

Resources

NEW RESEARCH FROM RFF

National Monuments Can Boost the Economy in the American West

CLIMATE

Florida Climate Outlook

Climate change is coming to Florida.

DISCUSSION

It's a Good Time for Women to Win the Nobel Prize

ENERGY

The Evolution of RGGI

A model for reducing greenhouse gas emissions.

ENVIRONMENT

Plants, Pests, and Perfecting Inspection Models

Expert Insight,
Accessible for
Everyone.

Resources Radio

A Note From RFF's President

Exploring the Natural World

A **Most 70 years ago**, Resources for the Future (RFF) was founded on the idea that our nation must examine the supply and use of its natural resources. This legacy has led to profound areas of work at RFF that have helped pioneer new ways of thinking about the connections among humans, ecosystems, and economies—including our need to balance the protection and development of our scarce resources. In our new issue of *Resources*, you will hear from some of our leading experts in these areas and the novel approaches that carry RFF's legacy forward.

In our cover story, RFF's Margaret Walls, Matthew Ashenfarb, and Patrick Lee explore national monuments—those often awe-inspiring public lands preserved by presidential proclamation—in the western part of the United States. They observe what happens to local economies when a president establishes or, more recently, downsizes a national monument in the area. Other articles in this issue consider the animals and plants that play critical roles in the world's ecosystems.

A *Resources Radio* interview takes a close look at recent changes to the Endangered Species Act, including the federal government's move to publicize the economic impacts of listing a species. This issue of *Resources* also tells a story about insects that hitchhike on imported plants. RFF's Rebecca Epanchin-Niell collaborates with other experts to improve our odds of intercepting those pests. And don't miss the striking infographics that submit Florida as a sobering case study for how climate change increases the risk of sea level rise and storm damage in the state. Finally, RFF's Yusuke Kuwayama propels the conversation about water resources past the atmosphere, explaining how satellite data can inform water management here on Earth.

We also touch on a couple of important milestones in history. RFF's Paul Picciano reviews the origin and evolution of the Regional Greenhouse Gas Initiative—a model that has inspired the development of similar policies around the world. And we are proud to include thoughts from RFF University Fellow Catherine Wolfram on women in economics, in light of Esther Duflo becoming the second woman in history to win the Nobel Prize in Economics.

Our commitment to rigorous, independent research and collaborative policy engagement is what enables RFF to make an impact in these areas—and your investment in our ideas makes this possible. As you read this issue, please consider becoming an RFF supporter and join us in our mission.



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President and CEO, Resources for the Future

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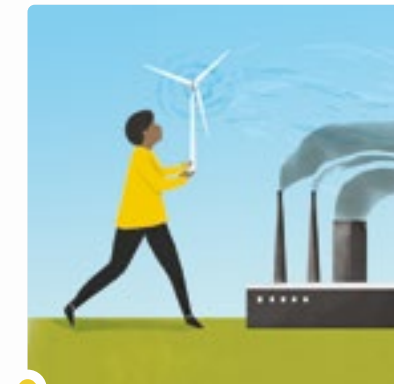
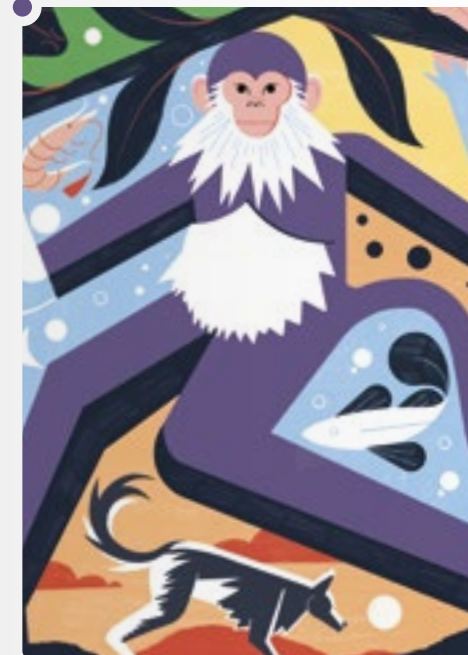
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National Monuments Can Boost the Economy in the American West

A highly charged belief pervades some communities in the American West—that national monuments detract from existing employment opportunities in the region.

But new research from scholars at Resources for the Future shows that establishing monuments actually can lead to economic benefits in some cases, with no evidence that monuments are bad for local economies.

As they always had, and as they always intended to do, a group of Wyoming ranchers led 500 or so cattle through the vast open grasslands that were great for grazing. But this time, they were angry. The space they'd long used for their livestock had become federally protected land, when President Franklin D. Roosevelt decided to create the Jackson Hole National Monument in 1943. The ranchers were so indignant about losing the land and their livelihood to the federal government that they'd armed themselves in protest with a flamboyant arsenal of guns, daring anybody to stop them.

In the western United States, some communities that currently earn their living from the land still harbor hard feelings about national monuments—those cumulative millions of acres, preserved by presidential decree, which often are closed to industries like ranching and mining. The prospect of lost livelihoods can produce conflict over the limits that monuments place on land use, but creating monuments can also create value by growing new industries related to recreation and tourism.

The push and pull of these economic arguments prompts an important question that has relevance to recent and future policy

decisions: Do monuments provide economic value to the local economy, or do they prevent the profitable use of land? New research from scholars at Resources for the Future (RFF) has taken a major step toward finding an answer, by explicitly exploring the effect of national monuments on local economies.

The controversial question comes especially close to people in the American West. In the eight states that make up the Mountain West region—Arizona, Colorado, Idaho, Montana, Nevada, New Mexico, Utah, and Wyoming—more than 50 percent of the land is federally owned. That's 574 million acres of restricted land that is close to home and very visible to communities in the western part of the country. Large monuments provoke anxiety for those who rely on that land for their industry, and who thus are especially susceptible to federal policies.

As for those Wyoming ranchers in 1943, their protest served well to bring publicity to their cause, but the protests otherwise dried up as the Jackson Hole National Monument merged with Grand Teton National Park. The protest had involved sympathizer Wallace Beery, an actor in Hollywood Westerns who was famous enough to warrant coverage of the event in *Time* magazine, but under other circumstances, the story might have been as ignored as the

TEXT

Elizabeth Wason

GRAPHICS

Matthew Ashenfarb

PICTURE

Río Grande del Norte National Monument in New Mexico / Bob Wick, Bureau of Land Management

“

In the eight states that make up the Mountain West region—Arizona, Colorado, Idaho, Montana, Nevada, New Mexico, Utah, and Wyoming—more than 50 percent of the land is federally owned.

That's 574 million acres of restricted land that is close to home and very visible to communities in the western part of the country.

”

ranchers themselves were by the National Park Service. Nonetheless, local uproar was loud enough that the state took up the fight. To this day, the US president cannot establish any monument anywhere in Wyoming without additional approval of Congress.

Unrest in the West

When it first passed, the Antiquities Act of 1906 gave the president the right to establish national monuments. The act arose originally to preserve land that contained early Native American sites, where the brutal dismantling of artifacts called for protection from vandalism. Since then, presidents have created national monuments to protect other cultural and historical sites such as battlegrounds and preserve ecosystems and unique natural resources. President Jimmy Carter set records for the amount of land that he turned into national monuments, while President Bill Clinton set the record for the highest number of monument proclamations. President Barack Obama later broke both Carter's record for monument acreage (by expanding marine national monuments by hundreds of millions of acres) and Clinton's record for quantity (by creating 34 monuments).

The Antiquities Act has inspired outrage and controversy from the very start and throughout its history. Armed protests over federally managed land still happen in the western United States, as in the case of Cliven Bundy, a Nevada rancher who went to jail in 2016 for a standoff he staged while refusing to pay a \$1-million backlog of livestock grazing fees. In recent years, the long tradition of rancher insurgency might be starting to pay off. The Trump administration significantly scaled

back the land area of two national monuments in Utah in 2017, effectively shrinking Grand Staircase-Escalante by nearly 50 percent and Bears Ears by 85 percent—areas totaling more than two million acres.

Given the longstanding and continued dispute over national monuments, policymakers and presidents probably should decide whether monuments are worth the trouble. On the one hand, monuments could be economically beneficial by creating jobs in surrounding communities, and furthermore save precious artifacts, preserve land, and help provide ecosystem services. Alternatively, national monuments may lead to lost livelihoods in traditional industries, punishing a region whose economy has seen better days.

The few related economic studies published to date have been limited in their approach. These prior studies have offered correlations that still leave causation unclear, and their analyses include data at the relatively low spatial resolution of the county level within states. Arizona, for example, has only 15 counties that average nearly five million acres each. (For comparison, the average number of counties per US state is about 62, with an average area of roughly 720,000 acres.) “We worked with extremely detailed economic data and employed modern econometric methods that are designed to identify cause and effect,” says lead author of the new paper and RFF Senior Fellow Margaret Walls. “We wanted to dig deep into the data and find out what impact the designation of these protected lands has had on local economies.”

With the paper they've published this year in *Science Advances*, Walls, RFF Research Assistant Matthew Ashenfarb, and former RFF

National Monuments

- 1 Upper Missouri River Breaks
- 2 Craters of the Moon
- 3 Grand Canyon - Parashant
- 4 Grand Staircase - Escalante
- 5 Vermilion Cliffs
- 6 Canyons of the Ancients
- 7 Chimney Rock
- 8 Río Grande del Norte
- 9 Kasha-Katuwe Tent Rocks
- 10 Agua Fria
- 11 Sonoran Desert
- 12 Ironwood Forest
- 13 Prehistoric Trackways
- 14 Organ Mountains - Desert Peaks

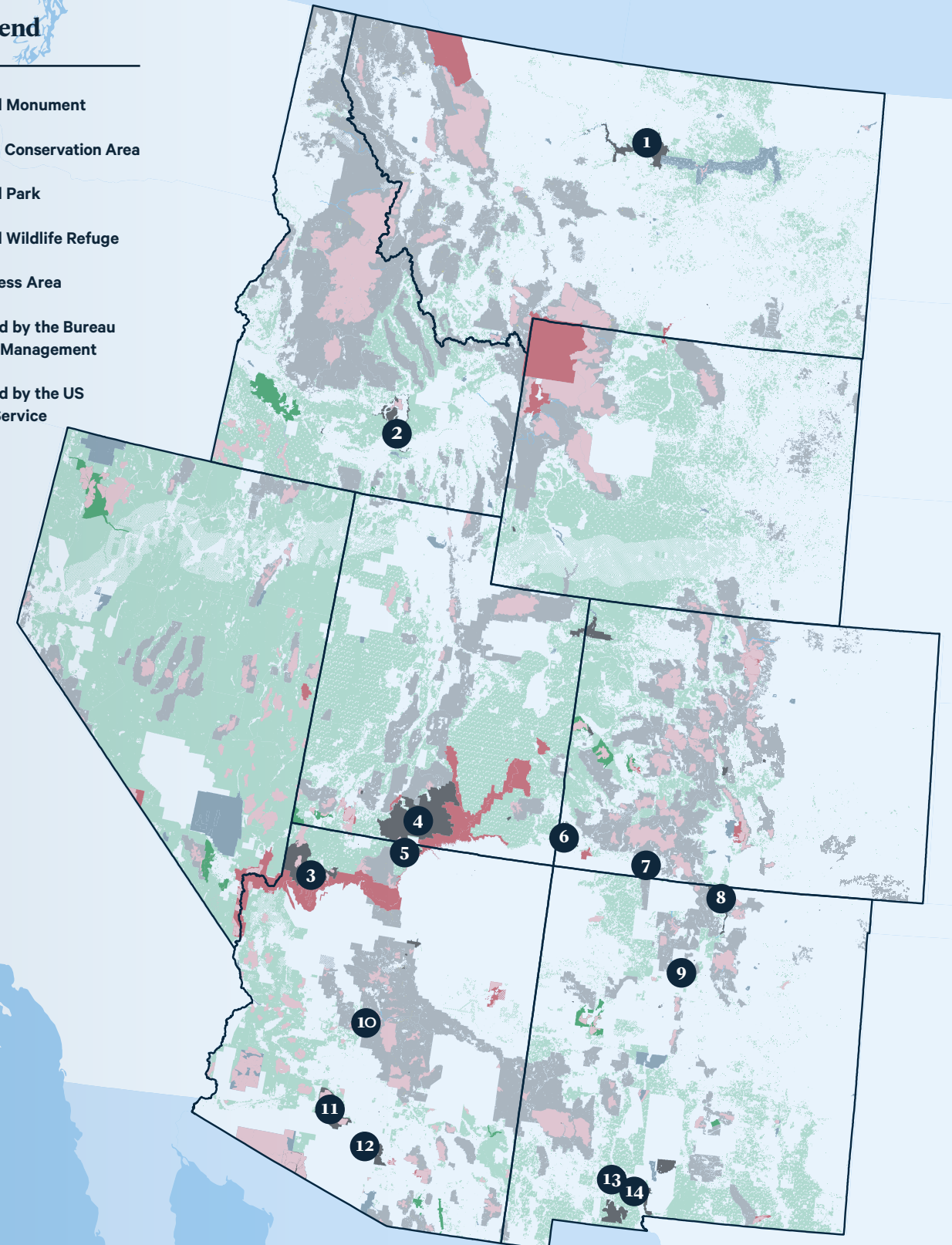
FIGURE ONE

Fourteen national monuments (of the 122 monuments in the United States as of 2017) were included in the recent RFF analysis, as indicated by numbers on the map.

These national monuments were established in the eight Mountain West states between 1990 and 2015. The researchers evaluated the number of businesses and jobs near each monument during this 25-year time period, at the detailed spatial resolution of latitude and longitude coordinates for each business.

Map Legend

- 1 National Monument
- 2 National Conservation Area
- 3 National Park
- 4 National Wildlife Refuge
- 5 Wilderness Area
- 6 Managed by the Bureau of Land Management
- 7 Managed by the US Forest Service



researcher Patrick Lee aim to see whether these monuments cause any change in employment and job growth by looking at economic variables in areas abutting a monument, compared with the same metrics from farther sites. Their quasi-experimental methods, which involve difference-in-differences regressions and counterfactuals, establish causation in a way that prior correlational studies cannot. Their data also gets more granular: the new analysis accounts for every individual business establishment in the area and their precise locations, rather than average numbers at the county level. With a focus on all 14 monuments created by presidential proclamation between 1990 and 2015 in the eight Mountain West states, the study tracks several specific economic metrics over that duration of time: the number of jobs per business, the total number of jobs and number of businesses, the yearly rate of change in number of jobs and number of businesses, and average wage income.

As it turns out, a local economy does not deflate when nearby land becomes a national monument. The total number of jobs near monuments actually increases by an average 8.5 percent, while the number of businesses near monuments grows by almost 10 percent—and at an accelerated rate. Estimates from regressions show that the economic growth happens in service industries related to hotels, lodging, health, finance, insurance, real estate, and construction.

National monuments thus boost local economies by some measures; but for the remaining economic variables, the change in land designation has neither a positive nor negative effect. In this context, the null effect itself has unusually big implications. “It means that concerns about monument designations harming local economies are unfounded,” says Walls. “For example, the average wage income does not change near new monuments, despite the common assumption that low-wage service jobs displace access to more lucrative livelihoods.” The RFF study also found that the number of jobs in extractive industries such as mining, forestry, and livestock grazing were unchanged as a result of the designations.

As the authors state in their new study: “Our results suggest that protecting some of these public lands as national monuments does not exacerbate [slow-growth trends in resource-dependent communities] but rather could even be reversing them and creating a new set of economic forces oriented around the historic, cultural, and scenic amenities that these public lands provide.”

