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Resources

EARTH DAY

What a Difference a Day Makes

Marking environmental milestones since the first Earth Day in 1970

MARKING A MILESTONE

Looking Back at 50 Years of the Clean Air Act

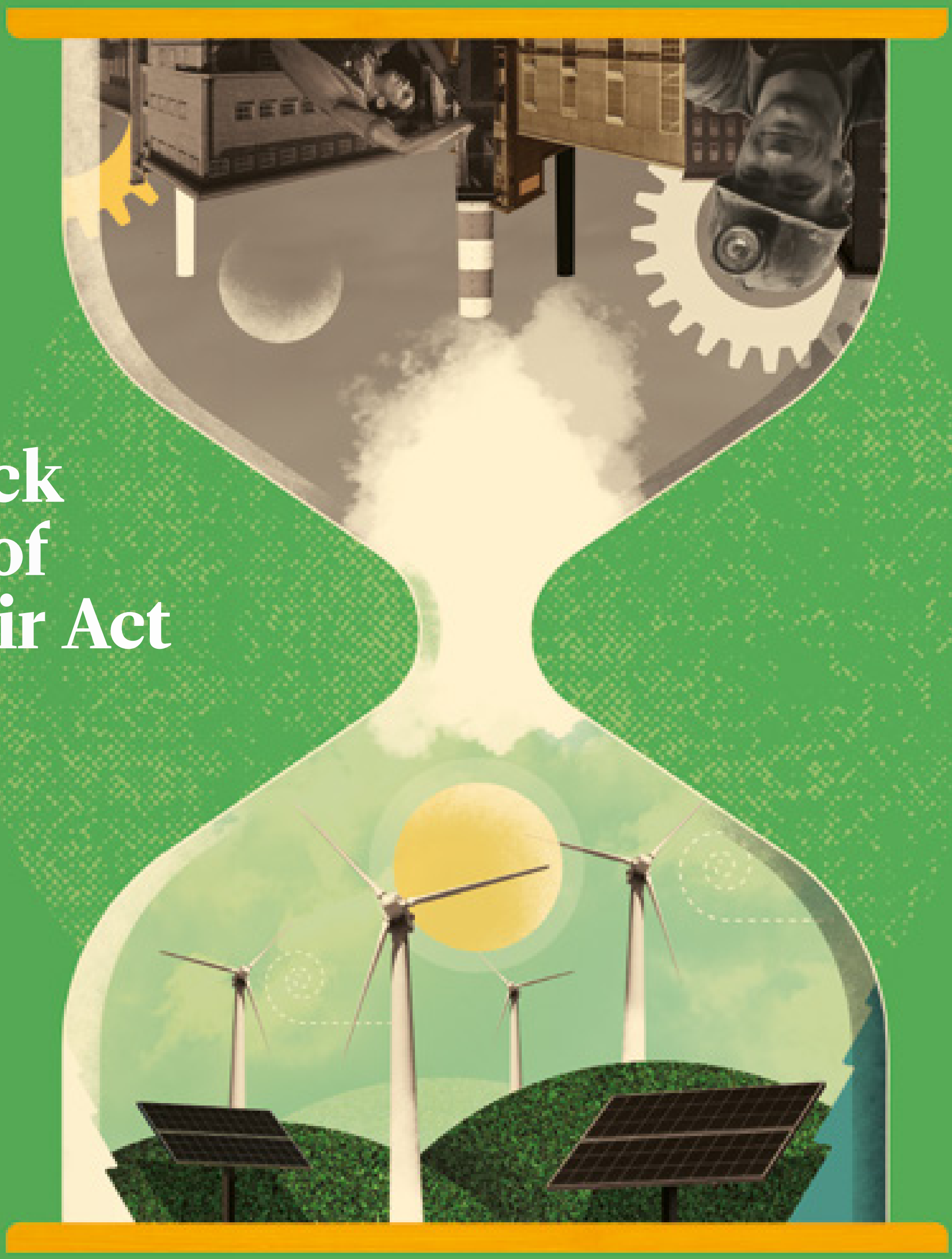
CORONAVIRUS

Pollution in a Pandemic

ECONOMICS

A Half Century of Economics at EPA

Reflections on combining economic research and environmental policy



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A Note from RFF's President

The History and Future of the Clean Air Act

This year marks 50 years of celebrating Earth Day; the existence of the US Environmental Protection Agency; and the 1970 Clean Air Act amendments, which expanded the law's federal mandate and enforcement. In the year 2020—and recognizing that hindsight is 20/20—we're looking back at our legislative and regulatory history and the important environmental accomplishments they have enabled. Retrospective analyses can give us the empirical data we need to make sound decisions moving forward—about how to modify current regulations so they work effectively and efficiently, prune policy elements that don't justify their costs, and employ groundbreaking incentive mechanisms to maintain a thriving economy and a healthy environment at the same time. This anniversary of the Clean Air Act is an excellent opportunity to showcase the value of empirical data in informing future policies and decisions.

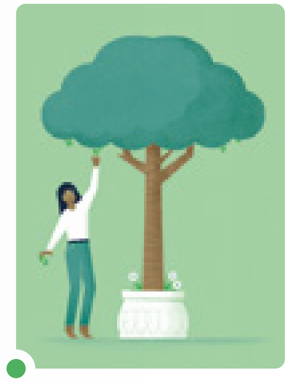
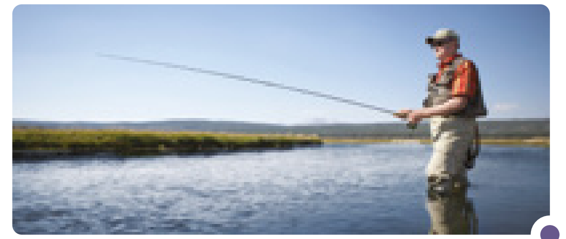
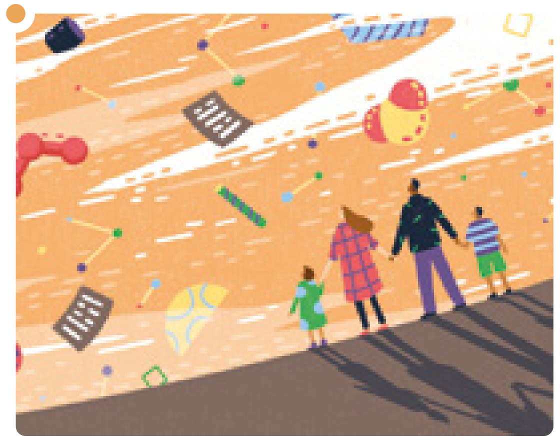
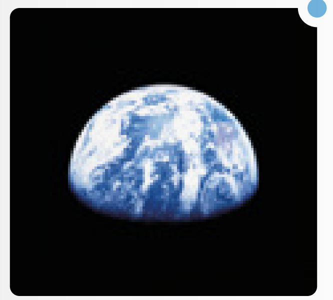
In this issue, two articles consider how the Clean Air Act has fared in practice: "Looking Back at 50 Years of the Clean Air Act of 1970," by Joseph E. Aldy (RFF university fellow), Maximilian Auffhammer, Maureen L. Cropper (RFF senior fellow), Arthur G. Fraas (RFF visiting fellow), and Richard D. Morgenstern (RFF senior fellow); and "Lessons from the Clean Air Act," which highlights a book by the same title published last year by RFF Senior Fellow Dallas Burtraw and UCLA Law Professor Ann Carlson.

The rest of this issue explores other topics related to air quality. RFF Senior Fellow Alan Krupnick's article explains how satellite data can supplement land-based monitoring to help states achieve compliance with National Ambient Air Quality Standards. RFF Senior Fellow Karen Palmer discusses recent proposed changes to the US Mercury and Air Toxics Standards. Nicholas Z. Muller, a faculty member at Carnegie Mellon University, joins us on the *Resources Radio* podcast to discuss how to measure health damages from air pollution in various economic sectors in the United States, relative to the economic contributions of those sectors.

RFF takes these ideas to heart: it is our mission to improve environmental, energy, and natural resource decisions through impartial economic research and policy engagement. If you're reading this magazine, you likely agree that such decisions are improved when supported by sound evidence and analysis. And our work is made possible by the continued support of each of you.

With many thanks and best wishes,

Richard G. Newell | **President and CEO, Resources for the Future**


Looking Back at 50 Years of the Clean Air Act of 1970

A major retrospective analysis of the Clean Air Act reveals its many public health benefits, along with its associated costs.

TEXT
Joseph E. Aldy
Maximilian Auffhammer
Maureen L. Cropper
Richard D. Morgenstern
Arthur G. Fraas

ILLUSTRATION
James Round

In the same year that saw the founding of Earth Day and the creation of the US Environmental Protection Agency (EPA), President Nixon signed into law the Clean Air Act of 1970 (CAA) on December 31, ushering in what is arguably the most important and far-reaching environmental statute enacted in the United States.

This legislation shifted the state-oriented focus of most air quality regulation to the federal government, under the purview of the newly created EPA. It stimulated a broad-based and costly effort to limit major air pollutants across the United States, with specific targets and timetables for action. It also empowered citizens to sue the government when it failed to perform its duties.

> **In the 50 years since the passage of the CAA, air pollution has dropped dramatically, even as gross domestic product has quadrupled.**

In the 50 years since the passage of the CAA, air pollution has dropped dramatically, even as gross domestic product has quadrupled (Figure 1). To better understand the CAA's role in the notable improvements in air quality, we have looked at retrospective studies of federal air quality rules, drawing insights on the environmental, economic, and public health impacts of the CAA. Areas of focus include the effects of geographically differentiated standards, the performance of cap-and-trade policies and technology standards, and the responses to regulation in imperfectly competitive markets.

One important takeaway from these studies is that a key feature of the CAA—the imposition of more stringent regulations where air quality is poorer—has sometimes resulted in more rapid air quality improvements in those areas, but at substantial cost to local economies.

We also find that cap-and-trade programs have delivered greater emissions reductions at lower cost than conventional regulatory mandates, but policy practice has fallen short of the ideal.

Finally, our review of the literature has provided information about two categories of benefits—lower medical expenditures and human capital gains—not previously associated with improvements in air quality in US regulatory impact analyses (the forward-looking assessments of a regulation's expected impacts).

1970

President Richard Nixon signs into law the Clean Air Act of 1970 (CAA) in the same year as the first Earth Day

1977

The CAA is amended to address problems with ambient air quality in US cities

1990

The CAA is amended with a significant expansion of air quality regulations, including a program to stop acid rain

1996

Through the CAA, EPA bans leaded gasoline in new vehicles, which helps to drive a massive drop in lead as an air pollutant

The Evolution of the Clean Air Act

By the middle of the twentieth century, a number of alarming smog episodes in US cities and industrial areas had raised public awareness about deteriorating air quality. In perhaps the most extreme case, a lethal smog enveloped the manufacturing town of Donora, Pennsylvania, in October 1948, making thousands sick and killing at least 20 people over the course of just five days. Hundreds of New Yorkers died in a smog episode in November 1953, and the following year in Los Angeles, heavy smog shut down industry and schools for most of October.

The federal government responded by enacting a series of air pollution bills, culminating in the Clean Air Act of 1970. Fundamental provisions of this law required the following:

- EPA to set National Ambient Air Quality Standards (NAAQS) for six major air pollutants: carbon monoxide, lead, nitrogen oxide (NO_x), ozone, particulate matter, and sulfur dioxide (SO_2). The CAA requires periodic review of these standards, and EPA has revised the NAAQS for several categories of pollutants over the years in response to the latest public health research.
- States to submit state implementation plans to EPA, which demonstrate how they intend to meet the standards.
- EPA to set uniform national emissions standards for new cars and light trucks. The law prescribed an ambitious 90 percent reduction in hydrocarbon, carbon monoxide, and NO_x emissions by 1975 via these standards.
- All steel plants, oil refineries, and other major industrial facilities built after 1970 to meet technology-based standards, dubbed "new source performance standards."

In 1977, the CAA was amended, primarily to address the problems major metropolitan areas were facing in achieving attainment with the NAAQS, especially ozone pollution standards. The amendments also imposed updated technology-based new source performance standards, which required that new and modified power plants achieve a 90 percent reduction in SO_2 emissions.

The CAA was amended again in 1990, representing a significant expansion of air quality regulation. The law authorized EPA to ban lead in fuel completely, the culmination of a two-decade phasedown of leaded gasoline. Further reductions in chlorofluorocarbons and hydrochlorofluorocarbons in refrigerants were also authorized, as was a new round of emissions standards for cars and light-duty trucks. The 1990 amendments also included new provisions to address acid rain, by introducing a cap-and-trade program to reduce SO_2 emissions. During the 1990s, state and local governments implemented regional cap-and-trade programs, including the NO_x Budget Trading Program and Southern California's Regional Clean Air Incentives Market program (RECLAIM), to make progress in attaining ozone and SO_2 NAAQS.

Congress subsequently has amended specific provisions of the CAA through appropriations riders or as a part of other legislative initiatives. For example, the Energy Policy Act of 2005 contains CAA provisions for fuel regulations, including the Renewable Fuel Standard (revised in 2007) and state boutique fuel programs. Other administrative initiatives include the development of cross-state programs to limit SO_2 and NO_x emissions from power plants, which rendered the 1990 acid rain provisions largely superfluous, along with regulations to address carbon dioxide and other greenhouse gas emissions.

Evaluating the Performance of the CAA

EPA routinely projects the potential effects of major rules (such as expected benefits and costs) to inform regulatory decisions, by preparing regulatory impact analyses. While these analyses draw on a now-extensive literature covering the atmospheric chemistry, epidemiology, and economics of air pollution, the analyses by definition forecast the future, rather than evaluate what happened in practice.

As we reflect on the 50th anniversary of the 1970 Clean Air Act, we've asked what we can learn about the law's causal economic, environmental, and public health impacts. Thanks to considerable advances in empirical economic research over the past two decades, existing retrospective studies use rigorous methods to study the effectiveness of regulations in achieving stated benefits and costs, along with any unintended consequences, often expressed as adverse economic impacts. A common approach is to look at two groups—one affected by a regulation and one not—and compare them before and after the regulation is implemented. For example, many studies compare counties that are in compliance with the NAAQS (so-called "attainment counties") with "nonattainment counties" that have been subject to more stringent regulation.

The largest number of papers we've reviewed speak to the impacts of spatially differentiated regulations. We use those papers to ask: What are the costs of imposing more stringent standards in nonattainment areas, and what are the benefits?

The CAA is also notable for promoting market-based cap-and-trade policies to reduce emissions. A significant portion of the retrospective literature is devoted to analyzing the performance of pollution allowance markets in the real world. Other papers examine the unanticipated consequences or failures of regulations to reduce emissions, including situations in which a regulation had no impact on ambient air quality.

Finally, the literature has provided information about categories of benefits—lower medical expenditures and human capital gains—that have not been previously associated with improvements in air quality in regulatory impact analyses.

The Performance of Standards Based on Attainment Status

An important feature of the CAA is that it originally required states to impose more stringent regulations on counties with nonattainment status under NAAQS. The 1977 amendments authorized adoption of stronger, direct emissions standards on industrial plants located in nonattainment areas. As a result, we would expect air quality to improve more in nonattainment counties than in attainment counties.

This hypothesis has been tested for three air pollutants (ozone, particulate matter, and SO_2), using nonattainment status per the 1977

1999

A program to mitigate NO_x emissions is introduced, eventually reducing mean ozone concentrations by 6 percent

2005

The Energy Policy Act of 2005 contains CAA provisions for fuel regulations

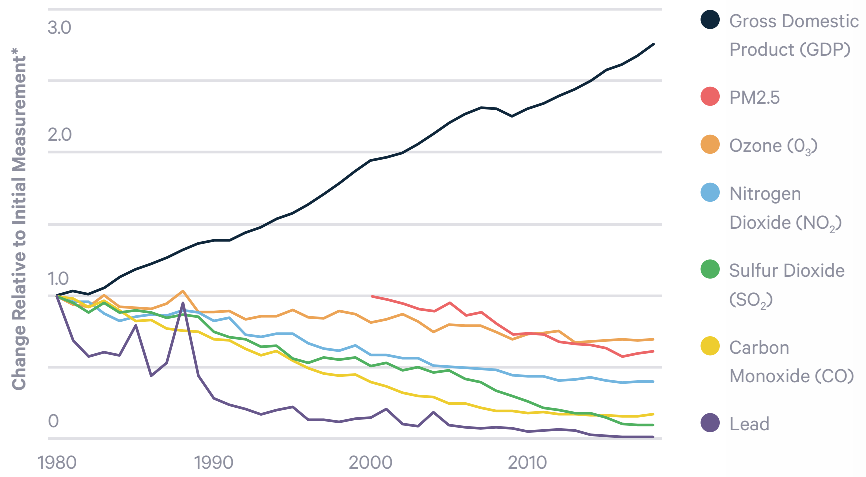
2011

EPA finalizes the Cross-State Air Pollution Rule, which regulates emissions that increase air pollution in other states

2020

On their 50th anniversary, the 1970 amendments to the CAA remain a benchmark for successful environmental policy

FIGURE 1 **Change in Gross Domestic Product and Six Common Air Pollutants, 1980–2018**



Source Federal Reserve Economic Data | Federal Reserve Bank of St. Louis. *The index begins at 1 in 1980, with the exception of PM2.5, which was measured beginning in 2000. The index for each year is the actual value divided by the initial value.

and 1990 CAA amendments. In all cases, at least some evidence over some periods shows that air pollution declined more rapidly in nonattainment counties—and at monitors that were out of attainment, regardless of location.

At the same time, research suggests that imposing tougher standards in nonattainment areas has led to fewer plant openings, lower employment, and losses in earnings for high-emitting industries, relative to attainment counties. For example, a 10-year study of pollution status and employment in four states—Illinois, Maryland, Washington, and Wisconsin—suggests that employment in newly regulated plants was approximately 15 percent lower in 2000 than in 1990, and that earnings over a nine-year period were 20 percent lower than pre-regulation earnings.

These results raise several questions for future study: Were the adjustment costs imposed on nonattainment counties by the CAA justified by the additional air quality improvements in these counties? What would have been the impact of imposing equally stringent standards on stationary sources in attainment counties? Could some of the adverse impacts on workers have been mitigated through a program that provides financial and professional support, similar to Trade Adjustment Assistance?

The Performance of Cap-and-Trade Programs

The CAA has been responsible for launching a national cap-and-trade program to reduce SO_2 emissions (the SO_2 allowance program), regional programs to address NO_x (the NO_x Budget Trading Program in the eastern part of the country), and Southern California's RECLAIM program. EPA designed a market for renewable fuel credits to implement the Renewable Fuel Standard.

The SO_2 allowance program has been widely heralded as the triumph of market-based instruments over command and control and was predicted to lead to large cost savings, compared to imposing a uniform performance standard on electric utilities. However, while the literature we review suggests that the program has indeed led to cost savings compared to a uniform performance standard, those savings are not as large as predicted ex ante. These lower cost savings are partly due to the decision of some utilities to install scrubbers rather than purchase allowances and/or switch to low-sulfur coal—a choice that is estimated to have increased annual compliance costs by nearly $100 million. Evidence also suggests that some of the potential cost savings were appropriated by railroads, which set relatively higher prices for transporting low-sulfur coal to Midwestern power plants.

Another important issue involves the impact of allowance markets on the distribution of damages. In the SO_2 market, the main purchasers of allowances were eastern power plants, which were located in more densely populated areas than most of the sellers, which in turn were located in more sparsely populated areas west of the Mississippi River. No evidence exists to suggest that the allowance program has led to more health damages than a uniform emissions standard; however, the evidence is mixed for the impact of the RECLAIM program on "hotspots," or local areas with higher emissions and associated damages.

The literature also has documented situations in which allowance market design could be improved. In the case of the market for renewable fuel credits—which refiners were required to produce to meet the Renewable Fuel Standard—annual (rather than multi-year) announcements by EPA of refiners' compliance obligations led to considerable uncertainty and volatility in the price of credits. Announcing renewable fuel mandates several years in advance, as was done under the SO_2 and NO_x Budget Trading Programs, would have helped the market function more effectively.

In addition to allowance trading, another method of reducing compliance costs is to allow firms flexibility in meeting regulatory standards, rather than prescribe a technology standard. However, in the case of reformulated gasoline, evidence indicates that flexible federal regulations that gave refiners latitude to choose which volatile chemicals to remove from gasoline were not effective in reducing ozone levels. Refiners chose the cheapest option—removing butane, which is less reactive than other volatiles. In contrast, more prescriptive rules issued by the California Air Resources Board did yield measurable benefits from the regulated gasoline in the California market.

