6 Standards for a Better Environment

Main messages

- Environmental standards can power green development, but only if the transitions needed to comply with the standards are affordable and inclusive. Nearly 99 percent of people worldwide breathe air that is dirtier than World Health Organization (WHO) guidelines, costing lives and productivity. Meeting WHO's guideline for atmospheric levels of particulate matter with a diameter of 2.5 micrometers or less ($PM_{2.5}$) could add almost two years to global life expectancy, but the costs of compliance can hit poor households hardest. Balancing ambition with affordability is key to a just green transition.
- Countries cannot manage what they cannot measure. In most low- and middle-income countries, pollution and disaster monitoring remain dangerously thin: Only 4 percent of African governments and 7 percent of governments in Asia provide reliable data on air quality. Investing in monitoring infrastructure—from sensors to satellites—turns invisible threats into actionable information.
- One-size-fits-all standards do not fit anyone well. Blindly copying international norms for pollution can impose crippling costs, whereas fragmented standards cause pollution leakage, as when tighter US battery rules in 2009 pushed recycling to Mexico, raising local rates of low birth weight there by 21 percent. Coordinated or tiered approaches, backed by complementary policies, can curb leakage and share the burden more fairly.
- Strong enforcement turns standards from paper promises into cleaner air and safer water. Where capacity grows, compliance follows: China's nationwide reform of its system for monitoring pollution cut atmospheric levels of $PM_{2.5}$ by 40 percent in five years, saving thousands of lives. Building capacity for enforcing standards, through local institutions, technology, and transparency makes every dollar spent on environmental standards count.
- Environmental standards work best when designed with other goals in mind. Trade-offs are real: A third of global waste is still openly dumped or burned, and adaptation to climate change gets just 5 percent of global financing. Integrating environmental, social, and economic objectives ensures standards raise overall welfare instead of shifting burdens from one country to another.

A reproducibility package is available for this book in the Reproducible Research Repository at https://reproducibility.worldbank.org/catalog/389.

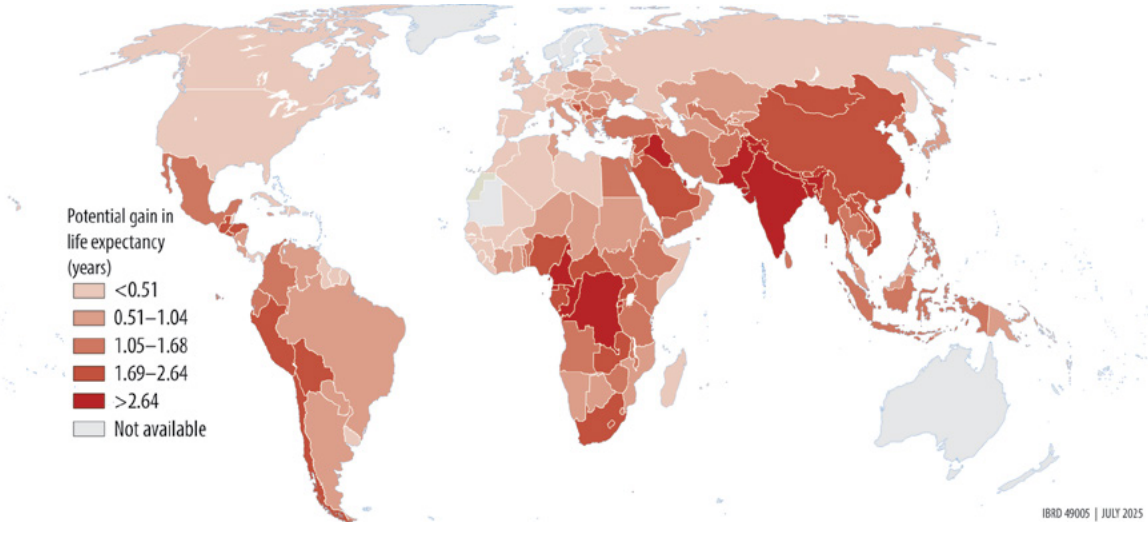
Worldwide environmental challenges

Human and economic activities inevitably generate waste and disruption, leading to a variety of environmental issues ranging from localized air pollution to water and soil contamination to land degradation and dispersed global emissions of greenhouse gases. These issues not only pose serious risks to human health[1] but also impose significant economic costs by reducing labor productivity, eroding human capital,[2] and increasing the frequency and severity of extreme heat, droughts, floods, and biodiversity loss.[3] Low- and middle-income countries urgently need to take steps to both mitigate pollution and adapt to climate change.

For instance, 99 percent of the world's population lives in areas in which pollution exceeds WHO Air Quality Guidelines, with the highest levels—and the fastest increases—concentrated in low- and middle-income countries.[4] Particulate matter, particularly $PM_{2.5}$ from combustion of fossil fuel, poses the greatest health risk among air pollutants. Meeting WHO's guideline for $PM_{2.5}$ levels of 5 micrograms per cubic meter ($\mu g/m^3$) could increase average life expectancy globally by 1.9 years, estimates indicate, as map 6.1 illustrates.[5]

Although environmental damage caused by human and economic activities imposes significant costs on others, market prices often do not reflect negative effects of this type, known as externalities. Moreover, effective adaptation to climate change often depends on public goods, such as resilient infrastructure and timely information about risks posed by climate change and strategies for adaptation to it, which are likely to be underprovided without proper incentives. Such market failures emphasize the crucial role of public policies in tackling environmental challenges more effectively.

Map 6.1 People in low- and middle-income countries, in particular, could gain years of life if air quality were improved



Source: Air Quality Life Index, EPIC Clean Air Program, Energy Policy Institute, University of Chicago, https://aqli.epic.uchicago.edu/.

Note: The map shows the potential gain in life expectancy (in years), as of 2022, from meeting the World Health Organization's guideline for atmospheric concentrations of particulate matter with a diameter of 2.5 micrometers or less ($PM_{2.5}$).

A natural case for environmental standards

Both market-based tools, such as pollution taxes and subsidies for climate-resilient technologies, and environmental standards can address environmental challenges by aligning private decisions with social costs. Market-based tools influence the prices of behaviors that either increase environmental challenges (actively or not) or help countries mitigate or adapt to them, whereas environmental standards require firms or individuals to follow established rules that reduce pollution, lessen damage, disclose emissions to the public or regulators, and facilitate climate change adaptation.

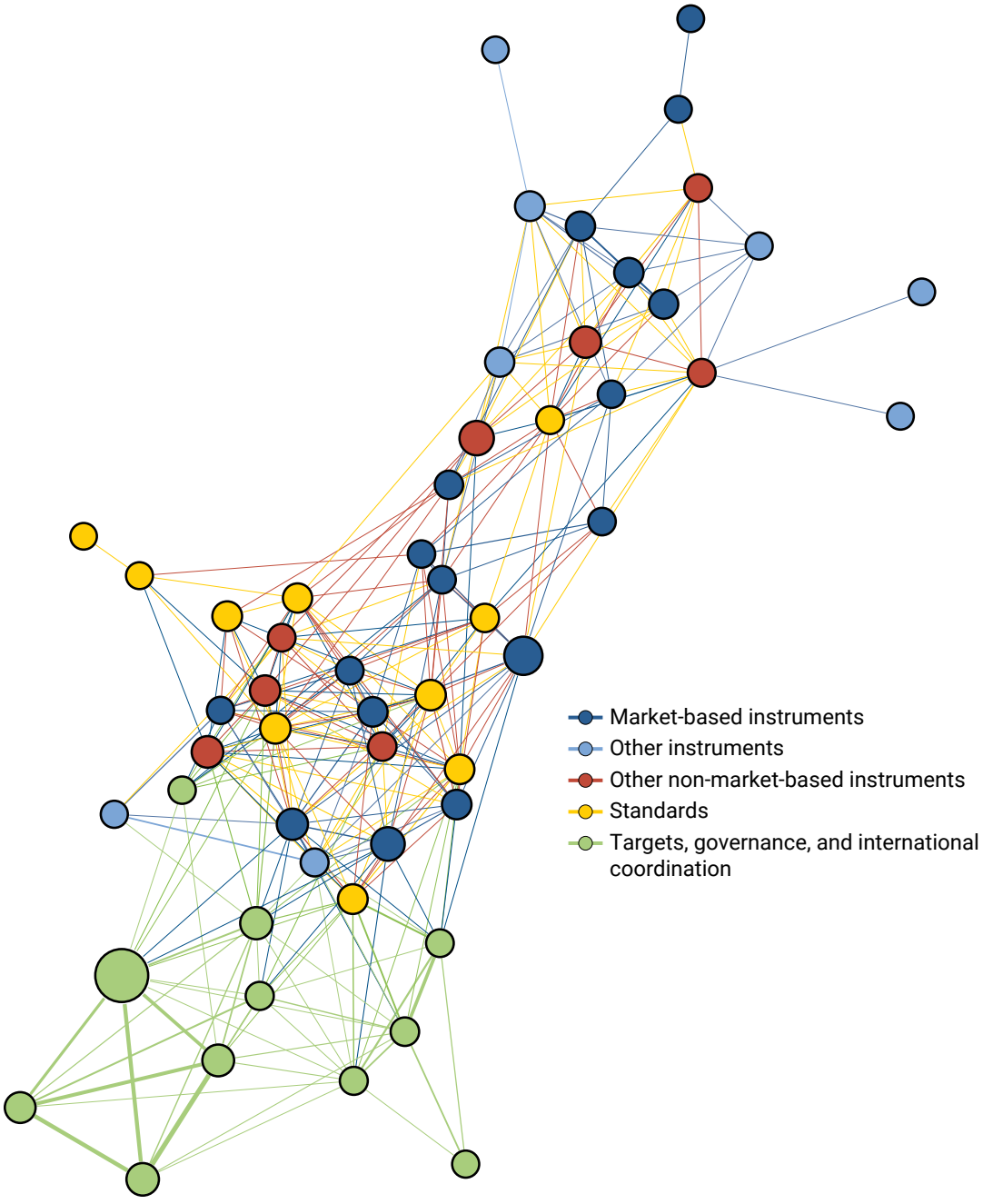
When are environmental standards most effective compared with alternative market-based policies such as taxes and emissions trading? A good starting point for answering this question is the work by economist Martin Weitzman,[6] which compares price-based and quantity-based regulations. It finds that emissions standards that set maximum thresholds for emissions can be more efficient when it is critical to reduce emissions to a specific level, such as keeping local pollution below thresholds found to impair health. In contrast, when the priority is to minimize high and uncertain costs of abating pollution, emissions pricing is preferable in theory because it offers firms the flexibility to cut emissions at the lowest possible cost. For example, a study in India found that pollution markets requiring firms to pay for emissions beyond allocated allowances decreased firms' costs of compliance by an average of 11 percent compared with traditional standards for emissions, while accomplishing the required reductions in emissions.[7]

However, in practice, emissions pricing often faces political resistance and has limited public support, making standards a more viable alternative in many cases. Additionally, it can be very difficult, if not impossible, to measure emissions for pricing purposes. For instance, directly pricing emissions from vehicles requires very costly real-time monitoring of emissions from individual cars.[8] In contrast, standards for fuel economy that mandate minimum levels of fuel efficiency are less visible to consumers and more politically acceptable and have been more widely adopted.[9] Even when pricing instruments are implemented, standards in measurement and reporting requirements can play a critical complementary role by ensuring transparency and consistency in enforcement.

In addition, standards rarely operate in isolation; they are typically part of a broader policy mix. For instance, they are often complemented by subsidies and investments in enhancing infrastructure for monitoring and by fostering green technologies and economic growth. Market-based instruments such as trading systems and taxes are also frequently implemented to achieve standards (refer to figure 6.1). This highlights the potential for combining standards with other policy tools to increase both compliance and overall effectiveness.

This chapter analyzes systematically when standards are effective tools for addressing environmental challenges, their limitations, and how thoughtful policy design and better enforcement can enhance their impact.

Figure 6.1 Environmental standards and other policies often coexist



Source: WDR 2025 team elaboration, based on 2021 data from Climate Policy Database, NewClimate Institute, https://newclimate.org/resources/tools/climate-policy-database.

Note: The climate policy space network depicted in the figure illustrates instruments for climate policy as nodes linked together based on their tendency to occur together in countries' mixes of climate policy (refer to Mealy et al. 2025). The size of the nodes reflects the number of times a given policy has been adopted across countries. The figure colors policy instruments according to broad policy categories. Standards (including those relating to products, sectors, vehicles, building codes, and performance labels) tend to occur together in policy mixes alongside other non-market-based instruments (such as auditing, monitoring, and reporting schemes) and market-based instruments (such as feed-in tariffs, carbon taxes, and schemes for trading emissions).

Setting and enforcing environmental standards in practice

The overall objective of environmental standards is to maximize the benefits of addressing environmental issues while minimizing the costs to individuals and organizations complying with those standards, taking into account the enforcement capacity. Because benefits, costs, and enforcement capacity can all vary by local context, a one-size-fits-all standard may not be appropriate.

How countries set and enforce environmental standards

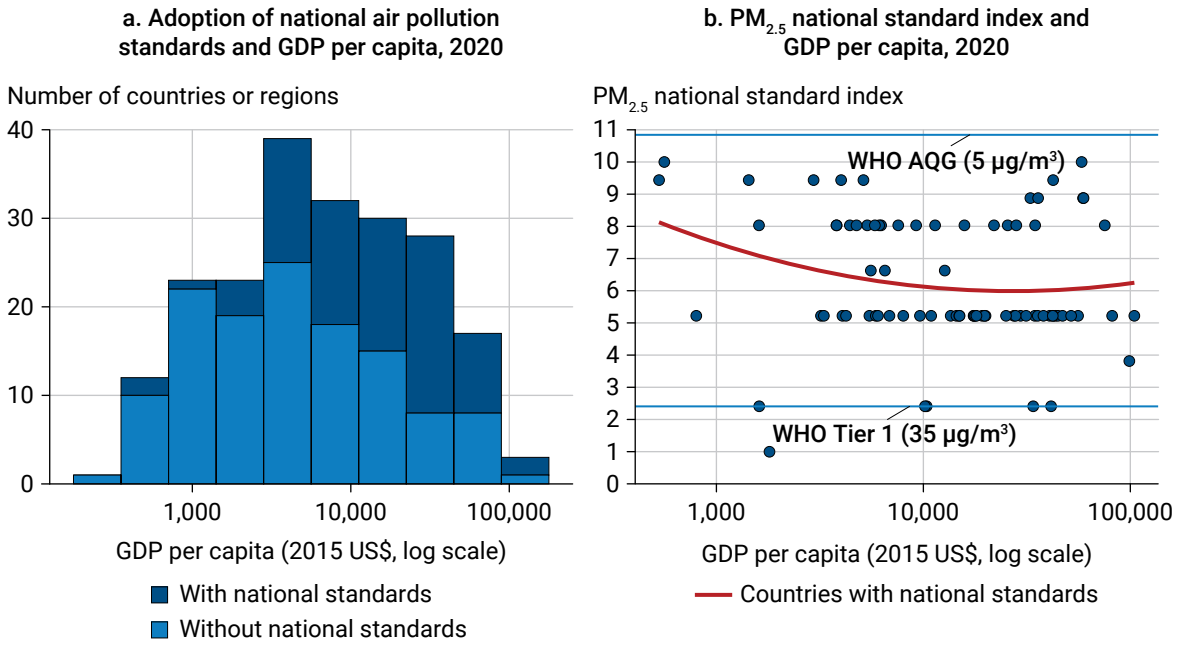
A top-down approach: Stronger standards to mitigate local pollution, driven by economic growth, along with the resulting pollution and improved capacity to manage local environmental issues

When do countries choose to adopt environmental standards? For local pollutants, countries tend to adopt more stringent standards as their economies grow, which contributes to increased air quality (refer to figure 6.2, panel a). Despite the significant health and economic costs of pollution and climate change, countries often do not make environmental issues a priority, especially those countries facing conflict or struggling to meet basic security needs.

However, a different pattern emerges for air quality when countries that have adopted national $PM_{2.5}$ standards are considered. Among such countries, both lower-income and higher-income countries tend to adopt relatively stringent standards, whereas middle-income countries adopt the least stringent ones (refer to figure 6.2, panel b). It appears that when setting pollution standards, countries do not follow the framework depicted in figure 2.5 in chapter 2, balancing the stringency of standards with countries' ability to comply with them. Instead, lower-income and higher-income countries adopt similarly stringent standards, although their enforcement capacity varies. Higher-income countries are more effective at implementing and enforcing standards, resulting in lower pollution levels. In contrast, lower-income countries often struggle with enforcing compliance, and pollution levels remain high, resulting in a compliance gap. The compliance gap—in this case, the failure to meet national standards—is more pronounced in lower-income countries.

In the case of dispersed global emissions of greenhouse gases, per capita emissions of carbon dioxide are higher in high-income countries than in low- and middle-income countries (refer to figure 6.3). This is because economic growth relies heavily on energy, often produced with fossil fuels. Also, countries have relatively weaker incentives to address global emissions compared with those for tackling local pollution. That is, whereas climate change mitigation has global benefits, the costs are borne locally. To encourage broader participation in efforts to address global emissions, it is important to emphasize local cobenefits, such as improved health and air quality, and to develop mechanisms that help monetize benefits to the global climate.

