

# Resources

**What do we**

**think about**

**climate**

**change?**

## The Climate Insights Survey

**EXPLORATION**

The World's Most Vertical Person

The adventures of sea and space pioneer Kathy Sullivan

**DISCUSSION**

Legislative Strategy for Durable Climate Policy

**ENVIRONMENT**

Underwriting Ecosystems  
Using insurance policies to conserve nature

**RESEARCH**

Carbon Taxes Do Not Harm Jobs or Economic Growth

Expert Insight,  
Accessible for  
Everyone.

# Resources Radio

# Our Attitudes, and Resilience

**As** I write this letter to you, I've been reflecting on the year to date, which has included the commemoration of a half century of major environmental landmarks: the Clean Air Act of 1970, the US Environmental Protection Agency, and Earth Day. We're also living in times unprecedented for recent generations of people. A pandemic has riven the global economy. Changes in our climate have contributed to frighteningly widespread wildfires; flooding that destroys entire communities; and farmers hit with both drought and derecho. Come November, we face an election that—unlike any in recent memory—will impact the future of environmental and energy legislation and regulation.

As such, this issue of *Resources* features survey results that detail American attitudes about climate change. In its 23rd year, the climate survey continues as a collaboration between researchers at Stanford University and Resources for the Future, along with survey research firm ReconMR. The survey results show that attitudes about climate change have stayed consistent, and the passionate group of people who prioritize climate change mitigation has grown—all in spite of a pandemic that easily could have pushed environmental concerns out of mind as people focused on other crises.

Alongside individual attitudes and behaviors, policy decisions matter greatly for most environmental and economic issues. Within these pages, Margaret Walls and Vincent Gonzales consider why so few private dam owners and public programs retire dams, even though dam removal is less expensive than dam maintenance and can ensure public safety more reliably. Carolyn Kousky shows the creativity of people in finding solutions to vexing problems, suggesting that creating insurance policies for ecosystems can promote conservation. Daniel Raimi discusses the potential for an equitable transition from fossil fuels to clean energy, and how we can benefit by expanding our focus from simply maximizing economic efficiency to including the goals of boosting equity and employment. This issue of *Resources* lets you sit in on a conversation with RFF scholars Dallas Burtraw, Marc Hafstead, and Kevin Rennert, who discuss the relative merits of different legislative strategies in pursuit of ambitious emissions reduction goals. And RFF Board Member Larry Linden tells us how he's steered his life and resources toward helping the environment, building on his experience in the financial sector.

This issue of the magazine also gives a glimpse of what it feels like to travel as close to the center of the Earth as humanly possible; it considers the furthest in outer space that economics can apply. Read on, reflect, and be resilient.



With best wishes for your health and happiness,

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

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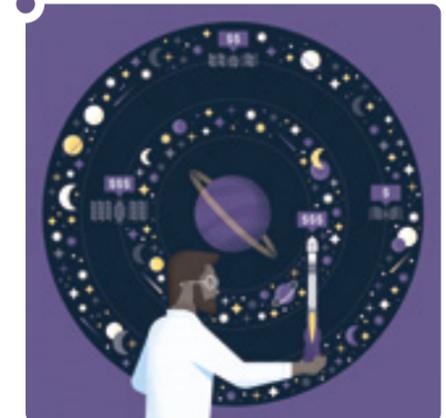
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An infographic pull-out poster about retired astronaut and deep sea explorer Kathy Sullivan.

# Climate Insights 2020 Survey

During the coronavirus pandemic, most Americans continue to believe climate change merits action

## TEXT

Jon Krosnick and Bo MacInnis

**Stanford University Professor and Resources for the Future (RFF) University Fellow Jon Krosnick has collaborated with RFF since 1997 to explore American public opinion on issues related to climate change. This year's report is the first in a new series by researchers at Stanford University, RFF, and survey research company ReconMR. The survey results show that opinions on climate change have become increasingly entrenched, and the group of people who care deeply about climate change has grown—all in spite of a pandemic that otherwise could have diverted attention and diminished support for climate change mitigation.**

**I**s concern about the natural environment a "luxury good," subject to fluctuations based on attention to other crises that take priority and have increased relevance in the moment? According

to one theoretical perspective, people can afford to worry about protecting the environment only if their basic survival needs have been satisfied. Although our survey results don't agree, a plausible foundation for such an argument is Abraham Maslow's "hierarchy of needs."

Maslow posits that people are motivated by the desire to satisfy various types of needs, which have been represented most often by a pyramid (Figure 1). Maslow calls the lower levels of the pyramid "deficiency needs"—the basic requirements for survival that must be satisfied, including having enough food, a place to sleep, and physical safety.

According to Maslow, until those basic needs are satisfied, an individual will focus on eliminating those deficiencies. Once those needs have been met, people have the opportunity to pursue psychic contentment

in the form of friendships, intimate relations with others, and feelings of self-esteem and worthwhile accomplishment.

Only after the four lower tiers of needs have been met does an individual enjoy the luxury of worrying about the greater good of societies, says Maslow. And perhaps concern over the environmental health of the planet, in the present and in the future, is a possible subject of a person's attention only if all deficiency needs have first been satisfied.

The novel coronavirus pandemic and the economic crash in the United States in 2020 offer an opportunity to explore the impact of economic change on opinions about climate change. Does a sudden decline in the satisfaction of deficiency needs—loss of a job, diminished feelings of safety, reduced economic security—affect American

concerns about the natural environment, public support for efforts to protect the environment, and even public belief in the existence of climate change?

In 2018, we collaborated with researchers at Resources for the Future (RFF) and ABC News to conduct a national survey, asking a wide array of questions on the topic of climate change, including questions about its existence, causes, and impacts; who should take action to address it; and more. Some of these same questions were posed again in a new survey we conducted with researchers at RFF and ReconMR, with 999 American adults who were interviewed between May 28, 2020, and August 16, 2020—in the midst of this year's global pandemic. In May 2020, when the survey went into the field, the national unemployment rate was 13 percent—a level not seen since the Great Depression. During the period the survey was

conducted, 19 million Americans filed new claims for unemployment benefits.

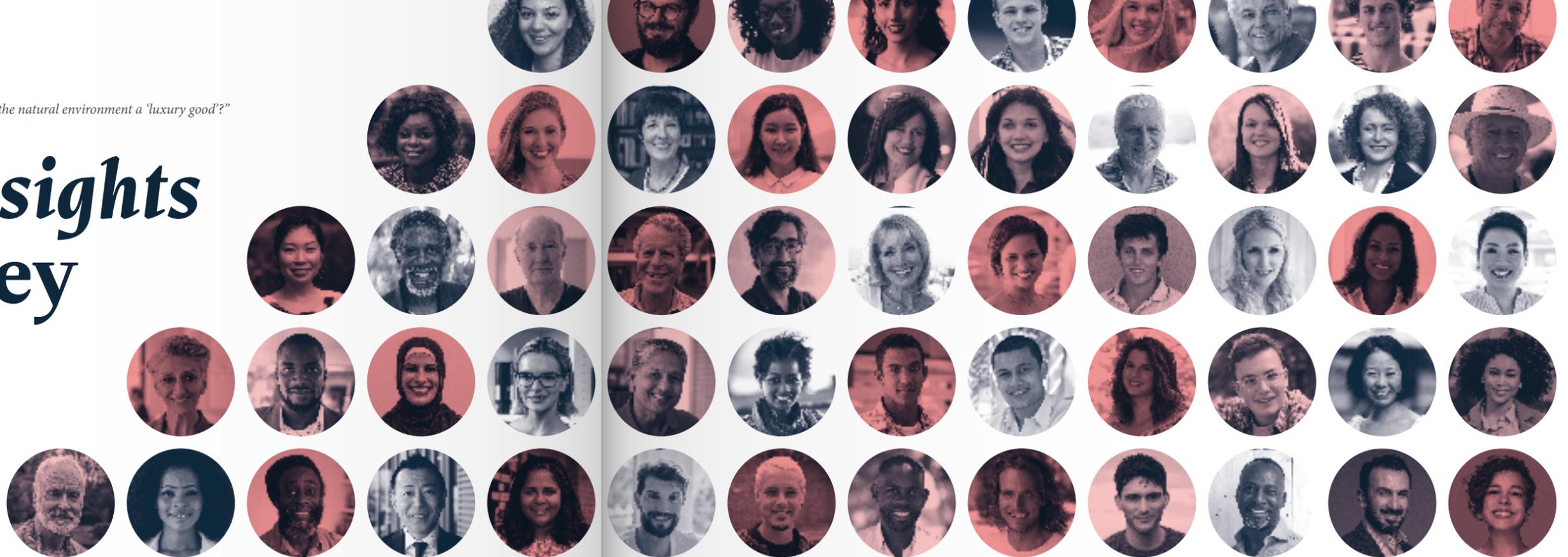
Comparing the 2018 and 2020 surveys allows us to assess whether the intervening public health crisis and economic upheaval

- have reduced the number of people who believe in the existence of global warming or the certainty with which people hold those beliefs, perhaps to rationalize reduced support for government action on the issue; and
- have reduced support for government efforts and policies intended to mitigate global warming, in favor of redirecting efforts to focus on the American economy and COVID-19.

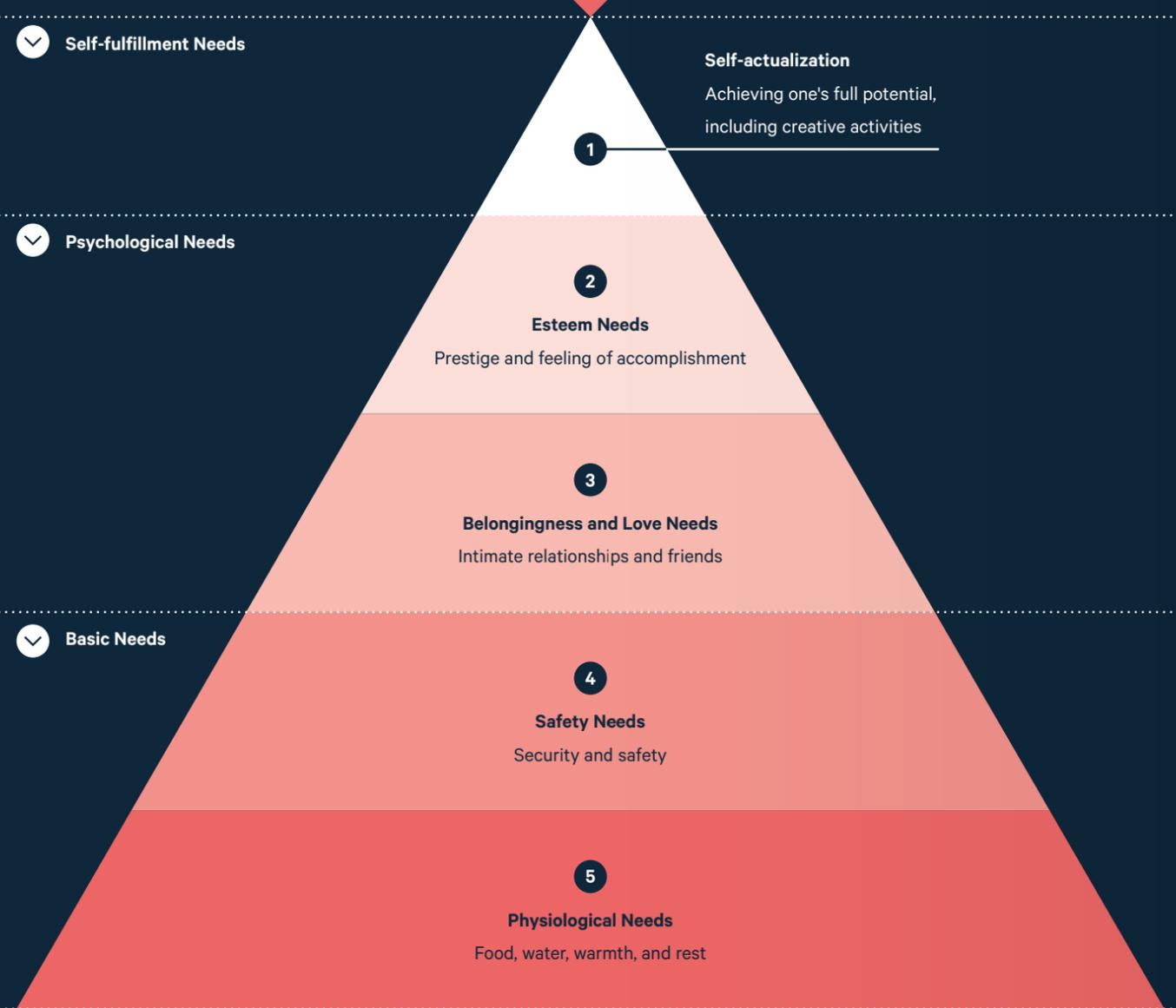
This survey provides a glimpse into the collective American psyche during a unique

time in the nation's history. The data from this survey show that, in spite of the array of social, economic, and public health issues affecting the United States today, considerable and sometimes huge majorities of Americans believe that global warming has been happening, will continue in the future, and requires ameliorative action.

*Note: When this research program began in 1997, "global warming" was the term in common parlance. That term was used throughout the surveys over the decades and was always defined for respondents, so it was properly understood. In recent years, the term "climate change" has risen in popularity, so both terms are used in this report interchangeably. Empirical studies, such as by Ana Villar and Jon Krosnick in 2011, have shown that survey respondents interpret the terms "global warming" and "climate change" to have equivalent meanings.*



**FIGURE 1** Maslow's Hierarchy of Needs



**Ann Bartuska**  
RFF Senior Advisor

**EXPERT INSIGHT**

“Rather than providing what the public might consider “definitive answers,” scientists regularly couch findings in uncertainty. This uncertainty often is perceived by nonscientists as a lack of clarity and agreement, feeding the idea that disagreement among scientists should raise

questions and mistrust. In addition, climate science doesn't happen in a vacuum. The public is also confronting disagreements around the coronavirus, vaccines, pesticides, and any number of issues where the scientific findings should drive the conclusions. But whose science?”

**EXPERT INSIGHT**

“The COVID-19 pandemic, the cratering economy, racial injustice, and so many other pressing societal issues have captured national attention and could have been expected to shift focus away from thinking and learning about climate change. Nevertheless, the fraction of the American public that believes global warming has probably been happening (a broad metric that helps gauge belief in climate change) is both high and stable over time at around 80% over two decades, and at 81% this year.

That this percentage is so high is indicative of bipartisan support, as the fraction of Americans who are Republicans is higher than 20%. This is good news for public support for future actions on climate change mitigation and adaptation.”



**Alan Krupnick**  
RFF Senior Fellow

**New Crises Do Not Take Public Attention Away from a Persistent Existential Threat**

The findings described here complement the work of several contemporary researchers who have studied the relationship between economic well-being and beliefs about climate change.

Maslow's theory, which suggests that the pursuit of economic well-being competes with advocacy for environmental protection, was the foundation of evidence offered in a 2011 paper in *Climate Change Economics* by economists Matthew Kahn and Matthew Kotchen. Their paper analyzes the frequency of Google searches between 2004 and 2010 for information about unemployment and information about global warming, on the assumption that searches on a topic reveal the extent of public concern about the topic. They conclude that “recessions increase concerns about unemployment at the expense of people's interest in climate change—in some cases leading them to deny its existence.”

Kahn and Kotchen also report evidence based on national survey data about the American “Great Recession” collected in 2008 and late 2009 through early 2010. Interestingly, unemployed Americans were no more or less likely than the employed to express belief in the existence of global warming, certainty about that belief, support for an American effort to combat warming, or support for more congressional action on the issue. This evidence refutes the most plausible version of the hierarchy of needs hypothesis: that economic suffering reduces an individual's concern about environmental protection

and reduces their belief in the existence of environmental threats.

However, the researchers did find a correlation between state unemployment levels and residents' beliefs—respondents living in states with smaller decreases in employment levels tended to believe in global warming more.

But not all evidence is consistent with this reasoning. For example, a 2008 paper by Hanno Sandvik found that, in a comparison of 46 countries, “gross domestic product is ... negatively correlated to the proportion of a population that regards global warming as a serious problem.” Thus, better economic conditions predicted less concern about global warming, rather than more concern. Complicating matters further, a 2012 analysis of data from the same surveys in 47 countries by Berit Kvaløy, Henning Finseraas, and Ola Listhaug found that GDP per capita did not predict respondents' ratings of the seriousness of global warming for the world.