Unexpected Benefits of the CAA

The economic literature on the CAA also reveals instances in which a program delivered a larger set of benefits than anticipated when it was designed. The NO_x Budget Trading Program and regulation of particulate matter by establishing NAAQS offer two examples.

Efforts to employ a cap-and-trade program to reduce NO_x in the eastern United States have resulted in an estimated 40 percent reduction in NO_x emissions during the summer months for sources in the states covered by the program. This NO_x reduction translates into declines of about 6 percent in mean ozone concentrations and 35 percent in the number of high-ozone days during the summer months.

The significant reductions in emissions and ozone concentrations in the covered states have contributed to substantial public health benefits, including greater-than-estimated reductions in ozone-related deaths (about 2,000 fewer individuals). Evidence also suggests that the program reduced medical expenditures—which had not previously been quantified as a category of benefits in air pollution regulatory impact analyses—by about $800 million per year.

More than any other pollutant regulated under the CAA, particulate matter has been linked in the epidemiological literature to premature mortality and morbidity. Exposure to particulate pollution in utero or during the first year of life also has been shown to have potentially lifelong effects, including on lung, heart, and brain development.

A 2017 study used nonattainment status under the 1970 CAA to examine how this early exposure impacts earnings and labor force participation later in life, focusing on ages 29–31. The researchers estimate that a 10 percent reduction in exposure to particulate matter during the first year of life increases the quarters worked by 0.7 percent and mean annual earnings by about 1 percent. Although these human capital impacts are small, they affect a large exposed population.

Taken together, these benefits represent a significant and potentially large category of benefits not previously considered in regulatory impact analyses of air pollution regulations.

Toward a Comprehensive Analysis of the CAA

The CAA has delivered clear success stories—removing lead from gasoline, phasing out chlorofluorocarbons and other substances that deplete the stratospheric ozone layer, and dramatically reducing sulfur emissions from power plants and transportation fuels. Emissions of air toxics also have declined substantially. These actions over the past 50 years raise the question of regulatory performance evaluation: What have been the causal economic, environmental, and public health impacts of the CAA? Fortunately, economic research on environmental regulation has progressed substantially in the past two decades and delivers at least partial answers to this important question.

Ideally, a retrospective analysis of the CAA would involve a comprehensive assessment of the law's contribution to observed air quality improvements, along with associated changes in human health and welfare. Such an analysis would focus on the realized benefits and costs of major regulations, and it would consider the role of economic incentive mechanisms in achieving emissions reductions. It would also consider the unintended (adverse or beneficial) consequences and distributional impacts. It would account for the impact of CAA rules and the distributional impacts of the rules. In short: a tall order.

Our review is best understood as a launching point toward a comprehensive retrospective assessment of the CAA. But evidence pointing to a larger set of benefits than expected—along with a number of unintended consequences of CAA rules—provides a compelling argument for continued study. ■

Joseph E. Aldy *is a university fellow at Resources for the Future and a professor at Harvard University.* **Maximilian Auffhammer** *is a professor at the University of California, Berkeley.* **Maureen L. Cropper** and **Richard D. Morgenstern** *are senior fellows at Resources for the Future.* **Arthur G. Fraas** *is a visiting fellow at Resources for the Future.*

Team of Economists Calls Out Flawed Methods Applied to Justify MATS Rollbacks

After the US Environmental Protection Agency (EPA) revised its assessment of a rule that limits mercury emissions and other pollutants from power plants, RFF Senior Fellow Karen Palmer and other economists convened as an independent review committee and released their own findings. In this Q&A, Palmer shares why she and the group of researchers banded together to offer their own analysis, and how EPA's new assessment downplays significant positive aspects of the rule.

In 2012, EPA issued the Mercury and Air Toxics Standards rule (MATS), which limits emissions of mercury and other toxic air pollutants from power plants. An early regulatory impact analysis conducted by EPA valued the benefits of MATS at $33 billion to $90 billion per year, compared to an annual cost of $9.6 billion.

Since then—and after an additional EPA assessment in 2016 concluded that the benefits of MATS far outweigh its costs—EPA revisited MATS in early 2019, reevaluating the findings of its prior analysis and reaching the opposite conclusion: that the costs of the regulation exceed its benefits. The agency's new analysis suggested that MATS is no longer appropriate and necessary, although EPA opted not to repeal the regulation outright. Just last month, in April 2020, EPA issued a final revised Supplemental Cost Finding, concluding that MATS is no longer appropriate and necessary.

Just prior to all this, in 2018, EPA dissolved its long-running Environmental Economics Advisory Committee (EEAC), which had served EPA's Science Advisory Board for 25 years. Stepping into this vacuum, an independent group of economists formed a new External Environmental Economics Advisory Committee (E-EEAC), which aims to restore the original function of the EEAC and provide evidence-based, nonpartisan, timely counsel about EPA regulations. The E-EEAC produced its first report this year, which focuses on MATS and EPA's new proposal from 2019. Among the report's authors are Resources for the Future (RFF) Senior Fellow Karen Palmer, along with RFF University Fellow and review committee co-chair Joseph E. Aldy.

The E-EEAC report finds that EPA's 2019 MATS proposal is flawed, for three major reasons: EPA's new proposal does not follow federally prescribed best practices for benefit-cost analysis because it neglects to include co-benefits; underestimates the benefits of mercury reductions; and does not account for significant, unexpected changes in the power sector.

Karen Palmer is a senior fellow and director of the Future of Power Initiative at Resources for the Future.

> **An early regulatory impact analysis conducted by EPA valued the benefits of MATS at $33 billion to $90 billion per year, compared to an annual cost of $9.6 billion.**

Far above We now know much more about the impacts of mercury on human health and how it accumulates in seafood, but EPA has not taken the latest science research into account when reevaluating MATS. *Getty Images*

Above left Prior evaluations of MATS did not anticipate recent investments in renewable energies, such as wind and solar power. *Nicholas Doherty on Unsplash*

Above right Recent large declines in coal-fired power generation mean that some of the costs to reduce emissions through MATS no longer apply; nonetheless, EPA still counts those outdated costs in its reevaluation. *Getty Images*

Resources magazine spoke with Palmer, the director of the Future of Power Initiative at RFF, to ask for more details about the unexpected changes in the power sector and what all of this means for the future of MATS.

***Resources* magazine: Can you describe what activity in the EPA motivated the E-EEAC to take on this work?**

Karen Palmer: The main motivation came from EPA's treatment of co-benefits in the recent proposal related to the MATS rule. In the new proposal, EPA claims that co-benefits from reductions in pollutants that are not directly targeted by MATS should not be considered. EPA now says that only direct benefits should be weighed among the benefits and costs. In the original regulatory impact analysis, most of the quantified benefits from MATS came from reductions in those other pollutants that constitute co-benefits—largely emissions of nitrogen oxides (NO_x) and sulfur dioxide (SO_2) that transform into fine particulates. Ignoring these co-benefits tips the balance in the benefit-cost analysis of the rule. EPA is now arguing that it wasn't appropriate and necessary to issue the regulations in the first place, although the agency hasn't gone so far as to propose retracting the rule.

In most air pollution regulations, balancing costs and benefits is not supposed to play a role in setting regulatory requirements relevant to clean air. That's because the Clean Air Act (CAA) generally requires that regulations reduce air pollution to a level that both protects human health with a margin of safety and protects the welfare of society.

But mercury is regulated under section 112 of the CAA, which does allow for balancing benefits and costs in setting standards. So, the outcomes of benefit-cost analysis can be particularly relevant in this context.

Another issue with EPA's reevaluation is that MATS has been in place for a while, and electricity-generating firms already have spent large amounts of money to comply, including some capital investments. Some of these costs are sunk and can't be undone. But the electric power industry also has changed in some unexpected ways since EPA's original regulatory impact analysis, and those changes should be reflected in any effort to review the regulation from today's vantage point. We wanted to address all these issues with our analysis.

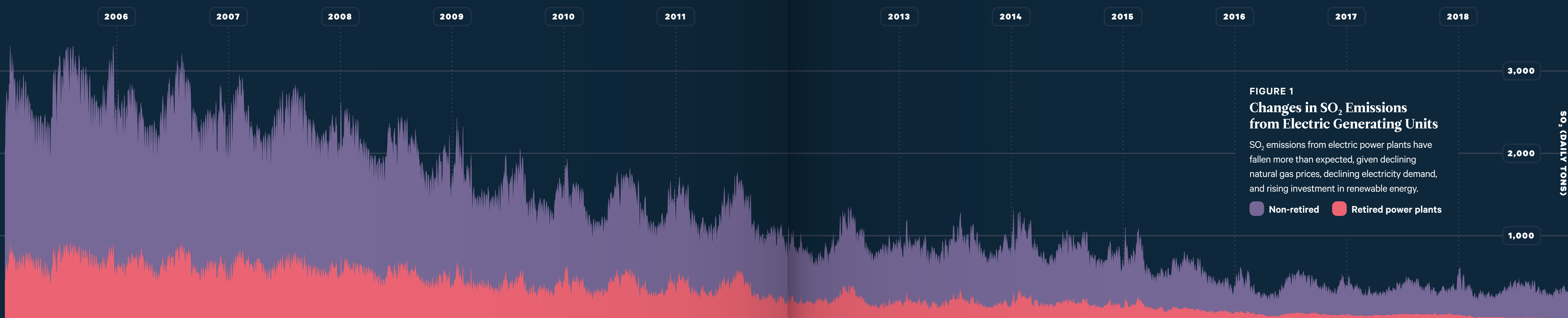


FIGURE 1

Changes in SO_2 Emissions from Electric Generating Units

SO_2 emissions from electric power plants have fallen more than expected, given declining natural gas prices, declining electricity demand, and rising investment in renewable energy.

Source External Environmental Economics Advisory Committee. 2019. *Report on the Proposed Changes to the Federal Mercury and Air Toxics Standards (MATS).*

How do EPA's recent estimates for the benefits and costs of MATS in 2019 compare to the regulatory impact analyses that they applied to MATS in the past?

EPA's 2019 proposal was a revision to the Supplemental Cost Finding issued by the Agency in 2016. The only real difference between the prior analyses in 2016 and in 2011 and this proposed revision in 2019 is that the new proposal dismisses the co-benefits of MATS—in other words, the pollution reductions beyond mercury and air toxics that are likely to result from compliance with the regulation.

Other than that, the analysis is unchanged—despite important changes in our understanding of the environmental and health impacts of mercury, and important changes in the electricity sector itself. We discuss all of this in our report.

Because the new proposal from EPA stays unchanged outside of eliminating important co-benefits, the agency implies that the *costs* from the earlier analysis still apply and are potentially avoidable, if the regulation would be undone in the future. But—and this is important—power plants have been in compliance since 2016, and some firms made major investments to come into compliance. A lot of the costs associated with controlling these emissions are capital costs—essentially sunk costs, and thus not avoidable if the regulation were repealed.

We find in our analysis that the actual compliance expenses for power plants were less capital intensive than EPA thought, when EPA was trying to project how firms were going to comply with the regulation—so, sunk costs are less than EPA anticipated they would be, but those costs are still highly relevant. If you were to take the flip-side view of this and say that the rule is not appropriate and necessary, and if we would go to the next step and undo the MATS regulation, then what would be the benefits? Well, the benefits would be the costs foregone, but the firms have already made a lot of investments, and those costs—they're not going to be undone. The only costs that would actually be avoided would be any operating costs associated with the pollution controls that are already in place.

Thus, the costs represented in that 2011 report (and EPA's 2019 report) overstate both total cost and avoidable costs, were the regulation to be undone.

It's important to recognize, too, that the size of the coal-fired generation fleet has gotten smaller. So, the emissions reductions from the rule also are probably overstated.

The report emphasizes that EPA's 2019 analysis fails to account for changes in the power sector that deviate from prior predictions. What effect do changes in the power sector have on clean air, in general?

There has been a steady decline in SO_2 emissions from electricity generators (Figure 1) due to a combination of factors.

The biggest effect on major pollution from the electricity sector (including SO_2, NO_x, and CO_2) comes from the fact that less electricity is being generated with coal—dramatically less than what was typical, historically—and more electricity is being generated by natural gas and renewables.

Probably one of the biggest factors influencing that shift is the reduction in natural gas prices resulting from the advent of fracking and the development of horizontal drilling, which together created the ability to extract abundant natural gas resources at low cost. When gas prices came way down, the electricity sector's investment in gas-fired generators went up, and the dispatch of the systems shifted away from coal, to gas.

Gas has no SO_2 emissions associated with it; it has substantially lower NO_x emissions; and it has roughly half the emissions of CO_2 per megawatt-hour than coal does.

In recent years, we've also seen policies that encourage renewables and declines in the costs of renewables, including wind and solar. So, those are starting to grow; we're in the early stages there. And those two technologies have no emissions associated with them.

This changing composition of electricity production is having a big effect. Also, when you look at old EPA forecasts of how electricity would be produced in the future, and then compare that with what actually happened, electricity demand has not grown as fast as expected. As a matter of fact, it's been pretty flat for the last decade or so—much below the growth in demand that people were expecting.

All these factors are contributing to emissions reductions.

How much has MATS itself influenced the electricity sector?

One thing we wanted to know is how many of the retirements of coal-fired power plants are due to MATS, and we looked at two different studies. One was by RFF colleagues Joshua Linn and Kristen McCormack (who was a research assistant at RFF at the time). They developed an economic model of the electricity sector and looked at the effects of various economic factors and environmental regulations on the retirement of coal plants. They found that something like five gigawatts of coal plant retirements (which is a really small fraction) were due to the MATS rule. A lot of the retirements that have happened in the intervening years have been largely attributed to the fact that natural gas is cheaper. The substantial amount is due to that—generators and electric utilities are opting to use more natural gas and less coal. A small fraction is due to the fact that electricity demand didn't grow as fast as people expected, back at the beginning of the decade. So, there's just a small fraction of retirements that are attributable to MATS, according to their analysis.

Another study was done by some folks at Harvard—James Stock and Todd Gerarden (when he was a student there). They focused on the effects of market forces and regulation on the

A Brief History of Benefit–Cost Analyses for MATS

2012 EPA establishes Mercury and Air Toxics Standards (MATS) to regulate the emissions of toxic air pollutants by electric power plants. EPA finds that promulgating the rule is appropriate and necessary, with annual benefits worth $33–90 billion compared to costs of $9.6 billion.

2015 The Supreme Court allows EPA to implement MATS, ruling that EPA must always take costs into account when deciding whether a regulation is appropriate and necessary.

2015 Electric power plants begin complying with MATS by adopting technologies that reduce emissions.

2016 EPA issues a Supplemental Cost Finding, again showing that the benefits of MATS far exceed the costs and confirming that MATS is appropriate and necessary.

MAY 2018 EPA disbands the Environmental Economics Advisory Committee (EEAC) that for 25 years had worked through the Science Advisory Board to provide evidence-based, impartial counsel and help inform EPA regulations.

SEP 2018 A group of environmental economists establishes the External Environmental Economics Advisory Committee (E-EEAC) independent of EPA.

FEB 2019 EPA changes tack, suggesting that the 2016 Supplemental Cost Finding should not qualify MATS as appropriate and necessary.

DEC 2019 The new E-EEAC releases its first report, which finds that EPA's justification for undermining MATS in February 2019 is based on flawed methods.

APR 2020 EPA issues a final revised Supplemental Cost Finding and concludes that MATS is no longer appropriate and necessary.

Source External Environmental Economics Advisory Committee. 2019. "Fact Sheet" for the *Report on the Proposed Changes to the Federal Mercury and Air Toxics Standards (MATS).*

coal mining industry and coal production. And they similarly found in their decomposition analysis that most of the effects were coming from reduced prices of natural gas. And, using completely different methods, they found a very similar result: that roughly five gigawatts of coal were retired due to the MATS rules.

Those two analyses didn't really focus on emissions so much, but they came to pretty similar conclusions about the effects of the rule, in the end, being fairly small, because the sector is changing so much as a consequence of other market forces.

How does EPA's latest evaluation of the MATS-related benefits and costs bear out in terms of how mercury affects public health?

Most of the benefits really come from the co-benefits. But EPA's recent analysis focuses on the mercury-related benefits, and it only looks at one pathway of mercury benefits that EPA was able to quantify in the original regulatory impact analysis from 2011: the effect on children's IQ of eating fish that are caught by recreational anglers. So, not commercial fisheries, but people fishing and then serving caught fish to their children, which exposes children to mercury and to potential negative IQ effects.

I'm not saying this is all completely settled—it's still an evolving area of epidemiology and science—but at the time, there was even more uncertainty about what the health impacts were of reduced mercury exposure and ingestion. Some more recent studies have suggested that reducing mercury emissions creates previously unknown benefits, in terms of other pathways of mercury exposure, such as fish caught through other means, like commercial fishing—and that cardiovascular

> **"Using completely different methods, they found a very similar result: that roughly five gigawatts of coal were retired due to the MATS rules."**

> **"Some more recent studies have suggested that reducing mercury emissions creates previously unknown benefits … and that cardiovascular effects are likely much bigger than the neurological effects."**

effects are likely much bigger than the neurological effects.

The studies that have looked at the health effects of mercury haven't looked in particular at the MATS-related emissions changes. So, you can't apply the numbers directly to the health benefits of reduced mercury ingestion based on MATS implementation, but you could say that there's a substantial unrecognized benefit that merits further attention by EPA.

And, of course, our committee was composed of economists—not epidemiologists. I'd say there needs to be more epidemiological work in conjunction with economics to flesh out what we know about the health benefits more fully. But I still do think there is enough new work that EPA could have taken their estimate of the health benefits further in the recent reevaluation.

What kind of impact do you hope the report will have?

I hope it will keep the agency focused on doing state-of-the-art ex ante benefit-cost analyses of regulatory proposals, and even push the envelope on that as science progresses. I hope it will show policymakers at EPA the value that independent analysis and adherence to best practices can bring to regulatory decisionmaking at the agency. I hope it will reemphasize the importance of including a comprehensive assessment of all benefits and costs in future EPA regulations.

I also hope it gives some insight into the types of lessons that might be possible with more concerted ex post analyses of existing regulations. Congress acknowledged the importance of bringing evidence of the impacts of past policies to bear on policy decisions going forward, when it passed the Evidence-Based Policymaking Commission Act of 2016 and the subsequent act in 2018. These acts established protocols for data collection and ex post analysis of policy effectiveness to the extent possible across federal agencies.

I hope EPA will look at our recommendations when implementing benefit-cost analyses going forward—that's what we hope.

And what kind of impact do you think the report is *likely* to have?

That's really hard to say. I think in the long run, it could have a substantial impact. In the short run, say the next year and a half—it's hard to say.

When I served on the EEAC with EPA years ago, the primary focus of our efforts at that time was on ex post benefit-cost analysis, which continues to be challenging. The agency has a mandate under a series of executive orders to conduct ex ante regulatory impact analyses for all major environmental regulations. But a lot can be learned from doing ex post reviews—going back and looking at what happened, and how it differed from our expectations, and why—which can inform the development of new regulations. It's possible that academics, or other people who want to inform better policymaking in the future, would pick up on the importance of ex post analyses. I guess that's the hope of the coauthors of this E-EEAC report.

Environmental policymaking is a process that unfolds and evolves over time, and it would be good to learn from experiences as much as possible, so that we can improve the next rounds of the process. ■

Resources Radio

Resources Radio, a podcast launched in late 2018 and produced by the *Resources* editorial team and Resources for the Future (RFF), releases new episodes weekly with hosts Daniel Raimi and Kristin Hayes. Each episode features a special guest who talks about a new or interesting idea in environmental and energy policy.

Transcribed here is one such episode, in which Daniel Raimi talks with Nicholas Z. Muller about measuring health damages from air pollution in various economic sectors in the United States, relative to the economic contributions of those sectors.

IN CONVERSATION
Nicholas Z. Muller and Daniel Raimi

ILLUSTRATION
James Round

Pollution and GDP

The transcript of this conversation has been edited for length and clarity.

Daniel Raimi: Let's talk a little bit about what's usually called "green accounting." When we think about economic well-being, the most common metrics that people use are things like gross domestic product, gross national product, and per capita income. What's the concept behind green accounting, and why might it be an improvement on these more traditional measures for assessing human well-being?

Nicholas Z. Muller: When you think about them in the broadest perspective, gross domestic product and measures like it are an amazing achievement.

In the late 1920s and early '30s, policymakers in the United States were dealing with a very large and well-known disruption called the Great Depression. And in some sense, they didn't have data to inform their decisionmaking in the way that we do today. So, during the early '30s, FDR commissioned economists to come up with systematic measurements that would allow him and his associates to make better decisions. And those metrics ultimately became what we think of now as gross domestic product, or GDP.