Figure 6.2 Higher-income countries are more likely to adopt standards for air pollution and to improve their air quality



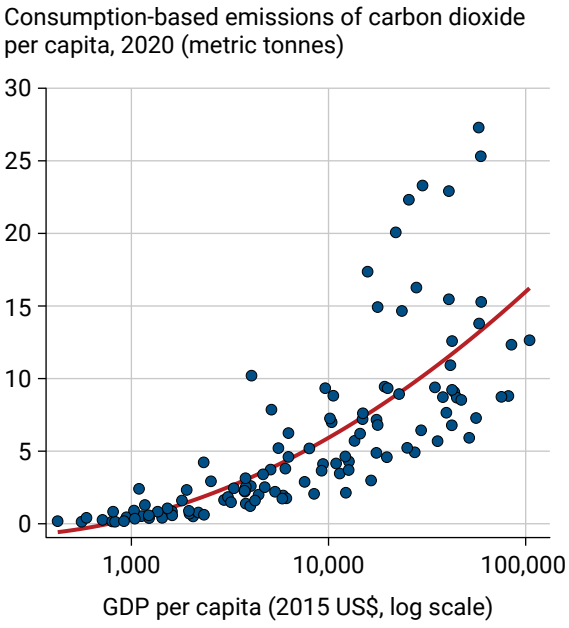
Source: WDR 2025 team, based on Air Quality Life Index, EPIC Clean Air Program, Energy Policy Institute, University of Chicago, https://aqli.epic.uchicago.edu/; World Bank data.

Note: In panel b, the national standard index for particulate matter with a diameter of 2.5 micrometers or less ($PM_{2.5}$) is constructed by standardizing each country's actual national standards for $PM_{2.5}$. A value of 10 represents the most stringent standard, whereas a value of 1 represents the least stringent, and a value of 0 indicates no national standard has been adopted. Data on national standards are sourced from the Air Quality Life Index (AQLI), and air pollution concentrations and GDP per capita are obtained from the World Bank. The World Health Organization (WHO) has set an annual average $PM_{2.5}$ concentration of 5 micrograms per cubic meter (µg/m³) as its Air Quality Guideline (AQG) and 35 µg/m³ as the Tier 1 interim target.

A bottom-up approach: Demand and enforcement of standards driven by public awareness

In addition to rising levels of pollution and a perceived need to enhance capacity to tackle local environmental problems caused by economic growth, public awareness and citizen complaints can also boost the demand for and enforcement of environmental regulations. One study found that after US embassies installed air quality monitors at US diplomatic sites and publicly shared real-time data on air pollution, concentrations of fine particulates dropped by 2 µg/m³ to 4 µg/m³, especially in countries with limited infrastructure for monitoring such pollution. Increased government efforts to reduce pollution likely caused the decline.[10] In China, public complaints submitted via social media have also proven effective in prompting more rigorous local inspections that help reduce violations of emissions standards and improve air quality.[11]

Figure 6.3 Emissions of carbon dioxide per capita often continue to rise as countries grow richer



Source: WDR 2025 team, based on 2020 data from Global Carbon Project, Future Earth, https://www.globalcarbonproject.org/.

Note: The red line represents the fitted values based on observations from countries and regions in 2020.

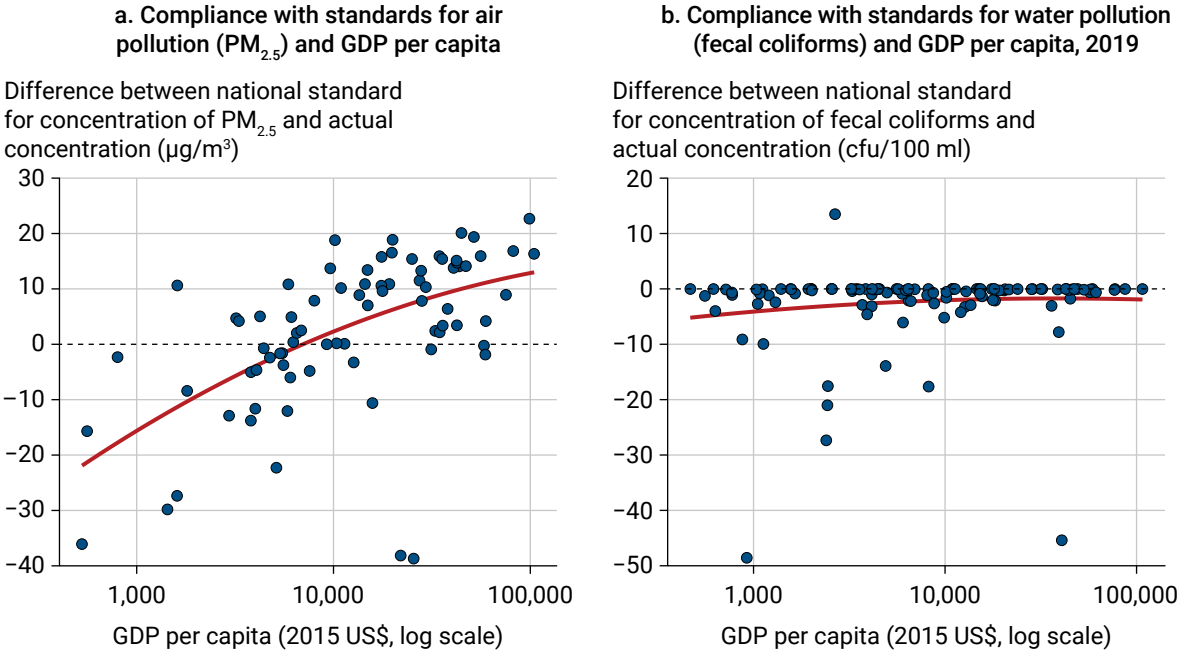
The importance of robust enforcement: The problem of the compliance gap

Effective environmental standards rely not only on proper design, but also on strong enforcement, which depends on adequate capacity for compliance. In practice, compliance with regulations regarding air pollution—the difference between de jure standards and actual pollution levels—increases as a country's income rises, indicating that lower-income countries tend to set pollution standards but fail to enforce compliance with them (refer to figure 6.4, panel a). Consistent with the framework described in chapter 2, standards greater than a country's compliance capacity can generate inefficiencies. Using the same data as in figure 6.4, panel a, yields the result that countries with larger compliance gaps in regard to standards for air pollution in 2010 reduced pollution less by 2020, even compared with peers at similar levels of development and pollution. In addition, corruption has been reported in various contexts in which inspectors were bribed to falsify results to enable responsible entities to appear compliant with environmental standards.[12] Also, it has been documented that enforcement of standards for water pollution has been strategically focused on firms located upstream of monitoring stations, resulting in unequal regulatory treatment and economic distortions.[13]

On average, countries with higher incomes, which are also correlated with greater state capacity, are more likely to enforce compliance with standards related to air and water quality (refer to figure 6.4).[14] This is partly because national standards rely on local inspectors to monitor compliance and enforce regulations, and enforcement can be compromised at the local level when state capacity is weak. When weak state capacity results from limited resources for local inspections, targeted inspections have been found to be more effective at reducing emissions than randomly assigned ones, as shown in a study conducted in Gujarat, India.[15] In addition, emerging satellite-based measures of pollution can also serve as an independent source for cross-checking the credibility of self-reported data on pollution, which are subject to data manipulation (refer to box 6.1).

However, even with strong state capacity, effective local enforcement can face challenges when the incentives of local regulators do not align with those of the national government. As a result, complementary policies and efforts are required to expand capacity for enforcing compliance. For instance, water pollution travels across jurisdictional boundaries. Local officials may be less concerned about pollution that flows

Figure 6.4 Compliance with environmental standards increases as countries develop



Sources: Air Quality Life Index, EPIC Clean Air Program, Energy Policy Institute, University of Chicago, https://aqli.epic.uchicago.edu/; Jones et al. 2023; WHO 2021.

Note: Data on national $PM_{2.5}$ standards for 78 countries and regions are collected through the Air Quality Life Index based on gazetted documents or official government press releases. National standards for drinking water quality for 125 countries and regions are collected from a 2021 survey by the World Health Organization (WHO 2021). Data on concentrations of fecal coliforms are from Jones et al. (2023). The red line represents the fitted values based on observations from countries and regions. The area below the zero line indicates noncompliance, and that above the zero line indicates compliance. cfu/ml = colony-forming units per milliliter; µg/m³ = micrograms per cubic meter; $PM_{2.5}$ = particulate matter with a diameter of 2.5 micrometers or less.

downstream, beyond their area of responsibility. Research in Brazil found that redrawing of county borders, which altered the distance to downstream boundaries, altered levels of water pollution. For every kilometer a river moves closer to a downstream border on a redrawn map, the concentration of bacteria—as measured by biochemical oxygen demand (a key indicator for organic pollution in water that quantifies the amount of oxygen that microorganisms require to decompose organic matter)—was found to increase by 1.5–3.0 percent, because standards become progressively more lax as the river moves downstream and across borders.[16]

Box 6.1 Nowhere to hide: Emerging satellite-based measures of pollution

Despite robust networks for monitoring exposure to pollution in many high-income countries, the majority of the world's population lives in areas for which high-quality data on such exposure are lacking. Only 3.7 percent of governments in Africa, 6.8 percent in Asia, and 19 percent in Latin America provide reliable data on air quality.[a]

Emerging technologies are beginning to fill the gaps in such coverage. Machine learning applied to satellite imagery now enables pollution levels to be estimated in greater detail. This includes levels of air pollution, water quality indicators, and emissions of greenhouse gases. Satellites detect pollution by using advanced sensors to measure how various substances absorb or reflect sunlight at specific wavelengths. This allows scientists to estimate concentrations of pollutants like nitrogen dioxide, particulate matter with a diameter of 2.5 micrometers or less, methane, and chlorophyll (a proxy for excessive nutrient enrichment and thus a sign that water quality has degraded) from space at fine spatial resolutions, such as less than one kilometer.[b]

However, given current technology, satellite data are best viewed as a supplement to, rather than a substitute for, ground-based monitoring. Factors like cloud cover and limited vertical resolution can influence the accuracy of satellite data at ground level, which is essential for evaluating human exposure. Therefore, it is important to account for prediction errors in satellite-based estimates. Additionally, satellite data generally cannot offer both high temporal and spatial resolution to the same degree as continuous ground-based monitoring. Combining satellite measurements with those provided by ground-based infrastructure can significantly and effectively lower the costs of monitoring air quality.[c]

Source: WDR 2025 team.

a. Hasenkopf et al. (2023).
b. Di et al. (2016); Fowlie et al. (2019); van Donkelaar et al. (2019).
c. Hoffmann and Milusheva (2024).

The evolution of standards as compliance capacity and pollution levels change

Expanding compliance capacity

To address the compliance gap stemming from limited state capacity and misalignment of local incentives with those of national regulators, many countries have worked to expand their capabilities for enforcing environmental standards in line with the ambition of these standards. In particular, advancements in technologies for monitoring pollution and institutional reforms have proven effective in strengthening capacity for enforcing compliance. For example, in China, automated systems for monitoring levels of particulate matter with a diameter of 10 micrometers or less (PM_{10}), installed starting in 2013 and centrally managed by 2015, increased reported levels of PM_{10} by 35 percent, indicating reduced local underreporting,[17] and led to greater enforcement and lower pollution.[18] Additionally, public access to monitoring data can increase awareness, encourage

adaptive behavior, and increase accountability.[19] Transparent, reliable systems for monitoring levels of pollution are thus critical for effective enforcement and pollution reduction.

Transparent data on pollution alone, however, may be insufficient to address the misalignment of the incentives of local regulators and those of central governments. For instance, regulators may respond strategically to data from pollution monitors by concentrating their enforcement efforts near those monitors rather than reducing pollution citywide.[20] In contrast, institutional reforms have been shown to effectively align the behavior of local regulators with national environmental goals. One strategy is to link outcomes of local enforcement to career incentives, for instance, by making promotions contingent on meeting national environmental targets[21] or by granting higher-level agencies for environmental protection direct authority over the promotion of local regulators.[22]

Regional and international institutions can also play a vital role in fostering cooperation on environmental challenges that cross national boundaries. For example, the United Nations Economic Commission for Europe's Convention on the Protection and Use of Transboundary Watercourses and International Lakes provides an international legal framework and platform for promoting the sustainable management of shared water resources. However, implementation remains limited. Only 43 of 153 countries with shared water resources have operational arrangements that cover at least 90 percent of their transboundary rivers, lakes, and aquifers.[23]

Finally, not all environmental standards are mandatory; voluntary standards can help ease resistance from industry by allowing firms to opt into compliance.[24] When credible and well enforced—for instance, through third-party verification—they can potentially encourage compliance, normalize responsible practices, and open access to sustainability-oriented markets. For example, certification under International Organization for Standardization (ISO) 14001 may offer economic benefits such as access to regulated markets and lower capital costs and appeal to environmentally conscious employees.[25] However, evidence on the environmental impact of voluntary standards is mixed, reflecting wide variation in both standards and baseline practices. Some studies find gains in forest habitat, climate change mitigation, and biodiversity;[26] others report only limited improvements.[27] Thus, voluntary standards should be adopted with caution and strengthened through transparency and third-party verification.

Adopting and upgrading standards

After adoption, environmental standards are often updated to reflect changes in pollution levels and enforcement capacity. Thailand, for instance, tightened its national standard for $PM_{2.5}$ levels in 2023 to better align it with observed declines in pollution, though $PM_{2.5}$ levels in the country still exceed the WHO Air Quality Guideline of 5 $\mu g/m^3$. Dhaka, Bangladesh, consistently recorded extremely high concentrations of $PM_{2.5}$, and it relaxed its national standard—previously more stringent than WHO's Tier 1 interim target of 35 $\mu g/m^3$—to match actual levels in the country, possibly reflecting persistent noncompliance with the stricter standard.

Numerous studies have documented that when standards are effectively implemented, they can significantly improve environmental outcomes in both high- and low- and middle-income countries.[28] For example, in the United States, the 1970 Clean Air Act, which set county-level limits on total amounts of suspended particulates in the air, led to a 10 percent reduction in these particulates within three years in counties that exceeded the thresholds.[29] The 1990 amendments to the act, which added PM_{10} as a targeted pollutant, reduced PM_{10} concentrations by 11–14 percent

(7–9 μg/m³) between 1990 and 2005 in noncompliant counties.[30] In 2014, China launched its "war on pollution," introducing national standards, annually adjusted, for $PM_{2.5}$ levels and strengthening air monitoring, data disclosure, and official accountability. By 2018, $PM_{2.5}$ levels in the country had fallen by 40 percent, levels of sulfur dioxide by 65 percent, and levels of carbon monoxide by 33 percent. Compliance with the standard for $PM_{2.5}$ levels rose from 20 percent of cities (13 percent of the population) in 2013 to 41 percent of cities (29 percent of the population) by 2018.[31]

Fully understanding the benefits and associated economic costs of environmental improvements

Using well-designed environmental standards to spur competitiveness and positive effects in the economy

A major concern for countries considering the adoption or strengthening of environmental standards is that such standards can increase compliance costs for polluting firms, potentially reducing their competitiveness with firms elsewhere, which may not be subject to the same standards.[32] Firms may be required to invest in abatement technologies or change production processes, increasing their operational costs. Abatement costs have been widely documented and quantified across various polluting sectors.[33] Importantly, such costs can vary significantly depending on factors like firm size, technological capacity, and market structure.[34]

However, more stringent regulations do not always diminish competitiveness in the long term.[35] According to the Porter hypothesis,[36] well-designed environmental policies have the potential to spur improvements in efficiency, overcome inertia in organizations, lower long-term costs, and promote innovation. Whether these positive effects are realized depends heavily on context, policy designs, and implementation.[37]

Developing countries may have the opportunity to leapfrog older technologies that cause more pollution and to facilitate green growth, particularly in sectors such as energy and transportation, by combining environmental standards with green industrial policies.[38] Such an approach can be especially effective when transitioning directly to cleaner technologies is more cost-effective in the long term and better aligned with a country's comparative advantage than retrofitting or cleaning up existing systems. For example, China's large-scale efforts to promote the production and adoption of electric vehicles not only have reduced local air pollution and emissions of greenhouse gases[39] but also have enabled the country to leapfrog technologies for internal combustion engines that were traditionally dominated by Germany, Japan, and the United States. As a result, China accounted for nearly 70 percent of global sales of electric vehicles in 2023.[40]

Reductions in pollution offer benefits beyond health improvements. They can enhance workers' productivity[41] and boost human capital, as reflected in standardized test scores[42] and labor market outcomes such as earnings;[43] increase housing values through better environmental amenities;[44] and make regions more attractive to skilled workers.[45] These benefits vary depending on factors such as population density, demographics, economic structure, and baseline levels of pollution. For instance, high-density urban areas may experience greater health gains per unit of pollution reduced than do sparsely populated regions.

Therefore, it is important to understand the benefits of environmental improvements and the associated economic costs. Environmental issues, especially mitigation of climate change, which imposes global costs rather than only local costs, are not realistically a top priority for low-income countries still struggling with poverty. Putting a priority on adaptation to climate change is more important for these countries, as climate change can lead to significant local economic

losses. Many middle-income countries, on the other hand, could achieve economic benefits by addressing environmental issues. The challenge is to fully understand the costs and benefits and to carefully design environmental policies that fit local contexts, rather than treating these issues as isolated concerns. Tailoring these policies to the local context is also consistent with the principle of Common but Differentiated Responsibilities and Respective Capabilities established in the 1992 United Nations Framework Convention on Climate Change at the Rio Earth Summit. This principle recognizes that countries share responsibility for addressing climate change, but responsibilities and capacities differ, with high-income countries expected to take the lead.

Addressing the issue of emissions leakage through coordination across jurisdictions

Setting standards at different levels across regions can help the standards reflect local variations in the costs and benefits of pollution reduction. However, such an approach introduces emissions leakage, in which polluting activities or products shift to jurisdictions with weaker standards. When emissions leakage worsens environmental outcomes, it reduces the overall effectiveness of efforts to reduce pollution. Additionally, low- and middle-income countries—often with less stringent environmental regulations—risk becoming "pollution havens," which can exacerbate global inequalities in environmental quality. These concerns highlight the need for coordination across jurisdictions to ensure both the effectiveness and the fairness of environmental standards.

