North Sumatra was among the most polluted regions in Indonesia, and yet also saw a decrease. Medan, for example, experienced pollution levels of 33.1 µg/m^3, down from 40 µg/m^3 in 2019. Here, residents stand to gain 2.8 years of life expectancy if pollution is reigned in to meet the WHO standard.

Cambodia, Thailand and Myanmar—all less impacted by Indonesia's fire events—saw increases in particulate pollution from 2019 to 2020. Myanmar was the most polluted country in Southeast Asia in 2020, a ranking it has held since 2012, with a population weighted-average particulate pollution concentration of 32.4 µg/m^3—more

Figure 9· Potential Gain in Years of Life Expectancy Through Permanently Reducing $PM_{2.5}$ from 2020 Concentrations to the WHO Guideline, in 10 Most Populated Regions in Southeast Asia



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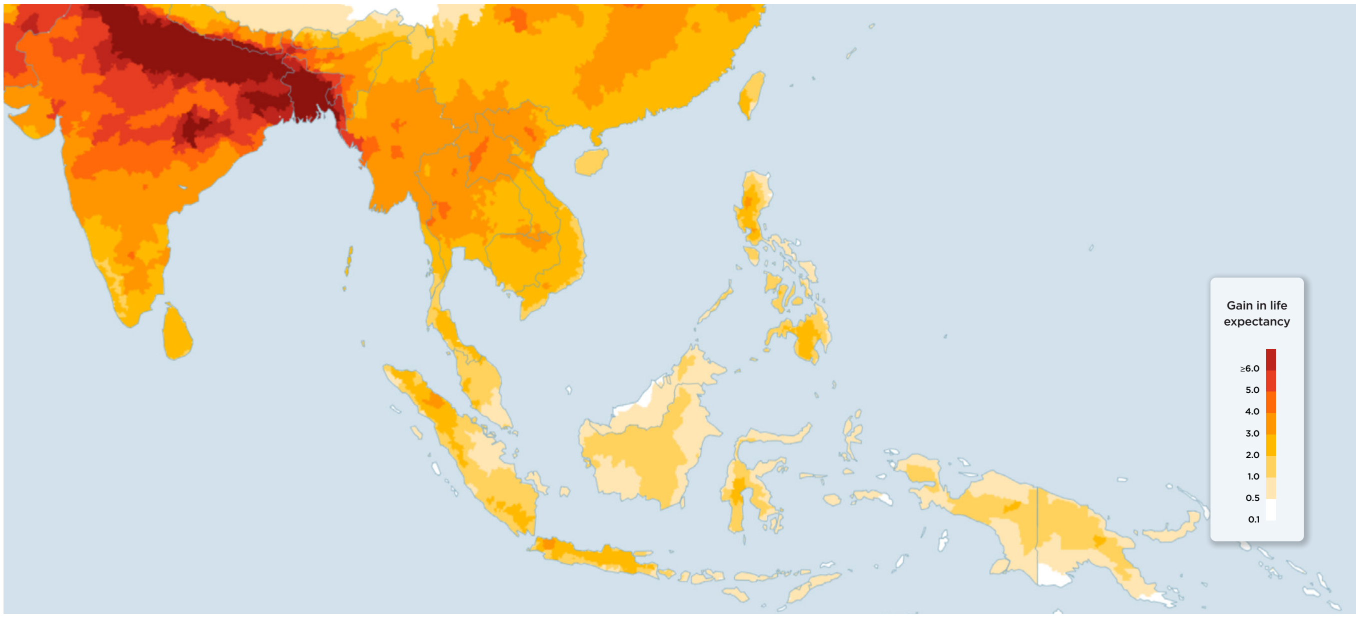
[9] Southeast Asia includes the following countries: Brunei, Cambodia, Indonesia, Laos, Malaysia, Myanmar, The Philippines, Singapore, Thailand, Timor-Leste, and Vietnam.

Figure 10 · Potential Gain in Years of Life Expectancy Through Permanently Reducing $PM_{2.5}$ from 2020 Concentrations to the WHO Guideline, Southeast Asia



than six times the WHO guideline. If the guideline were met, residents of Myanmar would gain 2.7 years of life expectancy. In Yangon and Mandalay, average pollution levels were 32.7 and 36 µg/m^3 in 2020, suggesting that if the WHO guideline were met, residents would gain 2.7 and 3 years, respectively.

Cambodia experienced the largest increase in $PM_{2.5}$ in 2020, with pollution levels rising 26 percent—from 16.5 to 20.8 µg/m^3. Based on current pollution levels, residents of Cambodia stand to gain 1.5 years if the WHO guideline is met. Both Cambodia and Myanmar have experienced high particulate pollution from agricultural fires.

In Thailand, particulate pollution was up 11 percent from 2019. The national average was 23.8 µg/m^3 in 2020, a level that—while a year-on-year increase—has been roughly constant since the mid-2000s. But overall, particulate concentrations varied widely in 2020, ranging from 34 to 36 µg/m^3 in parts of the North, to 20.8 µg/m^3 in the metropolis of Bangkok, to 11 to 15 µg/m^3 across much of the South. Based on the AQLI, the residents of Bangkok would gain 1.5 years if pollution levels met the WHO guideline. Fires in Thailand's northern region (including the regions surrounding Chiang Mai, Chiang Rai, and Kamphaeng Phet, for instance) have increased the amount of regional air pollution, reducing life expectancy by up to 3 years relative to life expectancy under the WHO guideline.

In Vietnam there are sharp differences between regions. In the northern Red River Delta region, which surrounds the capital city of Hanoi, home to seven million people, life expectancy would increase 3 years if air quality met the WHO guideline. The impacts are much lower in the southern regions, where the air quality is better. Overall, the average Vietnamese citizen stands to gain 1.9 years in life expectancy, if pollution was permanently reduced.

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, Vietnam, 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. That said, Vietnam is set to bring Euro-5 standards into effect in 2022.[10]

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[11]—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.[12] NOx and SO2, once emitted into the atmosphere, can form particulate matter.

Across the region, awareness is rising on 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.

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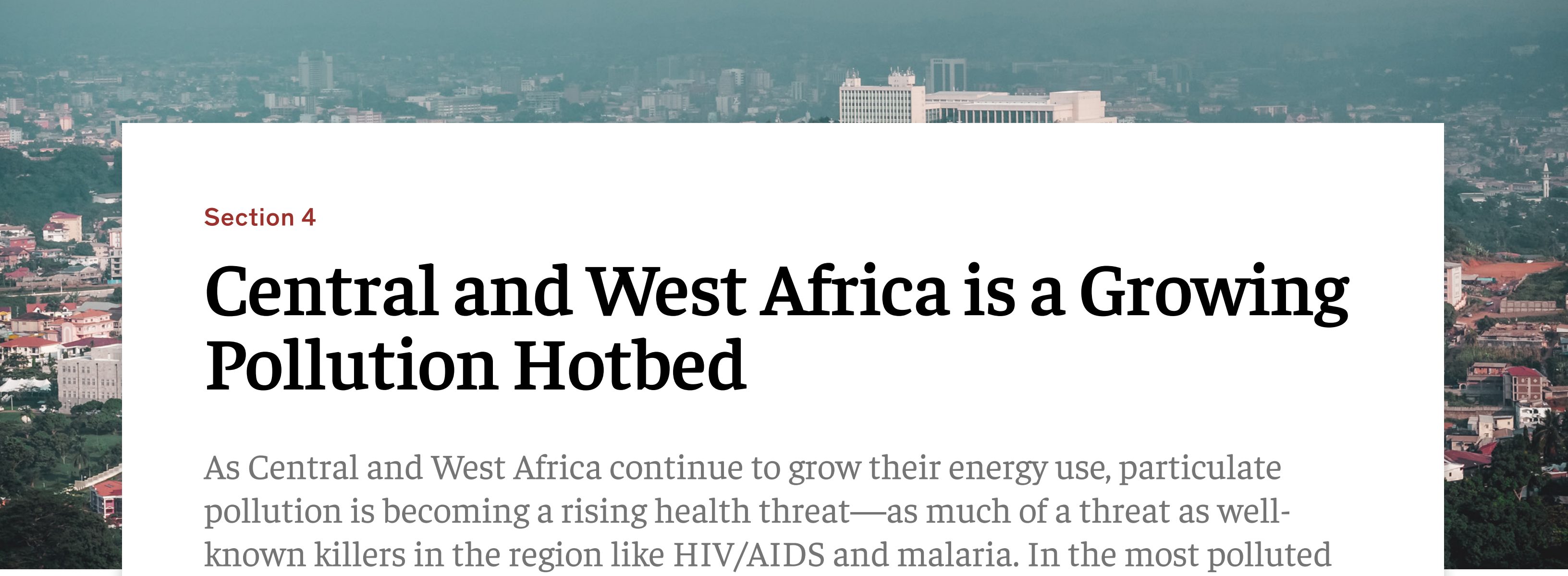
[10] Vietnam Plus, 2021.