Our 2020 survey has offered the opportunity to test these hypotheses again. The new survey shows that the COVID-19 crisis has not decreased American “green” attitudes or belief in the existence of global warming. At odds with Maslow's hierarchy of needs, the findings in this survey offer a new perspective on how global warming fits into individual and national priorities during a time of hardship.

**Survey Results**

This year's public health crisis has not affected the number of Americans who believe in the existence of climate change

**“A record-high number of Americans** believe that they know at least a moderate amount about global warming. Interestingly, it appears that increased knowledge has not been accompanied by a similar increase in the number of Americans who believe that climate change is happening.

One potential theory is that this increase in perceived knowledge is the result of confirmation bias. As people are increasingly able to seek out information that aligns with their beliefs, climate believers and deniers alike are able to find information that confirms their views. Therefore, people believe they know more about climate change without actually changing their opinions.”



**Kristin Hayes**

RFF Senior Director for Research and Policy Engagement

**B**elief in the existence of climate change is approaching the highest observed levels, and people have become increasingly certain of their beliefs about whether Earth has been warming in the past and will warm in the future. In 2020, 81% of Americans believe that Earth has been warming over the past 100 years—among the largest percentages observed since this surveying began in 1997, when the observed level of belief was 77% (Figure 2).

Certainty is on the rise, reflecting increasingly entrenched views. Among Americans who do and do not believe that global warming has been happening, the proportion of people who are highly certain of their beliefs about global warming’s existence has increased over the past 23 years.

Among people who believe that global warming has been occurring, the proportion of highly certain individuals was 45% in 1997 and has reached an all-time high of 63% in 2020 (Figure 3).

Among people who do *not* believe that global warming has been happening over the past 100 years, certainty also has escalated, reaching 44% in 2020. Interestingly, over the past 23 years, three spikes in certainty have arisen among people who are skeptical that Earth has been warming—all following striking declines in average global temperature. These spikes are consistent with the hypothesis that recent changes in average global temperature are important determinants of what we call “existence beliefs” among people who do not trust scientists who study Earth’s climate.

Since 1997, the proportion of Americans who believe that they are knowledgeable about global warming has increased steadily. In 1997,

42% of respondents said they know at least a moderate amount about the issue, and that figure rose to an all-time high of 75% in 2020.

One indicator of the crystallization of public opinion on an issue—and, consequently, the impact of people’s opinions—is the strength with which people say they hold those opinions. The proportion of people saying their opinions on global warming are extremely or very strong clocks in at 55% in 2020, up from 41% in June 2010 (Figure 4).

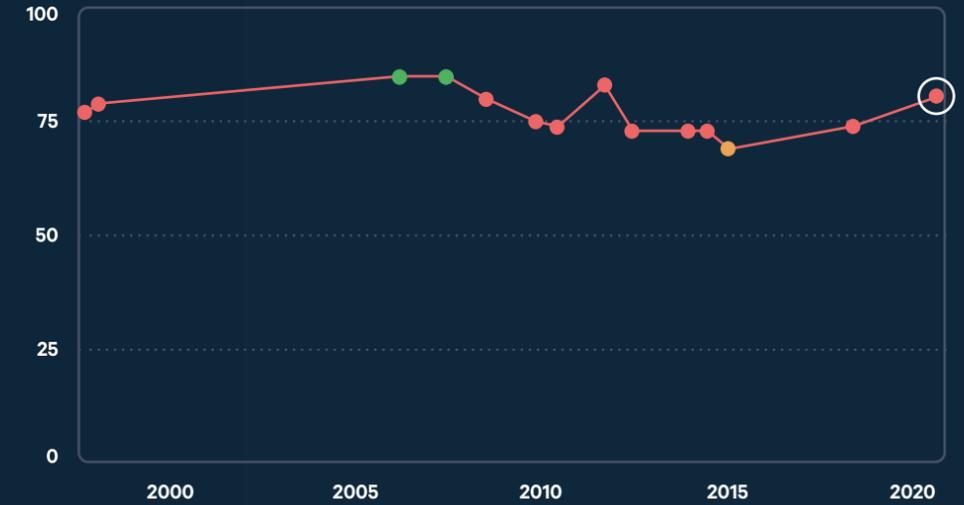
For most policy issues, a small group of people known as the “issue public” considers the matter to be of great personal importance. These are the people who pay careful attention to news on the subject, think and talk a lot about it, give money to lobbying groups to influence policy, and vote based on the issue.

In 2020, the global warming issue public constitutes an all-time high of 25% of Americans, up from 9% in 1997 (Figure 5). Thus, a growing proportion of people cares deeply about climate change. That a quarter of Americans comprise the issue public for climate change is particularly important, given that other well-known and controversial issues have attracted lower levels of passion.

**> This year’s public health crisis has not reduced support for efforts to mitigate climate change**

In 2020, 82% of respondents say that the US government should do at least a moderate amount to mitigate global warming—an

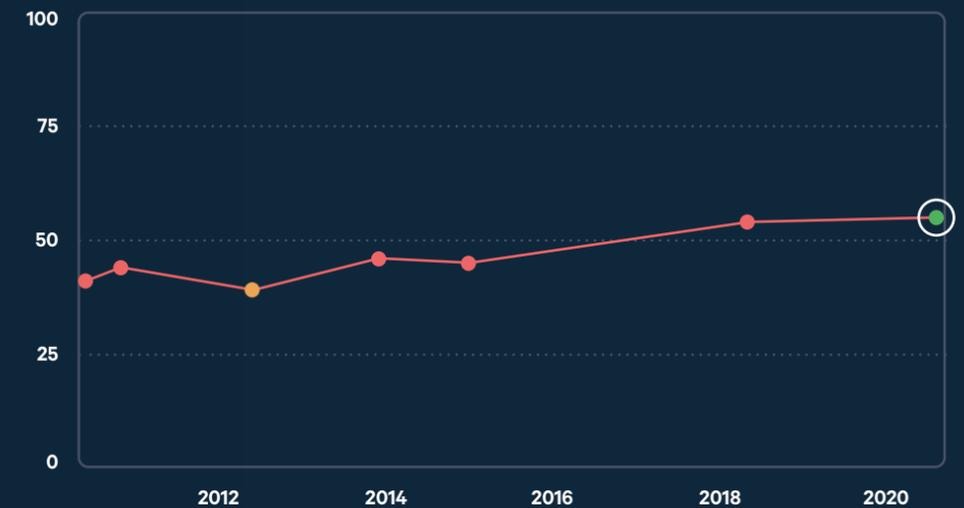
**FIGURE 2**  
Percentage of Americans who believe Earth’s temperature “has probably been increasing” over the past 100 years



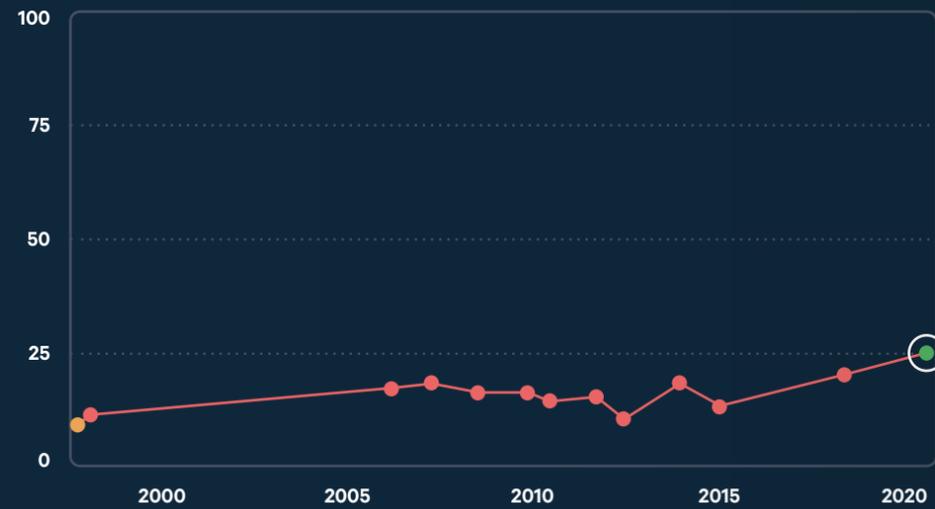
**FIGURE 3**  
Of the Americans who believe Earth’s temperature has been increasing, percentage who are extremely or very sure



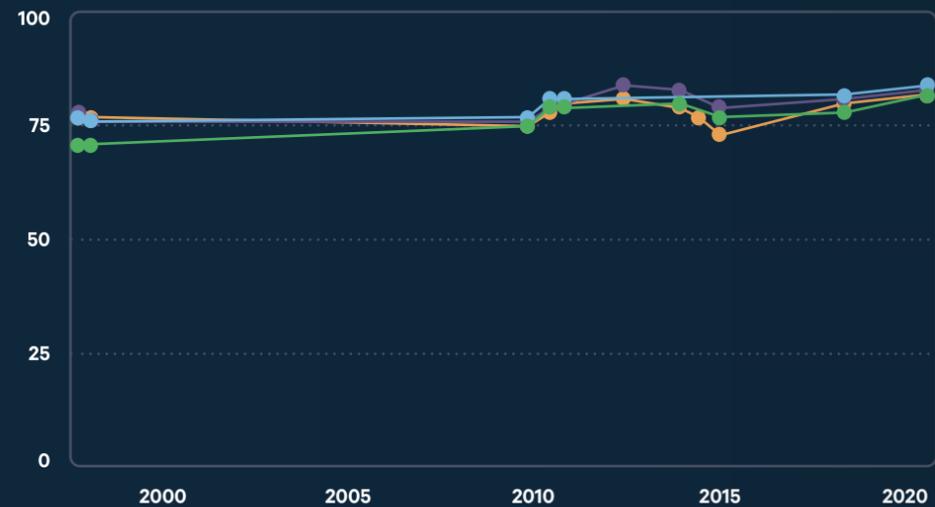
**FIGURE 4**  
Percentage of Americans who have very or extremely strong opinions on global warming



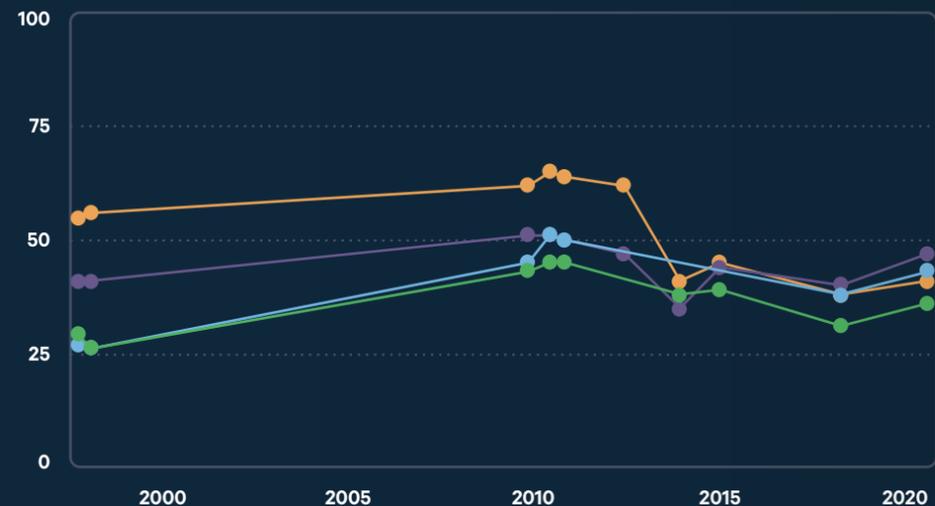
**FIGURE 5**  
Percentage of Americans who think global warming is extremely personally important (the global warming “issue public”)



**FIGURE 6**  
Percentage of Americans who believe governments, businesses, or average people *should do* “at least a moderate amount” to deal with global warming



**FIGURE 7**  
Percentage of Americans who believe that governments, businesses, or average people *are currently doing* “at least a moderate amount” to deal with global warming



all-time high for public opinion on the issue (Figure 6). Similar proportions of respondents believe that governments in other countries, businesses, and individuals should do at least a moderate amount to deal with climate change.

However, most people believe that governments, businesses, and individuals are not doing as much as they should on this issue. Compared to the 80% of people who think governments, businesses, and people should do at least a moderate amount to help mitigate climate change (Figure 6), far fewer believe that these groups are actually taking much action—only about 35% to 45% of people think these groups currently are doing at least a moderate amount to deal with climate change (Figure 7).

Most people want more action on climate change from each of the four groups mentioned. The proportion of people who believe that the US government, governments in other countries, businesses, or average people should do more to deal with climate change is about 70% across all categories. This desire for increased effort remains about what it was in 1997.

### Consistent Attitudes, Despite Unexpected Crises

The results of this survey illustrate that, despite numerous efforts over the past two decades to change public opinion, Americans’ views on climate change have been remarkably consistent. For numerous important issues in American politics, public opinion has changed extraordinarily slowly through the decades—if at all. As we see here, attitudes toward climate change have a similar inertia.

As in 1997, the 2020 survey results show considerable and sometimes huge majorities expressing what might be called “green” views on climate change and related issues. These high levels of agreement are not often seen in American politics these days, and the coherent response identifies an arena that crosses party lines. This is the sort of public opinion that policymakers hope for, so they can move forward by creating policies that carry the support of a large swath of their constituents. But although the majority of Americans believe that something should be done about climate change—whether by the federal government, world leaders, businesses, or individuals—the details of *how* something should be done remains a point of contention among legislators.

Even with so much evidence of continuity over time, we see signs of change in this survey. In particular, we see Americans believing they know more about this issue and are more certain of their opinions than in the past.

Taken together, this evidence appears to refute the theory that concern about climate change is a luxury good that the public cannot afford in times of crisis. This sort of evidence helps scholars of public opinion better understand the American public—and helps Americans better understand themselves. ■

Jon Krosnick is a professor at Stanford University and a university fellow at Resources for the Future. Bo MacInnis is an adjunct lecturer at Stanford University.

Article is based on Climate Insights 2020: Surveying American Public Opinion on Climate Change and the Environment, a report published by Resources for the Future in August 2020.

### EXPERT INSIGHT

“The COVID-19 pandemic has created an unprecedented global scenario for energy use and emissions. The past six months have shown us a dramatic example of how sudden action by multiple stakeholders can significantly impact emissions.

As RFF’s Global Energy Outlook report explains, energy demand contracted sharply as businesses shuttered and people traveled less with the onset of COVID-19. Some projections estimate that emissions could fall by roughly 8 percent this year, returning to 2010 levels. However, absent changes in public policies to address climate change, a return to economic growth likely means a return to *emissions* growth. Projections suggest that the world may be on the cusp of its first true energy transition, but more ambitious government policies and technological innovations are needed to satisfy the energy demands of a growing world while also achieving long-term environmental goals.”



**Richard G. Newell**  
RFF President and CEO

# More from *Climate Insights 2020*

## Surveying Public Opinion on Natural Disasters

**PHOTO**  
A couple takes in the orange sky above the San Francisco–Oakland Bay Bridge during this year’s exceptionally intense wildfire season.

MILKOVÍ on Unsplash

**C**limate change intensifies natural disasters such as wildfires and floods, making them increasingly destructive. As the world warms, the cost to Americans may justify public efforts to adapt to damage exacerbated by climate change, and the government can implement these efforts through the use of taxpayer dollars. Whether governments should undertake such efforts—and how these efforts should be paid for—are matters on which the American public can and does express preferences.

- A majority of Americans favor government efforts to protect people from future wildfire and flood damage through prevention and adaptation policies.
- Informing Americans about the links of fires and floods to climate change increases public support for adaptation efforts by the government, and those who believe in the existence of climate change are more likely to support adaptation policies.
- Although self-interest is a driver of public support for government adaptation policies, a concern for the greater social good is more consequential.
- Support for adaptation policies appears to be greater among groups who may feel especially vulnerable to the impact of disasters, including people of color and low-income individuals.
- Americans overwhelmingly favor the federal government’s involvement in enacting fire and flood adaptation policies, though most Americans prefer that people in fire- and flood-prone areas shoulder the costs of such policies. ■



# Jobs, Equity, and Efficiency: Reconciling Priorities in a Transition to a Clean Energy Economy

An equitable transition to a low-emissions economy will require difficult decisions about which policies can best achieve multiple goals. In the years ahead, policymakers will seek to find policies that can serve three masters in addition to reducing emissions: supporting jobs, reducing inequities, and limiting policy costs.

**C**lean energy is surging in the United States and around the world. With rapid cost declines and support from public policies, technologies such as wind, solar, and battery storage have been ramping up to provide larger proportions of energy globally. As policymakers look to reduce emissions of greenhouse gases and other pollutants from our energy system, clean sources will almost inevitably take center stage.