For example, huge volumes of plastic waste are traded globally (6.66 million tonnes in 2022 alone),[46] often shipped from high-income countries to lower-income ones for recycling or disposal. The prices paid for this waste typically do not reflect its full social and environmental costs, partly because the receiving countries lack adequate environmental standards for waste management. As a result, these countries disproportionately bear the environmental burden of waste generated elsewhere without fair compensation.

Complementary policies can help reduce emissions leakage, a topic later sections examine in more detail. Furthermore, as countries that import emissions develop, they may no longer remain passive recipients. Instead, emissions leakage could prompt them to adopt stricter environmental regulations and thus reduce the leakage.[47]

Importantly, not all leakage results in worse environmental outcomes. The context is key. For example, used vehicles exported from the United States to Mexico are often cleaner to operate than Mexico's domestic fleet, which lowers the country's average emissions per mile. However, because these vehicles tend to stay in use longer in Mexico, their lifetime emissions can increase.[48] Similarly, location mandates that require polluting industries to relocate from densely populated areas to less crowded ones can increase the quality of local air at or near the industries' original sites, although firms may incur higher costs in their new locations.[49]

Standards for localized air pollution, solid waste, emissions of greenhouse gases, and adaptation to climate change

There are multiple types of environmental standards, and each type addresses environmental challenges in a distinct way, making certain types more suitable and effective depending on the context. *Measurement standards* can provide information as a public good. *National targets*, such as national air quality standards, set overarching goals that guide policy development and regulatory action. *Technology standards*, such as bans or phase-outs of fossil-fuel-based equipment, directly promote

the adoption of cleaner technologies. In contrast, *performance standards*, including energy efficiency requirements or emissions standards, regulate environmental outcomes while allowing flexibility in how those outcomes are achieved. This section examines specific environmental standards aimed at addressing challenges ranging from localized air and water pollution, to solid waste that causes both localized and dispersed pollution, to emissions of greenhouse gases that are highly dispersed. It also explores the role of standards in enabling adaptation to climate change. The discussion focuses on the specific impacts of these standards, outlines the contexts in which they are most effectively applied, and provides policy recommendations for their practical implementation.

Standards for localized air pollution

Setting overarching goals: Place-based quality standards for ambient air

Governments can set quality standards for ambient air as a basis for broader environmental regulations, often informed by WHO guidelines but adapted to take into account local costs and benefits. These standards target overall environmental outcomes without mandating specific technologies, offering local flexibility. For instance, Brazil's 2024 National Air Quality Policy sets pollution limits nationwide under Federal Law No. 14,850/2024. However, without strong local enforcement, outcomes can vary, so quality standards for ambient air are often combined with other measures.

Nonetheless, place-based standards can also cause emissions leakage, as regions with stricter standards may lose production to less regulated ones. In China, such leakage offset up to 60 percent of reductions in local emissions achieved using place-based standards.[50] Similarly, tighter US standards for lead disposal in 2009 led to increased exports of batteries to Mexico and a 21 percent increase in low birth weight near recycling plants.[51]

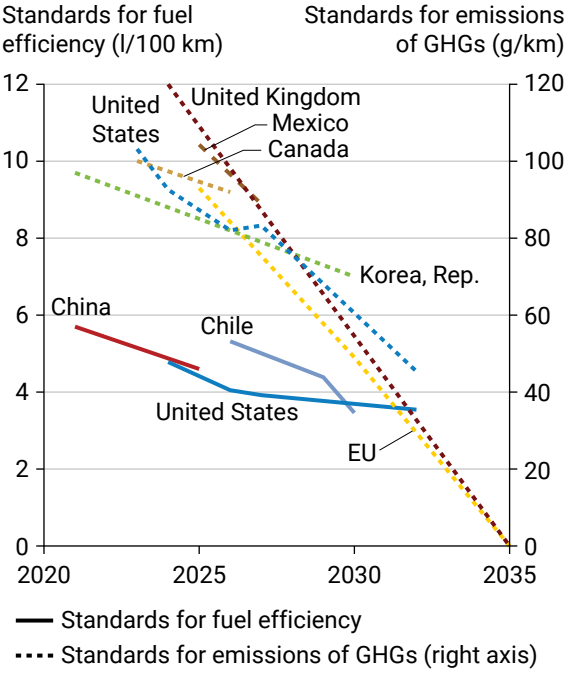
Moreover, when pollution levels are hard to measure, setting air quality standards can be challenging. For example, indoor air pollution is seldom regulated because monitoring it is difficult. However, it disproportionately harms women in countries like Ethiopia and Uganda where highly polluting forms of cooking fuel are used.[52] In such cases, promoting clean fuels and reducing barriers to adoption of standards may be more effective.[53]

Designing enforceable standards based on compliance capacity: Technology standards versus performance standards

National air quality standards set broad targets but are often accompanied by more practical tools like technology or performance standards. Technology standards mandate or prohibit the use of specific technologies (such as catalytic converters or coal), making enforcement easier when proven solutions are available. Manipulation of emissions data also affects this type of standard less.[54] Performance standards, by contrast, set emissions or efficiency thresholds, allowing firms flexibility in how they comply with them.

For example, the US Clean Air Act required catalytic converters on cars manufactured after 1975, cutting emissions by 50–99 percent per mile.[55] In India, similar mandates for catalytic converters have been shown to lower rates of infant mortality, whereas general air quality standards have had little effect on these rates.[56] When companies can choose among several technologies for pollution abatement, performance standards can be more effective. Standards for fuel economy set minimum thresholds for miles traveled per gallon of fuel instead of specifying engine design, and both high- and low- and middle-income countries have adopted them (refer to figure 6.5). Standards for industrial emissions often measure pollution per unit of output, allowing companies to choose the most cost-effective ways to meet the requirements.

Figure 6.5 Countries around the world have adopted standards for fuel economy



Source: ICCT 2023, table 4.

Note: EU = European Union; g = grams; GHGs = greenhouse gases; km = kilometers; l = liters.

Countries often decide on the stringency of performance standards using cost-benefit analysis, comparing the costs of compliance (such as increased expenses related to vehicle production or ownership) with potential benefits like fuel savings and environmental improvements. However, uniform standards for performance may not suit all countries, because they overlook differences in economic conditions and technological readiness. Additionally, when compliance costs are uncertain, fixed standards for performance can be too strict in contexts with high costs.[57]

When effectively designed and enforced, however, performance standards can substantially reduce emissions.[58] In China, stricter limits on sulfur dioxide cut diseases related to air pollution by 39 percent between 1998 and 2010, and Jakarta's 2018 adoption of Euro 4 emissions standards, which set stricter standards for vehicle emissions of various pollutants, led to 58 percent and 49 percent drops in emissions of nitrous oxides and carbon monoxide, respectively.[59] Performance standards also spur innovation, driving growth in patents for pollution abatement technologies and adoption of such technologies in middle- and high-income countries.[60]

In the design of technology or performance standards, it is critical to take a dynamic perspective, especially when the standards apply to long-lived assets. For instance, coal-fired power plants can remain in operation for 30–50 years, creating lock-in effects that delay the transition to cleaner alternatives. In such cases, if retrofitting is more expensive than building new facilities, early decisions regarding investment can have long-lasting consequences. Forward-looking mandates concerning technology can help steer investment toward cleaner options from the outset. Additionally, reducing uncertainty about the adoption and enforcement of performance standards before long-term investments are made can significantly influence technology choices and related outcomes for pollution.[61]

Both technology and performance standards, however, come with economic costs. In some cases, they can raise product prices, reduce firm productivity, and disrupt labor markets, requiring careful evaluation. For instance, electricity prices in the United States rose 11 percent after standards regarding renewable portfolios were put in place,[62] and pollution controls in Indian coal plants may increase generation costs by 9–25 percent.[63] Stricter standards reduced productivity by 4.8 percent in polluting plants in the United States[64] and by 24 percent in polluting firms in China.[65] Closures of coal plants also caused lasting income losses for US miners.[66] Complementary policies like energy subsidies,[67] green bonds,[68] and targeted job training[69] can help offset these costs and support a just transition.

Lastly, emissions leakage can occur when technology or performance standards apply only to parts of the market. For example, retired coal equipment may be exported to countries with weaker regulations than those in the exporting country, shifting emissions abroad.[70] In the United States, mandates like the one for catalytic converters and standards for fuel economy in new vehicles increased the costs of the latter, prompting some people to keep older, more polluting cars longer, offsetting environmental gains. Complementary measures such as scrappage incentives or higher fees for older vehicles can help, though they may burden low-income households.[71] Similar policies can also strengthen standards in the area of water pollution (refer to box 6.2).

Box 6.2 Advancing safe and efficient use of water through standards and complementary policies

Growing urbanization and climate change are making the need for safe and efficient use of water more critical. Contaminated water and inadequate sanitation contribute in a major way to the transmission of diseases, including cholera and diarrheal illness, and could increase mortality from digestive cancers.[a] Contaminations originate from diverse sources, including industrial waste, agricultural activities, and the infiltration of pathogen-laden surface water into groundwater as a result of weak infrastructure. In addition, water loss in distribution and inefficient use, in areas such as irrigation or industry, waste resources at a time of growing scarcity.[b]

Standards and complementary policies play a critical role in addressing these challenges by setting clear benchmarks for safety and efficiency, monitoring, and accountability. Recognizing the importance of controlling water pollution, 103 out of 125 countries in a World Health Organization survey had adopted national standards for fecal coliforms by 2019.[c]

Yet improving water quality is challenging on account of the relatively low visibility of water pollution, compared with that of air pollution, and the complexity of measuring it. Monitoring drinking water is particularly difficult, requiring household-level testing and accounting for contamination in distribution pipes.[d]

Two complementary policies have been shown to significantly enhance the effectiveness of standards regarding water pollution. First, complementary public investment, such as funding for infrastructure to treat wastewater, can lower compliance costs for polluters and increase compliance with standards.[e] However, these investments can have substantial costs. For example, the United States invested US$650 billion (in 2014 dollars) in such infrastructure between 1972 and 2001.[f]

(Box continues next page)

Box 6.2 Advancing safe and efficient use of water through standards and complementary policies *(continued)*

Second, strong enforcement and public awareness, including investments in monitoring technologies and increased transparency, can strengthen accountability and increase compliance.[g] In contrast, where enforcement is weak and public sector engagement is limited, standards regarding water pollution may fail to yield meaningful improvements in water quality.[h]

Standards that encourage water-saving technologies and monitoring systems to detect distribution losses can advance efficient use of water. Public campaigns, behavioral nudges, and financial incentives can further raise awareness and promote water conservation on the consumer side.[i]

Source: WDR 2025 team.

a. Ebenstein (2012); UNEP (2021).
b. Liemberger and Wyatt (2019).
c. WHO (2021).
d. Gazze (2024).
e. Keiser and Shapiro (2019).
f. Keiser and Shapiro (2019).
g. He et al. (2020); Olmstead and Zheng (2021).
h. Greenstone and Hanna (2014).
i. Akesson et al. (2023).

Standards for non-point-source solid waste

Municipal solid waste—waste generated by households, businesses, and institutions—can affect air, water, and soil pollution if mismanaged. Out of the estimated 2.24 billion tonnes of waste generated worldwide in 2020, about 37 percent was managed through some form of landfill, 13.5 percent was recycled, 5.5 percent was composted, 11 percent was incinerated, and 33 percent was openly dumped or burned.[72] Mismanaged waste directly dumped onto land or burned might contaminate land or water, exacerbate flooding if it clogs canals and waterways, cause air pollution, support the spread of vector-borne diseases, or any combination of these.[73]

Unlike air and water pollution, which come from single, identifiable sources, municipal solid waste, as a type of non-point-source pollution, originates from many dispersed sources, making it difficult to trace and manage.[74] As a result, governments play an essential role in providing public goods to facilitate waste management and in establishing comprehensive standards and policies to align the incentives of different actors and coordinate in the waste value chain to collectively manage waste. The goal is not only to reduce mismanaged waste, but also to curb the generation of waste.[75]

Standards for management of municipal solid waste are typically set at the national level and further refined and implemented at the local level, from those for waste generation and collection to

those for waste treatment and disposal. Although the minimum desired standards are universal waste collection and safe disposal, the provision of services will differ based on the local context. For example, in Tiquipaya, Bolivia, waste is collected twice a week, with a bell signaling that residents should bring their trash directly to the collection truck, an approach suited to the town's narrow streets and limited sidewalks.

Many countries set standards for postcollection management of waste to coordinate actors along the value chain. For instance, a World Bank project in Ningbo, China (2013–20), implemented a system for collecting certain types of waste separately from the remainder, with results-based payments giving residents an incentive to follow standards for sorting. This allowed the municipality, through a public-private partnership, to process uncontaminated organics using a new anaerobic digester, generating 29,000 cubic meters of biogas daily and increasing dry recyclables to 71,600 tonnes per year. The project resulted in a reduction of 1.94 million tonnes of carbon emissions.[76]

Solid waste can be transported and traded. In some cases, it is more cost-effective to export waste than to process it domestically, creating a global market. As a result, one country's standards for managing waste can have cross-border impacts.[77] Standards tailored to local needs may not suit other contexts, highlighting the need for international coordination (refer to box 6.3).

However, standards alone are insufficient to enable countries to effectively manage waste. Complementary policies that clearly define responsibility for waste management can enhance accountability and improve overall waste management practices. For example, Extended Producer Responsibility schemes require companies to take financial and operational responsibility for managing their product waste after consumer use. These schemes clearly define who is accountable for managing waste, helping to prevent free-riding among different actors in a supply chain. They also encourage environmentally conscious design, such as reduced packaging or increased recyclability of products as a result of making them easier to reuse, which helps reduce waste at the design stage.

Box 6.3 Standards for contamination from solid waste and their role in shaping global trade

The global trade in solid waste is extensive and can reduce domestic burdens involving waste disposal, but it poses a risk of pollution leakage, especially when waste is sent to countries with environmental standards that are weaker than those in the country that exports the waste. Since the late 1990s, high-income countries have increasingly exported plastic waste to low- and middle-income countries. Before 2018, China alone received more than 55 percent of global exported plastic waste, with an estimated 70.6 percent of it being placed in landfills or mismanaged, for example, dumped or burned openly or handled improperly in a way that causes environmental harm.[a]

Standards regulate the composition of imported plastics to address the environmental harms from imports of plastic waste. For instance, the Basel Convention on the Control

(Box continues next page)

Box 6.3 Standards for contamination from solid waste and their role in shaping global trade *(continued)*

of Transboundary Movements of Hazardous Wastes and Their Disposal, adopted in 1989, established expected practices for management of plastic waste, including minimum requirements for treatment and disposal facilities, that govern trade from countries that are members of the Organisation for Economic Co-operation and Development to countries that are not.

In 2018, China's Operation National Sword introduced a strict standard regarding contamination, limiting nontarget materials (such as food and other residues) in plastic waste to 0.5 percent, which effectively banned imports from Japan, the United States, and the European Union.[b] Global trade in plastic waste fell by more than 40 percent between 2017 and 2018 and continued declining through 2023. This triggered a shift toward Southeast Asia in trading routes, with Malaysia's imports of plastic waste rising from 176,000 tonnes to 900,000 tonnes from 2012 to 2018 and Türkiye's from 65,000 tonnes to more than 650,000 tonnes from 2013 to 2024.[c] In response, Thailand phased in restrictions, culminating in a full ban in 2025. Similarly, Malaysia tightened imports of plastic waste, resulting in a decrease in its imports of plastic waste to less than 335,000 tonnes in 2019.

Beyond reshaping global patterns of trade, Operation National Sword had notable implications for climate. As high-income countries struggled to manage larger volumes of plastic waste domestically, many resorted to incineration, a more carbon-intensive option compared with dumping plastic waste in landfills or recycling it. As a result, the net short-term impact of the operation's essential import ban included higher emissions of greenhouse gases associated with the treatment of plastic waste.[d]

The experience with Operation National Sword underscores the broader challenge of emissions leakage in the global management of plastic waste. To mitigate such leakage, countries need to invest in infrastructure to reduce marginal costs of waste processing (such as landfills and recycling facilities), offer or strengthen incentives for recycling, and reduce the generation of plastic waste at the source. At the same time, international coordination is essential to align standards, manage trade flows, and negotiate policies that minimize environmental and climate-related disruptions across borders.

Source: WDR 2025 team.

a. Wen et al. (2021).
b. Bourtsalas et al. (2023); Brooks et al. (2018); O'Neill (2017); O'Neill and Moon (2025).
c. Refer to United Nations Commodity Trade Statistics Database, Statistics Division, Department of Economic and Social Affairs, United Nations, https://comtradeplus.un.org/.
d. Wen et al. (2021).

Standards for mitigating dispersed global emissions of carbon

Although wealthier countries have higher emissions per capita, increasing emissions from low- and middle-income countries have also contributed to the global growth in carbon emissions, making cooperation among top emitters crucial. The 2015 Paris Agreement, adopted by 196 parties, aims to limit warming to well below 2 degrees Celsius, with efforts toward keeping it less than 1.5 degrees Celsius. This is to be accomplished through country-specific pledges to take specific climate-related actions and set targets for emissions of greenhouse gases, known as nationally determined contributions. A major challenge to commitment to carbon reduction, however, is that mitigation benefits are global, whereas its costs are local, especially for low- and middle-income countries dependent on fossil fuels, which made up 75.7 percent of emissions of greenhouse gases globally in 2021.[78] To broaden participation in the agreement, it is vital to emphasize local cobenefits such as better health and air quality and to develop tools that monetize global gains in regard to climate.