[11] Taylor, 2019.

[12] Zhang, 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. In the most polluted areas, pollution levels are 7 times greater than the WHO guideline, with more than 97 percent of people exposed to pollution levels that exceed that guideline. As a result, average life expectancy is 1.6 years shorter and as much as 5 years shorter in the most polluted spots.

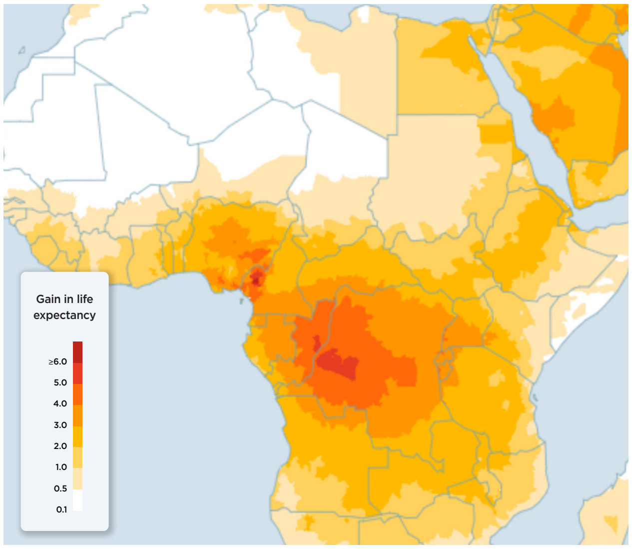
While South Asian countries rightly receive the most media coverage about extreme levels of air pollution, new and revised satellite data show that African countries like the Democratic Republic of Congo, Rwanda, Burundi, and the Republic of Congo are also among the most polluted countries in the world.

The first year of the Covid-19 pandemic did not bring substantial changes to the average quality of air in the region. The population weighted-average $PM_{2.5}$ concentration in 2020 was nearly identical to the average level in 2019, at 21.1 $\mu g/m^3$— more than 4 times higher than the new WHO-prescribed guideline.[13] As a result, in the Central and West Africa region—home to more than 600 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 a total of 971 million person-years that could be saved if the region reduced pollution to 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 nearly 100 million people and the most polluted country in 2020—where particulate pollution was 34.2 $\mu g/m^3$, or nearly 7 times higher than the WHO guideline. As a result, average life expectancy is 2.9 years lower than what it would be under the WHO guideline.

In Kinshasa, a city of more than 11 million people, residents are losing 3.2 years of life expectancy. However, even higher levels of pollution are observed in a cluster of provinces to the east of Kinshasa—namely, Mai-Ndombe, Kwilu, and Kasai—where the life expectancy gains of clean air range from 3.6 to 4 years. Here, 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.

Figure 11 · Potential Gain in Life Expectancy from Permanently Reducing $PM_{2.5}$ from 2020 Concentrations to the WHO Guideline, Central and West Africa



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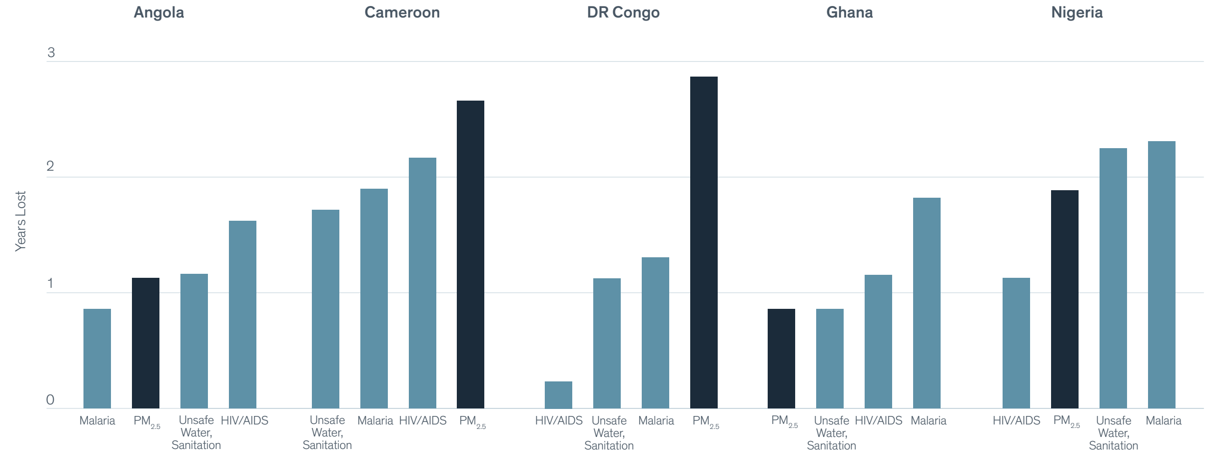
[13] Central Africa includes the 11 countries that comprise the Economic Community of Central African States. West Africa includes 16 countries, following the United Nations' definition for the region.

Figure 12 · Life Expectancy Impacts of Particulate Pollution and Other Health Threats in the Five Most Populous Countries in Central and West Africa



Burundi, the Republic of Congo, Cameroon, and Equatorial Guinea were the most polluted countries in Central and West Africa following the DRC. Their stories are similar. In Wouri and Mfoundi, Cameroon, residents are losing 3.6 and 2.7 years, respectively; in Brazzaville, Republic of Congo, it is 3.2 years; and in Abidjan, Cote d'Ivoire, the impact is 0.6 years.

Nigeria also faces a high pollution burden. In 2020, the particulate pollution level in Nigeria was 23.7 μg/m^3, 4.7 times higher than the WHO guideline. In Lagos, home to 20 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.[14] Residents there could see their life expectancy increase by 1.5 years if particulate pollution were permanently reduced to meet the WHO guideline.

In 2020, some of the highest pollution levels in Nigeria were observed in the Niger Delta, where oil refineries—many illegal—are linked to the grim daily reality of air pollution. In the states of Akwa Ibom, Taraba, Cross River, and Delta, average pollution levels ranged from 31.1 to 35.1 μg/m^3. According to the AQLI, residents in these states are losing 2.6 to 3 years relative to life expectancy under the WHO guideline. The most polluted Nigerian city in 2020 was Sardauna in Taraba state, where $PM_{2.5}$ concentrations averaged 45.3 μg/m^3, a level similar to Pakistan. Here, residents stand to lose 4 years of life expectancy.