But what are the economic, employment, and equity implications of ramping up these technologies, especially compared to the

incumbent sources they seek to displace? Will the number, type, and quality of jobs created by the growth of clean energy match those lost in coal, oil, and natural gas—and is that even the most useful question to ask? What has research told us about the cost-effectiveness of existing clean-energy deployment policies, and how do these policies stack up against alternatives? Can clean energy policies address the legacy of energy and environmental injustice that stretches back for decades?

For some of these questions, the answers are clear. But for others, new research is needed to inform future policymaking.

**TEXT**  
Daniel Raimi

**ILLUSTRATION**  
James Round

“  
Can clean energy policies address the legacy of energy and environmental injustice that stretches back for decades?  
”

## Jobs, Jobs, Jobs

**E**arlier this year, Democratic presidential nominee Joe Biden said: “When I think about climate change, the word I think of is ‘jobs.’” At the same time, President Donald Trump has criticized his opponent, warning of fossil energy job losses in key swing states such as Pennsylvania.

With such a clear focus on jobs, it’s worth considering the state of play on energy employment in the United States. COVID-19 has upended the economy—energy included—but data from 2019 can help us understand

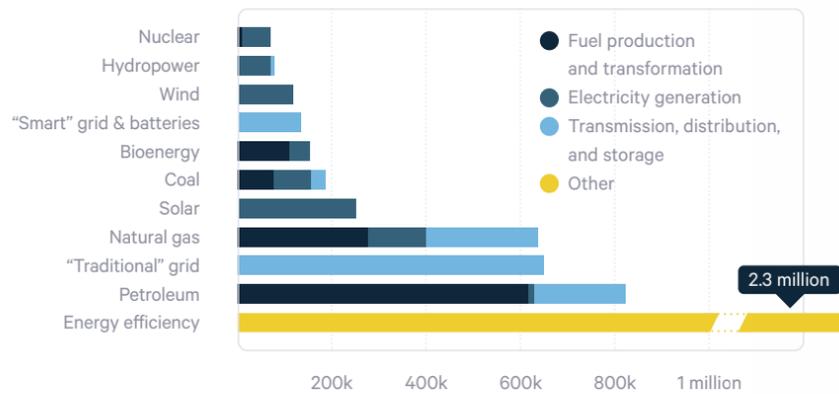
some fundamentals. Jobs in fossil fuels (which include energy extraction, processing, transportation, storage, and end uses for electricity and transportation) totaled more than 1.6 million, led by oil (822,000), natural gas (634,000), and coal (186,000). These figures lag behind the 2.3 million Americans working in energy efficiency (e.g., home weatherization, energy-efficient appliance manufacturing) but considerably exceed the nearly 500,000 Americans working in solar (248,000), wind (115,000), and nuclear (70,000) energy.

How might this distribution of jobs change in the context of an energy transition? Several

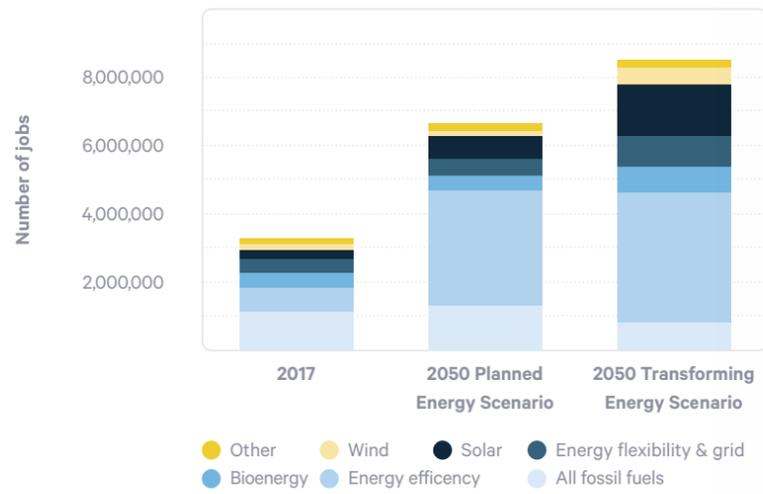
recent analyses by Fragkos and Paroussos (2018), Mercure et al. (2018), and Montt et al. (2018) have estimated that ambitious climate policies would lead to a net increase of jobs in various jurisdictions, with the number of lost jobs in fossil fuels more than made up for by jobs in renewables and energy efficiency.

In the broader context beyond the United States, the International Renewable Energy Agency estimates in a 2020 report that ambitious climate policies will lead to more energy jobs across North America. Under its “Transforming Energy Scenario,” which aligns with the long-term climate targets of

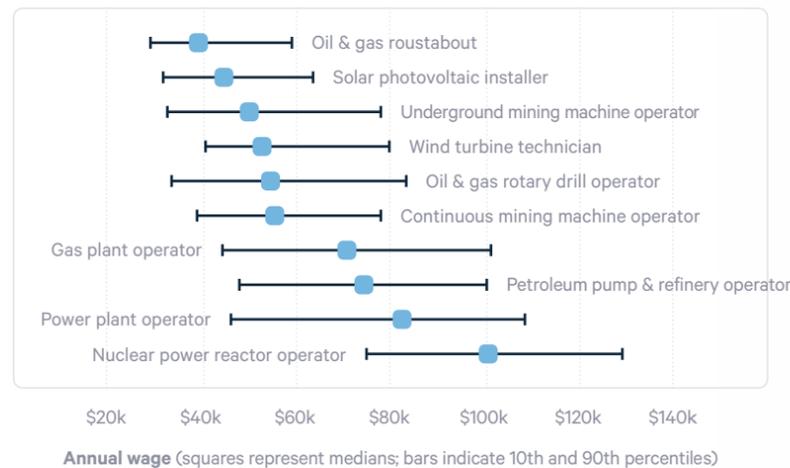
**FIGURE 1** Number of US Energy Jobs by Sector in 2019



**FIGURE 2** Number of North American Energy Jobs by Type



**FIGURE 3** Annual Wages for US Energy Jobs by Type



the 2015 Paris Agreement, the total number of energy jobs in 2050 will be 1.9 million greater than in a “Planned Energy Scenario,” under which governments implement current and announced policies.

While these projections may offer encouraging news, the number of jobs is just one of many considerations. For example, a 2020 analysis by North America’s Building Trades Unions using focus groups and surveys found that tradespeople in the United States perceive fossil energy jobs as providing better wages and benefits than renewable energy jobs.

Another relevant metric for assessing job quality is union density. Across the United States, overall union density averages about 6 percent, according to a 2020 report about energy and employment by the National Association of State Energy Officials and Energy Futures Initiative. In solar and wind, the rate is 4 and 6 percent respectively; but for workers in power plants fueled by coal, natural gas, and nuclear, the rate is 10 to 12 percent.

Unionization—along with education, training requirements, and other factors—all shape energy wages. Domestic wage data on energy jobs offer a nuanced picture: some fossil energy jobs, such as oil and gas rig employment or mining machine operation, offer similar wages as jobs related to the installation and service of wind and solar equipment. However, those who operate oil and gas processing facilities or thermal power plants (particularly nuclear plants) earn considerably more.

**Sources** Figure 1, National Association of State Energy Officials and Energy Federation Incorporated (2020). Figure 2, International Renewable Energy Agency (2020). Figure 3, US Bureau of Labor Statistics (2019).

A crucial question for policymakers in the years ahead will be: At what expense should we prioritize job creation in energy and environmental policies? For example, education policy focuses on achieving better student outcomes, while diplomacy seeks to advance US geopolitical interests. Although rhetoric around energy and environmental policy has focused on job creation (or destruction), policymakers will also need to focus on cost-effectiveness and the equity outcomes that result from their decisions.

### Equity and Efficiency

Scholarly research has paid relatively little attention to the employment implications of different energy policy choices. But plenty of research has covered the cost-effectiveness and distributional implications of energy policies, and here, the lessons are more straightforward.

A plethora of work has demonstrated that broad-based policies targeting entire sectors (e.g., performance standards in the electricity sector) or the wider economy (e.g., economy-wide carbon pricing) will tend to reduce emissions at lower cost than the types of technology-specific policies more often enacted by the federal government and many US states. What’s more, some of these policies, such as subsidies for rooftop solar, electric vehicle purchases, and certain energy efficiency programs, have tended to disproportionately benefit high earners, as noted by Borenstein and Davis (2016) and Fournier and other researchers (2020).

Despite these consistent findings, technology-specific subsidies and standards continue to

spread across the United States. Why? One reason is jobs.

From a political perspective, policymakers can easily point to technology-specific subsidies such as wind, solar, or energy efficiency and connect those policies with job growth in the relevant fields. For technology-neutral policies such as carbon pricing, the rhetorical link is less clear. In addition, the well-known political challenges of enacting a carbon price, along with persistent skepticism about the role of markets in reducing pollution, contribute to the growth of technology-specific policies.

### In Transition

So, is it feasible to serve three masters? Can policies thread the needle to support an energy transition while also providing jobs, enhancing equity, and achieving cost-effectiveness? We don’t have all the answers yet, but recent experience suggests that fully satisfying all three criteria will be a challenge.

In some cases, such as in California and the Regional Greenhouse Gas Initiative (not to mention most of Europe), policymakers have deployed a mix of carbon pricing and other policies, including renewables mandates and energy efficiency programs. Although this mixed-policy approach reduces the carbon price and the cost-effectiveness of the policy overall, it may offer a more politically viable path forward for policymakers who would prefer to focus their messaging on job creation rather than carbon taxation. But keeping a carbon price in the mix remains crucial, as carbon pricing raises revenue that can support those who are displaced from jobs in fossil energy and those who suffer from a legacy of environmental injustice.

A new series of reports I’m writing with RFF colleagues Wesley Look and Molly Robertson, along with Jake Higdon of the Environmental Defense Fund, lays out options for federal interventions that focus on supporting fossil fuel-dependent workers and communities, with the first report focused on economic development policies. This work is in early stages; future reports will cover workforce development, the social “safety net,” environmental remediation, and other policies that may play a meaningful role in what is often referred to as a “just transition.” Additional work will describe in detail the cost-effectiveness and energy justice impacts of different clean-energy deployment policies.

### Not Just a Transition

The economic effects of a transition to clean energy will be consequential for households across the United States and the world. Such a transition not only will prevent the worst impacts of climate change—it will also create new opportunities for entrepreneurs and workers in clean energy across the economy. But considerable uncertainties remain, particularly for people in fossil energy regions who worry about the backbone of their local economies, and for those who struggle to afford heating in winter and cooling in the summer.

Identifying an equitable path forward is more than a moral imperative; it can smooth the path to a politically viable climate policy for an issue that has become increasingly polarized. But we will need to be clear-eyed about the challenges, including the need to balance the competing priorities of jobs, equity, and efficiency.

*Daniel Raimi is a senior research associate at Resources for the Future.*

# Carbon Taxes Do Not Harm Jobs or Economic Growth

Results from two recent analyses suggest that implementing a carbon tax has no discernible detrimental effects on employment and GDP growth.

## TEXT

Gilbert E. Metcalf and James H. Stock

**E**conomists broadly agree that placing a price on carbon, whether through a cap-and-trade program or a tax, is a key element of an economically efficient suite of policies to reduce greenhouse gas emissions. In the current US Congress, numerous bills propose the establishment of national carbon tax systems, along with a few that push for cap-and-trade programs. These bills reflect a growing consensus that action is needed at the national level to curb carbon pollution in the United States and that a carbon tax is the most straightforward way to do that. The bills also reflect the existing consensus among economists, as typified by the more than 3,500 economists (including us) who signed the Climate Leadership Council’s statement published in the *Wall Street Journal* last year, which calls for a carbon tax as “the most cost-effective lever to

reduce carbon emissions at the scale and speed that is necessary.”

However, a major stumbling block to pricing carbon pollution is concern over the macroeconomic impacts of the policy. The Trump administration’s retreat from national climate policy reflects a belief that ambitious climate action could have detrimental consequences for economic growth and employment. While initiating a process to withdraw the United States from the global Paris Agreement, for example, the president claimed that the cost to the economy would be “close to \$3 trillion in lost GDP and 6.5 million industrial jobs.”

How should we assess the economic costs of a carbon tax? Until recently, most analyses have been based on large-scale computable general equilibrium models. One of these models, the Goulder-Hafstead E3 model, is

the engine behind one of Resources for the Future’s digital data tools, the Carbon Pricing Calculator. Today, we have enough experience with carbon tax systems around the world to carry out statistical analyses of existing carbon taxes: with the first carbon tax implemented in 1990, we can draw from up to three decades of data.

Directly examining the empirical evidence has two virtues. First, estimating the real-world effects of carbon taxes on GDP, employment, and emissions reductions speaks directly to concerns that carbon taxes kill jobs. Second, the empirical estimates provide a check on the calibrated theoretical models.

In two recent papers, we carry out an analysis of the 31 countries that comprise the European Union-wide emissions trading system (EU-ETS). While all of these countries price a portion of their emissions through

TABLE 1 Carbon Taxes in the European Union

Country	Year of enactment	Rate in 2018 (US\$ per metric ton)	Intended revenue recycling	Share of emissions in 2019 covered by tax	Carbon tax revenue in 2018 (US\$ millions)
Denmark	1992	24.92	Yes	40%	543.4
Estonia	2000	3.65	No	3%	2.8
Finland	1990	70.65	Yes	36%	1,458.6
France	2014	57.57	No	35%	9,263.0
Iceland	2010	25.88	No	29%	44.0
Ireland	2010	24.92	No	49%	488.8
Latvia	2004	9.01	No	15%	9.1
Norway	1991	49.30	Yes	62%	1,659.8
Poland	1990	0.16	No	4%	1.2
Portugal	2015	11.54	Yes	29%	154.9
Slovenia	1996	29.74	No	24%	83.1
Spain	2014	30.87	No	3%	123.6
Sweden	1991	128.91	Yes	40%	2,572.3
Switzerland	2008	80.70	Yes	33%	1,177.7
United Kingdom	2013	25.71	No	23%	1,091.0

Source World Bank Carbon Pricing Dashboard

“

**A major stumbling block to pricing carbon pollution is concern over the macroeconomic impacts of the policy.**

”

this cap-and-trade system, 15 of the countries also impose a carbon tax, mostly on emissions not covered by the EU-ETS. By limiting our analysis to countries that are part of the EU-ETS, we can identify the incremental impact of carbon taxes on economic output, employment, and emissions by leveraging the variation in carbon tax systems within this group of nations.

For a wide range of specifications, we find no evidence of adverse effects on GDP growth or total employment. We also find that long-

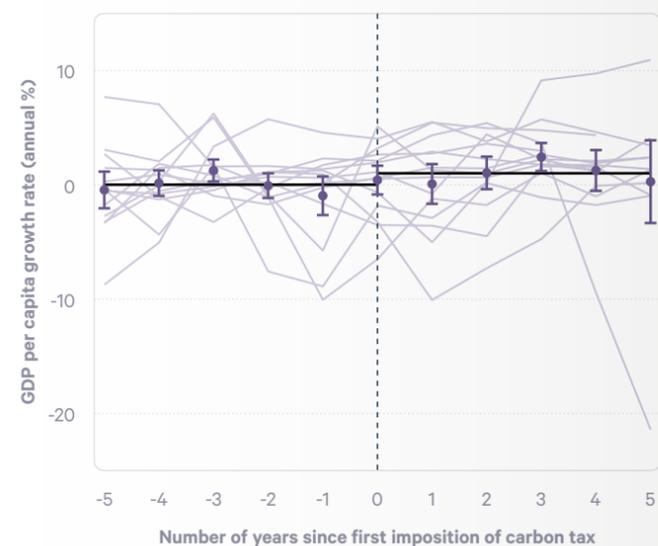
run growth rates of GDP and employment are unaffected by the tax. This latter finding is consistent with macroeconomic theory, which suggests that long-run growth rates are driven by fundamentals such as technological progress, which in turn are unaffected by changes in relative prices. Our results also are consistent with most general equilibrium modeling of climate policy. Finally, we find cumulative emissions reductions on the order of 4 to 6 percent for a tax of \$40 per ton of CO<sub>2</sub> covering 30 percent of emissions. We argue that this is likely

to be a lower bound on reductions for a broad-based carbon tax in the United States because European carbon taxes do not include in their tax base the power sector, which has the lowest marginal cost of carbon pollution abatement. (In Europe, power sector carbon emissions are priced under the EU-ETS.)

