RFF 70 | *Celebrating 70 years of Resources for the Future* | NO. 211 | FALL 2022

Resources

Planning for a Net-Zero Economy

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A Note from RFF's President

The Future Is a Net-Zero Resilient Economy

As Resources for the Future (RFF) finishes its 70th anniversary this year, our organization is in some ways just getting started, especially as we prepare for what's to come. Addressing the climate crisis—for society today and future generations—requires systemic economic change at the global scale. For solutions to be effective, efficient, equitable, and ultimately politically feasible, decisionmakers must solve novel, complex challenges across borders. We need to build a net-zero resilient economy that has a net-positive effect on our broader well-being. This is not an easy task and will take years to unfold. But we at RFF are up for our part.

The good news is that decisionmakers are seeking help. Leaders in Congress, in executive agencies, at the state level, in the private sector, and internationally are reaching out and looking for answers. As a trusted source of smart environmental policy design and innovation, RFF has the capability and responsibility to focus our expertise on designing smart emissions-reduction strategies and building resilience to the risks posed by climate change.

Just like we need innovation in zero-carbon technologies, we need innovation in the market, policy, and financial structures that must underpin a net-zero economy. For example, how do we build an electricity market and policy structure that enables 100 percent clean, reliable, and affordable power around the clock and across seasons? How do we deliver net-zero strategies for transport and industry that spur innovation in a diverse technology portfolio, to drive deployment at scale? How can we encourage increased global ambition to decarbonize while recognizing the need to maintain international competitiveness? How can we fully seize the power of land as a carbon sink to reduce emissions and sustain people and ecosystems? What actions must we take now to live in a changing world where sea level rise, wildfire, and flooding are increasing in both frequency and intensity?

In short, we need economics to work for the climate. As the articles in this magazine illustrate, RFF's advice will lay the groundwork for future policy implementation. We will leverage relationships built over many years that recognize the value of our independence and rely on the unique insights that RFF delivers as a trusted advisor.

Before the establishment of the Environmental Protection Agency, before the first Earth Day, was RFF. Founded in 1952 as the first think tank devoted to environmental issues, RFF built the economic tools that would shape generations of environmental progress. Today, RFF's team of economists and renowned policy experts is consistently ranked #1 nationally and globally for environmental, energy, and natural resource policy and economics. Read through these pages to get a sense of what the future looks like, as we focus on two priorities: designing smart emissions-reduction strategies and confronting risks while building resilience.

With high hopes for our future endeavors,

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

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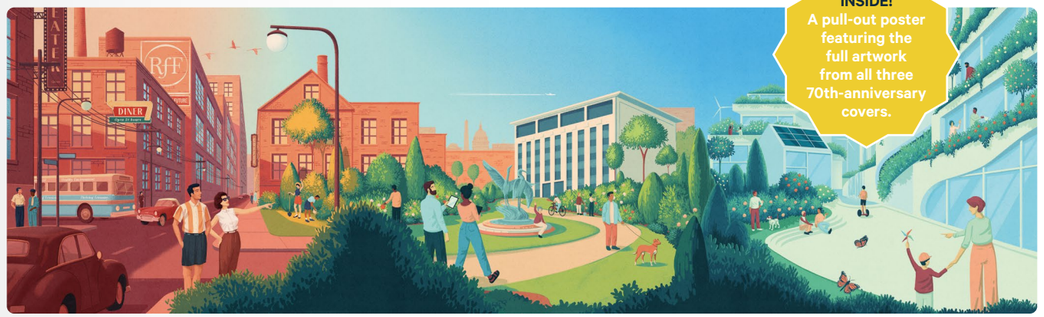

INSIDE!
A pull-out poster featuring the full artwork from all three 70th-anniversary covers.

04 **Getting to a Net-Zero Resilient Economy**
A conversation between Billy Pizer and Daniel Raimi
Bringing together experts and industry leaders to discuss how to achieve net-zero goals equitably and efficiently.

08 **The Social Cost of Carbon: Reaching a New Estimate**
By Brian C. Prest, Jordan Wingenroth, and Kevin Rennert
RFF scholars lay out their new calculation of the social cost of carbon.

14 **Taking the Long View to Achieve Decarbonization**
An interview with Evan Michelson
A program director at the Alfred P. Sloan Foundation discusses the role of philanthropy in advancing research.

16 **Decarbonizing the Transportation Sector Equitably**
By Beia Spiller
Proposals for net-zero transportation strategies that spur innovation in a diverse technology portfolio, to drive deployment at scale

20 **Air Pollution Exposure in New York City Schools**
A conversation between Beia Spiller and Daniel Raimi
Discussing a project to measure, analyze, and reduce exposure to air pollution for students in New York City.

26 **Getting Industry to Net Zero**
By Alan Krupnick
Exploring the tools needed to reach net zero, including innovations, regulations, incentives, and models.

28 **Coping with Climate Change and Building Resilience**
By Margaret A. Walls
What actions must we take now to build resilience in a world where sea level rise, wildfire, and flooding are increasing in both frequency and intensity?

32 **State-Level Roles in the Transition to Net Zero**
By Billy Pizer
Increased levels of individual state action will be important as decarbonization efforts ramp up federally and throughout the United States.

36 **Climate Change Risk in the Financial System**
By Marc Hafstead and Billy Pizer
Experts respond to the recently proposed climate disclosure rule and ask how climate risks actually can create opportunities.

40 **Nature-Based Forestry and Agriculture Solutions**
By James Boyd
How can we harness the nation's lands to meet climate goals and sustain people and ecosystems?

44 **International Climate Policy**
By Ray Kopp
How can we encourage increased global ambitions to decarbonize, while recognizing that countries need to maintain international competitiveness?

46 **Decarbonizing the Power Sector While Maintaining Reliability and Affordability**
By Karen Palmer and Molly Robertson
How can we build an electricity market and policy structure that enables 100 percent clean, reliable, and affordable power around the clock?

... and turn to the last page of this issue to enjoy a challenging crossword puzzle!

GETTING TO A NET-ZERO RESILIENT ECONOMY

The Net-Zero Economy Summit, hosted by Resources for the Future (RFF) as the culmination of our 70th-anniversary celebration, is bringing together a broad group of experts and industry leaders to discuss how to achieve goals for net-zero emissions and how to achieve those goals equitably and efficiently. As you'll see in reading through this magazine, RFF is structuring its future work around getting to a net-zero resilient economy. But what does that mean, exactly?

IN CONVERSATION Daniel Raimi and Billy Pizer **ILLUSTRATION** Jacopo Rosati

RFF's Vice President for Research and Policy Engagement, Billy Pizer, spoke with podcast host Daniel Raimi to discuss the suite of existing net-zero goals and pledges, whether we are on track to net zero, how recent federal policy moves us closer to those goals, and the potential tension between reducing emissions equitably versus reducing emissions quickly.

Daniel Raimi: Let's start by defining the term, "net-zero resilient economy."

Billy Pizer: First, we should unpack the meaning of "net zero." We're not necessarily going to reduce our emissions of carbon dioxide to exactly zero. We're going to reduce emissions a lot of the way, but there may be some sectors, like aviation and other industries, where it's not easy to get that last little bit of fossil fuels out of the system. Therefore, we'll use some sort of negative-emissions technology, nature-based solutions, or other options to compensate for what's left over—the positive emissions that remain.

The "resilient" part recognizes that, even if we manage to achieve net zero by midcentury according to the general timeline that's talked about, we'll still see significant climate impacts. We're already seeing wildfires and droughts and flooding. Those sorts of things will continue. So, we'll have to build resilience and adaptation into the economy to effectively manage the impacts of climate change.

When we say "net-zero resilient economy," we're combining all those things into one vision of the future of the economy.

Achieving a net-zero economy entails actions, and multiple routes are available to achieve this net-zero resilient economy. Private organizations, corporations, and governments have announced targets and timelines to achieve net-zero emissions in recent years. Some of those targets and timelines are on the order of net zero by midcentury—with some timelines landing earlier or later.

Can you give us a few examples of these targets—some that you think are particularly important? And can you highlight for us what the targets indicate about our collective ability to reach net zero, economy-wide?

At the highest level, we have commitments from governments in the form of their nationally determined contributions under the Paris Agreement, which are part of the international negotiations that occur every year. This year, the negotiations will be in Egypt.

For example, the United States has a goal of around 50 percent reductions from 2005 levels by 2030. This target is consistent with ultimately trying to get to net zero by midcentury and establishes a point along the way so we can measure progress.

If we add up all the commitments that countries have pledged under the Paris Agreement, the total probably still is not enough to get to net zero by midcentury. But summing them up gives us a starting point for that sort of calculation.

If we drill down further, as you've noted, different states, companies, academic institutions, and others also have set goals for reducing net emissions to a particular level by a particular date. It's these sorts of commitments that push toward net zero for the whole world by midcentury. But it's actually a bit of a chore to add them all up. The national-level targets

> **The 'resilient' part recognizes that, even if we manage to achieve net zero by 2050 according to the general timeline that's talked about, we'll still see significant climate impacts.**

> **The Inflation Reduction Act is providing a lot of incentives for all this to happen. It's all carrots and not really a lot of sticks.**

can be added up, but when we have all these different pieces inside the economies of particular countries, we can be worried about some people double-counting the emissions that somebody else is doing, and vice versa.

Do you have a gut sense about how close we are to achieving the Paris Agreement goal of keeping planetary warming under either 1.5°C or 2°C, based on your rough estimates that combine those private- and public-sector actions? When you think of the big picture, what percent of the way there are we?

I think, if we add up all the international commitments that have been made under the Paris Agreement, we would be falling quite a bit short of the goal. But it's also hard to know, because most of those sorts of commitments are only through 2030, rather than on a midcentury timeline.

A process in the negotiations, called the Global Stocktake, is attempting to do this sort of calculation; it will come out next year. But I think most of the folks who have considered this question are assessing that we're not exactly on track to get to net zero by midcentury. The goal is still within striking distance, perhaps, but it's certainly not where the current policies and even the commitments are necessarily headed.

Another relevant benchmark, maybe more immediate and tangible, is from the United States. As I mentioned, the United States has a goal of about a 50 percent reduction by 2030. And with the recent passage of the Inflation Reduction Act (IRA), that target really is much closer to being within grasp. Originally, projections predicted that we would hit about 30 percent below 2005 levels without the IRA, but now we are closer to 40 percent with the act in place. So, we're getting much closer to the goal.

As people wait for the Global Stocktake to come out, another resource available in the meantime is the Climate Action Tracker, which provides regular updates on where these nationally determined contributions are getting us.

I want to ask you more about the IRA, which passed in August this year. Most experts consider it to be the most substantial piece of climate policy that's ever been passed at the federal level in the United States. Can you talk about what the IRA does, along with other recent legislation, like the Infrastructure Investment and Jobs Act, the Creating Helpful Incentives to Produce Semiconductors (CHIPS) Act, and other recent policies?

The IRA certainly is the most significant piece of legislation to combat climate change that we've ever passed at the federal level, in terms of its scope.

The CHIPS Act and the Bipartisan Infrastructure Law both provide a lot of underpinnings. The Infrastructure Law, for example, focuses on transmission infrastructure for the electricity sector, with other smaller incentives. The CHIPS Act orients around industry and manufacturing. But neither of those on their own were projected to have a sizable impact on emissions. Consequences for emissions really come from the IRA.

The majority of the emissions reductions in the IRA will come from the power sector. That's not surprising, because the power sector is the most amenable to near-term emissions reductions. New technologies are available that work and are not too expensive. We know what we're doing, and we just have to do more of it. We have to provide the financial incentives for power companies and investors to build more wind and solar and maintain the nuclear fleet.

Another thing the IRA does is provide incentives for households to make investments in higher-efficiency appliances, including heating, cooling, and water heating. The IRA provides incentives for people to adopt electric vehicles. Those sorts of actions represent other chunks of the emissions reductions in the IRA—so, in the buildings and transportation sectors. And the IRA contains incentives in the industrial sector to improve production techniques and reduce emissions.

There's also money to encourage advanced technologies such as direct air capture (DAC). As I mentioned, to get to net zero, you can't just get all your emissions to zero. You're going to have some emissions left over, and you need to leverage negative-emissions technologies. DAC is a leading method that people want to employ for reducing emissions, but it's very expensive right now. The IRA provides additional incentives for DAC and hopefully can move it along, so that by the time we really need DAC at scale, it'll be ready to go. The IRA also has some support for managing carbon in forests, which can act as both a sink to store carbon or a source of emissions due to wildfires or land conversion. Major support for nature-based climate solutions, however, probably will come through other policies.

But 2030 is only seven or eight years away. The projections as you go past 2030 are where it gets more challenging, because at that point, we'll have to depend on technologies that haven't been commercialized yet. And we don't know whether we can bring down the costs as much as we might project—although history suggests that, when you invest a lot of money and provide incentives, people figure out how to leverage technology effectively.

The IRA is providing a lot of incentives for all this to happen. It's all carrots and not really a lot of sticks. No specific reductions are legally required. On the one hand, the estimated reductions are based on assumptions that we'll find ways around some of the barriers to reducing emissions that have existed in the past. On the other hand, I've heard speculation that a lot more take-up of these incentives—and more reductions—could happen in the future than these current best estimates. This speculation suggests that the estimate of 40 percent emissions reductions by 2030 is exactly that—an estimate with a bit of uncertainty.

What are some of the biggest pros or cons of taking this incentive-based approach?

Coming from a background in economics, I think the biggest con is that subsidies require government revenue to be operationalized. You have to either add new revenue or spend existing revenue on these efforts, rather than spend it on other things, which increases the societal cost of these policies. But the nice thing about subsidies is that they don't burden the people who receive them; instead, subsidies are a reward.

Some folks, especially environmental justice advocates, can be skeptical of the term "net zero" because they don't like the word "net." The implication of "net" is continued positive emissions from fossil fuels and industrial activities. Can you talk about this potential tension? Can we resolve the tension between trying to reduce emissions rapidly, and reducing emissions in a way that is equitable and addresses considerable historical environmental injustices?

You're pointing to a really important issue that folks at RFF are well-positioned to speak to, which is to think about the equity and distributional consequences of different policy choices. For example, how power lines connect different resources and load centers, and how those connections affect electricity prices and the costs and benefits to different customers and companies. Another example is the siting of technologies, and how siting influences patterns of pollution and harms to communities near those sites.

These communities have to be involved in the conversations—not just groups in Washington, DC, doing analysis and handing over conclusions. The communities have to be part of the process; they need to feel that their concerns have been thought about and addressed and that their ideas are analyzed by trusted sources and compared to other options.

At the end of the day, we all have to face the fact that we're all going to be burdened by climate change, and we all need to be part of the solution. But I think we all can agree that the only way we can achieve equitable outcomes is by having good information about who actually sees those costs and benefits. We won't be able to mitigate emissions fast enough, and we won't be able to employ all the environmental justice solutions brought forward by communities, but we have to do better than what we've done in the past.

Unfortunately, there's a lot of scope for improvement. I think we can demonstrate intent and effort, even as we admit that we haven't solved all the problems. We'll need to make efforts toward balance, even though we can't satisfy everybody at every moment in time. But these considerations are not an excuse for inaction. We have to move along and do the best we can. ■

> **At the end of the day, we all have to face the fact that we're all going to be burdened by climate change, and we all need to be part of the solution.**

Daniel Raimi is a fellow and the director of the Equity in the Energy Transition Initiative, and **Billy Pizer** is the Vice President for Research and Policy Engagement at Resources for the Future.