A Canyons of the Ancients National Monument, Colorado

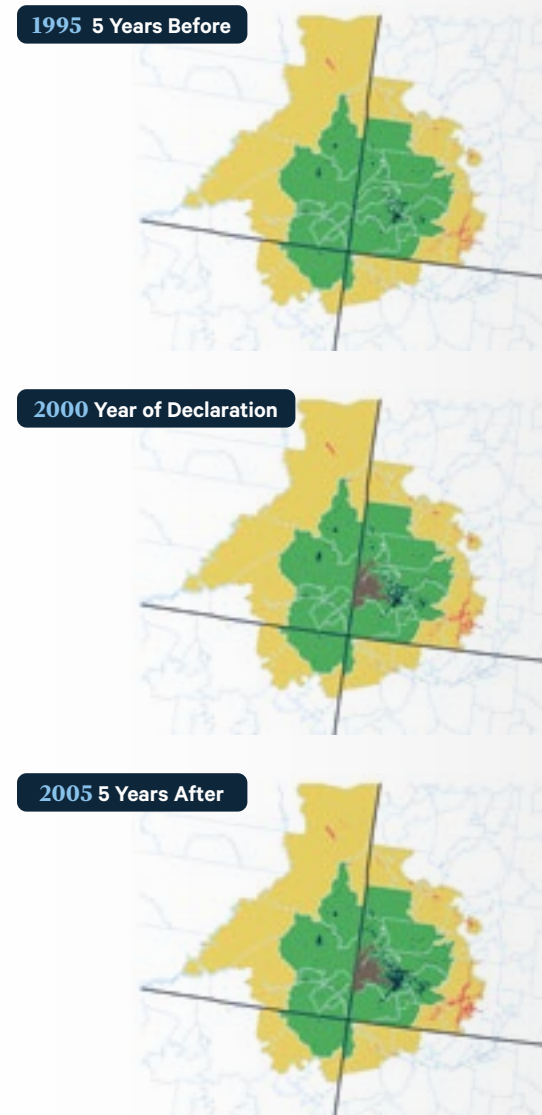
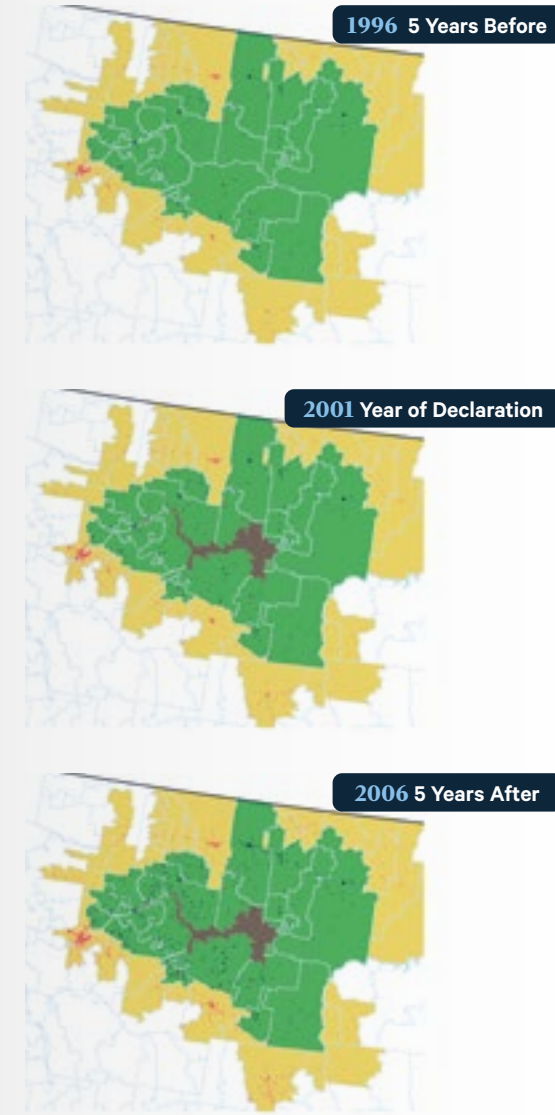


FIGURE TWO

Declaring a national monument (indicated in brown), such as Canyons of the Ancients (A) and Upper Missouri River Breaks (B), leads to an increase, on average, in the total number of business establishments (dots) and total number of jobs in Zip Code Tabulation Areas (ZCTAs) within 25 kilometers (km) of national monuments. ZCTAs within a 25-km buffer surrounding each national monument were designated as monument treatment areas (green); ZCTAs adjacent to treatment ZCTAs comprise control areas (yellow). Treatment and control areas showed similar historical economic trends. Treatment areas outperformed control areas, on average, after monument designation.

B Upper Missouri River Breaks National Monument, Montana



Map Legend



Resolving a Monumental Controversy

When President Bill Clinton established Grand Staircase-Escalante in 1996 as a national monument in Utah, local students released black balloons as a symbolic and ominous statement of mourning, protest, and warning. The Trump administration revisited the proclamation in 2017 and constricted the monument's borders down to half the original area, and a presidential decree in the same year pinched the neighboring Bears Ears national monument even further. These two proclamations represent the largest land reductions to national monuments in US history. While advocates of the recent reductions celebrated this news, millions of others pushed back with public comments and a handful of court cases to sue the president over recent changes to public lands. Based on their regression results, Walls, Lee, and Ashenfarb calculated a rough estimate of the effects of the scalebacks and found that reductions to the monuments may lead to 700 lost jobs—a two percent reduction in the number of jobs in those regions.

In the end, and in spite of economic anxieties in some rural communities in the American West, the new RFF study finds that it's not national monuments that are to blame for failing industries. Local economies can thrive even as limits to land use—and corollary protections for the environment—increase, particularly if established industries give way to different types of work. “While our results are suggestive of the impacts of monuments,” says Walls, “applying the average results to specific monuments and future decisions should involve caution. Important to keep in mind when applying these results to policy is that they do not rule out the possibility that specific monuments had either larger or smaller effects, or that future monument designations could have a different impact.”

Tempered by those caveats, this new evidence suggests that presidents and policymakers don't necessarily need to shy away from monument designations based on concern that local industries will suffer. Instead, the new research shows that future monument declarations likely will benefit not only the goals of environmental and cultural preservation, but also help to safeguard local economies ■

Elizabeth Wason is the managing editor and Matthew Ashenfarb is a research assistant at Resources for the Future.

The Pew Charitable Trusts and the Castle Rural Lands Fund award helped fund the research described in this article.



Satellite Data Can Inform Water Policy

With a little extra exposure to useful tools, willingness to take risks with new technologies, and exerted connections across disciplines, Earth scientists and water managers can gather and use Earth observation data to great effect in maintaining the quality and availability of water as a valuable natural resource.

TEXT / Yusuke Kuwayama

New opportunities continue to arise in environmental measurement through remote sensing, satellite data, and other Earth observations. But up until now, few clear examples of consistent and operational use of remotely sensed data specifically in water policy have been documented. Nonetheless, some clear examples exist of remotely sensed data being used in actual decisionmaking, and social scientists with expertise in water resources can play an important role in accelerating the use of satellite data in water management.

Formal uptake of satellite data on water resources has been slow for policymakers and managers. In the United States, satellite data have been used by the National Weather Service (NWS)

and the Federal Emergency Management Agency (FEMA), but the use of satellite data for managing water scarcity and water quality are less well documented. One example of satellite data leading to consequential decisions is the United States Drought Monitor (USDM), produced by the National Drought Mitigation Center. The USDM is a weekly map that indicates where drought is occurring, its severity, and its projected duration. The USDM informs decisions made within a variety of programs at the US Department of Agriculture and the Internal Revenue Service that are designed to mitigate the economic impacts of drought.

One of the most active water resource application areas for satellite data has been measurement of water quality. In addition to specific water quality parameters, remote sensing applications have been developed to measure the extent and severity of water pollution events such as harmful algal blooms, development of hypoxic and anoxic areas, and oil spills. For example, the state of Florida uses Earth observations to regulate coastal water pollution from nutrients under the Clean Water Act. Historically, in-situ water quality data were not of sufficient resolution to be used for this purpose, and it was impractical to enforce water quality standards using on-site measurements. Notably, Florida state law now specifies satellite monitoring in related regulations, with the specific provision, “Achievement of these criteria shall be assessed only by using satellite remote sensing data that are processed in a manner consistent with the derivation of the criteria.”

Another notable application is the Mapping Evapotranspiration with Internalized Calibration (METRIC) satellite-based image processing model, which can quantify evapotranspiration at the extraordinarily granular scale of individual

farm fields. Results from a METRIC analysis were used as part of expert testimony in a US Supreme Court case, in which Montana alleged that Wyoming violated the Yellowstone River Compact by diverting and storing water from the Tongue River. In the testimony, an expert from Montana used the measured evapotranspiration rates to identify irrigated acreage in Wyoming, which in turn was used to estimate the quantity of water used for irrigation.

In spite of these cases that demonstrate how Earth observations have contributed to policy and decisionmaking, challenges continue to hinder the adoption of satellite data for water management at an operational level. A limitation of satellite data applications is that they may require further refinement before they are put to use in decision contexts with socioeconomic consequences. One common obstacle is that the spatial and temporal resolutions of the data may not match the needs of a water manager, because sensors on board existing satellites may not have been built with specific water resource management applications in mind. Many sensors have only been operating for a short period of time, while some decisions associated with water management may require longer data records with established normals. Likewise, concerns regarding the continuity of a specific satellite mission may discourage investments by water managers to accommodate long-term use of data from that satellite.

Issues of institutional inertia may also hamper adoption of satellite data. Anecdotally, many water managers do not have an incentive to incorporate new forms of data into their decisionmaking. Water managers face the risk of being blamed for negative societal outcomes from decisions using new data, whereas they would not be at fault if they had made their

decision “by the books,” even if use of the new data would have yielded a less negative outcome.

But the opportunities associated with satellite data for water policy are clear. Satellites often allow for the measurement of hydrologic parameters at greater spatial resolution and coverage, higher temporal frequency, and lower latency, all at lower cost.

Here at Resources for the Future (RFF), the Consortium for the Valuation of Applications Benefits Linked with Earth Science (VALUABLES) works to quantify and communicate how the use of satellite information in decisions can improve outcomes for people and the environment. A cooperative agreement between RFF and NASA, VALUABLES brings together economists, NASA scientists, remote sensing experts, members of the wider Earth science community, and decisionmakers.

My experience directing the VALUABLES consortium suggests that social scientists can help bring the value of satellite data to water management. This is because social scientists who study water resources generally understand how hydrologic information influences water management decisions and how these decisions influence socioeconomically meaningful outcomes. Thus, social scientists who collaborate with Earth scientists working on remote sensing applications for water can help inform the design of project outputs that fits the needs of policymakers ■

Yusuke Kuwayama is a fellow and director of the VALUABLES Consortium at Resources for the Future. A version of this text was previously published as a policy note in Volume 5, Issue 3 (July 2019) of the journal *Water Economics and Policy*.



The Earth's Vulnerable Species

Mathematician and meteorologist Edward N. Lorenz once asked, “Does the flap of a butterfly’s wings in Brazil set off a tornado in Texas?” The small initial action of a butterfly might amplify into big unpredictable results, through an accumulation of events starting with that butterfly’s first move. And, as Lorenz points out, “If the flap of a butterfly’s wings can be instrumental in generating a tornado, it can equally well be instrumental in preventing a tornado.”

Any animal or plant on the globe might provide the initial conditions that help set the trajectory for an ecosystem. That trajectory matters for ecosystem services, such as pollinated crops and clean drinking water, which matter to people and have economic value. Policies and

regulations that protect the Earth’s species likewise can help protect ecosystem services.

Of course, federal projects such as highways and dams also matter to people, have economic value, and contribute to well-being at the large social scale. And where these projects collide with natural systems, some policies try to preserve the environment without breaking the bank. The US Endangered Species Act is one example of a policy that aims to balance these needs.

Lorenz’s butterfly helped him consider the limits of our ability to make predictions. Can we predict what happens if a change to policy influences how butterflies are protected? What happens if a butterfly does *not* flap its wings in Brazil? ■

- | | | | |
|---|--|----|---|
| 1 | Angel shark
<i>Squatina squatina</i> | 7 | Douc langur
<i>Pygathrix nemaeus</i> |
| 2 | Anchialine pool shrimp
<i>Procaris hawaiiana</i> | 8 | White River springfish
<i>Crenichthys baileyi</i> |
| 3 | Hawaiian picture-wing fly
<i>Drosophila</i> spp. | 9 | Poweshiek skipperling
<i>Oarisma poweshiek</i> |
| 4 | Scalloped hammerhead
<i>Sphyrna lewini</i> | 10 | Hook-billed hermit
<i>Glaucis dohrnii</i> |
| 5 | Gray wolf
<i>Canis lupus</i> | 11 | Appalachian elktoe
<i>Alasmidonta raveneliana</i> |
| 6 | Lobed star coral
<i>Orbicella annularis</i> | 12 | Sandplain gerardia
<i>Agalinis acuta</i> |

Is the Endangered Species Act under Threat?

Resources Radio, a podcast launched in late 2018 and produced by the *Resources* editorial team and Resources for the Future (RFF), releases new episodes weekly with hosts Daniel Raimi and Kristin Hayes. Each episode features a special guest who talks about a new or interesting idea in environmental and energy policy. Transcribed here is one such episode, in which Daniel Raimi talks with Ya-Wei Li about the Endangered Species Act (ESA), a law that showed up in the news last year when, in August, the Trump administration proposed a number of changes to the way the ESA is administered and enforced.

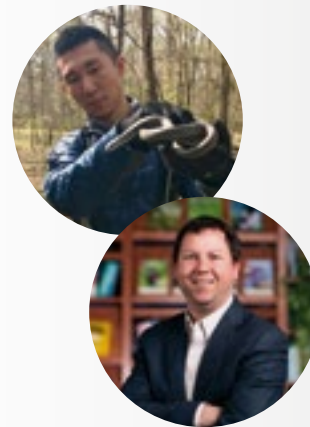
This interview was originally recorded on August 16, 2019, and the podcast episode was released on August 20, which closely followed the Trump administration's announcement on August 12. The transcript of this conversation has been edited for length and clarity.

Daniel Raimi: Before we dive into the Endangered Species Act (ESA), can you tell us how you first got interested in environmental issues?

Ya-Wei Li: There's actually a one-word answer that you probably don't get a lot, and that answer is: snakes.

I grew up in the East Village in New York City, where there aren't many natural areas; Central Park was about as natural as it got in Manhattan. But probably about 30 years ago, I developed a fascination with snakes, and I've been keeping snakes for about three decades. And that is what got me interested in wildlife conservation and why I'm here

today—it really started with this childhood fascination with a particular type of critter, and that of course expanded to other things like freshwater fish, and I kept turtles and all sorts of things. And I eventually became passionate about the natural world and conservation, especially after I got a car and was able to drive around. There wasn't much of an opportunity for camping or Boy Scouts or hiking in the wilderness in the middle of one of the largest cities in the world, so I made do with what I had.



IN CONVERSATION
Ya-Wei (Jake) Li
and Daniel Raimi

ILLUSTRATIONS
Michael Driver - Folio Art



American alligator
Alligator mississippiensis

California condor
Gymnogyps californianus



Can you give us a little bit of historical background on the ESA? It was signed in 1973 by President Nixon, and I noted that it passed both the Senate and the House with overwhelming majorities—it passed unanimously in the Senate. When the law was originally passed, what was it intended to accomplish?

The law was passed in response to a growing recognition among the American public and lawmakers that we were facing an extinction crisis. A number of species, both in America and overseas, were going extinct, and oftentimes because of human activities.

The Endangered Species Act was passed with really broad support—and it still enjoys that support among the American public today—with two main goals. The first, and the most urgent goal, is to prevent extinction. This is the crisis—the fire that we want to put out. And that's what animated Congress to pass legislation with prohibitions on certain human activities, in order to prevent species from sliding further into extinction.

But preventing extinction isn't enough, right? Because if you just have a species that's at the very edge of going extinct, that's not really what we would call success. That's why the Endangered Species Act has a second primary goal: to recover species to the point that they're secure in the long term. And if they can be secure in the long term, then the federal government can return the management of that species back to the states, which had legal authority over the species before it became listed under the ESA.

Oftentimes, people also talk about conserving ecosystems or conserving habitat. My view is

that conserving habitat and ecosystems are probably the primary means by which we can recover species, because for most species, we're not going to be able to get them to the point of recovery without protecting and managing their ecosystems.

I've gotten the sense that people have very different views about how successful the ESA has been to date. Can you give us some perspective on some of the historical successes the ESA has achieved, along with some of its shortcomings?