While about 10 percent of health expenditures in sub-Saharan Africa are targeted towards combating HIV/AIDS or malaria, air pollution is rarely acknowledged as a problem in the region.[15] For example, when the Niger Delta city of Port Harcourt was covered in soot beginning in November 2016, it took 4 months and public outcry before a state of emergency was declared—this, in a country where the government's response to the Ebola crisis has been praised for its promptness and effectiveness. Yet, compared to other environmental health risks and prominent communicable diseases in the DRC and Cameroon, air pollution is the biggest threat in terms of its impact on life expectancy—shaving off more years than child and maternal malnutrition, HIV/AIDS, malaria, unsafe water and sanitation, and other risks (see Figure 12).[16] In Nigeria, air pollution's impact on life expectancy is greater than that of HIV/AIDS; on par with malaria and unsafe water, sanitation; but less than child and maternal malnutrition (which is not shown in Figure 12).

Out of the 27 Central and West African countries, only one—Cameroon—has set a national standard for particulate pollution. Further, as of 2019, only three real-time air quality monitoring stations exist throughout the entire region, resulting in a near total lack of transparent and actionable pollution data.[17] In comparison, about 200 real-time monitors exist in India, which has a smaller land mass than Central and West Africa.

In Africa, energy consumption is expected to grow more rapidly than ever before: the projected increase in coal consumption between 2017 and 2040 is expected to be more than 3 times the increase observed between 1995 and 2017; and natural gas consumption is projected to increase by more than twice that observed from 1995 to 2017.[18] Unless actions are taken to address this growth in future emissions, air pollution will only become a greater problem in Africa.

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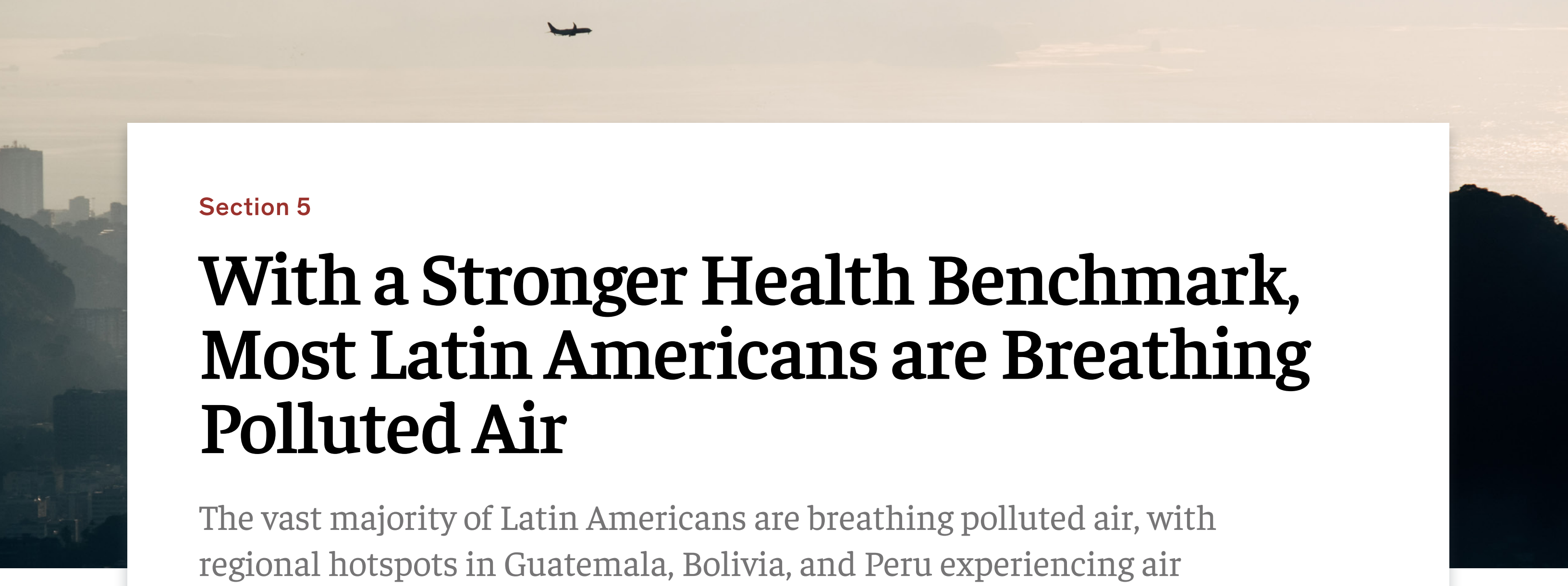
[14] Croitoru et al, 2020.

[15] $18 billion of combined domestic and foreign aid money was spent to combat HIV/AIDS in 2015, and $2.7 billion to combat malaria in 2016. Total health spending for sub-Saharan Africa was $194 billion. (Dieleman et al., 2018; Haakenstad et al., 2019).

[16] 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/.

[17] UNICEF, 2019.

[18] BP Energy Outlook 2019.



Section 5

With a Stronger Health Benchmark, Most Latin Americans are Breathing Polluted Air

The vast majority of Latin Americans are breathing polluted air, with regional hotspots in Guatemala, Bolivia, and Peru experiencing air quality similar to other highly-polluted metropolitan areas in the world. In these hotspots, pollution levels are more than 8 times greater than the WHO guideline. Here, the average resident stands to gain 3 to 4 years of life expectancy from cleaner air.

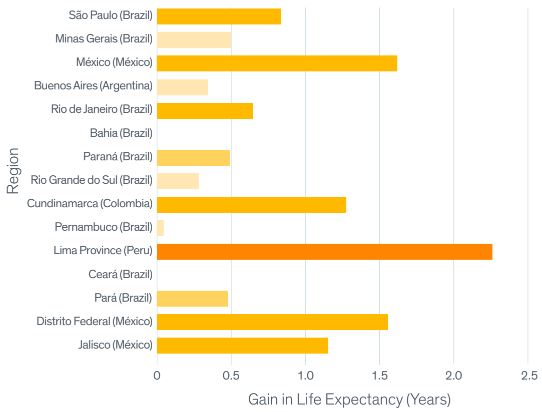
New and revised satellite-derived $PM_{2.5}$ data reveal that 93.1 percent of Latin America's 640 million people are exposed to particulate pollution levels that exceed the WHO guideline of 5 µg/m^3.[19] Although the average gain in life expectancy from cleaning up the air is relatively low—at just under 11 months—across the continent, the gain is substantially higher in regional hotspots. For example, in the city of Mixco, Guatemala, average pollution was 41.4 µg/m^3 in 2020, which translates into a gain of 3.6 years if the WHO guideline is permanently met. There is a similar story in Porto Velho, Brazil, where residents are losing 3 years; Andrés Ibáñez, Bolivia, where residents are losing 2.8 years, and Lima, Peru, where it is 2.2 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. For example, Bogota in Colombia—where average life expectancy gains from clean air are 1.3 years, based on 2020 levels—recently ranked first in the world in the highest average commute duration.[20] Long commutes are indicative of high levels of traffic congestion and higher levels of individual pollution exposure since commuters end up spending more time outside and on the roads. Across the region, driving restrictions have been a popular policy prescription. For example, license plate-based restrictions were introduced in Santiago, Chile in 1986, and in Mexico City in 1989. Following these two programs, several more Latin American cities introduced similar restrictions.

Latin America's air pollution is not only limited to its cities. Rural residents in Bolivia also face high levels of $PM_{2.5}$. For example, in El Beni, a rural region that contains some of the country's worst air quality, the average level of particulate pollution in 2020 was 37.4 µg/m^3. Here, the use of household solid fuels, mercury contamination, and deforestation are major contributors to air pollution.

In Brazil, particulate pollution levels are more than 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 1.6 years of life expectancy if the WHO guideline was permanently met.