The Social Cost of Carbon: Reaching a New Estimate

Resources for the Future scholars lay out their new calculation of the social cost of carbon—an estimate of the economic damages that result from an incremental ton of carbon dioxide emitted into the atmosphere—which can help assess the benefits and costs of US policy actions. Their new value of the social cost of carbon is substantially higher than the previous values used by the US government.

TEXT
Brian C. Prest,
Jordan Wingenroth,
and Kevin Rennert

IMAGE
Yosemite Valley
swissmediavision / Getty Images

Since 2017, Resources for the Future (RFF) has been working toward updating the scientific basis that underlies the social cost of carbon (SCC). The SCC is an estimate of the economic damages, in dollars, resulting from the addition of an incremental ton of carbon dioxide (CO_2) into Earth's atmosphere. The value has been used widely to quantify the economic benefits of policies that reduce greenhouse gas emissions, including vehicle fuel economy standards, power plant regulations, and rules that reduce emissions from oil and gas infrastructure.

As part of these efforts, RFF's Social Cost of Carbon Initiative assembled a large group of multidisciplinary researchers across many institutions to update the science that underlies the SCC in a manner fully responsive to a series of recommendations from a landmark 2017 report published by the National Academies of Sciences, Engineering, and Medicine (NASEM). That work has proven timely, given President Joe Biden's January 2021 executive order, which instructs his administration to update the official value for the SCC so that it takes into consideration these NASEM recommendations and the recent and ongoing scientific progress that the NASEM guidance has steered.

Accordingly, the federal government has been working to update the SCC over the past year, and our extensive work on this issue at RFF is perfectly positioned to contribute to the necessary science. In an article in the fall 2021 issue of *Resources*, we discussed the improvements that we made to three key aspects of SCC estimation: socioeconomic and emissions projections, climate modeling, and economic discounting. Here, we discuss our progress since then, which has led to a comprehensive new estimate of the SCC that we published recently in the leading peer-reviewed scientific journal *Nature*.

> **To bring things up to date, we reviewed the scientific literature on climate damages that have been published recently in peer-reviewed journals across multiple disciplines.**

Our new paper delivers an updated SCC that is fully responsive to the NASEM near-term recommendations for improving the scientific basis of the SCC. Before we dive into the details below, the key takeaway is that our comprehensive update delivers a central estimate of the SCC of $185 per ton of CO_2, which is 3.6 times larger than the US government's current interim estimate of $51 per ton. This updated estimate implies that the benefits of climate policies are much larger than what the US government historically has concluded.

Incorporating New Science on the Impacts of Climate Change

Building on the work we discussed in the fall 2021 issue of *Resources*, our latest research in the new *Nature* article concludes our comprehensive update of the SCC by completing our work on the last part—the "damage functions," which translate changes in global temperatures to dollar-value impacts for specific concerns, like human health, agriculture, and sea level rise. This last step completes the scientific updates to these four elements of SCC estimation as recommended by NASEM. The result is a complete, integrated climate-economic model for SCC estimation, which we call the "Greenhouse Gas Impact Value Estimator" (GIVE).

We have discussed the first three parts of the GIVE model at length in our previous articles; here, we dive into more detail on the updates to the damage functions. The damage functions are key inputs for understanding the economic consequences of greenhouse gas emissions, but many previously used damage functions are dated and do not adequately reflect recent research that estimates climate impacts.

To bring things up to date, we reviewed the scientific literature on climate damages that have been published recently in peer-reviewed journals across multiple disciplines. Prior studies emphasize the following four sectors, around which we built the damage components of the GIVE model: human mortality related to heat, agricultural productivity, energy expenditures for heating and cooling buildings, and the coastal impacts of rising sea levels.

Temperature-Related Mortality

Rising temperatures affect human mortality in many ways; for instance, by increasing the prevalence of and worsening the prognoses for cardiovascular and respiratory ailments, along with increasing the spread of some pathogenic diseases. These effects differ in severity among different regions of the globe. In a new meta-analysis published this year by Kevin R. Cromar and colleagues, a panel of 26 health experts combine results from numerous studies to characterize the effect of increased temperature on mortality from all causes for each of 10 regions around the world. We incorporate these results in our model by estimating the excess heat-driven deaths for each country for each future year, using the regionally disaggregated estimates produced in the study. We also measure uncertainty in the estimates by using the corresponding standard errors from the meta-analysis. All the estimates are monetized to calculate undiscounted damages for each year and country using the value of a statistical life, adjusted to reflect a given country's projected GDP per capita.

Agriculture

Rising temperatures also will affect the suitability of different agricultural products in different regions of the world. A 2017 study from Frances C. Moore and colleagues carries out a meta-analysis that quantifies the effects of temperature change on the crop yields of four of the world's most common crops: maize (corn), rice, wheat, and soybeans. The authors find that, while a few regions may benefit, the vast majority of regions are likely to suffer reduced crop yields and associated economic impacts due to the effects of climate change. This result is based on models that show how changes in crop yields affect regional production, trade flows, and consumption for a wide range of goods, while also accounting for adaptations that might be implemented in agriculture as a result of climate change, such as crop switching. Ultimately, the study presents three damage functions that represent low, central, and high estimates, each disaggregated across 16 globally comprehensive regions, which we incorporate into GIVE with three sets of coefficients that represent uncertainty in our modeling.

Heating and Cooling Costs

Due to both climate change and population growth, an increasing number of people are projected to live in hot places, where economic development will continue to increase access to air-conditioning. As a result, a hotter climate is expected to increase the cost of cooling, while at the same time reducing the cost of heating buildings. A 2018 study by Leon Clarke and coauthors uses the well-established Global Change Analysis Model (GCAM), an integrated assessment model that estimates the net effects of increased cooling costs and decreased heating costs amid future rising global temperatures and changing socioeconomic patterns. The authors find that, on net, continued future warming is likely to lead to increased building energy expenditures, but that these effects are relatively modest—on the order of 0.1 percent of global GDP for a 2°C rise in global temperatures. They also find substantial variation in this effect across countries, however. For example, continued warming would lead to large increases in overall energy costs in regions that already are hot, like the Middle East, Africa, and Southeast Asia—but also energy savings in frigid countries like Russia. We incorporate their results into our model by using their estimated monetary effects per degree of warming, accounting for variation in the impact of warming across the 12 regions in their model.

Sea Level Rise

Rising sea levels associated with climate change are expected to harm coastal properties over time. Yet, communities can adapt to rising sea levels with responses such as relocating structures inland ("retreat") or constructing physical infrastructure like seawalls and dikes to prevent flooding ("protect"). Nonetheless, these adaptation measures are themselves imperfect and often costly. A 2016 study by Delavane Diaz presents a Coastal Impact and Adaptation Model that estimates the costs of rising sea levels in the presence of these adaptation options. We incorporate this model directly into GIVE, coupled with a model of sea level rise built by Tony E. Wong and colleagues, allowing for an internally consistent estimate of the damages from sea level rise and accounting for adaptation and uncertainty about the magnitude of future sea level rise.

The Product: A New Social Cost of Carbon

The results of this multiyear effort are shown in Figure 1, which depicts uncertainty distributions of our SCC estimates, in terms of dollars per ton of CO_2, under two alternative approaches to discount rates. Discount rates translate the value of future impacts to equivalent values experienced today, reflecting that people generally tend to value benefits more when those benefits are received sooner rather than later. For example, a person who would demand a guaranteed $1.03 next year in exchange for $1.00 today is applying a discount rate of 3 percent. The discount rate can have major implications for how we evaluate impacts that occur far in the future.

The figure illustrates two key points. First, while the SCC often is referred to as a single number, it is important to note that a distribution of SCC values in fact reflects uncertainty about the inputs into its estimation. These inputs include the range of potential future economic growth, baseline emissions, and climate dynamics, as well as the economic impacts of rising temperatures embedded in the damage functions. As is standard in scientific analysis, we account for these uncertainties in key inputs by using Monte Carlo simulations, in which the SCC is estimated many thousands of times using different inputs within ranges that align with evidence about the estimated probabilities of those inputs. These simulations result in many thousands of SCC estimates, and the smoothed curves in the figure reflect their frequency distributions. These distributions are typically summarized by their average, or "expected," values, which are indicated at the top of the vertical dashed lines.

Second, as is well known, the SCC depends strongly on the discount rate. Historically, the US government has used a central discount rate of 3 percent for the SCC. (As explained in a previous *Resources* article, we use growth-linked discounting that's consistent with the indicated discount rates in the near term.) Using a 3 percent discount rate, we find an expected value for the SCC of $80 per ton of CO_2, which is about 60 percent higher than the interim value of $51 per ton that was issued by the US federal government in early 2021, which also was based on a 3 percent discount rate. But that 3 percent discount rate derives from an analysis of market interest rates that was conducted nearly two decades ago, whereas interest rates have fallen significantly since then. Recent research has consistently documented persistent declines in long-run interest rates, suggesting that lower discount rates are appropriate, particularly for long-lived impacts like climate change.

Reasonable discount rates suggested by the economics literature are typically around 2 percent, which we adopt as our preferred value for the SCC calculation. As mentioned previously and as seen in Figure 1, this preferred estimate of the average SCC is $185 per ton of CO_2, which is much higher than the value of $80 per ton under a 3 percent discount rate because the long-lived impacts of CO_2 emissions are discounted less.

Understanding the Change

Our preferred estimate of the SCC of $185 per ton of CO_2 is much higher than the $51-per-ton interim value that was issued by the Biden administration in 2021, which simply adjusted the previous government modeling results for inflation. As the 2017 NASEM report explains, that modeling does not reflect the recent scientific developments that we have accounted for here. Because we have updated all the inputs that underlie the SCC modeling—the socioeconomic and emissions projections, climate model, discounting approach, and damage functions—the $134-per-ton total change between the $185-per-ton and $51-per-ton estimates reflects the combination of all those changes.

To better illustrate how each change affects the estimate of the SCC, Table 1 decomposes the changes relative to the SCC value resulting from the widely used Dynamic Integrated Climate Economy (DICE) model developed by Nobel Laureate William Nordhaus. As seen in the first row of the table, the 2016 version of the DICE model produces an SCC value of $44 per ton (which is similar to the Biden administration's interim estimate of $51 per ton, which is based in part on the DICE model). In the second row, we retain the DICE damage function but implement the climate model, socioeconomic and emissions projections, and discounting

FIGURE 1 **Social Cost of Carbon Values, with Uncertainty Distribution**

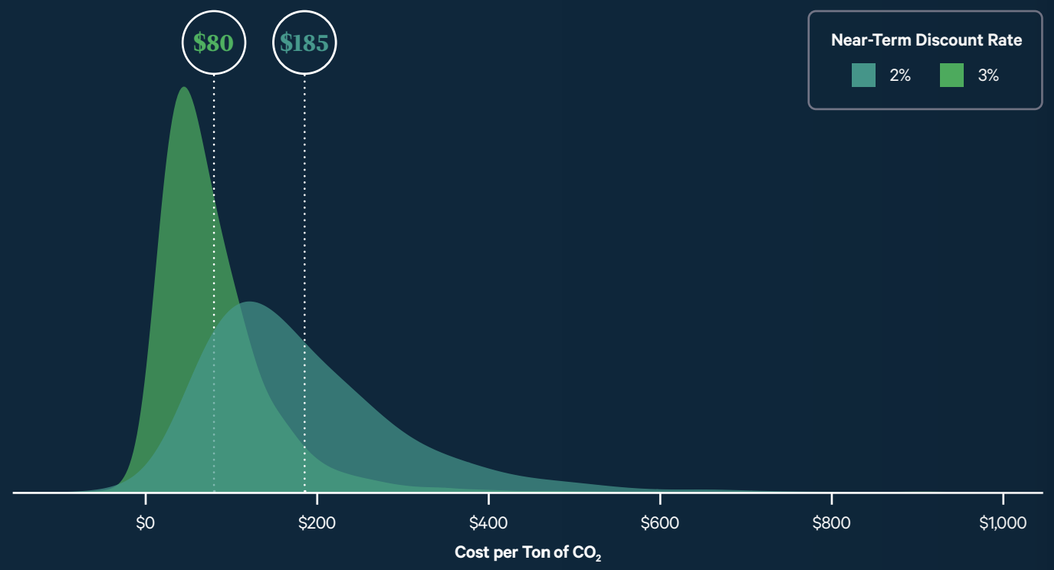

TABLE 1 **Average Values for the Social Cost of Carbon Vary among Different Models and Inputs**

Scenario	Change from Previous Row	Avg. Social Cost of Carbon ($/ton CO_2)	Incremental Change ($/ton CO_2)	Share of Total Change
DICE-2016R		$44		
GIVE with DICE damage function, 3% near-term discount rate	Updated climate model, socioeconomics, and discounting	$59	$15	11%
GIVE with sectoral damages, 3% near-term discount rate	Updated damage functions	$80	$21	15%
GIVE with sectoral damages, 2% near-term discount rate	Lower near-term discount rate	$185	$105	74%

Notes: DICE = Dynamic Integrated Climate Economy model, DICE-2016R = a version of the DICE model, GIVE = Greenhouse Gas Impact Value Estimator

procedure from GIVE, using a 3 percent near-term discount rate.

The combination of these changes increases the average SCC from $44 to $59 per ton—an increase of $15 per ton (about 11 percent of the total change). The third row shows that updating the damage functions discussed above increases the average SCC from $59 to $80, a further $21-per-ton increase (or about 15 percent of the total change). Finally, changing the discount rate from 3 percent to 2 percent increases the average SCC from $80 to $185—or $105 per ton (and about 74 percent of the total change).

This decomposition illustrates that the change in the discount rate is driving the majority of the increase in the SCC. This result is expected and is consistent with previous research. Nonetheless, even absent any change to the discount rate, our work shows a substantial increase in the average SCC to $80 per ton, due to the updated socioeconomic projections, improved climate model, and damage functions.

Implications for Policy

The SCC is an important input for many types of analysis that help inform policy decisions—including regulatory actions by the US federal government, such as emissions standards for power plants and vehicles, appliance efficiency standards, procurement decisions, and environmental impact analyses. As such, it is vital to ensure that the SCC values used are based on the latest science and calculated in a fully transparent and reproducible process.

Our research finding—that the value of the SCC is substantially higher than the previous values used by the US government—implies that, based on the latest science and economic conditions, policies to reduce greenhouse gas emissions provide significantly greater benefits than have been accounted for previously. Though most regulatory and policy decisions are not based solely on benefit-cost analysis, higher values of the SCC in general support more stringent policies while retaining positive net benefits.

The scientific process by which our SCC estimates have been generated—which incorporates the latest peer-reviewed research and involves making our source code freely available to download and run—is equally consequential for policymakers and public confidence in the updated estimates. In our work, we adhere to the recommendations of the NASEM report and assemble the GIVE model from scientific components, each of which has undergone independent scientific review. Additionally, the GIVE model itself has been subject to rigorous scientific review. We have designed our research approach to promote transparency and quantification of uncertainty in the final estimates, and these methods align with the principles laid out for the Interagency Working Group's update of the SCC estimates under Executive Order 13990 in early 2021. Independent, peer-reviewed research is vital for informing public policy on issues that are as critically important as climate change. ■

> **"It is vital to ensure that the social cost of carbon values used are based on the latest science and calculated in a fully transparent and reproducible process."**

IMAGE RFF Senior Fellow Maureen Cropper (left) moderates a discussion with Kevin Rennert, Brian C. Prest, and Richard G. Newell (left to right) at an RFF Live event in September. The research team revealed its updated estimate of the social cost of carbon at the event and discussed the implications for US and global climate policy.