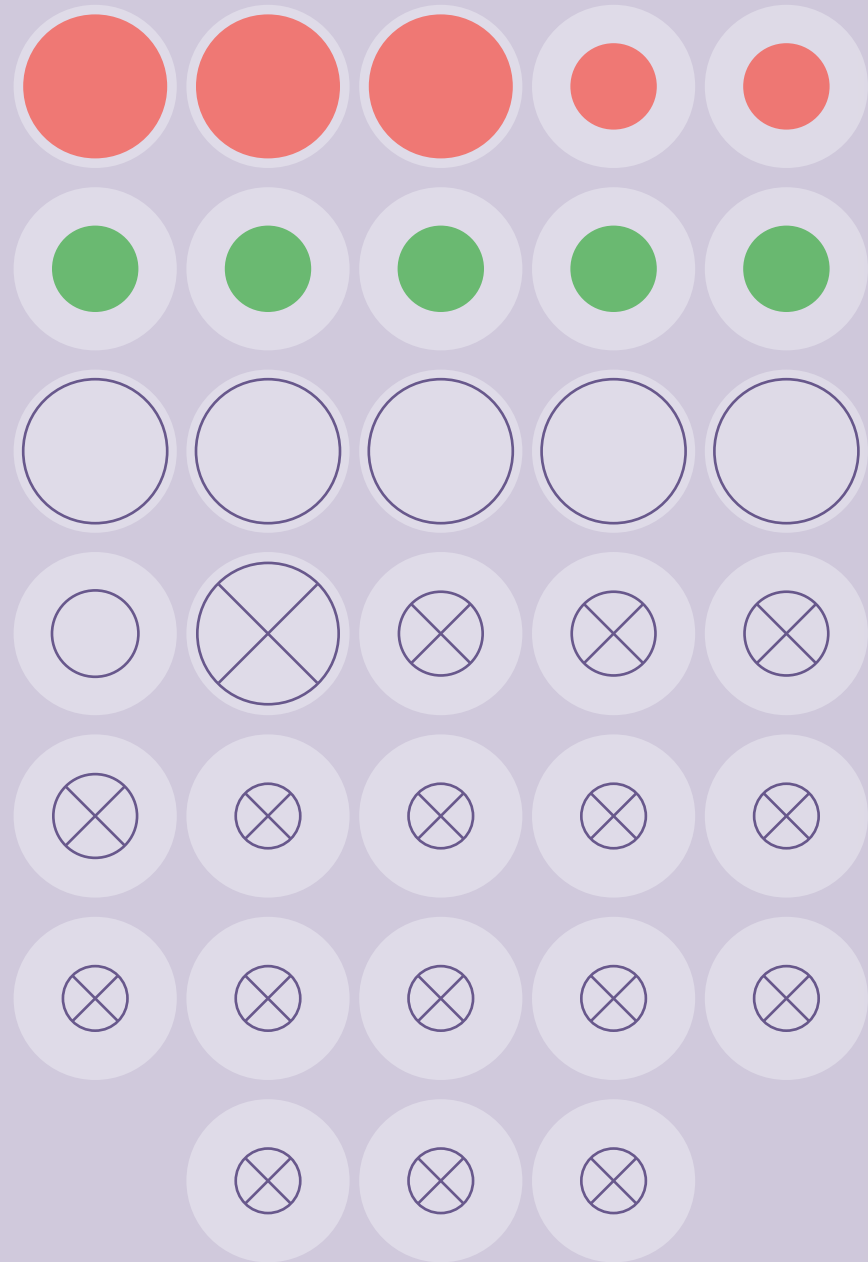
The act's success or lack of success is probably the most debated topic under the Endangered Species Act today. Let's take a minute to unpack what that really means.

For those who want to reform to act, they'll oftentimes emphasize that the act has recovered only about two percent of the nearly 2,350 species that have been listed. To some, a two percent recovery rate looks like a failure. After some 45 years, why do we only have 55 species that are recovered?

On the other side of the argument are those who resist reforms to the Endangered Species Act—typically conservationists—and they emphasize that the Endangered Species Act has been something along the lines of 95 to 99 percent effective at preventing extinction. They're looking at success using a completely different metric: not what's been recovered, but rather how many species are still with us today. And that's an astounding number. I mean, it really is remarkable that we've lost very few species after 45 years.

My perspective is that we're missing a huge chunk of the species by looking only at those two

How the Recent Revisions to the Endangered Species Act Will Affect Conservation



EFFECT ON CONSERVATION

- Red circle: Negative
- Green circle: Positive
- White circle: Depends on implementation
- Circle with X: Negligible

MAGNITUDE OF CHANGE

- Large circle: Moderate/Major Change
- Medium circle: Minor Change
- Small circle: Clarifies or codifies past practice

Each circle represents one of the 33 regulatory changes to the ESA. The recent changes fall into four categories:

1 / Undermine conservation
For example, publishing the economic impacts of decisions related to species listings.

2 / Depend mostly on implementation
The two wildlife agencies responsible for implementing the ESA, the US Fish and Wildlife Service and the National Marine Fisheries Service, can apply substantial discretion.

3 / May improve conservation
For example, creating an option for federal agencies to develop a more collaborative consultation process for projects that impact listed species.

4 / Maintain status quo
These changes include clarifications, definitions, and descriptions.

Source: Environmental Policy Innovation Center. 2019. "A Guide to the Revised Endangered Species Regulations."

extremes. On the one hand, you can look at the two percent of species that have been recovered. On the other hand, you can look at the roughly three to five percent of species that have gone extinct. My question is, what happened to the 95 percent of species in the middle? It's those species that are the focus of the day-to-day work of the Endangered Species Act.

And unfortunately, there just aren't good stats on how those species are doing. Are they moving closer to recovery? Are they moving further away from recovery? Are they stable? We have information here and there on particular species, but across the board, the US government doesn't keep good records of how the vast majority of species are doing on a year-to-year basis.

The best information we have today is actually a study that I was part of a few years ago, where we looked at some long-term trends using some imperfect data that the government had been collecting. And what we found was actually fairly disappointing. We found that roughly half of all listed species were still in long-term decline after being listed, and only roughly 30 percent of them were stable or improving.

So, my assessment is that the effectiveness of the ESA is mixed. We have had some great successes to date. The California condor is still soaring, American alligators have recovered, but we have a lot—a lot—of species that are slipping through the cracks. A bunch of Hawaiian plants are down to just a handful of individuals left.

It's interesting to note that the ESA doesn't just relate to animals; it applies to vegetation, as well.

That's a really interesting point, because what you see on a front page of the *New York Times*

or the *Washington Post*—the poster child of endangered species—will usually be an animal. Most people do not know that 57 percent of all US-listed species are plants.

Before we talk about the proposed changes to the ESA that the Trump administration has announced recently, are there changes to the act or its implementation that you think would be particularly valuable?

I have a very, very long list of possible improvements, but let me pick one or two ideas—especially ones that your listeners might not have heard much about.

The first one I'd like to start with is that I would really like to see the government make much better use of technology to improve how it administers the Endangered Species Act. For example, there are great opportunities to use satellite images, including the ones that you can find on Google Earth, to monitor the condition of habitats for endangered species and to determine whether people are actually violating the Endangered Species Act.

Another opportunity is our mobile phones: we can use these technologies to expedite the process of enrolling conservation agreements for private landowners. If you think about how you file your taxes, it's much easier than 20 years ago, when we were filling out paper forms, easily cutting down the number of hours we need to file taxes. In terms of enrolling landowners in endangered species agreements today, we're still doing it the old way. It can be cumbersome, and it's hard to track all the paperwork. If we can use technology like mobile phones and the internet to lower the "hassle barrier" for private landowners, we're much more likely to get them to voluntarily sign up to these agreements and

carry out conservation measures that are needed to recover species.

The federal government is really under-resourced; it simply doesn't have the capability of going out in the field and monitoring the thousands—really, the tens of thousands—of projects that are being permitted under the Endangered Species Act. But technology can increase the efficiency of how we carry out the ESA, and therefore allow us to do more with the same amount of resources.

Let's move on now to the changes proposed to the ESA by the Trump administration. I know these have gone through at least one round of public comment already, so there have been some changes to the changes, themselves. Without going too much into the weeds, can you give us a sense of some of the most important changes in the proposals that are currently on the table?

A lot of what I've seen reported is inaccurate or just plain wrong. So, I urge your listeners to take with a grain of salt some of the media stories about the consequences of these regulations. In particular, I've seen a lot of fairly apocalyptic claims of the regulations entirely uprooting the foundations of the Endangered Species Act, and I just don't believe that's correct.

The regulations form a fairly mixed bag. There are some bad things, there are a whole bunch of really boring things that we won't talk about, and there are one or two things that will make some marginal improvements to conservation.

With that said, let me answer your initial question, which is, what are some of the main elements in this set of regulations? I would highlight four or five.

First, according to the final regulations, the federal government will allow itself to gather and publish information on the economic impacts of listing a species. This is super, super controversial because the decision on whether or not to list a species is supposed to be based entirely on science and biology. And it's really clear, as everyone agrees—even the Trump administration—that the government cannot consider economic impacts as part of the listing decisions.

But what they're going to do is something somewhat different, which is that they'll publish the economic impacts for the public to see. And they're basically saying, "We won't use that information as part of the decision; we just want to let the public see what the economic impacts are." I see two problems with this: First, it's really hard to blind yourself to the economic impacts if you're a federal agency and pretend like you're not considering them, when you're releasing them simultaneously with your decision. And second, it really adds more fuel to the fire. A lot of endangered species decisions are already incredibly controversial, and putting out what I view as a fairly biased economic impact analysis—which is only going to focus on the negative economic impacts, not the positive ones—is really not going to be helpful for conservation.

The second main element of the new regulations is that the government has now removed automatic protections for species listed as what's called "threatened" under the Endangered Species Act. There are two categories by which a species can be listed: threatened or endangered. For the lesser category of threatened, those species will no longer get automatic protections; instead, the government has to decide on a case-by-case basis whether or not to extend protections to threatened species, and if so,

which specific types of protections. This approach creates some risk that a species may not get as much protection as it needs, so it's been quite controversial.

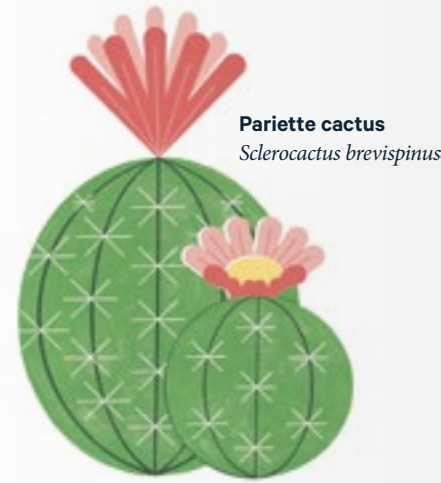
The third big change is around what's called "critical habitat," which are habitats that are needed to recover species. The short story on this is that it will become much harder to designate as critical a habitat that a species doesn't currently occupy. This concept of unoccupied critical habitat was the central issue in last year's Supreme Court case. Some of your listeners might remember that Weyerhaeuser case, which involved the habitat for the dusky gopher frog, which lives in the southern United States. The federal government designated unoccupied habitat for this species. It was really controversial, and the landowners brought the case all the way up to the Supreme Court. Basically, the Trump administration is responding to that by tightening up the ability to designate unoccupied critical habitat.

And the last thing I'll mention is that there is a new definition of how far into the future is "foreseeable" when it comes to deciding whether or not to list a species as threatened. This concept of "foreseeable future" has a lot of bearing on whether climate change is considered as part of a listing decision—and if so, how.

This is what you're going to see a lot of in the news, and these are some of the big-ticket items.

It sounds like, broadly speaking, most of those big-ticket items would be less protective of species, rather than more protective. Is that a fair characterization?

Yes, I would say that of the items I identified here, probably half of them will certainly result



in less protection, to some degree (Figure 1). I don't think it's apocalyptic in terms of completely gutting the Endangered Species Act, but absolutely, the regulations are going in the direction of less protection.

And then the other half is really a wait-and-see, honestly. That's my most objective assessment. It really depends on how the federal government will implement these new definitions.

And because the federal government has retained for itself so much discretion in how it interprets concepts like "foreseeable future" and how it issues protections for threatened species, we're really going to have to track what happens on a case-by-case basis. And that's something that my organization is going to be doing, so stay tuned for updates.

You've mentioned that it's a mixed bag. Are there any elements in the proposals that you think are positive steps? Are there any that you would highlight as particularly useful changes that would improve species or habitat protections?

“**What you see on a front page of the *New York Times* or the *Washington Post*—the poster child of endangered species—will usually be an animal.**”

Most people do not know that 57 percent of all US-listed species are plants.

” There's really nothing that I would applaud and say, "This is a progressive stance that will make species recovery easier and better." But there are a handful of things that will make marginal improvements to certain aspects of the Endangered Species Act. In particular, those improvements focus on something called the Section 7 Consultation process.

It's actually one of the most important parts of the Endangered Species Act—under Section 7, every federal agency is required to consult with expert wildlife agencies to ensure that their federal actions aren't going to jeopardize a species or destroy the species' critical habitat. For example, if the Army Corps of Engineers wants to fill and dredge a federal wetland, or build a bridge or highway, they have to speak with the US Fish and Wildlife Service to ensure that the destruction of the wetland doesn't jeopardize an endangered species. Every year, roughly 10,000 projects go through Section 7 review, and a few of the changes to the ESA will expedite the review process for federal agencies.

So that's good, right, because it's essentially creating an incentive for a federal agency to

say, "If we try to reduce the harmful impacts of our activities up front, we will get a benefit by having a faster Section 7 review process—our project will move forward more easily." And that's really important, if we think about the need to repair our infrastructure in America, because a lot of these infrastructure-repair projects will have impacts on endangered species and their critical habitat.

That's the main positive thing that I see from this rulemaking.

You've already mentioned a few things from the more negative, less protective side, but are there any more negative aspects of the proposed changes that you'd like to mention or anything else you'd like to highlight?

Sure, I'll just mention one more: In this Section 7 Consultation process we just talked about, a developer oftentimes needs to offset the harmful effects of their projects. Under the new regulations, that developer no longer needs to provide a specific plan showing that he or she will carry out those offset measures. So, it becomes very much an honor system.

I view that as really problematic, because the federal government almost never has had enough money to track whether commitments and promises are actually being followed up on. And under these new regulations, there's even less of a requirement to show up front that you're serious about actually following through on your promise.

These proposals are certain to be challenged in court by various state attorneys general. Do you have thoughts on the prospects for these cases in the federal court process? Will the cases hold up, or will they be struck down?

I do have an initial view based on reading the over 300 pages that were released to outline the recent proposed changes to the ESA: nothing jumps out to me as a slam-dunk legal argument.

There are certainly good arguments that the state attorneys general can make, and they've already made some in their comment letters last summer on the proposed regulations. But I do think this administration, in particular Secretary Bernhardt, has been pretty savvy legally to ensure that the changes don't put anything forward that is too patently illegal.

Let's close out this interview now with our "Top of the Stack" question, which asks, what's at the top of your literal or metaphorical reading stack?

I will recommend the best nontechnical book I've ever read on the ESA—and I've tried to read as many books as I can on the subject. It's called *Noah's Choice: The Future of the Endangered Species Act*, by Mann and Plummer. I think it's exceptional because it talks about the very difficult work of doing endangered species conservation when you have political and economic pressure from developers. It's not trying to vilify anyone—the book is saying that land development gives us wider highways, housing developments, and other things we need in our daily lives. But development also has impacts on endangered species. So, how do we balance these trade-offs? That is a perennially difficult question, and one that, if someone takes too extreme a view on the ESA, they sort of miss and think that the act is about saving every last population. In an ideal world, that would be great, but I think the politics of the ESA will not support such an extreme approach. *Noah's Choice* grapples with these very difficult trade-offs more effectively than any other book I've read ■



It’s a Good Time for Women to Win the Nobel Prize

Last year, Esther Duflo became the second woman, and the youngest person, to win the Nobel Prize in Economics (formally known as the Sveriges Riksbank Prize in Economic Sciences in Memory of Alfred Nobel). She shares the prize with Abhijit Banerjee and Michael Kremer; the three collaborate often and received the award for their experimental approach to alleviating global poverty using randomized controlled trials.

Catherine Wolfram, a university fellow with Resources for the Future (RFF), also relies on randomized controlled trials in some of her research—in her case, studying energy policy in both developed and developing countries. Thus, Wolfram is well-placed to comment on the significance of last year’s Nobel and share thoughts about being one of the mere 15 percent of economists who are working as full professors in the United States and who also happen to be women. The following Q&A is a condensed and edited version of a recent related conversation with Wolfram.

Resources magazine: Were you surprised that randomized controlled trials were the focus of this year’s Nobel Prize in Economics?

Catherine Wolfram: Honestly, I hadn’t been paying that much attention, but after the fact, it’s a phenomenal choice. I think they [Esther Duflo, Abhijit Banerjee, and Michael Kremer] really transformed not just the way development economics has worked, but in general, the way people are thinking about empirical economics.

Why do you think randomized controlled trials became so pervasive and important in the past 20 years?

Over that same time period, or maybe even 25 or 30 years ago, economists were starting what’s called the credibility revolution—thinking harder and harder about how to establish causality.

To use an energy example based on some of the work I’m doing, there’s a very strong

correlation at the country level between electricity consumption per capita and GDP [gross domestic product] per capita. But we don’t really know whether GDP growth leads to more electricity consumption. Maybe as people get richer, they have the income to be able to buy things like refrigerators, and then eventually air conditioners. That would be a GDP-causes-electrification explanation.