Table 1 shows the considerable variation in European carbon taxes in terms of their tax rates, coverage, and time of enactment. Figure 1 shows annual GDP growth rates before and after the implementation of a carbon tax in the individual countries. While the point estimate of the average GDP growth across countries that enacted a carbon tax suggests a modest increase in the growth rate, there is wide variation and—more importantly—no evidence of the tax hurting economic growth. Figure 1 is only suggestive, because it does not control for other factors that might influence growth or relate to a carbon tax, nor does it allow for the possibility that countries with existing strong GDP growth might feel confident enough to adopt a carbon tax. But in our recent papers, we address these econometric problems and estimate the causal effect of a carbon tax on GDP, employment, and emissions.

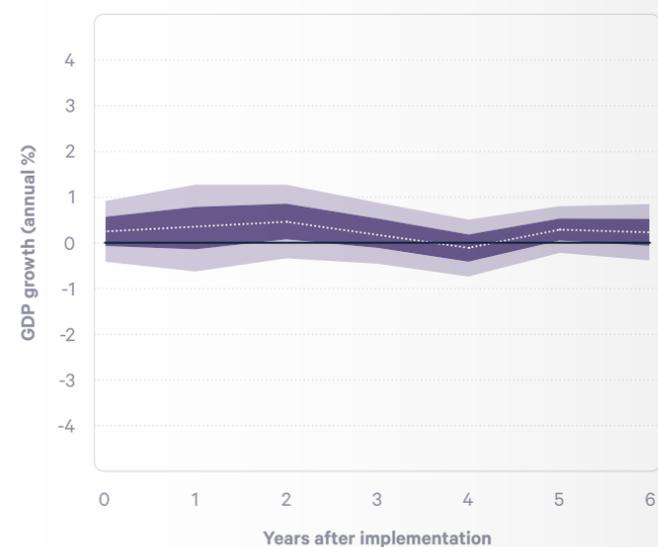
Identifying the dynamic causal effect of a carbon tax on GDP growth is complicated by the possibility of simultaneity: poor economic outcomes could lead tax authorities to reduce the rate or to postpone a planned increase. Our approach is based on the insight that changes to a carbon tax can be thought of as having two components: one that responds to historical economic growth, and another that's unrelated to past growth. The latter category can include tax changes based on legal mandates that follow a preordained schedule, changes in ambition based on the environmental preferences of the party in power, or responses to international pressure on climate policy. We argue that this latter category of changes—those not predicted by historical GDP growth or current and past international economic shocks—are exogenous. This assumption allows us to estimate the dynamic effect on GDP growth from the unexpected component of a carbon tax using a vector autoregressive framework.

**FIGURE 1** Carbon Tax Enactment and GDP Per Capita Growth Rate



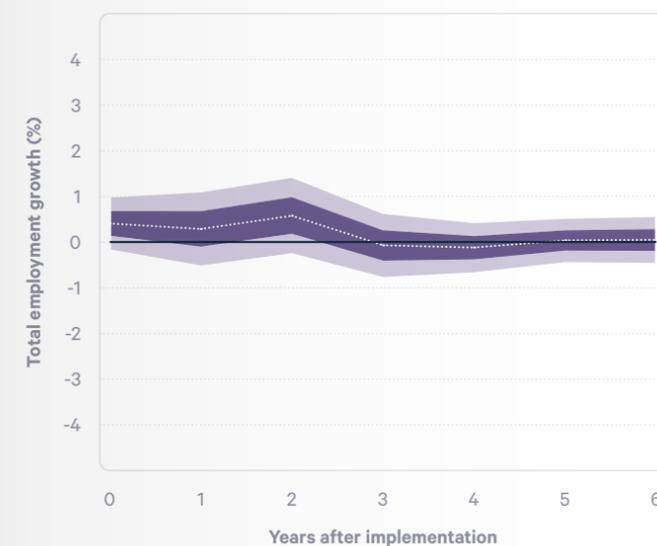
GDP growth before and after the imposition of a carbon tax among European countries covered by the EU Emissions Trading System. Light purple lines represent 15 countries; darker purple points indicate the average among countries, with associated confidence intervals; horizontal lines indicate the pre/post means.

**FIGURE 2** Estimated Annual GDP Growth in Response to a Carbon Tax



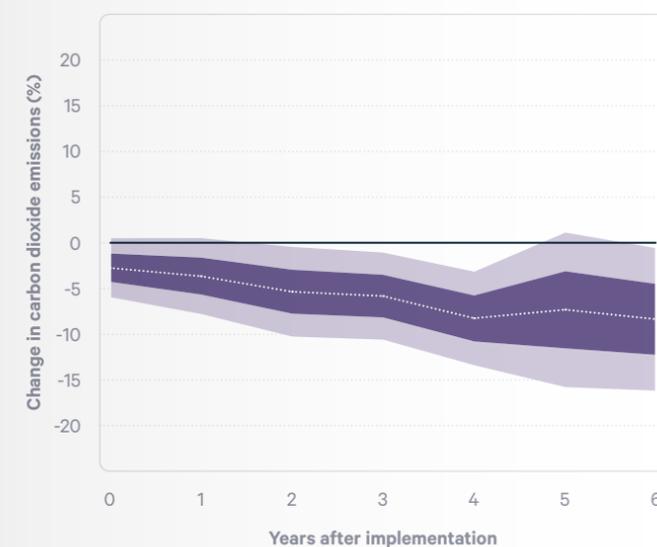
A typical impulse response function for the annual rate of growth of GDP in response to a permanent \$40 increase in a carbon tax, estimated using a structural vector autoregression. The white dotted line indicates the point estimate, and the two purple shaded areas indicate 67 percent and 95 percent confidence bands.

**FIGURE 3** Estimated Total Employment Growth in Response to a Carbon Tax



A typical impulse response function for annual rate of growth of employment in response to a permanent \$40 increase in a carbon tax, estimated using a structural vector autoregression. The white dotted line indicates the point estimate, and the two purple shaded areas indicate 67 percent and 95 percent confidence bands.

**FIGURE 4** Estimated Carbon Dioxide Emissions in Response to a Carbon Tax



A typical impulse response function for the percentage reduction in carbon emissions in response to a permanent \$40 increase in a carbon tax, estimated using a structural vector autoregression. The white dotted line indicates the point estimate, and the two purple shaded areas indicate 67 percent and 95 percent confidence bands.

We report results by simulating a one-time permanent increase of \$40 in a carbon tax that covers 30 percent of the country's emissions (a coverage rate close to the sample mean) and constructing impulse response functions. Figure 2 shows a typical impulse response function for GDP growth rates.

Three things stand out. First, the point estimate is positive, but small. Second, we cannot reject the possibility that the carbon tax has no effect on GDP growth. And third, we *can* reject the possibility that the carbon tax exerts an economically significant *negative* impact on GDP. These findings are consistent across our analyses: we find similar results for total employment growth rates (Figure 3) and manufacturing employment.

Finally, we estimate the impact of this \$40 carbon tax on cumulative carbon dioxide emissions. We find a point estimate of a 6.5 percent decline in emissions (Figure 4), though the error bands are wide. While we cannot reject the possibility that the carbon tax has zero impact in most years, we also cannot reject the possibility of double-digit declines in emissions. Worth noting is that countries applying a broad-based carbon tax should view these simulated reductions as lower bounds on potential emissions reductions, since the EU-ETS cap-and-trade system already covers those sectors where emissions reductions are least costly to implement, and so those sectors are generally not subject to the carbon tax.

Our results rebut the oft-cited argument that a carbon tax would harm the US economy, through detrimental effects on GDP and jobs. While our results suggest that a carbon tax would have a positive impact on GDP growth, our more cautious conclusion is that a carbon tax would not harm the US economy. Based on the European experience, at least, we find no support for the view that carbon taxes are job destroyers or growth killers. ■

Gilbert E. Metcalf, a professor at Tufts University, and James H. Stock, a professor at Harvard University, are university fellows at Resources for the Future.

# Legislative Strategy for Durable Climate Policy

ILLUSTRATIONS  
Barry Falls /  
Heart Agency



Marc Hafstead is a fellow at RFF and director of the Carbon Pricing Initiative.

Kevin Rennert is a fellow at RFF and director of the Social Cost of Carbon Initiative.

Dallas Burtraw is the Darius Gaskins Senior Fellow at RFF.



## VIEWPOINT

"Viewpoint" gives economists and climate researchers the opportunity to provide a new perspective on an important topic. In this issue, three RFF scholars sit down together to debate how to make policy last beyond a single political cycle.

### Thoughts on this?

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

Should we set broad goals first and get specific about the implementation details later, or take an alternative strategy of leading with legislative details to avoid "regulatory whiplash" and make sure goals can be achieved? Should carbon pricing and other policies begin with sectors or aim gung ho at the economy at large? How should decisionmakers reckon with uncertainty when implementing environmental policy? Three RFF scholars discuss the merits of delegating authority to an expert agency, the challenges of designing politically palatable carbon pricing policy, and more.

**D**allas Burtraw, the Darius Gaskins Senior Fellow at Resources for the Future (RFF), says that getting too specific about how to implement proposed legislation can get in the way of achieving outcomes. Getting buy-in for big goals and delegating the implementation to agencies allows laws to be flexible, adaptable, and—most importantly—durable.

**Dallas Burtraw** For climate and energy policy to be successful, legislation needs to be durable and adaptable. We've learned this from 50 years of implementing the Clean Air Act. We've learned this from 50 years of implementing the Clean Air Act—and by that, I mean borrowing the formal process and apparatus of the Clean Air Act, but not specific regulations like technology standards. Flexible regulations such as tradable performance standards, a carbon tax, or cap and trade could be implemented under this type of apparatus.

The Clean Air Act has been an enormously successful piece of legislation because, by its very design, it established goals and delegated to an expert agency the responsibility of achieving those goals. The success of the Clean Air Act came from the understanding that the legislation needed to be adaptable in order to be durable: in the context of climate and energy policy, uncertainty related to the underlying science, economics, and technology is especially prevalent, making adaptability so necessary.

“These considerations make me question any ‘one-and-done’ approaches to addressing climate; related policy will need to be constantly evaluated.”



These considerations make me question any “one-and-done” approaches to addressing climate; related policy will need to be constantly evaluated. It’s challenging to imagine any policymaker setting a course at the outset that’s going to chart a straight path through the issues that are sure to arise in the coming decades.

In addition, we need to consider the dilemma of the nondelegation doctrine and the major questions doctrine. The doctrine of nondelegation says that the legislative branch shouldn’t delegate to an agency the authority to execute too much discretion in achieving a directive set forth in legislation. The major questions doctrine reserves major decisions for the purview of the most relevant branch of government—in other words, the pertinent question is regarded as too important for that branch to delegate to an agency.

These doctrines are surfacing because of opinions expressed by recently appointed members of the Supreme Court, who may want to revisit the ability of Congress to delegate to an executive agency and avoid technical implementation measures that go far beyond what might have been specified in the original statute. This all relates to the idea that Congress doesn’t “hide elephants in mouseholes”—so the agency can’t say, “Here’s a little phrase in a bill that expresses concern about climate change, and through it, we’re going to redesign the entire US economy.”

The Supreme Court justices’ perspectives on nondelegation and major questions doctrines, which have become evident in some of their recently expressed views, make delegation to an expert agency legally risky; some advocates view the court as an obstacle to meaningful climate policy. Various legislative strategies to anticipate the court’s objections include not only careful legislative design, but also a severable hammer provision that can be put into legislation to trigger specific and stringent outcomes if preferable agency-led provisions are struck down. Hammer provisions might provide cover to those who are unprepared to talk about the specifics of policy design and would rather establish firm goals and delegate to an expert agency to develop the policy.

The approach of delegating regulatory implementation to expert agencies—governed by a formal process of fact-finding and citizen involvement—is, in a rational world, a preferable pathway than that of specifying and locking in the methods and process of implementation in legislation. Where you have trust across different

branches of government or within society, you can allow an agency to develop programs that align with the regulatory goals you’ve set. But constitutional concerns, along with political and legal challenges, get in the way of delegating to expert agencies.

Sometimes—in the 1980s, for example—inaction and recalcitrance by the expert agency led Congress to become increasingly specific, and that’s what happened with the 1990 amendments to the Clean Air Act. As the executive branch sweepingly changed the direction of the US Environmental Protection Agency, Congress said, “Wait a second—if the agency is potentially under political capture, then we need to get more specific with what we write into the legislation.”

Importantly, all of these issues constitute a huge coordination problem—not only between demand and supply in the market, but also of infrastructure, long-lived investment of private-sector capital, and changes in consumer and personal behavioral norms.

**K**evin Rennert, an RFF fellow and director of RFF’s Social Cost of Carbon Initiative, says that policies that combine economy-wide and sector-by-sector approaches probably will find more success than either approach in isolation. Combining these approaches facilitates bespoke strategies that can achieve goals with economic efficiency and garner buy-in from policymakers across the board.

**Kevin Rennert** Dallas, if I can try to summarize what you’re saying: Your view is that the regulatory approach of delegating to different agencies the authority to reach a policy goal has the benefit of potentially being more flexible, adaptable, and durable over time. In comparison, the legislative approach doesn’t work as well if it means Congress must continually revisit the legislation to keep pace with updated science or economics. And on the political front, it may be easier to get sufficient agreement in Congress around a set of overarching goals for reducing emissions, empowering agencies to do the work to achieve those goals, rather than to try and get agreement on the specific policy approach.

I think those are really interesting points. I agree that it’s probably easier to get policymakers to agree on the general scale of ambition for emissions reductions if that conversation is separate from the conversation about the policy specifics of getting to those goals. Some supporting evidence for this strategy is the much greater number of cosponsors that you see

for target-setting proposals like the 100% Clean Economy Act of 2019 introduced in the House, or the Clean Economy Act of 2020 introduced in the Senate, compared with the cosponsors for any of the other more policy-specific approaches.

But we’ve seen an important tension between these two approaches play out over time as Congress has considered climate legislation. If you look at the evolution of climate proposals across multiple Congresses, you see that past proposals generally started out relatively streamlined, tight, and concise—maybe on the order of 100 or 200 pages of bill text. But then, as the sponsors continued working toward passing the bills, more and more issues came up, and more and more tweaks were required to address additional policy details. If you look at page length as an indicator of how complex a bill has become (which, to be clear, is far from a perfect indicator), you see that the big cap-and-trade bills ballooned to well over a thousand pages of legislative text, because Congress was trying to account for all these additional details. Over time, Congress demonstrated that it was less comfortable with delegating to an agency to figure out the policy details, and wanted instead to own the specific solutions and build something flexible enough to account for future circumstances.

If the congressional debate on climate policy gets serious, and a bill has a chance of moving, I suspect you’ll see that the same tension still exists in Congress. You might get agreement on an emissions goal, but many members of Congress still would feel significant discomfort at giving up control over how to achieve that goal. Part of that discomfort comes from potentially relinquishing control, but also from the reasonable view that Congress, by virtue of its ability to write laws, has the ultimate flexibility to work toward an emissions goal, because it can work across the full economy with a truly expansive set of tools—whereas an individual agency will have limitations in accordance with jurisdiction and statutory authority.

In addition to this question of “goals versus policy prescriptions,” another issue looming before the Congress is whether climate policy should take an economy-wide approach using a single policy instrument, or an approach that varies by economic sector.

Economists and many others favor using a single instrument uniformly across the entire economy, such as a carbon price, because it is the most economically efficient solution. It allows you to get the cheapest

reductions throughout the economy, and it has the added benefit of raising revenue that can be used in a number of ways to support policy goals. So, it's no surprise that quite a few carbon pricing bills have been proposed this Congress.

At the same time, policymakers have some valid, real-world reasons to explore more tailored approaches through sector-by-sector policy solutions. That exploration has been on display in legislation put forward by the Energy and Commerce Committee, reports put out by the House Select Committee on the Climate Crisis and the Senate Democrats' Special Committee on the Climate Crisis, and elsewhere.

I'd suggest that part of the reason for this interest in the sectoral approach is that—based on what we know from economic modeling—the power sector can decarbonize at a relatively low carbon price, while other sectors, such as transportation and industry, would require relatively higher carbon prices to significantly reduce their emissions. An important question to consider is this: Even if enough momentum exists to put an economy-wide carbon price in place, are the momentum and political will sufficient to allow for a high enough carbon price to decarbonize the more difficult sectors, as well? It's an additional lens on this question—not just, “Can you get it passed?” But also, “Can you get it passed at a level that will really get you to your broader goals?”

Working on sector-specific policies doesn't necessarily reduce the challenge of decarbonizing these sectors overall, but it does allow for tailoring the approach to the different challenges specific to those sectors.