Ronald Flores

Brian C. Prest is a fellow and the director of the Social Cost of Carbon Initiative, **Jordan Wingenroth** is a research associate, and **Kevin Rennert** is a fellow and the director of the Federal Climate Policy Initiative at Resources for the Future.

NO. 211 | FALL 2022 | *"Funding research—and doing it well—is actually quite challenging."*

Taking the Long View to Achieve Decarbonization

In this issue, we hear from a philanthropic institution that has long supported Resources for the Future (RFF) through its grantmaking. *Resources* recently spoke with Evan Michelson, a program director at the Alfred P. Sloan Foundation who oversees the foundation's energy and environment program. Below are excerpts from the conversation, which touched on the importance of taking a holistic approach to address energy and environmental challenges, the role of philanthropy in advancing research, and more.

Supporter Spotlight

In the RFF Supporter Spotlight, our partners share their insights about climate, energy, and environmental issues and how they've made a difference by working with Resources for the Future—all in their own words.

I think RFF is well poised to provide research that cuts across those different levels of governance and different sectoral interventions over the short, medium, and long term.

***Resources* magazine: From your perspective, how has RFF evolved as an organization since you first started working with us as the program director at the Sloan Foundation who oversees RFF's grants?**

Evan Michelson: RFF has always been one of the preeminent institutions for energy and environmental economics. What I've noticed over the past few years, as I've had the opportunity to work closely with RFF, is that the organization has started to look more broadly across fields to bring interdisciplinary answers to the most pressing questions on energy, the environment, and climate change. I think RFF has integrated a more technical understanding of the energy system in its work. RFF really has been on the forefront of asking some critical and underexplored questions about energy-technology development, energy equity, and how the energy system as a whole might work together in a decarbonized future.

How would you describe the role of the Sloan Foundation, and foundations more broadly, in supporting research and analysis?

It is rather unusual for philanthropies to support research. I think that's because funding research—and doing it well—is actually quite challenging. It requires a high level of expertise. It requires a willingness to advance high-quality data collection and analysis. And perhaps most importantly, it takes a lot of time. One of the reasons foundations tend not to support research is that they're looking for more immediate impact, which of course I think is really important. But one of the benefits we have in working at a foundation is that we can take the long-term view.

IMAGE Photo Courtesy of Alfred P. Sloan Foundation.

Chris Richardson

Our energy and environment program at the Sloan Foundation is deliberately framed as an interdisciplinary research effort, and more and more of the work that we support brings together scholars from different fields and different institutions. I think the future is going to involve bringing to bear researchers from different fields to answer these very complicated problems and challenges.

For this issue of the magazine, which celebrates RFF's 70th anniversary, we're highlighting the organization's future. What do you see as the biggest needs for RFF's work moving forward?

It's clear that we are moving into an era in which energy policy happens at lots of different levels and in lots of different sectors of the economy. The ability to work across time frames and at various levels—state, local, national, and even global—is going to be critical as we move forward. I think RFF is well poised to provide research that cuts across those different levels of governance and different sectoral interventions over the short, medium, and long term. The ability to combine rapid research and high-quality analysis with longer-term thinking about how energy-system transformation might happen is critical and unique.

What do you see as the value of the type of independent analysis that RFF, and places like it, provides?

RFF might be one of the only places where that kind of independent, nonpartisan analysis takes place. If you look ahead to the next 70 years, having that kind of analysis is going to be even more critical than the last 70 years. No other organization in the landscape is able to provide that kind of comprehensive outlook. My hope is not only that RFF continues to flourish, but that its influence continues to grow—from the United States to other countries, from looking at a handful of topics to covering the entire landscape of research related to energy and climate change. I think RFF is going to find itself even more central to a lot of these key questions than it has been over the past 70 years. ■

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Discover other ways to give at rff.org/waystogive or contact Tommy Wrenn at twrenn@rff.org

Decarbonizing the Transportation Sector Equitably

The transportation sector is the largest source of greenhouse gases in the United States. Net-zero goals will demand major strides to decarbonize the sector. Moving forward, Resources for the Future will continue delivering net-zero transportation strategies that spur innovation to drive deployment at scale, through a diverse technology portfolio that includes electric vehicles, fuels, freight, and aviation.

TEXT Beia Spiller **ILLUSTRATION** Nathalie Lees

The transportation sector—which includes economic activity from all forms of travel—accounted for 29 percent of total greenhouse gas emissions in the United States in 2019. Over the past 30 years, emissions from the transportation sector have grown by about 24 percent and have become the largest source of greenhouse gas emissions nationally since surpassing power-sector emissions in 2017. Most modes of transportation depend heavily on fossil fuels for energy: passenger vehicles largely burn gasoline, delivery trucks typically use diesel fuel, and aircraft rely exclusively on jet fuel. Each of these fuels is derived from crude oil, causing the transportation sector to be a large source of greenhouse gas emissions.

The Transportation Program at Resources for the Future (RFF) aims to address the current heavy reliance on fossil fuels by exploring net-zero strategies for the transportation sector through technology and policy design. The program primarily will focus on achieving cost-effective decarbonization of both the passenger vehicle fleet and the medium- and heavy-duty fleet, while policies and approaches such as vehicle electrification, building out public charging infrastructure, and efficiency standards will play a significant role in accelerating the transition to a clean transportation sector. Our work in this area also provides an opportunity to identify equitable solutions for transportation challenges that historically have had a disproportionately negative impact

"Most modes of transportation depend heavily on fossil fuels for energy: passenger vehicles largely burn gasoline, delivery trucks typically use diesel fuel, and aircraft rely exclusively on jet fuel."

on overburdened communities (see related material on page 20 in this magazine).

Here's how we plan to achieve these goals.

We will ramp up our modeling and simulation efforts in the transportation sector, which will help us empirically evaluate policies that promote low-carbon options.

Understanding the effects of different policies on demand, supply, and prices within the transportation sector will be key to ensuring that transportation policies are both cost-effective and environmentally beneficial. To that end, quantitative models and simulations can provide the robust analyses that are needed to help inform policymaking within the field of transportation decarbonization. RFF's Transportation Program will work to develop these models for use in policy analysis.

We have developed a robust model for light-duty vehicles, which allows us to estimate the impact of policies such as new and used vehicle subsidies, efficiency standards, manufacturing mandates, and more. Our model has been used to analyze electric vehicle policies and subsidies within the Infrastructure and Investment Jobs Act, the Build Back Better legislation, and the Inflation Reduction Act; it's also helped in the context of tightened fuel economy standards. Tightening fuel economy standards will be an important tool to reduce emissions among the remaining gasoline-powered vehicles in the on-road fleet during a transition to electric vehicles. Even after a complete decarbonization of new vehicles, the existing fleet will continue to include gas-powered vehicles for some time. Moving forward, we will continue to leverage the model to help inform policymaking around the decarbonization of personal cars and light trucks.

Within the truck and bus sector, however, quantitative models and simulations are scarce. This lack of modeling data means that we're missing information about how trucks are bought, used, and scrapped; how manufacturers choose the price, fuel efficiency, and technology in their vehicles; how policies affect decisions for consumers and manufacturers; and the resulting costs and benefits to society. These unknowns will be an obstacle in cases when the US Environmental Protection Agency sets new emissions standards for trucks, when states debate subsidizing electric charging and hydrogen infrastructure, or when school jurisdictions consider purchasing electric buses. Modeling efforts tend to be scarce because of two related challenges: a lack of data, and limited adoption of new types of vehicles and technologies. Given low adoption rates to date, it's difficult to estimate future consumer demand for electric trucks and buses and to determine how that demand depends on factors like refueling infrastructure.

We plan to confront these challenges through the development of two models. The first will model the demand and supply of vehicles in the trucking sector, allowing us to estimate the impact of transportation policies on market conditions and environmental outcomes. The second will simulate the effects of electricity tariff structures on electric truck and bus fleets, to better understand how utilities can leverage smart pricing to simultaneously accelerate adoption of these electric vehicles while also reducing environmental and electric grid impacts associated with charging the large batteries in these vehicles.

Distinct from our work to model policy effects on vehicle fleets, we will continue to explore related transportation policies and topics, including biofuels and low-carbon fuel standards, critical minerals, and hydrogen infrastructure.

We will explore options in the transportation sector that can help ensure equity across communities in terms of clean air, access to mobility services, and more.

As the country moves toward a decarbonized transportation sector, ensuring that decarbonization strategies are equitable will be key. The Biden administration's Justice40 Initiative demonstrates the federal government's commitment to improving equity in our decarbonization pathway, but the efforts require careful consideration about clean energy investments and the resulting benefits. Looking at the transportation sector, we will explore questions such as: How can electric vehicle charging stations be deployed in a way that ensures access for low-income and disadvantaged communities, while helping accelerate electric vehicle adoption by these households? What are the distributional impacts of decarbonization policies, which will include vehicle efficiency standards, electric vehicle subsidies, and electric vehicle mandates? How will the recent ban on new gasoline vehicles in New York affect emissions in disadvantaged communities?

For example, traffic pollution can negatively affect educational outcomes for students in schools that are located near major roadways and freeways. We'll develop a high-resolution network of air-quality and weather monitors in New York City, which will allow us to gauge the effects of traffic pollution on the indoor air quality of urban schools and, relatedly, on educational outcomes. We will use these data to provide information to community members about the air quality in their neighborhoods and schools. Furthermore, in the event that we observe indoor air pollution concentration in classrooms that reach levels of concern, we'll advise the schools on improving indoor air quality based on guidelines from the US Environmental Protection Agency.

We will coordinate with stakeholder groups to produce the most promising and effective solutions for the transportation sector.

Decarbonizing the transportation sector will require coordination among various stakeholders—including vehicle and battery manufacturers, charging station owners, electric utilities, local and federal government, fleets, and communities—to ensure that the transition to a clean transportation sector is cost-effective, equitable, and environmentally friendly. The most effective solutions will incorporate viewpoints and concerns that affect all stakeholders. To that end, RFF's Transportation Program will host convenings to bring together diverse stakeholders in conversations around the development and implementation of policies that are effective, efficient, and equitable. These convenings will be used to develop recommendations for optimal approaches to decarbonizing transportation. ■

IMAGE A subway train in Queens with the Manhattan skyline in the background.

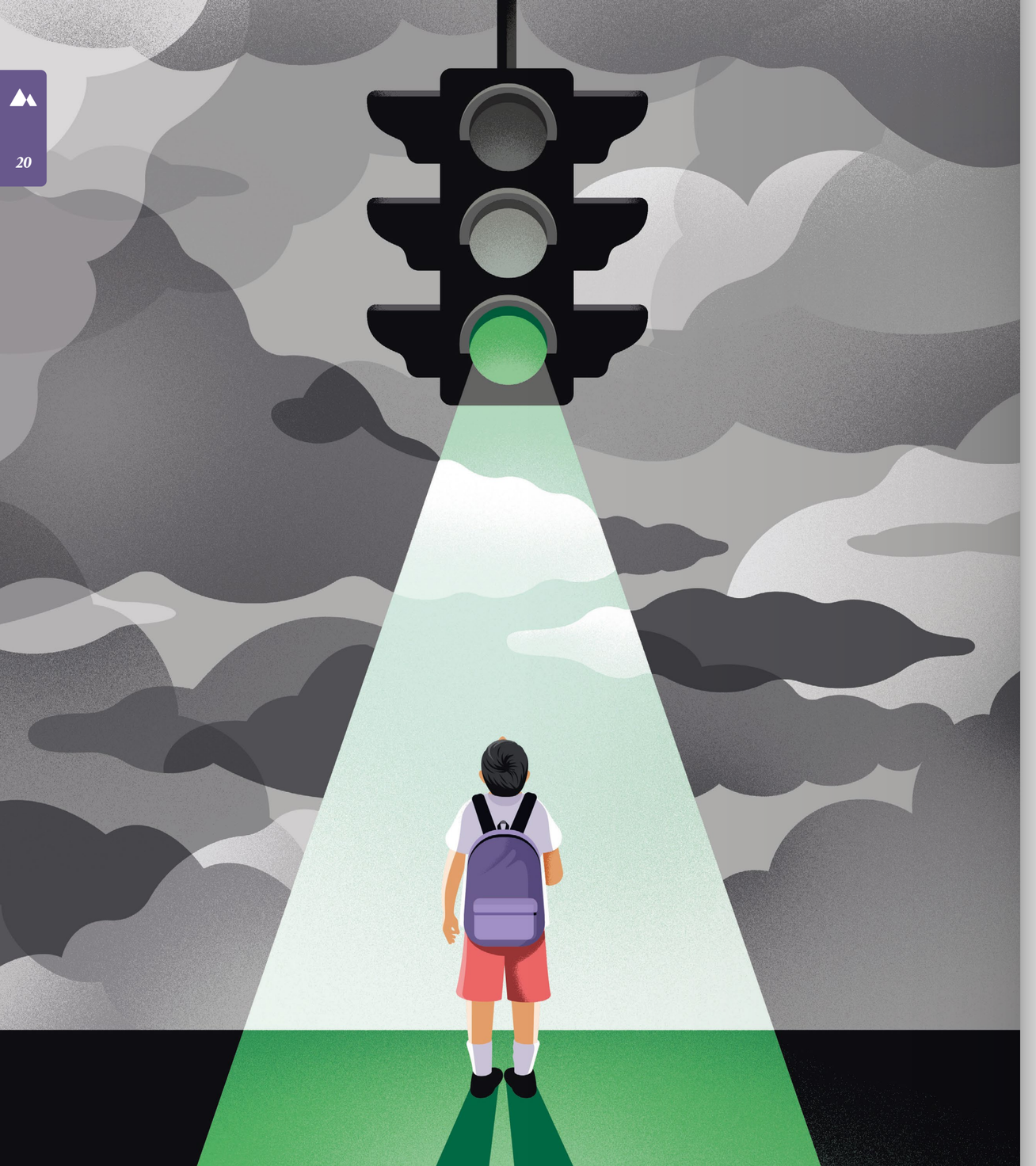
Marco Bottigelli / Getty Images

> **Understanding the effects of different policies on demand, supply, and prices within the transportation sector will be key to ensuring that transportation policies are both cost-effective and environmentally beneficial.**

Getting to a Net-Zero Resilient Economy by Supporting Reduced Emissions and Equity in the Transportation Sector

A growing economy relies on an effective and efficient transportation system—but climate change, pollution, congestion, and safety issues reduce the value of the sector. In the months and years to come, RFF experts will analyze the effectiveness, benefits, costs, and distributional consequences of transportation policies that reduce emissions and positively influence the behavior of consumers and producers.

Beia Spiller is a fellow and the director of the Transportation Program at Resources for the Future.



Air Pollution Exposure in New York City Schools

Daniel Raimi talks with Beia Spiller, who recently joined Resources for the Future (RFF) as a fellow and the director of RFF's Transportation Program; she's also a member of the board of directors at the Association of Environmental and Resource Economists. Spiller's latest project is a collaboration with colleagues and community organizations to measure, analyze, and reduce exposure to air pollution for students in New York City, particularly in the Bronx. She and Raimi discuss how this type of community-engaged research produces new knowledge, informs policymaking, and benefits communities that are engaged in the research.