But maybe electrification causes GDP growth—with more electricity per capita, you literally have the physical means to make things and to have a big manufacturing sector. That’s the electricity-causes-GDP explanation. We don’t really know which explanation is correct, and it’s really important to figure out whether Y causes X, or X causes Y.

Can you briefly describe how a randomized controlled trial works? How does it establish causality better than other methods?

The key behind establishing causality is to establish a counterfactual—to establish what would have happened, but for the treatment. Let’s start with a medical example, where the treatment is usually a new drug.

With a randomized controlled trial, say you have a population of 1,000 people. You flip a coin and allocate heads into the control group, and tails into the treatment group. The control group gets the placebo, and the treatment group gets the drug. Because of randomization, everything about those two different groups is statistically the same, so you’re doing a true apples-to-apples comparison. Potential differences among people, like average age, health status,



Catherine Wolfram is a university fellow with Resources for the Future and a professor of business administration at the University of California, Berkeley.

ILLUSTRATION
Maria Fabrizio

“Essentially, there’s a risk that we’re looking under the lamp post—that we’re going to be doing a lot of randomized controlled trials around things that are easy to manipulate, and not other important questions.”

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propensity to exercise, diet, hours of sleep, stress, anxiety—all these things can be hard to measure. But because of the law of averages, they all should be statistically identical between the two groups. Because every single person had an equal chance of being either in the treatment group or the control group, then the only difference is that the treatment group got the drug, and the control group got the placebo.

It's not a simple extension to economics, because we're not talking about treatments where you can just sit there and watch whether the person takes the drug or not—we're talking about social programs, and things where people have to agree to participate. So, there's a reason that [Duflo, Banerjee, and Kremer] won the Nobel Prize for extending randomized controlled trials into a field like economics, where there are much more complicated treatments at work.

How did you start incorporating randomized controlled trials into your own research?

In general, I guess I got a little bit frustrated with the methods that people had been using to establish causality. There are methods called difference in differences, where you're praying to the causality gods that you got it right—that the group you're claiming is the control group is actually similar to the treatment group.

So, running a randomized controlled trial—it's just beautiful that you're able to establish causality purely by the way you design the experiment.

How have randomized controlled trials influenced environmental economics?

One example in the United States is a recent paper that's tackling environmental justice. Some early work suggested that maybe low-income and minority communities were more likely to experience pollution, kind of by choice: people were making the trade-off for good schools versus bad pollution. They were willing to experience high pollution because they could get some other amenity with it. It's an explanation that's consistent with the way economists like to view the world—that there's this big market, and everyone's making these rational cost-benefit calculations.

But this recent paper found that, particularly in low-pollution areas, renters with names that were clearly black and Latinx did not get responses to their inquiries for housing. Basically, the research showed that it's not this kind of rational cost-benefit calculus that people are making—there's discrimination in the housing market, and that's part of why black and Latinx and low-income people are more likely to be living near pollution. They're literally only getting responded to for housing in areas that are more polluted.

For a lot of papers related to the environment, they're looking at the health effects of pollution. But it's hard to think about randomly manipulating the amount of pollution. So, I think for some reasons, environmental economics has been one of the later fields to see randomized controlled trials used extensively. But people are getting more and more creative in finding ways to answer environmental questions with randomized controlled trials.

It's been acknowledged that randomized controlled trials don't always work so well, but when they do, they can be brilliant and amazing. Can you talk about what works well, and what proves to be too difficult, when you're using randomized controlled trials?

People argue that randomized controlled trials are not good at capturing spillover effects. In other words, you're looking at this treatment in a particular group, but what if people close to the treatment group were also impacted? I think that's a bit of a red herring, because there are ways to address this problem with a well-designed randomized controlled trial. If you think spillovers are important, then you can usually capture them.

And, as I said earlier, there are definitely things that are harder to manipulate, like pollution. You can't really randomly manipulate pollution—it would be politically and ethically challenging. One example that I've done is a randomized controlled trial on rural electrification in Kenya. Before that, there really hadn't been that much development economics work using randomized controlled trials to study questions in the energy sector. I think it's because of the big infrastructure investments—it's hard to think about how to randomize those. But I think people have gotten more creative and have been able to address some of the critiques.

I think the biggest thing is that you can't answer the more macro-oriented questions. Randomized controlled trials are not being used to study things like how changing the interest rate affects the overall economy; you can't just randomly change interest rates. So, in general, there's a limited scope, and randomized controlled trials are better for more micro-level questions. Essentially, there's a risk that we're looking under the lamp post—that we're going to be doing a lot of randomized controlled trials around things that are easy to manipulate, and not other important questions.

If a young economist is interested in making the largest possible impact with their research, how would you say they should choose their study system or their methods?

I guess it depends on what you mean by maximizing impact. I've often thought about the difference between medicine, for instance, and economics. In medicine, if you become a doctor, you're very clearly having a profound impact on people's lives, but just not that many of them. Whereas if you go into economics and try to argue for a carbon tax, you would potentially have a massive impact on billions of people's lives if you could get the policy enacted. But the chances of getting it enacted are really slim.

It just depends on whether you'd rather be sure that you could help a wastewater treatment plant get built in your city, for example, or whether you'd rather have some small part to play in influencing the discussions about climate change. So, it depends on whether you prefer the doctor model, or what I would characterize as the economist model.

Do you have other general advice that you would give a young economist who's coming up in the field today?

I would just say, pick something that you're passionate about, because it's great to wake up in the morning and be excited by what you're going to be spending your day on.

Do you think that advice would differ for an economist who also happens to be a woman?

Esther Duflo has been very critical of sexism in the field, and I agree 100 percent with the way she's characterized it. Historically, there has been this kind of macho, locker-room atmosphere, especially

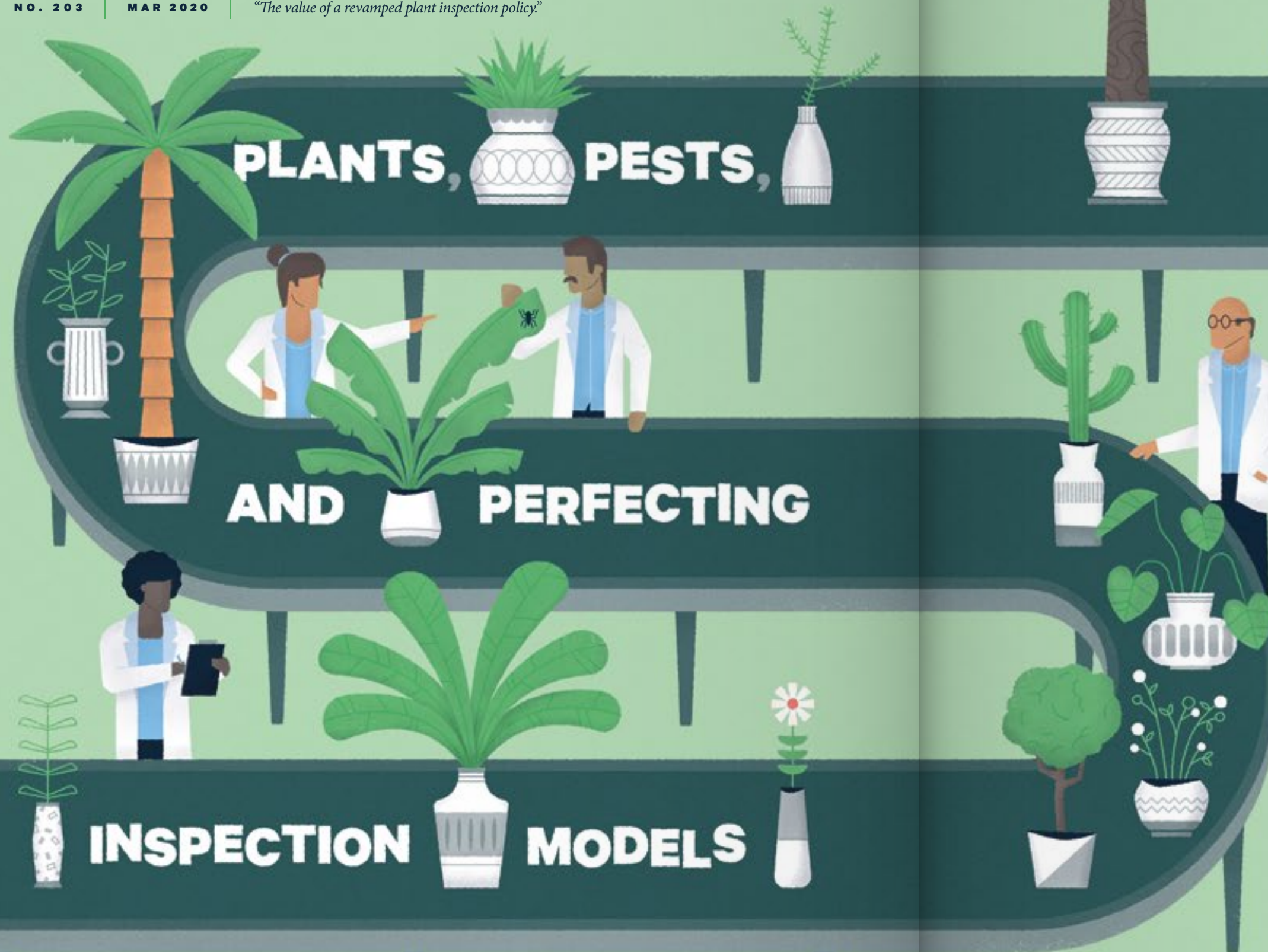
in seminars. On the job market, for instance, you're presenting what you've spent years working on; people then try to suggest that it's either not interesting, not right, or that you've done something wrong. So it can be really disheartening. I went to a seminar once that was joint with a discipline outside of economics. The economists started asking what I thought were some pretty benign questions of the job market candidate. The people in the audience from the school of social work turned to the economists and said, "Jeez, leave him alone. You're being so mean." So it just reminded me that there are different seminar cultures, and the culture in economics is particularly aggressive. And hopefully changing.

I was at an environmental economics conference recently, and it was really noticeable to me how constructive the questions were—there are just different ways of asking questions. One is, "You idiot, why didn't you think of X, Y, or Z?" And another is to say, "This is really interesting. It might be even more interesting to think about X, Y, or Z." So, a lot of it is just common courtesy and culture.

I am relatively optimistic that things are changing. I think that people are talking about it, and that's the first step toward change. So, I guess I would say, just hang on. Hopefully things will be better in five or 10 years. I do think having more women around is just more comforting. You don't feel like such an outsider. You don't have the experience of being the only woman in the seminar room if there are more women in the field. Hopefully it's one of those virtuous cycles that the more women we get, the more comfortable women will feel in the field.

The field will be that much better off by having more women, because we won't lose them to statistics, or engineering, or finance, or whatever they're doing instead. Culturally, women are encouraged to think about different things, so maybe we'll broaden the set of topics studied in the field. But I think the first-order effect is that we'll retain the smart, creative women in this field and not lose them to other fields.

And I guess that the suggestion to find something that you're passionate about is even more relevant to women, because there will be days where you're subject to some kind of sexism, and you've just got to remind yourself why you love what you're doing and why it's important. Walk beyond that and keep going ■



Distinguished by tiny yellow flowers that bloom each spring, the Scotch broom seemed a natural addition to Thomas Jefferson's exotic private garden. One of America's earliest horticulturists, Jefferson imported many of his plants from outside the continent—but this shrub's influence would prove unusually enduring. Native to Europe, the Scotch broom now extends as far west as California. It causes millions of dollars in damage each year, displacing native plants and releasing seeds that are toxic to livestock.

That a Founding Father might be responsible for introducing an invasive species to the continent neatly encapsulates how central plant imports have been to America's development and how easy it is for nonnative species to wreak havoc in a new land. The economic benefits of the global plant trade are varied: most plants currently used across the agriculture, forestry, and horticultural industries were originally imported. But the consequences of invasive species like the Scotch broom can be stark. "Invasive species disrupt agriculture and other managed landscapes, they cause loss of ecosystem services, and they can either cause or help to spread disease," says Michael Springborn, an associate professor at the University of California, Davis. One widely cited study out of Cornell University estimates that invasive species can run up recurring damages of \$120 billion annually.

The international plant trade still creates opportunities for invasive plants to thrive, but the trickier challenge nowadays is invasive insects and plant diseases, which can hitch rides on plant shipments sent to America and more easily evade detection than a rogue shrub. "Live plant imports have historically been a primary pathway for invasive pest introduction. They're the perfect place for insects or diseases to come into the country, because the pests are riding on their host material," explains Dr. Rebecca Epanchin-Niell, a fellow at Resources for the Future (RFF) who closely studies invasive pests. "You're trying to keep the plants alive, so therefore, you're also helping keep the pests alive as they come in."

Research conducted by Epanchin-Niell and Springborn, along with a working group of experts supported by the University of Maryland's National Socio-Environmental Synthesis Center (SESYNC), is helping to inform a recent policy shift in how the US government inspects plant imports. Based on years of research and collaboration, their proposed policy solution works within established regulatory frameworks but allocates existing resources in a novel way, ultimately incentivizing plant producers to keep pests out.

Lay of the Land

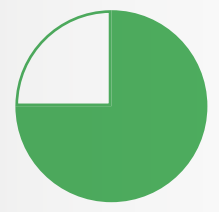
While pest-infested plants represent only a tiny proportion of all shipments that enter the United States, one study, whose authors include some members of the SESYNC working group, affirms that infested plant shipments have passed through US ports undetected in spite of the risk mitigation policies that had been in place in 2009. Another study estimates that, even as inspection and other biosecurity policies have improved over the decades, an average of 2.5 new species of invasive insects establish in the United States every year.

Regulations governing the spread of plant species have existed since at least the 1700s, but since the introduction of the Plant Protection Act in 2000, the Animal and Plant Health Inspection Service (APHIS) has had sole discretion over inspecting plant imports. For many years, the agency employed a model that instructed inspectors to examine about two percent of each arriving shipment. In effect, this approach led to oversampling large shipments and undersampling small

TEXT
Cole Martin
ILLUSTRATIONS
James Round

“**All those plants go through one of just 16 plant inspection stations, from Guam to New Jersey to Puerto Rico, where inspectors look for impossibly small damages or discolorations in impossibly large plant shipments.**”

Invasive Species by the Numbers



Invasive species potentially pose a risk to more than 75% of US-listed endangered and threatened species. The only threat that ranks higher is habitat loss and degradation.

\$120 billion

Estimated cost of damages caused by invasive species in the United States each year.



An estimated average of 2.5 new invasive insects establish in the United States every year

43m plants

Approximate workload per year for a plant inspector in the United States.

1 foot

Daily growth rate of kudzu, an invasive vine that smothers native plants (and any other surface) with its dense mats.

ones. "[APHIS] recognized that this might not be the most efficient strategy, both because it was an inconsistent means for gathering information, but also because it equally targeted low- and high-risk material," Epanchin-Niell says.

So, in 2011, the agency publicly indicated that it was looking to implement a "risk-based sampling and inspection approach" for managing plant imports. This would involve two major shifts: APHIS would inspect different amounts of each shipment depending on the shipment's size, and APHIS also would prioritize the inspection of shipments that were deemed to be a higher risk. Epanchin-Niell and Springborn answered the call to devise the optimal policy—one applicable to the nation's needs and one that was possible, given the resources available to APHIS. A major problem: there was no scholarly consensus as to which type of risk-based model would be ideal, especially given the immensity of the global plant trade.

Hatching a Plan

Instead of setting out to develop a brand new solution, Epanchin-Niell and the other researchers first looked to other countries for guidance, but the ways in which different leading economies inspect incoming plants and record data vary wildly. A very restrictive policy—like New Zealand's system, where most imported plants have to be quarantined and observed before being allowed entry—would slow down a booming trade and require more resources than APHIS has available. Conversely, a too-lax policy might make it easier for nonnative pests to invade local ecosystems.

The central challenge that Epanchin-Niell and Springborn faced was the seeming inevitability of new pests escaping detection, especially as government resources failed to match the rate of new imports. An estimated five billion plants enter the United States every year, and that number has grown precipitously over recent decades. All those plants go through one of just 16 plant inspection stations, from Guam to New Jersey to Puerto Rico, where inspectors look for impossibly small damages or discolorations in impossibly large plant shipments. One study estimates that the average workload for an APHIS inspector in 2010 was 43 million plants per inspector per year.

Ideally, the optimal inspection model would keep pests out; gather information about the risk posed by different exporters; and, to reduce the burden on inspectors, create incentives for producers to hold themselves to higher standards.