High-income countries: Leading the efforts

Higher-income countries tend to introduce a greater number of climate-related standards, including all standards adopted over time, and on an earlier timescale than low-income countries (refer to figure 6.6, panel a). Many have adopted a broad mix of policies, including carbon pricing and standards such as those requiring portfolios of renewable energy. However, lower-income countries today tend to adopt more standards than higher-income countries did when they were at similar levels of development. In addition, high-income countries tend to adopt a greater number of climate-related standards as total costs from disasters increase (refer to figure 6.6, panel b).

It appears that many early standards related to climate in high-income countries were not initially driven by climate but were instead introduced to address concerns such as energy security, air pollution, or industrial modernization. They gradually evolved into more comprehensive tools for climate change mitigation that include market-based instruments.[79] However, climate shocks, such as extreme weather events, do not consistently translate into stronger standards unless countries' reactions are channeled through responsive political systems and institutional frameworks.

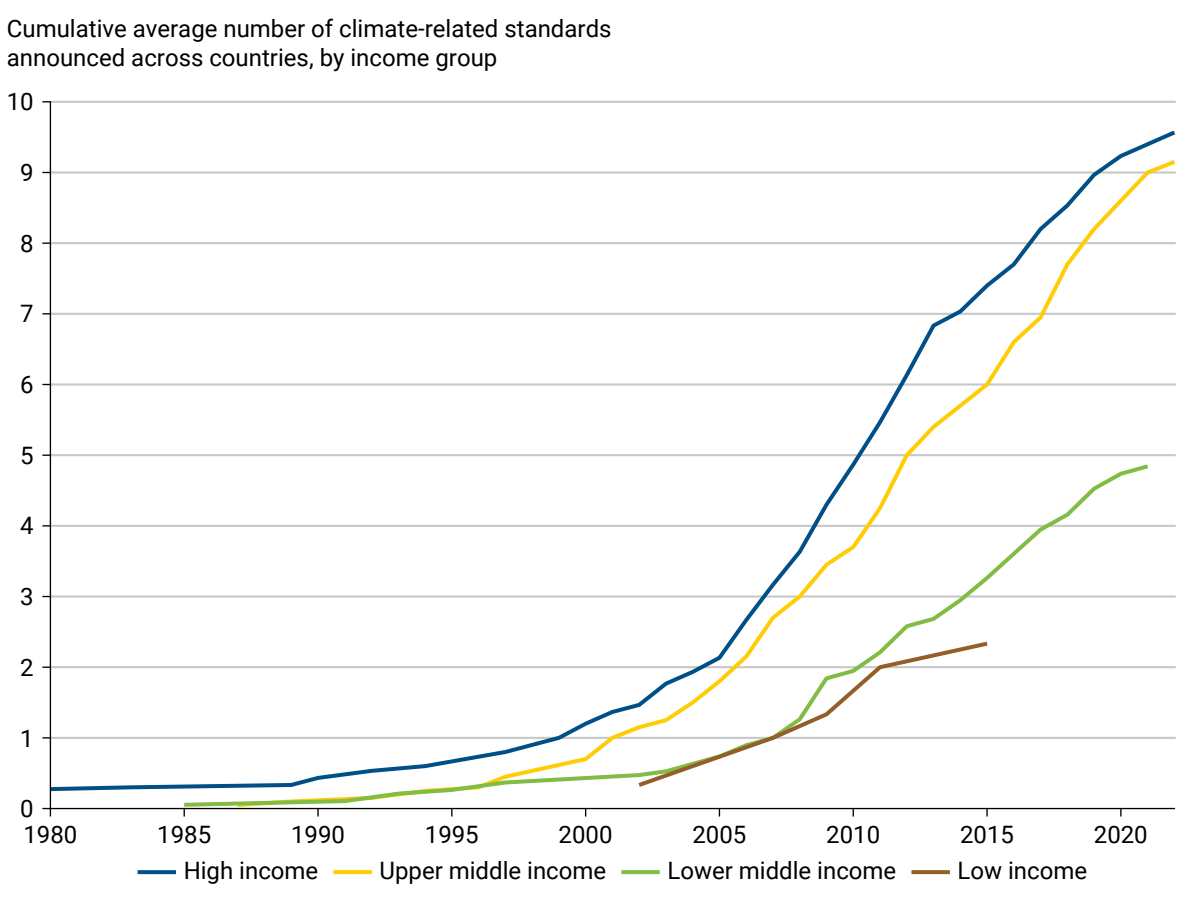
Compared with standards, carbon pricing directly addresses the externality of carbon emissions by making polluters pay for their emissions. It does not require regulators to have private information about firms' abatement costs, because firms can choose their preferred strategy for abatement. As of 2025, instruments for carbon pricing covered 28 percent of global emissions, including 27 percent in high-income countries and 30 percent in middle-income countries. No low-income or lower-middle-income country has adopted such instruments to date (refer to figure 6.7). In addition, revenues from carbon pricing can be used to fund complementary policies, such as subsidies for implementation of low-carbon

technologies, to support a more equitable and effective transition to a green economy.

However, standards still play a critical role in climate change mitigation. Price signals alone may not be sufficient to induce change in all sectors. In the residential sector, for instance, information gaps, financing barriers, risk aversion, and behavioral inertia often constrain the adoption of energy-efficient technologies like heat pumps. Innovators also face uncertainty about future demand, which carbon pricing alone may not address. In such cases, standards can mandate action and help overcome failures in coordination, thereby enhancing the effectiveness of carbon pricing.[80]

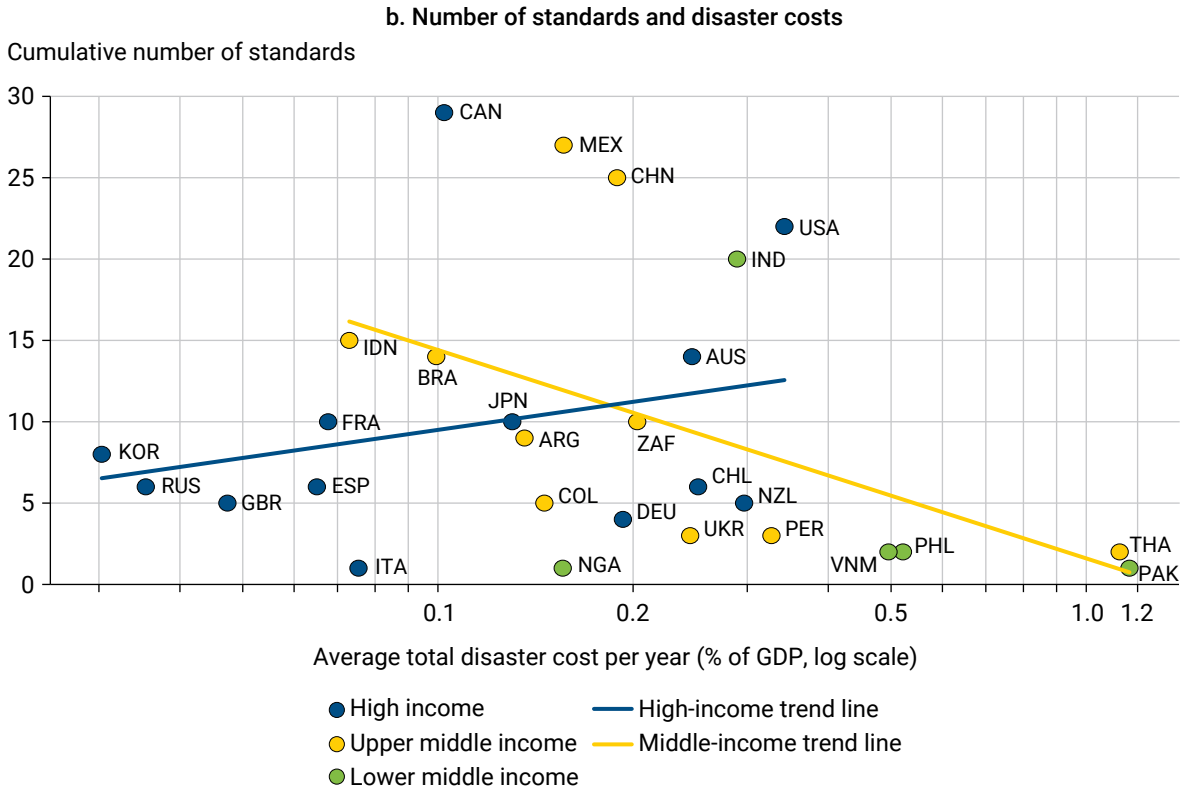
Figure 6.6 The number of climate-related standards has grown in higher-income countries, and disaster costs have affected that number more than in lower-income countries

a. Number of standards over time



(Figure continues next page)

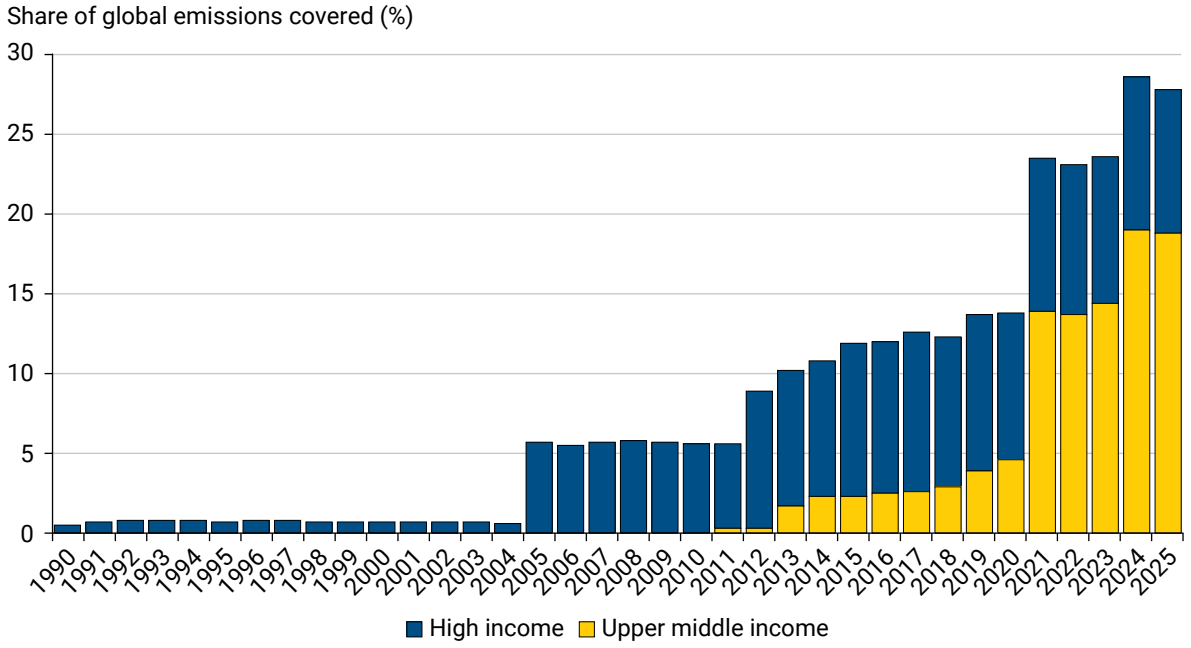
Figure 6.6 The number of climate-related standards has grown in higher-income countries, and disaster costs have affected that number more than in lower-income countries *(continued)*



Sources: WDR 2025 team elaboration, based on 2023 data from Climate Policy Database, NewClimate Institute for Climate Policy and Global Sustainability, https://newclimate.org/resources/tools/climate-policy-database; EM-DAT (International Disaster Database), Centre for Research on the Epidemiology of Disasters, Institute of Health and Society, Université Catholique de Louvain, https://www.emdat.be/.

Note: The Climate Policy Database is used to track the number of standards. The data on total disaster damage come from the EM-DAT database and include damage from meteorological, hydrological, and climatological disasters that occurred between 2010 and 2023. Panel b includes only countries for which data for cost of damage have been reported for at least five years. Accordingly, the analysis consists of 28 countries: 13 high-income countries and 15 middle-income countries. The income classification is based on World Bank Income Groups, 2023, Our World in Data, World Bank, https://archive.ourworldindata.org/20250624-125417/grapher/world-bank-income-groups.html. The solid lines in panel b represent fitted values using countries in the database. For the country labels used in the figure, refer to International Organization for Standardization, https://www.iso.org/obp/ui/#search (select "country codes").

Figure 6.7 Carbon pricing covers a growing share of global emissions of carbon in higher-income countries, but not in lower-income countries



Source: State and Trends of Carbon Pricing Dashboard, World Bank, https://carbonpricingdashboard.worldbank.org/compliance/price.

Note: No low- or lower-middle-income country has adopted carbon-pricing instruments to date.

Also, standards for measuring efforts to mitigate carbon are essential for ensuring credibility and unlocking financing for measures related to climate change adaptation. Markets for carbon credits allow firms in high-income countries to purchase credits generated from mitigation activities in low- and middle-income countries as a way of offsetting the firms' own emissions, potentially offering lower-cost pathways to reduce global emissions. However, the effectiveness of these markets hinges on accurately measuring the actual reductions in emissions achieved by the mitigation activities. Challenges such as *additionality* (when credits are awarded for activities that would have occurred anyway) and *leakage* (when emissions shift outside the boundaries of credited projects rather than actually being mitigated) can undermine their environmental integrity.[81] Standards that mandate third-party verification of reductions in emissions, supported by objective sources of data, can strengthen the credibility of market-based efforts to reduce emissions.

Tradable performance standards, a hybrid of market-based mechanisms and standards, have emerged as a policy tool for reducing carbon emissions while supporting domestic production, particularly in low- and middle-income countries. Unlike emissions-trading systems, which cap total emissions, tradable performance standards set intensity-based benchmarks (such as emissions per unit of output), allowing output to grow while providing incentives for lowering emissions even more than the benchmark requires. However, many programs of this type assign more lenient benchmarks to higher-emitting sources, effectively providing larger implicit subsidies to producers that pollute more heavily. Such a design

reduces the programs' cost-effectiveness and weakens incentives for adopting cleaner technologies. Complementary policies, such as targeted green subsidies, are often needed to correct these distortions and enhance the environmental integrity of tradable performance standard schemes.[82]

As with those for local pollution, policies for mitigating emissions can lead to emissions leakage when regulatory stringency differs across countries. However, because greenhouse gases are global pollutants, leakage is particularly damaging. Complementary policies can be designed to address emissions leakage. For example, when targeted at firms with a high risk of leakage, output-based subsidies help maintain the competitiveness of domestic industries while providing them with incentives for cleaner production under environmental regulations, which mitigates the risk of leakage of carbon emissions.[83] The European Union's Carbon Border Adjustment Mechanism, introduced in 2023, aims to prevent leakage of carbon emissions by charging fees on carbon-intensive imports from countries with regulations weaker than those in the importing countries. Evidence shows that this mechanism and a comparable one in the United Kingdom have increased domestic competitiveness and reduced leakage. And because exporters may prefer domestic carbon pricing to avoid border tariffs and retain revenue, such mechanisms have provided incentives for other countries to adopt stronger climate policies.[84] However, they may disproportionately burden low- and middle-income countries that have limited financial and technological capacities.[85]

Low- and middle-income countries: Standards that emphasize local cobenefits to encourage mitigation of emissions of greenhouse gases

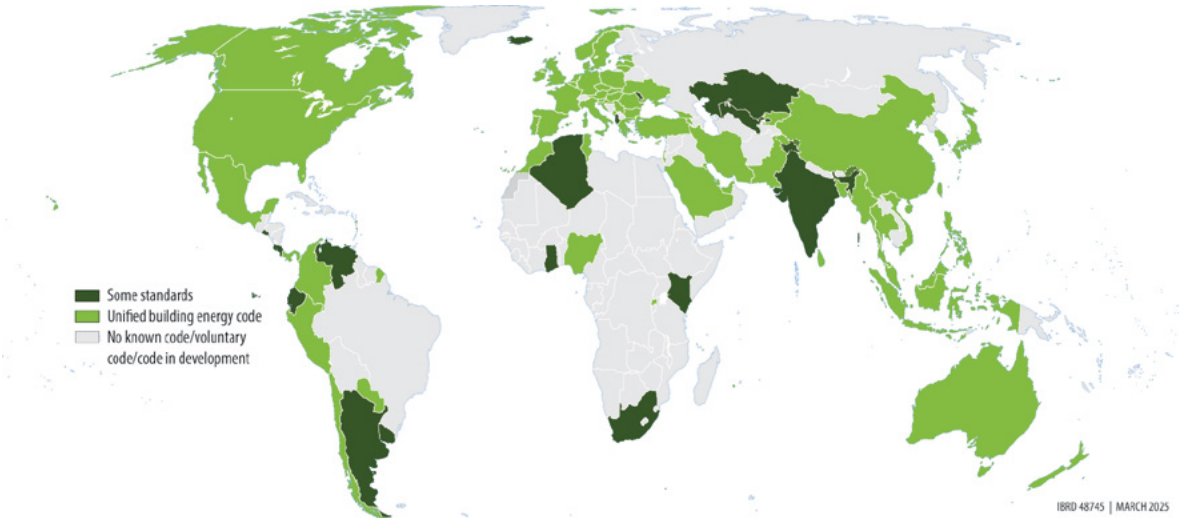
For low- and middle-income countries, economic growth is still the priority, and addressing global emissions of greenhouse gases may compromise that objective. However, standards that generate substantial local benefits may also generate climate cobenefits. These standards can serve as an entry point from which low- and middle-income countries can engage in global efforts to combat climate change.