**Dallas Burtraw** In deciding how low or high a carbon price should be, we should also consider impacts beyond the sectors being regulated. We celebrate prices in the economy because they're a fantastic coordination mechanism for allocating resources. But if you set price signals that are high enough to achieve that coordination purpose, they can have some very disruptive effects—especially on some vulnerable communities, or on the competitiveness of some industries. The transition may be eased with directed policies, such as sector-specific performance standards to drive innovation, as opposed to relying on a price signal alone.

**Kevin Rennert** Right. And all these concerns have led many people to think, “Maybe we should take a more tailored approach. Maybe we should try to work on sectors that are more tractable in the short term, such as the power sector, while laying a foundation for building

the transition in other sectors, such as the transportation or industrial sectors.” You've seen these deliberations woven throughout what's come out of this Congress.

I think there's a lot to recommend the sector-by-sector approach, because it allows policymakers to leverage lots of different tools. You might want to leverage the benefits of a clean electricity standard for the power sector. You might want to give the US Environmental Protection Agency additional authority over fuel economy regulations or other tools to address challenges in the transportation sector. You might want to assist industry in transitioning to lower-emissions processes in ways that a carbon price on its own wouldn't do, or might do more slowly. Both the sectoral and carbon-price approaches have their proponents, but I think the current balance of political momentum is a bit on the side of that sector-focused approach.

**Marc Hafstead**, an RFF fellow and director of RFF's Carbon Pricing Initiative, is wary of simply delegating power to agencies because the rules can (and often do) change with each administration, but he agrees that flexible policy is necessary. He looks to US states as empirical examples: places like California, New York, and Colorado have set big policy goals, and they vary in how closely they specify implementation strategies versus provide leeway to agencies in their methods of implementation.

**Marc Hafstead** Climate change is a long-term problem; it's something that we need to work on over decades. I certainly don't think we can establish a single policy, walk away, and say, “Our hands are clean; we solved it.” That would be naïveté of the highest order. It's going to take revisiting. As Dallas says, it's going to take a flexible, adaptable policy.

There's value to setting goals first and then delegating the specifics to agencies, because setting the goals first gives an idea of where we want to go. And I think that, especially for a long-term problem, it's good to know where we want to go.

But I'm also skeptical of delegating authority to agencies, for a couple of reasons.

First, when you have a new administration, that administration is in charge of the agencies, and you can get regulatory whiplash pretty quickly. I don't think that seesawing of regulations is going to get us to

where we need to go. Second, policymakers can design policies to put in place today and make sure they're flexible, without specifically relying on executive agencies.

I'm thinking of the example of the Regional Greenhouse Gas Initiative. A cap-and-trade program, the initiative has regular reviews every few years, when it's allowed to change the cap and evaluate how the program is doing. For carbon tax proposals, flexibility could look like an automatic tax adjustment mechanism, which I've worked on, or the proposal by Joseph E. Aldy for a set of regulatory agencies to get together and make a recommendation to the president for what a new carbon price should be.

So, I don't think we're going to solve this problem without flexibility and adaptability in our policy approach.

If we look at examples up to this point from US states, clearly the states come at it with the approach of setting goals and delegating authority. I think that's where we can look to learn lessons and draw from their success.

California is an example where delegation was successful. What California did was set its goals and allow the state agencies to figure out how they wanted to reach those goals. I think the reason it was successful was because they included language that allowed the state to consider a policy that many (including us) think is a pretty good one, which is the economy-wide cap-and-trade program. It's not clear that other states following similar patterns are going to be as successful if they don't give a similar flexibility to the state agencies.

New York, as a counterexample, passed its climate law—a goals-based approach that delegates authority to a committee. But at the same time, they're tying the hands of the committee by requiring X amount of solar and Y amount of wind power. So, they're delegating the authority, but at the same time, they're putting clear preferences on what they want that authority to do.

The state of Colorado is taking an approach that creates goals first and sets policy specifics later. In 2019, Colorado passed sweeping, quite ambitious goals, and they delegated authority to the Air Quality Control Commission, whose job this summer was to come up with the rules that will help the state achieve those goals. We will see where their process will go.

California was a success; I think the jury's out on New York and Colorado.

“Having a hybrid approach that includes stated goals, along with some sort of policy structure to get you to those goals, is probably what would carry the day here.”



“I don’t think we’re going to solve this problem without flexibility and adaptability in our policy approach.”



**Dallas Burtraw** Marc, I appreciate what you’ve said, but California also has coupled carbon pricing with policies to force innovation. California led the nation in vehicle fuel efficiency standards, and had renewable portfolio standards that have now morphed into a clean energy standard that’s quite ambitious, to keep their finger on the scales with respect to directed technological change, even while they have an economy-wide carbon price.

While I think all decisionmakers would share the view that a carbon price has great potential to be effective, they also realize that a high enough carbon price is not politically sustainable. So, many decisionmakers would consider a policy mix to be the best way to move forward.

**Marc Hafstead** Maybe a better question for this discussion is, Could California have passed an economy-wide cap-and-trade bill that would have achieved the same types of reductions that they’ve been achieving through the policy approach they actually took, which is allowing the state agencies to figure out how to do it? Dallas, you know California better than I do, but my guess is the answer is probably no.

**Dallas Burtraw** I love that question, and I’ve never heard it asked quite that way. I don’t think anybody would say yes. I don’t think that California could have taken an alternative economy-wide approach only and achieved the same result.

**Marc Hafstead** If states want to go and address climate change on their own, in the absence of federal policy, I think a goals-first approach would be preferable and probably would be more politically feasible. The goals-first approach also allows for flexibility when and if there’s ever federal policy. But I think language needs to be included that can set the boundaries of what agencies can do, at the expense of a little flexibility.

At the federal level, I would think that, to succeed, we’re going to need a hybrid approach that provides some language about our stated goals, but also sets up a framework that doesn’t allow regulatory backlash when administrations inevitably change.

**Dallas Burtraw** I’m totally on board with what Marc just said.

**Kevin Rennert** I completely agree, as well. I think having a hybrid approach that includes stated goals, along with some sort of policy structure to get you to those goals, is probably what would carry the day here. ■

# Puns That Only Resources for the Future Could Love

TEXT  
Sarah Tung, with contribution from Hillary Alvaré

Review this Top 10 list of puns that made it through editorial review and into various newsletters and social media posts over the past few months ... and groan along with us.

- 10 **You won’t be-leaf your luck!**  
Forest Resources newsletter
- 9 **Planting a Seed for One Trillion Trees: Trees are having their day in the sun.**  
Forest Resources newsletter, with reference to the Trillion Trees Act
- 8 **FoCCUSing on Carbon Capture and Sequestration**  
Future of Power newsletter, with reference to carbon capture, utilization, and storage (CCUS)
- 7 **EaaSing into an Electrified Economy**  
Future of Power newsletter, with reference to energy-as-a-service (EaaS) business models
- 6 **Brush up on the ABCs (or AC/DCs) of electricity.**  
Future of Power newsletter
- 5 **Where You LED, Cost Savings Will Likely Follow**  
Future of Power newsletter
- 4 **Three Peas in a Podcast**  
Carbon Pricing Initiative newsletter
- 3 **See You Later, Calculator**  
Carbon Pricing Initiative newsletter, with reference to RFF’s Carbon Pricing Calculator updates
- 2 **Are You RGGI for It?**  
Carbon Pricing Initiative newsletter, with reference to the Regional Greenhouse Gas Initiative (RGGI)

**Tied for 1**

**What’s in a carbon pricing bill? That which we call a tax by any other name would be as efficient. —Juliet Cap(and trade)ulet**  
Twitter @RFF, with reference to RFF’s Carbon Pricing Bill Tracker

**Do you feel good about FERC’s MOPR order? Vote here:**  
 YUPR  NOPR  SO-SOPR  What is the MOPR?  
Twitter @RFF, with reference to the US Federal Energy Regulatory Commission (FERC) order that directs the PJM electric utility company to expand its Minimum Offer Price Rule (MOPR)

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# Dismantling Dams Can Help Address US Infrastructure Problems

**TEXT**  
Margaret Walls and  
Vincent Gonzales

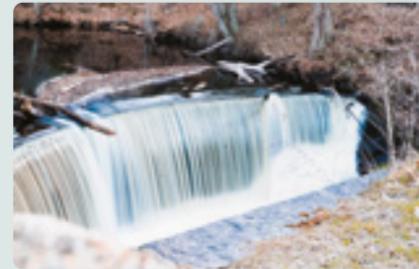
Dam failure, though rare, can cause catastrophic destruction of property and lives. Repairing hazardous dams can help, but simply removing them can be a better, more cost-effective option with accompanying environmental benefits. Why, then, do so few dam owners and decisionmakers consider removal as an option?

**T**he United States has an aging infrastructure problem. The country’s roads and bridges, drinking water and wastewater facilities, ports, levees, dams, and more are in need of upgrades and repairs. The American Society of Civil Engineers (ASCE) has given US dam infrastructure a D grade, noting that the number of dams in poor condition is on the rise. This grade for dams is even lower than the D+ that the organization gave US infrastructure as a whole in its 2017 “Infrastructure Report Card.” In 2019, the

Association of State Dam Safety Officials (ASDSO) estimated that \$66 billion is needed to repair all deficient dams in the United States.

A more affordable option could be to remove, rather than repair, the most hazardous dams—but dams continue to deteriorate in place across the United States.

Built to hold back and control the flow of water, dams are physical barriers across streams, rivers, and waterways. They vary in size and type, from



**PHOTOS (FROM TOP)**

Thacher Andraee / EyeEm / Getty Images

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“If removal often is less costly than repair, and river conditions improve when a dam goes away, then why don’t we see more removals?”

small earthen embankments to high concrete structures, and serve a diverse set of functions that include flood protection, water storage, hydroelectric power production, irrigation, ponds for farm livestock and fire protection, and recreation. Unlike most other kinds of infrastructure, such as roads and bridges, the vast majority of dams are privately owned.

Most dams in the United States were built decades ago, and some are more than a century old. The average age of the 91,500 dams in the US Army Corps of Engineers’ National Inventory of Dams (NID), a database that includes relatively large (at least 25 feet tall) and “high-hazard” (posing a risk to human life if they fail) dams, is 57 years old.

The failure of two dams in Michigan in May 2020 illustrates what can happen in some situations when dam deficiencies go unaddressed. After five inches of rain fell in two days, on top of saturated ground from earlier rainfall, the Edenville Dam on the Tittabawassee River collapsed, sending torrents of floodwaters downstream and causing a second dam, the Sanford Dam, to also fail. The town of Midland, Michigan, and surrounding communities were inundated, and approximately 40,000 people evacuated. No one died in the event, but property damages totaled \$175 million.

The Edenville Dam was a 54-foot-tall earthen dam used for hydropower production until September 2018, when its license was revoked by the Federal Energy Regulatory Commission (FERC). The owner of the Edenville Dam, Boyce Hydro Power LLC, had been ordered by FERC, which licenses and regulates all hydropower dams in the United States, to increase the dam’s spillway capacity in 2004. The company failed to comply.

Fourteen years later, after many additional problems had developed at the dam, FERC finally revoked the license, and Boyce Hydro Power stopped producing power. Nonetheless, the dam remained in the river. Regulatory authority was transferred from FERC to the state of Michigan’s Dam Safety Program. And this year, the dam failed.

Catastrophic dam failure of this type is rare. A 2018 report by Stanford University’s National Performance of Dams Program tallies 1,645 dam failures in the United States between 1848 and 2017, but most of these failures happen at dams much smaller than the Edenville Dam; thus, the failures cause less flooding and property damage. Climate change is expected to cause many regions of the United States to become wetter, however, and extreme precipitation events to happen more frequently. This change in weather conditions—in combination with aging dam infrastructure and population growth that increases the number of people at risk—has heightened concerns about potential dam failures.

## Dams by the Numbers

**O**f the approximately 91,500 dams in the NID, 63 percent are privately owned. This includes dams like the Edenville and Sanford dams in Michigan, owned by power companies, along with scores of others owned by individual property owners, businesses, irrigation districts, country clubs, colleges and universities, and homeowners associations. The next-largest ownership group, accounting for 20 percent of dams, is local governments.

Dams have been erected all over the United States, but Texas has the most and Delaware the fewest, according to the NID. Relative to state land and

water area, Connecticut has the most, with 57 dams per square mile. Three more New England states join Connecticut among the top six states in terms of number of dams relative to state size. The six states with the fewest dams are all in the West. Alaska has the fewest by far, relative to its size, followed by Arizona and New Mexico. The oldest dams are in New England, but old dams exist all across the United States. In six states—Maine, Vermont, Massachusetts, Colorado, South Dakota, and Montana—more than three-fourths of the dams are more than 50 years old.

Dams serve a wide variety of purposes. Hydropower dams make up only 2 percent of all dams in the NID. Across 13 dam purpose

categories, recreation is the most common, accounting for 32 percent of all dams, followed by flood protection at 19 percent and fire protection at 12 percent. Figure 1 shows a map of the most common dam purpose in each state.

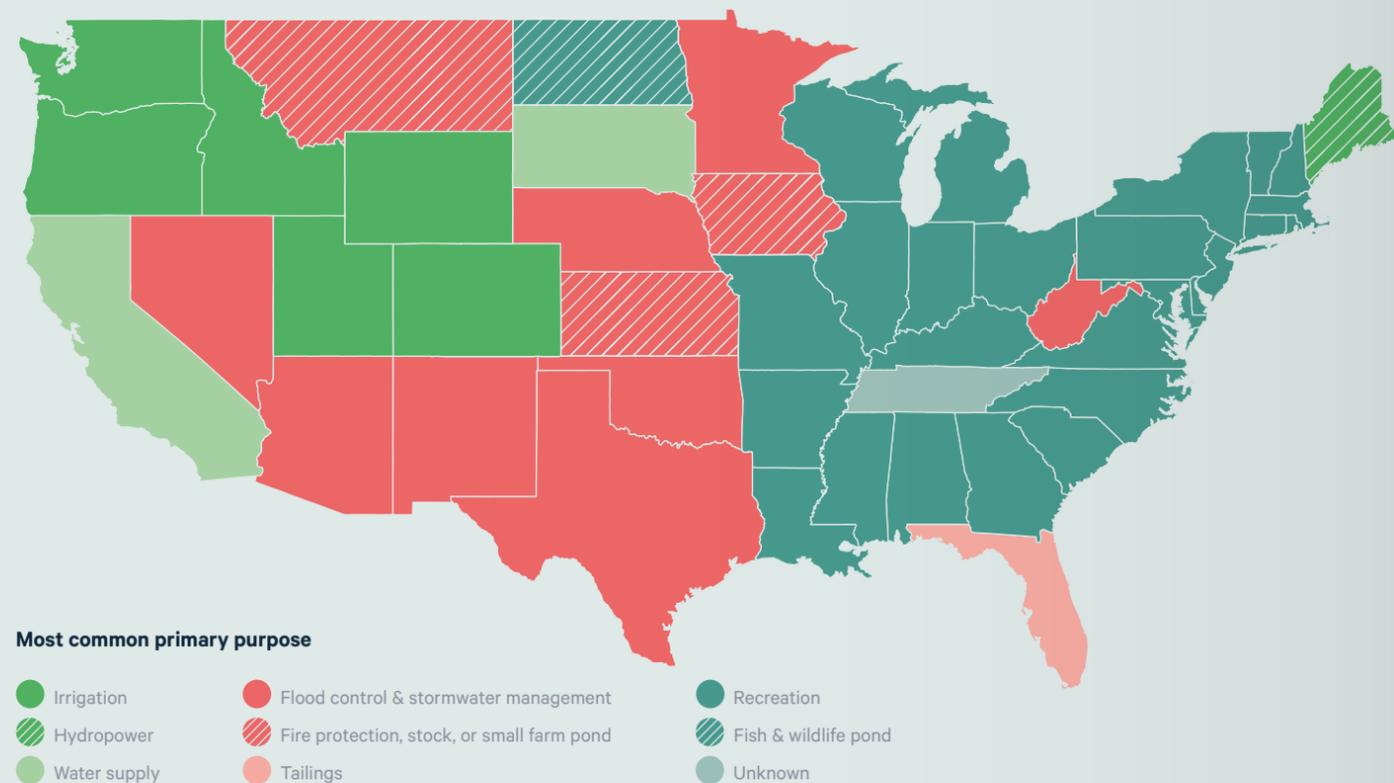
In the western states of Colorado, Idaho, Oregon, Utah, and Wyoming, where agriculture relies on irrigation, irrigation dams account for between 44 percent (Colorado) and 59 percent (Oregon) of all dams. One-third of the dams in California and nearly half of the dams in South Dakota primarily supply water, but only 6 percent of dams nationwide are in this category. Flood control dams make up 66 percent of dams in Nebraska and 48 percent in Oklahoma.