Figure 13 · Potential Gain in Years of Life Expectancy Through Permanently Reducing $PM_{2.5}$ from 2020 Concentrations to the WHO Guideline, in 15 Most Populated Regions in Latin America



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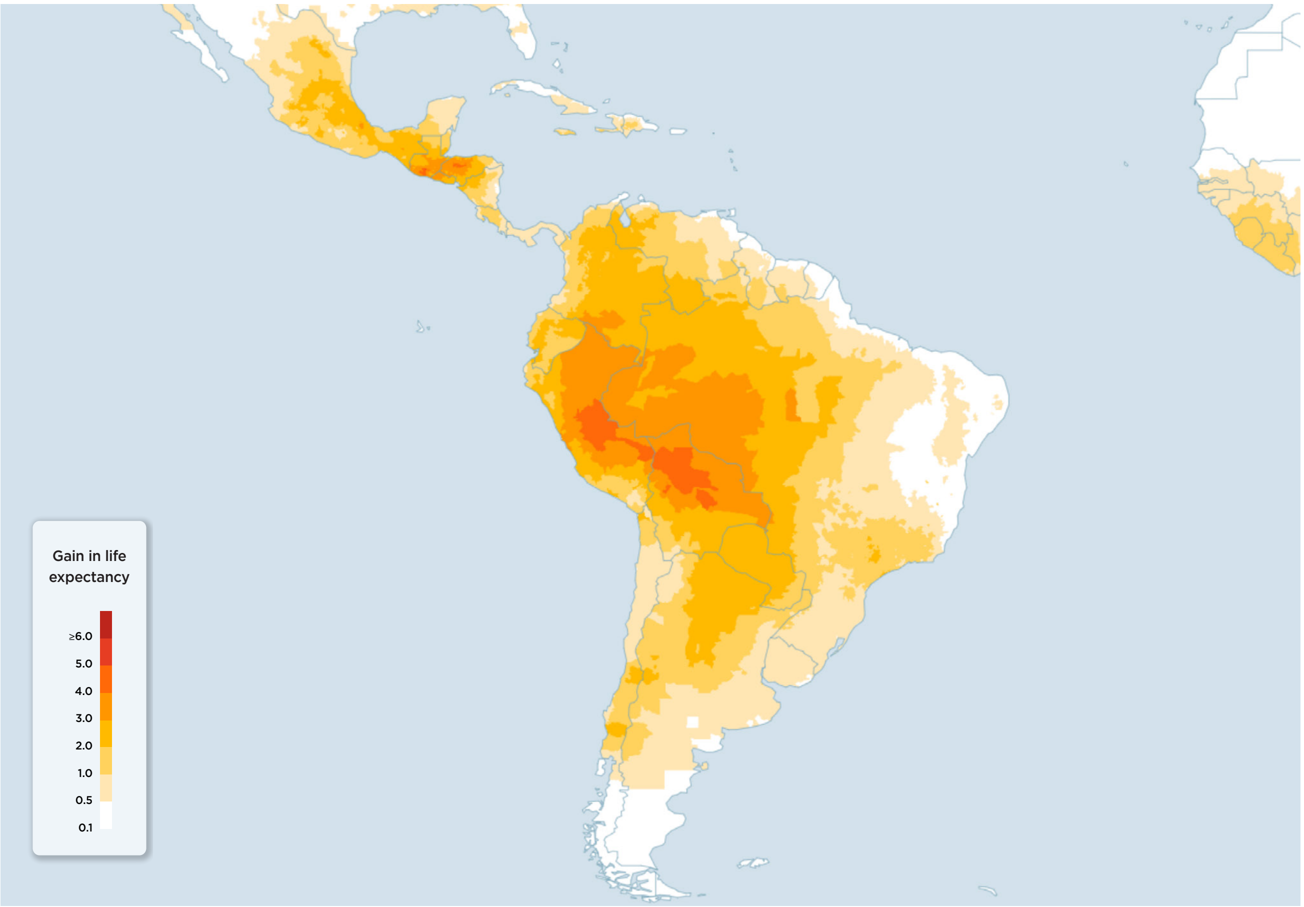
[19] Latin America includes 27 Spanish or Portuguese-speaking countries in North, Central, and South America.

[20] INRIX, 2020.

Figure 14 · Potential Gain in Life Expectancy from Permanently Reducing $PM_{2.5}$ from 2020 Concentrations to the WHO Guideline, Latin America



Section 6

China's War Against Pollution Continues Successfully

China's pollution has been decreasing since the country began a "war against pollution" seven years ago. This decline continued through 2020, with pollution levels down 39.6 percent compared to 2013. Due to these improvements, the average Chinese citizen can expect to live 2 years longer, provided the reductions are sustained. Nevertheless, work remains. While China has met its national air quality standard, pollution levels still significantly exceed the WHO guideline.

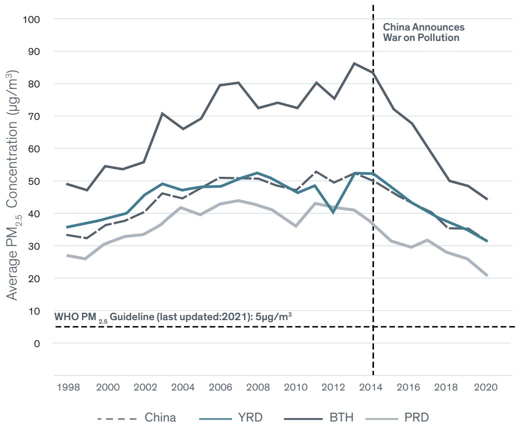
While much of the world has seen a rise in pollution in recent years, global average pollution has declined since 2013. That decline is due entirely to China. Between 2013 and 2020, the population-weighted global average particulate pollution would have ticked up slightly without China's steep decline in pollution. China's pollution has declined year-on-year, and 2020 was no exception. Pollution has fallen by 39.6 percent between 2013 and 2020 and by 9.1 percent from 2019 to 2020. Beijing experienced the largest decline in air pollution over this period of 2013 to 2020, with $PM_{2.5}$ levels falling from 85 to 38 µg/m³ in just seven years—a 55 percent decline. From 2019 to 2020, Beijing's pollution fell by 8.7 percent.

Figure 16 translates these air quality improvements into the number of additional years that an average person would live, assuming these reductions are sustained. In Beijing, the AQLI suggests that the average person could expect to live 4.6 years longer due to the steady decline in pollution since 2013, assuming the reduction is permanent. In Shanghai, where $PM_{2.5}$ fell from 50 to 28 µg/m³, the average person could expect to live 2.2 years longer. Across the country, the life expectancy gain is 2 years longer relative to 2013.

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 initiative to reduce pollution in the densely populated Beijing-Tianjin-Hebei area by 25 percent, and in the Pearl and Yangtze River Delta regions by 15 and 20 percent, respectively[21].

At the 2014 annual meeting of the People's Congress, Premier Li Keqiang declared a "war against pollution." The timing of this declaration—at the kickoff of a nationally-televised conference typically reserved for discussing key economic targets—marked an important shift in the country's long-standing policy of prioritizing

Figure 15 · $PM_{2.5}$ Concentrations in Major Regions in Mainland China Over Time



Note: See footnote 21

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[21] 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 the entire Jiangsu and Zhejiang areas. Others may define the YRD region different than how we have defined it in this report.

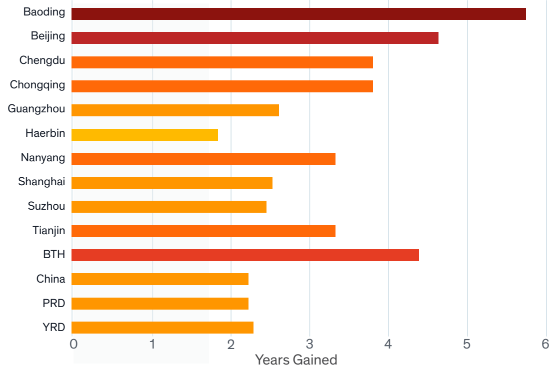
economic growth over concerns about environmental protection.[22] It also marked an important change in the government's official rhetoric about the country's air quality. In the past, state media had deflected concerns about air quality by claiming that poor visibility was due to "fog" and that emissions had no effect on smog. Now, the government stressed environmental responsibility.