For as long as that measurement of performance has been around, economists have known that it's incomplete. It's incomplete in many ways, but the literature has really focused on three areas: the value of leisure time, the value of home production, and environment and natural resources.

Against that backdrop, green accounting works in that third area. It's in principle working toward a more comprehensive measure of economic performance (or output), and looking across time and growth by including the value of environmental pollution damages that escape the boundaries created by GDP—that is, these damages can extend into non-market impacts.

Green accounting also explores the value of natural resources in place. And by that I mean, when we have standing forests, GDP tends to include the value of those forests when they get used—that is, cut down—and green accounting says, "No, wait a minute. There are other services that the forests are actually producing."

Some of the earliest work in green accounting was done in the early 1970s by two Nobel Prize–winning economists, James Tobin and Bill Nordhaus. Their paper really laid out the research agenda; it provided estimates of the value of these different components, of what was missing. Although very insightful, their paper used the primitive empirical techniques that were available back in 1973.

As you mentioned, some of the most accomplished economists have realized and advocated for a long time that incorporating some of these measures is useful and would help us get a better sense of the economy at large, and accounting for things that are outside of markets. But to my knowledge, green accounting hasn't really been adopted widely across the United States or other nations. Why do you think we haven't seen these measures incorporated at large scales?

Taking the long view, by thinking back to that initial work by Nordhaus and Tobin in the '70s, there were empirical obstacles. On the one hand, there are actually the approaches that economists use to derive monetary values for things like recreation experiences, or aesthetics, or existence values for different species. The measurement of some of these values, which are key ingredients in an extended set of green accounts, is frankly very hard.

On the other end of the spectrum, in terms of thinking about steps to incorporate green accounting: we have pollution damage measurements that, just like the valuation metrics, have matured between 1973 and today, such as some of the environmental modeling methods. For instance, if we're thinking about the impacts of pollution emitted by a power plant, we need to know something about where that pollution goes, what it might turn into along the way, some of the chemistry involved, who or what is exposed to it, their response in terms of elevated health risks, and then, ultimately, what is the value of those impacts. There are empirical challenges all along the way in that modeling chain.

It's nice to be able to say in 2019 that we've made great progress in some of those empirical steps that allow us to now have rigorous estimates of the damage for some of these pollutants. Of course, uncertainties remain, as they always will with any modeling exercise. But we've made a lot of progress. We're now in a position where we can credibly report to policymakers what these values might be, and have a serious discussion about extending the existing accounts to include the green accounts.

There's another side to this, which is vested interests. Firms in certain industries may not want environmental accounts to be officially on the books. For example, think about firms that own or consume large quantities of pollution-intensive fossil fuels. They may not want to have their value-added be the net of the pollution damage that their production activities cause. This is not a statement about their production activities not having value—just that the existing accounts turn out to mismeasure that net value, when one takes into account pollution damage.

Really, the obstacles are twofold. There's an historic, practical, empirical set of obstacles; and there's the obstacle of the status-quo way of doing things.

Let's get into some of the research. The paper we're going to talk about, from the journal *Proceedings of the National Academy of Sciences*, is called, "Fine particulate matter damages and value added in the US economy." It's a paper you've authored with your colleagues Peter Tschofen and Inês L. Azevedo. You measure something called "gross external damages" from PM2.5 (fine particulate matter that measures 2.5 microns or less). You assess the health damages from this kind of pollution across different sectors of the economy.

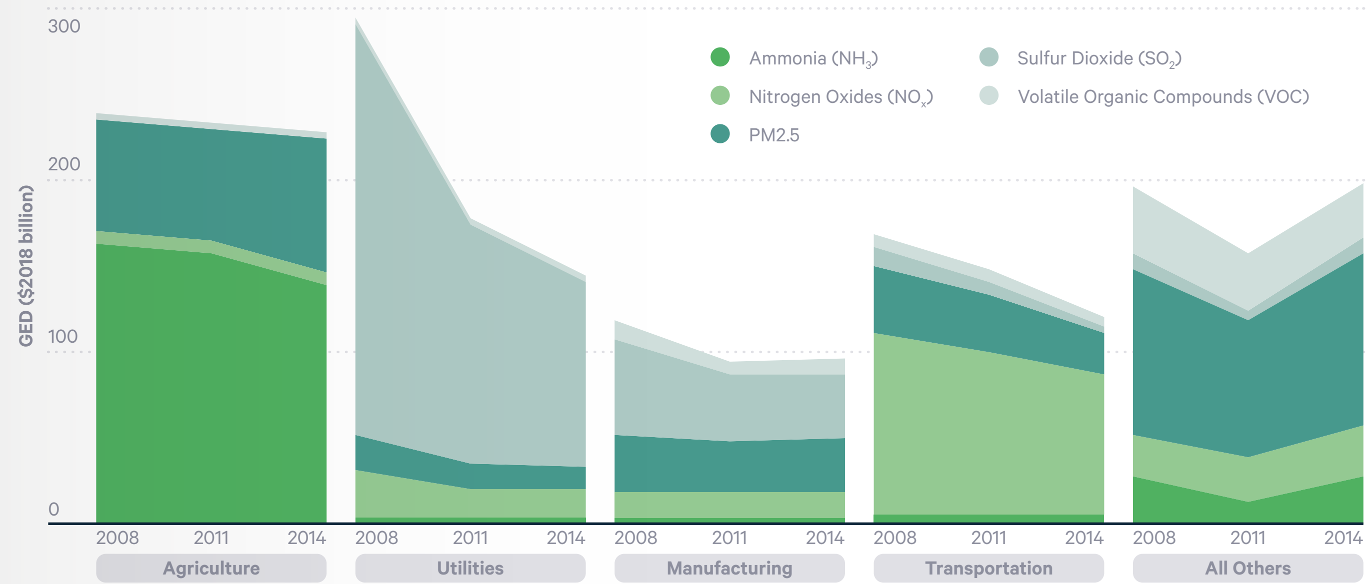
Writ large, how do these gross external damages from PM2.5 compare with the traditional measure of GDP that we've been talking about, and how has that changed over time?

In the most recent year for which we have the data necessary to do the modeling exercise that was conducted for the paper—which is 2014—we find that the gross external damages amount to about 4 or 5 percent of GDP, which might not sound like much, but it's really a pretty big number. That 5 percent number is, of course, subject to assumptions made in the models about various key parameters, such as the value of damages and how sensitive humans are to PM2.5 exposure. We certainly go to the literature to find appropriate choices for those parameters, but I'll just note that there are other ways to do this that can make that 5 percent number go up or down.

Generally, as a long-term trend, PM2.5 and associated damages have fallen precipitously in the United States since the 1970s. In some of my additional work, I've found that the share of GDP contributed by PM2.5 damage was much, much higher back in the '70s. Not coincidentally, the Clean Air Act—our primary set of regulatory tools in the United States—was passed in 1970, and it was implemented meaningfully throughout the '70s. I think those two things are certainly related.

When I have looked at the pollution monitoring data for years more recent than 2014 (just looking at the air pollution monitoring network in a collection of cities in the United States, and not the full modeling exercise that Tschofen and Azevedo and I conducted), I find a disturbing trend that the PM2.5 levels have started to go *up* in both 2017 and 2018, after a decade of continuous decline.

FIGURE 1 Gross External Damages (Due to Premature Mortality from Fine Particulate Matter Pollution) among Select US Economic Sectors



Source "Fine particulate matter damages and value added in the US economy." Peter Tschofen, Inês L. Azevedo, and Nicholas Z. Muller. *Proceedings of the National Academy of Sciences.* Oct 2019, 116 (40) 19857–19862; DOI: 10.1073/pnas.1905030116.

> **I would argue that it is a very bad idea to relax or not enforce the current standards, which have been very hard won.**

Just to put some numbers on the trends that you identify in the paper, in terms of the gross external damages from PM2.5: you find about 6 percent in 2008, about 4.6 percent in 2011, and then declining to 4.2 percent in 2014. But, as far as you know, 2014 is the most recent year for which the full set of data is available.

In the paper, you note that a relatively small number of economic sectors contribute a large share of these PM2.5 emissions and associated damages. Can you talk about those economic sectors, and which of them might offer some of the best opportunities for near-term emissions reductions?

We find this result is associated with damages from the agriculture sector, the utility sector, the manufacturing sector, and transportation. As you stated, those sectors together contribute just 20 percent of GDP, and they contribute three-quarters of the total air pollution damages that we track.

If we were to think about the value that those sectors contribute to economic performance, it's important to note that we as authors of the paper are not arguing for the elimination of the agriculture sector, or utilities, or anything of the sort. What we're doing is merely saying, "Here's a way that you can characterize the value-added that those sectors contribute to the US economy." And when you build in some of these extra-market, or non-market, impacts (the costs that they confer on the population) their value-added really changes appreciably—especially agriculture and utilities.

From the point of view of policies and additional abatement opportunities, I think the first thing I want to say is that the United States has made a lot of progress in improving our air quality over the 50 years that the Clean Air Act has been in place. And I would argue that it is a very bad idea to relax or not enforce the current standards, which have been very hard won. I'm thinking about things like fuel economy and the vehicle fleet, or relaxing

TABLE 1 Ratio of Gross Economic Damages (GED) to Value Added (VA) in the US Economy across Years for the 10 Highest-Ranked Industry Groups

Industry group (2008)	GED/VA	Industry group (2011)	GED/VA	Industry group (2014)	GED/VA
Water transportation	1.9	Animal production and aquaculture	1.7	Animal production and aquaculture	2.0
Animal production and aquaculture	1.6	Water transportation	1.2	Waste management and remediation services	0.87
Electric power generation, transmission, and distribution	1.4	Crop production	1.1	Water transportation	0.78
Crop production	1.2	Electric power generation, transmission, and distribution	0.76	Crop production	0.72
Truck transportation	0.86	Truck transportation	0.76	Electric power generation, transmission, and distribution	0.63
Waste management and remediation services	0.63	Rail transportation	0.37	Truck transportation	0.56
Nonmetallic mineral products	0.35	Waste management and remediation services	0.35	Rail transportation	0.35
Rail transportation	0.32	Nonmetallic mineral products	0.29	Nonmetallic mineral products	0.28
Iron and steel mills and manufacturing from purchased steel	0.32	Iron and steel mills and manufacturing from purchased steel	0.28	Transit and ground passenger transportation	0.28
Transit and ground passenger transportation	0.27	Transportation structures and highways and streets	0.26	Iron and steel mills and manufacturing from purchased steel	0.23

Source "Fine particulate matter damages and value added in the US economy." Peter Tschofen, Inês L. Azevedo, and Nicholas Z. Muller. *Proceedings of the National Academy of Sciences.* Oct 2019, 116 (40) 19857–19862; DOI: 10.1073/pnas.1905030116.

or not enforcing some of the ambient standards for PM2.5. I would suggest that we work (at least initially) on maintaining our current goals as stated—statutorily and administratively.

I would also note that the agriculture sector is a really interesting place to think about additional abatement, because we traditionally think about air pollution control from smokestacks and tailpipes. (At least, that's the way I think about it.) Agriculture offers different opportunities: We might consider changes in the composition or intensity of fertilizer, which contributes to emissions of ammonia, which contributes greatly to the damages that we're measuring in that sector. Additionally, animal wastes that are produced in the course of producing livestock are also important contributors. If we can manage that waste in a way that's more cognizant of the air pollution impacts from those production activities, that would be great.

In a more broad sense, it also speaks to how we as consumers think about the composition of our menus or the composition of our diet—right? If we're more aware of these upstream costs associated with the production of livestock for food, then we may decide to change our habits, or we may need nudges in the form of public policy to help us do that.

The most dramatic trend is a steep reduction in sulfur dioxide (SO_2) emissions from the utility sector. And I imagine that's mostly the decline of coal-fired electricity generation in the United States—is that right?

> "If a five-to-one or a ten-to-one ratio is not low-hanging fruit, I frankly don't know what is."

Yes. It's not only the decline in how much electricity we're producing by burning coal, which is largely about the switch to natural gas. But it's also the fact that many of the remaining coal-fired power generators are using flue-gas desulfurization (scrubbers), which removes SO_2 from the waste stream quite a bit—to the tune of 80 percent or more. Both of those market and regulatory forces are associated with or causing that steep decline in SO_2 emissions.

And that, of course, brings us back to the Clean Air Act and the importance of policy measures to deal with some of these issues.

Another really interesting feature is Table 1 of the paper. This table shows the ratio of damages to value-added across different economic sectors—how much health damage is associated with a given sector, and how much value-added is associated with that sector. Let's compare this simple metric across different parts of the economy. Can you talk a little bit about which economic sectors are most damaging, relative to their economic contributions, and which are the least damaging? How has that changed over time?

One interesting question is: How do we assess "most damaging"?

One perspective might be: You total up all the impacts, you get a gross external damage (GED) number, and then you rank the sectors and say the one at the top is the most damaging. As an economist, my view is that's not quite right, because we need to remember that these sectors are there for a reason—they're producing something of value (at least in principle) to the economy. So, we need to compare both the external damages (the air pollution impacts from these sectors) to the monetary value of the products that those sectors are producing. That's what really leads us to this GED-to-value-added ratio that we report in the table.

From that perspective, it appears that livestock production is the most damaging relative to value-added in 2014. We estimate that the gross external damages from that sector are greater than their market value-added.

A cautionary note is that the fact that damages from that sector exceed its value-added should not suggest that we shut that sector down or ban its production. What it does say is that the regulatory apparatus, insofar as it's targeting air pollution and air pollution damages, is probably not stringent enough for that sector. We need to bring that ratio down. This is evidence that the regulatory stringency applied to that sector is apparently far too lax.

We also see evidence that sectors, or subsectors like waste management, are generating lots of damage relative to value-added—these are things like incinerators. But I would note that we need to think carefully about what value-added is for the waste management sector. There are probably non-market health sanitation benefits associated with waste management that may not be included in the value-added figure, which might inflate the ratio of damages from air pollution to value-added for that sector.

So, the measures that we're using here in this work may not account for the health values of having clean homes, clean streets, clean parks, and so on.

Absolutely.

When you look across these different economic sectors at their health damages and their value-added, do you see any particularly low-hanging fruit for either the private sector or public policies, to address emissions at low cost?

As a microeconomist, I don't typically think about businesses pursuing emission reductions as a primary objective. What we need to think carefully about is whether or not there are complementarities between profit maximization as the objective and emissions reductions.

I'll note something about low-hanging fruit, for continuing to reduce emissions and improve the environment: when EPA and other scholars have historically looked back at the Clean Air Act and assessed the benefits and costs associated with pollution improvements, they typically find ratios of benefits to costs in excess of five to one, or even ten to one. So, every dollar that's invested in pollution control, according to those studies, is leading to an additional \$5 or \$10 in human health and environmental improvement. Continuing to maintain or even strengthen standards, and to enforce existing standards, is not generally acting as a drag on economic performance—provided your measure of economic performance is inclusive of both the benefits (which may extend beyond measures like GDP) and the costs. If a five-to-one or a ten-to-one ratio is not low-hanging fruit, I frankly don't know what is. ■

Lessons from the Clean Air Act

A book coedited by Resources for the Future's Dallas Burtraw finds contemporary relevance in the decades-old environmental bill.

In a series of workshops organized by the American Academy of Arts and Sciences and initially led by former RFF President Robert Fri, scholars convened from across disciplines to study policies that embodied elements of both durability and adaptability. They hoped to find legislation that balanced the two seemingly contradictory ideas—the ability of a law to persist through upheaval, and the ability of a law to shift course as necessary. These collaborative workshops also revealed the importance of offering flexibility in meeting regulatory standards. While the participants cast a wide net, considering legislation that covered issues from healthcare to technology, the Clean Air Act of 1970 emerged as an ideal case study for analyzing all three of these concepts.

A **nd that was the origin of the project that became a book. *Lessons from the Clean Air Act: Building Durability and Adaptability into US Climate and Energy Policy*, published in April last year, is an ambitious collection. A compendium of contributions from legal scholars, economists, political scientists, and environmental policy experts, the book surveys key lessons gleaned from one of the most significant environmental laws in American history.**

"We realized that we had, in the Clean Air Act, a broad portfolio of policy designs that were related to each other and exhibited different degrees of durability and adaptability and flexibility," says Dallas Burtraw, the Darius Gaskins Senior Fellow at RFF who coedited the book with UCLA Law's Ann Carlson.

The Clean Air Act of 1970 (CAA) is an uncommonly sweeping piece of legislation: over its half-century history, the act has been used to enforce limits on both stationary and mobile sources of pollution; set standards for the chemical composition of fuels; impose maximum concentrations of key pollutants, from carbon monoxide to lead to particulate matter; catalyze markets to protect public health; and much more.

The act itself has endured a number of changes, too: contemporary regulations under the CAA are based on an early, mostly limited version of the law passed in 1963; substantive revisions in 1970, 1977, and 1990; and an evolving understanding of air pollution, public health, and the regulatory power of the US Environmental Protection Agency (EPA)—all of which have impacted how the law is implemented.

This is all to say that the CAA is unique in its scope, its ambition, and its ability to withstand change over the decades. And as the book makes clear, studying the law's historic successes—as well as its deficiencies—offers pivotal lessons to policymakers.

"No major environmental legislation has passed Congress since 1990. As a result, we need to think hard about building durability, adaptability, and flexibility into legislation in the first instance, since we may not get another bite at the apple," Carlson says.

Durability

As Burtraw and Carlson write in their introduction to the book, "durability" does not mean that a law remains fixed in time. Rather, durable legislation "continues to accomplish the objectives for which it was adopted" and "remains effective after the coalition that led to its adoption … no longer holds the reins of power." A law can be durable even if implemented in different ways, years after its passage—if policymakers, private sector innovators, and the public trust that the law is fulfilling its initial goals.

One example of remarkable durability, as political scientist Barry Rabe explains in the book, is the law's unique treatment of automobile emissions in California. The arrangement, known colloquially as the California waiver, grants California the authority to propose regulations on automobile pollution more stringent than federal prescriptions. This framework emerged because of California's unique problems with air pollution and its long history of environmental legislation—state laws passed in 1947 and 1960 are considered "the world's first auto emission regulations."

TEXT
Cole Martin
ILLUSTRATION
Yukai Du

> **"We realized that we had, in the Clean Air Act, a broad portfolio of policy designs that were related to each other and exhibited different degrees of durability and adaptability and flexibility."**

Under the arrangement, California can apply for a waiver to implement stricter regulations—and, as of 1977, other states can choose to implement California's standards. Historically, the federal government has approved the overwhelming majority of California's waivers and has implemented new federal guidelines based on programs first piloted in California, including rules on sulfur dioxide pollution and standards for low-emission vehicles.

A regulatory regime "likely without parallel in the United States, both in environmental policy and in other areas of regulatory federalism," according to Rabe, the California waiver has nevertheless persisted. At its most complex, it creates a two-part national market for vehicles: the system streamlines standards for automobile manufacturers, rather than letting every state impose their own standards, and it allows new regulations to be tested statewide before expanding nationally, if the new regulations come at minimal cost.

Some regulations under the CAA have been durable—sometimes to the detriment of the law's success. RFF University Fellow Joseph E. Aldy explains how Congress's 2007 revamp of its Renewable Fuel Standard program has prompted few environmental benefits, for instance. The new regulations set volume requirements for low-carbon biofuels that increase each year, but they also allow EPA to waive a year's renewable fuel standards if they impose a significant economic burden, or if there is "inadequate domestic supply."

The goals laid out in the statute have been infeasible: according to Aldy, US production of cellulosic ethanol fell below five percent of the statutory goal for 2016. The Government Accountability Office has deemed the statute's ultimate goal of selling 36 billion gallons of renewable fuels in America by 2022 to be unlikely. EPA thus has had to issue frequent revised guidelines for biofuel production, leaving automobile manufacturers unsure about which standards they are expected to meet each year. The revamped Renewable Fuel Standard regulations, rather than offering trustworthy standards and encouraging innovation in low-carbon fuels, have been unpredictable, provoking frequent calls for legislative reform.

Adaptability

B rown University's Eric Patashnik defines "adaptability" as "the capacity of policymakers to recalibrate policy commitments and programs through midcourse adjustments." The CAA's adaptability—most exemplified by EPA using its authority under the act to continually update environmental rules—has proved especially important, given the infrequency of significant legislative revisions.

UCLA Law Professor William Boyd asserts that the CAA's National Ambient Air Quality Standards (NAAQS), which impose limits on "criteria pollutants" deemed by EPA to threaten public health, "can make a strong claim to being the most ambitious and successful major program in US environmental law." And the program's durability can be attributed at least in part to the discretion granted to EPA administrators.