Daniel Raimi: Beia, I've really been looking forward to today's conversation, because you're going to help us learn about issues related to environmental justice and the transportation system. We know that negative environmental impacts often disproportionately fall on low-income communities and communities of color. Can you tell us about the specific issue that you're addressing in your latest research project and the motivation for doing the analysis in the first place?

Beia Spiller: Overall, the objective of this project is to estimate the effect of traffic pollution on indoor air quality in New York City schools and understand how that influx of transportation pollution into the schools affects educational outcomes.

We want to explore two specific inequities: The first inequity has to do with the placement of transportation infrastructure. Across the country, communities of color are more likely to live near highways and freeways due to racist policies that specifically sited this

Resources Radio, a podcast produced by the *Resources* editorial team, releases new episodes weekly with hosts Daniel Raimi and Kristin Hayes. Each episode features a discussion with a guest about a new or interesting idea in environmental and energy policy.

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

IN CONVERSATION
Daniel Raimi
and Beia Spiller

ILLUSTRATION
Nathalie Lees

infrastructure throughout or across these communities. And in New York City, this is really true. If you look at a map of New York City, you'll see major freeways running through the Bronx and Brooklyn, directly through communities of color. So, there's this inequitable impact in terms of exposure to transportation pollution.

And the second inequity that we're exploring has to do with the ability of communities to invest in defensive behaviors that can help protect them from exposure to that pollution. This would include things like HEPA [high-efficiency particulate air] filters in HVAC [heating, ventilation, and air conditioning] systems.

These two inequities interact in a really interesting way in New York City. What we see, as I mentioned, are the freeways going through the Bronx and Brooklyn. You would expect a lot more pollution in these neighborhoods—but actually, if you look at pollution maps, we see that the majority of the pollution is located in Manhattan. However, when we look at the health impacts that are typically associated with exposure to pollution, such as asthma, the worst outcomes are in the Bronx. We see asthma concentrations in the Bronx that are at really high levels compared to anywhere else in the country. How do we explain this?

We could explain this in a couple different ways. One is scientific: Perhaps pollution coming from highways is different than pollution from just road traffic because of the types of vehicles that are on those roads. For example, perhaps long-haul vehicles on highways have more black-carbon emissions or other types of pollutants that could cause asthma. But another way that we can explain this could be through defensive mechanisms: that richer, whiter neighborhoods located in Manhattan might be better able to access defensive mechanisms and protect themselves more.

What we want to understand is not just how exposure to transportation pollution affects educational outcomes but also how the ability to protect oneself from that exposure, and protect children from this exposure through investments in building infrastructure, differs across community groups.

I think this is really important, because there's a ton of research, both in epidemiology and economics, showing that when you're exposed to pollution as a child, it can have long-lasting impacts on your health and well-being. We're talking further into your future: reduced wages in the future, reduced ability to accumulate wealth, and human capital. If we really care about intergenerational equity and changing the tide of wealth and equity across race and ethnicity, then we need to be exploring these types of issues and interactions.

Can you tell us how this research project came about? Who are you working with?

This project was a long time coming. I had been having conversations with a professor from Fordham named Marc Conte. Marc and I had been talking for at least a couple years, trying to come up with some sort of research project around air pollution or air monitoring, but nothing was really panning out. And then, one day, Marc goes to a climate rally in New York and meets a community organizer named Victor Davila. And Victor works as a community organizer at the Point Community Development Corporation, which is a local, community-based organization in Hunts Point in the Bronx.

Marc tells Victor about his interest in air-pollution monitoring, and Victor graciously suggests, "I'd be interested in working together." Then, Marc and I are having lunch one day, and he tells me, "I met this great guy, Victor. Why don't we come to him with some of our ideas?"

And I said, "Let's have a call with Victor. Let's ask him what he's most concerned about. What are the major concerns within the community? Let's try to understand where our research could fit into these concerns and begin to help."

We have a call with Victor; it's a great conversation. Victor tells us that they're concerned about traffic pollution in the Bronx. They're also really concerned about indoor air quality in schools. We're like, "Maybe there's something to be done about traffic pollution affecting indoor air quality in schools." So, Marc and I huddle.

> **"If you look at a map of New York City, you'll see major freeways running through the Bronx and Brooklyn, directly through communities of color. So, there's this inequitable impact in terms of exposure to transportation pollution."**

And during this time, Marc meets a physicist from Fordham named Stephen Holler. Steve had been going around to schools in New York City conducting STEM education [science, technology, engineering, and math] for kids. What Steve would do is install air-quality monitors inside and outside the schools. And he'd work with the students to build their own air-quality monitors and help them understand the importance of monitoring the air. So we thought, why don't we expand on what Steve is doing and install a bunch of paired indoor-outdoor air-quality monitors across schools in the city? That way, we could identify the effect of transportation pollution on indoor air quality.

Victor loves the idea, and he suggests bringing other organizations into the fold: The first one is TREEage, a youth-led group in New York City that works with schools on environmental education. And the second is the New York Civil Liberties Union, which actually had been working a lot on issues associated with transportation-pollution impacts on schools. The project was formed, and the partners were chosen. Everybody came together. We decided this was a really great idea, and we moved forward from there.

In the world of environmental economics, researchers historically focus on existing data sets rather than partnering with local organizations, gathering original data, and focusing specifically on local community concerns. From your perspective—and that of researchers who carry out similar work in environmental economics—what's your sense of the motivation for engaging with partners in this new way? What are some of the benefits of it? Do you see it as a trend that's growing in environmental economics, or is it static or shrinking—or how do you characterize it?

I do think this is a trend that is growing, and I'm very excited to see it growing. I hope more academics will choose to do this as we move forward and understand more about the importance of working with communities.

The reason I think it's so important to work with communities is that I just don't think academics are the correct individuals to know exactly what the worst problems are that a community faces. Academics are sitting in a different location, where we don't have our finger on the pulse of what's happening in the community. The way we've been trained to approach problems is to think of a policy (one that has been or will be implemented) and analyze it to see whether it was cost-effective—if it had the environmental outcomes that we expected the policy to have. To give credit to the researchers, we do ask whether we can observe distributional impacts and how these benefits vary across space and across the community. But the distributional impacts of the environmental justice angle of our work is usually just a tack-on to the work.

What ends up happening is that, many times, the policy solution that the research tells us is the right one may not be the right one for the community. I've seen this a lot of times, where researchers might say, "We did this analysis. Hey, community—this is good for you." Yet the communities are up in arms against the policy. Why the clash? I think there's a fundamental misunderstanding of what's going on here from the researcher's perspective. What this means is that, when we begin to work with a community-based group, we can revisit the way we're asking our research questions. We can formulate the questions in a way that could potentially have real, actionable outcomes for the community—and do so with an understanding of where the community is currently at. What I've seen and heard is that communities have really felt burned by researchers coming in, analyzing the community, identifying a problem, and then leaving. The community is left holding the bag, with nothing to show for it.

So, when researchers work with communities, we can develop questions that are useful for the community, and the research can build something for the community that lasts beyond when the researchers actually leave. I think our project is a good example, because it allows community members to collaborate with reputable academic institutions to collect data that are causal, that communities can have real scientific trust in, and that community members can trust because they were involved in the data-gathering process.

Let's talk about the study itself that you're going to carry out with your partners. You mentioned that air-quality monitors are going to be involved. Can you tell us more about how you're going to gather the data for this analysis, and what you've learned so far as you're getting ready to install the equipment in the schools?

We received a grant from Environmental Defense Fund to purchase air-quality monitors and install them in schools beginning in the summer of this year, and we expect the installation process to continue through the end of this year. We're going to install them in 45 schools across New York City—one indoor air-quality monitor and one outdoor air-quality monitor at each school. The monitors will tell us how traffic pollution affects outdoor and indoor air quality.

To understand how the relationship between outdoor and indoor air quality is affected by characteristics of the buildings, we will conduct building surveys. We'll ask questions like, Do these schools have windows that open? Do they have weatherization? Do they have central HVAC systems? Do they have HEPA filters? And so on.

Another key piece of data that we'll collect is information on wind direction. We will install a weather station right outside the schools. What the weather station can tell us is which way the wind is blowing, so we can establish causality. You could imagine a freeway where you have two schools within 500 feet of that freeway, but one is upwind of the freeway, and one is downwind. The school that's downwind will be affected much more by the freeway pollution than the school that's upwind. But if we didn't know which school was upwind, we wouldn't be able to assign the transportation pollution in a causal manner.

But two important issues come with installing these monitors in schools. The first is addressing data-privacy issues and the other is Wi-Fi connectivity. On the data-privacy issues, New York City high schools are competitive and have to attract students.

Schools might not want these data about air quality to be made publicly available, because a school wouldn't want potentially bad indoor air quality to affect who chooses to go to the school.

To maintain that data privacy, we decided to move toward a different type of monitor. The PurpleAir monitors we had in mind are user friendly and generally post the data immediately on the internet. Online, you can see the location of monitors of interest and what the air-pollution level is at each monitor in real time. But alternatively, we can store the data locally on an embedded USB chip, such that the data are private and not immediately accessible to the public.

Wi-Fi connectivity is another issue. A lot of these schools don't have strong access to Wi-Fi. Victor, one of our community partners, has been working on this issue a lot, trying to get broadband connectivity to his community. That was another challenge with using the PurpleAir monitors, as they need Wi-Fi connectivity to post the data online.

Storing the data locally dealt with those two concerns.

What are some of the most interesting ways in which this type of community-engaged research project differs from research that does not engage the community—whether it's from designing or implementing the research process, or policy implications and impacts on the ground?

One way is the fact that communities can benefit from the research. And communities get to work with the data; gather the data; and have access to the data, so they can advocate for themselves. The results that come out of this research are much more likely to be beneficial to the community.

Because the project and the research have been co-developed with the communities, the solutions that emerge are much less likely to be top-down. One thing that economists tend to be criticized for is that we can be a little condescending, with assumptions like, "We know what's good for you. We have these solutions, and this is what's best for you." That's a really problematic approach to policymaking. If researchers work with the community, the solutions can be a lot more collaborative and much less top-down, in a way that the community members feel heard and that works for the community.

The final point I want to mention is the benefit to the researchers, who can learn a lot from working with community groups. These learnings and the empathy these projects can foster stay with the researchers beyond the finalization of a project.

And for the communities that we're working with, this work is personal. This is affecting them directly. It's affecting their day-to-day lives. It's not like an academic sitting in her ivory tower saying, "That's an issue that affects them." Rather, this is an issue that affects *me*. And that personalization is something that, again, fosters this type of empathy.

For example, I went with Victor to a public hearing, and he stood up to talk about why we need climate policy in New York. The first thing he said was, "I live in the Bronx. I have asthma because of the pollution." So, for him, it's really personal.

I want to read a short quote from Victor that demonstrates this sensation. He writes, "Infrastructure is a language. Infrastructure can communicate what we think about a culture and what we believe a community deserves. The city of New York has been saying for decades that the residents of the South Bronx are uncared for and unwanted, through its infrastructure. In the neighborhood where I grew up, the term 'environmental justice' was literally coined."

For him, the fact that these freeways go through the middle of his community is a personal issue. And it's made real by his day-to-day struggles with asthma. When we're working with people for whom this matters and has an impact every day, the research takes on a different meaning and importance to the researcher and to the outcomes.

I couldn't agree with that more, and you've stated it so nicely. My own experience is in a very different context—researching the impacts of oil and gas development on local communities. Had I only read journal articles and books about what that was like, I would've had a very different picture from what I actually have, which of course is based on reading journal articles and books, but also on spending a lot of time in communities, meeting people, talking to people, getting a feel for places and for what's important to people. So, that resonates with me strongly, as well.

New York is taking environmental justice issues quite seriously through various pieces of legislation. Can you help us understand the most relevant laws that the state is or is considering implementing, which are seeking to address the types of environmental justice issues that you are looking at?

I know of three relevant pieces of legislation. The first one is the Environmental Rights Amendment, which was passed recently and states that everyone has a right to clean air. If everyone has a right to clean air, and if we're demonstrating that some people do not have clean air because of proximity to traffic or because they lack a defensive mechanism, then our work can help build on it.

Another piece of legislation is the Climate Leadership and Community Protection Act, which is massive climate legislation at the New York State level. The goal is to achieve net-zero emissions by 2050, but specifically, it provides funding that's dedicated to disadvantaged communities. So, 35 percent of the benefits of clean-energy funding need to go to these communities. It also creates new air quality monitoring requirements. And the work I'm doing fits into this ongoing legislation.

One piece of legislation is just spot on, and that's the Schools Impacted by Gross Highways Act. This act, besides just preventing the building of schools within 600 feet of major roadways and freeways, also prevents roadways from being built near existing schools by requiring developers to include in their environmental-impact statement the location of nearby schools. And finally, it funds retrofits for schools that are within 600 feet of major roadways. Our research doesn't just help identify which retrofits would be most valuable, but also can show the benefits of identifying the downwind schools to target first with these funds. ■

OPPOSITE PAGE A school bus drives under the Brooklyn Bridge in New York City.

Pabkov / Shutterstock

> **"When researchers work with communities, we can develop questions that are useful for the community, and the research can build something for the community that lasts beyond when the researchers actually leave."**

Getting Industry to Net Zero

How can we decarbonize the industrial sector? Moving forward, Resources for the Future will explore the tools that are needed to meet the challenge, including innovations to reduce the costs of cleaner fuels and processes, regulations and incentives for decarbonization, and models to identify such opportunities and help design policies.

TEXT Alan Krupnick

The complexity of the industrial sector means that we won't find any cookie-cutter answers and approaches to decarbonizing it. A combination of strategies for reducing emissions is likely necessary—which could include incentivizing low-carbon processes, electrification, capturing carbon, increasing energy efficiency, reducing waste, and developing technological innovations. With these transformations being essential to meeting climate policy goals, policymakers and regulators face the challenges of an evolving set of technologies; changing demand for energy and products; a complex market influenced by a mix of policies from the federal government, Native nations, states, and regional authorities; and a growing concern about tracking and mitigating the negative effects of decarbonization on disadvantaged communities.

The Industry and Fuels Program at Resources for the Future (RFF) engages with policy leaders, experts, and stakeholders to inform the continuing transformation and decarbonization of the US industrial sector—particularly those industries that are most carbon intensive, such as cement, refining, and steel; industries related to fossil fuels, such as the oil and gas sector; and low-carbon fuel producers, distributors, and users. We will expand our interactions with decisionmakers at the federal and state levels, with the aim of helping develop successful hubs for hydrogen and carbon dioxide, design policies for direct air capture, support decisionmaking by Native nations to enable energy sovereignty, and support policies that help decarbonize industry quickly and cost-effectively.

We will focus on three priorities in the foreseeable future: modeling and analyzing key industrial sectors; designing markets and incentives for low-carbon innovation; and designing and scaling up hubs for hydrogen use, along with carbon capture and storage.

Here's how we will follow through on these priorities.

We'll design regulatory policies that cost-effectively reduce carbon emissions from key industrial sectors.