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 other 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.

Today, seven years after the start of China's "war against pollution," the impacts are persistent and tangible. As noted, pollution fell 39.6 percent. Thanks to these, and other, strict pollution policies, China's overall (country level) $PM_{2.5}$ average is in compliance with the national standard. However, 37.9 percent of the population still lives in areas where the pollution levels don't comply with the country's own national standard and 99.9 percent of the population lives in areas that exceed the WHO guideline. The country level particulate pollution exposure is 6 times greater than the WHO guideline. Using an international lens, Beijing is still 3 times more polluted than Los Angeles, the most polluted city in the United States. Overall, if China were able to reduce its pollution from 2020 levels to meet the WHO guideline, and those reductions were sustained permanently, average life expectancies would be extended by 2.6 years. The expected gains are even larger in the more heavily polluted provinces of Hebei, Henan and Tianjin, where residents stand to gain up to 4.1 additional years of life expectancy from clean air, respectively. Residents of Beijing stand to gain 3.2 years.

Can China meet and sustain these further pollution reductions? To this point, 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. For example, when the Beijing-Tianjin-Hebei region was not on track to meet its goals as late as summer 2017, just months before the targeted deadline, the government responded with an aggressive 143-page "battle plan" released in August 2017 that called for major reductions in industrial and residential coal consumption through March of the following year. The ensuing campaign included the removal of coal-fired boilers in some cases before the natural gas or electric replacements were available, leaving some households in large northern cities without winter heat.

Figure 16 · Potential Gain in Life Expectancy from Reducing $PM_{2.5}$ to the WHO Guideline in Mainland China, 2013 vs. 2020



This is one concrete example of the high cost of one policy. But almost all of the policies come from a "command and control" playbook that generally does not consider how to minimize the costs of achieving their goals. Thus, the Chinese government closed, relocated, and reduced the production capacity of a large number of polluting firms, enforced tighter emission standards across many industries, assigned binding abatement targets to local governments, and sent thousands of discipline teams to inspect local environmental performances. These measures, while being effective in reducing the total emissions in the country, ignored the significant differences in the abatement costs across firms, industries, and regions, and led to large economic and administrative costs in achieving the policy goal. They also led to social media complaints from stakeholders that environmental regulations are too stringent, protests from workers being laid off by the polluting firms, and resistance from local governments for enforcing tighter environmental standards.

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 and without intense stakeholder pressure. Such approaches at 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 20 percent. China's introduction of a national carbon market in July 2021, which upon completion will be the largest such market in the world, positions the country well for the adoption of a particulate pollution and/or sulfur dioxide market.

Note: For a detailed look at how China improved pollution from the 2008 Olympics to the 2022 Olympics, see "The 2008 Olympics to the 2022 Olympics: China's Fight to Win its War Against Pollution," February 2022

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[22] Greenstone et al., 2020.

Section 7

A Stronger Health Benchmark Uncovers Pollution Gaps in the United States and Europe

While sustained enforcement of strong air pollution policies in the United States and Europe have significantly reduced particulate pollution—allowing citizens to live longer and healthier lives because of it—new scientific understanding on the effect of even low levels of pollution on health reveal the need for greater focus on clean air in areas previously understood to be safe.

After periods of industrialization that swelled pollution in Europe and the United States decades ago, the two regions have largely been successfully enforcing strong pollution rules. For example, in the United States, the Clean Air Act was enacted in 1970. The Act established the National Ambient Air Quality Standards (NAAQS), setting maximum allowable concentrations of particulate matter, among other pollutants. It also created emissions standards for pollution sources, leading industrial facilities to install pollution control technologies and automakers to produce cleaner, more fuel-efficient vehicles. Further, it required each state government to devise its own plan for achieving and sustaining compliance with the standards.

The Act rapidly improved the air Americans breathed.[23] By 1980, albeit aided by the economic slowdown of the 1970s, the United States recorded a 50 percent decrease in particulate pollution compared to 1970 and a 44 percent decrease in ambient concentrations of SO2, a precursor to particulate matter.[24]

Today, on average, Americans are exposed to 66.9 percent less particulate pollution than they would have been in 1970. And, they're living longer lives because of it, with life expectancy increasing by 1.3 years for the average American from 1970 to today.[25] For those living in the former smog capital of Los Angeles, particulate pollution has declined by almost 53 percent since 1970, extending life expectancy for the average Angeleno by 1.3 years. In Philadelphia and Washington, DC, the gain is 2.4 and 3.1 years.

The history of Europe tells a similar story. Among the policy improvements, the European Environment Agency was created in the mid-1990s to provide independent information to policymakers and the public. In subsequent years, the European Union set emissions targets, created a pollution standard, and introduced a comprehensive clean air program with support measures to ensure that targets are met. The European Union's air pollution regulations, such as fuel emissions standards, have formed the basis of standards in many other countries from Argentina to India to Turkey. Today, on average, Europeans are exposed to 24.1 percent less particulate pollution than they were two decades ago (2000), gaining 4 months of life expectancy because of it. Areas that were historically more polluted have seen even greater gains.

Due largely to these gains, the United States and Europe—which

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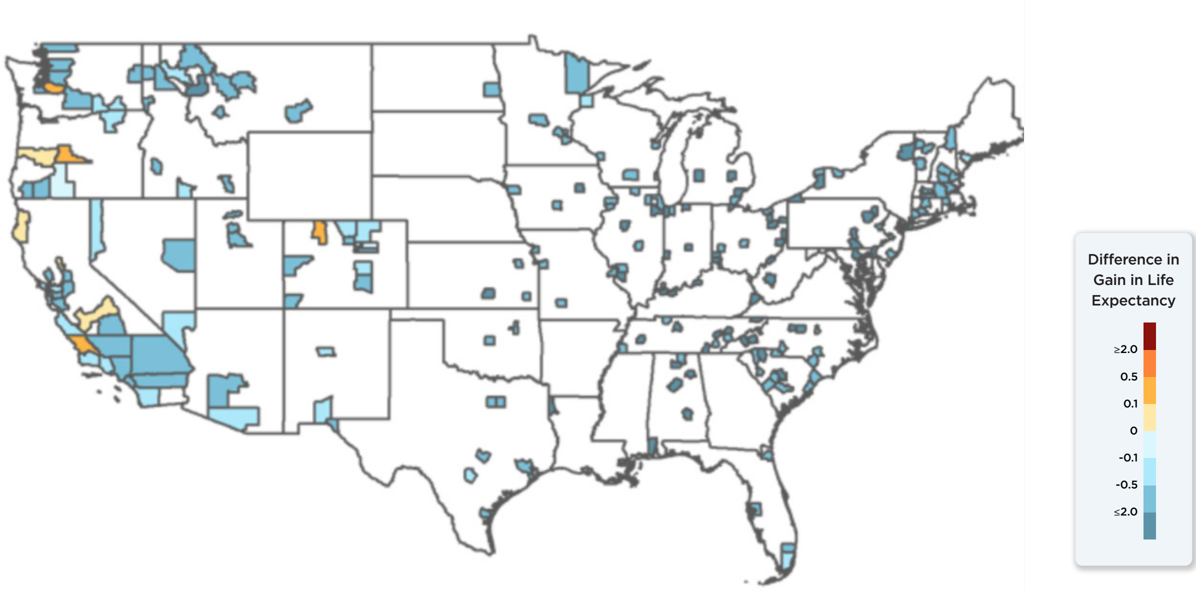
[23] Several factors that could have affected air pollution have been at play simultaneously since 1970, but research supports an outsize role of the Clean Air Act. For example, Shapiro and Walker (2018) decompose the decline in emissions from manufacturing plants from 1990-2008 into the portions caused by (1) the use of pollution abatement technologies as required by CAA environmental regulations, (2) changes in what Americans produce (i.e. offshoring of pollution-intensive industries), and (3) increases in production efficiency. They find that the total pollution emissions decline is primarily driven by (1).