The original CAA in 1970 mandated that EPA begin regulating six key "criteria pollutants" based on the best available scientific knowledge of their health impacts. As scientists outside the agency have improved their understanding of how air pollutants threaten public health, EPA has modified the standards accordingly. Lead was added as a new criteria pollutant in 1976; restrictions on particulate matter have become more specific; and, as recently as 2015, the NAAQS program reduced its acceptable level of ground-level ozone from 72 to 70 parts per billion—all without the need for congressional approval.

As with the 1977 amendments, EPA makes adjustments to NAAQS based on a mandated system of review every five years. These amendments also created the Clean Air Science Advisory Committee, tasked with recommending changes to the regulations for criteria pollutants and evaluating the effectiveness of the review process.

In sum, the program has dependable procedures to respond to updates in scientific knowledge and make necessary adjustments to protect public health—but also constrains EPA's power by requiring sufficient scientific evidence to support adjustments. Allowing some (but not too much) discretion has largely proven successful: according to Boyd, "aggregate national emissions of the six criteria declined by an average of 71 percent while … gross domestic product [grew] by 246 percent" from 1970 to 2015. Other design elements across various CAA programs place similar constraints on regulators, from formal fact-finding procedures and expert review committees to opportunities for citizens to bring lawsuits.

Florida State University's Hannah Wiseman shows that the CAA has not been universally successful at prescribing clear rules while still allowing adaptability. Acknowledging that the law's regulation of stationary sources remains a "remarkable achievement," Wiseman nonetheless finds that 1977 reforms, which imposed stringent rules on new stationary sources of emissions in an effort to meet NAAQS, created a rigid, bifurcated regulatory regime, wherein old sources and new sources receive different treatment.

This system, known as New Source Review, set standards that new proposed projects to build stationary sources of criteria pollutants had to meet before construction. But the law applied only to "major new sources," meaning that older sources were not subject to New Source Review regulations, unless a "major" renovation was planned that would significantly increase emissions. This inflexible arrangement, in which EPA is incapable of adapting to contemporary needs and regulating older sources of pollution as stringently as newer sources, ultimately "detracts from progress under the act."

Flexibility

Burtraw and Carlson conceptualize "flexibility" as easing the burden of compliance—giving energy producers options as to how to reduce emissions through incentive mechanisms, rather than prescriptive regulations. Flexible legislation allows those affected to draw on their own knowledge and work within their own capabilities to meet standards.

Patashnik describes a number of early CAA programs that utilized market mechanisms, including the Acid Rain Program, now "universally regarded as an environmental success story." Sulfur dioxide and nitrogen oxide emissions react with other atmospheric chemicals and fall to the Earth again as acid rain, threatening ecosystems and human health. Before lawmakers took action, acid rain was largely attributable to long-running coal plants in the American South and Midwest, which burned high-sulfur coal. But these plants—nicknamed the "Big Dirties"—threatened more than just nearby ecosystems, as acid rain can fall hundreds of miles away from pollution sources.

As part of the 1990 amendments, Congress established a sulfur dioxide allowance trading program, which set ambitious emissions reductions targets affecting all continental states. The policy phased in slowly, initially affecting only 110 power plants in 1995 and later expanding to include more than 3,000 by the year 2000. EPA granted each of these plants "allowances," which they could buy from or sell to other plants. The flexible system reduced costs for polluters, who could prioritize the emissions reductions technologies that made the most sense for their companies, while also incentivizing innovation. Energy producers experimented with cost-effective coal mixtures and constructed more efficient "scrubbers" to desulfurize coal. Consequently, even as electricity production from coal-fired power plants increased 25 percent from 1990 to 2004, emissions fell by five million tons.

The CAA also illuminates the drawbacks of too much flexibility. Aldy describes how the 1990 amendments created the reformulated gasoline (RFG) program, which aimed to reduce volatile organic compounds in gasoline, which can cause ozone pollution. The policy mandated that producers residing in designated counties reduce aggregate volatiles in their fuel by 27 percent and allowed other counties and states to opt in. As of the book's publication, the RFG program impacted 30 percent of the American market in the summer, when ozone pollution is at its worst.

Notably, under the RFG program, all volatiles are treated the same, so producers have discretion to decide which types of volatile chemicals to reduce. The problem with this flexible arrangement is that not all volatile chemicals are equally likely to create smog; thus, the large majority of refiners have reduced concentrations of less reactive volatiles, complying with CAA regulations but without significantly reducing emissions. The only state to see significant reductions in ozone concentrations is California, largely because the state has enacted fuel controls more stringent than the national RFG program requirements.

The Future

One lesson from the book is that the scientific understanding of air pollution is constantly evolving—so it's no surprise that since the book's publication just last year, new policy developments have shifted how air pollution is regulated.

For instance, Rabe alludes to "continuing support for California's efforts to continually push the envelope" on automobile emissions rules. However, more recently, the state has encountered resistance from the federal government. Last September, the Trump administration moved to revoke California's ability to set more ambitious restrictions on automobiles than federal standards, prompting a lawsuit from California and 22 other states. This provision of the CAA, noted for its durability, nonetheless faces new threats.

> **The transition to a largely decarbonized economy in the next four decades will be enormously complex and massive in scope.**

> **What enabled progress to happen was this machinery of process that had been built into the Clean Air Act, which just kept driving things forward.**

"It's not that the Clean Air Act gave states the authority to regulate—it *required* them to regulate," Burtraw says. "It empowered states and put them in a leadership role through the framework of 'cooperative federalism,' putting a strong social goal in place and leaving states responsible for implementation and enforcement."

"It may be up to the courts to protect California's special role, or a new administration may recognize the extraordinary benefits the country has received by allowing California to lead under the waiver provision," Carlson says.

Importantly, the CAA does not allow so much adaptability that any administration can restructure regulations as it sees fit. The book emphasizes that much of the act's durability stems from the processes encoded in the law, which ensure that any proposed regulatory change has been thoroughly vetted and empirically justified. That lesson holds true today, especially as data cited by EPA officials in scientific reviews becomes fodder for lawsuits against proposed regulatory changes. For instance, a long-awaited curtailment of fuel efficiency standards was delayed, in part because internal findings from EPA officials found that the rule would harm consumers.

Meanwhile, in Oregon, lawmakers walked out of the state legislature for the second year in a row to protest a bill that proposes economy-wide carbon pricing, which would help Oregon make meaningful reductions in greenhouse gas emissions. Burtraw notes that the recent walkout reflects continuing challenges for states, which largely operate at a "decentralized level without federal coordination." But he emphasizes that the prognosis is hardly catastrophic, as other states have made progress in implementing ambitious environmental agendas. Virginia and New York have mandated a transition to clean energy, for example, and other states look poised to follow their lead.

Carlson agrees. "We get a lot of creativity coming out of state policymaking that might not occur if all regulatory power were consolidated at the federal level," she says.

As Burtraw and Carlson explain in the conclusion of the book, "The transition to a largely decarbonized economy in the next four decades will be enormously complex and massive in scope." The CAA, as a historically successful environmental law, provides a literal legal framework under which future regulations can proceed, along with a rich history of regulations succeeding, failing, and adapting, which can guide policymakers as they craft contemporary legislation with similarly sweeping aims. Some CAA programs might need revision, but through new administrations, new regulations, and new scientific assessments of the impacts of hazardous air pollutants, the CAA has persisted.

"There was a lot of uncertainty when the Clean Air Act was passed, about how and if those goals could be achieved," Burtraw says. "But what enabled progress to happen was this machinery of process that had been built into the Clean Air Act, which just kept driving things forward."

"I like to say that the Clean Air Act is like a freight train: it's slow, but it's very hard to stop." ■

Cole Martin *is a staff writer and reporter at Resources for the Future.*

Satellites Can Supplement the Clean Air Act's Land-Based Air Monitoring Network

The current land-based pollution monitoring network in the United States fails to account for fine particulate matter pollution across much of the country. Satellite data can help fill in the gaps.

TEXT
Alan Krupnick

ILLUSTRATION
James Round

Clean air is invisible. But sometimes polluted air is, too—even according to the network of monitors in the United States that's specifically designed to show us what we can't see.

The air pollution monitoring network run by the US Environmental Protection Agency (EPA) has shown that air pollution in the form of fine particulates (termed PM2.5, which is particulate matter that has a diameter of 2.5 microns or less) violates this pollutant's air quality standard for 23.3 million people. But former RFF Fellow Daniel Sullivan and I have found that EPA's national network of land-based air quality monitors is so thin that it misses many other areas of the country that also violate the standard. Our work shows that EPA and its land-based monitoring network have failed to identify 54 counties and another 25 million people in the United States who live in areas that violate these air quality standards.

Satellite data can help with the shortcomings of our land-based monitoring network. Satellites now are pervasive and accessible; they can provide comprehensive, up-to-date, high-resolution data to estimate PM2.5 concentrations across the country. With all these data coming from satellites, it is time for some serious re-thinking of Title I of the Clean Air Act (CAA) and the regulation concerning how areas are designated as meeting or violating the air quality standard.

How Has the Current Monitoring System Gotten Things so Wrong?

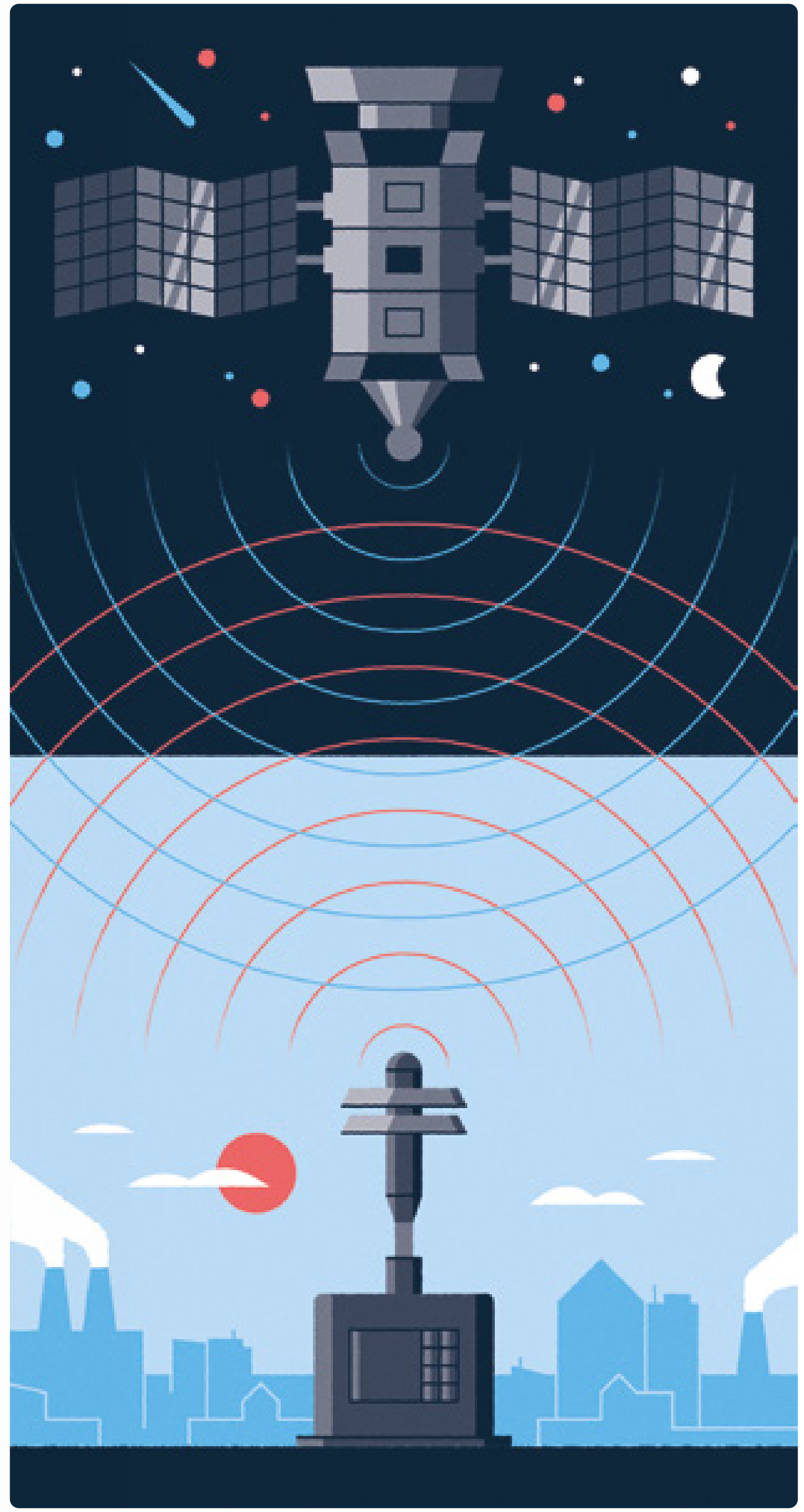
One big downside to this system is that the land-based monitoring network is sparse. As Daniel Sullivan and I have shown, the majority of US counties lack monitors altogether. Of 3,100 counties in the United States, only 651 (21 percent) have any PM2.5 monitors at all. Among those 651 counties as of 2015, about 48 percent had a single monitor, 24 percent had two monitors, and only 29 percent had three or more. Furthermore, readings at an air pollution monitor do not necessarily represent the full range of concentrations across areas as large as a county.

Why are monitors so sparse? One reason is that they are expensive. EPA identifies specific "federal reference monitors" as appropriate for monitoring air pollution consistent with the CAA (as documented in 40 CFR part 53). EPA says that the cost of buying the approved monitors varies between $15,000 to $50,000, with additional operating costs labeled as "expensive." However, "expensive" is relative, and other options exist. States have access to a suite of air quality sensors that can be purchased for under $2,500. These sensors are meant to be relatively cheap and to supplement, rather than replace, devices that follow federal reference methods for sampling and analyzing ambient air. As we recommend below, satellite data could be used similarly, but with better results.

With a limited number of monitors in an area, their placement is critical. Even more so if pollution concentrations have steep spatial gradients and vary a lot with weather conditions, economic activity changes from day to day, and economic growth continues over the longer term. All these conditions generally hold.

Conventional wisdom is to assume that the concentrations registered by the required monitoring network are representative of concentrations throughout the area in question, and good monitor placement is critical to this assumption. EPA has rules for where monitors must be placed (per 40 CFR part 58 of the CAA), and the EPA administrator has ultimate authority to approve a monitor network. But the rules explicitly (and understandably) balance data needs with government resources.

While more technical documents may help govern monitor placement, the main document noted in the "Network Design Criteria



for Ambient Air Quality Monitoring" appendix of the related federal regulations code outlines minimum monitoring requirements only. For example, only three monitors are required for PM2.5 in designated metropolitan areas over 1,000,000 people and with design values near or exceeding the CAA's established National Ambient Air Quality Standards. Minimum requirements mandate one near a roadway and one in an area of expected maximum concentration at the neighborhood or urban scale. The rules also designate that monitors should not be located "in the immediate vicinity of any single dominant source [of emissions]."

Thus, the states get plenty of leeway in where they place monitors, due to EPA's desire to be flexible and mindful of the cost that monitor placement imposes on localities. Recent research by Corbett Grainger, Andrew Schreiber, and Wonjun Chang in 2018 shows that some monitors appear to be placed in areas of low pollution relative to elsewhere in the county, such as upwind of major point sources. Given the potentially high administrative cost to a local government of nonattainment status, and the high associated costs of coming into attainment for the region so classified, it would not be surprising to find that some local and state governments would be tempted to—or actually do—game the system, as to where they place monitors.

But statistical research cannot illuminate motive; research can only show that pollution hotspots are being missed, as Daniel and I show in a working paper published in 2018.

Land-based monitors have another problem: they don't all run all the time. Again, this problem is because of cost and, relatedly, old monitor technologies. Processing the data that monitors collect is expensive, and better technology comes with a high replacement cost. While new PM2.5 monitors tend to operate at least 300 days per year, we have found that 56 percent of PM2.5 monitors gathered data on fewer than 121 days in 2015, and 23 percent gathered data on fewer than 80 days. If these days were randomly distributed over the year, then setting the design value that characterizes air quality should not lead to bias. Unfortunately, the operating times of monitors are announced ahead of time. Because of the high cost to firms if their area is classified as nonattainment, and possible extra scrutiny from the local authorities if the firms are found to contribute to air pollution problems, firms have incentive to pollute more on days when the monitors are not operating. If air pollution "hangs around" for a few days, this strategy would not be particularly productive. But PM2.5 pollution can move quickly. And in fact, recent evidence from Eric Zou in 2018 has shown that firms emit less on days when monitors measuring PM2.5 and PM10 (particles 10 microns or less in diameter) are in operation. These effects persist even after correcting for weekends and holidays.

Can We Fix These Problems?

Satellite data can help solve the problems that get in the way of accurately tracking air quality. Satellites provide the spatial and temporal concentration detail that's needed to reliably detect and monitor pollution on the ground. For example, sensors sent into orbit on satellites, such as NASA's Moderate Resolution Imaging Spectroradiometer (MODIS), offer at least one

"Statistical research cannot illuminate motive; research can only show that pollution hotspots are being missed."

concentration reading for a 1- to 3-km² grid over the entire country each day and at roughly the same time. And because those data are freely available (although processing the data has a high start-up cost), satellites eliminate the underlying cost and incentive issues that otherwise prevent a more comprehensive and appropriately placed land-based monitoring network from being developed and operated daily.

But are satellite data a panacea, and should they replace land-based monitoring in the attainment designation of areas? Evidence suggests that the answer to both questions, in the short term, is no.

Let's consider satellite data in a bit of detail. Satellites do not actually measure PM2.5 on the ground as such. They measure something called aerosol optical depth (AOD), which represents the density of aerosol particles. The measure is itself the difference between the solar radiation at the top of the atmosphere and the radiation that reaches the Earth's surface. The more airborne particles there are, the less radiation is detected at the surface, and the larger is AOD. On cloudy days, no measurements are possible.

AOD must be converted to PM2.5. This is done using statistical methods combined with a global atmospheric chemistry transport model called GEOS-Chem (where "GEOS" stands for Goddard Earth Observing System). GEOS-Chem provides information about how pollutants are transported from one area to another by the wind, and how chemical compounds change as they travel. The resulting estimates are calibrated by lining up the estimated PM2.5 concentrations with the land-based readings. Thus, land-based monitors are critical inputs to the data conversion process.

In our study, Daniel Sullivan and I took PM2.5 estimates from satellite data for the grid cells surrounding land-based monitors and compared those estimates to PM2.5 readings from the monitors themselves. When we used PM2.5 concentrations calibrated for the entire globe, we observed serious errors and, more importantly, biases in the US satellite readings. Initially, we saw that PM2.5 concentrations from satellite data actually *overestimated* the readings from ground-based monitors when the latter registered high readings. However, using PM2.5 data calibrated only with North American monitors eliminated the bias, although the satellite readings became small *underestimates* of ground-based monitors with high concentration readings, and "small" errors around the true value remained.

Thus, we recommend that satellite-based PM2.5 readings be used to supplement, but not replace, land-based monitors in the air quality designation process. Implementing a plan like this could also involve shifting the locations of land-based monitors to better measure pollution hotspots, installing new land-based monitors in areas that have none, and providing satellite readings of PM2.5 concentrations on days when the land-based system is not operating. For the last of these ideas, firms could be told that satellite data will be examined on such days; if hotspots flare up during the unmonitored periods, likely sources will be held to account. Of course, an easier (if costly) solution to the unmonitored-days problem is to replace the less frequently run monitors with devices that continuously operate. And cheaper still would be to keep secret the days

"We recommend that satellite-based PM2.5 readings be used to supplement, but not replace, land-based monitors in the air quality designation process."

during which the less frequently operating monitoring stations are scheduled to run.

While EPA has not yet embraced satellite monitoring data to supplement federally standardized monitoring, the agency has nonetheless embraced cheap sensor technology for the same purpose, as noted above. These devices are described in EPA guidance as useful for localities to "locate hotspots, identify pollution sources, and supplement monitoring data," as well as provide more timely data. However, these supplemental monitoring devices generally perform very poorly, compared to data from monitors that operate by EPA's federal reference methods. Satellite data could do better.

Setting Boundaries

We have left a fundamental and important issue for last: How should boundaries for nonattainment areas be determined, given that satellite data comes in at the relatively high resolution of 1- to 3-km²?