Standards targeting local pollution can deliver climate cobenefits when they reduce reliance on fossil fuels. Electricity generation contributes about one-seventh of harmful air pollution and 40 percent of climate impacts globally. Phasing out coal as a fuel for generating electricity, for example, improves air quality while cutting emissions of carbon dioxide.[86] Similarly, energy efficiency standards, especially for buildings, which account for 34 percent of global emissions of carbon dioxide, can curb emissions as urbanization drives energy demand, particularly in emerging market economies.[87]

Energy codes for buildings are among the most effective policy tools for reducing emissions in the construction sector. Efficient buildings could yield more than US$1 trillion in savings in energy costs by 2050, the International Energy Agency (IEA) estimates.[88] In the European Union, buildings constructed under modern codes consume about half the energy of those built before such regulations, with even greater improvements seen in some countries.[89] Each dollar invested in building efficiency typically delivers a return of three dollars in lifetime savings, along with cobenefits such as improved health outcomes and enhanced energy security.[90]

As of 2025, 88 countries have energy codes for buildings, but only 52 enforce them consistently, reducing energy savings by up to 70 percent from their potential (refer to map 6.2).[91] Enforcement is strongest in high-income countries, with lower compliance in middle- and lower-income countries as a result of limited capacity. Closing this gap requires aligning codes with broader regulations and strengthening institutional support through technical assistance, training, and financial incentives, especially for households and small businesses in lower-income countries.

Map 6.2 Many low- and middle-income countries have not adopted strong energy codes for buildings



Source: 2025 data from Building Green (global data set), Global Indicators Group, World Bank, https://www.worldbank.org/en/building-green.

Standards for adaptation to climate change

Disaster-related losses are rising rapidly, fueled by growing climate risks and intensified by urbanization. In 2023 alone, global disasters resulted in more than 86,000 fatalities and more than US$200 billion in economic damages.[92] Although wealthier countries are typically the largest emitters of greenhouse gases, poorer countries bear the brunt of the impacts of climate change and suffer more severe consequences from it. In this context, low- and middle-income countries have a particularly pressing need for climate change adaptation.

Despite the urgency, regulating adaptation is challenging because it is context specific and measuring outcomes to attract investment is difficult (refer to box 6.4). In addition, private capital alone is often insufficient to finance needs related to climate change adaptation because high-risk areas, where adaptation is most needed, tend to deter investors or require high returns to motivate them to invest. In Brazil, regulations requiring banks to hold additional capital for loans directed toward activities that present greater climate risk have led banks to reduce lending to vulnerable sectors.[93] Because adaptation also requires significant investments in large-scale infrastructure, public funding is essential. This section explores how standards can support climate change adaptation.

Box 6.4 The importance of standards in increasing financing for climate change adaptation

Access to financing, particularly credit for investments in measures for adaptation to climate change, has been shown to support such adaptation in low- and middle-income countries.[a] However, providing such finance, whereby institutions or individuals backstop loans contingent on the returns to adaptation measures, depends on the ability to measure those returns. Mitigation is easier to measure because it is tracked through emissions reductions. In contrast, measuring adaptation is more challenging owing to its context-specific outcomes and difficulty in quantification. Even when investments for the purpose of adaptation reduce long-term climate risks, it remains challenging for private investors to reflect these benefits in pricing because of the lack of clear, quantifiable metrics and the difficulty of attributing the results of such investments to mitigation of potential future losses. Thus, the lack of reliable measurement remains a major barrier to financing climate change adaptation.

Currently, nearly all funding related to climate change continues to finance mitigation rather than adaptation. Of the US$1.27 trillion in climate-change-related finance disbursed in 2021/22, 91 percent supported mitigation, and only 5 percent (US$63 billion) went to adaptation and 4 percent to initiatives for the dual purposes of mitigation and adaptation.[b] This distribution stands in contrast to low- and middle-income countries' self-reported needs: Adaptation accounts for about 20 percent of funding requirements.[c] Financial institutions need to participate more broadly in financing investments in climate change adaptation to address the growing demand for adaptation financing.

Standards can play a key role in addressing needs for financing climate change adaptation by offering a consistent framework grounded in expert knowledge for guiding and assessing adaptation strategies. In 2019, the International Organization for Standardization (ISO) released ISO 14090, which provides principles, requirements, and guidelines for organizations to use in identifying risks from climate change and developing adaptation plans. In 2024, the Climate Bonds Initiative introduced its first adaptation and resilience taxonomy, identifying 1,444 investments across sectors for addressing various climate hazards that are eligible for financing under the initiative.[d] Green taxonomies—frameworks that define what constitutes "green" or sustainable activities—have expanded significantly in recent years. By 2024, the European Union had issued 47 such taxonomies, other jurisdictions 20, and international organizations several to help direct finance toward investments aligned with adaptation to climate change.[e]

(Box continues next page)

Box 6.4 The importance of standards in increasing financing for climate change adaptation *(continued)*

However, translating these frameworks into practical decision-making remains difficult. For example, Mexico's sustainable taxonomy incorporates adaptation as a core pillar alongside mitigation and social inclusion. A pilot involving 10 financial institutions revealed that only 3 percent of their operations could be clearly classified as aligned with adaptation, underscoring the complexity of implementation, especially when criteria require detailed and localized data.

Source: WDR 2025 team.

a. Berg et al. (2025); Bryan et al. (2009); Da Mata and Resende (2020); Lane (2024).
b. CPI and GCA (2023).
c. Isah et al. (2025).
d. Azizuddin (2024).
e. SBFN (2024).

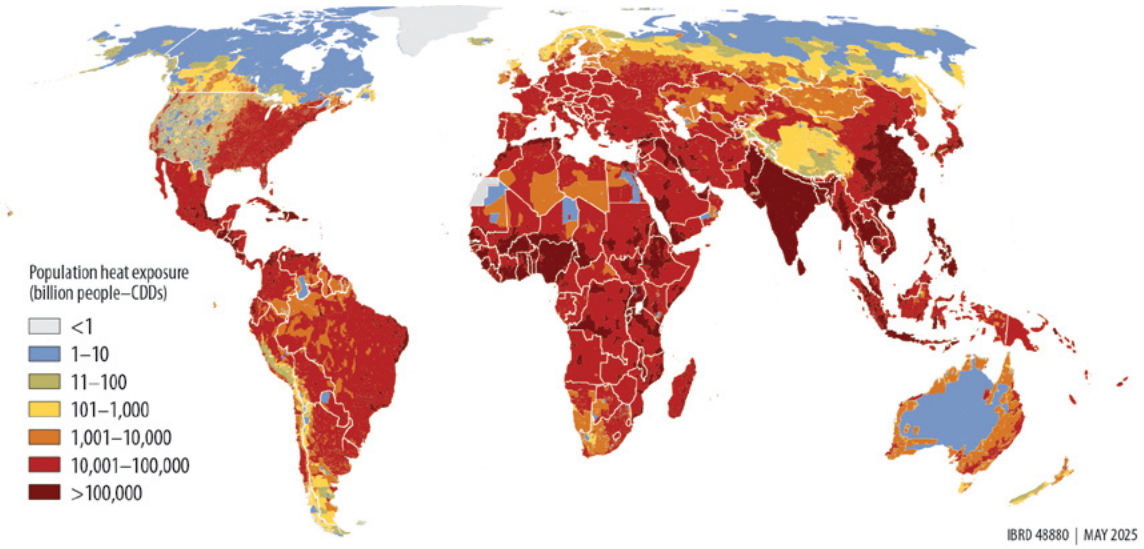
Standards for expanding access to solutions to adapt to climate change: Coping with extreme heat

Today, more than 70 percent of the global workforce—approximately 2.4 billion people—faces high risks from heat stress, resulting in millions of injuries and thousands of deaths each year.[94] Despite widespread exposure to extreme heat, particularly in low- and middle-income countries (refer to map 6.3), the penetration of air conditioning, a widely used adaptation strategy, remains below 10 percent in many low-income countries. To support climate change adaptation as a basic human need, standards that address market failures in adaptation must also focus on equitable access to effective solutions for cooling.

Cooling technologies generally fall into two categories: active and passive. Active cooling involves electricity-powered systems such as fans and air conditioners, whereas passive cooling relies on design strategies, such as natural ventilation and shading, that harness local environmental resources at low operating costs.[95] The two technologies complement one another but involve trade-offs. An integrated strategy that promotes access to both can help standards more effectively expand access to cooling options and address these trade-offs.

Active cooling, especially with air conditioning, is highly effective across various climates but is energy intensive, currently accounting for about 20 percent of electricity use globally.[96] As adoption rises, it will place an increasing strain on power grids and may contribute to outages. Energy efficiency standards can help ease this burden (refer to box 6.5). Moreover, emissions from cooling could reach about 6 billion tonnes of carbon dioxide equivalent by 2050, more than 10 percent of projected global emissions.[97] Thus, standards must carefully balance climate change mitigation and adaptation goals, ensuring energy efficiency while promoting equitable access to cooling.

Map 6.3 Exposure to extreme heat is widespread, especially in low- and middle-income countries



Sources: Global 1-km Downscaled Population Base Year and Projection Grids Based on the Shared Socioeconomic Pathways, Revision 01 (data portal), National Aeronautics and Space Administration, https://data.nasa.gov/dataset/global-1-km-downscaled-population-base-year-and-projection-grids-based-on-the-shared-socio; Lizana et al. 2024.

Note: The map shows the heat-exposed population in 2030, measured as billion people-cooling degree days (CDDs), for a global mean temperature rise of 1.5° Celsius.

Box 6.5 Using standards to meet the increasing demand for electricity

Reliable access to electricity is essential to both economic growth and adaptation to climate change, particularly in response to extreme heat. Energy efficiency standards for common appliances play a critical role in curbing demand in this context. They help mitigate carbon emissions, which are often unaccounted for at the point of purchase, especially in countries that still largely generate electricity from fossil fuels. In addition, by reducing energy demand, these standards ease pressure on the power grid, alleviating congestion and power outages, which in turn enable broader and more equitable access to electricity.

However, in many low- and middle-income countries, where credit constraints are widespread, implementing energy efficiency standards can present trade-offs. Energy-efficient appliances typically have higher up-front costs, even though they offer long-term savings through reduced consumption of electricity (refer to table B6.5.1). These higher initial costs can present a barrier for many households, preventing them from reaping long-term

(Box continues next page)

Box 6.5 Using standards to meet the increasing demand for electricity *(continued)*

financial and energy benefits. Policies complementing energy efficiency standards, such as targeted subsidies or financing options for low-income households, can boost the adoption of energy-efficient appliances.[a]

Table B6.5.1 Energy-efficient appliances typically offer long-term savings but have higher up-front costs

APPLIANCE	COUNTRY	TYPE[a]	INITIAL COST (US$)	ANNUAL ELECTRICITY USAGE (kWh)	ANNUAL ELECTRICITY COST (US$)	AVERAGE LIFE CYCLE (YEARS)	TOTAL COST OVER 10 YEARS (US$)[a]
Fan	India	Energy efficient	44	22	2	7	**80**
		Regular	27	60	5	3	135
	Nigeria	Energy efficient	25	36	1	4	**74**
		Regular	20	120	4	2	140
	United States	Energy efficient	140	12	2	8	197
		Regular	30	24	4	5	**103**
Refrigerator	India	Energy efficient	289	526	39	10	**683**
		Regular	197	876	66	8	903
	Nigeria	Energy efficient	262	438	14	12	**363**
		Regular	121	1,051	35	10	468
	United States	Energy efficient	800	876	158	12	**2,243**
		Regular	500	1,314	237	10	2,865

Source: WDR 2025 team.

Note: This table assumes the following usage patterns: for fans, 8 hours per day for 100 days per year in India, 250 days in Nigeria, and 50 days in the United States; for refrigerators, continuous operation. Energy-efficient models are assumed to meet or exceed Energy Star standards or their equivalent. Initial costs are based on the average market prices in 2025 for basic models. Electricity costs are estimated to be US$0.075 per kilowatt-hour (kWH) in India, US$0.033 per kWh in Nigeria, and US$0.18 per kWh in the United States. Unreliable electricity grids could further reduce appliance lifespan (Akpojedje 2017).

a. The lower-cost option over the 10-year life of the appliance appears in boldface in the final column.

(Box continues next page)

Box 6.5 Using standards to meet the increasing demand for electricity *(continued)*

In addition, improvements in energy efficiency often involve trade-offs with other product attributes, highlighting the importance of an integrated approach that balances multiple objectives.[b] These trade-offs can be addressed through sound technical evidence, broad stakeholder consensus, and regulatory coordination grounded in international standards. For example, International Organization for Standardization standard 817, shaped significantly by Japan, provides harmonized safety classifications for refrigerants with low potential for contributing to global warming. This standard has allowed manufacturers to bring more climate-friendly cooling solutions to market while maintaining safety and regulatory acceptance across jurisdictions.

On the supply side, standards can enhance the reliability of energy supply by fostering coordination across the supply chain and ensuring the quality of production and operations. For example, technical standards on voltage and frequency enable different generators and transmission systems to operate seamlessly within and across countries, facilitating electricity trade across regions and strengthening resilience. Likewise, quality standards for transformers and cables, along with guidelines for the operation and maintenance of transmission lines, help ensure the reliability of the energy supply.

Source: WDR 2025 team.

a. Taylor et al. (2008).
b. Gerarden et al. (2017).

Passive cooling does not rely on electricity and involves lower operating costs. However, its effectiveness and cost-efficiency are highly localized, depending on microclimatic conditions, architectural norms, and cultural practices. As a result, it is difficult to regulate passive cooling through specific technology or performance standards.

Instead, building codes that integrate minimum energy performance standards while incorporating passive strategies for cooling can support energy efficiency in active cooling while promoting passive approaches at the design stage.[98] This could lower the overall cost of cooling technologies and expand households' access to them. As of May 2023, 42 percent of countries, including both high- and low- and middle-income countries, had implemented minimum energy performance standards for space cooling.[99] Evidence from India, Indonesia, and Nigeria shows that doubling the energy efficiency of room air conditioners by 2030 could reduce their life-cycle costs by 60 percent and provide an additional 320 million people with access to them by 2050.[100] Combining minimum energy performance standards with building codes allows for flexible, context-specific solutions aligned with local climate and housing conditions.

In addition to promoting access to adaptation solutions such as active and passive technologies for cooling, standards can also support emergency response measures to ensure basic access to essential resources during extreme events. For example, the city of Ahmedabad in India was one of the first in South Asia to implement a heat action plan.[101]

During periods of extreme heat, the city uses localized thresholds for temperature to activate a set of responses, including emergency hotlines, public advisories, outreach to vulnerable populations, and the provision of cooling shelters and drinking water.[102]

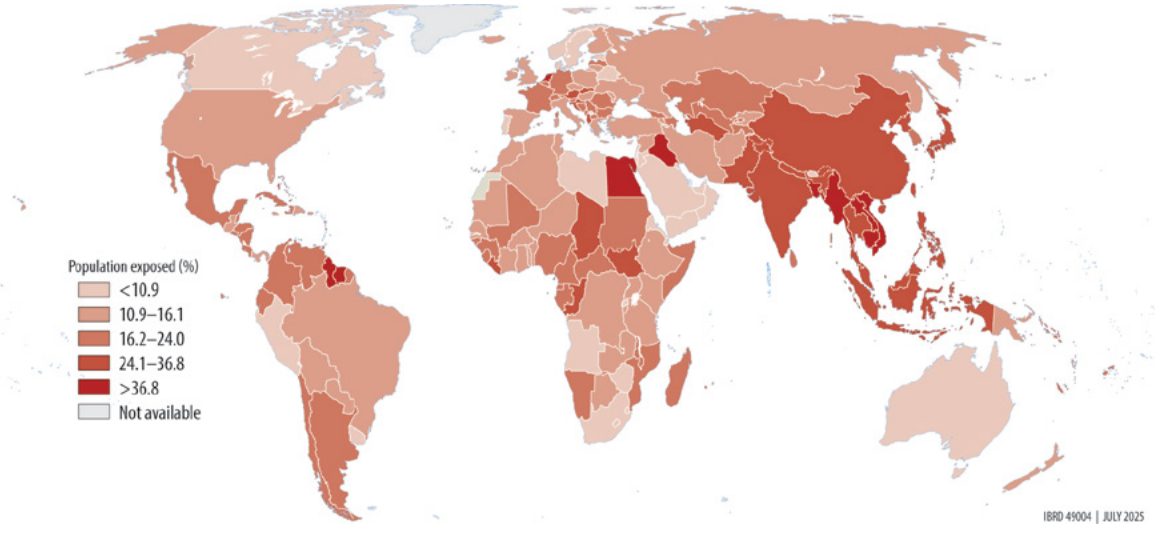
Standards for fostering coordination: Enhancing flood resilience

Some 1.81 billion people, or 23 percent of the global population, live in areas exposed to significant risks of flooding (refer to map 6.4). Despite growing risks of flooding as a result of climate change, human settlements have continued to expand rapidly into flood-prone areas, often at a faster pace than into safer zones across many regions.[103] Globally, nearly 1 billion people live in substandard housing with inadequate sanitation and stormwater drainage, further compounding their vulnerability. Because urban planning, infrastructure quality, and individual building design all shape flood risk, enhancing resilience requires coordinated efforts across all levels.