Altering producer behavior was the most necessary goal of a new inspection model—and simultaneously the most vexing. "Perhaps most importantly, inspections [should] motivate exporters to try to keep their shipments clean," Springborn says. "No exporter wants their shipment stopped at the border, nor do they want to become flagged as a higher risk worthy of greater inspection intensity in the future."

The collaborators at SESYNC were able to estimate the economic impact of three major invasive pests in North America, compare importation policies and best practices across a variety of countries, and eventually propose a risk-based inspection model that is applicable to American needs and regulatory frameworks.

“The goal of the research was both to provide some empirical and theoretical support for how shifting to [a risk-based] policy could improve outcomes, and also to figure out how to implement that policy, for it to be most effective,” Epanchin-Niell says.

Making Moves

Ultimately, their proposed solution was nominally straightforward: separate producers into one high-risk group and one

low-risk group. Exporters with a history of good behavior and low interception rates would face less scrutiny in future shipments, while exporters whose shipments contained pests more often would be subject to a more intensive screening. Rather than devoting resources equally to all producers, more would be devoted to those that posed the greater risk. Based on their analysis, 20 percent fewer infested shipments would enter the United States if APHIS enacted the suggested policy—with no increase in funding or resources required.

The most surprising part of this research to Epanchin-Niell was “the magnitude to which the behavior response [to the risk groups] affects the anticipated rate of introduction of pests.” Essentially, producers designated to the high-risk group have obvious reason to put more effort into ensuring their plant shipments

are uninfected, because better performance means a chance to move into the quicker low-risk inspection group. But those producers designated as low risk have reason to adjust their behavior, too: so they can remain in the expedient inspection group and avoid more burdensome inspection procedures. A simple designation encourages all kinds of producers to improve their behavior, whereas a uniform inspection model—where good behavior is not rewarded, and bad behavior isn’t punished—provides a much weaker incentive for improvement.

“The response of the low-risk exporters is what’s neat. Even though they enjoy a lower inspection rate, they still have a very strong incentive to stay clean, because they don’t want to risk falling into the high-risk group. Economists call this ‘enforcement leverage,’” Springborn says.



“**If a plant inspection policy is working, the ecosystem around us ideally grows undisturbed.**

But the consequences of a malfunctioning inspection system might become more noticeable: new pests invade forests, ravage ecosystems, and spread more quickly than humans can stop them.



Informed in part by the research of Epanchin-Niell and Springborn, APHIS is in the process of implementing significant changes to its inspection model. It has already moved away from the uniform two percent model in favor of a risk-based sampling system, which prompts inspectors to examine more than two percent of small shipments and less than two percent of larger shipments. The agency has yet to fully implement the more substantial policy shift of splitting producers into low- and high-risk groups, but APHIS has signaled it is moving in that direction. Understandably, rolling out a comprehensive policy shift across APHIS’s 16 inspection sites, gathering enough evidence to gauge the relative risk posed by thousands of international plant producers, and applying enough enforcement to meaningfully alter behavior will take time.

Once the new rules are fully enacted, little will appear to change, at least to the average consumer who buys a garden shrub or looks out over the landscape. If a plant inspection policy is working, the ecosystem around us ideally grows undisturbed. But the consequences of a malfunctioning inspection system might become more noticeable: new pests invade forests, ravage ecosystems, and spread more quickly than humans can stop them. The value of a revamped plant inspection policy is, in part, the assurance that the plants we use to structure our lives, that have been central to American life for decades and more, will keep growing ■

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

#MyResources

The Association of Environmental and Resource Economists (AERE) met in Lake Tahoe, Nevada, for last year's summer conference. In January this year, Karen Palmer began her term as president-elect of AERE, which established in 1979 and calls RFF its "working heart."

Pictured, from left to right

RFF Senior Fellows Dallas Burtraw, Margaret Walls, Alan Krupnick, and Karen Palmer.

“

More post--#AERE2019 hiking. The @rff crowd. Fun way to end a great conference.

”

PHOTO
Margaret Walls
Senior Fellow at RFF



Florida Climate Outlook

A case study for estimating the effects of climate change

TEXT

Daniel Raimi,
Amelia Keyes,
and Cora Kingdon

INFOGRAPHICS

James Round

Climate change is affecting our world today, and these effects will become more significant in the years to come. In the United States, one state that is particularly susceptible to some of the most damaging consequences of climate change is Florida.

Florida’s long coastline and low-lying land make it particularly vulnerable to the damaging impacts of rising sea levels, which are projected to rise faster in Florida than the global average. Florida is also more exposed than any other US state to damages from tropical storms. Because the average age in Florida is higher than in most other states (with a larger share of the population older than 65), some communities in Florida are at higher risk due to rising temperatures.

The discussion that follows, punctuated in the next several pages by illustrations, provides an overview of the implications of a changing climate for Florida and the people who live there, mostly drawn from projections over a 20-year horizon. We examine climate change projections in

Florida under two plausible scenarios: a moderate-emissions scenario, where global greenhouse gas emissions rise by roughly 1 percent annually over the next 20 years; and a high-emissions scenario, where emissions rise by 3 percent annually. These scenarios are drawn from an extensive literature and correspond with climate scenarios known as Representative Concentration Pathways (RCP) 4.5 and 8.5. We apply similar scenarios for future sea level rise.

These projections include substantial uncertainty ranges for two key reasons. First, the future level of greenhouse gas emissions is unknown. Generally speaking, lower levels of emissions lead to lower damages. Second, despite major advances in climate science over the past several decades, there is still large uncertainty surrounding the Earth’s response to a given level of emissions. For example, the IPCC in its most recent Assessment Report estimates that the long-term warming associated with a doubling of atmospheric carbon dioxide levels spans a “likely” (66% probability) range of between 3°F and 8°F.

Results are based on our review of the available literature and rely in several cases on the work of the Climate Impact Lab, an interdisciplinary group producing detailed local projections of the effects of climate change.

Sea Level Rise

Understanding Sea Level Rise in Florida, 2040

Infographic on page 33 ▶

Climate change raises sea levels by increasing ocean temperatures (which causes water to expand) and by melting glaciers and ice sheets (which adds water to the oceans). Before land is permanently submerged, rising seas will lead to higher and more frequent coastal flooding. Several major tourist attractions, including the Everglades, Biscayne National Park, and Miami Beach, are largely situated on land less than three feet above the high-water mark and may become permanently submerged by the end of the century. Higher sea levels can also raise the groundwater level, indirectly increasing the severity of flooding by decreasing the capacity of the soil to help with drainage, which results in floodwaters remaining higher for longer periods of time. Extreme flooding that previously would have been expected to occur just once every 100 years (a “100-year” flood), with waters reaching 2–3 feet above the high-water mark, will become more frequent.

As sea levels rise, ocean water will continue to move farther inland into freshwater aquifers in a process known as saltwater intrusion, posing a contamination threat to drinking water and

agriculture. Particularly at risk is the Biscayne aquifer, located under Miami-Dade County, which provides drinking water to around 4.5 million people ■

Storms

Effects of Climate Change

on Storms in Florida

Infographic on page 35 ▶

More than any other US state, Florida is susceptible to damages from tropical storms, and climate change is projected to increase these risks. The most severe property damage from tropical storms is typically caused by storm surges. Although many communities have prepared for a certain level of surge, small increases above that preplanned level can lead to a large increase in damages and even disruption of evacuation routes. More severe storms not only pose risks to human lives and prosperity—they also reduce regional economic output over the short and long term. While a variety of protective measures can reduce damages, existing research suggests that the most economically rational option in some cases will be to abandon substantial areas of currently inhabited land, by the end of the century ■

Human Mortality

Effects of Climate Change on

Human Mortality in Florida

Infographic on page 37 ▶

Climate change directly affects mortality rates through physiological responses to heat or cold. Climate change also is likely to indirectly affect human health through changing patterns of disease vectors (i.e., mosquitoes and other organisms that

can transmit diseases), extreme weather, human conflict, and other environmental or socioeconomic pathways. Other risks that increase due to climate change result from energy supply disruptions, storm-related flooding, suicide, and wildfire ■

Climate Policy

Impacts of Federal Climate

Policies on Florida Households

Infographic on page 39 ▶

Momentum is growing in the US Congress to address climate change, and many legislators are turning to carbon pricing to reduce greenhouse gas emissions quickly and efficiently. These carbon pricing policies charge emitters for the carbon dioxide (CO₂) they release into the atmosphere through the combustion of fossil fuels. Our analysis uses two models of the US economy, built by RFF researchers to estimate the effects of these proposed policies on US and Florida households. Importantly, the models do not account for the benefits of avoiding climate change or the benefits of investments in infrastructure and green technologies. (Explore the impacts in greater depth using RFF’s interactive Carbon Pricing Calculator tool at www.rff.org/cpc.)

Of the eight policy proposals we analyze, initial carbon prices range from \$15 to \$52 per ton of CO₂, rising at different rates over time. The most important policy design choice that determines how households are affected is how the revenues from carbon pricing are used. We find that climate policies can reduce household income; however, carbon pricing also generates substantial revenues that can significantly benefit households by,

for example, distributing dividends (lump-sum payments to households) or reducing taxes. Most existing proposals that distribute dividends leave low-income households better off, while high-income households are made worse off ■

Agriculture

Effects of Climate Change

on Agriculture in Florida

Infographic on page 41 ▶

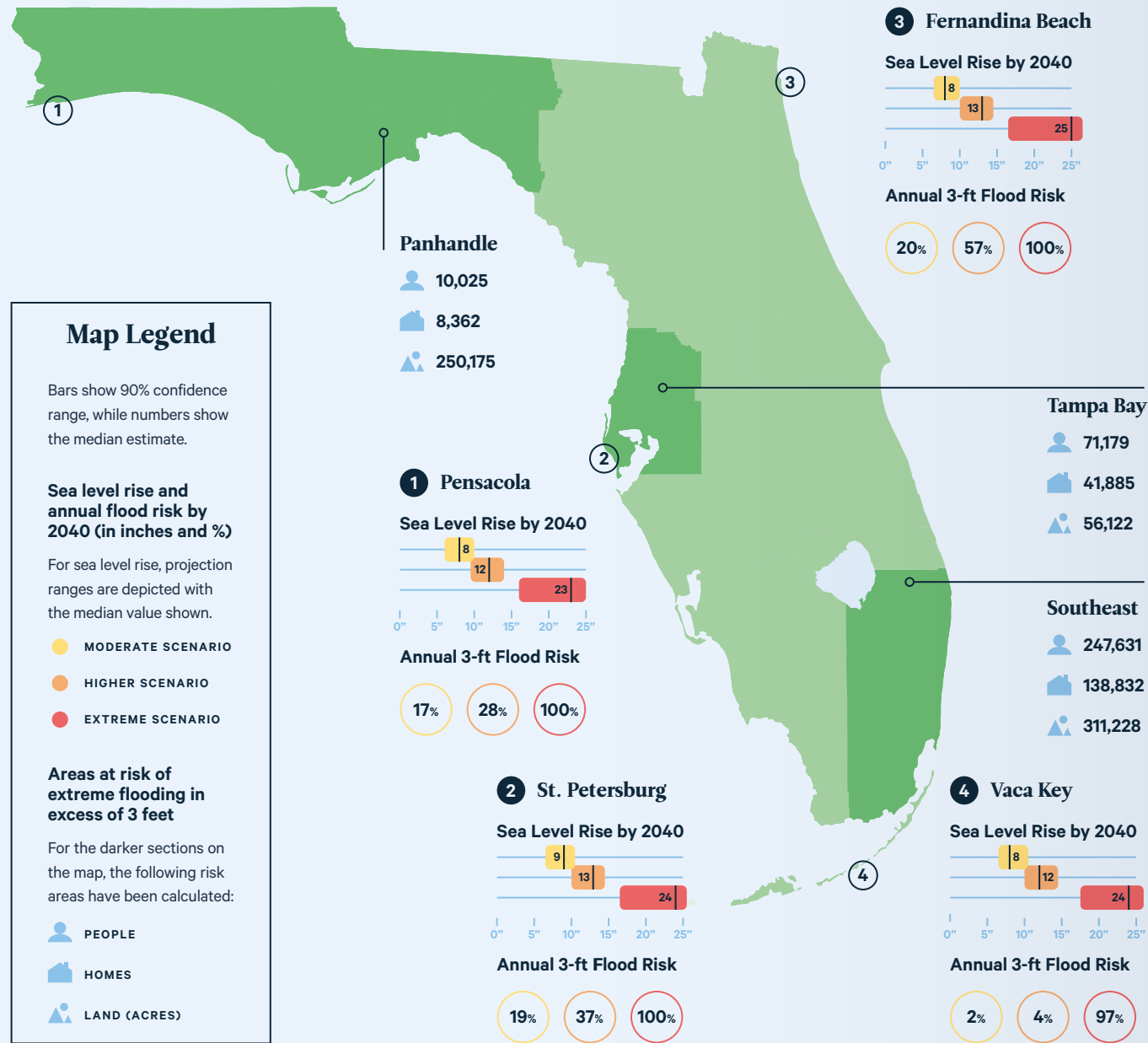
The relatively small role of agriculture in Florida’s economy suggests that any impacts are unlikely to have major economic consequences for the state as a whole. However, climate change is projected to increase the frequency and severity of droughts in Florida, which would exacerbate competition for Florida’s water resources. In 2015, the state’s farms consumed 3.2 billion gallons of fresh water per day—and this figure is projected to rise by 17 percent through 2035. In 2017, roughly 75 percent of Florida’s planted cropland was irrigated mechanically (i.e., not rain-fed). As droughts intensify, crop irrigation may become more costly.

Warmer temperatures are projected to have a variety of other negative effects, including reduced labor productivity for outdoor farmworkers and reduced productivity of livestock and dairy cows ■

Daniel Raimi is a senior research associate, **Amelia Keyes** is a research associate, and **Cora Kingdon** is a research assistant at Resources for the Future.

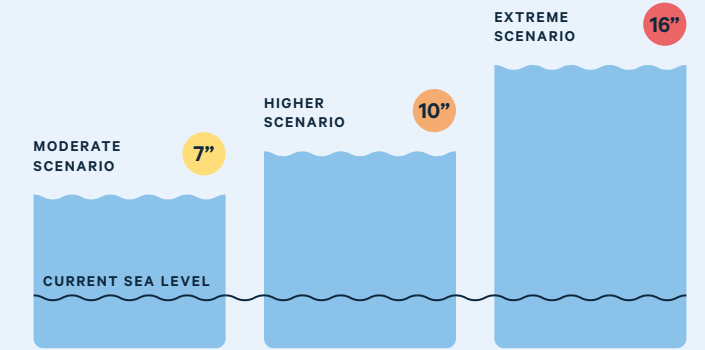
The authors acknowledge the VoLo Foundation for funding this project.

Understanding Sea Level Rise in Florida, 2040



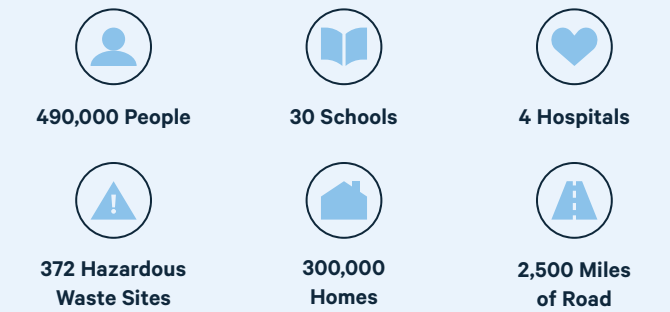
Global sea level rise scenarios reveal an uncertain future

Future sea level depends on greenhouse gas emissions and atmospheric / oceanic processes. Moderate and higher scenarios represent a plausible range, while the extreme scenario is very unlikely, but still possible (<1% likelihood).