The core of our efforts will be to develop new models and collect data in the industrial sector. Such information can help estimate benchmarks for emissions intensity and abatement costs in key US industries, which in turn can contribute to the design of better domestic policies. These models also can inform policies related to internationally harmonized trade and the reduction of emissions in carbon-intensive, competitive industries.

Few existing models go beyond crude calibrations for calculating emissions; rarely do models take a nuanced look at industrial sectors and the costs of reducing emissions in these sectors. RFF researchers will develop sector-level models of emissions and abatement costs that can consider sector-level policies and can contribute to larger aggregate models. The main focus of these models will be iron and steel; cement; aluminum; and chemicals, including fertilizer.

Complementing this US focus, scholars at the RFF-CMCC European Institute on Economics and the Environment and RFF together will examine global data and models, so we can inform discussions on trade policies including international tariffs, along with associated "climate clubs" and similar alliances. By combining technology-oriented modeling and data-based simulations with engagement from policymakers and industry leaders, RFF will advance new policies that can encourage low-carbon products and address international competitiveness pressures.

We'll continue assessing the interactions of industrial-sector tradable performance standards with carbon pricing in Sweden and use these insights to address similar policy options in the United States. With this project, we'll try to understand how the prices of products influence the incentives that drive innovation and investment in clean processes and fuels. We also will explore how that influence changes over the life cycle of regulation and what happens to these interactions when emissions rates go down.

RFF will provide data, economic analyses, technical expertise, and connections to US policymakers and international actors who seek to design and implement a set of globally harmonized emissions-reduction policies across competing nations in the industrial sector. This coordination can accelerate innovation while reducing concerns about competitiveness in hard-to-abate sectors like steel, aluminum, aviation, shipping, and chemicals.

We'll design markets for innovative products that offer climate-friendly alternatives to current industrial products.

In addition to focusing on specific industries and actions, we'll also make recommendations on the best practices for policies and corporate actions that spur innovation. In addition to loan and grant programs, we will consider rarely used demand-pull policies, such as advance market commitments, prizes, green public procurement, and other actions that create new markets or otherwise establish demand for carbon-free products and processes. Demand-pull policies have been highly effective in some markets (e.g., vaccine development spurred by advance market commitments) but have been less common in the energy and climate areas. We aim to understand what drives success for these types of policies in different contexts, so we can identify approaches and design features that can overcome barriers and effectively stimulate advanced technology development in carbon-intensive industrial sectors.

While net-zero emissions ultimately means that most fossil fuel use will be eliminated, reducing emissions from existing fossil fuel production also is important, particularly in the transition to net zero. We plan to measure the potential demand for "green" gas, and we'll engage with stakeholders over the creation of a market for green natural gas and oil, which can minimize methane emissions. If buyers are willing to pay a premium for green gas—and recent sales of certified low-leak natural gas suggest that they are—a market for such green gas could be developed to more fully incentivize the oil and gas sector to produce cleaner fuels.

We'll build the regulatory and policy structure that supports greater use of unconventional fuels such as hydrogen along with carbon capture and storage.

Policymakers have developed tax cuts for both decarbonized hydrogen and carbon capture, utilization, and storage; they've also implemented funding for hydrogen hubs, which are networks of clean hydrogen producers, consumers, and related infrastructure. RFF is positioned to provide timely analysis that helps policymakers understand how hubs for hydrogen and carbon may impact emissions and communities, given different hub designs and funding decisions. One hub in particular is on our radar: the Western Inter-States Hydrogen Hub, which is a hub formed by four states in the Intermountain West. RFF has studied the policy landscape undergirding this proposed hub extensively through our participation in the Intermountain West Project, which aims to develop hydrogen, bioenergy, and low-carbon economies in this region. RFF will evaluate the impact of hydrogen-hub policies on emissions reductions, cost competitiveness, and communities to inform the Western Inter-States Hydrogen Hub and other proposed hubs, as well as policies established by the US Department of Energy in developing the hubs program.

We'll also continue our work on designing and evaluating the success of hydrogen tax credits, such as the new "45V" credit listed in the Inflation Reduction Act. And we will delve deeply into the technological and policy landscape for direct air capture and other approaches to "capturing" carbon in the agriculture and forest sectors. ■

Getting to a Net-Zero Resilient Economy by Decarbonizing the Industrial Sector

RFF researchers are exploring technological and policy solutions that can decarbonize the industrial sector, including regulations, performance standards, policies for public procurement, market-creation approaches, and policies to fund innovation—alongside the equity, financing, and economic considerations that accompany decarbonization.

Alan Krupnick is a senior fellow and the director of the Industry and Fuels Program at Resources for the Future.

Coping with Climate Change and Building Resilience

What actions must we take now to live in a world where sea level rise, wildfire, and flooding are increasing in both frequency and intensity? Moving forward, Resources for the Future will explore the strategies and policies that can help build more just and equitable resilience in the face of disproportionate climate impacts, along with the steps required to build resilience into an effective policy package that incorporates climate mitigation.

Decisionmakers across the globe are grappling with how to account for risk and uncertainty about the impacts of climate change, even as communities already are experiencing significant impacts. Global average temperatures have increased significantly since the turn of the twentieth century and produced the warmest period in modern history. Even with aggressive greenhouse gas mitigation and the most optimistic outlook for future emissions, scientists predict that average temperatures will continue rising through 2100. Global average sea levels have risen by seven to eight inches since 1900, a trend that scientists predict will deliver one to four feet of additional sea level rise by the end of the twenty-first century. Along the US Atlantic and Gulf Coasts, the rise is expected to be even higher, accelerating tidal flooding and worsening hurricane storm surge.

We live now in a period of climate-related weather extremes, too: the frequency and intensity of extreme heat and heavy precipitation events has risen in most parts of the world, including the United States. The western part of the United States, for example, has been in a "mega-drought" since 2000, and the hot, dry conditions in the region have contributed to a significant increase in wildfire frequency and intensity.

These manifestations of climate change are having impacts on people, neighborhoods, and communities in myriad ways. According to the Centers for Disease Control and Prevention,

TEXT
Margaret A. Walls

IMAGE
Two people help a stranded motorist in Mississippi after Hurricane Ida brought flooding and other destruction to the Gulf Coast.

Sean Rayford / Getty Images

Effective resilience and adaptation policies, informed by RFF research, ultimately will improve the lives of individuals in communities at the front lines of climate change.

Margaret A. Walls is a senior fellow and the director of the Climate Risks and Impacts Program, the Adaptation and Resilience Program, and the Environmental Justice Initiative at Resources for the Future.

nearly 600 people die each year in the United States from exposure to extreme heat. The country has been hit by 291 major climate and weather disasters since 1980, according to the National Oceanic and Atmospheric Administration, imposing costs in excess of $1.9 trillion. The number of days with tidal flooding in the United States—often referred to as "nuisance" or "sunny-day" flooding—has reached an all-time high in recent years, causing roadway and parking problems, saltwater intrusion in farmlands, degradation of septic systems, and many disruptions to daily life. A recent study found that smoke from wildfires now is responsible for approximately half of all air pollution in some parts of the western United States, creating serious respiratory health problems and interrupting daily activities. Typically, the most vulnerable members of society—those in the lowest income groups, senior citizens, people with underlying health conditions, racial and ethnic minorities, and others—are most hurt by these weather extremes. Climate change exacerbates these underlying inequities.

The Climate Risks and Impacts Program at Resources for the Future (RFF) aims to improve our understanding of climate change risks and impacts across sectors and regions. This better understanding will lead to better decisionmaking by federal, state, and local governments in their design of adaptation policies, disaster mitigation programs, infrastructure financing, zoning and land use regulations, and other policies that can increase resilience and promote adaptation. Effective resilience and adaptation policies, informed by RFF research, ultimately will improve the lives of individuals in communities at the front lines of climate change.

Here's how.

We will quantify the economic and social impacts of climate and weather disasters, weather volatility, extreme heat events, floods, wildfires, and sea level rise.

Research in this area takes a deep dive into the impacts of climate change on people, property, businesses, and communities. RFF researchers will assess how various climate risks are manifested in property markets, labor markets, local economies, and at-risk populations. We'll provide policymakers with important baseline information about the extent of climate risks and the underlying causes of various climate impacts. This analytical information will help industry leaders understand the impacts that climate change has on businesses, which ultimately informs employment, investment, and where those businesses are located. This work also can drive policies that help communities cope with change and build resilience.

For example, communities now are confronting whether and how to allow further residential development in high-wildfire-hazard areas. For homeowners in these areas, insurance premiums have ballooned, with insurers refusing to renew coverage in some cases. Increased exposure to wildfire risk also increases the costs for electric utilities—which may be held liable when their equipment ignites a fire—and electricity consumers, along with the federal and state agencies that manage wildfire incidents. We'll analyze the extent to which housing markets are incorporating wildfire risks and document whether households are choosing locations based on those risks, which often are highly correlated with environmental amenities. We'll also evaluate policy options that could reduce household exposure to wildfires.

RFF's work on updating the estimate for the social cost of carbon (see page 8 in this issue of the magazine) has great relevance to quantifying these types of climate impacts. The social cost of carbon provides an estimate of the economic damages that result from an incremental ton of carbon dioxide emitted into the atmosphere, and this number can help assess the benefits and costs of US policy actions. We will integrate our latest estimate of the social cost of carbon into RFF's research efforts when evaluating the social impacts of climate change–related risks and disasters.

We will assess the environmental justice implications of climate-related weather events and identify equitable solutions for mitigating the effects of those events.

The impacts of climate change are a function of the frequency and severity of weather events, exposure of people and property to those events, and underlying vulnerability of the exposed populations. Vulnerability, often a function of underlying socioeconomic factors, is now recognized as especially important.

RFF researchers will measure the extent of inequities in climate impacts and identify who bears the burden of weather extremes, flood risks, and wildfire risks. We'll analyze climate impacts on minority-owned businesses and jobs in disadvantaged communities. Our research will help decisionmakers understand the nature of these inequities and how to address these issues by, for example, designing policies that implement disaster recovery and infrastructure investment. The new Justice40 initiative from the Biden administration holds agencies in the federal government responsible for ensuring that 40 percent of the benefits of federal investments go to disadvantaged communities; RFF researchers will help determine where investments are needed and how to meet the Justice40 goals.

One such project will identify environmental justice–focused strategies for addressing coastal septic failures caused by sea level rise and increased flooding. Increased flooding and sea level rise will cause septic systems to fail, both mechanistically and in terms of nutrient and pathogen removal, which can lead to gastrointestinal illness and parasitic infections in people. We will evaluate a range of policy interventions that can feasibly, equitably, and cost-effectively reduce risk and improve health outcomes for households and communities that rely on septic systems in flood-prone areas.

Septic failures are acutely problematic in areas with higher proportions of people of color and comparatively lower incomes, who are more likely to reside on flood-prone land and less likely to be connected to municipal sewer systems. With our collaborators, we'll look in detail at which populations are at risk of septic system failures now and in the future, while addressing conditions (some systemic and some historical) that may exacerbate this exposure. Ultimately, by using empirical data and community input, we'll evaluate where and how specific policy and technology solutions can address the compounded risk and ensure that the benefits accrue in a way that addresses past discriminatory practices.

We will evaluate the benefits and costs of policies that enhance resilience to extreme weather events and encourage effective community adaptation.

Reducing exposure and vulnerability to climate change will require creative policy approaches at the federal, state, and local levels. We want to know which policy options are the most effective, efficient, and fair. We will analyze reforms to the National Flood Insurance Program, which will improve the financial viability of the program and increase coverage gaps. We'll assess options for financing investments in resilient infrastructure, including natural and nature-based solutions. We'll evaluate forest policies and management strategies for mitigating wildfire risk. And we'll directly engage with communities directly to get a sense of the local feasibility of potential options—what works on the ground, for all communities, including historically disadvantaged ones.

As natural disasters grow in frequency and intensity under climate change, limiting populations and properties in harm's way will be the key to adaptation. In one crucial project, we'll examine an approach to discourage development in risky areas: eliminating federal incentives for development. We'll use the Coastal Barrier Resources Act of 1982 as a natural experiment to study whether removing government incentives for development can provide a cost-effective policy option for discouraging overdevelopment in areas that are at risk from climate change. The Coastal Barrier Resources Act designated certain areas along the Atlantic and Gulf Coasts as a Coastal Barrier Resources System within which federal funding for infrastructure, disaster relief, mortgage guarantees, and flood insurance are banned. We'll figure out whether the act has effectively discouraged development in coastal areas and reduced flood damage to nearby properties and neighborhoods. And we'll assess the overall effects on property tax revenues in jurisdictions that contain Coastal Barrier Resources System lands. ■

Getting to a Net-Zero Resilient Economy through Assessing Climate Risks and Strategies for Community Resilience

Armed with data and analysis from RFF experts, state and local governments can better target land conservation and infrastructure investments to improve resilience, design more effective zoning and land use regulations, and understand the trade-offs involved in alternative approaches to adaptation. Our work on local economic impacts and financial risks from climate change also provides critical information to the business community, with which firms can develop their own plans for improving resilience. RFF research will tackle all these considerations, from various angles, in the months and years to come.

Reducing exposure and vulnerability to climate change will require creative policy approaches at the federal, state, and local levels.

State-Level Roles in the Transition to Net Zero

Increased levels of individual state action will be important as decarbonization efforts ramp up federally and throughout the United States. Moving forward, Resources for the Future will work with state decisionmakers to support climate goals in areas like energy transmission and distribution planning, resilience and reliability in the electric grid, and emissions in the transportation sector.

TEXT Billy Pizer **ILLUSTRATION** James Round

Climate change is the single greatest environmental threat of our time, with pervasive economic consequences. Given the presence of greenhouse gas emissions throughout the whole economy, actions are needed at multiple levels of government to facilitate and drive the necessary changes.

At the federal level, a substantial step forward in climate legislation emerged this summer when President Joe Biden signed the Inflation Reduction Act into law. At the same time, some states have been expanding the ambition and breadth of their own efforts. These efforts include policy frameworks such as emissions markets, alongside the development of renewable energy sources, alternative fuels, vehicle efficiency improvements, and electric vehicle markets. States with significant fossil fuel extraction and processing also are grappling with how to transition their economies away from these activities effectively and equitably.

In this legislative landscape, we expect that insights from Resources for the Future (RFF) will be in high demand from state decisionmakers. RFF will engage with these decisionmakers, who push the frontier when federal action lags and yet often wind up at the front lines of implementing federal policies (including actions related to the bipartisan Infrastructure Investment and Jobs Act of 2021 and the Inflation Reduction Act of 2022). State-level policy development consistently has been a test bed and catalyst for additional federal climate action. RFF will provide state-level policymakers the best available information to make smart and equitable decisions that benefit people, health outcomes, and the environment and economy we all depend on.

Our policy engagement with the states falls into two broad categories. First, we help design smart emissions-reduction strategies at the state level. We recognize the complexity of the climate challenge and the clean energy transition. Second, we focus on state implementation of federal action, alongside regional efforts coordinated among the states. Of course, we aim to create comprehensive climate solutions that are equitable and to achieve emissions goals at lower cost to the economy. Accordingly, we intend to integrate environmental justice concerns into all of this work.

Here are examples of what this work will look like in practice.

We will support various state-level efforts toward reaching decarbonization goals.