First, we need to understand how these boundaries are traditionally determined. Basically, states propose nonattainment area boundaries by combining contiguous areas that violate the standard, along with "nearby" areas that contain sources which might be leading to violations. States are required to use five types of information to propose these suggested boundaries: jurisdictional boundaries, air quality data, emissions data, geography and topography information, and weather data. States also use air quality modeling that shows where the pollution comes from and goes to. EPA is ultimately responsible for approving or setting boundaries of nonattainment, attainment, and unclassifiable areas.

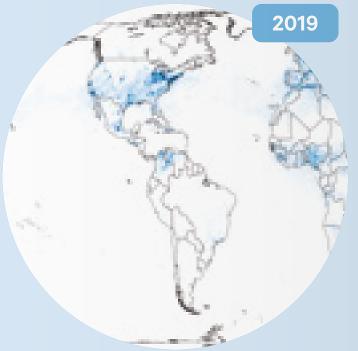
Because pollution disperses, nonattainment boundaries work best when they err on the side of being more geographically expansive, rather than precisely drawn. High-resolution satellite data could provide for more tightly drawn boundary estimates, which may cut abatement costs in the long run, but erring on the side of public health with larger area boundaries seems wise, in general.

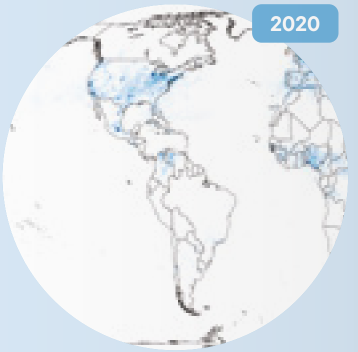
Still, EPA has ample opportunities to accept satellite data as a supplement to land-based monitor data in making decisions about attainment borders. Notably, adding satellite data would necessitate a change in EPA rules. Because of the high resolution of satellite data, their use would make clearer which jurisdictions should be included as violating. But these data—and indeed, any monitoring data—need to be supplemented with other types of data and air quality modeling to most effectively identify areas that contribute to air quality violations and which, therefore, are areas that should be included within nonattainment boundaries.

None of these methods is perfectly reliable, and particularly not on their own. But satellite data can provide an indispensable—and inexpensive—supplementary source of air quality data that can check against cheaters and weak analyses. By combining land-based data with satellite monitoring data, we can have much more confidence that our communities get an accurate gauge of their local air quality and are, therefore, properly classified. ■

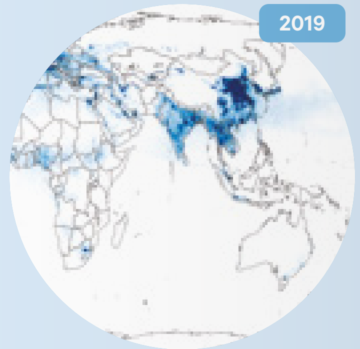
Alan Krupnick is a senior fellow at Resources for the Future.

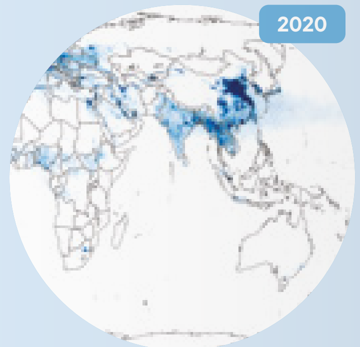
Western Hemisphere



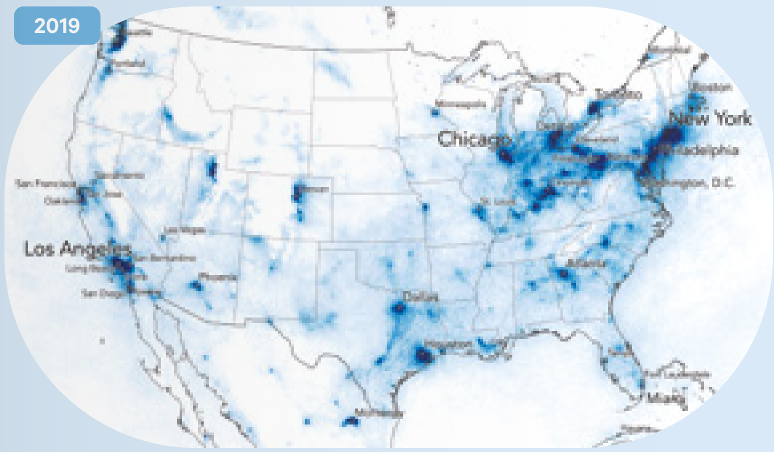


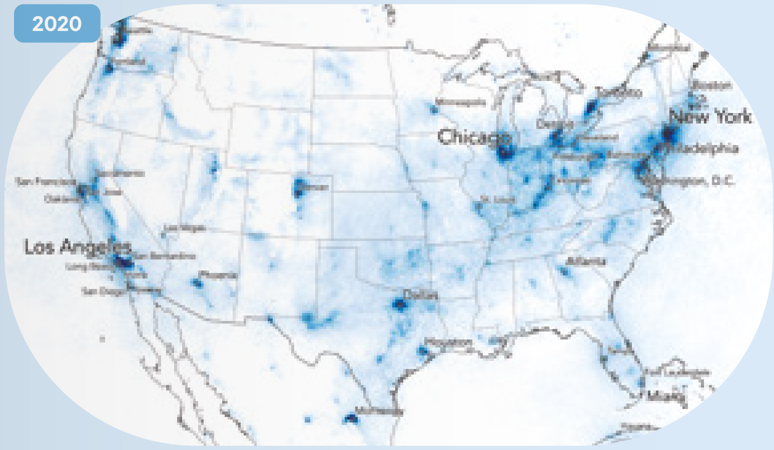
Eastern Hemisphere



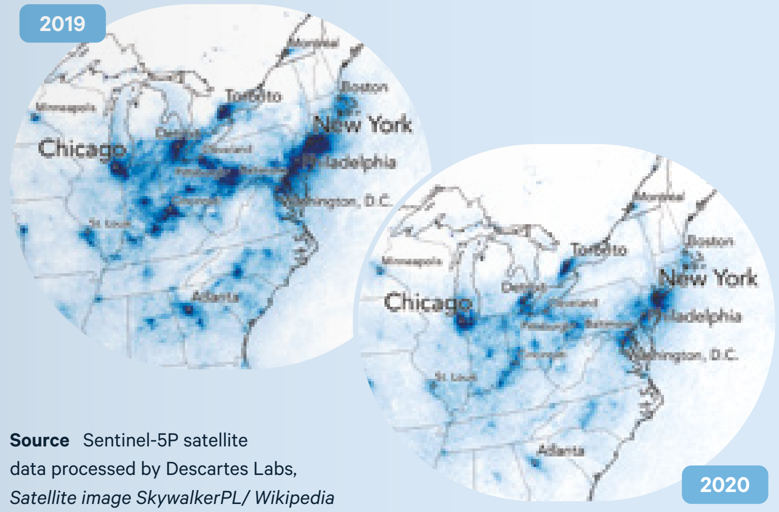


United States





Eastern United States



Source Sentinel-5P satellite data processed by Descartes Labs, *Satellite image SkywalkerPL/ Wikipedia*

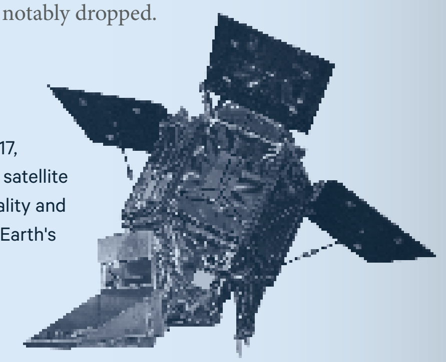
Pollution in a Pandemic

Satellites can measure air quality in real time, including in a time of crisis.

Reports of a novel coronavirus, SARS-CoV-2, increased in volume and urgency during the first few months of this year. Countries around the world began enforcing lockdowns and, by early March, US cities and states encouraged residents to stay at home to help stop the spread of illness. As one source of mortality was rising, another source was declining: air pollution decreased in urban centers around the world during the lockdowns.

These maps show nitrogen dioxide (NO_2) concentrations detected in the atmosphere over the United States and the entire globe by the satellite Sentinel-5P, between March 1 and April 5, before the virus in 2019 and during the lockdowns in 2020. Darker blue indicates higher levels of detected NO_2.

Major sources of atmospheric NO_2 are anthropogenic, including fossil fuel combustion by power plants and vehicle traffic. As the coronavirus threat cleared traffic off the roads and shut down industry, NO_2 notably dropped.



Launched in 2017, the Sentinel-5P satellite monitors air quality and pollution in the Earth's atmosphere.

The Path to Earth Day

Before global warming even entered the public consciousness, an environmental movement was heating up.

1962 *Silent Spring*, written by Rachel Carson, helps to mobilize environmentalism through her accounts of chemical pollution.

1963 The Clean Air Act becomes the first legislation to control air pollution in the entire United States and gives rights of enforcement to the states.

1967 RFF fellow John Krutilla publishes the seminal article "Conservation Reconsidered" in the *American Economic Review*.

What a Difference a Day Makes

INFOGRAPHIC
James Round

To mark the 50th anniversary of Earth Day, RFF explores some of the biggest events and milestones that have shaped our environment over these past 50 years.

Wisconsin Senator Gaylord Nelson saw an opportunity. The anti-war protests of the 1960s made clear that the public could mobilize en masse around social movements. Simultaneously, a growing consciousness was emerging about how people impact the environment. So, the Democrat Nelson teamed up with a Republican congressperson and hired a young Harvard graduate student to serve as coordinator for a "national teach-in on the environment." On April 22, 1970, Earth Day was born. The environmental movement began in earnest, elevating the importance of Resources for the Future's work (begun 17 years earlier) to advance both a healthy environment and economic well-being.

In the 50 years since, much has changed. To reflect on the most consequential developments, we at Resources for the Future have crafted a visual representation of 50 of the most significant environmental milestones from the last five decades. Our relationship with the environment has been shaped by legislative progress and research breakthroughs—along with swings in the regulatory pendulum and devastating disasters. It is a continuing story of researchers, political leaders, activists, the business community, and the public at large responding to changes in our environment and occasionally mobilizing for substantial changes in environmental, energy, and resource policy.

The timeline does not display the full cascade of executive orders, regulatory changes, and subsequent rollbacks that have come with changes in presidential administrations. And while executive regulatory action has become far more common in recent years than significant environmental legislation, some of the milestones here—along with the retrospective research featured in this issue of *Resources*—suggest that legislation can and does have a lasting impact.

1970

The First Earth Day

Spurred by a call to action from Senator Gaylord Nelson (D-WI), 20 million Americans—at the time, 10 percent of the total population of the United States—take to the streets during the first Earth Day to demand that the US government step up to protect the environment.

PICTURED New Yorkers commute to work on roller skates to do their part and help the environment on the first Earth Day. *Archive Photos/Getty Images*

Timelime Legend

Open this page to reveal a timeline that features a selection of notable environmental milestones from the last half century. Different types of moment are indicated by the following colored symbols:

- Legislation and Policy
- Seminal Research
- Environmental Disaster
- Environmental Justice
- Event

The timeline also includes some key population milestones:

- Global Population

Open here to see the timeline

01 • JAN 1970
National Environmental Policy Act requires federal agencies to consider the environmental impacts of their decisions.

02 • APR 1970
20 million Americans—10 percent of the total US population—take to the streets to celebrate the first Earth Day.

03 • DEC 1970
EPA is established, and amendments to the Clean Air Act give enforcement authority to the US federal government.

04 • OCT 1972
Clean Water Act becomes federal law, safeguarding surface waters from pollution and helping to maintain wetlands.

05 • OCT 1973
Start of the oil crisis, during which the cost of oil increases from $3 per barrel to nearly $12 over a period of five months.

06 • DEC 1973
Endangered Species Act introduces federal protection for endangered or threatened species and their critical habitats.

07 • JUN 1974
CFCs are implicated in the destruction of the Earth's ozone layer when related research is published in the journal *Nature*.

08 • DEC 1974
Safe Drinking Water Act is set in place to protect the quality of drinking water across the United States.

09 • MAY 1975
RFF's Marion Clawson publishes *Forests for Whom and for What?*, a book about forestry that catalyzes forest economics research.

Four Billion

10 • OCT 1976
Resource Conservation and Recovery Act directs EPA to protect people and the environment from hazardous wastes.

11 • JUL 1977
First oil delivered to the newly constructed Strategic Petroleum Reserve, in the amount of 412,000 barrels of light sweet crude.

12 • MAR 1979
Three Mile Island nuclear accident. The partial meltdown is the worst accident in US commercial nuclear power plant history.

13 • JUL 1979
The Charney Report is the first comprehensive scientific report on the relationship between CO_2 and climate change.

14 • DEC 1980
Superfund Act is created to clean up heavily polluted areas, in response to the threat of hazardous waste sites.

15 • JUN 1981
RFF develops the "water quality ladder," an intuitive ten-point scale that describes willingness to pay for water quality.

16 • SEP 1982
Warren County PCB Landfill is created, cited by some as the spark that leads to the modern environmental justice movement.

17 • JUN 1983
Study shows that average blood lead levels in the United States have fallen by 37 percent between 1976 and 1980.

18 • DEC 1984
Bhopal disaster becomes world's worst industrial disaster in India, with over 500,000 people exposed to a highly toxic gas.

19 • APR 1986
An accident at the Chernobyl nuclear plant in Soviet Ukraine becomes the worst nuclear disaster in history.

20 • MAR 1987
Garbage barge *Mobro 4000* is forced to return to New York after being denied harbor by numerous port cities in the Gulf of Mexico.

Five Billion

21 • SEP 1987
Montreal Protocol, an international treaty, restricts the production of chemicals that damage the ozone layer.

22 • NOV 1988
Intergovernmental Panel on Climate Change (IPCC) is established to increase understanding and awareness of climate change.

23 • MAR 1989
Exxon Valdez runs aground and spills more than 10 million gallons of crude oil, eventually affecting 1,300 miles of coastline.

24 • JUL 1990
First report released by the Intergovernmental Panel on Climate Change shows a clear link between humans and the changing climate.

25 • NOV 1990
Further amendments to the CAA pave the way for cap-and-trade programs that have since reduced pollution such as acid rain.

26 • JUN 1992
Earth Summit is held in Rio by the UN Framework Convention on Climate Change, with aims of a unified climate policy.

27 • OCT 1992
Energy Policy Act of 1992 incentivizes clean and renewable energy, along with energy efficiency and conservation.

28 • JAN 1996
Under the Clean Air Act, leaded gasoline is banned from use in most new vehicles in the United States.

29 • DEC 1997
The Kyoto Protocol, an international treaty, operationalizes the goal of limiting and reducing greenhouse gas emissions.

30 • APR 1998
Controversial hockey stick graph is published in the journal *Nature* and is used by skeptics to cast doubt on climate science.

Six Billion

31 • JAN 2001
Roadless Rule prohibits road construction and deforestation on millions of acres of National Forest System land.

32 • AUG 2002
Research finds 11,700 fewer carbon monoxide–related deaths due to emissions declines under the Clean Air Act.

33 • SEP 2002
Kolka Glacier surges in Russia, causing an avalanche that ends up killing more than 100 people.

34 • JUL 2005
The Millennium Ecosystem Assessment evaluates global ecosystems and their contributions to human well-being.

35 • AUG 2005
Energy Policy Act of 2005 promotes the construction of nuclear reactors in the United States, as a means to improve energy efficiency.

36 • SEP 2005
Hurricane Rita and Hurricane Katrina happen within a month of each other, causing devastation across the southern United States.

37 • JUN 2006
China overtakes the United States as highest global emitter of CO_2, producing 6.2 billion tons in 2006.

38 • SEP 2006
Emissions trading system launches in California to help slow climate change by reducing emissions throughout the state.

39 • APR 2007
Supreme Court rules in *Massachusetts v. EPA* that EPA is required to regulate greenhouse gases by the Clean Air Act.

40 • OCT 2007
Nobel Peace Prize awarded to IPCC and Al Gore for efforts to share knowledge about human-induced climate change.

41 • DEC 2007
Energy Independence and Security Act significantly raises efficiency standards for cars and appliances.

42 • JAN 2009
The Regional Greenhouse Gas Initiative (RGGI), a market-based program to reduce emissions, launches in seven US states.

43 • DEC 2009
COP15 inspires hope for climate action that ultimately does not materialize, except for an agreement to limit global warming to 2°C.

44 • NOV 2010
Deepwater Horizon oil spill becomes one of the worst environmental disasters in US history, leaking 4.9 million barrels of oil.

45 • MAR 2011
In the aftermath of an earthquake and tsunami, the Fukushima Daiichi nuclear disaster becomes the worst since Chernobyl.

Seven Billion

46 • JUN 2012
Rio+20, the United Nations Conference on Sustainable Development, results in a non-binding document titled *The Future We Want*.

47 • OCT 2012
Superstorm Sandy kills more than 200 people and causes $70 billion of damage across the US East Coast.

48 • MAY 2013
Atmospheric CO_2 measured at the Mauna Loa Observatory exceeds 400 ppm for the first time on record.

49 • MAY 2015
Atmospheric CO_2 globally exceeds 400 ppm for the first time on record, signaling the urgent need for climate action.

50 • AUG 2015
Clean Power Plan sets the first national limits on carbon pollution emitted by US power plants.

51 • DEC 2015
United Nations Climate Change Conference meets in Paris and becomes the high-water mark for ambitious climate policy.

52 • APR 2016
The Paris Agreement is adopted by 195 signatories who aim to limit the temperature increase in this century to 2°C.

53 • APR 2017
Sunrise Movement is founded as a youth-led movement that advocates for political action to mitigate climate change.

54 • NOV 2018
Worst wildfire season ever recorded for California, with over 8,500 fires covering an area of almost 1.9 million acres.

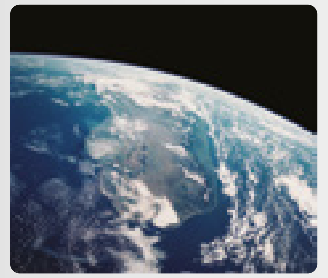
55 • FEB 2019
Green New Deal congressional resolution is introduced, calling for rapid decreases in US greenhouse gas emissions.

Sources Federal Reserve Economic Data | Federal Reserve Bank of St. Louis (figure below); Resources for the Future researchers and staff (timeline content)

1969 Air Quality Act expands enforcement activities, emissions inventories, and air quality monitoring by the federal government.

1969 Santa Barbara oil spill becomes the largest in US waters (now ranks third, after Deepwater Horizon in 2010 and *Exxon Valdez* in 1989).

1969 The polluted Cuyahoga River in Cleveland lights on fire, representing the environmental degradation that inspires the introduction of the Clean Water Act.



1988

Status Report

The Intergovernmental Panel on Climate Change forms to provide science-based updates about our current understanding of the risks and impacts of climate change on the environment, human communities, and the economy, with the aim of implementing realistic response strategies.

PICTURED A view of deforestation in the southern half of Madagascar, as seen by the crew of the space shuttle *Discovery* in 1989. *NASA*

1997

Emissions Omissions

The Kyoto Protocol, a unique international agreement, aims to limit and reduce greenhouse gas emissions by legally binding the participating industrialized countries to reduce their emissions, according to targets and timelines.

PICTURED Al Gore, pictured here as US vice president in 2000, helped mediate the agreement and pushed for its passage. *Tim Boyle/Newsmakers*

2007

Reign Supreme

The *Massachusetts v. EPA* Supreme Court case rules that the US Environmental Protection Agency (EPA) is required to regulate greenhouse gases by the Clean Air Act. Some point toward this case as one of the most important environmental decisions of all time.

PICTURED The US Supreme Court in Washington, DC. *Massachusetts v. EPA* was the first environmental case heard by the court. *Getty Images*

2016

Je Suis Agree

Following the 21st Conference of the Parties (COP21), the Paris Agreement is adopted by 195 signatories that set out to limit the global temperature increase in this century to well below 2°C, improve the ability of countries to respond effectively to climate change, and assist each other in doing so.