[24] Hunt and Lillis, 1981.

[25] These estimates are based on the 236 US counties for which 1970 $PM_{2.5}$ concentrations could be estimated. US data is derived from EPA data on Total Suspended Particulates(TSPs). Using these data,we impute $PM_{2.5}$ values for the period spanning 1970 to 1997 by assuming a constant ratio between $PM_{2.5}$, PM1.0, and TSPs. For consistency with the satellite measurements (which are available from 1998 onwards), we then scale these imputed values by the average ratio of satellite to monitor measurements. This approach should be interpreted with caution as it is less reliable than the satellite-derived measurements that are available in the years following 1998. For further information, see the Technical Appendix available at https://aqli.epic.uchicago.edu/policy-impacts/united-states-clean-air-act/.

Figure 17 · Change in Life Expectancy Due to Change in PM$_{2.5}$ in United States, 1970-2020



make up 15.7 percent of the world's population—account for only about 4.1 percent of the health burden from particulate pollution. Yet, with the latest scientific evidence on the impact of air pollution at even the low levels that exist in much of the United States and Europe now built into the WHO's assessment of what is considered a safe level of exposure, the new data suggest that 92.8 and 95.5 percent of people in the United States and Europe, respectively, are now considered to be living in polluted areas. That's up from just 7.6 and 47.3 percent of people in the United States and Europe, respectively, based on the previous knowledge and guidelines. The take-away of this may be that clean air has not received the level of government focus it deserves in recent years.

While there is potential for further progress, the health benefits of clean air in Europe and the United States are modest. In the United States, average pollution was 7.1 µg/m^3 in 2020, slightly above the WHO guideline. At this level, residents could expect to gain roughly 2.5 months from clean air, equivalent to 68 million total life years, by coming into compliance with WHO standards. The average European was exposed to a particulate pollution concentration of 11.2 µg/m^3 in 2020, meeting the European Union's air pollution standard of 25 µg/m^3 but falling short of the revised WHO guideline. If particulate pollution were to meet this standard, average life expectancy across Europe would improve by 7.3 months, equivalent to 527 million total life years.

The largest benefits from improved pollution in the United States and Europe are 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 2020—a year in which California experienced yet another year of intense wildfires—19 out of the top 20 most polluted counties were in California, where average pollution concentrations ranged from 13 µg/m^3 in Sierra County to 22.6 µg/m^3 in Mariposa County. In Mariposa, residents stand to gain 1.7 years of life expectancy if air quality were kept below the WHO guideline permanently, rather than at the 2020 level. In some counties, pollution levels in 2020 were higher than their estimated levels in 1970.

Figure 18 · Change in Life Expectancy Due to Change in PM$_{2.5}$ Concentrations in Europe, 1998-2020

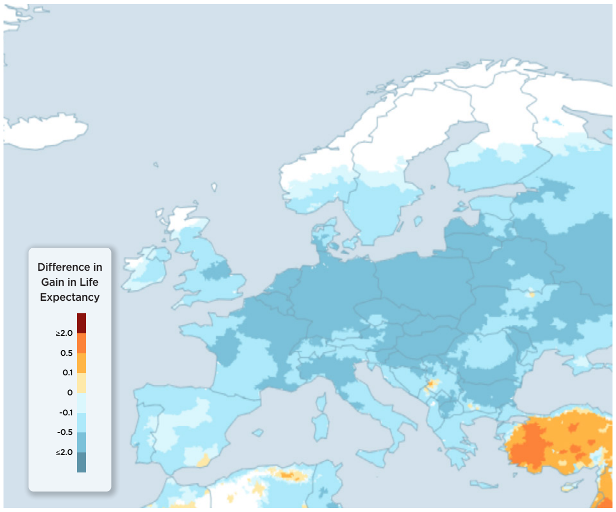
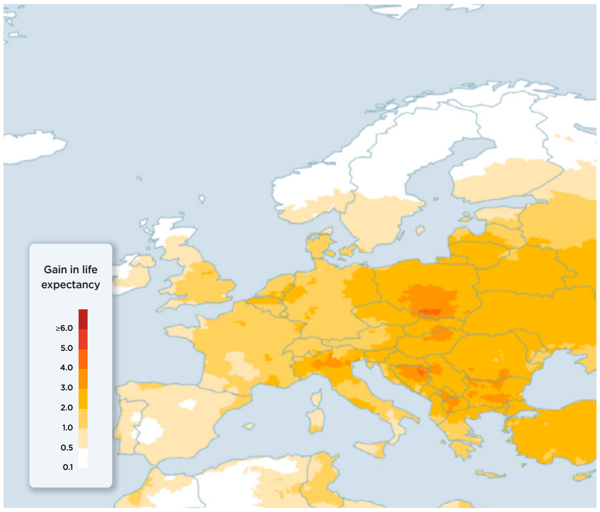


Figure 19 · Potential Gain in Life Expectancy From Permanently Reducing $PM_{2.5}$ From 2020 Concentrations to the WHO Guideline, Europe



The story is broadly similar in Europe, where large health benefits stand to be gained in more concentrated areas such as the eastern part of the continent, where the entire populations of Poland, Belarus, Slovakia, Hungary, Lithuania, Armenia, Moldova, Cyprus, as well as Bosnia and Herzegovina do not meet the WHO's guideline. Outside of Eastern Europe, high pollution remains in areas such as Italy's Po Valley, including the city of Milan, as well as the industrial center of Bursa in Turkey. In Milan and Bursa, residents would gain 1.6 and 1.9 years, respectively, if particulate pollution levels met the WHO guideline.

Conclusion

Despite pandemic lockdowns that stalled economies throughout the world, particulate pollution remained a steady challenge in 2020, with 17 billion life-years potentially being lost to pollution if today's high levels remain unchanged globally. In some of the most polluted regions of the world, pollution continued to increase, such as in South Asia where more than half of the life burden of pollution occurs. Residents there are expected to lose about 5 years off their lives if the high levels of pollution continue, and more in the most polluted regions.

Further, the incorporation of the latest scientific evidence into WHO guidance on the safe level of pollution, underscores that even low levels of pollution affect human health. As a result, countries where pollution has not seemed to be as much of a concern, are now rising from the shadows. Latin American pollution hotspots have emerged and almost all of the United States and Europe now do not meet the WHO guideline, indicating that government focus on pollution has been undervalued. If pollution were to meet the WHO guideline, 68 million life-years in the United States and 527 million life-years in Europe could be saved. Meanwhile, across Central and West African countries, air pollution often flies under the radar of public awareness and policy, yet it inflicts a burden of disease comparable—and often exceeding—that caused by HIV/AIDS, malaria, and water sanitation issues. Assuming business as usual, the situation could worsen as energy demands are expected to triple across the African continent by 2030.

Yet, while the stubborn nature of the pollution challenge may seem daunting, China's success in reducing pollution is a strong indication of the opportunities that could lie ahead for other nations if they were to impose strong pollution policies—as some are beginning to do. Global pollution has decreased in recent years due entirely to China's impact. Without China's significant decline in pollution since the country imposed a "war against pollution" in 2013, global average pollution would have slightly increased in that time.

Lowering pollution while still growing an economy in countries like the United States, across Europe and now China show that pollution concentrations are not a law of nature. The quality of the air that citizens breathe reflects how their country understands the risks and prioritizes the health of its people. The AQLI demonstrates the opportunity countries have to improve the health and lengthen the lives of their citizens if they are willing to accept the costs of environmental regulations.