Sea levels are projected to rise faster in Florida than the global average

By 2100, large swaths of coastal land in Florida will be permanently submerged. In the shorter term, rising seas will increase the frequency and severity of coastal flooding. Statewide, three feet of flooding puts at risk:

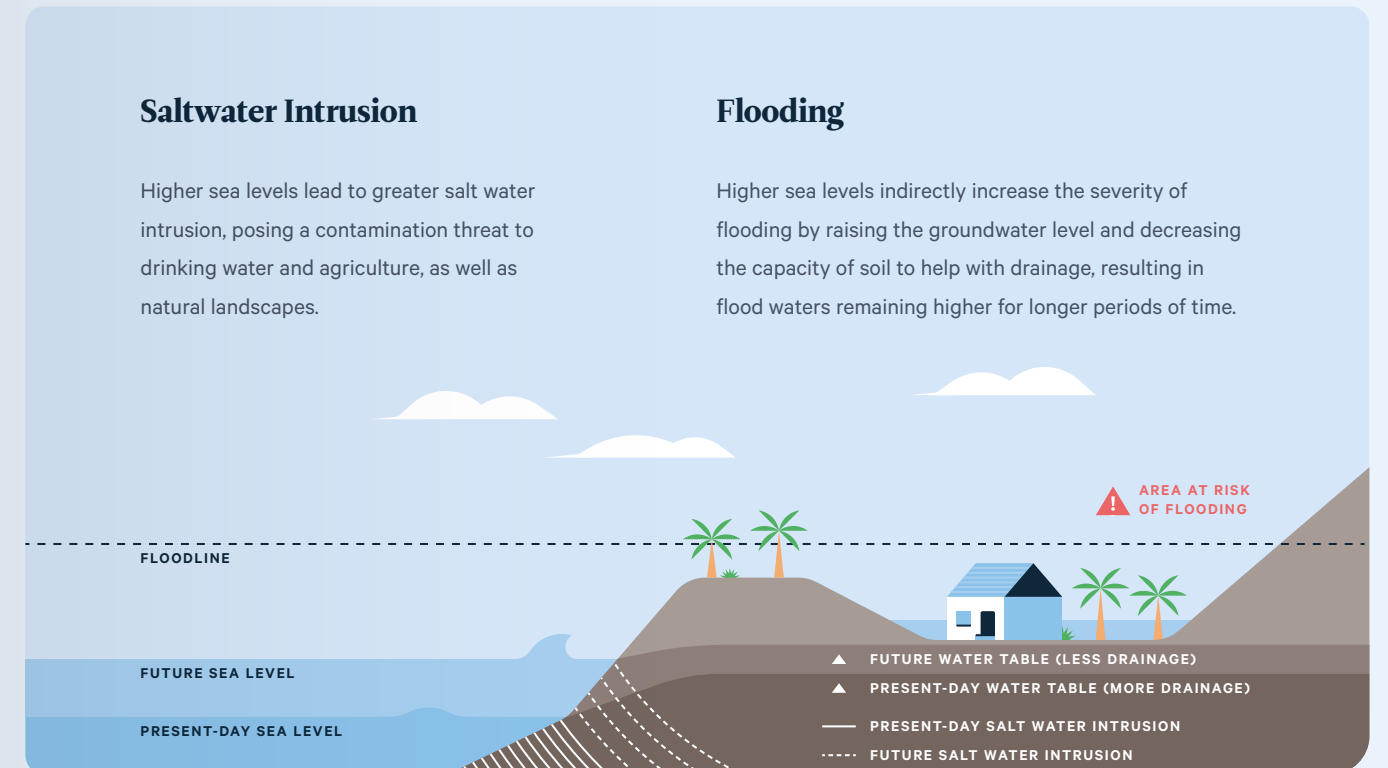


Saltwater Intrusion

Higher sea levels lead to greater salt water intrusion, posing a contamination threat to drinking water and agriculture, as well as natural landscapes.

Flooding

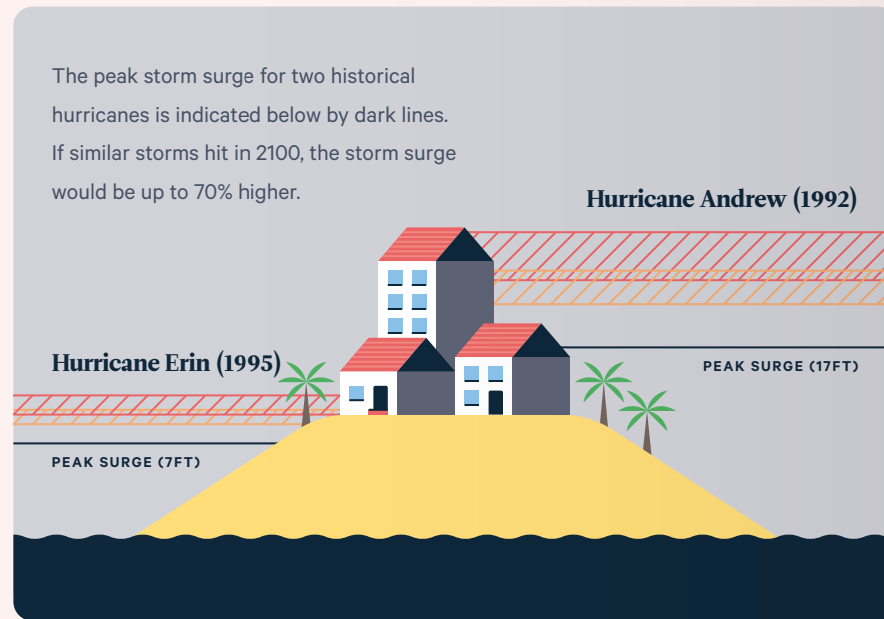
Higher sea levels indirectly increase the severity of flooding by raising the groundwater level and decreasing the capacity of soil to help with drainage, resulting in flood waters remaining higher for longer periods of time.



Effects of Climate Change on Storms in Florida

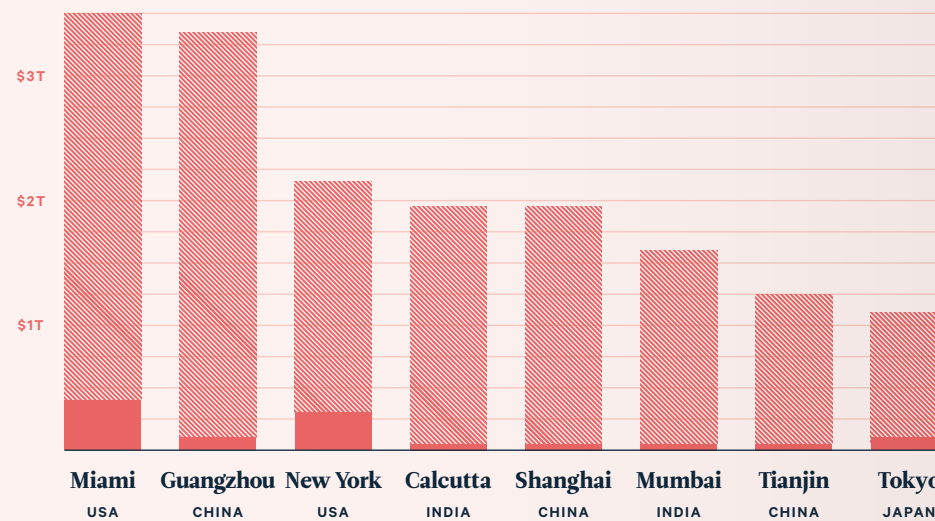
More than any other US state, Florida is susceptible to damages from tropical storms

By 2100, rising seas and more intense storms will increase storm surge by 25–47% under a moderate emissions scenario and by 40–70% under a higher emissions scenario.



Miami is one of the world's most at-risk cities for coastal flooding

By one measure, Miami faces the largest risk of any major coastal city, with \$400 billion in assets at risk as of 2005, growing to \$3.5 trillion by the 2070s.



Florida cities are investing to protect against the risks ahead

- ### 1 Beach Nourishment

Fortifying existing beaches can help protect low-lying coastal property.
- ### 2 Building Protective Barriers

In some cases, hard barriers such as sea walls may be needed.
- ### 3 Raising Infrastructure

Some buildings, roads, and other infrastructure will need to be raised.
- ### 4 Restoring Natural Habitats

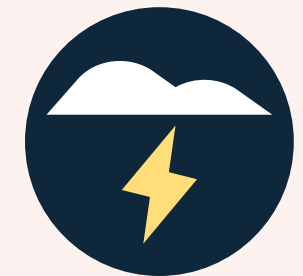
Wetlands and other coastal ecosystems provide natural protection.

These protections won't prevent all damages



Population Displacement

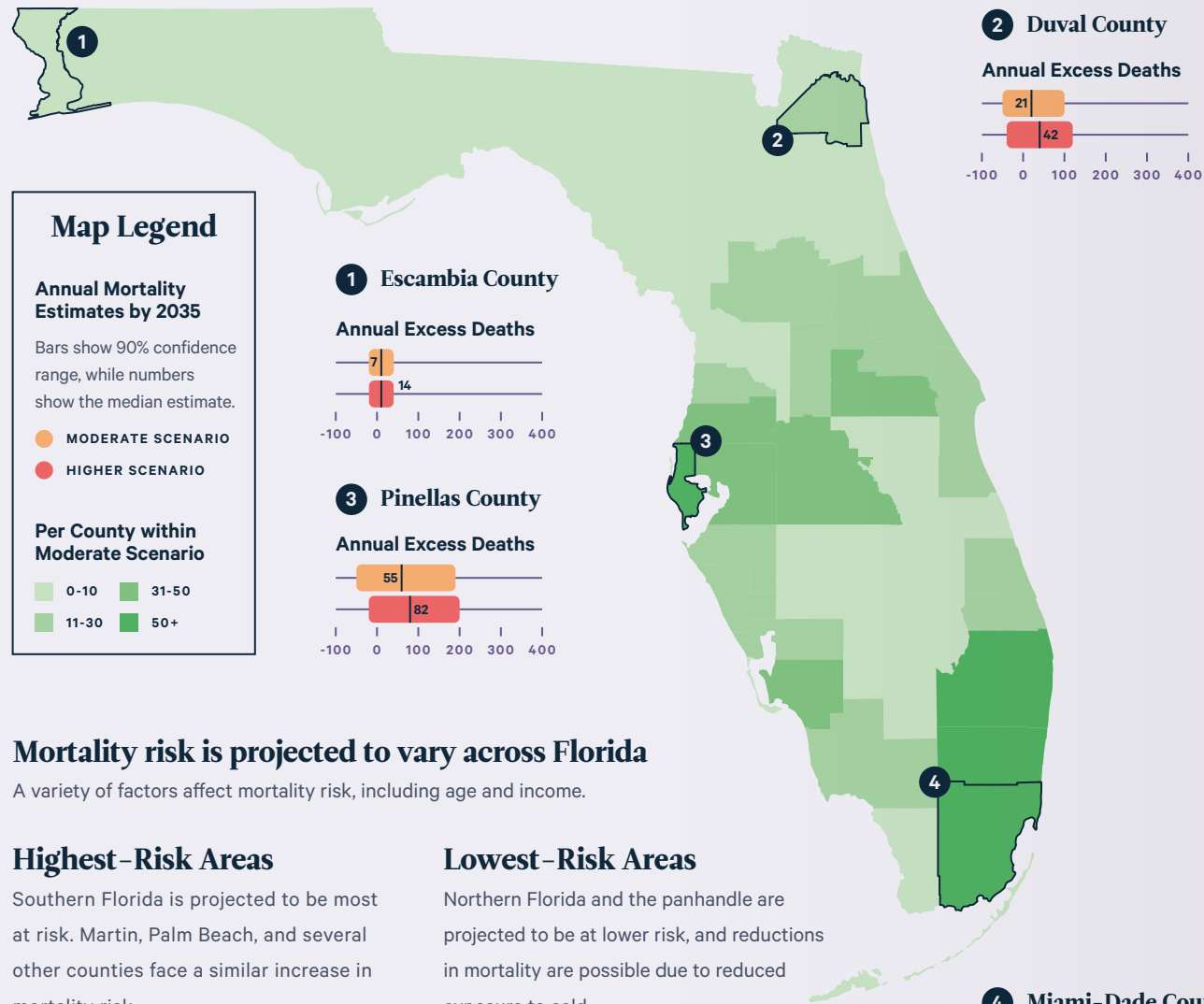
The high cost of protection in some areas, like parts of Tampa Bay, suggest the most economically rational option will be to abandon substantial areas of inhabited land.



Other Severe Weather

Scientists are currently unsure whether climate change will increase the frequency or severity of storms that produce damaging hail or tornadoes.

Effects of Climate Change on Human Mortality in Florida



Mortality risk is projected to vary across Florida

A variety of factors affect mortality risk, including age and income.

Highest-Risk Areas

Southern Florida is projected to be most at risk. Martin, Palm Beach, and several other counties face a similar increase in mortality risk.



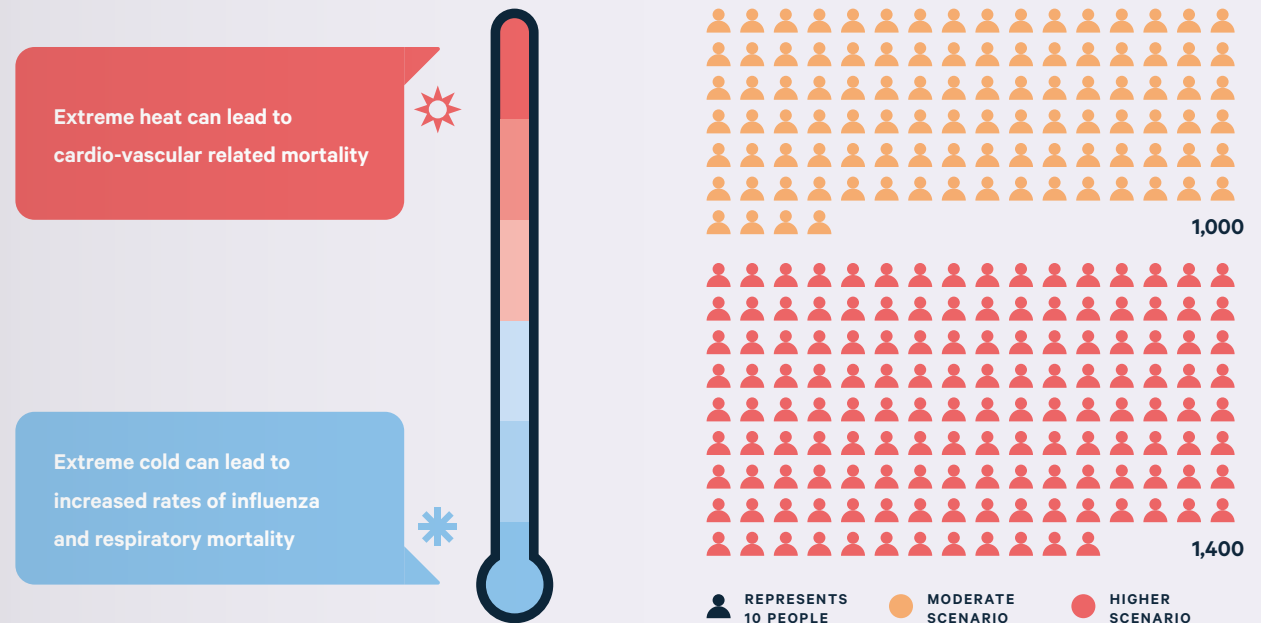
Lowest-Risk Areas

Northern Florida and the panhandle are projected to be at lower risk, and reductions in mortality are possible due to reduced exposure to cold.



Extreme heat and cold are both factors that can directly increase mortality

Extreme temperatures lead to physiological responses (e.g., increased heart rate) that can endanger well-being through cardiovascular, cerebrovascular, and respiratory pathways. Studies consistently find higher mortality rates at very high and very low temperatures.



Other factors are likely to increase mortality risk in Florida

An older population

20.5% Florida vs 16% US Avg.

A larger share of Floridians are above age 65 than the US average, meaning higher risks from temperature extremes.

Disease risks will increase

Risks of chikungunya, dengue, and Zika will become greater as mosquitos become active for more of the year.

Research highlights new risks

Climate change may also increase mortality risk from energy disruptions, storm-related flooding, suicide, and wildfire.

Impacts of Federal Climate Policies on Florida Households

Legislators are turning to carbon pricing plans to reduce emissions quickly and efficiently

We analyzed eight proposed federal carbon pricing policies to understand their impact on Florida. The policies have initial carbon prices ranging from \$15 to \$52 per ton of CO₂ and have various means of revenue usage. The bills are labeled by their primary sponsor.

1 Payroll Tax Cuts

Two bills use most revenues to reduce payroll taxes.

- Rep. Rooney
- Rep. Lipinski

3 Dividends

Four bills use most revenues to return dividends (direct payments) to households.

- Sen. Coons
- Sen. Whitehouse
- Sen. Van Hollen
- Rep. Deutch

2 Infrastructure Spending

Two bills use most revenues to invest in infrastructure.

- Rep. Fitzpatrick
- Rep. Larson

4 Impact Areas

Policy impacts are driven by changes in household expenditures and income. Ranges depict the bill with the smallest impact up to the bill with the largest impact.