Recreation dams include those that create large reservoirs for flat water recreation such as boating and swimming—in a state park, for example—or small ponds that serve an aesthetic function in a community or business development. “Recreation” also can serve as a catch-all category for dams that no longer serve their original purpose, or the purpose has become unclear. This is another way in which dams differ from most other infrastructure: a large number are still in place, in varying states of repair and disrepair, built in the nineteenth and early twentieth century, and no longer serve a useful function.

Many early dams were built to provide power for textile mills, gristmills, steel plants, and

**FIGURE 1** Most Common Dam Purpose, by State

Source US Army Corps of Engineers’ National Inventory of Dams (2018)



other industrial activities. Over the years, the plants closed, but the dams stayed behind. The Whittenton Pond Dam on the Mill River about 40 miles south of Boston in Taunton, Massachusetts, highlights issues that can arise with these dams. The wooden dam, built in 1832, originally provided power for a mill complex, but over the years, the condition of the dam deteriorated. After several days of heavy rains in October 2005, the dam began to buckle and was on the verge of failure. Local officials evacuated downtown Taunton and called in the National Guard. The dam was eventually shored up, which prevented its failure, and it was removed several years later. The event was an eye-opener for Massachusetts

state officials, who realized that thousands of similar dams existed all over the state. In 2014, Massachusetts launched the Dam and Seawall Repair or Removal Program, which has since provided \$34 million in grants and loans for dam repairs and removals.

### Dam Removal

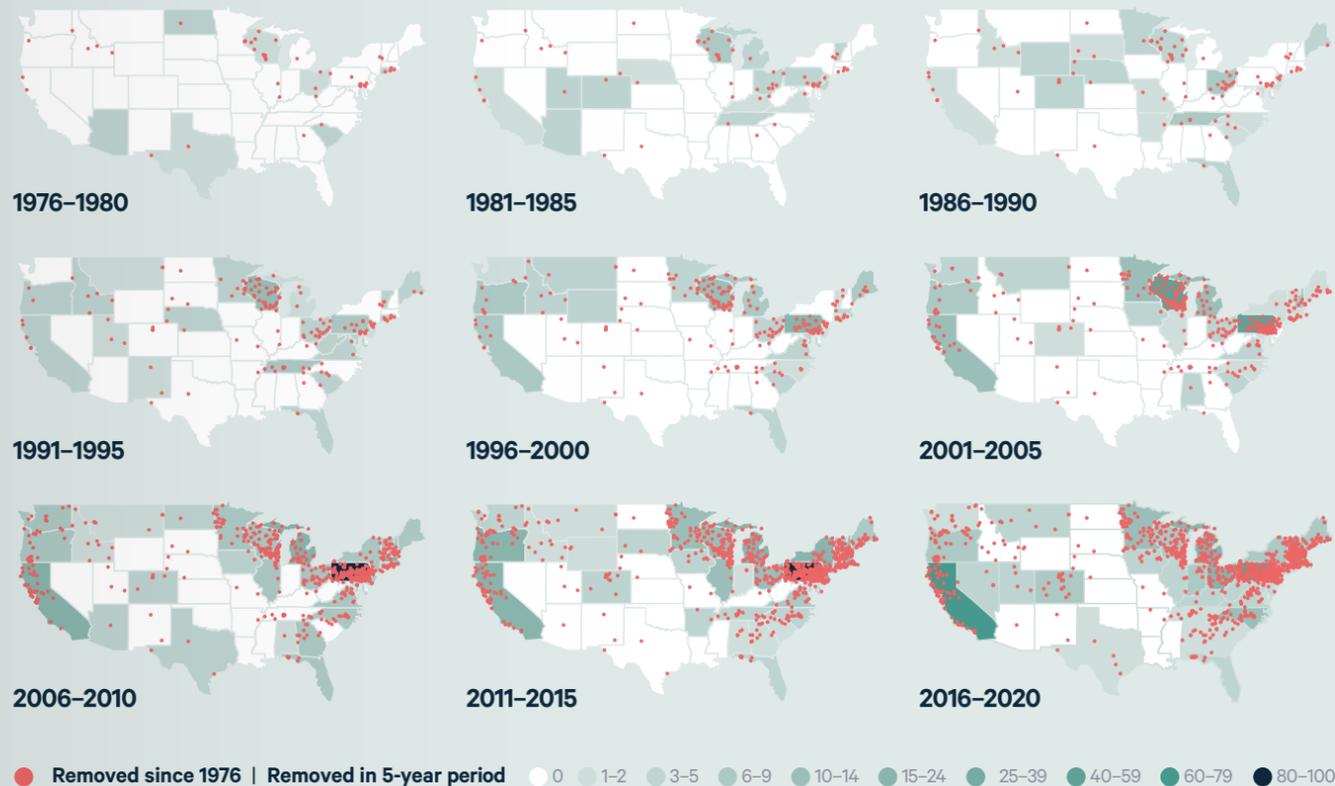
Removing an obsolete or deteriorating dam can often be a better option than repairing it. In many cases, removal is less costly than repair, and if the dam no longer provides services of sufficient value, spending money on repairs makes little sense.

Removing a dam can have many environmental benefits. Dam removal restores a river’s natural function, improving water quality and conditions for aquatic habitat by increasing flows, reducing water temperatures, and providing passage to and from the ocean for anadromous fish species such as salmon. Most dam removals on the West Coast have been motivated by the need to improve passage for salmon and steelhead trout, several species of which are listed as threatened or endangered under the Endangered Species Act.

The removals have ranged from very small dams, such as the 81 dams removed from the Cleveland National Forest in Southern

**FIGURE 2** Dam Removals in the United States (1976–2020)

Source American Rivers Dam Removal Database (February 2020)



California, to large dams with removal costs in the tens of millions of dollars, such as the 106-foot-tall San Clemente Dam in California and the Elwha and Glines Canyon Dams in Washington. On the East Coast, removals of dams such as the Edwards Dam on the Kennebec River in Maine and the Embrey Dam on Virginia's Rappahannock River have benefited oceangoing species including the American shad, alewife, blueback herring, and American eel (a catadromous species that lives in freshwater and returns to the ocean to breed).

Dam removal also can create new river recreation opportunities by providing unimpeded boat passage and restoring whitewater conditions. The removal of three dams on the Cuyahoga River in Ohio was motivated by concerns over water quality, but removing the dams actually spurred growth in the local outdoor recreation economy by producing Class 5 rapids in downtown Cuyahoga Falls. The final dam slated to come down on the Cuyahoga River, the 60-foot-tall Gorge Dam, is expected to reveal a buried 200-foot natural waterfall.

The removal of certain kinds of dams can improve river safety. Low-head (or "run-of-the-river") dams, which lie across the width of a river or stream and typically form only a minimal reservoir, create underwater circulating hydraulics that have caused hundreds of drowning deaths. After six deaths in one summer at low-head dams in Iowa, the state launched the Water Trails and Low-head Dam Mitigation Program, which focuses on removing and reengineering low-head dams around the state while providing canoe and kayak trails to enhance river recreation.

Despite these success stories, as of January 2020, only an estimated 1,700 dams have been removed in the United States. Numbers are

on the rise—nearly half of the removals have taken place in the last ten years—but are low relative to the total number of dams. Moreover, a mere five states account for half of all removals: Pennsylvania (343), California (173), Wisconsin (141), Michigan (94), and Ohio (82). Figure 2 shows dam removals by state in five-year increments from 1976 to 2020.

If removal often is less costly than repair, and river conditions improve when a dam goes away, then why don't we see more removals? The answer lies in a combination of factors.

### Limited Enforcement of Regulations

Private dam owners, and even many government agencies, are unlikely to consider removing a dam unless they are faced with making costly repairs required by dam safety regulators. State dam safety programs vary in the stringency with which they enforce regulations, but in many states, enforcement relies mainly on voluntary compliance by dam owners. Rarely do state regulators impose financial penalties or take legal action against recalcitrant owners. Federal regulators may not always do better: FERC gave the Edenville Dam owner more than a decade to fix problems before revoking its hydropower license. And even then, the dam remained in the river.

### Regulatory Focus on High-Hazard Dams

When enforcement is strict, efforts are directed at high-hazard dams—those that would lead to a probable loss of life should they fail. As a result, many other dams fall through the regulatory cracks. For instance, many smaller dams are exempt from regulations altogether, including most low-head dams, and dams that have "significant" or "low" hazard ratings are

## Studies Show that Dam Removal Costs Less Than Repair

Dam maintenance is expensive, with costs that include general operations, repair, insurance, water quality maintenance, and meeting dam safety regulatory requirements. And while removal is neither cheap nor easy and can have unexpected complications, it still often costs less than repair.



Source ICF Consulting analysis of 26 dams removed between the mid-1990s and 2004



Source Born et al. (1998) study of 14 dams removed in Wisconsin



Source Industrial Economics, Incorporated, study conducted over a 30-year period

“**Dam removal can help with this infrastructure problem [in the United States], and numerous success stories provide good examples.**”



## Moving Forward

**A**lthough removing a dam from a river isn't always realistic—many dams in the United States still provide valuable water storage, hydropower, recreation, and other benefits—thousands of aging dams are in disrepair and no longer provide valuable services. Dam removal can help with this infrastructure problem, and numerous success stories provide good examples.

In Oregon's Rogue River, an old and crumbling irrigation diversion dam, the Savage Rapids Dam, was removed in 2009 after 15 years of controversy and heated debate. The removal led to a ripple effect: five more large dams and several smaller structures have been removed, with several more in the works, opening up 400 miles of the Rogue River and its tributaries. In Lexington, Virginia, the Jordan's Point Dam on the Maury River, built in 1890, was similarly controversial, with many local citizens opposed to removal based on the dam's historical significance. But the dam no longer served its original purpose, was the site of a drowning death in 2006, and had been determined by the Virginia Dam Safety Program to be structurally unsound. Owned by the city of Lexington, which faced repair cost estimates as high as \$3 million, the dam was removed in 2019.

Correcting the factors that sideline dam removal as an option—most importantly, the limited enforcement of dam safety regulations and inadequate funding for dam removals—will lead to even more success stories that can help protect the environment, people, and property. ■

Margaret Walls is a senior fellow and Vincent Gonzales is a research analyst at Resources for the Future. The William and Flora Hewlett Foundation and the August Heid Trust helped fund the research described in this article.

inspected less frequently and are required to meet less stringent regulatory standards. Yet, many of these dams—especially if they have limited use and are in poor condition—are good candidates for removal.

### Underfunded State Dam Safety Programs

Most state dam safety programs are woefully underfunded and understaffed. According to ASDSO, approximately \$59 million nationally is spent on state dam safety programs each year. California's budget is \$20 million; thus, a single state accounts for almost one-third of national spending. The average for the remaining 48 states (Alabama does not have a state dam safety program) is a mere \$805,000. The average number of full-time equivalent staff per state dam safety office, according to ASDSO, is 7.6 (excluding California, which has 77 full-time employees working on dam safety).

### Limited Advocacy

In states where advocacy groups have a sizable presence and work with state agencies, more dams have been removed. But advocacy for dam removal in the environmental community is diffuse and quite limited in many areas of the country. In some states, such as Pennsylvania, advocacy organizations are quite engaged and work with state agencies. In other states, their presence is minimal. In the West, strong advocacy surrounds fish passage and habitat, but removing a dam can mean the loss of valuable water rights. As a result, some advocacy groups tend to focus on other means of improving passage and habitat for salmon, steelhead, and other species; for example, by replacing road culverts. Many advocacy groups, including whitewater recreationists, focus attention on hydropower

dams because FERC is required to consider the effects of those dams on the environment when relicensing. However, hydropower accounts for just a small number of dams nationwide.

### High Costs and Inadequate Funding for Removal

Given the general reluctance to make dam owners pay for the cost of removal, most removals rely on grant funding, which is quite limited. The Massachusetts Dam and Seawall Repair or Removal Program mentioned above is one of the few state programs that provides generous levels of grant funding. Wisconsin has had the longest-running grant program and ranks third among states in the number of removals. The federal government provides funding through a few programs, but most of the money is tied to fish passage and habitat—which often leads to a mismatch between dam removal needs and the type of funding available.

### Lack of Coordination across State Agencies

State dam safety programs are variously housed in natural resource departments, or departments of the environment, or water resource management agencies (the latter of which are responsible for administering the complex systems of water rights in western states). The states that ensure dam removal gets the attention it deserves are those with a high level of cooperation across state agencies or across various programs within an agency. For example, when dam safety agency staff work together with program staff who manage fish habitat and conservation, river restoration, and other functions, the removal option is more likely to be considered in lieu of repair.

# Underwriting Ecosystems: Using Insurance Policies to Conserve Nature

TEXT  
Cole Martin

ILLUSTRATION  
Kati Närhi

The coronavirus pandemic has shown just how easily and unexpectedly zoonotic diseases can spread—and ecosystem degradation may be a driving force. To save disappearing habitats, RFF University Fellow Carolyn Kousky offers a novel solution: create insurance policies for nature itself.

**As** the coronavirus pandemic threatens public health and pummels the global economy, the world confronts a related—and similarly destructive—crisis.

The natural world is deteriorating at an unprecedented rate, according to a series of recent reports from the United Nations’ Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES). Human activity, pollution, and climate change have caused much of the damage, in part because of misaligned economic incentives, which have “favored expanding economic activity, and often environmental harm, over conservation,” according to the IPBES. In other words, the rapid degradation of nature is merely a symptom of a larger illness: a global economy that undervalues the ecosystem services that the natural world provides.

Carolyn Kousky, a university fellow at Resources for the Future, puts it like this: “Ecosystems are public goods, and public goods are underprovided in the market. These are classic market failure problems.”

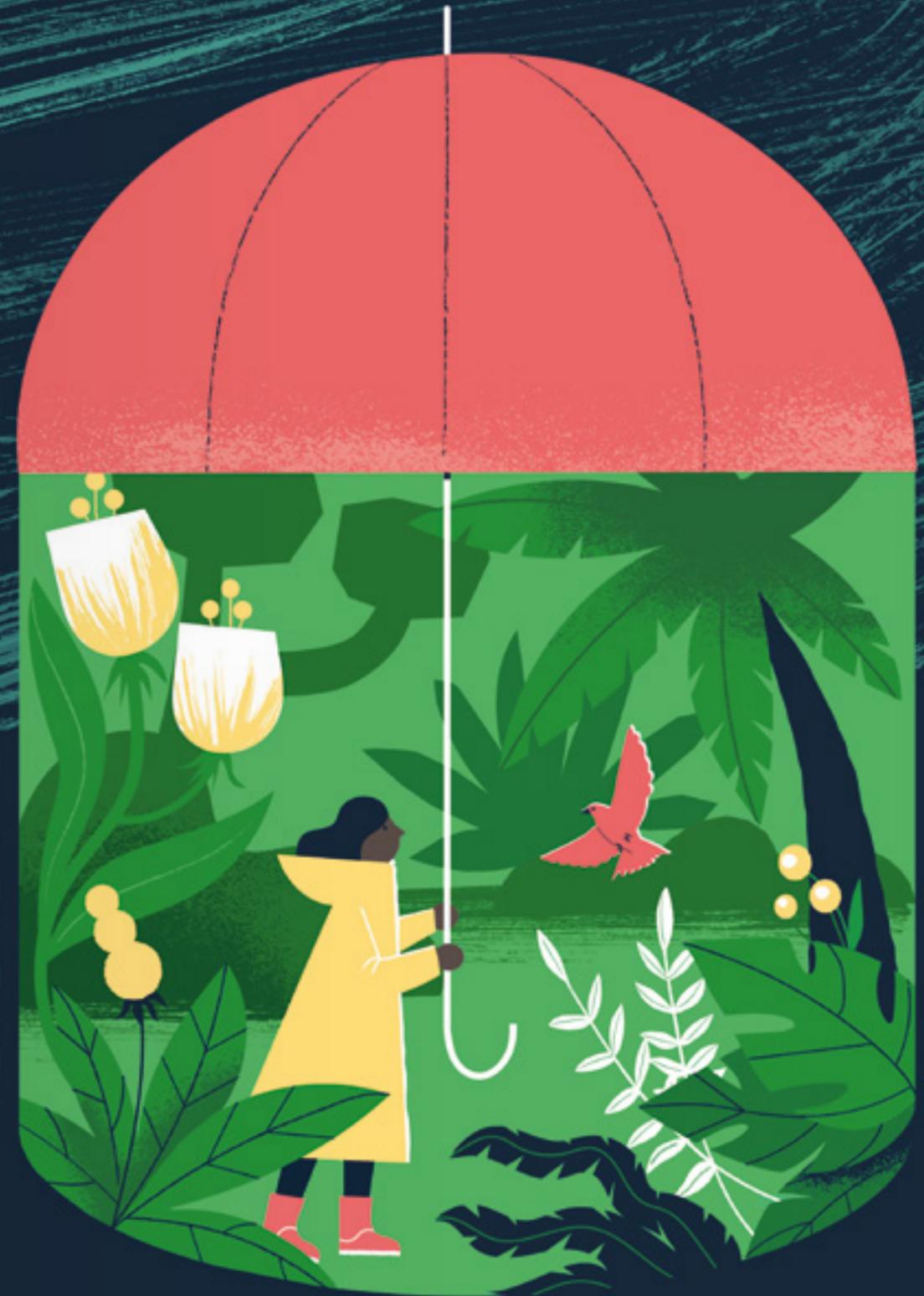
The two crises—one involving the health of ecosystems, and the other involving the health of humans—might seem independent. But evidence increasingly suggests that habitat loss is a key driver of the spread of animal-borne illnesses like COVID-19. That’s why some experts at IPBES are sounding the alarm that “future pandemics are likely to happen more frequently, spread more rapidly, [and] have greater economic impact” if little is done to “incentivize behavior change on the frontlines of pandemic risk.”