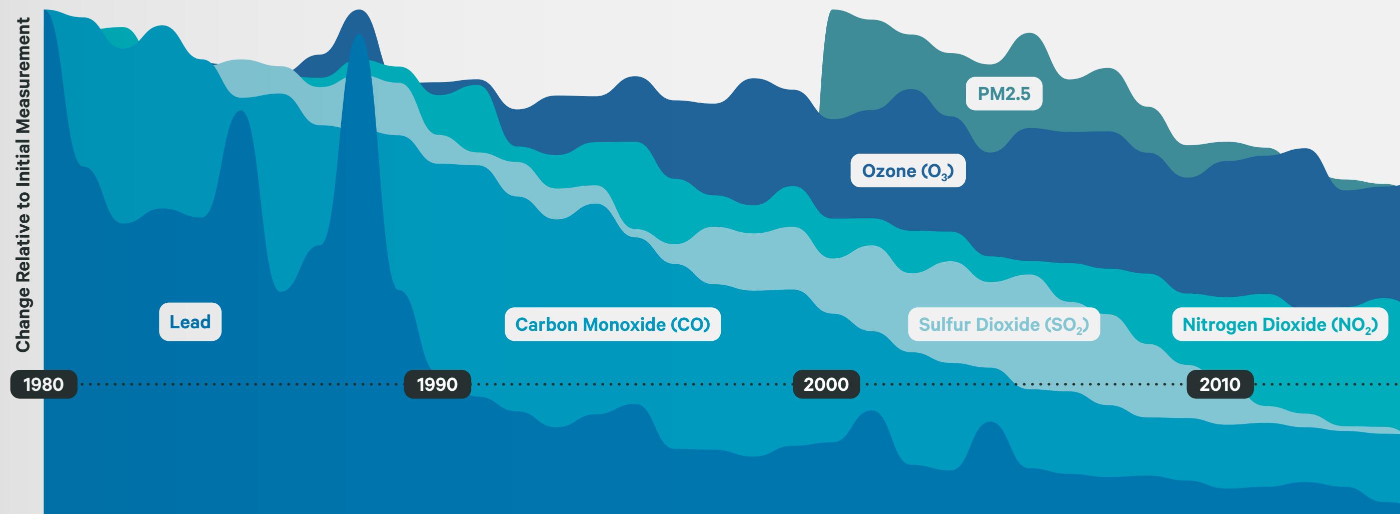
PICTURED US Secretary of State John Kerry speaks at the United Nations in New York, prior to signing the Paris Agreement. *Jemal Countess/Getty Images*

Declining Air Pollution in the United States

The Clean Air Act (CAA) represented the first piece of legislation to control air pollution for all of the United States in 1963, gave enforcement authority over air pollutants to the federal government in 1970, and became the most recent transformative piece of US environmental legislation with its cap-and-trade programs in 1990. This graph shows one significant outcome of the CAA: major air pollutants have declined substantially over the past few decades.

Shown here is the change in concentration of these major air pollutants, relative to their initial measurements in 1980. (Note that all pollutants but PM2.5 were measured in 1980–2018. PM2.5 was measured in 2000–2018.)

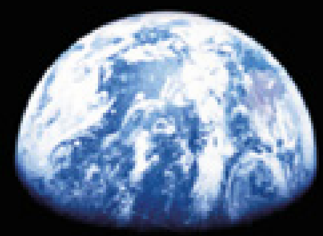
ON THE TIMELINE
The semicircles depict the average relative change in all these pollutants combined each year

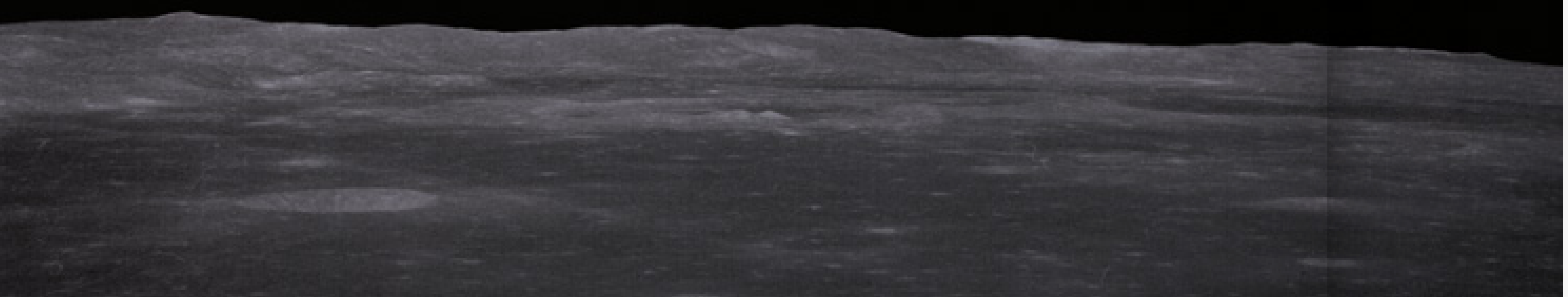


NO. 204 | MAY 2020 | *"A retrospective lens to consider environmental policy success that may still be imminent."*

EARTH DAY AT 50

In this landmark year, we revisit a couple of articles from the *Resources* magazine archive; looking back may help with planning ahead.





This year, during the 50th anniversaries of Earth Day, the 1970 amendments to the Clean Air Act, and the creation of the US Environmental Protection Agency—a year that also marks three decades since the first large-scale application of cap-and-trade programs in the United States—we can use a retrospective lens to consider environmental policy success that may still be imminent. Here, *Resources* has drawn two articles from the archive that speak to these issues. Read Allen V. Kneese's 1990 article and Paul R. Portney's 2003 article for snapshots from the past.

For a contemporary take on those historical moments, read the new article that Portney has contributed to this issue of *Resources*, in which he reflects on Kneese's remarks now, three decades later, in 2020.

We live in a global community that shares an economy and environment at an unprecedented scale. It's become harder to consider the old claim that a falling tree might not make a sound because no one was there to hear it. On this 50th anniversary of Earth Day, perhaps the question becomes: When a tree falls in the woods, does anybody listen?

Photo The partly illuminated Earth rising over the lunar horizon, taken from Apollo 11 in 1969. *NASA*

1990

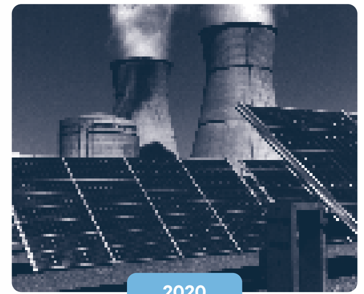
Confronting Future Environmental Challenges

By Allen V. Kneese P.38

In this archived article drawn from a 1990 issue of *Resources*, Allen V. Kneese looks back from the 20th anniversary of Earth Day, noting that the United States and the world were confronting even greater environmental challenges than in 1970, given that local and regional pollution problems had become more far-ranging.

Now, on the 50th anniversary of Earth Day, as climate change and novel pandemics resonate with us today at the global scale, Kneese helps us consider the progress we've made in the 30 years since this article was first published, and how we might consider tackling environmental challenges of the future.

> **"We have no choice but to make technology serve human interest."**



2020

Confronting a New Future of Environmental Challenges

By Paul R. Portney P.42

In this new article, former RFF President Paul R. Portney reflects on Kneese's remarks from 30 years ago. As a friend to Kneese for several decades, Portney shares a warm and thoughtful account of the personal and professional values that informed Kneese's perspective.

Portney acknowledges some of Kneese's insights that remain true today and speculates on what Kneese might have highlighted in an updated article this year, if only he were still around. Portney notes that Kneese probably would express alarm at the widespread habitat destruction and its consequences in our contemporary world.

> **"He would no doubt take satisfaction in having highlighted global warming."**

2003

Market-Based Approaches to Environmental Policy

By Paul R. Portney P.44

This archived article drawn from a 2003 issue of *Resources* expounds on the effectiveness of market-based solutions to pollution problems, particularly as alternatives to command-and-control regulatory solutions. Portney notes that the cap-and-trade systems launched alongside amendments to the Clean Air Act in 1990 "resulted in the most significant environmental policy success since 1970."

Portney's article may encourage us to consider whether his assessment still stands. What even greater policy successes might now be accessible, perhaps through innovations in economic incentives and market-based instruments?

> **"Market-based approaches ... are a clever form of government regulation."**

1990

Confronting Future Environmental Challenges

TEXT
Allen V. Kneese

The early 1970s saw the greatest outpouring of legislative initiatives ever on a single issue—the environment. Just a few months after the first Earth Day on April 22, 1970, President Nixon proposed the establishment of the Environmental Protection Agency, which would consolidate federal environmental programs. Earlier that year, he signed legislation that established the Council on Environmental Quality and required environmental impact statements for large federal projects. In 1970, Congress also passed the Clean Air amendments, which called for the establishment of national air quality standards, and the Water Quality Improvement Act, which established liability for oil spill clean-up costs. Over the next 20 years, Congress would enact over 20 other major environmental laws, including the Federal Water Pollution Control Act of 1972 and amendments to the Clean Air, Water Quality Improvement, and Federal Water Pollution Control Acts in 1977.

Perhaps more important than these legislative actions, however, has been a fundamental change in the attitude of the American public toward the environment. The environmental concern that began emerging in 1970 has now so thoroughly penetrated American society that even industry has seen the need to cooperate in preserving environmental quality. This was not always the case, as an incident during the 1970 Earth Day ceremonies at Colorado College illustrates.

Among the speakers at the ceremonies was Charles Wurster, who had recently established the connection between traces of the pesticide DDT in the environment and the thinning of eggshells of carnivorous birds—especially those of the peregrine falcon, which was about to become extinct. The atmosphere became emotionally charged as a Colorado College biology professor walked on stage bearing a falcon on his arm. Still struck by the beauty and majesty of the bird, the audience was now treated to a slide show courtesy of a chemical company representative. The show depicted how herbicides were aiding in the construction of interstate highways. The first slide featured a bulldozer crashing through a magnificent fir forest in the Pacific Northwest. The assembled students groaned. The next two slides showed how a particular herbicide controlled foliage on roadbeds by killing plant roots. As each new slide was presented, it was greeted with jeers and catcalls. Then, suddenly, the humor of the situation dawned on everyone, and the rest of the slides were met with gales of laughter. The chemical company representative, who plodded through his entire prepared show, received a tremendous ovation at the end.

Happily, the great gulf that has existed between industry and environmentalists is beginning to diminish. The vice president of Dow Chemical was recently quoted as saying that industry should change its goal from environmental "compliance" to environmental "stewardship." This new attitude is fortunate indeed, since the country will need all of industry's technological powers to meet the demand for both environmental protection and economic growth.

Photo Living through three wars before his middle age (including the Vietnam conflict depicted here) may have informed Allen V. Kneese's concerns about nuclear waste disposal. *Getty Images*

> **"Happily, the great gulf that has existed between industry and environmentalists is beginning to diminish."**

Despite the shift in American thinking concerning the environment and the avalanche of environmental legislation since the first Earth Day, much of the environmental agenda of the 1970s and 1980s remains unfulfilled. Automotive and industrial emissions still diminish air quality in many metropolitan areas. Water quality has not improved much in some places. Experts and private citizens still debate how and where to manage both hazardous and household solid wastes.

Efforts to deal with these and emerging environmental problems will be complicated by several factors. First, sources of pollution are widespread and sometimes diffuse. Second, the effects of most kinds of pollution on human health and the environment are uncertain. Along with the first factor, this uncertainty makes the costs and benefits of environmental protection measures difficult to gauge. Third, some environmental problems are global in scope and cannot be managed through domestic efforts alone; international cooperation is required if they are to be effectively controlled.

One or more of these factors apply to each of three environmental issues that are the subject of increasing debate as we commemorate the twentieth anniversary of Earth Day. They are the long-range transport and accumulation of pollutants in environmental media, the effects of agriculture on the environment, and nuclear waste management.

Acid Rain, Global Warming

Before the early 1970s, it was common to think of the sources and manifestations of environmental problems as mostly local or regional in scope. More recently, scientists have observed that pollutants, particularly those emitted into the air, can be transported and can accumulate far from the place of origin, causing widespread environmental degradation. Two phenomena associated with the long-range transport and accumulation of pollutants in environmental media are acid rain and global warming.

Acid rain occurs when sulfur dioxide (SO_2) and nitrogen dioxide (NO_2), which are emitted in industrial operations such as electricity generation, chemically react in the atmosphere to form sulfuric and nitric acids. These acids can accumulate in soil and bodies of water, retarding plant growth and killing fish. Sulfur dioxide and nitrogen dioxide emissions in the United States are blamed for acid rains that may damage forests as far away as Canada.

This year, Congress is considering a major reauthorization of the Clean Air Act, as part of which it is investigating the trading of emissions allowance permits among electricity generating plants—a major source of SO_2 emissions. Under this approach, a plant that would be required to reduce its SO_2 emissions would have the option of making the reduction itself or paying other plants to reduce their emissions in excess of their required amounts. Such a purchase would be allowed as long as the total emissions reduction target was met. Emissions permit trading would be pursued by those plants that find it cheaper to buy emissions reductions than to improve their own emissions control. Economists say that such trading would probably prove a more efficient way of meeting national SO_2 emissions standards than the traditional regulatory approach, perhaps saving billions of dollars.

A more difficult problem, since it will require more than domestic initiatives, is global warming, a phenomenon many scientists believe will result from the accumulation in the atmosphere of carbon dioxide emissions and other so-called greenhouse gases. These gas emissions, some say, will create a blanket around the Earth, causing the Earth to retain heat. The potential effects of this rise in temperatures worldwide include coastal inundation and erosion, resulting from a rise in sea levels, and ecological and agricultural changes.

A comparison of global warming with ozone depletion, another atmospheric change phenomenon, is instructive. Ozone depletion was the subject of a recent international agreement calling for a reduction in the production of chlorofluorocarbons (CFCs), which destroy ozone in the stratosphere. The United States is one of 39 countries that have signed the Montreal Protocol on Substances that Deplete the Ozone Layer, which went into effect in 1989. Whether the agreement in practice will be adequate to prevent further ozone depletion remains uncertain.

As Peter M. Morrisette points out in this issue in "Negotiating Agreements on Global Change," the problem of global warming differs from that of ozone depletion in several significant ways, making an international agreement on global warming much more difficult to achieve. For one thing, there is no consensus in the scientific community about the consequences of global warming. While scientists agree that emissions of CFCs have resulted in ozone depletion, they are in less accord about the effects of carbon dioxide and other greenhouse gases on the Earth's lower atmosphere, land, and oceans. Some question whether global warming would cause a rise in sea level as previously thought. According to one theory, precipitation will increase as a result of increased evaporation caused by warmer temperatures. But if that precipitation takes the form of snow on Greenland, and there is cold enough for the snow to stick despite the temperature increase, the rise in sea level would be small or nonexistent. In the face of such uncertainties, it may be difficult for nations to decide if they should do anything about global warming. In addition, getting countries to agree to control emissions of greenhouse gases will be more difficult than getting them to agree to control CFC production. Chlorofluorocarbons are an important industrial chemical, but not one upon which any country's economy hinges. By contrast, reducing fossil fuel use to lower carbon dioxide emissions could come at the cost of economic growth, or economic decline, in some countries.

For the present, it appears prudent to continue monitoring climatic changes and developing more capable models for predicting the consequences of a global rise in temperature. Other well-advised actions would include controlling fossil fuel use, perhaps by taxing it more steeply; using renewable resources better; and designing safer and more dependable nuclear energy technologies (which produce no greenhouse gases), including better technologies for nuclear waste disposal.

> **"A more difficult problem … is global warming, a phenomenon many scientists believe will result from the accumulation in the atmosphere of carbon dioxide emissions and other so-called greenhouse gases."**

Agriculture and the Environment

The impact of agricultural activities on the environment was not a major concern of the environmental legislation of the 1970s. For example, in focusing on "point," or direct, sources of water pollution, which are mainly industrial and municipal, the Federal Water Pollution Control Act of 1972 gave little consideration to "non-point," or diffuse, sources of pollution, which are often agricultural. Yet today, the major pollutant load on US water courses is from non-point sources, primarily agriculture. Runoff from cultivated land can contaminate water with agricultural chemicals, as well as deplete oxygen in water and add excess nutrients and salt to it. In addition, soil eroded from farmland can silt up reservoirs, destroy fish habitat, and constrict river channels (which leads to increased flooding). It is likely that future water quality improvement will be possible only through further control of non-point sources of pollution. However, controlling these sources presents far more complex regulatory problems than does controlling point sources.

Scientists now recognize that agricultural activities have far-reaching impacts on the environment. They even affect the Earth's carbon cycle, which in turn affects weather and climate. For instance, the burning of trees to clear land for crop cultivation releases carbon dioxide. This contributes to global warming and may reduce the Earth's ability to absorb carbon through the process of photosynthesis. As these effects become more clear, the United States and other countries must determine which circumstances are likely to permit both indefinite development of profitable agriculture and environmental protection. The United States has already begun to examine policies that might better integrate the different objectives of agricultural and environmental programs. For the first time, broad environmental concerns will be a major factor in formulating agricultural policies, as Congress debates the 1990 farm bill.

Nuclear Waste

Thus far, efforts to deal with both civilian and military nuclear wastes in a decisive way have come to nought. For some years, the Department of Energy (DOE), which is responsible for nuclear waste disposal in the United States, has been trying to find a place to store the most dangerous of nuclear wastes—those that must be isolated from ecological systems for at least 10,000 years. The search for a geological formation suitable for long-term storage of high-level nuclear waste has come to focus on Yucca Mountain in Nevada. However, political resistance from Nevada plus doubts about the geological integrity of the site have led to a standoff between the state of Nevada and the DOE. Although the federal government has spent more than half-a-billion dollars studying the mountain's suitability as a nuclear waste storage site, DOE Secretary James D. Watkins recently reported that the site assessment work performed thus far was not of sufficient quality to allow the Nuclear Regulatory Commission to grant the necessary licenses for nuclear waste disposal at Yucca Mountain.

Waste storage is not the only issue. Soil contamination exists at federal nuclear weapons facilities, including Hanford in Washington, Rocky Flats in Colorado, and Savannah River in Georgia. No one knows how much it would cost to clean up these sites or even whether it is possible to do so for any amount of money. Currently, no technological means are available to speed up the degradation of the substances involved. At present, the objective of nuclear waste management is to better shield the environment from nuclear waste than it has been shielded in the past. Estimates of the costs of doing this range into the hundreds of billions of dollars.

Sustainable Development

Discussion of the new generation of concerns often proceeds under the terminological umbrella of "sustainable development," a concept that spans a range of moral and economic considerations. The general concerns it envelops are continued improvements in the well-being of people in developed countries and protection and maintenance of a safe and attractive environment.

These goals cannot be achieved without a better understanding of the natural world than we now possess and a much greater ability to put that understanding into practical use through technology. Thus, we have no choice but to make technology serve human interest better than ever before. In this context, the conventional distinctions among natural resources, the environment, and human resources blur. Indeed, the central focus becomes human knowledge, skills, and innovative and adventurous behavior, all of which are beyond our present ability to measure and assess, despite their clear importance. What we do know is that education is a prerequisite for most of them. In that connection, on every test of scientific and intellectual attainment, our young people rank behind every other industrialized country. That may be our greatest challenge for Earth Day 1990. ■

Allen V. Kneese *was a senior fellow at Resources for the Future in 1961–2001 and served as the first president of the Association of Environmental and Resources Economists in 1979. He passed away in 2001. The original text of this article comes from a 1990 issue of Resources magazine.*

Photo Science in HD on Unsplash

2020

Confronting a New Future of Environmental Challenges

TEXT
Paul R. Portney

Allen Kneese was only 42 years old when I joined the research staff at Resources for the Future (RFF) in 1972 as a newly minted PhD in economics from Northwestern University. In many ways, he was the kind of mid-career colleague and mentor that every young researcher would love to have. He was accessible, joining us younger scholars for lunch in the Brookings cafeteria almost every day (RFF rented office space on Massachusetts Avenue from Brookings at that time); when asked to contribute papers to academic journals or edited volumes, he almost always invited one or more of us to collaborate with him, sharing the credit generously; he attended seminars at which we presented our ongoing work and provided always-constructive feedback; and finally, his office door was always open for a discussion or a hearty laugh.

Nevertheless, there was a world-weariness or melancholy side to Allen, even at that relatively young age. Perhaps this was a result of having experienced a World War, the Korean War, and then the conflict in Vietnam, all before he turned 40. Perhaps it was because he cared deeply and personally about our shared global environment and the problems that were becoming obvious to all after many decades of industrial expansion in the United States and around the world; for Allen, at least, the environment wasn't just an interesting area to which to apply economic thinking. And perhaps it was because he was a deeply philosophical person who was particularly sensitive to the pain of those less fortunate, either at home or half the world away.

Allen was a very good economist. Indeed, he and his RFF colleague John Krutilla were awarded the very first Volvo Environment Prize in 1990—an award that has sometimes presaged future Nobel Prizes. Although Allen never aspired to become a top economic theoretician, he reminded me very much of two of the very best of his time—the late Kenneth Arrow and Robert Solow (a former RFF board member), both Nobel laureates in economics. Like them, Allen was not only very smart, but also very wise. He sensed when the results emanating from an apparently well-designed economic model or experiment didn't quite "feel" right. More often than not, that inkling was right. He shared one other admirable quality with the likes of Arrow and Solow—an unshakable belief that research on any public policy issue was of little use were it not applied to make policy better. He, like they, wanted to make his country and the world a better place for everyone.