California currently leads the nation in state-level ambition and policy implementation. We will identify opportunities to reform California's cap-and-trade program through assessment and modeling, which then can be used for subsequent policy engagement. We'll plan to explore how cap-and-trade reform in California may affect allowance prices, how auction revenues can support investments granted by the Greenhouse Gas Reduction Fund, which industries may see benefits or negative consequences, and more. This work can be a platform for a broader examination of potential market reforms, such as changes in the annual introduction and value of emissions allowances, changes in the auction price floor, adjustments to the supply schedule for allowances, and reconsideration of the allocation of free allowances to industry.

Other states have been following California's lead. We will evaluate how emissions-reduction targets in New Mexico and Nevada (both aiming for emissions reductions of 45 percent below 2005 levels by 2030) can be achieved through an economy-wide cap-and-trade program. Washington State already has implemented cap and trade, with the state aiming for emissions reductions of 45 percent by 2030 and 95 percent by midcentury. We'll evaluate the following three things: the impact on emissions of a cap-and-trade program in concert with existing and anticipated future policies; how an economy-wide cap-and-trade program performs in terms of costs and certainty of emissions-reduction outcomes, relative to a purely sector-by-sector policy approach; and opportunities to drive cost-effective reductions by linking programs across states that have comparable climate policy objectives.

One such program, the Regional Greenhouse Gas Initiative, is growing. Over 10 years ago, nine northeastern states joined together to create a regional cap-and-trade program for the electricity sector. The initiative continues to explore growth opportunities in terms of ambitious emissions targets, expansion to other sectors, and expansion to other states. Through modeling, convening, and informal consultation, we have informed those decisions in the past and will continue to do so in the future.

Finally, much of the burden of the energy transition falls on states and communities with substantial fossil resources that will need to find equitable ways to transition their economies toward a future of net-zero emissions. RFF's Equity in the Energy Transition Initiative has led the way in both understanding the likely impacts of the transition and exploring opportunities. This work will continue, with additional place-based analysis and, equally importantly, engagement with local communities.

We'll help state decisionmakers decarbonize the transportation sector.

Along with incentives in the Infrastructure Investment and Jobs Act, the recently passed Inflation Reduction Act helps facilitate decarbonization of the transportation sector in the United States. Related strategies include improving the affordability and accessibility of electric vehicle charging, accelerating investment in public charging stations, and managing the costs of delivering electricity to charging infrastructure. Much of the implementation of these provisions will be carried out by the states. We will work with federal agencies and state governments to help model various options that can maximize the effectiveness of federal spending.

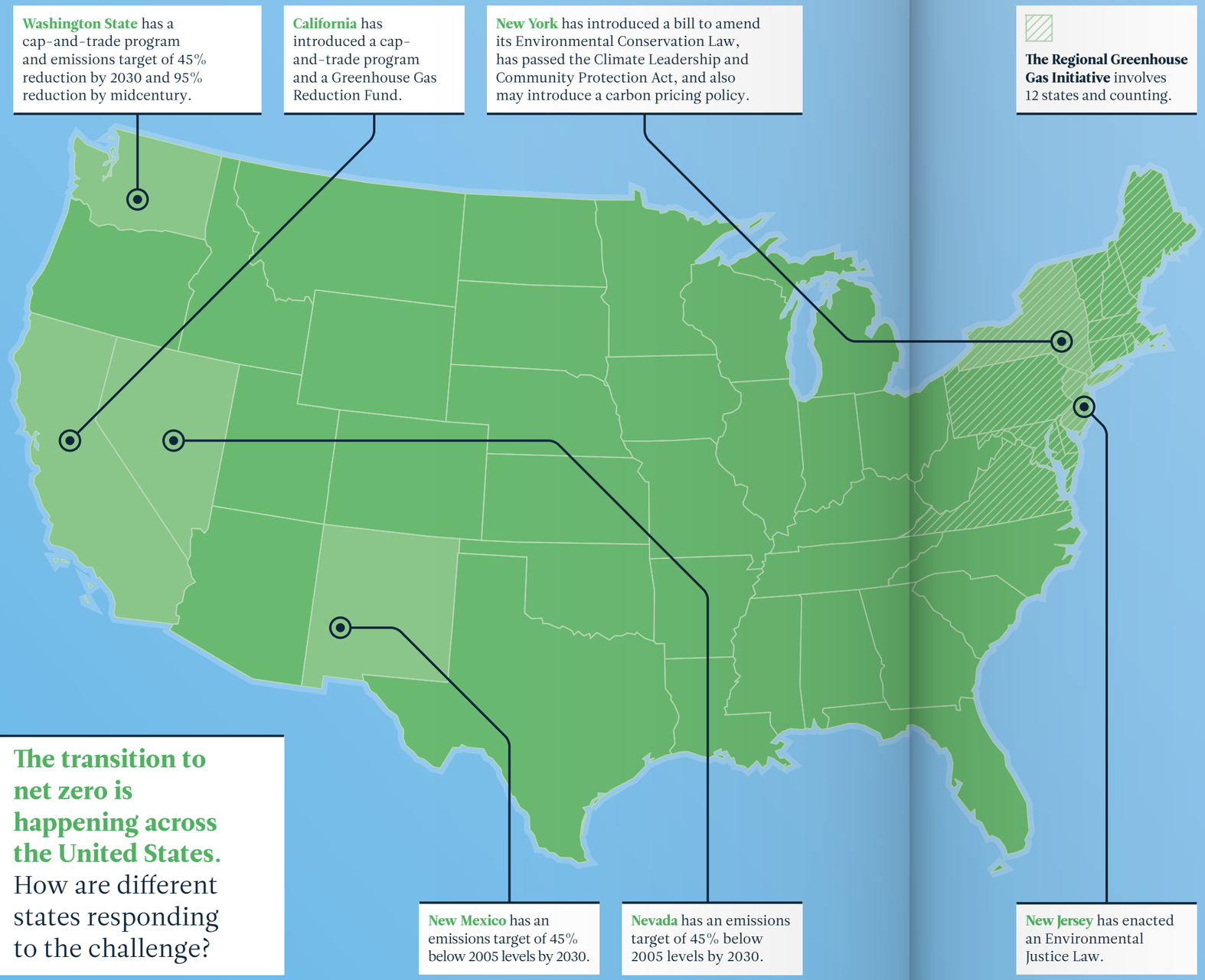
We'll help figure out ways to enhance the resilience of the electric grid.

The Infrastructure Investment and Jobs Act also directs the US Department of Energy to establish a grant program that helps mitigate impacts to the grid due to extreme weather, wildfires, and natural disasters. The act calls for another program, based on a collaboration of the states with owners and operators in the electricity sector, to create innovative ways of

Getting to a Net-Zero Resilient Economy by Informing US State Climate Policies

RFF researchers have generated critical policy studies that have been used in the crafting of every major piece of energy and environmental legislation and policy that's been signed into law over the past 70 years. We'll be there to offer states this same expertise as critical new elements of policy start addressing inequities and environmental justice, and as energy and environmental policy efforts evolve.

Billy Pizer is the Vice President for Research and Engagement at Resources for the Future.



The transition to net zero is happening across the United States. How are different states responding to the challenge?

enhancing regional grid resilience through research, development, and demonstration. The Inflation Reduction Act includes funding to help state-siting authorities expedite siting and to facilitate related activities, including transmission studies and stakeholder convening. We'll assist states in evaluating the options for designing electricity programs and allocating funds, so we can help optimize related decisionmaking and support stakeholder engagement.

We will consider and address the environmental justice implications of climate policies and state initiatives.

While California has been an ambitious leader in climate change mitigation, New York State has led the nation in its own efforts to consider mitigation alongside environmental justice concerns. We've been working with the New York City Environmental Justice Alliance and other research partners to help New York State credibly measure the environmental justice implications of climate policies under the state's Climate Leadership and Community Protection Act. RFF researchers will model different policy options crafted by both the state and the environmental justice community, respecting their different positions and enabling policymakers and others to transparently evaluate the trade-offs involved. Specifically, we'll be looking at how different greenhouse gas mitigation policies can affect air pollutant emissions and how changes in those pollutants would affect air quality on a hyperlocal scale. This work will allow us to identify the expected impacts on specific disadvantaged communities.

With the New York State Energy Research and Development Authority, we will assess the viability of potential carbon pricing regimes. Policymakers in New York State need to design an administratively functional, effective, and durable carbon pricing policy. To be most effective, the policy needs to limit emissions and the loss of capital to surrounding regions and proactively address the potential adverse effects on disadvantaged communities.

Any potential carbon pricing policy must accommodate other state and regional policy priorities; the composition of the economy, the electricity grid, and transportation needs in New York; and the state's commitment to economic and racial justice as articulated in the Climate Leadership and Community Protection Act. We will illuminate how carbon pricing has performed in various real-world settings and how a carbon pricing policy can be designed to complement other policies and avoid pitfalls. We'll concentrate on the role of policy design and policy sequencing in shaping the expectations of New York residents and the business community, and how those variables may contribute to the success of climate policies. Our work in New York could be expanded to other states, too.

Beyond New York, the Inflation Reduction Act includes provisions that states can leverage for environmental justice efforts, which RFF scholars will be tracking in the near future. For example, the law allocates $3 billion for a new environmental and climate justice block grant program for community-led pollution monitoring, prevention, and remediation, alongside investments in low- and zero-emissions technologies. The funding also will support workforce development, risk mitigation for extreme heat and wildfires, climate resilience and adaptation, the reduction of indoor toxins and air pollution, and procedural justice for disadvantaged communities at the state and federal levels. Further provisions of the law are related to energy and reductions in greenhouse gas emissions; for example, special incentives and additional funding are available for disadvantaged or underserved communities.

Federal funding alone can go only so far in addressing environmental justice concerns. Many problems can be addressed only at the state and local levels. For example, states handle permits for industrial facilities, and environmental justice communities have concerns about the cumulative environmental impacts from such facilities. A landmark New Jersey law, adopted in 2020, addresses these types of issues, with a similar bill passed recently in New York. And states often can determine how they spend funding received from the federal government—though this discretion does not always benefit environmental justice communities. ■

Climate Change Risk in the Financial System

Both climate change and the transition to a net-zero resilient economy pose risks to financial assets and the broader financial system—but these same risks can create opportunities for firms and investors. Moving forward, Resources for the Future will identify and improve the measurement of these risks to support financial stability, a thriving economy, and a healthy environment.

For this work, our scholars will aim to address four overarching research questions, which are summarized in the sidebars throughout this article.

> **"As the US Securities and Exchange Commission works on finalizing its proposed climate disclosure rule, the agency can note insights from how other jurisdictions have approached this issue."**

NO. 211 | FALL 2022 | *"The proposed rule is ... 500 pages long."*

Experts Focus on the Climate Disclosure Rule

Earlier this year, the US Securities and Exchange Commission proposed a climate disclosure rule. In the wake of the rule's announcement, Resources for the Future experts and colleagues weighed in on the question: Why do investors need or want the climate disclosure rule?

TEXT Marc Hafstead and Billy Pizer

On March 21, 2022, the US Securities and Exchange Commission (SEC) released a proposal for rules on climate-related disclosures that apply to publicly traded companies. Among other stipulations, the proposal requires companies to disclose the following information:

- their greenhouse gas emissions footprint, their plans to achieve goals (if any) for reducing greenhouse gas emissions, and how they will use carbon offsets to help achieve their emissions goals
- how their board of directors governs climate-related risks and how their management identifies, assesses, and manages these risks
- the climate-related risks they've identified, which have or are likely to have a material impact on business in the short, medium, or long term, and how those risks affect their business model and strategy
- when climate-related risks would have an impact on line items in consolidated financial statements

The proposed rule is vast and detailed—500 pages long, with over 800 specific questions posed to solicit input. A diverse group of experts shared their views on a set of questions that we believe are of particularly broad interest. These selected issues range from why investors need a disclosure rule in the first place to the particulars of exactly what types of emissions will be reported under the rule. We published these questions and responses from experts on the *Common Resources* blog this year, to inform the public comment period that accompanied the rule's announcement and revisions to the rule that will be finalized by the SEC in the coming months.

Why Do Investors Need or Want the Climate Disclosure Rule?

For more than a decade, companies voluntarily have reported climate-related information in response to investor demand. Previously, the SEC has emphasized that such disclosure might be part of a company's required reporting of business activities, risk factors, and management discussions. Until now, no further guidance has detailed what specifically needed to be reported, where the information would be reported, and any stipulations about information quality.

So, why do investors need or want an SEC climate disclosure rule?

"I would point out that rigor, consistency, comparability, and verifiability of these disclosures will be necessary. Otherwise, these companies cannot be held accountable for the promises they make in terms of carbon reduction."
Shivaram Rajgopal
Columbia University

"This rule is in the best interest of investors because it will improve the consistency of disclosures and data, which will allow investors to clearly evaluate climate risks in their portfolios."
Barbara Buchner and Nicole Pinko
Climate Policy Initiative

"This rule clearly is necessary, as climate-related risks have become, in many cases, a material risk to a lender or equity holder."
Bob Litterman
Resources for the Future and Kepos Capital

Indirect Emissions Disclosures Are Important but Tricky

The proposed rule requires companies to report Scope 1 and Scope 2 emissions. Scope 1 emissions are direct emissions by facilities that a company owns or controls. Scope 2 emissions are emissions associated with electricity, steam, heat, or cooling that a company purchases. The proposed rule further requires the disclosure of Scope 3 emissions when those emissions are material or when a company has announced a net-zero pledge that includes Scope 3 emissions. Scope 3 emissions include all other indirect emissions associated with a company's activities, including both "upstream" Scope 3 emissions, which are emissions associated with a company's purchase of greenhouse gas–intensive inputs such as iron and steel, and "downstream" Scope 3 emissions, which are emissions associated with the use of a company's products after the products are purchased.

So, what are some of the main concerns surrounding this Scope 3 emissions disclosure, and what does it mean for investors and companies?

"Reporting on Scope 3 greenhouse gas emissions may give rise to higher liability risk for companies compared to other climate disclosures, since the reporting company cannot ensure the quality and accuracy of the information that it gets from third parties."
Virginia Harper Ho
City University of Hong Kong

"Early adopters of Scope 3 reporting will benefit greatly from their proactive decisions; they will be ready for the new carbon reporting requirements from the SEC."
Christian Blanco
The Ohio State University

Research Focus 1

How do we make climate modeling and uncertainty analysis most relevant for companies and stakeholders in the financial sector?

Climate modeling on both the mitigation and impacts of climate change has not been designed to support risk analysis by firms and the financial sector. We will explore how to connect these modeling results to outcomes that firms, financial-sector regulators, and even citizens care about.

Research Focus 2

What's the role of financial-sector regulators in addressing the financial risks associated with climate change?

Beyond thinking about the disclosure of information, we will examine how the Federal Reserve Board and other agencies can address the energy transition and risks of climate impacts while remaining consistent with the agency's legislated mandate. We will assess whether and how jurisdictions at the national and international scales should consider harmonizing their approaches.

Research Focus 3

How can voluntary carbon offset markets contribute to mitigating both climate change and financial risks?

Looking at things from a corporate perspective: We will explore what can be done to support well-intentioned corporations in making the best decisions about carbon offsets. Looking at things from a societal perspective: We will explore how to leverage the existing interest and momentum among companies, in the form of voluntary pledges to maximize societal benefits. These voluntary pledges largely may take the form of emissions mitigation, but we also can explore other co-benefits such as improved human and ecosystem health, or the potential for technology investment and reduced mitigation costs in the future, such as investment in direct air capture.