Urban planning

To reduce exposure to flood hazards, urban planning must integrate considerations related to risks from climate change. Zoning standards can prohibit construction in areas that are highly prone to floods by defining hazard thresholds. Also, uncontrolled urban sprawl, especially where green spaces are scarce, can exacerbate flood risks and disproportionately affect low-income households, which often reside in high-risk zones. In Dhaka, Bangladesh, for example, slums are concentrated in flood-prone areas.[104] Implementing zoning regulations that require buffer zones or protective greenbelts can mitigate risks of flooding. In addition, early warning systems can be established to provide timely alerts, and homebuyers can be provided with information on flood risks to enable them to make informed decisions, both helping to mitigate flood-related losses.[105]

Map 6.4 Nearly one-quarter of the world's population is exposed to at least medium-level risks of flooding



Source: Rentschler et al. 2022.
Note: The map shows risks at the subnational level.

Infrastructure

With climate change intensifying natural hazards, standards for new and existing infrastructure must evolve accordingly.[106] For example, increased variability in rainfall levels, with alternating periods of dryness and drenching rains, can make peak river flows higher and overwhelm dams. Overtopping, the most common cause of dam failure, occurs when water exceeds the capacity of spillways. In Libya, devastating dam failures during extreme flooding in September 2023 destroyed entire neighborhoods and claimed more than 4,000 lives, highlighting the urgent need for reviewing and strengthening national standards for designing dams so that they take climate change into account.

International bodies like the International Commission on Large Dams (ICOLD) play a key role in shaping global practices regarding dam safety by leveraging member expertise and promoting knowledge sharing. As of 2025, ICOLD had 106 member countries, many of which align their national regulations with its guidance. In countries without formal guidelines for dam safety, a common situation in low- and middle-income settings, practitioners often rely directly on ICOLD standards. Development partners such as the World Bank also promote international good practices through project financing and advisory support.

At the same time, infrastructure such as dams can help manage flood risks. For example, Poland's Racibórz Dolny Flood Protection Reservoir reduced downstream peaks during a major 2024 flood, protecting more than 2.5 million people from severe damage. Yet only 18 percent of large dams globally are designated for flood control.[107] With more than 60,000 large dams worldwide, many more than 50 years old, there is an opportunity for rehabilitation, retrofitting, and reoperation to strengthen their role in climate change adaptation. These investments can generate substantial public benefits and may require public financing to ensure regional resilience.

Buildings

Beyond planning and infrastructure, building design could also play a pivotal role in increasing resilience to floods. In the US state of Florida, updated building codes that incorporate risks of disasters have measurably reduced hurricane-related damages, saving an estimated US$911 million annually.[108] In low-income settings, however, modern building codes designed for high-income countries are not always the best choice. In Pakistan, bamboo homes largely withstood the historic 2022 floods that destroyed more than 2 million houses, mostly of other constructions. This example highlights the importance of locally appropriate and culturally relevant building standards for resilience.

International efforts such as the World Bank's Building Regulation for Resilience Program[109] can support countries by sharing knowledge, offering technical assistance, and providing financial resources. In Japan, where seismic risk is high, investments in earthquake-resistant infrastructure have saved an estimated US$2.2 billion annually in avoided reconstruction costs. Japan has also contributed globally by sharing its technical expertise and experience through international initiatives.

However, building codes may involve trade-offs between competing priorities. For example, compliance with building codes can increase construction costs, which may in turn affect housing affordability.[110] Also, pursuing energy efficiency may, in some cases, raise safety concerns. As a cautionary example, in Mexico City, a seven-story building retrofitted solely for energy efficiency partly collapsed during the 2017 earthquake.[111] This example highlights the need for integrated building codes that balance objectives relating to climate change mitigation and adaptation against those that pertain to maintaining resilience to other challenges and preserving affordability.

Recommendations for standards for a better environment

Emphasize the broader benefits of environmental standards. Countries, especially low- and middle-income countries, should not view environmental standards as separate from growth goals. Pollution reduction yields broad benefits, including increasing productivity,[112] human capital,[113] and housing values and attracting talent.[114] Integrating standards with green industrial policies may give countries the opportunity to leapfrog polluting technologies and pursue green growth in sectors like energy and transport.[115] Overlooking these benefits risks underusing environmental standards.

- At the firm level, for instance, a study in Bangladesh found that installing air purifiers in randomly selected firms not only reduced indoor concentrations of $PM_{2.5}$ by 15 percent but also delivered significant economic returns: boosting daily labor productivity by 10 percent and monthly profits by 18 percent, compared with those in control firms without air purifiers.[116]
- At the economy level, China's push for electric vehicles—driven by strict air quality standards and green industrial policies—has cut pollution and emissions[117] while enabling the country to leapfrog traditional auto leaders. By 2023, China was the overwhelming market leader in global sales of electric vehicles.[118]

Design standards in a policy mix to achieve goals related to emissions reduction effectively. Standards are often more effective than market-based instruments, such as emissions pricing, when specific reductions are needed to meet environmental or public health thresholds. However, when multiple market failures are present, relying on a single policy may be insufficient. Complementary policies can strengthen the overall effectiveness of standards by addressing different market failures simultaneously, enabling countries to take a more comprehensive and efficient approach to reducing emissions.

- The compliance costs associated with water quality standards can decline over time through learning by doing, economies of scale, and innovations in water treatment technologies. However, such advancements may be underprovided in the absence of supportive policies, which justifies public investment.[119] In the United States, for instance, grants for building infrastructure for wastewater treatment under the Clean Water Act have been shown to reduce compliance costs for polluters and decrease the likelihood of violations of water quality standards by 0.5 percentage point per grant.[120]

Adapt standards to local contexts while taking potential leakage of emissions into account. Countries should tailor environmental standards to local environmental challenges, economic conditions, technological readiness, and enforcement capacity. A careful analysis of the costs and benefits of setting standards and of firms' capacity to comply with any standards that are set will help countries develop and enact more effective standards that are sensitive to context. However, different standards across regions and sectors may result in emissions leakage. When this leads to negative environmental outcomes, well-designed unilateral measures or coordinated international efforts could help mitigate and compensate for these losses.

- The European Union, for instance, addresses transboundary water pollution primarily through the Water Framework Directive, which mandates integrated management of river basins and cross-border cooperation to achieve "good status" for all water bodies. Policies under the directive have improved

water quality in major rivers shared by multiple countries like the Rhine and Danube and fostered strong cross-country coordination.[121]

Meet future demand and drive innovation through forward-looking standards. Standards can have long-lasting impacts, especially when applied to long-lived assets. For instance, coal-fired power plants can operate for 30–50 years, creating lock-in effects that delay the transition to cleaner alternatives. In a fast-evolving world, standards need to be forward looking to meet future demand and support the development of emerging technologies. Specifically, standards should be evaluated from a longer time horizon, not just contemporaneously, to take future demand into consideration. Also, when technologies are rapidly advancing, standards should be flexible enough to enable and encourage innovation.

- Active cooling, particularly through air conditioning, is a highly effective way to adapt to extreme heat but remains energy intensive. As adoption increases, it will increasingly strain power grids, especially in regions with limited electricity infrastructure. In Nigeria, for instance, the federal government approved new minimum energy performance standards for air conditioners in 2025. The standards aim to save 11.5 terawatt-hours of electricity annually and reduce carbon emissions by 39 million tonnes of carbon dioxide by 2040.[122]
- The introduction of an emissions standard for automobiles across the European Union that limits sales-weighted emissions of carbon dioxide across manufacturers' fleets has been shown to have given firms incentives to invest significantly in new technologies to meet compliance requirements. As a result, average vehicle efficiency in regard to emissions of carbon dioxide improved by approximately 14 percent from 2007 to 2011, leading to lower fuel costs over the lifetime of vehicles.[123]

Enhance and leverage monitoring and measurement infrastructure. Expanding and improving systems for environmental monitoring, particularly in areas with limited infrastructure, is crucial for identifying environmental challenges, enhancing the enforcement of standards, and ensuring accountability. Data collected from such systems can be further leveraged through public information campaigns to raise awareness of local pollution and promote adaptive behavior. Furthermore, accessible infrastructure for monitoring and measurement standards allow independent third-party verification of claims that emissions have been reduced, which is crucial for maintaining the credibility and effectiveness of climate-change-related initiatives such as carbon credit markets.

- In 2013, China launched a nationwide initiative regarding air quality monitoring that began providing real-time data on pollution to the public through daily newspapers and other media outlets. Increased access to information spurred widespread behavioral adaptations, such as increased investment in air purifiers, which are estimated to generate a minimum of US$13 billion in annual health benefits.[124]
- A recent study in Colombia evaluated carbon credit projects using satellite-based images to measure forest cover and found that natural forest cover increased by 4 percentage points over 12 years.[125] Evaluations of this type are possible only with publicly available data on land cover and emissions monitoring.

As these examples and recommendations show, a balanced, forward-looking, and context-specific approach to environmental standards, making good use of complementary policies, can yield powerful results.

Notes

1. Greenstone et al. (2024); Tanaka (2015).
2. Chang et al. (2019); Graff Zivin and Neidell (2012); Ortiz-Bobea et al. (2021); Shaddick et al. (2020).
3. IPCC (2021).
4. Shaddick et al. (2020).
5. Greenstone et al. (2024).
6. Weitzman (1974).
7. Greenstone et al. (2025).
8. Jacobsen et al. (2023).
9. Li et al. (2024).
10. Jha and La Nauze (2022).
11. Buntaine et al. (2024).
12. Oliva (2015); Sundström (2013); Williams and Dupuy (2017).
13. He et al. (2020).
14. For analytical purposes, this Report measures state capacity using the Worldwide Governance Indicators, which reflect broad perceptions of governance quality. Refer to Worldwide Governance Indicators (dashboard), World Bank, https://www.worldbank.org/en/publication/worldwide-governance-indicators.
15. Duflo et al. (2018). Given the current inspection rate in Gujarat, India, the inspections chosen by the regulator have been shown to induce three times more abatement than would the same number of randomly assigned inspections.
16. Lipscomb and Mobarak (2016).
17. Greenstone et al. (2022).
18. Axbard and Deng (2024).
19. Buntaine et al. (2024); Jha and La Nauze (2022).
20. Yang et al. (2024).
21. Kahn et al. (2015).
22. Chen et al. (2024).
23. UNECE et al. (2024).
24. Ambec (2025).
25. Ambec and Lanoie (2008). ISO 14001 certification validates that an organization meets the internationally recognized standard for environmental management, ISO 14001.
26. Heilmayr and Lambin (2016); Jyväsjärvi et al. (2020); Zwerts et al. (2024).
27. Barla (2007); Blackman et al. (2018); Vidovic and Khanna (2007).
28. Greenstone and Hanna (2014); Greenstone et al. (2021); Isen et al. (2017); Keiser and Shapiro (2019).
29. Isen et al. (2017).
30. Auffhammer et al. (2009).
31. Greenstone et al. (2021).
32. Dechezleprêtre and Sato (2017).
33. Fowlie et al. (2016).
34. Lyubich et al. (2018); Su et al. (2022).
35. OECD (2021).
36. Porter and van der Linde (1995).
37. Lu and Pless (2024).
38. Rodrik (2014); World Bank (2024).
39. Hsieh et al. (2022).
40. IEA (2024a).
41. Chang et al. (2019); Graff Zivin and Neidell (2012).
42. Lavy et al. (2014).
43. Isen et al. (2017).
44. Behrer et al. (2023); Chay and Greenstone (2005).
45. Chen et al. (2022).
46. Houssini et al. (2025).
47. Li and Song (2024).
48. Davis and Kahn (2010).
49. Gechter and Kala (2025).
50. Zhang and Zhao (2023).
51. Tanaka et al. (2022).
52. Okello et al. (2018).
53. Baylis et al. (2024); Ito and Zhang (2020).
54. Oliva (2015).
55. Jacobsen et al. (2023).
56. Greenstone and Hanna (2014).
57. Kellogg (2018).
58. Tang et al. (2019).
59. Mahalana et al. (2022).
60. Cieply and Wang (2025); Reynaert (2021); Rozendaal and Vollebergh (2025).
61. Gowrisankaran et al. (2025).
62. Greenstone and Nath (2024).
63. Nazar et al. (2021).
64. Greenstone et al. (2012).
65. He et al. (2020).
66. Colmer et al. (2024).
67. Khan et al. (2023).
68. Luo et al. (2021).
69. IEA (2024b).
70. Du et al. (2025).
71. Bento et al. (2020); Jacobsen (2013); Jacobsen et al. (2023).
72. Kaza et al. (2018); Kaza et al. (2021).
73. Ritchie (2023).
74. UNEP (2024).
75. O'Neill and Moon (2025).
76. World Bank (2021).
77. Ley et al. (2000).
78. Ge et al. (2024).
79. Aklin and Urpelainen (2018).
80. IMF et al. (2024).
81. Calel et al. (2025); Filewod and McCarney (2023).
82. Fischer et al. (2024).
83. Fowlie and Reguant (2022).
84. Clausing et al. (2025); Fischer and Fox (2012).
85. Böhringer et al. (2018).
86. Tong et al. (2021); Trencher et al. (2022); Wang et al. (2021).
87. IEA (2023); UNEP (2025).
88. IEA (2019).
89. Liu et al. (2010).
90. Refer to "Rules of Thumb" (tables), State and Local Climate and Energy Program, US Environmental Protection Agency, https://archive.epa.gov/epa/sites/production/files/2016-03/documents/table_rules_of_thumb.pdf.
91. World Bank (2025).
92. CRED (2024).
93. Aguilar-Gómez et al. (2024); Miguel et al. (2024).
94. ILO (2024).

95. Antinucci et al. (1992); Nghlovu (2020).
96. UNEP (2023a).
97. UNEP (2023a).
98. Khosla (2025).
99. UNEP (2023b).
100. CLASP (2025).
101. Knowlton et al. (2014).
102. Casanueva et al. (2019).
103. Rentschler et al. (2023).
104. Shilpi et al. (2025).
105. Burlig et al. (2025); Fairweather et al. (2024).
106. Hallegatte et al. (2019).
107. Refer to World Register of Dams: General Synthesis (portal), International Commission on Large Dams (accessed April 29, 2025), https://www.icold-cigb.org/GB/world_register/general_synthesis.asp.
108. FEMA (2020).
109. The Building Regulation for Resilience Program supports cities, states, and countries in strengthening building regulations, control processes, and implementation capacity to create safer, greener, and more inclusive built environments. It provides technical assistance to help governments advance regulatory, policy, and institutional reforms and increase compliance. For more information, refer to Building Regulation for Resilience (portal), Global Facility for Disaster Reduction and Recovery, World Bank, https://www.gfdrr.org/en/building-regulation-for-resilience.
110. Glaeser and Gyourko (2003).
111. Margani et al. (2020).
112. Chang et al. (2019); Graff Zivin and Neidell (2012).
113. Isen et al. (2017); Lavy et al. (2014).
114. Chen et al. (2022).
115. Rodrik (2014); World Bank (2024).
116. Garg and Jagnani (2025).
117. Hsieh et al. (2022).
118. IEA (2024a).
119. Keiser and Shapiro (2019); Olmstead (2010).
120. Keiser and Shapiro (2019).
121. ICPDR (2021).
122. UNEP (2023c).
123. Reynaert (2021).
124. Barwick et al. (2024).
125. Bruhn et al. (forthcoming).

References

Aguilar-Gómez, Sandra, Emilio Gutiérrez, David Heres, David Jaume, and Martin Tobal. 2024. "Thermal Stress and Financial Distress: Extreme Temperatures and Firms' Loan Defaults in Mexico." *Journal of Development Economics* 168 (May): 103246.

Akesson, Jesper, Robert W. Hahn, Rajat Kochhar, and Robert D. Metcalfe. 2023. "Do Water Audits Work?" NBER Working Paper 31831, National Bureau of Economic Research. http://www.nber.org/papers/w31831.

Aklin, Michaël, and Johannes Urpelainen. 2018. *Renewables: The Politics of a Global Energy Transition*. MIT Press.

Akpojedje, France O. 2017. "Causes and Modelling of Power Losses on Electric Power Distributors and Its Effects on Household Appliances in the Nigerian Power Distribution Network." *International Journal of Innovative Science, Engineering, and Technology* 4 (6): 281–90.

Ambec, Stefan. 2025. "Using Standards to Promote Sustainable Development." Background paper prepared for *World Development Report 2025: Standards for Development*, World Bank. https://www.worldbank.org/en/publication/wdr2025/brief/world-development-report-2025-background-papers.

Ambec, Stefan, and Paul Lanoie. 2008. "Does It Pay to Be Green? A Systematic Overview." *Academy of Management Perspectives* 22 (4): 45–62.

Antinucci, Marcello, Bernard Fleury, David Asiain, et al. 1992. "Passive and Hybrid Cooling of Buildings: State of the Art." *International Journal of Solar Energy* 11 (3–4): 251–71.

Auffhammer, Maximilian, Antonio M. Bento, and Scott E. Lowe. 2009. "Measuring the Effects of the Clean Air Act Amendments on Ambient PM_{10} Concentrations: The Critical Importance of a Spatially Disaggregated Analysis." *Journal of Environmental Economics and Management* 58 (1): 15–26.

Axbard, Sebastian, and Zichen Deng. 2024. "Informed Enforcement: Lessons from Pollution Monitoring in China." *American Economic Journal: Applied Economics* 16 (1): 213–52.

Azizuddin, Khalid. 2024. "CBI Launches Resilience and Adaptation Taxonomy." *Responsible Investor: Taxonomy* (blog), September 25. https://www.responsible-investor.com/cbi-launches-resilience-and-adaptation-taxonomy/.

Barla, Philippe. 2007. "ISO 14001 Certification and Environmental Performance in Quebec's Pulp and Paper Industry." *Journal of Environmental Economics and Management* 53 (3): 291–306.

Barwick, Panle Jia, Shanjun Li, Liguo Lin, and Eric Yongchen Zou. 2024. "From Fog to Smog: The Value of Pollution Information." *American Economic Review* 114 (5): 1338–81.