With this as a backdrop, how might Allen have looked back from today's perspective on his article of 30 years ago? First, I believe he'd be dismayed and deeply discouraged at the way environmental protection has come to be so sharply politicized. As he noted, it was a Republican president, Richard Nixon, who signed much of the sweeping new environmental legislation of the early 1970s. The 1990 amendments to the Clean Air Act that Allen foreshadowed in his article were championed and signed by another Republican president, George H. W. Bush. Those amendments were implemented initially and enthusiastically by William Reilly, who, along with William Ruckelshaus, another Republican, are arguably the two best administrators in the 50-year history of the US Environmental Protection Agency. Suffice it to say that the dramatic U-turns on environmental regulation taken by the current Republican administration would infuriate Allen, I believe.

As for the substantive issues Allen identified as being worthy of mention, he would no doubt take satisfaction in having highlighted global warming. It is widely believed to be the paramount environmental challenge of our time. While some progress has been made in the United States, along with other countries that are large emitters of greenhouse gases, much more and harder work still needs doing. Thanks to the 1990 Clean Air Act amendments, the United States also has made considerable progress in reducing acid rain. Emissions of sulfur dioxide and nitrogen oxides from electricity-generating stations, as well as emissions of nitrogen oxide from motor vehicles, have fallen significantly. Yet here, too, backsliding is taking place.

While this is pure guesswork on my part, Allen might well reconsider the other two issues he highlighted—the environmental impacts associated with agriculture and the problem of nuclear waste. It is not that these issues are unimportant. They were in 1990, and they still are today, despite the fact that progress has been made in reducing the impacts of agricultural run-off and other non-point sources. From the vantage point of 2020, however, my guess is that Allen would choose to call attention to habitat destruction and the global loss of species—from the depth of the ocean floor to the skies above. It is not just the pesticides and fertilizers used in agriculture that create these threats. In addition, the land clearing to make way for increased urbanization (and yes, for agriculture, too) destroys the habitat for many species. Similarly, industrial fishing, in which the ocean floor is sometimes literally scraped, has resulted in the extinction or significant diminishment of many aquatic species. It's hard to imagine Allen Kneese not identifying that as a paramount threat.

In some respects, Allen's most interesting choice in his 1990 *Resources* article was the question of nuclear waste. Like the environmental impacts of agriculture, it was a thorny problem then and, if anything, is a more pressing one today. This is so if only because we have 30 more years of accumulated spent fuel from nuclear generating stations being stored in "temporary" casks on the grounds of those plants. The Yucca Mountain repository would appear to be no closer to accepting wastes from these plants than it was when Allen wrote about it.

Allen thought in great depth about the promises and perils of commercial nuclear power—he was one of many wise people who referred to it as a "Faustian bargain." On the one hand, he recognized that nuclear-generating plants produce the electricity that modern societies cannot live without, and they do so with absolutely no emissions of carbon dioxide or other conventional pollutants. In that respect, nuclear power plants are a blessing in the fight against global climate change. Moreover, despite a number of well-publicized accidents, the combined safety record of the 100+ nuclear plants in the United States that have been in service for the past 50 or so years has been exemplary. During that time, hundreds of thousands of lives, if not more, have likely been lost due to the fine particulate emissions from coal-fired power plants.

Despite what he said in his article, I believe Allen's principal concern about commercial nuclear power was not with how we would safely dispose of the spent fuel here in the United States. Rather, he was terrified that the construction of nuclear power plants all around the world would one day enable a nation so disposed to enrich the spent fuel from one or more of its plants and use it to make a nuclear weapon. With Allen a 15-year-old at the time that atomic bombs were dropped on Hiroshima and Nagasaki, how could he *not* have had this concern?

To repeat, I have only speculated here how the Allen Kneese of the year 2020 might look back on what he had to say 30 years previously. The one thing I can say for certain is that the world would be a better place today, if only he were here to ask! ■

Paul R. Portney *was a member of the research staff at Resources for the Future in 1972–2005 and was its president in 1995–2005.*

2003

Market-Based Approaches to Environmental Policy: A "Refresher" Course

TEXT
Paul R. Portney

Upon hearing the term "market-based approaches to (or economic incentives for) environmental protection," some people assume this means letting unfettered competition between unregulated private firms determine how clean our air or water will be, how much open space we will have, or how many fish stocks will be driven to collapse.

Nothing of the sort is intended. In fact, market-based approaches to environmental protection are a clever form of government regulation. They are premised on the recognition that, while competitive markets are a wonderfully efficient means of deciding what types and quantities of consumer goods should be produced, they generally fail with respect to environmental quality, the provision of "public goods" like open space, and common-property resources like fisheries. Every undergraduate and graduate economics textbook discusses this notion of "market failure," and the environment is always the first illustration that is used.

Given the very necessary government role in protecting the environment, the real question becomes how best to do this. Market-based approaches to environmental protection are premised on the idea that it is possible to confront private firms, individuals, and even other levels of government with the same kinds of incentives they face in markets for labor, capital, and raw materials—that is, prices that force them to economize. The rationale for market-based approaches, in other words, is to try to put the powerful advantages of markets to work in service to the environment.

Command-and-Control Era

To paint a quick picture of traditional regulation, consider the case of air and water pollution control. Prior to the early 1970s, the regulation of air and water pollution was almost exclusively the responsibility of state and local governments. In fact, the Clean Air Act amendments of 1970 and the Federal Water Pollution Control Act Amendments of 1972 marked the first really substantial federal involvement in environmental protection.

Under the Clean Air Act, the federal government (in the form of the then-new US Environmental Protection Agency, or EPA) began specifying the pollution control equipment that any new plant had to embody. In addition, EPA required local areas to formulate plans to reduce pollution from existing sources, so that the air quality standards that EPA began issuing would be met. These plans typically required large, privately owned industrial facilities to reduce their pollution the most, and often required other sources to roll back their pollution by uniform amounts. Both new and old facilities had to apply for and receive operating permits from EPA that specified allowable emissions. In addition, the federal government also began limiting for the first time the tailpipe emissions of new cars rolling off the assembly lines of both domestic and foreign manufacturers. While the emerging water pollution regulations differed somewhat, at their heart, too, were a series of technological requirements for both newly constructed and existing plants, coupled with mandatory permits that specified allowable emissions.

Despite protests to the contrary, both programs have had significant successes, most notably in the case of the Clean Air Act. Since 1970, air quality around the United States has improved dramatically in almost every metropolitan area and for almost every air pollutant. For one notable example, airborne concentrations of lead, an especially insidious threat to health, were 93 percent lower in 2000 than they were in 1980. Success under the Clean Water Act has been less dramatic, though quite obvious in many places. Rivers that 30 years ago had almost ceased to support aquatic life have seen fish strongly rebound (even if it is still inadvisable to eat the fish one catches in some places).

Despite these successes, by the late 1980s, dissatisfaction with the technology-based standards approach had become rampant. First, by requiring sources of air and water pollution control to meet emissions standards keyed to a particular type of technology, many regulations had effectively "frozen" pollution control technology in place. No one had an incentive to invent a more effective and/or less expensive pollution control technology as long as some other technology had received EPA's blessing. Second, by requiring regulated firms to have specific types of pollution control in place, the regulations denied firms the flexibility to modify their production process or reformulate their product(s) in such a way as to reduce their emissions, because the firms would still be required to use whatever technology was applicable. Finally, it was becoming clear that the technology-based command-and-control system was overly expensive. Study after study showed that it would be possible to meet the same environmental goals—either in terms of ambient air quality or in terms of emissions from affected sources—for much less money than the current approach was costing.

Cap and Trade vs. Pollution Taxes

There are two principal market-based approaches to environmental protection, both of which owe much of their popularity today to a small group of economists, most notably the late Allen Kneese of RFF. While mirror images of one another in many important respects, one market-based approach looks not unlike the current regulatory system, while the other appears to be a more radical departure. The more familiar-looking approach to air or water pollution control would still be based on a system of required emissions permits. Under this approach—generally referred to as a "cap-and-trade" system—each pollution source is given an initial emissions limitation. It can elect to meet this limit any way it sees fit: rather than being required to install specific types of control technology, the source can reduce its pollution through energy conservation, product or process reformulation (including substitution of cleaner fuels), end-of-pipe pollution control, or any other means. Importantly, and not surprisingly, each source will elect to reduce its pollution using the least expensive approach available to it.

More surprisingly, a source has one additional option under the cap-and-trade system: it can elect to discharge more than it is required so long as it buys at least equivalent emissions reductions from one or more of the other sources of that pollutant. All that matters is that the total amount of emissions reductions that take place from all sources are equal to the initial cap established by EPA (or another regulatory authority). Those sources that will elect to make significant emissions reductions under this system are precisely those that can do so inexpensively; likewise, those that elect to buy emissions reductions from other sources rather than cut back themselves will be those that find it very expensive to reduce. (This is the analogue to Adam Smith's famous "invisible hand" that steers producers and consumers to the most efficient allocation of resources.) Moreover, all sources have a continuing incentive to reduce their pollution—the more a source's emissions fall short of its limitation, the more emissions permits it will have to sell to other sources.

The flip side of this approach is one in which no limits are placed on each ton of pollution that a source emits, but in which each ton is taxed. Pollution taxes are paid to the government, which is then free to use the revenues as it sees fit—to reduce other taxes, spend on pollution control R&D, reduce the national debt, etc. While appearing very different from the cap-and-trade approach, this system creates the very same set of incentives. That is, the firms that can reduce their pollution inexpensively will invest in doing so, because each unit of pollution reduced is that much less paid in pollution taxes. Firms that find it very expensive to reduce their pollution will continue to discharge and pay the taxes; note, however, the strong and continuing incentive the latter have to find ways to cut their emissions—and the higher the taxes on pollution, the stronger that incentive. Also, both a cap-and-trade system and a pollution tax create the same incentive to reduce pollution that the wage rate creates for firms to minimize the amount of labor they use or that the interest rate has in disciplining firms' borrowing.

The cap-and-trade approach began to be implemented in a small-scale way in the late 1970s and early 1980s in both Democratic and Republican administrations. But the first really large-scale application of cap-and-trade—which resulted in the most significant environmental policy success since 1970—came in the 1990 amendments to the Clean Air Act. In order to reduce emissions of sulfur dioxide by 50 percent in the eastern half of the United States, an ambitious cap-and-trade system was created, under which more than 100 large coal-fired power plants were given initial emissions reductions. These plants could meet their emissions reductions targets themselves, through any means they selected, including shifting from high- to low-sulfur coal. However, the affected plants were also given the ability to purchase excess emissions reductions generated by other plants that found it easy to reduce their sulfur dioxide.

This approach has resulted in reductions in sulfur dioxide emissions that have been both larger and faster than required by the law. Moreover, the annual savings to electricity ratepayers nationally (compared to the previous command-and-control approach) range from 50 to 80 percent, and these savings amount to $1–6 billion annually, depending on whose estimates one wants to use. As a result of this success, cap-and-trade approaches are now being proposed for additional reductions of sulfur dioxide, nitrogen oxides, and mercury under the Bush administration's Clear Skies Initiative. They have also been put forward by former EPA Administrator Christie Todd Whitman for reducing water pollution in certain watersheds, by state and local governments seeking smog reductions, and by foreign governments exploring lower-cost approaches to a variety of environmental problems. The European Union has just announced that it will use a cap-and-trade system to control carbon dioxide as it struggles to comply with the terms of the Kyoto Protocol, which is still alive in Europe.

Uncertainties Created by Each System

Large-scale experiments with pollution taxes are harder to find in the United States. Under the 1987 Montreal Protocol to phase out worldwide use of chlorofluorocarbons (CFCs) and other ozone-depleting substances, a tax was levied on CFC production during the time mandatory phase-out was taking place, although this is clearly a hybrid system under which command-and-control regulation was augmented by a pollution tax. The evidence to date suggests that this hybrid approach is working well—CFC emissions have fallen, and early evidence is that the stratospheric ozone "hole" has stopped growing.

Interestingly, perhaps the most ambitious application of pollution taxes is occurring not at the federal or even state level of government, but at the local level. Hundreds of communities around the United States have adopted "pay-as-you-throw" systems for household garbage collection. Rather than charge every household the same amount for refuse collection, these communities are charging households a fixed amount per bag of garbage collected at curbside. This has had the effect of reducing the amount of yard wastes that end up in municipal landfills (households are composting more) and possibly even changing households' purchasing decisions toward products which come with less packaging.

Why have cap-and-trade policies flourished in comparison to pollution taxes in the United States? Perhaps most obviously, a system in which discharge permits are issued, but made salable, looks rather like the regulatory system currently in place in the United States, with the added twist of marketability. Another reason has to do with the uncertainty each system creates. Specifically, under a cap-and-trade system, the total amount of pollution is firmly fixed—that is the purpose of the cap. What is uncertain is exactly where the emissions will occur (this depends upon who trades with whom), and how much an emissions permit (the right to emit one ton in a given year, say) will cost—the latter is determined in a competitive market.

Under a pollution tax, sources are allowed to discharge as much as they want, as long as they pay the per-unit charge for each ton emitted. Thus, there is uncertainty about the total amount of pollution discharged (though we can be sure that the higher the tax, the lower the amount of pollution discharged). There is no uncertainty under the latter system about the maximum amount it will cost to reduce a ton of pollution, though, because that will not exceed the per-ton tax. The total amount of revenue raised by such a system is not predictable, because if sources can reduce their emissions less expensively than is believed to be the case, they will discharge less to avoid the tax. In years past, environmentalists objected to pollution taxes on the grounds that sources faced no pollution limits at all and could continue to pollute as long as they paid the corresponding taxes. Note, however, that this approach makes sources pay for every single unit of pollution that they discharge—unlike the command-and-control system in which firms are given considerable amounts of "free" emissions in the form of any discharges they may make, so long as they are beneath their permitted levels.

The choice between cap-and-trade systems and pollution taxes rests in part on the pollutant in question. For pollutants like sulfur dioxide, CFCs, or carbon dioxide that mix equally in the atmosphere and that pose few or no local health effects, cap and trade works well because we are unconcerned about where emissions take place. On the other hand, if we are concerned that limiting emissions might impose too big a burden on the economy, the pollution tax approach is best because sources know that they will never have to pay more for a ton of pollution discharged than the tax. Effluent charges also raise revenue—not a trivial issue in many places, including developing countries.

One thing is for sure. Market-based approaches to environmental protection have become the default option in much of modern environmental policy, both in the United States and abroad. But it would be a mistake to claim that command-and-control regulation is dead. First, there are some cases where market-like solutions won't do the job. If an imminent, serious hazard to human health and the environment is discovered, an outright ban is likely to be the appropriate policy response. Second, some still prefer that companies be punished for their emissions by making them pay as much as possible to alleviate them. But this is premised on the misguided notion that firms pollute because they are malevolent, rather than because pollution is one consequence of making things that society demands. Moreover, such an approach really only punishes the customers, employees, and shareholders of the firm, for they are the ones who will end up bearing the costs. ■

Paul R. Portney *was a member of the research staff at Resources for the Future in 1972–2005 and was its president in 1995–2005. He's now retired, but continues taking on just enough work to stay out of trouble. He still has an association with RFF, which makes him very happy. The original text of this article comes from a 2003 issue of* Resources *magazine.*

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Getty Images

“**Market-based approaches to environmental protection have become the default option in much of modern environmental policy, both in the United States and abroad.**”

The Rise and Fall of Clean Air Act Climate Policy

Is the Clean Air Act a viable vehicle for broad climate policy? Perhaps not.

VIEWPOINT

In this issue of *Resources*, we're introducing a new feature called "Viewpoint," which gives an economist or climate researcher the opportunity to provide a new perspective on an important topic.

Here, we're offering the floor to Nathan Richardson, who shares his view on whether the Clean Air Act can be a vehicle for climate policy.

Thoughts on this? Disagree? Send a response to the editor by letter at *attn: Managing Editor, 1616 P St NW, Suite 600, Washington, DC 20036* or email at *wason@rff.org* for possible inclusion in the next issue of *Resources* or on the *Common Resources* blog.

Nathan Richardson is a university fellow at Resources for the Future and an associate professor at the University of South Carolina School of Law.

Add the most important environmental case to one of the most successful environmental statutes, and you get (it was hoped) a powerful and effective means of cutting emissions.

The Clean Air Act (CAA) is among the most successful statutes in American law, directly responsible for major improvements in health and welfare over the 50 years of its existence in its modern form. As RFF's Dallas Burtraw and UCLA's Ann Carlson have noted with their book *Lessons from the Clean Air Act*, its durability, flexibility, and adaptability have made the CAA an enduring example of successful legislation in an era when such examples are few and far between.

The Supreme Court's 2007 decision in *Massachusetts v. EPA* was almost immediately hailed as among the most important environmental decisions of all time. That reputation persists more than a decade later; one of the nation's leading environmental law professors has just written a book (Richard Lazarus's *The Rule of Five: Making Climate History at the Supreme Court*), which presents a behind-the-scenes account of the case. *Massachusetts* primarily did one thing: it brought the CAA to bear on the most pressing environmental problem of our time—climate change. (It did a lot of other things, too, in many areas of law, but the CAA's relevance to climate is the core environmental holding.) Maybe the CAA wasn't the first, best way to do it, but with Congress unwilling to pass comprehensive climate legislation, the CAA would do just fine.

And so it seemed, through most of the Obama administration. Building on *Massachusetts*, the Obama-era EPA assembled the most significant federal carbon emissions reduction program ever—by a wide margin—from a collection of regulatory actions under the CAA. While the twin centerpieces were a series of rules that set stringent fuel economy standards for road vehicles, along with the Clean Power Plan, which aimed to reduce carbon emissions from fossil fuel power plants, the Obama-era EPA made many smaller regulatory moves aimed at limiting emissions from smaller sectors like oil and gas wells and refrigerants. Some of these rules were painfully slow to be finalized and implemented, and some critics called them insufficiently ambitious. But, taken together, they promised to reduce carbon emissions more than anything else the federal government had ever done, and to lay a firm, durable foundation for future action.

That's what I and many others thought at the time, at least. I've spent much of the last ten years thinking and writing about how climate policy could fit within the CAA. And I still think the rules could have succeeded in the long term. But I don't make the calls on environmental law. Ultimately, the president and the Supreme Court do.

Now, five years after the Clean Power Plan was finalized, little remains of CAA climate regulation. Some of its rules never went into effect. The Clean Power Plan had not cut one single ton of emissions before it was halted by litigation and replaced by the Trump EPA's far weaker Affordable Clean Energy rule. The Trump EPA has rolled back other rules, including most of the fuel economy standards, or is in the process of doing so. Many of these rollbacks are being litigated—and the Trump administration has a poor record in administrative law cases, in which courts are typically quite deferential to the government. But, at least right now, it appears that (unlike previous CAA programs) climate regulations have not been durable in the face of a successor administration that's skeptical of their value.