Appendix

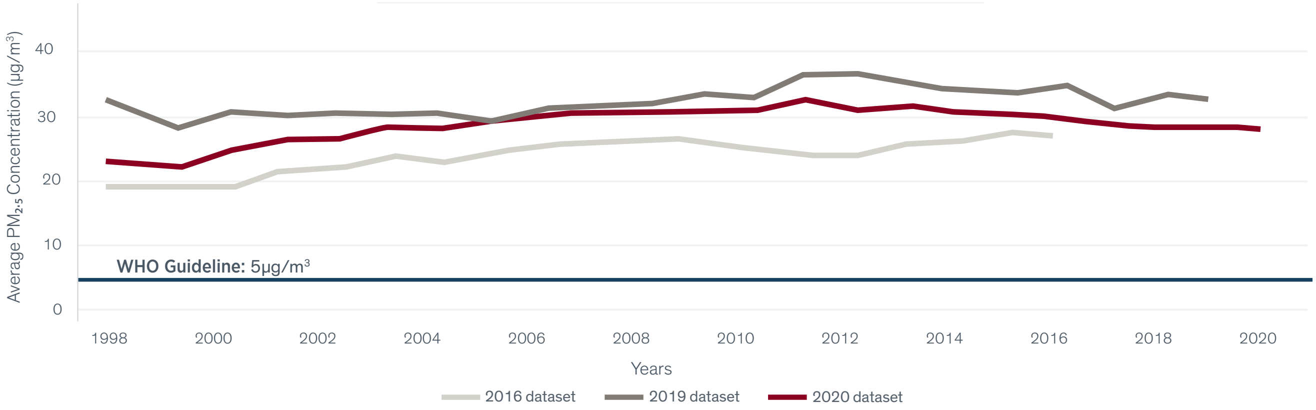
Reliable, geographically extensive pollution measurements are critical to understanding the extent of air pollution and its health impacts. Unfortunately, many areas around the world either lack extensive pollution monitoring systems or did not begin monitoring $PM_{2.5}$ until recently, making it impossible 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 AQLI incorporates satellite-derived annual ambient $PM_{2.5}$ concentration estimates spanning 23 years from 1998-2020, developed in van Donkelaar et al. (2021).

There are significant 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 dataset, the estimated global population-weighted average $PM_{2.5}$ concentration for the year 2019 has been revised downwards from roughly 32 to 28 µg/m^3. The historical $PM_{2.5}$ time series has also been affected, with large downward revisions in South Asia, Southeast Asia, and Africa.

Satellite-derived $PM_{2.5}$ data are 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 are then calibrated using $PM_{2.5}$ readings from available ground-level monitors. Over time, improvements in the model and calibration inputs necessitate periodic updates to the historical $PM_{2.5}$ dataset. The AQLI uses a version of the data that excludes sea salt and dust.

In Figure 20, we plot and compare the global population-weighted $PM_{2.5}$ time trend using variations of the $PM_{2.5}$ dataset. Although the new and revised $PM_{2.5}$ dataset yields global average concentration levels that are lower than those estimated in earlier datasets, the overall picture remains the same. Since 1998, the global $PM_{2.5}$ level has been 4.4 to 6.5 times higher than the WHO standard for the past two decades, making air pollution the greatest threat to human health globally.

Figure 20 ·Global population-Weighted $PM_{2.5}$ Concentration Over Time



Note: The "2020 dataset" line plots the global population-weighted average $PM_{2.5}$ 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.

Appendix Table

Country	Average PM$_{2.5}$ Country (μg/m^3)	National Standard (μg/m^3)	Life Expectancy Gains (in years) from reducing pollution to WHO Standard (5 μg/m^3)	Life Expectancy Gains (in years) from reducing pollution to the country's National Standard
Afghanistan	16.2	10	1.1	0.6
Akrotiri and Dhekelia	11.3	*	0.6	*
Åland	3.8	*	0	*
Albania	12.7	15	0.8	0
Algeria	5.5	*	0	*
American Samoa	0.7	*	0	*
Andorra	6.4	25	0.1	*
Angola	17.4	*	1.2	*
Anguilla	1.8	*	0	*
Antigua and Barbuda	1.7	*	0	*
Argentina	11.6	15	0.6	0
Armenia	19.1	*	1.4	*
Aruba	2.8	*	0	*
Australia	4.7	8	0	0
Austria	9.6	25	0.5	0
Azerbaijan	11.7	*	0.7	*
Bahamas	2.8	*	0	*
Bahrain	17.8	*	1.2	*
Bangladesh	75.8	15	6.9	6
Barbados	1.9	*	0	*
Belarus	11.1	15	0.6	0
Belgium	7.9	25	0.3	0
Belize	11.8	*	0.7	*
Benin	16.8	*	1.2	*
Bermuda	2.6	30	0	0
Bhutan	28.7	*	2.3	*
Bolivia	27.9	10	2.2	1.8
Bonaire, Sint Eustatius and Saba	2.6	*	0	*
Bosnia and Herzegovina	23.8	25	1.8	0
Botswana	11.3	*	0.6	*
Brazil	10	*	0.5	*
British Virgin Islands	1.6	*	0	*
Brunei	5.5	*	0	*
Bulgaria	18	25	1.3	0
Burkina Faso	7.6	*	0.3	*
Burundi	31.8	*	2.6	*
Cambodia	20.8	*	1.6	*
Cameroon	31.4	10	2.6	2.1
Canada	5.6	10	0.1	0
Cape Verde	1.8	*	0	*
Caspian Sea	9.1	*	0.4	*
Cayman Islands	6.4	*	0.1	*
Central African Republic	26.9	*	2.1	*
Chad	11.4	*	0.6	0.6
Chile	14.2	20	0.9	0
China	31.6	35	2.6	*
Christmas Island	2.2	*	0	0
Cocos Islands	1.3	*	0	*
Colombia	15	25	1	0
Comoros	5.5	*	0	0
Cook Islands	0.8	*	0	*
Costa Rica	11.1	*	0.6	*
Côte d'Ivoire	10.4	*	0.5	*
Croatia	13.7	25	0.9	0
Cuba	6.1	*	0.1	*
Curaçao	3	*	0	*
Cyprus	12.3	25	0.7	0
Czech Republic	11.9	25	0.7	0
Democratic Republic of the Congo	34.2	*	2.9	*
Denmark	6.9	25	0.2	0
Djibouti	16.7	*	1.1	*
Dominica	2	*	0	*
Dominican Republic	6.7	15	0.2	*
Ecuador	15.7	15	1	0.1
Egypt	17.9	*	1.3	*
El Salvador	25.6	15	2	*
Equatorial Guinea	28.6	*	2.3	*
Eritrea	11.7	*	0.7	*
Estonia	5.2	25	0	0
Ethiopia	16.7	*	1.1	*
Falkland Islands	1.2	*	0	*
Faroe Islands	1.9	*	0	*
Fiji	1.5	*	0	*
Finland	4.1	25	0	0
France	7.2	25	0.2	0
French Guiana	4.4	*	0	*
French Polynesia	0.9	*	0	*
French Southern Territories	7.8	*	0.3	*
Gabon	23.8	*	1.8	*