Kousky, who serves as the executive director of the Wharton Risk Management and Decision Processes Center at the University

of Pennsylvania, closely studies strategies for funding conservation. A *Duke Law Journal* paper Kousky coauthored last year with Wharton Professor Sarah E. Light was not originally conceived with a pandemic in mind, yet their research offers lessons for policymakers who might feel a renewed passion for protecting ecosystems—lest more zoonotic diseases spread. In assessing how insurance regimes can help restore ecosystems, Kousky and Light say that their article “turns climate governance literature on its head” by exploring contexts in which nature *itself* can be insured directly.

## Habitat Destruction and Human Health

**W**hy is habitat loss associated with the spread of zoonotic diseases? The answer is simple: when nonhuman animals



come into closer contact with people, the risk of a pathogen jumping from one species to another increases.

As human populations grow, they expand into regions formerly dominated by natural ecosystems, which pushes other species to increasingly small and dense areas, ever closer to humans. A disease can then infect people if a sick organism contaminates a local water source, or if a human consumes the meat of a sick animal.

Humans have a hand in habitat loss indirectly, too—principally by contributing to climate change. Extreme storms can destroy habitats, and changes in local temperature and precipitation can prompt organisms to migrate elsewhere.

The public health consequences of habitat loss are already observable across the globe. Expanding suburbs in the forested American northeast brought humans in closer contact with ticks, which has spread illnesses like Lyme disease. Ebola outbreaks are more common in deforested areas of Africa, according to one 2017 study. Plus, the spread of coronavirus—likely transmitted from bats to pangolins to humans—is already being connected to habitat loss.

The coronavirus pandemic might seem like a historic anomaly—a once-in-a-century event akin to the 1918 flu. But climate change will only further degrade ecosystems, increasing the likelihood of major zoonotic disease events. Reducing emissions will help mitigate the worst impacts of climate change, but temperatures are already rising—other policy interventions to reshape economic incentives and protect nature are necessary, too.

### Insurance Policies in the Wild

Some of the most common mechanisms for managing nature are bans on certain actions in protected ecosystems, or permit systems to regulate behavior. But these prevailing systems offer minimal protection when no one owns the land and no one can be held responsible for damages. As Kousky and Light emphasize in their paper: “A catastrophic weather event ... will not seek a permit from regulators before destroying a coral reef.”

“For a long time, the conservation world has been trying to figure out how to mobilize more resources for conservation and restoration,” Kousky notes. “They say things like: ‘The insurance sector is out there. Is this something that could be harnessed?’”

For certain ecosystems—say, a large forest that nearby property owners want to restore in the event of a wildfire—an insurance regime could prompt lasting environmental and economic benefits. Insurance could help guarantee that necessary funds are quickly available when disaster strikes, facilitate cooperation among parties who would otherwise be unwilling to fund restoration efforts on their own, and allow for international cooperation to protect ecosystems that cross political boundaries.

Not all natural resources are directly insurable, however. First, some entity must have the financial ability to purchase insurance and an interest in paying to protect land they do not own. The habitat in question must also be recoverable after damage, and must face random threats—for example, the possibility of an unusually extreme storm—rather than an inevitable outcome, such as incremental sea level rise.

“**The rapid degradation of nature is merely a symptom of a larger illness: a global economy that undervalues the ecosystem services that the natural world provides.**”

### Insuring Nature

While their idea is largely novel, Kousky and Light point to one prominent real-world example: an insurance arrangement that protects coral reefs along a hundred miles of the Mexican coastline. Using both Mexican tax dollars and private funds, the Coastal Zone Management Trust—a partnership that involves the state government of Quintana Roo, local hotel associations, and the environmental nonprofit the Nature Conservancy—has purchased an insurance policy that provides money to restore coral reefs ravaged by storms.

Despite all the involved stakeholders having an interest in preserving nature, none actually owns the coral reef. Without the trust in place to enable their cooperation, the area might otherwise have exemplified the tragedy of the commons. Traditional arrangements would do little to restore the reef after a disaster.

“If hotel owners adjacent to a coral reef simply purchase property insurance to protect against flood damage, they will reap a benefit in the event of a storm,” Light says. “But that money is likely to fund property renovations—not restoration of the ecosystem itself.”

Other programs are currently operational in small areas or theoretically feasible, but have yet to be leveraged on a large scale. Some private forests have insurance to cover the value of lost timber after extreme weather or wildfires, and similar policies could be taken out to protect public lands, as well. Likewise, public earthquake insurance policies in California do not provide funds for restoring land damaged by sinkholes, land fissures, or erosion—but New Zealand’s public program, which covers

a broader range of potential damages, shows that such insurance policies can succeed with a wider scope.

Where insuring nature itself is not possible, working to “better link the protective services of ecosystems to standard property insurance” can confer similar benefits, Kousky says. She points to other programs that incentivize the restoration of nature as potentially more feasible on a wider scale than insurance might be. Kousky highlights the United Services Automobile Association’s Firewise USA program and the National Flood Insurance Program’s Community Rating System, both of which offer discounts to policyholders who live in communities that make efforts to reduce fire and flood risks, respectively.

### The Future of Nature-Based Insurance Solutions

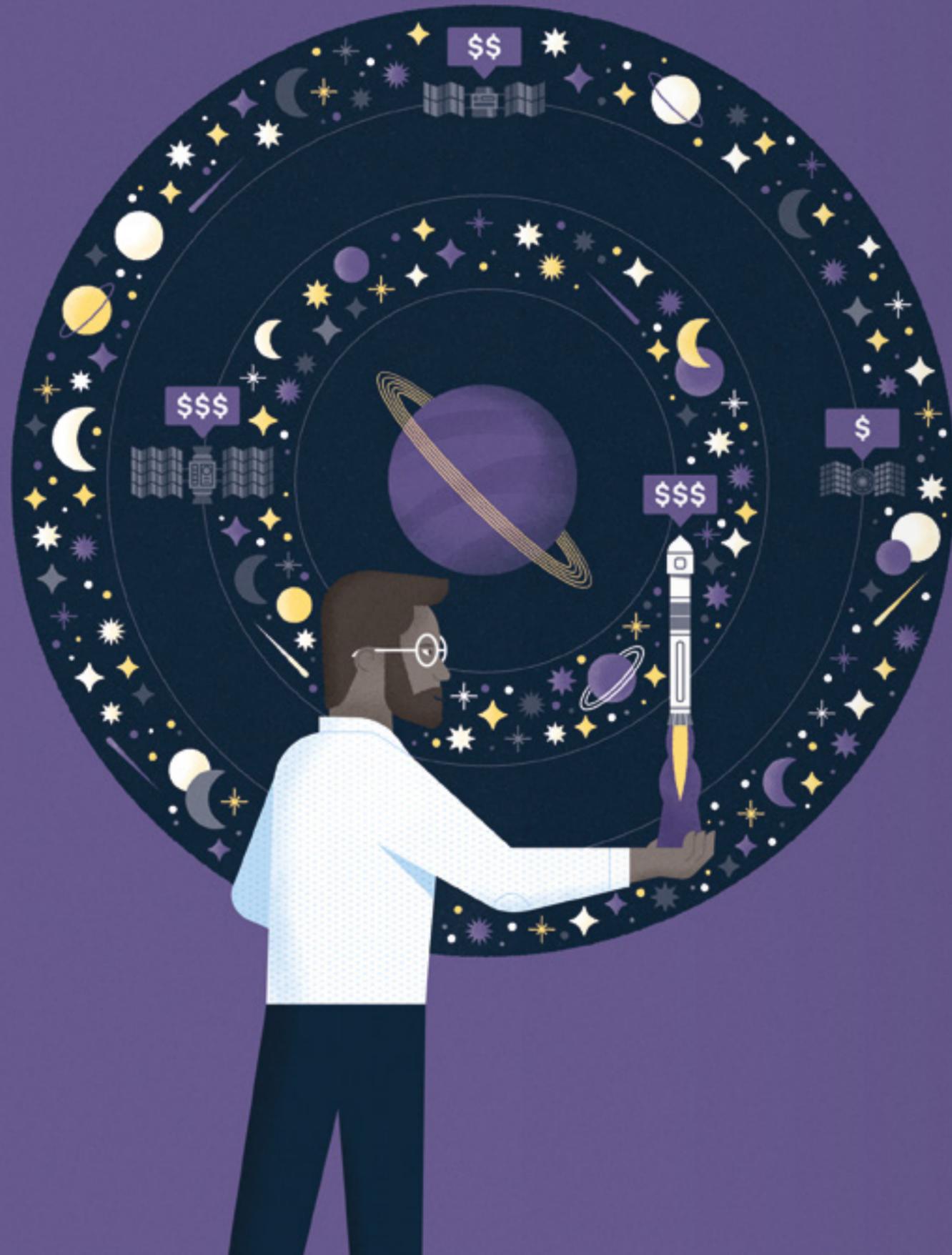
The insurance purchased by the Coastal Zone Management Trust, while easier to spearhead in a community dependent on tourism, has inspired similar strategies for protecting ecosystems elsewhere. Last year, the Nature Conservancy announced plans to expand its idea to natural areas along the coasts of Hawaii and Florida, and Bank of America offered its support by contributing \$1 million. Following these successes, California passed a law in 2018 that requires the state insurance commissioner to “identify, assess, and recommend risk transfer market mechanisms that promote investment in natural infrastructure.” Kousky is now a member of the California Climate Insurance Working Group, a state government group formed in the wake of that law.

For its part, IPBES is planning subsequent reports that relate biodiversity concerns to the current pandemic, while the Intergovernmental Panel on Climate Change is preparing an assessment of the human role in destroying the natural world and promoting pandemics. Such international guidance will be important, not just as nations continue grappling with COVID-19, but in the coming years, as the spread of zoonotic diseases is expected to increase.

That’s why innovating novel mechanisms for protecting and restoring nature will be so important: policies that incentivize the protection of fragile habitats come with corollary benefits, like limiting the proliferation of zoonotic diseases. Still, Kousky emphasizes that insuring nature is hardly a panacea for the world’s interrelated environmental challenges. “It’s more a way to spread and manage losses over time, than some sort of magic money,” Kousky says. “There are times when it’s going to be helpful, and times when it really doesn’t make sense.”

But therein lies a lesson: even when insurance is not the ideal conservation method, the ability of insurance regimes to protect ecosystems in certain contexts can guide policymakers as they devise other remedies. Whatever the mechanism for protecting and restoring nature, financial incentives help; setting aside money in advance to fund eventual restoration efforts helps; systems that facilitate cooperation between disparate parties help. And for policymakers working to address this pandemic and prevent future outbreaks, a key takeaway is clear: protecting the natural world definitely will help, too. ■

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



# Space ♦ The Next Great Market Opportunity

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

**K**ristin Hayes: You and [former RFF VP for Research] Molly Macauley wrote a letter in *Science* in 1986 on the economics of the US space program, which was quite forward looking. How did the issue of the economics of space first come on your radar? (Apologies for the pun.)

**Michael Toman:** We'll just rocket ahead, no matter how bad the puns get. Molly joined RFF in 1983, and I was part of the group that helped recruit her. I mention that because Molly actually came to RFF with a fully formed idea of how to think about economics in the context of space. Her PhD dissertation

was about looking at the orbit around the Earth where a satellite stays in the same relative position the whole time—it's called the geosynchronous orbit, and it's where all the big communications satellites used to park in order to send telephone signals and faxes and other information across long distances. She had this stuff already figured out to a considerable extent when she came to RFF.

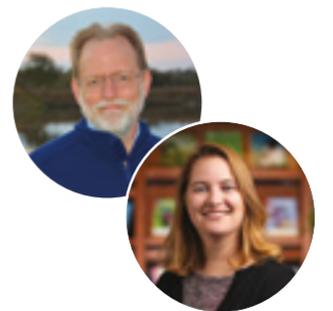
The thing that drew her to RFF was that this orbit is basically a natural resource. That was the first really big insight into how this fits together with what had been the mainstream of RFF work on forests, water resources, and energy—which had been one of my topics. Something out there has value (location is everything, as they say in real estate); where you parked your



## Resources Radio

*Resources Radio*, a podcast launched in late 2018 and produced by the *Resources* editorial team and Resources for the Future (RFF), releases new episodes weekly with hosts Kristin Hayes and Daniel Raimi. Each episode features a special guest who talks about a new or interesting idea in environmental and energy policy. Transcribed here is one such episode, in which Kristin Hayes talks with Michael Toman about the commercialization and privatization of outer space.

Michael Toman is lead economist on climate change for the World Bank's Development Research Group. Prior to that, he worked at RFF for many years, during which he collaborated with former RFF Vice President for Research Molly Macauley in her pioneering effort to develop the economics of space as a topic for research and policy analysis.



**IN CONVERSATION**  
Michael Toman  
and Kristin Hayes

**ILLUSTRATIONS**  
James Round

## Space Economics

Space exploration is an expensive proposition. How much money do you need in your wallet for a trip to outer space?



**\$18,500**

Average cost of launching one kilogram into space between 1970 and 2000



**\$2,720**

Cost of launching one kilogram into space via SpaceX's Falcon 9 rocket



**\$22,500**

Daily cost of supplies per crew member on the ISS, including food ... and air!



**\$20 million**

Cost of a trip to the ISS for the first space tourist, Dennis Tito, in 2001



**\$150 billion**

Estimated cost of the ISS—likely the most expensive object ever built

satellite really mattered in terms of the value you could get from having it up there.

Molly's insight (and I was glad to jump in and try to help her push it forward) was that orbits, space, room in the International Space Station (ISS) for experiments—all these things were valuable and scarce, which is exactly what we talk about with natural resources.

The next insight was that it doesn't automatically follow that the government should be producing space missions, or even necessarily regulating them—that we should start thinking about whether we really need one large, vertically integrated monopoly on planning missions, building spacecraft, and launching rockets.

Starting from then would be when I would pinpoint the interest that Molly had in advancing this idea—that this is something we need to think about in the same way we think about a lot of other resource-related topics.

### How do the economics of outer space differ from the economics of other resources?

Here's an analogy. If fish aren't easily caught in location *A*, you can move your fishing trawler over to location *B*, and you can probably catch better fish there; there's a lot of flexibility in that situation. The thing that's really unique about space resources is that they are something for which there's no realistic

substitute. The geosynchronous orbit is the only geosynchronous orbit, and the only thing you can do to try to put more stuff in there is figure out how to pack the satellites more closely together.

Now, more recently, people have started to work on using little satellites that fly around like gnats instead of just one big satellite in the geosynchronous orbit. But, for a long time, that particular orbit was the only game in town. It was as if you could only catch the fish in that one place, which meant that if you used up all the fish, then that was it—if you used up the geosynchronous orbit, you were done.

### For most of the history of NASA, it's been a vertically integrated system—but it seems like that's changing with the advent of SpaceX. What can you tell us about the mix of public and private interests in space exploration?

We started talking about these things in the 1980s, and I think it hit a pinnacle with the SpaceX launch [the first private shuttle launch involving a crew of astronauts, who rode the *Endeavour* to the ISS on May 30]. Do we always need NASA to write the contract and specifications for the rocket, bid it out to a large aerospace contractor, get it built, put the people and experiments on it, launch it, and retrieve it? What we were learning—even in the '80s and well into the '90s—is that the answer is no.