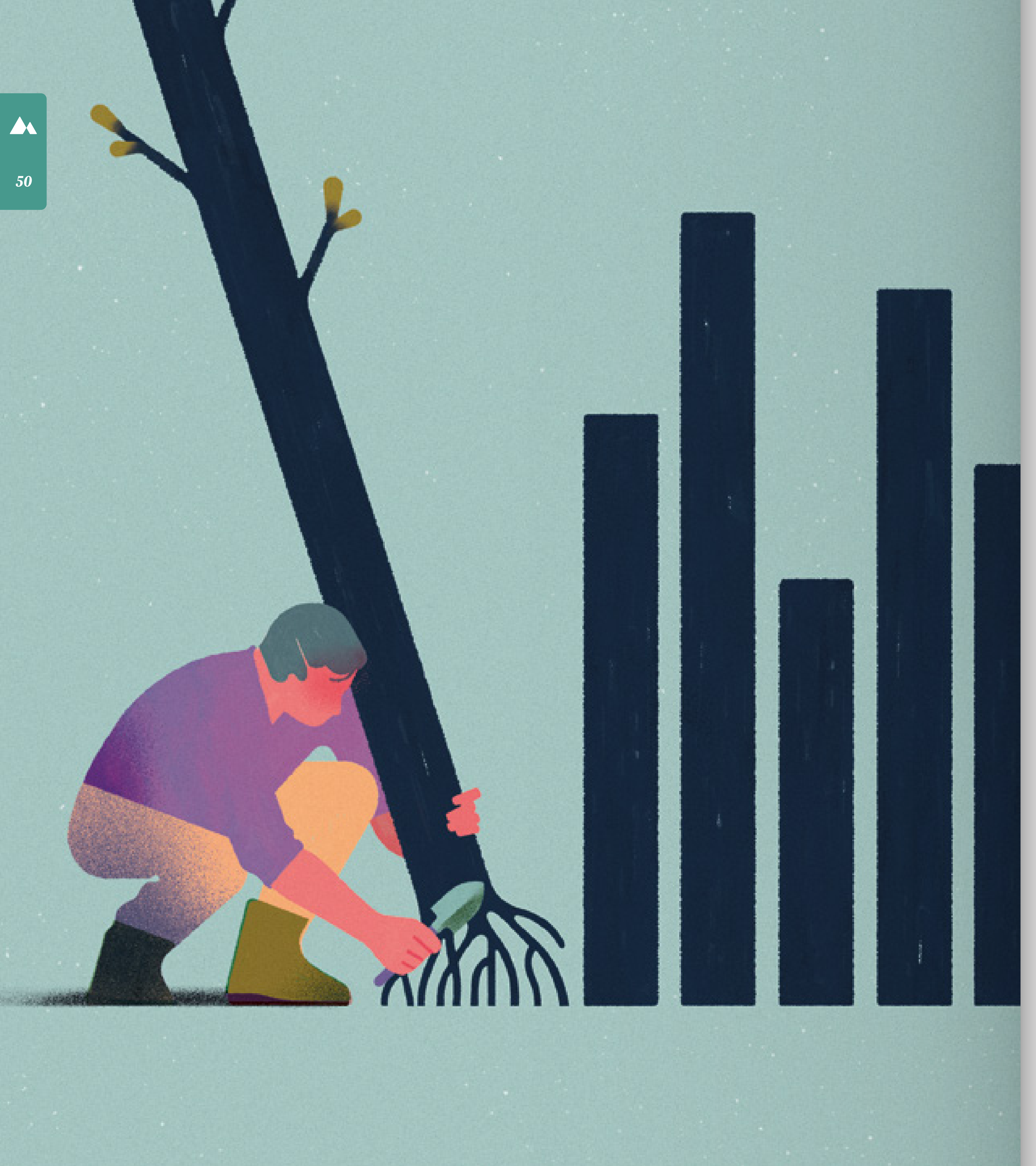
Critics of the Trump administration may blame its norm-breaking tendencies and climate skepticism for stunting the progress of a promising climate policy program—to call Trump the outlier that leads to recent failures of CAA policy, not anything about the climate issue itself or its compatibility with the CAA. Surely those norm-breaking instincts, and the transformation of climate into a polarized political issue over the last 10 years, are important factors. But as I argue in a paper (forthcoming in the *Michigan Journal of Environmental and Administrative Law*), an at least equally important cause is the Supreme Court's undercutting of its own decision in *Massachusetts*, which has encouraged and effectively given license to rollbacks of climate regulations.

Some Supreme Court justices never accepted *Massachusetts* as settled law, consistently calling for its reconsideration. While it has not been overruled, the case was substantially undermined by the *Utility Air Regulatory Group v. EPA (UARG)* decision in 2014. Skilled tactical maneuvering by Chief Justice Roberts allowed him to assign the majority opinion to Justice Scalia, the author of the dissent in *Massachusetts*. The resulting *UARG* majority opinion eroded *Massachusetts*'s foundations, without (at least openly) disturbing it; in the *Harvard Environmental Law Review*, Jody Freeman described *UARG* as "laced with the legal equivalent of improvised explosive devices." The Supreme Court continued by halting the Clean Power Plan before lower courts had considered it—an unprecedented move. The addition of Justices Gorsuch and Kavanaugh to the Supreme Court has likely further reduced its willingness to countenance meaningful climate policy under the CAA, particularly because the latter replaced Justice Kennedy, the swing vote in *Massachusetts*.

This trend on the Supreme Court is not (or at least not *just*) driven by a desire by some justices to undo *Massachusetts*, or by an antipathy toward EPA or climate policy specifically. Instead, CAA climate policy has been drawn into and become a vehicle for a wider anti-administrative turn on the Supreme Court, with a majority increasingly skeptical of regulatory authority.

The result is that, in my view, the CAA can no longer be considered a reliable and effective vehicle for climate policy. Regulations beyond standards for new vehicles are unlikely to survive court challenge, and any regulations (including vehicle rules) appear vulnerable to rollback by a future president, more so than other environmental rules.

As has been true for decades now, comprehensive federal climate change legislation from Congress is probably needed for enduring and effective policy (whether that's a carbon tax, policies associated with the Green New Deal, or something else). Consistent failure of Congress to act has led some to rely on state and local governments or the private sector. But federal action is necessary in the long run. If Congress will not act, a future president forced to act alone cannot (in my view) rely on the CAA, as former President Obama did. CAA vehicle standards remain a tool in the box so long as *Massachusetts* is not overturned, but they can't do the job alone. A Clean Power Plan 2.0 (for example) is likely to be a waste of administrative resources and political capital. Other presidential moves (none of them based on CAA authority), like halting fossil fuel extraction on federal lands, border carbon tariffs, using FERC authority over electric power system operators, or even assertion of emergency powers, could be considered. But as the CAA experience over the last few years illustrates, an enduring and comprehensive climate policy will likely only be achieved through legislative (and, before that, political) means, not through any creative use of existing executive power—even powers as durable, flexible, and adaptable as the CAA. To put the same thing differently, meaningful progress on climate is in my view no longer a legal question, but a political one. Maybe it always was. ■



A Half Century of Economics at EPA

As the field of economics has developed, so too has EPA's use of economic research in designing environmental policies in the United States. But economics can be leveraged even more at the agency to encourage innovations, reduce costs, and protect the environment.

TEXT
Richard D. Morgenstern

ILLUSTRATION
Chiara Ghigliazza

In the 50 years since its founding, the US Environmental Protection Agency (EPA) has seen enormous changes in both the practice and influence of economics. Early on, relatively little was known about the economic benefits or the net social costs of environmental regulation, and market-based mechanisms did not exist as options.

As an economist serving at the agency for more than a decade, initially as the career director of the agency's policy office, and then acting in political positions in both Republican and Democratic administrations, I had a seat at the table, near the action. Since leaving government in the late 1990s, my research has continued to examine the evolving role of economic analysis at EPA.

In sync with continued growth in the academic discipline of environmental and resource economics, EPA has conducted increasingly broad and data-driven assessments of the social costs of environmental protection, including some analysis of the distribution of environmental costs and benefits. To address the potential trade-offs associated with new regulations, EPA adopted a neo-classical, net-benefits framework, often referred to as the Kaldor-Hicks criterion. This criterion deems a regulation or other resource reallocation as beneficial if the entities made better off could hypothetically compensate those harmed by the rule, even if the compensation does not actually occur.

The agency generally has rejected normative analyses in favor of the more mainstream positive economics, focusing on cause-and-effect behavioral relationships. Over the years, EPA's growing capacity to conduct quality economic studies has put it solidly in the top tier of federal regulatory agencies.

Despite the limited support for economic criteria in many environmental statutes, history reveals many examples of how economic analysis has helped inform and shape major EPA regulations and policy decisions. Over the years, the emphasis has moved from a focus on costs,

> **"Over the years, EPA's growing capacity to conduct quality economic studies has put it solidly in the top tier of federal regulatory agencies."**

affordability, and potential job losses to other important issues, including the benefits of new regulations and comparisons of benefits and costs. Market mechanisms have been applied successfully, along with innovations related to the value of information, the value of a statistical life, the analysis of risk and uncertainty, and the use of "big data." Most of EPA's now-substantial economics-trained staff initially were located in the agency's central policy office, but today, all major program offices have some in-house economics capabilities of their own.

Origins

The founding of EPA in 1970 is widely seen as a response to public outcry over polluted air and water, as was much of the agency's early legislation. Relatively little was known at the time about the costs and benefits of environmental protection.

Arguably, the roots of EPA's focus on net-benefits analysis can be traced to the Reagan administration, especially Executive Order (E.O.) 12291, which requires major rules to be accompanied by regulatory impact analyses (RIAs) of benefits and costs, and for those results to be considered in decisionmaking, where legally permissible. While this executive order—which also established the Office of Management and Budget as a gatekeeper role—was widely seen as deregulatory in nature, EPA's response of building strong economics capacity has, in many cases, helped support stronger regulation.

In the late 1970s, EPA also began considering economic incentive mechanisms to achieve regulatory objectives, including pollution offsets, banking, netting, and trading.

Expansions and Evolution

In the early 1980s, benefit-cost analysis expanded dramatically at EPA. Arguably, this analysis has been used most extensively in EPA's Office of Air and Radiation and, more recently, to assess climate-related regulations; in contrast, such analysis has played a traditionally smaller (but growing) role in water, waste, and pesticide issues. EPA scientists and economists, along with researchers from RFF and other institutions, pioneered the estimation of damages to human health caused by pollution. As this research has evolved over the years, mortality due to particulate matter became (and remains) the largest single benefit category among major pollutants.

Over time, EPA has developed high-quality, often peer-reviewed RIAs and other economic studies. Most famously, the 1985 RIA on lead in fuels spurred a dramatic reduction in the lead content of gasoline. My best estimate is that EPA has prepared more than 150 RIAs on major regulations since 1981, while hundreds of other rules have undergone more limited economic studies. Measuring the acceptance of economic analysis as part of the regulatory process, however, is far more challenging.

Growing Pains

From the very beginning, EPA's use of benefit-cost analysis faced resistance from the environmental community, Congress, and even many agency staff who were unfamiliar with or uncomfortable with the approach.

In the 1990s, there was serious internal debate within the Clinton administration about scaling back E.O. 12291; however, Clinton's E.O. 12866 represented only a modest revision, with slightly more emphasis on equity and transparency. Later embraced by Presidents Bush and Obama, Clinton's executive order retained the requirement for analyses of benefits and costs—quantified to the maximum extent possible—and adopted the principle that the benefits of regulations should *justify*, rather than *minimize*, the costs.

The use of market mechanisms got a major boost in Title IV of the Clean Air Act Amendments of 1990, when Congress authorized the Acid Rain Program. Although many of the key design parameters were set in the statute, in cases where the law allowed discretion, EPA generally deferred to the use of private markets. Most experts now agree that the agency made sound choices related to private markets for this program.

Notwithstanding some skirmishes, EPA generally has adhered to the mainstream economic approaches established over the prior decades.

EPA Today

Recently, the Trump administration has introduced a number of challenges to the established use of economics in environmental decisionmaking, and in general has de-emphasized benefits analysis—in large part by scaling back the role of ancillary benefits, also known as co-benefits, in RIAs. For example, the case for withdrawing the Mercury and Air Toxics Standards rests almost entirely on the cost analysis, despite the substantial co-benefits driven by mortality due to particulate matter. The recently updated RIA ignores the previously calculated co-benefits, despite the absence of an alternative, more cost-effective means of achieving those benefits.

Another example can be found in the dramatic downward revisions of the social cost of carbon (SCC), which was developed by EPA economists and others in an Obama-era interagency working group. The SCC represents the monetized damages of a one-ton increase in CO_2 emissions, including changes in agricultural productivity, human health, property damages, power systems, ecosystems, and other effects. In the RIA supporting a repeal of the Clean Power Plan, the Trump EPA ignored the global implications of the issue and argued that the prior administration used too low a discount rate, which gave greater weight to future benefits. On that logic, EPA more recently added a new scenario using a higher discount rate (7 percent) and limited the calculations to only the benefits that accrue directly to the United States. Together, these changes lower the SCC values for the year 2020 by 85 percent or more, depending on the discount rate used (3 or 7 percent).

Beyond these revisions to rules related to air pollution and climate, the Trump EPA has made other changes that are inconsistent with established approaches to economic analyses. For example, the Trump administration replaced the Waters of the United States (WOTUS) rule from 2015—which had originally increased the number of wetlands subject to federal regulation under the Clean Water Act—with a new, less stringent regulation. EPA justified this change by excluding the wetlands-related benefits previously estimated by EPA itself and the Army Corps of Engineers. Also noteworthy is the dissolution of EPA's Environmental Economics Advisory Committee (EEAC), a group that had operated for more than 25 years within EPA's Science Advisory Board. During its existence, the EEAC had served as an important source of peer review for EPA's economic analyses. Fortunately, the agency is now establishing an ad hoc committee to review its *Guidelines for Preparing Economic Analyses.*

Looking ahead, the next presidential election is likely to have major impacts on the near-term direction of economics at EPA.

Recommendation: Apply Best Practices

Several future challenges related to economics at EPA merit comment. First and foremost is the importance of mandating consistent adherence to the agency's economics guidelines. Such a move would restore effective benefit-cost analyses for RIAs and could strengthen both the agency's legal defenses and its standing in the court of public opinion.

Second is the need to expand analyses of the distributional impacts of major environmental problems, including the potential for some risks to disproportionately burden low-income households, communities of color, or specific regions of the country. Similar questions need to be asked about the policy remedies crafted to address those risks. Who wins from these policies? Who loses? EPA already has carried out some relevant studies, but much more can be done.

A third challenge is for EPA to recognize the importance of institutional learning. Despite the growing importance of environmental economics at EPA over the past five decades, most current efforts focus on ex ante analyses, often in the form of RIAs, which estimate the projected future impacts of major policies. A limited—but expanding—literature conducts ex post analyses, which look back at existing regulations and assess the observed policy impacts. The late Senator Daniel Patrick Moynihan deserves credit for identifying the importance of such retrospective analyses.

A key next step for EPA is to support a systematic comparison of ex ante analyses and ex post analyses of major environmental rules. Such critical comparative evaluations can provide a much-needed validation (or not) of ex ante analyses. Retrospective analyses can produce essential evidence of both the successes and shortcomings of environmental regulations, including any unintended consequences. High-quality retrospective analyses can help shape future regulations and policy, while revealing appropriate analytic frameworks that can be applied for forward-looking ex ante assessments. To EPA's credit, the agency has begun some work in this area. Much more is needed.

Economics at EPA has come a long way over the past half century, and these efforts remain very much a work in progress. Historically, conflicts over the role of economics in shaping policy originated in a concern that economics would undermine the agency's regulatory efforts, and more recently because of a concern that economic analysis in excess can bolster regulation. If EPA continues to embrace economics—and, more importantly, a commitment to best practices in economic analysis—then the next half century will lead to better decisionmaking and strong policy design for a healthy environment. ■

Richard D. Morgenstern *is a senior fellow at Resources for the Future. He served at the US Environmental Protection Agency in 1983–1995.*

What's at the Top of Your Stack?

A recurring segment on *Resources Radio* is "Top of the Stack," when podcast hosts Daniel Raimi and Kristin Hayes ask each guest what is on the top of their literal or metaphorical reading stack. With these recommendations, guests end the episodes by sending listeners away with something interesting to read or watch or listen to—often material that departs from typical readings for research.

See if some of these can carry you through quarantine!

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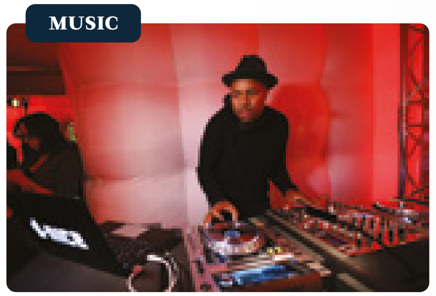
MUSIC

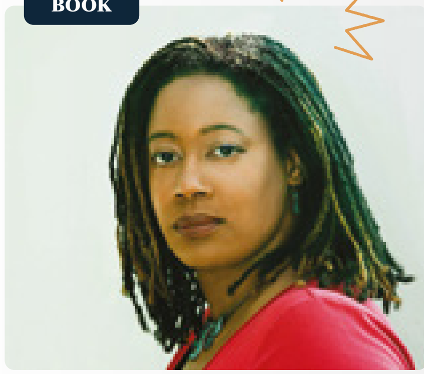


DJ D-Nice spinning on Instagram Live with Club Quarantine

Over the past few weeks, I have experienced a lot of joy listening to a DJ who has started to spin on Instagram Live almost every night during the week. His name is D-Nice, and he calls the virtual community he's created, 'Club Quarantine.' (As you said, this is an unusual time.) It started out with a hundred or so listeners, and I think one evening, over 100,000 people were tuning in to listen. He plays a mixture of genres, but he's pretty heavy on hip-hop and R&B from the '90s.

Mary Evans, Associate Professor, Claremont McKenna College

BOOK

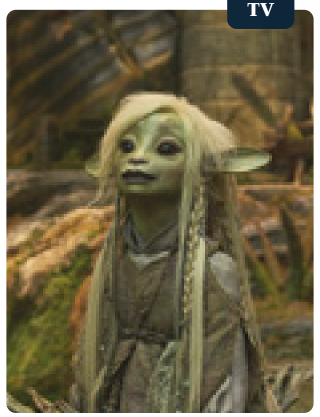


The Broken Earth trilogy by N. K. Jemisin

It touches on the environment in an indirect way—a really interesting look at a fictional world that's defined by tectonics and geology, exploring how that might shape societies. I think it's the first time an author has ever won three Hugo Awards in a row for a trilogy.

Zeke Hausfather, Director of Climate and Energy, Breakthrough Institute

TV

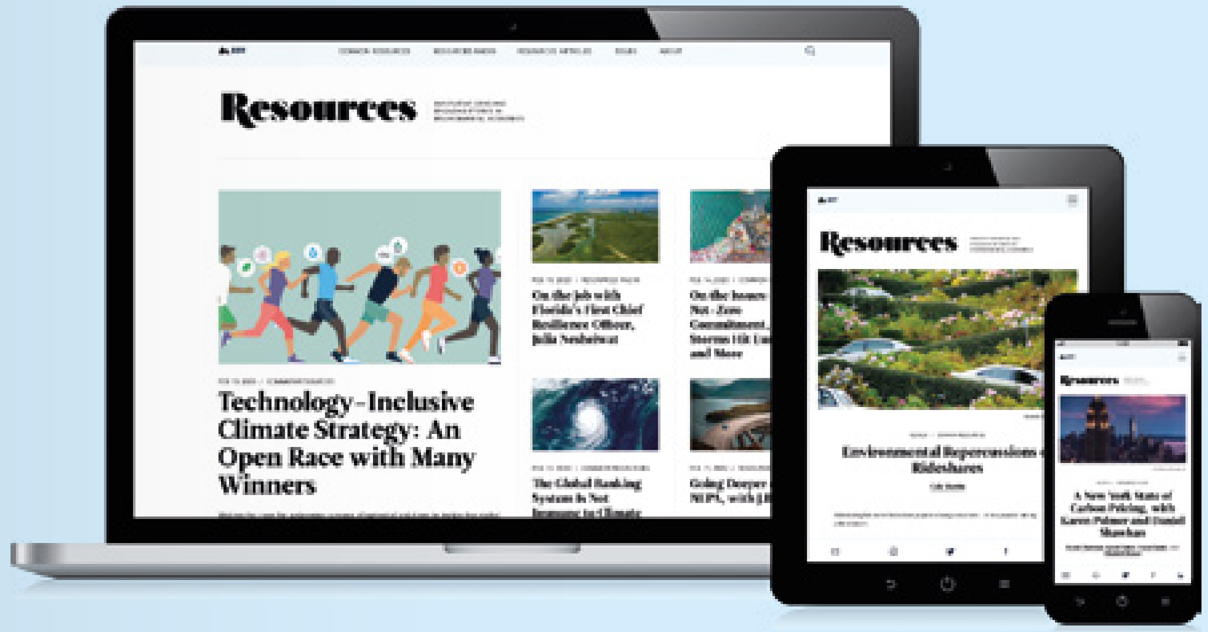


The Dark Crystal: Age of Resistance

I'm really interested in how climate change appears—or, more commonly, doesn't appear—in music and movies and TV, and what the broader public is seeing and thinking about climate change. One thing that interested me recently was the series *The Dark Crystal: Age of Resistance*, which is a prequel to the old *Dark Crystal* movie by Jim Henson. There's an allegory in it for climate change. And like an allegory, it's very simple: there's good, and there's evil, with sharply drawn lines. But underneath is a complex treatment of what we owe one another and how we might come together across differences to confront this common challenge. And in addition to that, there are some really beautiful puppets.

Megan Mullin, Associate Professor, Duke University

> **"But underneath is a complex treatment of what we owe one another and how we might come together across differences to confront this common challenge."**



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Resources readers: We'd like to get to know members of our community and help you all get to know each other a little better, too.

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