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Resources

In a New Era, Staying on Track Toward Decarbonization

Illustration by Nils-Petter Ekwall

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A Note from
RFF's President

Despite Transitions, Our Organization Stands Strong

At this time, we are on the precipice of a new era.

Resources for the Future (RFF), even while persisting as a stable and ongoing champion for rigorous economic research that has informed environmental, energy, and climate policy decisions for more than 72 years, has undergone some significant changes from within.

In 2024, we lost one of our longest-serving researchers, Ray Kopp, whose legacy you will read about in this issue. Ray was with RFF for a remarkable 47 of the organization's 72 years, serving in positions of fellow, director, and vice president. But more importantly to the people he worked with, he was a mentor and friend.

Alongside this news were changes for the current RFF executive leadership as we announced my own hiring into the role of president and CEO and Carlos Martín as vice president for research and policy engagement. There is indeed a bittersweet nature of having an institution last nearly three-quarters of a century and seeing that it can commit to fulfill its mission even as we mourn, remember, and honor institutional leaders like Ray and bring in the new and valuable perspectives of leaders like Carlos. And despite the changing of the guard at RFF, we know that the organization will be around much longer than any of us will be.

On a larger scale, we can also look to the ongoing evolution of the United States. It may be too early to know the extent of changes in the federal policy landscape following the 2024 elections, but certainly the American people chose a different pathway from the last administration. However, as with every election before this one, RFF will continue to work in a nonpartisan way to inform climate policies. Economic analysis arguably matters more than ever, as the economy figured prominently in campaign rhetoric. Critically, RFF will focus on connecting key policy choices to the lives of everyday people in all communities. In that context, one article here explores ways to include and prioritize community benefits when implementing federal energy investments.

As I said in my introduction to the previous issue of *Resources*, change may be the only constant. But even as we enter this new era of RFF and federal policymaking, you have my commitment, and that of the entire RFF staff, to remain dedicated to the mission of providing rigorous, nonpartisan research and policy engagement for decades to come. Thank you for your support in that commitment.

Sincerely,

Billy Pizer
President and CEO, Resources for the Future

Resources

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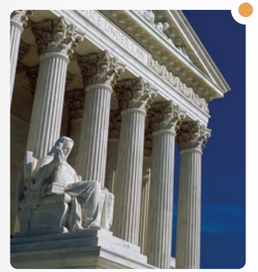
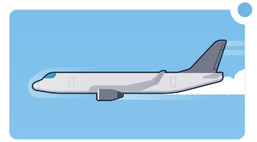
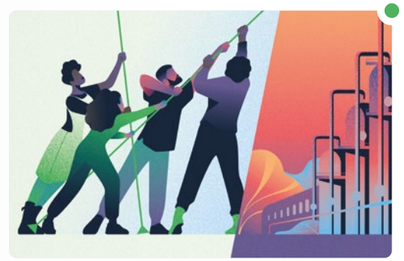
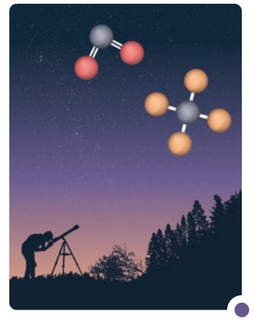








NO. 217 | WINTER 2025 | *"Facilitating engagement and input from communities takes considerable time."*

Improving Community Benefits Plans Can Optimize Local Outcomes

Community Benefits Plans and Agreements can safeguard the communities that will be affected by infrastructure development projects, delivering beneficial outcomes and mitigating harms. Successful examples exist, with applicable lessons outlined here.

TEXT Brandon Holmes and Suzanne Russo **ILLUSTRATION** Maria Fedoseeva

The process of transforming the energy infrastructure of the United States to meet ambitious climate targets and support a low-carbon economy will attract tens of billions of dollars in private and public investment over the coming decades. This redevelopment of US energy infrastructure will bring extensive opportunities and challenges to communities, particularly communities near oil and gas installations. These frontline communities are more likely than others to also host new large clean energy projects, such as Regional Clean Hydrogen Hubs through US Department of Energy (DOE) efforts and carbon capture and storage facilities.

Large capital investments already have been deployed through the Biden-Harris administration's Inflation Reduction Act and Bipartisan Infrastructure Law. As the sustainable energy transition ushers in a new era of constructing large-scale energy facilities, additional community engagement, planning, and agreement will be needed to ensure that communities benefit from the clean energy transition—particularly the communities that are near existing and new energy investments.

Local residents often are economically dependent on the fossil fuel industry for direct employment; local tax revenues; and spillover demand that supports local restaurants, shops, and other small businesses. However, fossil fuel communities can suffer social and environmental harms from new energy infrastructure. Neighborhoods that are adjacent to oil and gas wells and refineries, for example, have been exposed disproportionately to harmful air and water pollution for decades, resulting in worse public health outcomes. The section of the lower Mississippi River in Louisiana between Baton Rouge and New Orleans has earned the infamous nickname "Cancer Alley" in reference to the more than 200 local fossil fuel installations that are responsible for a quarter of total domestic petrochemical production.