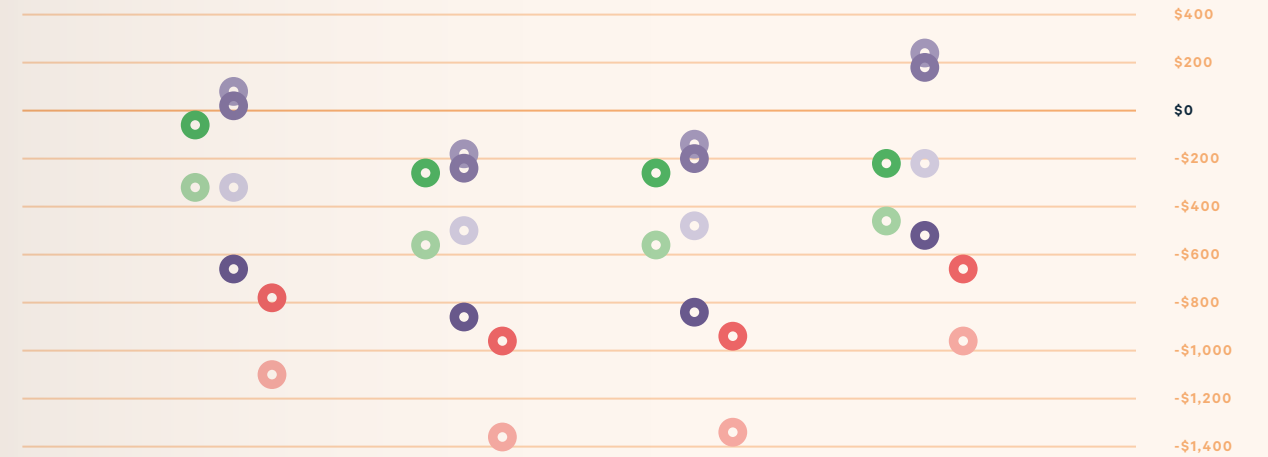
- Energy Goods**
e.g., gasoline and electricity
- Other Goods**
e.g., healthcare and food
- Sources of Income**
e.g., wages and dividends
- Total Impact**

How will the policies affect Florida compared to the rest of the United States?

US VS. Florida

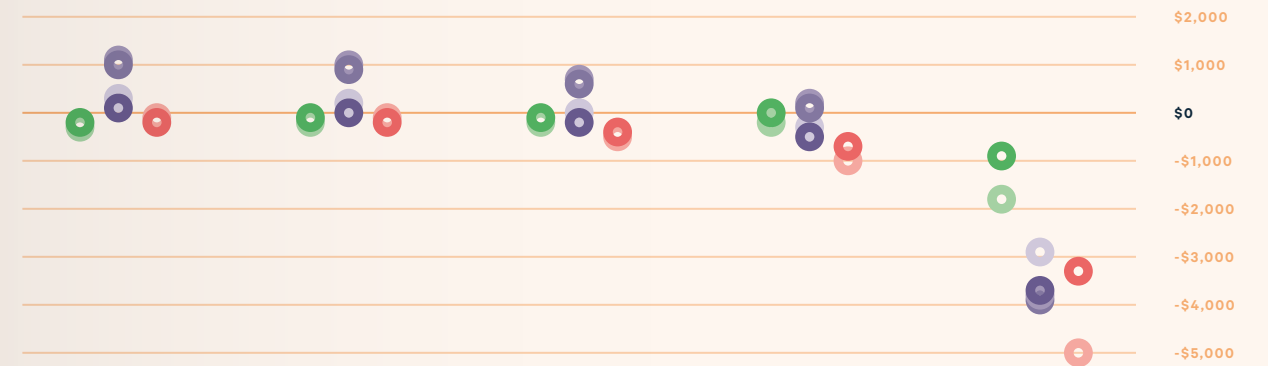
How will the policies affect urban and rural households in Florida differently?

Urban VS. Rural



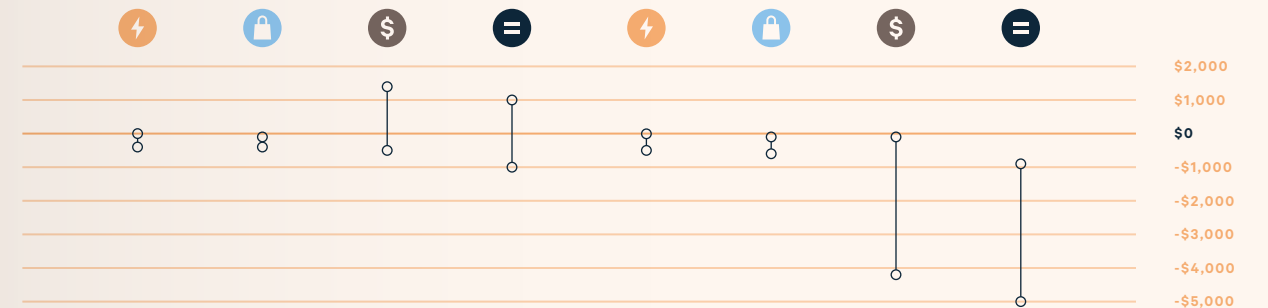
How will the policies affect households in Florida at different income levels?

QUINTILE 1: Below \$21k, QUINTILE 2: \$21k - \$39k, QUINTILE 3: \$39k - \$61k, QUINTILE 4: \$61k - \$99k, QUINTILE 5: Above \$99k



How will the policies affect income and spending?

QUINTILES 1 - 4: Household income under \$99k, QUINTILE 5: Household income over \$99k



Effects of Climate Change on Agriculture in Florida

More than any other US state, Florida is susceptible to damages from tropical storms

By 2100, rising seas and more intense storms will increase storm surge by 25–47% under a moderate emissions scenario, and by 40–70% under a higher emissions scenario.

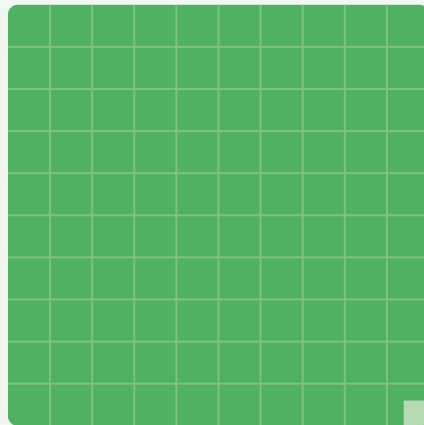
0.2%

The sector employs just a small percent of Florida's workforce.

\$25k

Workers are paid well below the state average of \$46,000 per year.

Florida's Economy



Agriculture makes up only 0.6% ▲

Florida's Agricultural Economy



Sum may not total 100% due to rounding

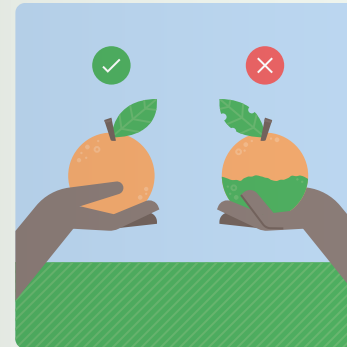
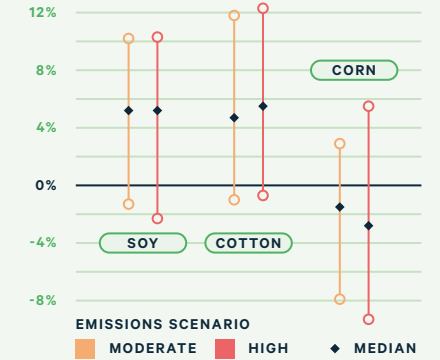
Grains / 1% ▲



Staple crops may benefit somewhat from climate change in Florida

Cotton and soy yields increase by 5–6%, and grains increase by 1.5–3% under moderate and high scenarios, but with large uncertainty.

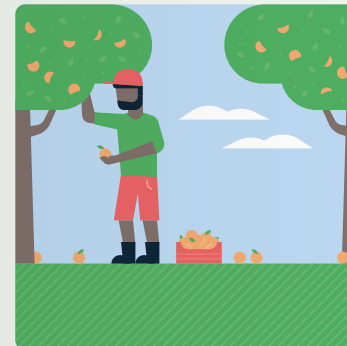
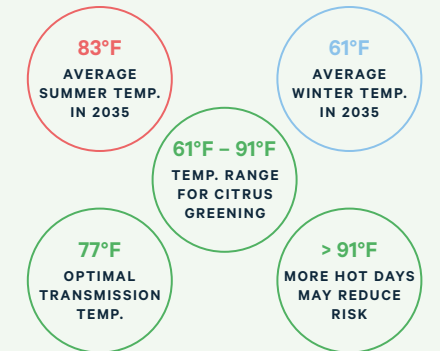
PROJECTED EFFECTS OF CLIMATE CHANGE ON CROP YIELDS BY 2035 →



Citrus greening poses a threat to Florida's iconic agricultural products

Climate change will affect the risks of citrus greening, making transmission more likely in the winter but less likely during hot days in the summer.

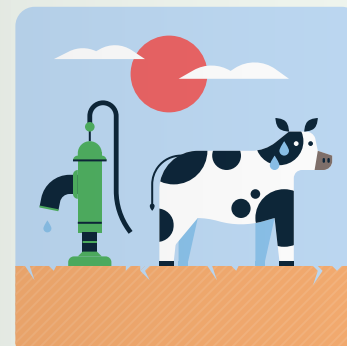
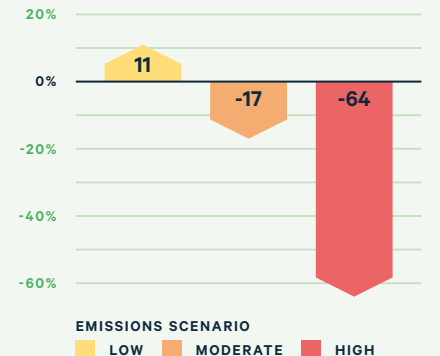
CITRUS GREENING TRANSMISSION IN A CHANGING CLIMATE →



Outdoor farmworkers in Florida face challenging working conditions

Under a moderate emissions scenario, labor productivity for outdoor workers decreases by 17% per worker, but there is substantial uncertainty.

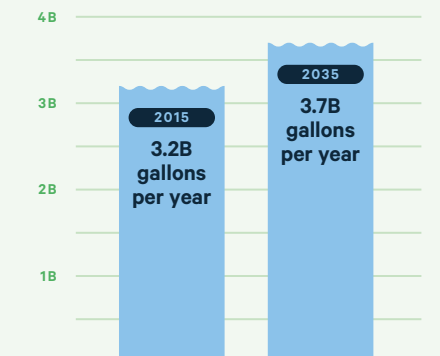
CLIMATE IMPACTS RANGE FROM SLIGHTLY POSITIVE TO VERY NEGATIVE →



Increased heat and drought across Florida are projected to have negative effects

Increased frequency and severity of drought will exacerbate water stress. Higher temperatures will reduce livestock output and breeding productivity.

FLORIDA AGRICULTURE RELIES HEAVILY ON IRRIGATION →





A Blueprint for Durable Climate Policy: the Evolution of RGGI

How the Regional Greenhouse Gas Initiative (RGGI), a program to reduce greenhouse gas emissions, has become a model that inspires other similar programs in the United States and around the world.

TEXT / Paul Picciano

ILLUSTRATION / Maria Fabrizio

Just over a decade ago, the first mandatory carbon emissions abatement program in the United States launched, with the Regional Greenhouse Gas Initiative (RGGI). This market-based system currently spans nine northeastern states and aims to reduce greenhouse gas emissions. Through RGGI, emissions from the power sector are capped at a maximum amount (in tons of carbon dioxide), and electricity generators within the participating states trade “allowances” that permit them to emit carbon up to this total limit. The emissions cap declines over time, most recently set to require a 30 percent reduction from 2020 levels by the year 2030, with some flexibility for generators to make even greater reductions in the near term and “bank” unused allowances for future compliance. Periodic reviews are carried out to refine the program as necessary, including adjustments of the cap and other design features.

From the outset, RGGI has implemented innovative features for cap-and-trade mechanisms. For example, it introduced an allowance auction, which raises valuable revenue for states (that they’ve mostly invested in energy efficiency thus far) and reveals a more accurate market price for emissions abatement. An auction also prevents the possibility of generators in competitive electricity markets from earning windfall profits when allowances are freely distributed: without an auction, generators could include in their electricity prices the opportunity cost of selling allowances, thereby imposing higher costs on consumers, despite paying no initial cost for the allowances.

In a rapidly evolving electricity industry that has been experiencing declining costs of renewable technologies, slowed growth in electricity demand, and the closing of coal-fired power plants—trends that accelerate emissions reductions but threaten to

render RGGI’s emissions cap irrelevant—RGGI has demonstrated the ability to evolve and continues to deliver climate progress. Along the way, research from Resources for the Future (RFF) has informed the evolution of RGGI’s design and scope.

For example, RGGI has adopted features of both cap and price mechanisms, a “hybrid” approach in which the emissions cap can respond to the allowance price. RGGI was the first trading program to include a minimum price in its auction (a so-called price floor): if costs fall below that level, fewer allowances are sold, and emissions fall automatically. Subsequently, the program introduced a price for an emissions containment reserve, which is set above the price floor and below which ten percent of the allowances do not sell. Conversely, the program also has a cost containment reserve, which expands the cap if prices rise above a certain level. With these features, the program can contain costs and leverage low allowance prices to deliver further reductions beyond the initial targets. Similar features have since been adopted in cap-and-trade programs in California and Europe. Through this kind of innovation, RGGI has maintained relevance and established a blueprint for durable climate policy that programs near and far have begun to adopt and that has enabled the program’s outsized, and growing, leadership.

With shifting attitudes toward addressing climate challenges, along with RGGI’s demonstrated success, the program is attracting the interest of new states. New Jersey, an initial member that exited the program in 2012 due to cost considerations, will now re-enter in 2020 with the support of Governor Phil Murphy. The mandate for New Jersey to re-join RGGI reflects a commitment to climate action and the appeal

of program benefits, including opportunities to raise revenue that could be used for investment in clean energy and energy efficiency or to reduce electricity rates for consumers.

In addition, Virginia has finalized a regulation to implement a carbon pricing program with the intent to link it with RGGI. Pennsylvania, another significant carbon emitter and net exporter of power, formalized a similar intent to develop a plan to join RGGI through an executive order in October 2019. Lastly, North Carolina’s recent Clean Energy Plan signals that the state is considering the use of carbon pricing to reduce its emissions, including a potential cap-and-trade program that could potentially link with RGGI. By modeling these scenarios, RFF and other researchers have shown how these states can reduce emissions while supporting renewables and nuclear generation, with relatively small impacts on electricity prices.

RGGI’s influence extends beyond the expansion of state membership. In a current parallel effort in the northeast, the Transportation and Climate Initiative (TCI) aims to enforce emissions reductions from the transportation sector through a cap-and-trade program. TCI’s draft Memorandum of Understanding (released in December 2019) indicates that the new program intends to borrow key features from the RGGI architecture, including a price floor, an emissions containment reserve, and a cost containment reserve. As TCI covers similar geographic territories, the programs will likely interact, and the similar program structure raises the question and possibility of the programs linking in the future.

Other overlapping climate efforts also have implications on the impact and ultimate

success of RGGI. New York, a current RGGI member, committed in June 2019 to the Climate Leadership and Community Protection Act, which contains the most ambitious climate and clean energy goals adopted by any state in the nation. Efforts by the state to achieve net-zero emissions by mid-century, with interim requirements along the way, such as 70 percent renewable electricity by 2030 and 100 percent clean electricity by 2040, could reduce the burden on other RGGI states to comply with the regional cap, which in turn could reduce the program’s allowance price and effective stringency in those states. However, an RFF simulation study has found that an additional carbon price in New York—which has been proposed as an option to help meet its ambitious climate targets—could trigger RGGI’s emissions containment reserve, driving even greater emissions reductions in the region. These kinds of overlapping policies may pose new challenges, but RGGI’s robust features and ability to adapt suggest that the program will continue to be successful and model best practices for resilient and effective climate policy.

Through more than a decade of existence, RGGI has evolved by embracing new and innovative features that help it maintain relevance in a rapidly transitioning electricity sector. The program has established a blueprint for durable climate policy that has rippled well beyond its initial geographic borders. From its growing membership to its increasing interactions with other ambitious climate efforts, RGGI is poised for continued outsized leadership in the transition to a cleaner and healthier future ■

Paul Picciano is a senior research assistant at Resources for the Future.



Technology-Inclusive Climate Strategy: An Open Race with Many Winners

RFF President Richard G. Newell makes the case for welcoming a range of potential solutions to tackle the global climate challenge while meeting the world’s energy and economic needs.

Over roughly the last decade, renewable energy sources—wind and solar in particular—have become dramatically less costly and are starting to play a major role in parts of our energy system. But at the global level, these technologies have mostly added to—not displaced—the incumbent energy sources of the past. The world uses more coal than ever before, more oil, and more natural gas. Today, fossil fuels still account for over 80 percent of global primary energy demand.