"Limiting the reporting requirements to just the Scope 1 and Scope 2 emissions would keep the greenhouse gas accounting relatively simple and transparent. But if investors are concerned about a firm's contribution to global greenhouse gas emissions, a limited accounting is akin to measuring a firm's greenhouse gas weight with one foot off the scale."
Meredith Fowlie
University of California, Berkeley

Even with Moves toward Transparency, Corporate Climate Pledges and Carbon Offsets Will Be Complicated

Nearly 700 of the world's 2,000 largest publicly traded firms have committed to some type of voluntary net-zero goal or emissions pledge by midcentury. However, the details about how these goals and pledges will be achieved vary widely across firms, and firms currently are not required to divulge their progress toward meeting these goals over time. The proposed rule from the SEC requires companies with these voluntary commitments to be more explicit about their goals and to report regularly on how progress is being made. In particular, the rule requires firms with pledges to report the use of offsets in achieving emissions reductions outside of their own greenhouse gas footprints by requiring the disclosure of the source of the offset, the underlying offset projects, any registries or authentication of the offsets, and the cost of the offsets.

So, what are some of the main concerns about corporate climate pledges and carbon offsets? How does this disclosure address—or not address—the concerns?

"As an alternative, the SEC climate disclosure rule could promote enhanced environmental integrity and more efficient offset markets by indicating that corporations covered by these requirements also should disclose how they have insured the environmental integrity of the offsets."
Joseph E. Aldy
Resources for the Future
and Harvard Kennedy School

"The efficacy of these provisions will depend on the information that companies actually disclose in response to the SEC's requirements."
Margaret Peloso
Vinson & Elkins

"Determining quality standards for carbon offsets clearly is beyond the scope of the SEC's technical capacity or mandate. But the draft of the rule does provide some limited guidance."
Alex Rau
Environmental Commodity Partners

Will the Proposed Climate Disclosure Rule from the US Securities and Exchange Commission Come Up against Legal and Economic Challenges?

Once the proposed climate disclosure rule from the SEC is finalized, stakeholders may challenge the final rule in court. Such challenges may hinge on both legal and economic arguments. For example, in dissenting from the three SEC commissioners who supported the proposal, Commissioner Hester M. Peirce argued that the proposal exceeds the SEC's statutory authority to require mandatory climate-related disclosures, an argument elaborated by others, as well. Meanwhile, in 2009 and 2011, the SEC lost federal court cases on the basis that the agency did not adequately calculate the costs and benefits of its rules.

So, what are some potential concerns about the legal basis for the rule or its economic costs and benefits?

"Staying in one's lane when proposing far-reaching climate disclosure requirements is a necessary (though not sufficient) step toward valid rulemaking. So much depends on how the SEC responds to the commentary it receives in response to its thoughtful proposals."
James D. Cox
Duke University

"Developing and implementing a regulatory performance evaluation plan would provide quantitative evidence of the benefits, costs, and impacts on efficiency, competition, and capital formation … and could inform future efforts to improve climate-related disclosure."
Joseph E. Aldy
Resources for the Future
and Harvard Kennedy School

International Context of the Proposed Climate Disclosure Rule from the US Securities and Exchange Commission

In the past decade, regulatory authorities around the globe have introduced voluntary and mandatory climate-related disclosures. As the SEC works on finalizing its proposed climate disclosure rule, the agency can note insights from how other jurisdictions have approached this issue.

How does the proposed rule compare to approaches in other jurisdictions, and can we expect to see an international climate disclosure standard? Has the SEC followed similar methods as in the examples set by the United Kingdom, the European Union, and others? Or is the SEC's proposed approach fundamentally different in any key aspects? Will investors have enough information to accurately assess the climate risks disclosed by firms in different countries? Would a global standard be better than a mix of approaches across the globe?

"There's good reason to be optimistic that the SEC's proposed rules will support the current momentum toward an international climate disclosure standard."
Virginia Harper Ho
City University of Hong Kong

"While significant progress has been made in terms of country-specific regulations, this progress has been uneven internationally; crucially, the efforts of individual countries must not be distorted by regulatory loopholes, and disclosures need to be coordinated as much as possible."
Marcin Kacperczyk
Imperial College London

Research Focus 4

How can investors keep up with the landscape of climate finance and financial risk, and what type of information should be disclosed by firms?

We will determine how to make it easier for investors to understand the energy transition and its implications for companies in terms of climate risks. We'll also explore how investors might better recognize the companies that are significantly supporting (or hindering) a transition to a net-zero resilient economy.

Marc Hafstead is a fellow and the director of the Carbon Pricing Initiative and the Climate Finance and Financial Risk Initiative, and **Billy Pizer** is the Vice President for Research and Engagement at Resources for the Future.

Nature-Based Forestry and Agriculture Solutions

IMAGE
A view of farmlands from Steptoe Butte State Park in Washington State.

Edmund Lowe Photography / Getty Images

How can we harness the nation's lands—cultivated, wild, and urban—to meet climate goals and sustain people and ecosystems? Moving forward, Resources for the Future will explore ways to expand nature-based greenhouse gas storage and removal and reduce emissions related to agricultural production and increasingly frequent wildfires.

TEXT James Boyd

Land-sector policies related to forests, farms, rangelands, and urban areas are fundamental to achieving net-zero emissions and other climate goals. Clearly, nature-based greenhouse gas sequestration—that is, the removal and storage of greenhouse gases by forests, crops, and soils—is already important. US lands currently remove 13 percent of the nation's total emissions every year. US lands also store emissions—currently 50 years' worth of what the United States emits annually. And the role of the land sector in climate policy is poised to grow significantly.

Net-zero commitments by nations, cities, companies, and investors are creating a huge voluntary market for sequestration credits (worth $50 billion by 2030, according to one estimate), with the majority likely to come from forest- and agriculture-offset projects. The agriculture and forestry provisions of the Infrastructure and Jobs Act and Inflation Reduction Act also are notable. These acts provide billions of dollars in new funding and significantly expand federal programs to support innovative nature-based strategies.

Going forward, new policies will encourage afforestation, forest restoration, and forest protection to expand the carbon sink; promote agricultural practices that reduce greenhouse gas emissions; discourage emissions from forest fires; and incentivize the use of renewable forest and agriculture products in energy production.

With this growth in opportunity and demand comes a set of urgent questions, to which our attention is directed. One set of questions relates to the effectiveness of nature-based strategies and our ability to monitor and verify removal and storage. The costs of different types of nature-based solutions, who bears those costs, and where policy incentives and impacts will occur geographically also will be important to evaluate. Finally, the way we use and manage land affects not just greenhouse gases, but also a much broader portfolio of things that matter to communities, including

Getting to a Net-Zero Resilient Economy through the Nature-Based Management of Agriculture and Forestry

A net-zero commitment requires not just reduced greenhouse gas emissions, but also the removal and storage of greenhouse gases. The land sector in the United States provides a consequential carbon sink that could be enhanced by policies and market forces that shift land to more carbon-dense uses and convert more harvested biomass into energy and commercial materials with stored carbon content. US lands present an opportunity for rural, forest-adjacent, and agricultural communities to play a frontline role in climate solutions and other important objectives, such as reduced wildfire risk.

However, the coming expansion in nature-based climate investment requires innovative policy design and implementation, consideration of community impacts, an ability to evaluate success and cost-effectiveness, and attention to the market forces and incentives that can stimulate or inhibit climate progress. RFF research and policy engagement will tackle all these considerations, from various angles, in the months and years to come.

jobs, tax revenues, commercial and public infrastructure, clean and abundant water, wildfire risks, biodiversity, and recreation. Our great reliance on land as a natural resource means that nature-based solutions need to be deployed in a political and legal context in which many other things matter and may complicate policy implementation.

The Land Use, Forestry, and Agriculture Program at Resources for the Future (RFF) works with decisionmakers in Congress, federal agencies, states, nongovernmental organizations, and the private sector to find the most effective ways to use natural systems to enhance carbon storage and reduce greenhouse gas emissions. And we do this with full consideration of the ways that communities and ecosystems will be affected (both positively and negatively) by the land-management changes to come.

With our detailed knowledge of policy frameworks, alongside our network of decisionmaker and stakeholder partners, RFF will help chart a course through the implementation challenges arising from the coming wave of nature-based climate activity. We'll assess how greenhouse gas storage and emissions policies affect other environmental and social goals, including the protection of species and water resources, reduction of wildfire risks and damages, community well-being, and social equity. We will use our economic expertise to assess the performance, benefits, and costs of nature-based strategies and provide actionable data on land-related greenhouse gas storage and emissions. And we will analyze the ways in which policy options harness economic incentives and market forces to change land use, management, and production to meet our climate, social, and ecological ambitions.

Here's how.

We will assess best practices for managing forests and reducing wildfire risk.

Wildfires not only emit large amounts of greenhouse gases—they also threaten the nation's carbon sink (which is mostly forests), life and property, and water resources. With the extent and severity of wildfires increasing, cost-effective wildfire management and forest stewardship are national priorities. We are analyzing the use of mechanical thinning and controlled burns (i.e., forest fuels management) to reduce the risk and severity of wildfire events. Fuels management can protect communities and forest resources but is not without risks and often is politically controversial. We also are analyzing the ways that biomass removed via mechanical thinning can be marketable as an input to bioenergy production.

We are assessing the social impacts of wildfires on life, property, and communities at the wildland-urban interface. The identification and quantification of these impacts can contribute to the way in which wildfire management is targeted geographically. We also will conduct policy analysis for the private sector and nongovernmental organizations, whose participation will be essential to find enduring solutions for landscape-scale wildfires. We aim to help firms and organizations answer questions such as: How can we best take advantage of complementary federal programs and funding? Where can we be involved in collaborative wildfire planning and decisionmaking? Do gaps exist in federal programs and activities that cry out for nongovernmental action?

We will quantitatively assess the potential for, and costs of, nature-based carbon sequestration on US lands.

As decisionmakers consider climate policies such as government payments for carbon sequestration, voluntary offset markets, carbon pricing, and tax incentives, they need to know the long-run effects of such policies on greenhouse gas inventories, the cost-effectiveness and permanence of greenhouse gas emissions reductions, and specific communities and places. To meet this need, RFF will develop its national-scale model that estimates the effects of policies on nature-based carbon sequestration. With our Carbon and Land Use Model (CALM), policymakers can examine how policies affecting forests, agriculture, and urban land use quantitatively affect the sequestration of carbon. CALM features sophisticated, dynamic modeling of all US land use, land use change, and the dynamics of nature-based carbon removal and storage. Our modeling efforts will provide a critical "reality check" on projections and important estimates of uncertainty. The model also will help evaluate US climate change policies by supporting the cost-benefit analysis of nature-based carbon policies.

We'll take a detailed look at how nature-based climate policies will affect communities.

Increased government and private-sector funding for nature-based carbon sequestration, along with stimulus for the development of new bioenergy and wood-product markets, soon will flow into rural US communities. While the economic impact of these policies on rural communities, forest owners, and managers likely will be positive overall, the socioeconomic effects are likely to be unevenly distributed and, for some communities, negative. For example, new policies are likely to change land values, patterns of land ownership, employment, tax revenues, and local non-forest, non-agriculture business conditions. Our work will explore questions such as, How will impacts differ between large- and small-scale landowners? How will differences in access to skills, labor, and technology affect the distribution of gains? How are disadvantaged (poorer and/or minority) owners, workers, and communities likely to fare?

We'll look into the potential and risks of increased forest-biomass energy production.

Forest-biomass energy can be harnessed from fire-prone fuels and managed-forest systems. But although the environmental footprint of forest biomass has been the subject of substantial analysis and engagement by academic researchers, private-sector stakeholders, nongovernmental organizations, and government agencies, disagreement remains about the ultimate environmental and economic impacts of biomass combustion. Our work will involve the continued analysis of the risks and benefits of biomass energy, along with extensive engagement with stakeholders around specific advantages and disadvantages; how these advantages and disadvantages vary across contexts; and opportunities to minimize risks and maximize benefits. This engagement and analysis will allow us to illustrate future economic, social, and environmental outcomes associated with ramped-up bioenergy use; document areas of agreement, disagreement, and conflict; and outline how policies can be designed to maximize the overall benefits.

We'll explore the integration of nature-based strategies into broader climate-policy frameworks.

Nature-based strategies operate alongside an array of technological options that also capture and store greenhouse gases (e.g., direct air capture) and strategies to reduce emissions (e.g., mitigation programs). These parallel frameworks and approaches raise a set of questions about how nature-based sequestration should be integrated with, compared to, and incentivized alongside more technological forms of sequestration and mitigation. We will analyze for the US climate-policy community the pros and cons of a policy framework that integrates rules and incentives across diverse removal and mitigation approaches. For example, is it desirable for the United States to have a consistent, integrated policy toward all removal and storage approaches—whether technological or nature-based? And if so, what should such a policy framework look like? Then we have the long-standing question of whether, and under what conditions, nature-based sequestration is eligible to offset emissions-mitigation commitments.

Nature-based strategies also play a role in both voluntary and compliance-based carbon markets. Interactions between voluntary and compliance markets raise their own related questions, such as how voluntary incentives affect compliance-driven incentives (and vice versa) and how existing voluntary markets for nature-based sequestration might support or constrain a movement to future compliance-based markets or carbon taxes. ■

"With our detailed knowledge of policy frameworks, alongside our network of decisionmaker and stakeholder partners, RFF will help chart a course through the implementation challenges arising from the coming wave of nature-based climate activity."

James Boyd is a senior fellow; the Thomas Klutznick Chair in Environmental Policy; and the director of the Land Use, Forestry, and Agriculture Program at Resources for the Future.

International Climate Policy

How can we encourage increased global ambitions to decarbonize, while recognizing that countries need to maintain international competitiveness? Moving forward, Resources for the Future will assemble data and conduct analysis to support the design of policies that maintain industrial competitiveness, minimize emissions leakage, and encourage ambition as nations decarbonize.

TEXT Ray Kopp

Since the Paris Agreement in 2015, policymakers and stakeholders have focused on the objective of limiting global warming to well below 2°C. Over the past few years, an increasing number of national pledges of net-zero emissions projected for midcentury have come out of the European Union and countries such as Japan, China, and the United States. These pledges have been accompanied by nearer-term targets with 2030 deadlines that arguably coincide with the midcentury pathways to net zero. The nearer-term targets are considerably more ambitious than any previous policies in terms of mitigation, costs, technology development, and policy demands.

Achieving these ambitious targets requires the rapid replacement of fossil energy with carbon-free, low-emissions alternatives, along with the rapid reduction of emissions from manufacturing processes related to commodities like iron, steel, aluminum, cement, and chemicals, which are difficult to decarbonize. These mitigation actions can increase the costs of production in the internationally competitive commodity sector—and the more ambitious and rapid the actions, the greater can be the increases in costs.

For countries that have high ambitions for climate change mitigation, rising production costs can force economically sensitive industries to move to countries with less ambitious emissions goals. This displacement of industries to areas with lenient standards causes emissions to rise in the countries with lax climate policies (a phenomenon that economists call "leakage") and causes economic activity to decline in countries with ambitious climate regulations. Both of these outcomes—emissions "leakage" and lost economic activity—have been decreasing support for aggressive policies that reduce emissions in climate-ambitious countries.