* No national standard specified

Country	Average PM$_{2.5}$ Country (µg/m³)	National Standard (µg/m³)	Life Expectancy Gains (in years) from reducing pollution to WHO Standard (5 µg/m³)	Life Expectancy Gains (in years) from reducing pollution to the country's National Standard
Gambia	6.8	*	0.2	*
Georgia	14.3	*	0.9	*
Germany	8	25	0.3	0
Ghana	13.1	*	0.8	*
Gibraltar	8.7	*	0.4	*
Greece	11.2	25	0.6	0
Greenland	0.9	*	0	*
Grenada	1.9	*	0	*
Guadeloupe	2.2	25	0	0
Guam	0.7	12	0	0
Guatemala	28.4	10	2.3	1.8
Guernsey	5.6	*	0.1	*
Guinea	10.6	*	0.6	*
Guinea-Bissau	8.2	*	0.3	*
Guyana	5.6	*	0	*
Haiti	8.7	*	0.4	*
Honduras	27.3	*	2.2	*
Hungary	12.8	25	0.8	0
Iceland	2.1	*	0	*
India	55.8	40	5	1.6
Indonesia	17	*	1.2	*
Iran	17.2	10	1.2	0.7
Iraq	23.7	*	1.8	*
Ireland	4.6	25	0	0
Isle of Man	4.7	*	0	*
Israel	12.4	25	0.7	0
Italy	12.7	25	0.8	0
Jamaica	12.1	15	0.7	0
Japan	10.3	15	0.5	0
Jersey	5.6	*	0.1	*
Jordan	17.7	15	1.2	0.3
Kazakhstan	14.1	*	0.9	*
Kenya	17.7	35	1.2	0
Kiribati	0.8	*	0	*
Kosovo	20.9	*	1.6	*
Kuwait	17.3	15	1.2	0.2
Kyrgyzstan	14.9	*	1	*
Laos	28	*	2.2	*
Latvia	11.2	25	0.6	0
Lebanon	16.4	*	1.1	*
Lesotho	22.9	*	1.8	*
Liberia	10.7	*	0.6	*
Libya	6.7	*	0.2	*
Liechtenstein	8.5	*	0.3	*
Lithuania	10.1	25	0.5	0
Luxembourg	7.2	25	0.2	0
Macedonia	20.3	*	1.5	*
Madagascar	7.1	*	0.2	*
Malawi	14.8	8	1	0.7
Malaysia	12.7	35	0.8	0
Maldives	12	*	0.7	*
Mali	5.5	*	0	*
Malta	6.5	*	0.1	*
Marshall Islands	0.6	*	0	*
Martinique	2.6	25	0	0
Mauritania	3.2	*	0	*
Mauritius	3.6	*	0	*
Mayotte	6.9	25	0.2	0
Mexico	16.2	15	1.1	0.1
Micronesia	0.6	*	0	*
Moldova	12.8	*	0.8	*
Monaco	9.5	*	0.4	*
Mongolia	31.5	25	2.6	0.6
Montenegro	15.9	20	1.1	0
Montserrat	2.2	*	0	*
Morocco	7.4	*	0.2	*
Mozambique	10.3	*	0.5	*
Myanmar	32.4	*	2.7	*
Namibia	10.6	*	0.6	*
Nauru	1	*	0	*
Nepal	47.1	*	4.1	*
Netherlands	7.8	25	0.3	0
New Caledonia	2.2	25	0	0
New Zealand	2.7	*	0	*
Nicaragua	13.3	*	0.8	*
Niger	10	*	0.5	*
Nigeria	23.7	*	1.8	*
Niue	0.6	*	0	*
Norfolk Island	1.7	*	0	*
North Korea	20.6	*	1.5	*
Northern Cyprus	12.3	*	0.7	*
Northern Mariana Islands	0.6	*	0	*
Norway	3.8	15	0	0
Oman	11.1	*	0.6	*
Pakistan	44.2	15`	3.8	2.9
Palau	1.8	*	0	*
Palestina	12.4	*	0.7	*

* No national standard specified

Country	Average $PM_{2.5}$ Country ($\mu g/m^3$)	National Standard ($\mu g/m^3$)	Life Expectancy Gains (in years) from reducing pollution to WHO Standard ($5 \mu g/m^3$)	Life Expectancy Gains (in years) from reducing pollution to the country's National Standard
Panama	7.8	*	0.3	*
Papua New Guinea	10.8	*	0.6	*
Paraguay	16.3	15	1.1	0.1
Peru	23.9	25	1.9	0
Philippines	16.4	25	1.1	0
Poland	15	25	1	0
Portugal	5	25	0	0
Puerto Rico	2.2	15	0	0
Qatar	29.2	*	2.4	*
Republic of Congo	31.6	*	2.6	*
Reunion	1.8	*	0	*
Romania	13.8	25	0.9	0
Russia	10	25	0.5	0
Rwanda	33	*	2.7	*
Saint-Barthélemy	2	*	0	*
Saint-Martin	1.9	*	0	*
Saint Helena	1.9	*	0	*
Saint Kitts and Nevis	2.3	*	0	*
Saint Lucia	1.8	*	0	*
Saint Pierre and Miquelon	3.4	*	0	*
Saint Vincent and the Grenadines	1.9	*	0	*
Samoa	0.8	*	0	*
San Marino	10.7	*	0.6	*
São Tomé and	10.7	*	0.6	*
Saudi Arabia	23	15	1.8	0.8
Senegal	5.3	*	0	*
Serbia	19.4	25	1.4	0
Seychelles	3.1	*	0	*
Sierra Leone	11.7	*	0.7	*
Singapore	10.9	12	0.6	0
Sint Maarten	1.9	*	0	*
Slovakia	12.9	25	0.8	0
Slovenia	12.8	*	0.8	*
Solomon Islands	5.5	*	0	*
Somalia	7	*	0.2	*
South Africa	20.3	20	1.5	0
South Korea	20.3	25	1.5	0
South Sudan	15	*	1	*
Spain	6.7	25	0.2	0
Sri Lanka	18.6	25	1.3	0
Sudan	9.7	*	0.5	*
Suriname	4.9	*	0	*
Swaziland	12.8	*	0.8	*
Sweden	4.6	25	0	0
Switzerland	7.8	*	0.3	*
Syria	19.6	*	1.4	*
Taiwan	14.5	15	0.9	0
Tajikistan	18.6	*	1.3	*
Tanzania	16.6	*	1.1	*
Thailand	23.8	25	1.8	0
Timor-Leste	8	*	0.3	*
Togo	15	*	1	*
Tokelau	1.3	*	0	*
Tonga	1	*	0	*
Trinidad and Tobago	3.4	15	0	0
Tunisia	8.4	*	0.3	*
Turkey	21.6	*	1.6	*
Turkmenistan	9.9	*	0.5	*
Turks and Caicos Islands	2.2	25	0	0
Tuvalu	1.3	*	0	*
Uganda	26.9	*	2.1	*
Ukraine	13.7	*	0.9	*
United Arab Emirates	15.4	*	1	*
United Kingdom	7.2	25	0.2	0
United States	7.1	12	0.2	0
United States Minor Outlying Islands	1.6	*	0	*
Uruguay	7.8	*	0.3	*
Uzbekistan	21.3	*	1.6	*
Vanuatu	3.1	*	0	*
Vatican City	10.9	*	0.6	*
Venezuela	11.5	*	0.6	*
Vietnam	24.4	25	1.9	0
Virgin Islands, U.S.	1.7	12	0	0
Wallis and Futuna	0.9	*	0	*
Western Sahara	3.4	*	0	*
Yemen	14.2	*	0.9	*
Zambia	17.7	*	1.2	*
Zimbabwe	11.7	*	0.7	*

* No national standard specified

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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.

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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.

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Ken Lee is the former Director of Air Quality Life Index (AQLI) and a former Senior Research Associate at the Department of Economics, University of Chicago. Prior to this role, Ken served as the Executive Director of EPIC India, and a Research Fellow at the Center for Effective Global Action (CEGA) and the Energy Institute at Haas. Ken researches questions in the areas of development economics, environmental, and energy economics, and has designed field experiments in Kenya and India. He holds a PhD from the University of California, Berkeley, and an MIA from the School of International and Public Affairs (SIPA) at Columbia 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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