This energy, and the emissions that come with it, are used across the economy—in industry, buildings, and transportation. In addition, a sizable portion of global greenhouse gas emissions comes from non-

energy activities, such as agriculture, forestry, and other land-use practices, plus process emissions from cement, chemicals, steel, and other industries. So, as we think about the climate challenge, let’s keep in mind that while energy accounts for about 70 percent of global emissions, it is not the only source. We therefore require a wide range of solutions that cut across disparate sectors of the economy.

As global population and income continue to rise, the world has made modest progress on bending the emissions curve. The US and global energy systems have become more efficient, with less energy input per unit of gross domestic product. The carbon intensity of the energy system has also declined—slightly at a global level and more so in the

United States and Europe. Nonetheless, global carbon dioxide emissions continue to rise. After an additional 50 gigatons of carbon dioxide equivalent entered the atmosphere just last year, the atmospheric concentration of carbon dioxide now hovers at around 410 parts per million. For all greenhouse gases, the concentration is at 450 parts per million of carbon dioxide equivalent—higher than it has been for at least 800,000 years. As long as net emissions are above zero, global concentrations will continue to rise.

The consequences of this increasing concentration of greenhouse gases are stark. The average global temperature has already risen by 1°C, and some regions have had to confront temperature increases more than twice that amount. As more gases accumulate in our atmosphere, global temperatures will only increase.

Changing our global energy system comes with many challenges and costs. But the costs of inaction are clearly much higher.

At the rate we have been adding emissions, we're on a path to more than triple the amount of greenhouse gases in the atmosphere by the end of the century, leading to average temperature increases of more than 4°C (or 7°F). This is the global average; in some regions, the temperature increase would be much higher. If we include commitments made by nations under the Paris Agreement, some estimates suggest that we could limit average warming to around 3°C by 2100.

The resulting negative impacts are well known, including more heat waves, extreme weather, wildfires, rising sea levels, increased acidification of oceans, and a heightened risk of abrupt and irreversible damage to our planet. To reduce the likelihood of the worst outcomes of climate change, we need to accelerate the shifts in our energy systems and look toward new solutions to manage risks.

The Ultimate Endpoint

Since the beginning of international cooperation on the climate issue, global goals for managing greenhouse gas emissions have been ambitious. Back in 1992, virtually all nations agreed in the UN Framework Convention on Climate Change to the objective of “stabilization of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system.”

“Stabilization” here implies that humans must head in a direction where our *net* contribution of greenhouse gases to the atmosphere is zero, meaning we cannot add more than we take out. Defining “dangerous interference” is more complex, but the special report on 1.5°C of warming from the Intergovernmental Panel on Climate Change makes a strong case that we are fast approaching such “dangerous interference.” If, in fact, we pass that point, then we will need to begin pulling out more than we are putting in. We will need to achieve net negative emissions.



Richard G. Newell is the president and CEO of RFF. He has served as Administrator of the US Energy Information Administration and as Senior Economist for Energy and Environment on the President's Council of Economic Advisers.

This article is based on remarks delivered at the T20 Inception Conference in January 2020.

ILLUSTRATION
James Round

“

Enabling the vast majority of the current system to see an opportunity in climate action—rather than just a threat—could leverage massive capabilities.

”

The international community has articulated numerous long-term stabilization targets, including 2°C and, in the Paris Accord, “well below” 2°C. But looking across the policy and technology landscape, it is clear that our current strategy for climate action is insufficient to achieve those targets. If the true goal is to stabilize concentrations at a level that avoids dangerous interference, then the world needs to commit itself not just to ambitious targets, but ambitious *actions*, as well.

More Proximate Objectives

Now, these goals can seem daunting—or even downright impossible—given political and economic realities. Obviously, no individual policymaker or nation has direct control over global temperature changes or the atmospheric concentration of greenhouse gases. There is an essential need for leaders to seek out more proximate targets, commitments, and frameworks that can help the world eventually achieve our loftier goals.

In recent years, leaders have emerged at the national and subnational level. Countries like the United Kingdom and France have substantially reduced their emissions and are looking to build on that progress by committing to net-zero emissions by 2050. The European Union recently announced a goal of net-zero emissions by 2050. In the United States, California and New York now have laws aiming for economy-wide reductions of 80 to 85 percent by 2050, and in New York's case, net-zero emissions by 2050. Canadian leaders have also announced the goal of achieving a net-zero emissions economy by 2050.

Many of these goals depend on rapid progress in reducing emissions from the power sector. California, which would be the world's fifth-largest economy if it were its own country, has committed to 100 percent carbon-free electricity by 2045, including options like natural gas with carbon capture and storage. A diverse array of other US states, including New York, Washington, Hawaii, and New Mexico, have each adopted similar goals.

Widening the Track

These ambitious goals will not be easy to meet, and there has been much discussion about what range of options should be on the table. Should the strategy focus solely on energy efficiency, renewables, and electrification? Or should we pursue a “technology-inclusive” approach, where other technologies are welcome to play a role, whether that's nuclear energy; fossil fuels with carbon capture, utilization, and storage; or so-called “negative emissions” technologies such as direct air capture or biomass energy with carbon capture and storage?

A technology-inclusive strategy has a number of advantages.

Expanding our solution set makes more ambitious and comprehensive strategies more feasible and cost effective. In addition to renewable power and solutions for long-duration energy storage, moving the global power system to net-zero emissions is also likely to require firm, dispatchable power sources such as nuclear, and natural gas with carbon capture. Certain transportation emission sources, such as aviation, shipping, and long-haul trucking are hard to electrify, opening an opportunity for net-zero liquid fuels, hydrogen, or other options.

Industrial processes that require very high temperatures or come with process-related emissions require yet another set of solutions—possibly carbon capture and storage, hydrogen, certain advanced nuclear technologies, or other as-yet-undiscovered alternatives. Agriculture, forestry, and other land-use emission sources present a distinct group of challenges; they also present an array of opportunities for emissions offsets through biomass carbon sequestration.

Widening our aperture will allow any effective and safe technology to compete, increase the feasibility of deep reductions, and lower the cost of meeting climate goals, since the best options can be applied to each individual circumstance.

By broadening the set of stakeholders, interest groups, companies, constituencies, and even countries that see themselves as capable of contributing, we also expand the reach and accessibility of climate action. Recall that 85 percent of the global energy system is currently based on fossil fuels and nuclear power, or 95 percent if you include hydrocarbons in the form of combustible biomass energy. Enabling the vast majority of the current system to see an *opportunity* in climate action—rather than just a threat—could leverage massive capabilities and help turn the tide in a positive direction.

A technology-inclusive approach also expands the possibilities for emerging technologies to play a role and for entirely new innovations to be created. In simple terms, we don't know how technologies will develop over time. For example, no one outside of a small group of industry insiders anticipated the shale revolution in the United States.

A wide array of technologies are already available and developing to help us with this approach to climate action. Wind, solar, and other renewable energy technologies are the fastest-growing energy sources and are being supported by improvements in our ability to store power in batteries and

other systems. Who's to say that a major breakthrough in carbon capture, utilization, and storage; new nuclear; or other technologies isn't coming in the 2020s or 2030s?

For example, carbon-capture-utilization-and-storage mechanisms allow us to sequester emissions and can be jump-started through coupling with existing activities like "enhanced oil recovery." In Norway and Iceland, carbon is being stored in underground saline aquifers and in basalt-type rocks.

In the United States, oil and gas companies are investing in direct air capture technology with the goal of producing net-zero or even "negative-emissions" oil. Entrepreneurs in the United States, Canada, and Europe are also experimenting with direct air capture technologies capable of producing what has been called "air-to-fuels." If we can find a way to put carbon dioxide to beneficial use, we have the potential to address the climate challenge while reducing the near-term disruption to economies, communities, and systems that depend on the production and transformation of fossil fuels and liquid fuels.

In the realm of nuclear energy, new designs are being tested that could lead to the deployment of small modular reactors, or even microreactors, in remote locations.

Outside of energy, nascent efforts are under way to develop low-emissions technologies for the production of cement, chemicals, steel, and other materials that lay the foundation for modern life.

Policy Design Principles

What does a comprehensive and technology-inclusive strategy, that drives toward net-zero emissions, imply for policy design? It means we frame our ultimate policy goals in terms of *net emissions*, rather than limiting ourselves only to goals that specify the set of viable technologies, or to policies that require every individual source to release zero emissions. Such policies would become increasingly difficult as deeper reductions are sought. The clean energy sources that are thriving today, such as wind and solar energy, may well play a dominant role in achieving those goals. But the key is that we don't predetermine the outcome; instead, we allow a diverse set of technologies to compete to achieve our goals at the lowest possible cost and to the greatest effect.

A technology-inclusive approach is facilitated by broad carbon pricing. This policy shift creates the right incentives for producers and consumers and is feasible the world over: governments around the world and in various US states have adopted some version of carbon pricing, either in the form of carbon fees or cap-and-trade programs.

Properly pricing carbon can also take the form of incentives for early-stage deployment of low-carbon technologies and correct accounting for climate risks in public and private investment decisions, using metrics such as the social cost of carbon.

A technology-inclusive approach applies performance standards that are flexible, tradable, and can be met through a range of approaches, rather than limited to only a subset of technologies. Automobile fuel economy and appliance efficiency standards are two examples that require companies to meet certain benchmarks of performance for the products they sell. And increased interest in low-carbon alternatives is emerging for a range of products—from fuels to concrete to food—and coming from both producers and consumers.

Companies themselves are seeing value in achieving higher performance in the products they manufacture and buy than may be required by policy. Take, for example, the wide range of companies that have committed to using 100 percent clean power, or have set ambitious goals for decarbonizing their business.

In the United States, there is substantial interest in the possibility of Clean Energy Standards for electricity, through which a range of technologies—from renewables and nuclear to natural gas and carbon capture and storage—could make the power sector 100 percent clean (net-zero emissions) over time. For liquid fuels, California's low-carbon fuel standard includes a broad set of pathways for lowering carbon content, from biofuels and electric vehicles to emission offsets through direct air capture.

And, crucially, a technology-inclusive approach means investing heavily in developing new innovations; seeking the approaches that are the most effective, scalable, and cost efficient; and ultimately deploying the most promising technologies to address the multitude of emissions sources across the globe. This approach is a humble one; it acknowledges that governments do not—and cannot—predict the future of technological development. Nor can any of us. Instead, the approach leverages a confidence that human ingenuity will surprise us all, as it has many times in the past.

If we want these new technologies to move from the lab or the pilot stage to widespread deployment, we should remember that innovation accelerates where a vibrant private sector and competition flourish. Governments certainly have a role in funding research, development, and demonstration of technologies, and policy can play a role in supporting early deployment of these technologies, as they enter into commerce. At the mass commercialization stage, a diverse and competitive marketplace—guided by the right market and policy signals to demand improved performance—can work wonders in incentivizing the best mix of approaches to achieve emissions reduction goals.

At Resources for the Future (RFF), many individuals are working today on policy approaches that can enable this type of technology-inclusive approach, including research and policy engagement in the energy and power sector, new initiatives to address industrial emissions, carbon in forests and other land uses, and more. We're also looking at how communities that have historically depended on the production and transformation of fossil fuels can become more economically resilient while taking advantage of the potential that a wide range of new technologies can offer to create economic and job opportunities, while reducing emissions.

Setting the Pace to the Finish Line

This technology-inclusive approach allows for ambitious clean energy and climate goals, but it doesn't make any particular technology a prerequisite for climate action. It engages more stakeholders, making climate action more accessible, more feasible, more globally impactful, and cheaper. It asks governments to use policy instruments to price carbon, set market-based performance standards that target net emissions, and invest in new innovations. And it welcomes a wide range of technologies in the solution set, whether they facilitate an expansion of renewables, nuclear, carbon capture, synthetic fuels, or any other climate-friendly solution. A technology-inclusive approach will likely require all of the above.

We have an enormous challenge ahead of us. But instead of growing intimidated by the scale of our energy and climate challenge, we should be invigorated by the variety of potential solutions and excited to see what solutions we can devise to maintain a thriving economy and a healthy environment. What we need now is dynamic decisionmaking that can set a framework in place for this transition ■



What's at the Top of Your Stack?

“We are creating a world that is different from the one we grew up in, and we're going to need courage to deal with that—not just hope that it will be a better place.”



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. Here's some of the recommended reading from recent episodes.

BOOK

Between Two Fires
by Stephen Pyne

“It's a great history of how the Forest Service pioneered wildland firefighting in the United States, and then how firefighting policy developed and changed; how California invented this particularly aggressive, interventionist form of fire management; the implications that has had for fire and urban development—and, more recently, for attempts to live more in balance, you might say, with fire.”

Judson Boomhower, Assistant professor, University of California San Diego

MISC.

The writings of Thomas Kuhn and Karl Popper

“Some of the work they did was about how difficult it is to shift paradigms and shift thinking on major theoretical issues. And I think there are some great lessons there for all of us who are talking about huge technology changes, like moving from an internal combustion engine to an electrified vehicle, and what that means for improving our environmental outcomes.”

Ellen Hughes-Cromwick, Senior economist, University of Michigan Energy Institute

BOOK

The Overstory
by Richard Powers

“He connects using a piece of toilet paper to a giant redwood tree—and you know, it just makes you step back and think about how systems are connected.”

Shahzeen Attari, Associate professor, Indiana University

BOOK

One Person, No Vote: How Voter Suppression Is Destroying Our Democracy
by Carol Anderson

“I literally looked at the top of my stack, and at the top is an amazing book about the history of voter suppression in this country and what we can do about it. It's a reminder that democracies work only if people participate. And we need to make sure that everybody has the opportunity to participate, as our constitution guarantees.”

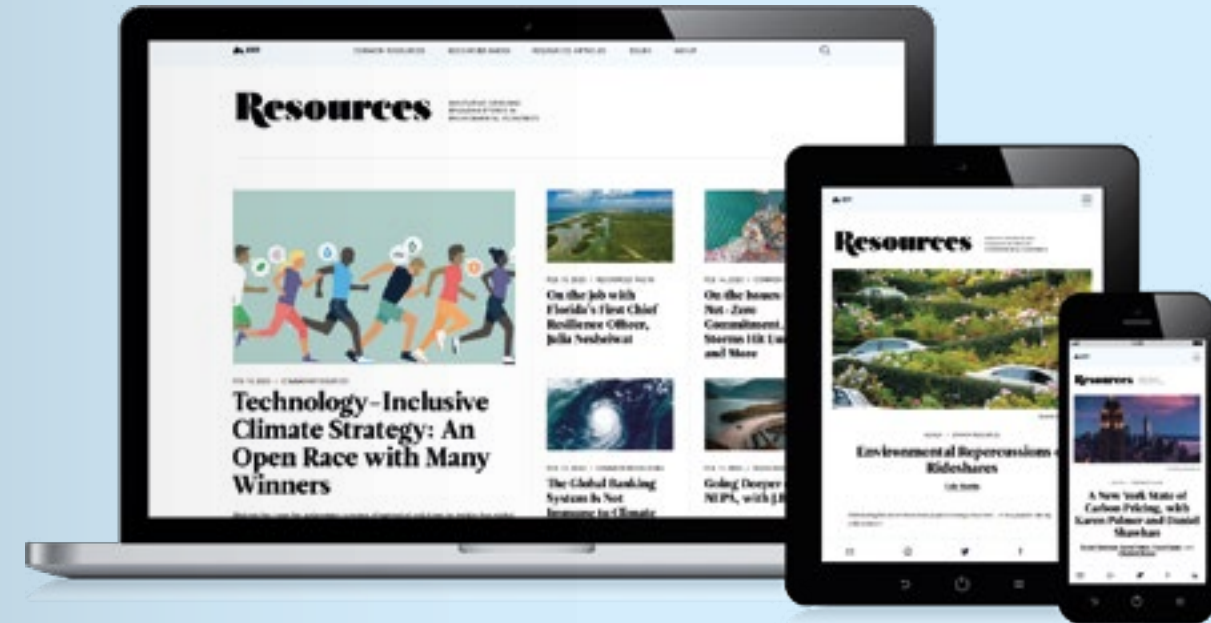
Tina Smith, Minnesota senator

ARTICLE

“We Need Courage, Not Hope, to Face Climate Change,”
by **Kate Marvel in the *On Being* blog**

“It's a personal reflection, where she argues that we shouldn't be thinking about this in terms of hope—we should be thinking about this in terms of courage. We are creating a world that is different from the one we grew up in, and we're going to need courage to deal with that—not just hope that it will be a better place.”

Robert Kopp, Professor, Rutgers University



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