The International Climate Policy Initiative at Resources for the Future (RFF) provides the global economic analysis; insights; and creative, effective, and equitable policy solutions that are needed to achieve ambitious climate targets while supporting the competitiveness of domestic manufacturing.

Here's how.

We are building a global network of research institutions that can help major economies and businesses achieve ambitious climate goals.

To help major economies and businesses achieve their climate-neutrality objectives efficiently and inclusively, we're building the Global Climate Policy Partnership (GCPP), which engages an international network of leading economic and policy research institutes. The GCPP facilitates a greater understanding of climate policies across national boundaries, quantifying and evaluating their economic, financial, and social impacts at various geographic scales. The network strives to aid decisionmakers as they craft policies to achieve climate goals, reduce emissions, and adapt and build resilience to climate risks. We aim to analyze what makes certain climate policies durable and resilient and incorporate climate risks and impacts into the policy-evaluation process. Members in the network currently include institutions from Europe, the United States, Brazil, India, China, Japan, and South Korea, with additional countries expected to join the partnership.

The GCPP will tackle research and analysis that focuses on the race to net zero, emphasizing the structural economic changes, technological development, and suite of policy solutions that are needed to achieve emissions targets. We will conduct research to identify and quantify the policy-induced benefits of avoided climate change; improvements in local environmental quality; and changes to economic activity, labor markets, equity, and inequality. We'll also consider climate finance and financial risk at the international scale, by assessing climate transition risk, the role of central banks and other governmental financial institutions in developing policies to manage risk, how private investment institutions contribute to the assessment of climate risk, and the impact of climate risk on investment portfolios. And we will look at the potential of advanced technology development and deployment, in terms of enhancing low- and zero-carbon energy technologies, carbon-removal technologies, and international cooperation that can accelerate these efforts.

We will monitor advancements in carbon border adjustments and assess the economic impacts of related policies.

The European Union and United States are considering actions to reduce leakage and loss of economic activity by imposing tariffs on imports of carbon-intensive goods (so-called "carbon border adjustments") from countries that implement relatively less stringent climate policies. Leakage and lost economic activity are most acute for industrial sectors that sell products in highly competitive international markets. Topping the list of these sectors are iron, steel, and aluminum, which tend to rely on energy inputs for manufacturing, involve production processes that emit greenhouse gases, and face high costs for reducing emissions.

Reducing the leakage and lost economic activity in these sectors can be accomplished by trading partners who agree that the production of commodities like iron, steel, and aluminum should meet certain agreed-upon emissions standards. Countries that agree to these standards form a "club" in which club members face no tariffs, but countries outside the club must pay the tariffs. Club members can further agree to collaborate and cooperate on the development and deployment of advanced technologies that accelerate the decarbonization of these industrial sectors.

RFF researchers, along with international partners in the GCPP and the RFF-CMCC European Institute on Economics and the Environment, will track the continuing development of policies related to carbon border adjustments and carbon and technology clubs. We'll also aid in their design and assess the economic impacts of these types of policies. We'll use modeling to investigate the options and feasibility of adding advanced low- and zero-carbon technology options in hard-to-abate sectors such as iron, steel, and aluminum. ■

Getting to a Net-Zero Resilient Economy through International Climate Policy and Comprehensive Climate Strategies

Moving forward, our aim at RFF is to objectively design and evaluate strategies that governments around the world can employ to drive their economies toward net-zero emissions while addressing equity and cost.

Ray Kopp is a senior fellow and the director of the International Climate Policy Initiative and the Comprehensive Climate Strategies Program at Resources for the Future.

NO. 211 | FALL 2022 | *"Many states are pursuing ambitious decarbonization goals for the power sector."*

Decarbonizing the Power Sector While Maintaining Reliability and Affordability

How can we build an electricity market and policy structure that enables 100 percent clean, reliable, and affordable power around the clock? What are the biggest challenges to implementation? Moving forward, Resources for the Future will explore the opportunities and implications of total decarbonization of the power sector.

TEXT
Karen Palmer and Molly Robertson
ILLUSTRATIONS
James Round

Addressing global climate change will require widespread decarbonization of the power sector and electrification of the economy. Policymakers, regulators, citizen groups, the corporate community, and other stakeholders face the challenges of an evolving set of technologies; growing demand from electrification of other sectors; and a complex market influenced by a mix of federal, state, and regional policies. Evaluating market designs and federal, state, and local policies can help facilitate the transition to a decarbonized power sector that serves a broad range of energy needs.

The Electric Power Program at Resources for the Future (RFF) brings economic insights to bear on the design, functioning, and evolution of electricity markets and a broad span of related government policies to help policymakers and stakeholders address emerging challenges. The program focuses on two major questions facing the sector: how to rapidly and feasibly decarbonize a growing power sector to meet climate goals, and how to maintain system reliability and affordability while doing so.

Decarbonizing the Power Sector

Many states are pursuing ambitious decarbonization goals for the power sector, and the Biden administration has embraced the decarbonization of the power grid by adopting goals of 80 percent clean power by 2030 and 100 percent clean power by 2035. The recent passage of the Inflation Reduction Act offers a new commitment from the US Congress to bolster clean energy

"The program focuses on two major questions facing the sector: how to rapidly and feasibly decarbonize a growing power sector to meet climate goals, and how to maintain system reliability and affordability while doing so."

development in the United States. In both state and federal settings, policymakers are looking for decarbonization policies that efficiently keep electricity prices low and encourage electrification, while meeting other objectives and political constraints. Congress also has approved the funding of research and development for advanced technologies, which could contribute to these efforts.

The successful design of decarbonization policies and strategies requires rigorous analysis to understand their effects on investment, the power generation mix, electricity affordability, and emissions of carbon dioxide and other pollutants. RFF researchers already have employed computational models and empirical approaches to inform the development of federal, state, and regional policies, including proposals for pricing carbon and clean energy standards, tax credits for clean energy technologies, and potential means of regulating greenhouse gas emissions under the Clean Air Act. We will continue to use our models to inform climate policies and clean energy policies that are directed at the electricity sector, along with policies that aim to increase the electrification of other end uses.

Maintaining Reliability and Affordability in the Power Sector

Energy regulators are seeking to reform market rules, regulations, and planning processes to facilitate clean energy investments, updates to infrastructure, and greater grid flexibility. Improved electric rate design, expansion of wholesale markets, and opportunities to shift demand all are being explored to ensure system reliability and affordability. These ideas call for research and analysis to help guide decisionmakers toward effective, efficient, and equitable solutions. RFF researchers will continue to track and inform the evolution of regulatory policies and market rules that will shape this continuing evolution of the power sector.

RFF's Electric Power Program will address these challenges in the electricity industry in the near term, while keeping an eye on the long game.

Here's how.

We will focus on decarbonizing the power sector.

We'll support federal and state policy discussions surrounding the issue of decarbonization. At the federal level, our modeling evaluates the consequences of various climate policy options on carbon emissions—such as regulations from the US Environmental Protection Agency on existing coal plants under the Clean Air Act—and their implications for local air quality. We'll also investigate the impacts of different policies in light of the recent passage of the Inflation Reduction Act.

At the state level, legislators and governors are adopting ambitious clean energy goals and policies. For example, some have implemented clean energy standards, and a group of mid-Atlantic states have joined the Regional Greenhouse Gas Initiative that was launched in the Northeast over 10 years ago. RFF researchers recently completed work with the state of Virginia to analyze policy options for deep decarbonization of electricity and will continue to explore additional hurdles that states face in their efforts to decarbonize their electricity supply.

We will explore how to design the market structures and regulations that are needed for an affordable, reliable, and clean energy transition.

We will continue to explore how different electricity market structures and regulatory policies impact decarbonization, the speed of the energy transition, and electricity bills. One major challenge has been building transmission lines that integrate regional networks, which can reduce electricity costs and enable greater access to renewable resources. Our work informs ongoing discussions related to the advancement of federal-state cooperation on transmission planning and development, efforts spearheaded by the Federal Energy Regulatory Commission and the National Association of Regulatory Utility Commissioners.

Market design also is important for enabling and guiding the investments needed for an affordable, reliable, deeply decarbonized electric

"As a part of our research on electric power, we plan to expand our understanding of how the benefits and costs of policies and behaviors related to climate, the electricity market, and electricity pricing are distributed among communities."

> **Electrification will play a large role in climate resilience and adaptation as temperatures rise across the globe.**

Karen Palmer is a senior fellow and the director of the Electric Power Program, and **Molly Robertson** is a research associate at Resources for the Future.

grid which serves loads that could grow rapidly in the decades ahead. RFF scholars will continue tracking market rule changes with near-term impacts and weigh in with analysis and advice. We will explore how emerging regional markets can evolve to limit emissions leakage from state carbon pricing policies. We'll also continue exploring how wholesale market designs might need to change to help ensure a reliable and affordable supply of electricity in the future.

We will share insights that facilitate effective and efficient electrification.

Our work examines the policies and pricing structures that can encourage electrification, along with the welfare benefits; consequences for emissions levels; and costs of different approaches that utilities, device manufacturers, or state regulators could pursue. We'll work to understand how changes to electricity retail rate design could encourage electrification and how electricity prices have influenced electrification to date. We'll also explore how policies that aim to encourage electric vehicle adoption in the long term may affect electricity-sector emissions and air pollution, and we'll study the impacts of electric vehicle policies on electricity load and emissions.

We're developing new simulation models that will examine the economics of electrifying certain energy services and various ways to optimize their operation. We'll also use empirical approaches and big data to understand how consumers respond to time-varying electricity rates and how automation can facilitate those responses.

We will expand our exploration of the distributional impacts of policies in the power sector.

As a part of our research on electric power, we plan to expand our understanding of how the benefits and costs of policies and behaviors related to climate, the electricity market, and electricity pricing are distributed among communities. We will continue to consider how different policies affect electricity rates and affordability for the most vulnerable households. We also will evaluate how climate policies affect the health of environmental justice communities. We may expand on our work in New York State by investigating how different climate policies, prompted by the passing of the Climate Leadership and Community Protection Act, will affect carbon dioxide emissions, local air pollution, and community health outcomes at the local level.

Our planned work to develop our models will further support the evaluation of environmental justice outcomes by allowing us to determine the economic and pollution impacts of energy facility siting decisions. This work will enable us to evaluate policies that are designed to protect communities that have been historically exposed to pollution. For example, a New Jersey law that requires new electricity generators to prove they will not negatively impact historically burdened communities opens the door to modeling work that could be undertaken to determine where new generators could be built that would be in compliance with the law.

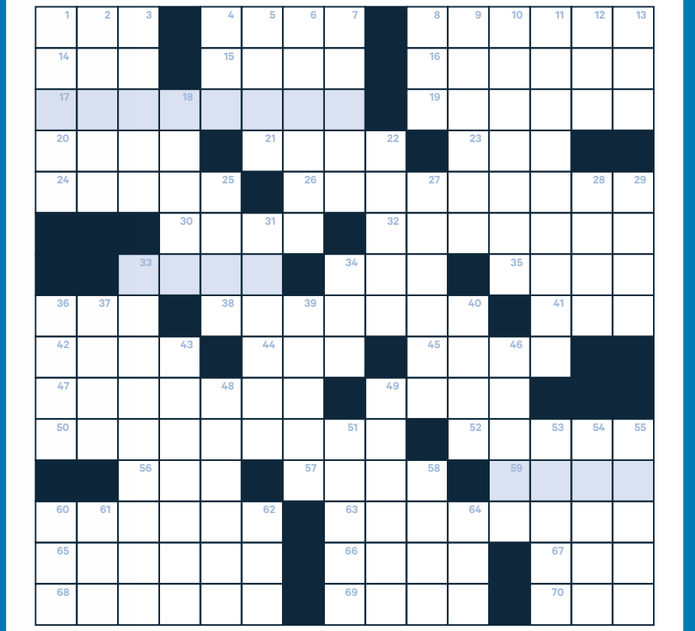
Collaboration with Other RFF Programs and Initiatives

In addition to pursuing the core goals of the Electric Power Program, RFF researchers will seek opportunities to collaborate across program areas to help inform broader societal decarbonization efforts, climate change resilience, and adaptation. Electrification will play a large role in climate resilience and adaptation as temperatures rise across the globe. Understanding the climate vulnerability of electric-power infrastructure and ensuring its climate resilience will be important to maintaining service reliability in light of growing demand. Siting of new generators, and the employment opportunities they bring, will have implications for energy communities in transition. Electricity markets and rate design have meaningful implications for the decarbonization of the transportation sector. These are just a few examples of the complex research topics that span various programs and expertise housed at RFF. Understanding what it takes to bring about a zero-carbon future will require thoughtful consideration of how all these spaces interact and build on one another. ■

Try to solve it!

None of us knows what the future holds until we start filling in the blanks. The fun is in finding the solutions.

CROSSWORD BY
Ross van der Linde



Across

1 Damages of a ton of CO_2 emissions
4 Croatian island with four UNESCO World Heritage sites
8 Tool for forming flat surfaces
14 Lowest point of a ridge
15 Nordhaus econ. model
16 Cement-sand-water mixture
17 When combined with 33 and 59 across, a clue to 50 across and 6, 11, and 27 down
19 Short snooze
20 Climate writer Stokes
21 Individual: prefix
23 Japanese currency
24 Nest
26 Personified
30 "Atlantis" org.
32 Hypnotized
33 See 17 across
34 Flames' campus
35 German supermarket chain
36 Joburg-based flier
38 Portion of a financial transaction
41 No. after a no.
42 Depose
44 Pipe bend
45 Tradable instrument in C.P.P.
47 First word in many recipes
49 Yale environmental lawyer
50 Maui volcano
52 Growl
56 Tax agency
57 With 49 down, metals used in smartphones
59 See 17 across
60 Mustachioed writers
63 Sewed
65 Amazing deals
66 Rather, to Ralf
67 Sugar suffix
68 Evaluate
69 E.P.A. toxic chemicals model
70 100 yrs

Down

1 Richter or Beaufort
2 Former FBI director James
3 Transparent
4 U.N. welfare measurement
5 "Veni, vidi, —"
6 Maine attraction
7 Sticky tree secretion
8 22nd and 24th president of the U.S.
9 Pagani sports car
10 It's used to catch waves
11 Summits
12 Itinerary info
13 Member of Congress, for short
18 Cologne river
22 Of the eighth degree
25 Toward the dawn
27 Foot parts
28 Lecture series offshoot
29 Add or subtract, say
31 String of wins
33 Business-as-usual runs of a model
34 Cornhuskers' campus
36 Future junior
37 Glow
39 Place to exchange vows
40 Landsat 1, previously
43 Baths of ancient Rome
46 Naysayer
48 Art stands
49 See 57 across
51 Industrial cutter
53 As needed
54 Witherspoon of *Wild*
55 Weighed down
58 E.U. climate research group
60 Ad for a good cause, briefly
61 The E.U. uses one to combat climate change
62 Obama-era atomic conferences
64 Start to cycle?

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Read more about options to support RFF on page 15 of this issue.

Don't Look Yet!

This key shows the answers to a crossword puzzle that's contained inside the magazine. Try the puzzle first! Then, come back to the key and check your work.

S	C	C	■	H	V	A*	R	■	S	H	A	P*	E	R
C	O	L	■	D	I	C	E	■	G	U	N	I	T	E
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H*	A	L	E	A	K	A	L	A	■	S	N	A	R	L
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A	S	S	E	S	S	■	R	S	E	I	■	C	E	N