Baylis, Patrick, Michael Greenstone, Kenneth Lee, and Harshil Sahai. 2024. "Is the Demand for Clean Air Too Low? Experimental Evidence from Delhi." Paper presented at the National Bureau of Economic Research's Environment and Energy Economics Program Meeting, Spring 2024, March 7–8.

Behrer, Arnold Patrick, Rishabh Choudhary, and Dhruv Sharma. 2023. "Air Pollution Reduces Economic Activity: Evidence from India." Policy Research Working Paper 10515, World Bank.

Bento, Antonio M., Mark R. Jacobsen, Christopher R. Knittel, and Arthur A. van Benthem. 2020. "Estimating the Costs and Benefits of Fuel-Economy Standards." *Environmental and Energy Policy and the Economy* 1 (1): 129–57.

Berg, Claudia N., Luca Bettarelli, Davide Furceri, et al. 2025. "Firm-Level Climate Change Adaptation: Micro Evidence from 134 Nations." Policy Research Working Paper 11081, World Bank.

Blackman, Allen, Leonard Goff, and Marisol Rivera Planter. 2018. "Does Eco-Certification Stem Tropical Deforestation? Forest Stewardship Council Certification in Mexico." *Journal of Environmental Economics and Management* 89 (May): 306–33.

Böhringer, Christoph, Jared C. Carbone, and Thomas F. Rutherford. 2018. "Embodied Carbon Tariffs." *Scandinavian Journal of Economics* 120 (1): 183–210.

Bourtsalas, A. C., Isabela Maria Yepes, and Yixi Tian. 2023. "U.S. Plastic Waste Exports: A State-by-State Analysis Pre- and Post-China Import Ban." *Journal of Environmental Management* 344 (October): 118604.

Brooks, Amy L., Shunli Wang, and Jenna R. Jambeck. 2018. "The Chinese Import Ban and Its Impact on Global Plastic Waste Trade." *Science Advances* 4 (6): eaat0131.

Bruhn, Miriam, Johan Andrey Ortega Hernandez, Alvaro Pedraza, and Claudia Ruiz-Ortega. Forthcoming. "Certification and Forest Outcomes: Lessons from Colombia's Carbon Credit Market." Development Research, World Bank.

Bryan, Elizabeth, Temesgen T. Deressa, Glwadys A. Gbetibouo, and Claudia Ringler. 2009. "Adaptation to Climate Change in Ethiopia and South Africa: Options and Constraints." *Environmental Science and Policy* 12 (4): 413–26.

Buntaine, Mark T., Michael Greenstone, Guojun He, Mengdi Liu, Shaoda Wang, and Bing Zhang. 2024. "Does the Squeaky Wheel Get More Grease? The Direct and Indirect Effects of Citizen Participation on Environmental Governance in China." *American Economic Review* 114 (3): 815–50.

Burlig, Fiona, Amir Jina, Erin M. Kelley, Gregory V. Lane, and Harshil Sahai. 2025. "The Value of Forecasts: Experimental Evidence from India." NBER Working Paper 32173, National Bureau of Economic Research. https://www.nber.org/papers/w32173.

Calel, Raphael, Jonathan M. Colmer, Antoine Dechezleprêtre, and Matthieu Glachant. 2025. "Do Carbon Offsets Offset Carbon?" *American Economic Journal: Applied Economics* 17 (1): 1–40.

Casanueva, Ana, Annkatrin Burgstall, Sven Kotlarski, et al. 2019. "Overview of Existing Heat-Health Warning Systems in Europe." *International Journal of Environmental Research and Public Health* 16 (15): 2657.

Chang, Tom Y., Joshua S. Graff Zivin, Tal Gross, and Matthew J. Neidell. 2019. "The Effect of Pollution on Worker Productivity: Evidence from Call Center Workers in China." *American Economic Journal: Applied Economics* 11 (1): 151–72.

Chay, Kenneth Y., and Michael Greenstone. 2005. "Does Air Quality Matter? Evidence from the Housing Market." *Journal of Political Economy* 113 (2): 376–424.

Chen, Jidong, Xnzheng Shi, Ming-ang Zhang, and Sihan Zhang. 2024. "Centralization of Environmental Administration and Air Pollution: Evidence from China." *Journal of Environmental Economics and Management* 126 (July): 103016.

Chen, Shuai, Paulina Oliva, and Peng Zhang. 2022. "The Effect of Air Pollution on Migration: Evidence from China." *Journal of Development Economics* 156 (May): 102833.

Cieply, Isea, and Feicheng Wang. 2025. "Does Pollution Control Foster Innovation? Quasi-Experimental Evidence from China's Two-Control Zone Policy." *Review of Development Economics* 29 (3): 1808–33.

CLASP. 2025. "World's Best MEPS: Tracking Leaders in Appliance Energy Efficiency Standards." June, CLASP. https://www.clasp.ngo/tools/worlds-best-meps/.

Clausing, Kimberly A., Johathan M. Colmer, Allan Hsiao, and Catherine Wolfram. 2025. "The Global Effects of Carbon Border Adjustment Mechanisms." NBER Working Paper 33723, National Bureau of Economic Research.

Colmer, Jonathan M., Eleanor Krause, Eva Lyubich, and John Voorheis. 2024. "Transitional Costs and the Decline of Coal: Worker-Level Evidence." Working Paper CES 24-53, Center for Economic Studies, US Census Bureau.

CPI (Climate Policy Initiative) and GCA (Global Center on Adaptation). 2023. "State and Trends in Climate Adaptation Finance 2023." Conference Version, CPI. https://www.climatepolicyinitiative.org/wp-content/uploads/2023/12/State-and-Trends-in-Climate-Adaptation-Finance-2023_.pdf.

CRED (Centre for Research on the Epidemiology of Disasters). 2024. "2023 Disasters in Numbers: A Significant Year of Disaster Impact." CRED, Institute of Health and Society, Université Catholique de Louvain.

Da Mata, Daniel, and Guilherme Mendes Resende. 2020. "Changing the Climate for Banking: The Economic Effects of Credit in a Climate-Vulnerable Area." *Journal of Development Economics* 146 (September): 102459.

Davis, Lucas W., and Matthew E. Kahn. 2010. "International Trade in Used Vehicles: The Environmental Consequences of NAFTA." *American Economic Journal: Economic Policy* 2 (4): 58–82.

Dechezleprêtre, Antoine, and Misato Sato. 2017. "The Impacts of Environmental Regulations on Competitiveness." *Review of Environmental Economics and Policy* 11 (2): 183–206.

Di, Qian, Itai Kloog, Petros Koutrakis, Alexei Lyapustin, Yujie Wang, and Joel Schwartz. 2016. "Assessing $PM_{2.5}$ Exposures with High Spatiotemporal Resolution Across the Continental United States." *Environmental Science and Technology* 50 (9): 4712–21.

Du, Xinming, Devaki Ghose, and Ruozi Song. 2025. "Decarbonize or Relocate? Trading Stranded Assets After Coal Power Plant Closure." Paper presented at the Association of Environmental and Resource Economists Summer Conference, May 28–30.

Duflo, Esther, Michael Greenstone, Rohini P. Pande, and Nicholas Ryan. 2018. "The Value of Regulatory Discretion: Estimates from Environmental Inspections in India." *Econometrica* 86 (6): 2123–60.

Ebenstein, Avraham. 2012. "The Consequences of Industrialization: Evidence from Water Pollution and Digestive Cancers in China." *Review of Economics and Statistics* 94 (1): 186–201.

Fairweather, Daryl, Matthew E. Kahn, Robert D. Metcalfe, and Sebastian Sandoval Olascoaga. 2024. "Expecting Climate Change: A Nationwide Field Experiment in the Housing Market." NBER Working Paper 33119, National Bureau of Economic Research.

FEMA (Federal Emergency Management Agency). 2020. "Building Codes Save: A Nationwide Study; Losses Avoided as a Result of Adopting Hazard-Resistant Building Codes." FEMA, US Department of Homeland Security.

Filewod, Ben, and Geoff McCarney. 2023. "Avoiding Leakage from Nature-Based Offsets by Design." Working Paper 415, Centre for Climate Change Economics and Policy, University of Leeds and London School of Economics and Political Science.

Fischer, Carolyn, and Alan Keith Fox. 2012. "Comparing Policies to Combat Emissions Leakage: Border Carbon Adjustments Versus Rebates." *Journal of Environmental Economics and Management* 64 (2): 199–216.

Fischer, Carolyn, Chenfei Qu, and Lawrence H. Goulder. 2024. "Rate-Based Emissions Trading with Overlapping Policies: Insights from Theory and an Application to China." NBER Working Paper 33197, National Bureau of Economic Research.

Fowlie, Meredith L., and Mar Reguant. 2022. "Mitigating Emissions Leakage in Incomplete Carbon Markets." *Journal of the Association of Environmental and Resource Economists* 9 (2): 307–43.

Fowlie, Meredith L., Mar Reguant, and Stephen P. Ryan. 2016. "Market-Based Emissions Regulation and Industry Dynamics." *Journal of Political Economy* 124 (1): 249–302.

Fowlie, Meredith L., Edward A. Rubin, and Reed Walker. 2019. "Bringing Satellite-Based Air Quality Estimates Down to Earth." *AEA Papers and Proceedings* 109 (May): 283–88.

Garg, Teevrat, and Maulik Jagnani. 2025. "High Returns, Low Adoption: Air Purifiers in Bangladeshi Firms." Policy Brief BGD-20296, Sustainable Growth, Firms, and Energy, International Growth Centre. https://www.theigc.org/publications/high-returns-low-adoption-air-purifiers-bangladeshi-firms-0.

Gazze, Ludovica. 2024. "Hassles and Environmental Health Screenings: Evidence from Lead Tests in Illinois." *Journal of Human Resources* 59 (4): 1090–1121.

Ge, Mengpin, Johannes Friedrich, and Leandro Vigna. 2024. "Where Do Emissions Come From? 4 Charts Explain Greenhouse Gas Emissions by Sector." *World Resources Institute: Climate* (blog), December 5. https://www.wri.org/insights/4-charts-explain-greenhouse-gas-emissions-countries-and-sectors.

Gechter, Michael, and Namrata Kala. 2025. "Firm Presence, Pollution, and Agglomeration: Evidence from a Randomized Environmental Place-Based Policy." NBER Working Paper 33707, National Bureau of Economic Research.

Gerarden, Todd D., Richard G. Newell, and Robert Norman Stavins. 2017. "Assessing the Energy-Efficiency Gap." *Journal of Economic Literature* 55 (4): 1486–525.

Glaeser, Edward Ludwig, and Joseph Gyourko. 2003. "The Impact of Building Restrictions on Housing Affordability." *Economic Policy Review* 9 (2): 21–39.

Gowrisankaran, Gautam, Ashley Langer, and Wendan Zhang. 2025. "Policy Uncertainty in the Market for Coal Electricity: The Case of Air Toxics Standards." *Journal of Political Economy* 133 (6): 1757–95.

Graff Zivin, Joshua S., and Matthew J. Neidell. 2012. "The Impact of Pollution on Worker Productivity." *American Economic Review* 102 (7): 3652–73.

Greenstone, Michael, Tanushree Ganguly, Christa Hasenkopf, Nishka Sharma, and Hrishikesh Gautam. 2024. "Air Quality Life Index 2024: Annual Update." EPIC Clean Air Program, Energy Policy Institute, University of Chicago.

Greenstone, Michael, and Rema Hanna. 2014. "Environmental Regulations, Air and Water Pollution, and Infant Mortality in India." *American Economic Review* 104 (10): 3038–72.

Greenstone, Michael, Guojun He, Ruixue Jia, and Tong Liu. 2022. "Can Technology Solve the Principal-Agent Problem? Evidence from China's War on Air Pollution." *American Economic Review: Insights* 4 (1): 54–70.

Greenstone, Michael, Guojun He, Shanjun Li, and Eric Yongchen Zou. 2021. "China's War on Pollution: Evidence from the First 5 Years." *Review of Environmental Economics and Policy* 15 (2): 281–99.

Greenstone, Michael, John A. List, and Chad Syverson. 2012. "The Effects of Environmental Regulation on the Competitiveness of U.S. Manufacturing." NBER Working Paper 18392, National Bureau of Economic Research.

Greenstone, Michael, and Ishan Nath. 2024. "Do Renewable Portfolio Standards Deliver Cost-Effective Carbon Abatement?" BFI Working Paper 2019-62, Becker Friedman Institute for Economics, University of Chicago.

Greenstone, Michael, Rohini P. Pande, Anant Sudarshan, and Nicholas Ryan. 2025. "Can Pollution Markets Work in Developing Countries? Experimental Evidence from India." *Quarterly Journal of Economics* 140 (2): 1003–60.

Hallegatte, Stéphane, Jun Erik Maruyama Rentschler, and Julie Rozenberg. 2019. *Lifelines: The Resilient Infrastructure Opportunity*. Sustainable Infrastructure Series. World Bank.

Hasenkopf, Christa, Nishka Sharma, Farah Kazi, Polash Mukerjee, and Michael Greenstone. 2023. "The Case for Closing Global Air Quality Data Gaps with Local Actors: A Golden Opportunity for the Philanthropic Community." White Paper, Energy Policy Institute, University of Chicago. https://epic.uchicago.edu/research/the-case-for-closing-global-air-quality-data-gaps-with-local-actors-a-golden-opportunity-for-the-philanthropic-community/.

He, Guojun, Shaoda Wang, and Bing Zhang. 2020. "Watering Down Environmental Regulation in

China." *Quarterly Journal of Economics* 135 (4): 2135–85.
Heilmayr, Robert, and Eric F. Lambin. 2016. "Impacts of Nonstate, Market-Driven Governance on Chilean Forests." *Proceedings of the National Academy of Sciences* 113 (11): 2910–15.
Hoffmann, Bridget, and Svetoslava Petkova Milusheva. 2024. "Designing Air Quality Measurement Systems in Data-Scarce Settings." Policy Research Working Paper 10957, World Bank.
Houssini, Khaoula, Jinhui Li, and Quanyin Tan. 2025. "Complexities of the Global Plastics Supply Chain Revealed in a Trade-Linked Material Flow Analysis." *Communications Earth and Environment* 6 (April): 257.
Hsieh, I-Yun Lisa, Guillaume P. Chossière, Emre Gençer, Hao Chen, Steven Barrett, and William H. Green. 2022. "An Integrated Assessment of Emissions, Air Quality, and Public Health Impacts of China's Transition to Electric Vehicles." *Environmental Science and Technology* 56 (11): 6836–46.
ICCT (International Council on Clean Transportation). 2023. "Overview of Fuel Efficiency and CO_2 Emission Standards of Passenger Cars and Light-Commercial Vehicles Around the World." ICCT. https://theicct.org/pv-fuel-economy/.
ICPDR (International Commission for the Protection of the Danube River). 2021. *Danube River Basin Management Plan: Update 2021*. ICPDR.
IEA (International Energy Agency). 2019. *Perspectives for the Clean Energy Transition: The Critical Role of Buildings*. IEA.
IEA (International Energy Agency). 2023. "Tracking Clean Energy Progress 2023." IEA. https://www.iea.org/reports/tracking-clean-energy-progress-2023.
IEA (International Energy Agency). 2024a. *Global EV Outlook 2024: Moving Towards Increased Affordability*. IEA. https://iea.blob.core.windows.net/assets/a9e3544b-0b12-4e15-b407-65f5c8ce1b5f/GlobalEVOutlook2024.pdf.
IEA (International Energy Agency). 2024b. "Key Policy Design Considerations for Affordable and Fair Transitions." Global Commission on People-Centred Clean Energy Transitions, IEA.
ILO (International Labour Organization). 2024. *Heat at Work: Implications for Safety and Health; A Global Review of the Science, Policy and Practice.* ILO.
IMF (International Monetary Fund), OECD (Organisation for Economic Co-operation and Development), UNCTAD (formerly United Nations Conference on Trade and Development), World Bank, and WTO (World Trade Organization). 2024. "Working Together for Better Climate Action: Carbon Pricing, Policy Spillovers, and Global Climate Goals." WTO.
IPCC (Intergovernmental Panel on Climate Change). 2021. *Climate Change 2021: The Physical Science Basis; Working Group I Contribution to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change.* IPCC; Cambridge University Press. https://www.ipcc.ch/report/ar6/wg1/downloads/report/IPCC_AR6_WGI_FullReport.pdf.
Isah, Abdulrasheed, Florian Egli, Tobias S. Schmidt, and Anna Stünzi. 2025. "Quantifying Climate Finance Needs in the Nationally Determined Contributions of Developing Countries." *Climate Policy*. Published ahead of print, February 21. https://doi.org/10.1080/14693062.2025.2460607.
Isen, Adam, Maya Rossin-Slater, and W. Reed Walker. 2017. "Every Breath You Take, Every Dollar You'll Make: The Long-Term Consequences of the Clean Air Act of 1970." *Journal of Political Economy* 125 (3): 848–902.
Ito, Koichiro, and Shuang Zhang. 2020. "Willingness to Pay for Clean Air: Evidence from Air Purifier Markets in China." *Journal of Political Economy* 128 (5): 1627–72.
Jacobsen, Mark R. 2013. "Evaluating US Fuel Economy Standards in a Model with Producer and Household Heterogeneity." *American Economic Journal: Economic Policy* 5 (2): 148–87.
Jacobsen, Mark R., James M. Saliee, Joseph S. Shapiro, and Arthur A. van Benthem. 2023. "Regulating Untaxable Externalities: Are Vehicle Air Pollution Standards Effective and Efficient?" *Quarterly Journal of Economics* 138 (3): 1907–76.
Jha, Akshaya, and Andrea La Nauze. 2022. "US Embassy Air-Quality Tweets Led to Global Health Benefits." *Proceedings of the National Academy of Sciences* 119 (44): e2201092119.
Jones, Edward R., Marc F. P. Bierkens, Niko Wanders, Edwin H. Sutanudjaja, Ludovicus P. H. van Beek, and Michelle T. H. van Vliet. 2023. "DynQual v1.0: A High-Resolution Global Surface Water Quality Model." *Geosciific Model Development* 16 (15): 4481–500.
Jyväsjärvi, Jussi, Iina Koivunen, and Timo Muotka. 2020. "Does the Buffer Width Matter? Testing the Effectiveness of Forest Certificates in the Protection of Headwater Stream Ecosystems." *Forest Ecology and Management* 478: 118532.
Kahn, Matthew E., Pei Li, and Daxuan Zhao. 2015. "Water Pollution Progress at Borders: The Role of Changes in China's Political Promotion Incentives." *American Economic Journal: Economic Policy* 7 (4): 223–42.
Kaza, Silpa, Siddarth Shrikanth, and Sarur Chaudhary. 2021. "More Growth, Less Garbage." Urban Development Series, World Bank.
Kaza, Silpa, Lisa C. Yao, Perinaz Bhada-Tata, and Frank Van Woerden. 2018. *What a Waste 2.0: A Global Snapshot of Solid Waste Management to 2050*. Urban Development Series. World Bank.
Keiser, David A., and Joseph S. Shapiro. 2019. "Consequences of the Clean Water Act and the Demand for Water Quality." *Quarterly Journal of Economics* 134 (1): 349–96.
Kellogg, Ryan. 2018. "Gasoline Price Uncertainty and the Design of Fuel Economy Standards." *Journal of Public Economics* 160 (April): 14–32.
Khan, Hafiz Anwar Ullah, Burçin Ünel, and Yury Dvorkin. 2023. "Electricity Tariff Design via Lens of Energy Justice." *Omega* 117 (June): 102822.
Khosla, Radhika. 2025. "The Role of Cooling Standards in Climate Adaptation to Extreme Heat." Background paper prepared for *World Development Report 2025: Standards for Development*, World Bank.