But there was always this thought: Are we willing to trust a non-NASA entity to build and launch missions when we're going to have human beings on board? And that was the big breakthrough with SpaceX.

We now see that, with a mission where standards of safety have to be met, we don't need NASA to do it. We do not need a government entity to be in charge of the safety of astronauts. NASA was still very involved in the SpaceX launch, of course, because SpaceX used the NASA launch facilities and telemetry and all that, but we can now see that the movement of things and people can be outsourced to a private company.

In other cases, we need the government to have a large role. But even then, we can talk about a public-private partnership. For example: the ISS. It's hugely expensive and multinational, and it would be hard to imagine any company on the face of the Earth, even with the deepest of deep pockets, being willing to put that much money down to build something of that nature, when the demand for it is so unknown.

If I go out as a venture capitalist and build the ISS for some huge amount of money, trying to recoup that cost by renting shelf space there for biology experiments—that's a big ask. So, what we've seen with the ISS is that it's more like a public good, something that you really look to the government to provide, because the private sector can't do a good job of it, for various

reasons. It's natural that the government would be involved in doing that.

One of the things that Molly talked and wrote about was: When you've got room in a space shuttle or on the ISS for experiments, how do you decide which experiments to send up, how long they should run, and what you do after that?

Well, one of the things that we've done with radio frequencies for a long time is have auctions. People bid for room in the radio frequency to operate cell phones, or emergency warning systems, or television, or anything like that. Molly advocated that it was sensible to think about having (at least partly) market-like mechanisms to allocate the space. Let people bid to have the space. Part of the problem is that some of these experiments are basic science, and we can't do a good job by having just one private company supply basic science, any more than we can have one company supply a space station.

But if you just randomize access on a first-come, first-served basis, you may be allocating the space in a very, very inefficient way.

### You've mentioned the ISS as something unlikely for even a very deep-pocketed company to create. What about the launch facilities themselves? Can you imagine a private entity building another Cape Canaveral, or will these types of resources stay nationalized?

I'm not actually sure about that, but I don't see any barriers that can't be overcome. I think it's pure economics.

As long as the launch facilities are there, being maintained and paid for through the NASA budget—with taxpayer money, by the way—the economics probably favor continuing to launch with existing resources. Should the government decide that it wants to get out of the launch business entirely, somebody would figure out how to privately finance and construct an alternative launch pad. But I think, right now, there's no real reason to do that, partly because we're essentially subsidizing all those private-sector launches with the launch facility paid for by the government.

But even with private launches, you still have to coordinate with NASA and the US Department of Defense, because any time a rocket goes up from the Earth into space, these folks need to know about it. You're never going to be able to step away entirely from an interface with the government. You certainly don't want your friendly little communications satellite launch to be seen as a Russian nuclear-tipped missile.

### Who is involved in setting space policy right now? As an economist, how do you think about governance mechanisms for shared resources in outer space?

Right now on the ISS, we have top-down coordination among the principal actors that were involved in building and staffing the station. So, you have the big actors who are dividing up the time slots and the real-estate slots—kind of like a timeshare system for a vacation—and they've got a certain amount that they're allocating through some sort of handshake agreement that I'm sure works very well, because it's been going on for a long time. It's essentially being worked out by a lot of scientists, engineers, and, ultimately, the political leaderships of the various countries involved. And that's probably not going to change anytime soon.

It would be interesting if the major partners in the ISS decided, "We're going to make 20 percent of the time and real estate available for experiments by anybody all over the world, but they'll have to pay to get it." And then they could have the kind of auction I mentioned. This sort of thing could emerge, but I suspect we're still a ways off before we get that far into a more decentralized, incentive-based approach with the ISS.

In terms of the regulation of space activities within the United States, various entities are involved—NASA, the National Oceanic and Atmospheric Administration, the US Department of Defense. In terms of national security and public safety, you're not allowed to drop the first stage of a rocket in a large city, for example. These kinds of things are written in

regulations in very large books that basically set up performance standards. Rockets and escape plans have to have certain characteristics. And the issue of how well those regulations work is something that's never really been evaluated. In fact, it would probably be really hard to evaluate the effectiveness of these regulations.

I think in any regulation system the United States could have—even one that's more decentralized—you could count on certain things being involved. For national security, you would have to make sure you knew what was being launched and that it was being tracked. Basic safety: nobody wants a mission to blow up on the pad or to land in the middle of Manhattan. But the ways that people meet those standards might be more flexible.

And the last thing to mention here, because people often forget it, is that the part of outer space concerned with international telecommunications has an international regulatory body housed in Geneva. This is the body that says, "You can't park your satellites too close together. If you're going to use this frequency for cellular phones, you have to make sure you're not causing too much interference." This body is what keeps the geosynchronous orbit from getting too junked up.

**We've been talking about geosynchronous orbit and the growing number of satellites in that orbit. One of the issues that Molly looked at in her career was space debris. Do we need to start thinking about preserving the environmental health of outer space, the way we think about pollution and preserving natural resources here on Earth?**

Absolutely. That's definitely what Molly was thinking about before her untimely death a few

years ago. The big problem with space junk, as with problems like air pollution and polluted groundwater, is its legacy.

Space junk is, in some ways, a lot like air pollution. It comes from a number of different sources, and there's a lot of it up there. It's not like you can just tell Mr. Brown or Mrs. Black, "Get your junk out of there," because it's all just floating around. These are big hunks of metal, plastic, and, in some cases, even spent nuclear engines.

So, the question is: How do we manage pollution in outer space?

One thing you can do is keep beefing up your vehicles with thicker armor, so even if you start colliding with space junk, your vehicle won't get too damaged. What makes space economics more complicated is that, just to go into orbit and complete a mission, you've got to be dodging a bunch of junk. This makes the risk of failure higher and the return on investment lower.

I don't think we yet have a grasp on that. If you took another area that was very much represented in Molly's research over the years—recycling—you could try to develop some notion, as SpaceX now does with its first launch stage, that when you put something up, there's a standard of care—that when you launch something, you're also going to figure out how to get it back down. The problem is, that's going to make things a lot more expensive—but it would prevent the congestion up there from becoming totally unmanageable. Working on this problem just by navigating better around the space junk or thickening shuttle armor—at some point, you're going to run out of that ability. Are we going to send up big spacecraft to try to collect this stuff?

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**[The International Space Station is] ... hugely expensive and multinational, and it would be hard to imagine any company on the face of the Earth, even with the deepest of deep pockets, being willing to put that much money down to build something of that nature, when the demand for it is so unknown.**

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**We're going to have to start building environmental responsibility into the way we use space.**

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If you put up a satellite and you know you're going to use it for six years, you could add a little thruster, so that at the end of the mission, you can turn on the thruster one more time and push the satellite out of orbit, so it burns up in the atmosphere. This wouldn't be difficult.

We're going to have to start building environmental responsibility into the way we use space. Because—like on Earth—when you're allowed to have adverse effects on other people and not pay for those adverse effects, the situation creates negative incentives for the positive use of a resource.

**Before we close, I have one more question for you. Let's say money were no object.**

**(I'm going to take the economics of space exploration out of the equation for just a second.) Would you go into space? How would you feel about flying up there, yourself?**

In a heartbeat. Molly and I both dreamed, at times, of being able to go up someday. It would be a joy for me to go; I would love it.

**I know we all have different visions about what happens after we leave the Earth, but if there is anyone in this world who I hope is among the stars, it's Molly.**

I would love to see somebody name a comet after her someday: Comet Macauley. ■



## Supporter Spotlight

In this RFF Supporter Spotlight feature, we hear from donors directly about their commitment to issues in climate, energy, and the environment; how they make a difference; and why they support Resources for the Future—all in their own words.

# Addressing a Global Crisis with Good Science and Sound Policy

Resources magazine recently spoke with Larry Linden, founder of the Linden Trust for Conservation and chair emeritus of the Resources for the Future (RFF) Board of Directors. Here are excerpts from the conversation, from his approach to supporting an organization to his passion for combating climate change, and more.

Photos Top: Resources for the Future. Bottom: © Ball & Albanese/WWF-US



**R**esources magazine: You have focused your efforts on climate change as a philanthropist and interested citizen. Why this issue?

**Larry Linden:** When I look back, climate change has been a thread throughout my entire life. I grew up in Pasadena, California, in the 1950s, when the air was seriously brown. Over the years, the air has gotten much cleaner, showing what good science and sound policy can accomplish. When I served as a young Air Force officer in the Pentagon, I wrote one of the first environmental impact statements, which assessed B-70 bombers. I later worked in the Carter administration, in the Office of Science and Technology Policy (OSTP). Eventually, I moved to New York and spent most of the next 25 years at McKinsey and Goldman Sachs. I followed the emerging science of climate change the whole time, and it was becoming clear that we were seeing a global crisis in the making.

**What brought you to Resources for the Future?**

I first learned about RFF during graduate school. I was a student in the MIT Energy Laboratory, where we studied resource economics. So I knew RFF, and I knew the quality of the work, even then. Later, as I left Goldman Sachs and was asked, "What are you going to do now?" I said, "I'm going to see if I can slow down the rate at which we're destroying the planet."

I had already known Paul Portney, who was then the president of RFF. When I was working at OSTP, he also worked in the White House, as a staff economist at the Council on Environmental Quality. So, in 2001 when Paul asked me to join RFF's Board of Directors, I did, because I had great regard for RFF.

**Do you have a "donor philosophy"? How does RFF fit into it?**

I feel like I've been a tremendously fortunate individual, and after my years as a partner at Goldman Sachs, I felt that my task was to "give back"—but I had no idea how to do that. I knew I would need to learn a lot to become a value-added player, rather than just a check writer.

Joining the RFF Board of Directors gave me a learning opportunity and a chance to reimmerse myself in environmental policy—to interact with RFF researchers and other board members who brought a wealth of diverse perspectives.

**What do you think RFF's greatest impact has been over the time you've supported the organization?**

Beginning in the 1980s, RFF came up with a conceptual framework for pollution pricing and credit trading. With efforts shared among RFF, the Environmental Defense Fund, Harvard, and others, creating the actual cap-and-trade market—not just some economic theory, but the actual design of the Clean Air Act Amendments of 1990—was an enormous achievement.

RFF has for years now been the go-to center for expertise on carbon pricing, and largely for cap-and-trade analysis, as well. RFF has the highest-quality research, the best tool sets, great relationships in the policy community, and a commitment to address these kinds of problems. So, it's not just that RFF has a legacy; RFF is an enormous asset that has great future significance. I am so proud to be a part of RFF.

## Four ways you can support RFF



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## What's at the Top of Your Stack?

A recurring segment on *Resources Radio* is "Top of the Stack," when podcast hosts Daniel Raimi and Kristin Hayes ask each guest what is on the top of their literal or metaphorical reading stack.

See if some of their book recommendations can carry you safely through this year's election cycle and our first COVID-19/flu season.

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**I like to think about the tension between the advocacy and scientific communities as being a potentially positive force, if we can only try and figure out how to direct it in that way.”**

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### Uninformed by Arthur Lupia



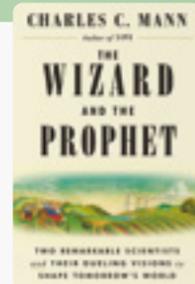
“If listeners would like to be enlightened about how to think differently and more deeply about the American public and its opinions and involvement in politics, I recommend this book. It's an intriguing and powerful treatise that gives insight into the psychological, political science, and economics perspectives on the question of whether Americans actually know enough to keep the democracy boat floating and directed in good ways.”

**Jon Krosnick, Professor, Stanford University, and University Fellow, Resources for the Future**

“This book forces me to take a historical look at the tension between environmental policymakers and advocates. How do you engage with the environment from various levels: social, practical, regulatory, policy, and scientific? How do you find engineering and technological solutions to some of our environmental challenges? I like it because we tend to think about our time today as being particularly divisive, but I like to think about the tension between the advocacy and scientific communities as being a potentially positive force, if we can only try and figure out how to direct it in that way.”

**Sarah Ladislaw, Senior Vice President and Director, Center for Strategic and International Studies, Energy and National Security Program**

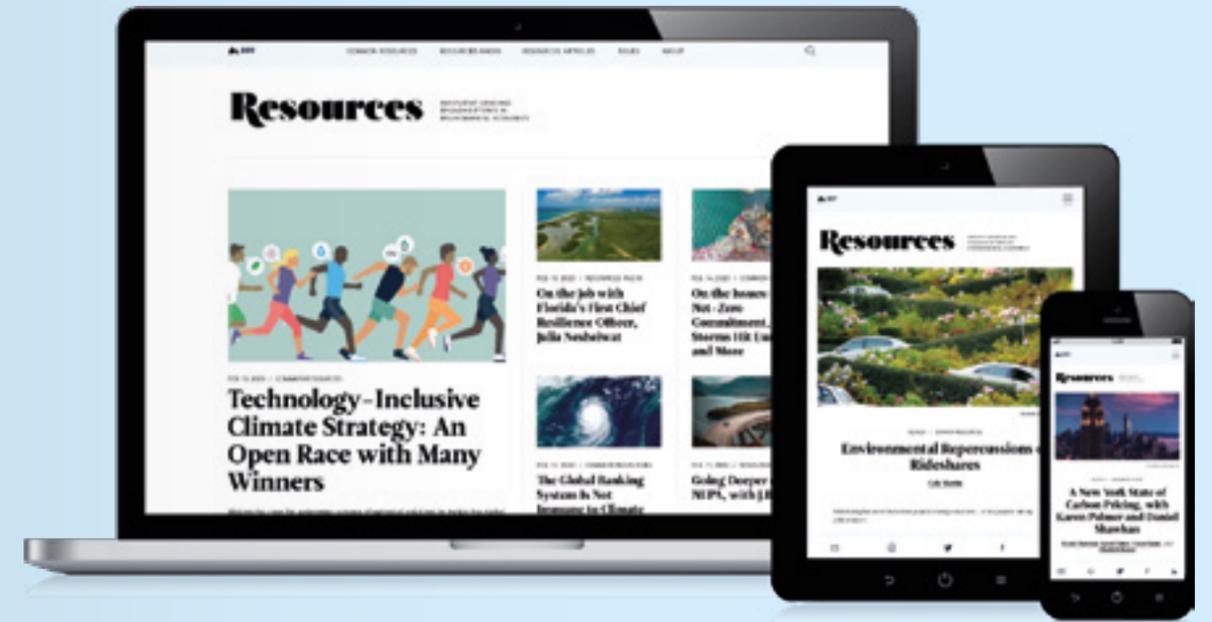
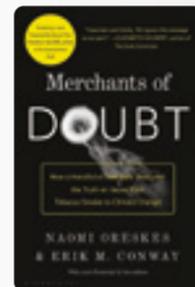
### The Wizard and the Prophet by Charles C. Mann



“The book explores the links between the tobacco industry and the oil industry, laying out the ways in which science denial across both of those industries was constructed with the same strategies and sometimes even by the same people. It's been really formative in how I've thought about climate policy in recent years. One especially striking thing is the repeated pattern of industry successfully framing attempts to protect the collective good as affronts to individual freedom and, in turn, as affronts to American values. We're seeing that conflict play out in real time now, with the way COVID is being handled. I think it's an important dynamic to be aware of when creating policy that deals with externalities. If you don't feel like you have enough to be mad about already, *Merchants of Doubt* is a must-read, in my view.”

**Eva Lyubich, PhD Student and Researcher, University of California, Berkeley, and the Energy Institute at Haas**

### Merchants of Doubt by Naomi Oreskes and Erik M. Conway



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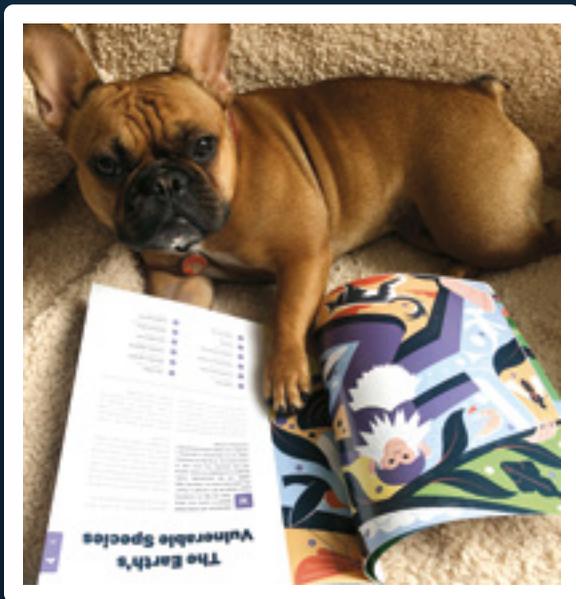


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