https://www.worldbank.org/en/publication/wdr2025/brief/world-development-report-2025-background-papers.
Knowlton, Kim, Suhas P. Kulkarni, Gulrez Shah Azhar, et al. 2014. "Development and Implementation of South Asia's First Heat-Health Action Plan in Ahmedabad (Gujarat, India)." *International Journal of Environmental Research and Public Health* 11 (4): 3473–92.
Lane, Gregory, 2024. "Adapting to Climate Risk with Guaranteed Credit: Evidence from Bangladesh." *Econometrica* 92 (2): 355–86.
Lavy, Victor, Avraham Ebenstein, and Sefi Roth. 2014. "The Impact of Short Term Exposure to Ambient Air Pollution on Cognitive Performance and Human Capital Formation." NBER Working Paper 20648, National Bureau of Economic Research.
Ley, Eduardo, Molly Kenna Macauley, and Stephen Walter Salant. 2000. "Restricting the Trash Trade." *American Economic Review* 90 (2): 243–46.
Li, Shanjun, Binglin Wang, and Hui Zhou. 2024. "Decarbonizing Passenger Transportation in Developing Countries: Lessons and Perspectives." *Regional Science and Urban Economics* 107 (July): 103977.
Li, Xiongfei, and Ruozi Song. 2024. "Environmental Policy Coordination." World Bank. https://xiongfeili.com/files/carbon.pdf.
Liemberger, Roland, and Alan Wyatt. 2019. "Quantifying the Global Non-Revenue Water Problem." *Water Supply* 19 (3): 831–37.
Lipscomb, Molly, and Ahmed Mushfiq Mobarak. 2016. "Decentralization and Pollution Spillovers: Evidence from the Re-Drawing of County Borders in Brazil." *Review of Economic Studies* 84 (1): 464–502.
Liu, Feng, Anke S. Meyer, and John F. Hogan. 2010. "Mainstreaming Building Energy Efficiency Codes in Developing Countries: Global Experiences and Lessons from Early Adopters." World Bank Working Paper 204, Energy Sector Management Assistance Program, World Bank. https://www.esmap.org/node/755.
Lizana, Jesus, Nicole D. Miranda, Sarah N. Sparrow, David C. H. Wallom, Radhika Khosla, and Malcolm McCulloch. 2024. "Global Land Surface Dataset of Heating and Cooling Degree Days from a Bias-Corrected HadAM4-Based Temperature Ensemble under 1.0°C, 1.5°C, and 2.0°C Climate Scenarios." Data Set (January 1), Oxford Climate Research Network, Oxford University Centre for the Environment, University of Oxford. https://www.climate.ox.ac.uk/publication/1994805/ora-hyrax.
Lu, Yangsiyu, and Jacquelyn Pless. 2024. "Greening to Grow: Evidence from Environmental Regulation and Industrial Firm Productivity in China." MIT Sloan Research Paper 6487-21, MIT Sloan School of Management, Massachusetts Institute of Technology. https://papers.ssrn.com/sol3/papers.cfm?abstract_id=5014283.
Luo, Yan, Shu Tn, and Hao Yang. 2021. "Green Bonds, Air Quality, and Mortality: Evidence from the People's Republic of China." Economics Working Paper 641 (November), Asian Development Bank.
Lyubich, Eva, Joseph S. Shapiro, and Reed Walker. 2018. "Regulating Mismeasured Pollution: Implications of Firm Heterogeneity for Environmental Policy." *AEA Papers and Proceedings* 108 (May): 136–42.
Mahalana, Aditya, Liuhanzi Yang, Tim Dallmann, Puji Lestari, Khafid Maulana, and Nurendra Kusuma. 2022. "Measurement of Real-World Motor Vehicle Emissions in Jakarta." TRUE Report, Real Urban Emissions Initiative.
Margani, Giuseppe, Gianpiero Evola, Carola Tardo, and Edoardo Michele Marino. 2020. "Energy, Seismic, and Architectural Renovation of RC Framed Buildings with Prefabricated Timber Panels." *Sustainability* 12 (12): 4845.
Mealy, Penelope Ann, Michael Ganslmeier, and Stéphane Hallegatte. 2025. "Climate Policies Are Path-Dependent: Implications for Policy Sequencing and Feasibility." Policy Research Working Paper 11094, World Bank.
Miguel, Faruk, Alvaro Pedraza, and Claudia Ruiz-Ortega. 2024. "Climate-Change Regulations: Bank Lending and Real Effects." *Journal of Financial Stability* 70 (February): 101212.
Nazar, Roshna, Shweta L. Srinivasan, Amit Kanudia, and Jai Asundi. 2021. "Implication of Emission Regulation on Cost and Tariffs of Coal-Based Power Plants in India: A System Modelling Approach." *Energy Policy* 148, Part B (January): 111924.
Nghlovu, Lungelo. 2020. "High and Dry: Flood-Hit Zimbabweans Look Back to Stilt Homes." *Reuters Climate News* (blog), March 13. https://news.trust.org/item/20200313102808-snn5h/.
OECD (Organisation for Economic Co-operation and Development). 2021. *Assessing the Economic Impacts of Environmental Policies: Evidence from a Decade of OECD Research*. OECD. https://doi.org/10.1787/bf2fb156-en.
Okello, Gabriel, Graham Devereux, and Sean Semple. 2018. "Women and Girls in Resource Poor Countries Experience Much Greater Exposure to Household Air Pollutants Than Men: Results from Uganda and Ethiopia." *Environment International* 119 (October): 429–37.
Oliva, Paulina. 2015. "Environmental Regulations and Corruption: Automobile Emissions in Mexico City." *Journal of Political Economy* 123 (3): 686–724.
Olmstead, Sheila M. 2010. "The Economics of Managing Scarce Water Resources." *Review of Environmental Economics and Policy* 4 (2): 179–98.
Olmstead, Sheila M., and Jiameng Zheng. 2021. "Water Pollution Control in Developing Countries: Policy Instruments and Empirical Evidence." *Review of Environmental Economics and Policy* 15 (2): 261–80.
O'Neill, Kate. 2017. "Will China's Crackdown on 'Foreign Garbage' Force Wealthy Countries to Recycle More of Their Own Waste?" *The Conversation* (blog), December 13. https://doi.org/10.64628/AAI.7ahyr7665.
O'Neill, Kate, and Sangcheol Moon. 2025. "Standards and the Regulation of Plastic Wastes in Developing Countries." Background paper prepared for *World Development Report 2025: Standards for Development*, World Bank. https://www.worldbank.org/en

/publication/wdr2025/brief/world-development-report-2025-background-papers.
Ortiz-Bobea, Ariel, Toby Rollin Ault, Carlos M. Carrillo, Robert G. Chambers, and David B. Lobell. 2021. "Anthropogenic Climate Change Has Slowed Global Agricultural Productivity Growth." *Nature Climate Change* 11 (4): 306–12.
Porter, Michael E., and Claas van der Linde. 1995. "Green and Competitive: Ending the Stalemate." *Harvard Business Review* 73 (5): 120–34.
Rentschler, Jun Erik Maruyama, Paolo Avner, Mattia Marconcini, Rui Su, Emanuele Strano, Michalis Vousdoukas, and Stéphane Hallegatte. 2023. "Global Evidence of Rapid Urban Growth in Flood Zones Since 1985." *Nature* 622 (7981): 87–92.
Rentschler, Jun Erik Maruyama, Melda Salhab, and Bramka Arga Jafino. 2022. "Flood Exposure and Poverty in 188 Countries." *Nature Communications* 13 (1): 3527.
Reynaert, Mathias. 2021. "Abatement Strategies and the Cost of Environmental Regulation: Emission Standards on the European Car Market." *Review of Economic Studies* 88 (1): 454–88.
Ritchie, Hannah. 2023. "How Much of Global Greenhouse Gas Emissions Come from Plastics?" *Our World in Data* (blog), October 5. https://ourworldindata.org/ghg-emissions-plastics.
Rodrik, Dani. 2014. "Green Industrial Policy." *Oxford Review of Economic Policy* 30 (3): 469–91.
Rozendaal, Rik, and Herman R. J. Vollebergh. 2025. "Policy-Induced Innovation in Clean Technologies: Evidence from the Car Market." *Journal of the Association of Environmental and Resource Economists* 12 (3): 565–98.
SBFN (Sustainable Banking and Finance Network). 2024. *SBFN Toolkit: Sustainable Finance Taxonomies*. Version 1.0 (November). SBFN Secretariat, International Finance Corporation.
Shaddick, Gavin, Michael L. Thomas, Paolo Mudu, Gabriella Ruggeri, and Sylvie Gumy. 2020. "Half the World's Population Are Exposed to Increasing Air Pollution." *Climate and Atmospheric Science* 3 (June): 23.
Shilpi, Forhad J., Claudia N. Berg, and Matthew E. Kahn. 2025. *Rethinking Resilience: How to Help People Adapt to Climate Change*. Policy Research Report. World Bank.
Su, Hanshi, Hang Yi, Weiyi Gu, Qi Wang, Beibei Liu, and Bing Zhang. 2022. "Cost of Raising Discharge Standards: A Plant-by-Plant Assessment from Wastewater Sector in China." *Journal of Environmental Management* 308 (April): 114642.
Sundström, Aksel. 2013. "Corruption in the Commons: Why Bribery Hampers Enforcement of Environmental Regulations in South African Fisheries." *International Journal of the Commons* 7 (2): 454–72.
Tanaka, Shinsuke. 2015 "Environmental Regulations on Air Pollution in China and Their Impact on Infant Mortality." *Journal of Health Economics* 42 (July): 90–103.
Tanaka, Shinsuke, Kensuke Teshima, and Eric A. Verhoogen. 2022. "North-South Displacement Effects of Environmental Regulation: The Case of Battery Recycling." *American Economic Review: Insights* 4 (3): 271–88.
Tang, Ling, Jiabao Qu, Zhifu Mi, et al. 2019. "Substantial Emission Reductions from Chinese Power Plants After the Introduction of Ultra-Low Emissions Standards." *Nature Energy* 4 (11): 929–38.
Taylor, Robert Prescott, Chandrasekar Govindarajalu, Jeremy Levin, Anke S. Meyer, and William A. Ward. 2008. *Financing Energy Efficiency: Lessons from Brazil, China, India, and Beyond*. World Bank.
Tong, Dan, Guannan Geng, Qiang Zhang, et al. 2021. "Health Co-Benefits of Climate Change Mitigation Depend on Strategic Power Plant Retirements and Pollution Controls." *Nature Climate Change* 11 (12): 1077–83.
Trencher, Gregory, Adrian Rinscheid, Daniel Rosenbloom, and Nhi Truong. 2022 "The Rise of Phase-Out as a Critical Decarbonisation Approach: A Systematic Review." *Environmental Research Letters* 17 (12): 123002.
UNECE (United Nations Economic Commission for Europe), UNESCO (United Nations Educational, Scientific and Cultural Organization), and UN-Water. 2024. *Progress on Transboundary Water Cooperation: Mid-Term Status of SDG Indicator 6.5.2, with a Special Focus on Climate Change*. United Nations and UNESCO.
UNEP (United Nations Environment Programme). 2021. "Globally, 3 Billion People at Health Risk Due to Scarce Data on Water Quality." *Story: Fresh Water* (blog), March 19. https://www.unep.org/news-and-stories/story/globally-3-billion-people-health-risk-due-scarce-data-water-quality.
UNEP (United Nations Environment Programme). 2023a. *Emissions Gap Report 2023: Broken Record—Temperatures Hit New Highs, Yet World Fails to Cut Emissions (Again)*. UNEP. https://doi.org/10.59117/20.500.11822/43922.
UNEP (United Nations Environment Programme). 2023b. *Global Cooling Watch 2023—Keeping It Chill: How to Meet Cooling Demands While Cutting Emissions*. UNEP. https://doi.org/10.59117/20.500.11822/44243.
UNEP (United Nations Environment Programme). 2023c. "Using Finance to Accelerate Adoption of More Energy-Efficient and Climate-Friendly Appliances: Insights from Ghana, Senegal, and Rwanda." U4E Initiative, United for Efficiency, UNEP. https://united4efficiency.org/wp-content/uploads/2023/10/20230926_Financing-Mechanisms-Lessons-Learned-Final-Report.pdf.
UNEP (United Nations Environment Programme). 2024. *Global Waste Management Outlook 2024: Beyond an Age of Waste—Turning Rubbish into a Resource*. UNEP. https://wedocs.unep.org/20.500.11822/44939.
UNEP (United Nations Environment Programme). 2025. "Global Status Report for Buildings and Construction 2024/25: Not Just Another Brick in the Wall; The Solutions Exist; Scaling Them Will Build on Progress and Cut Emissions Fast." UNEP. https://www.unep.org/resources/report/global-status-report-buildings-and-construction-20242025.

van Donkelaar, Aaron, Randall V. Martin, Chi Li, and Richard T. Burnett. 2019. "Regional Estimates of Chemical Composition of Fine Particulate Matter Using a Combined Geoscience-Statistical Method with Information from Satellites, Models, and Monitors." *Environmental Science and Technology* 53 (5): 2595–611.

Vidovic, Martina, and Neha Khanna. 2007. "Can Voluntary Pollution Prevention Programs Fulfill Their Promises? Further Evidence from the EPA's 33/50 Program." *Journal of Environmental Economics and Management* 53 (2): 180–95.

Wang, Pu, Cheng-Kuan Lin, Yi Wang, Dachuan Liu, Dunjiang Song, and Tong Wu. 2021. "Location-Specific Co-Benefits of Carbon Emissions Reduction from Coal-Fired Power Plants in China." *Nature Communications* 12 (November): 6948.

Weitzman, Martin L. 1974. "Price vs Quantities." *Review of Economic Studies* 41 (4): 477–91.

Wen, Zongguo, Yiling Xie, Muhan Chen, and Christian Doh Dinga. 2021. "China's Plastic Import Ban Increases Prospects of Environmental Impact Mitigation of Plastic Waste Trade Flow Worldwide." *Nature Communications* 12 (1): 425.

WHO (World Health Organization). 2021. *A Global Overview of National Regulations and Standards for Drinking-Water Quality*. 2nd ed. WHO.

Williams, Aled, and Kendra Dupuy. 2017. "Deciding over Nature: Corruption and Environmental Impact Assessments." *Environmental Impact Assessment Review* 65 (July): 118–24.

World Bank. 2021. "Improving Waste Management and Resource Efficiency: The Ningbo Experience." *Results Briefs* (blog), April 27. https://www.worldbank.org/en/results/2021/04/27/improving-waste-management-and-resource-efficiency-the-ningbo-experience?

World Bank. 2024. *World Development Report 2024: The Middle-Income Trap.* World Bank.

World Bank. 2025. *Unlocking Efficiency: The Global Landscape of Building Energy Regulations and Their Enforcement.* World Bank.

Yang, Lin, Yatang Lin, Jin Wang, and Fangyuan Peng. 2024. "Achieving Air Pollution Control Targets with Technology-Aided Monitoring: Better Enforcement or Localized Efforts?" *American Economic Journal: Economic Policy* 16 (4): 280–315.

Zhang, Bing, and Daxuan Zhao. 2023. "Emission Leakage and the Effectiveness of Regional Environmental Regulation in China." *Journal of Environmental Economics and Management* 121 (September): 102869.

Zwerts, Joeri A., E. H. M. Sterck, Pita A. Verweij, Fiona Maisels, Jaap van der Waarde, Emma A. M. Geelen, et al. 2024. "FSC-Certified Forest Management Benefits Large Mammals Compared to Non-FSC." *Nature* 628 (8008): 563–68.