Low-income people of color often constitute a significant proportion of the population in fossil fuel communities. Black Americans are three-quarters more likely than other racial groups, on average, to reside near polluting sites, and more than one million Black residents live less than half a mile from a petrochemical plant. Historically disadvantaged communities have lacked the bargaining power to ensure that developers invest in local economies as part of their projects and to hold industry accountable for pollution and other environmental impacts.

In recognition of the need for community representation and economic benefits in the clean energy transition, DOE currently requires the submission of Community Benefits Plans (CBPs) for large-scale energy facilities that are funded through the agency's Office of Clean Energy Demonstrations, the Bipartisan Infrastructure Law, or the Inflation Reduction Act. DOE also recently launched the Regional Energy Democracy Initiative, which aims to provide technical assistance and build capacity to support communities in their meaningful engagement with the design and implementation of DOE-funded projects.

When done well, CBPs take considerable effort from community members and project developers. Whether CBPs should continue as the preferred community engagement and benefits tool for DOE-funded projects will depend on whether CBPs optimally generate community representation in planning decisions and deliver social, economic, and environmental benefits at the local scale. We sought to understand how the DOE CBP process currently is unfolding, any opportunities for improvement, and if related legally binding contracts between communities and developers can help improve outcomes for communities.

Although specific documentation about the effectiveness of CBPs currently is limited to high-level community benefits commitment summaries, lessons nonetheless can be learned to guide future public-sector efforts to ensure representative community participation, benefits sharing, and reduction of negative impacts. We conducted a literature review and evaluation of community-generated statements to explore these topics and present our results here.

Policy Priorities for Community Benefits Plans

Engage Communities and Labor
Ensure two-way engagement and align benefits to community needs.

> **"Low-income people of color often constitute a significant proportion of the population in fossil fuel communities."**

> **"By focusing only on potential economic benefits and ignoring potential harms to the local community from a project, Community Benefits Plans only partially meet the needs for community engagement in project planning."**

Policy Priorities for Community Benefits Plans

Invest in the US Workforce
Draw from the domestic supply chain. Provide good jobs, training, and education.

Community Benefits Plans in Projects Funded by the Department of Energy

DOE requires CBPs as part of all funding opportunity announcements that come through the Bipartisan Infrastructure Law and the Inflation Reduction Act. These CBPs are designed to achieve four outcomes:

1. Engage communities and labor

2. Invest in America's workforce

3. Advance diversity, equity, inclusion, and accessibility

4. Implement the Justice40 Initiative

Notably missing from the CBPs is an outcome focused on harm identification, reduction, and mitigation. By focusing only on potential economic benefits and ignoring potential harms to the local community from a project, CBPs only partially meet the needs for community engagement in project planning.

DOE has stated that these CBPs are intentionally flexible, while at the same time are specific, actionable, and measurable. The CBP portion of each project proposal accounts for approximately 20 percent of the technical merit review. The hope for CBPs is that they help structure community engagement and ensure input on key project-planning decisions, such as siting and environmental-impacts mitigation, while generating local social, economic, and environmental improvements as co-benefits of the project. From a developer's perspective, CBPs can improve public support of a project, thereby reducing risks in securing local approvals or other funding.

Projects that win funding will incorporate elements of the CBP into the contractual obligations of the DOE grant. The approach thus contains legally binding elements. However, because the original CBP and the contract are not made available to the public, community members lack transparency into the specific commitments, the timeline, and the developer's progress toward meeting those commitments. As a result, the developer is not accountable to the community, which limits meaningful community engagement in the process. Useful insights for researchers and community members could be gained through public access to proposed CBPs and the specific, measurable community benefits required in DOE contracts—even if these are made available after the project contract is finalized.

Limitations of Community Benefits Plans

Representation

Surveys have indicated that a majority of residents tend to be unaware of plans to build a major energy infrastructure project in their community, whether it be a hydrogen hub or direct air capture facility, prior to DOE award announcements and public releases. Given that CBPs are a requirement in project applications, this lack of awareness raises questions about which parts of a community get engaged in the CBP development process and why others are left out.

Complementary policy tools enacted at the local level can enhance the efficacy of CBP processes and commitments. The Initiative for Energy Justice provides a comprehensive overview of such tools, including codifying community right-to-refuse or consent-based siting; codifying the principle of free and prior informed consent, especially for Indigenous communities; and establishing democratically governed funds and trusts that can support communities with legal representation or enable community ownership.

Best practices for community benefits planning start with a community-engagement process in which community members inform the menu and prioritization of benefits and can weigh in on whether a new facility represents an unacceptable level of harm. Community consultations can be conducted through multiple channels, including surveys, town hall meetings, public workshops, and webinars involving local organizations that hold trust with the community.

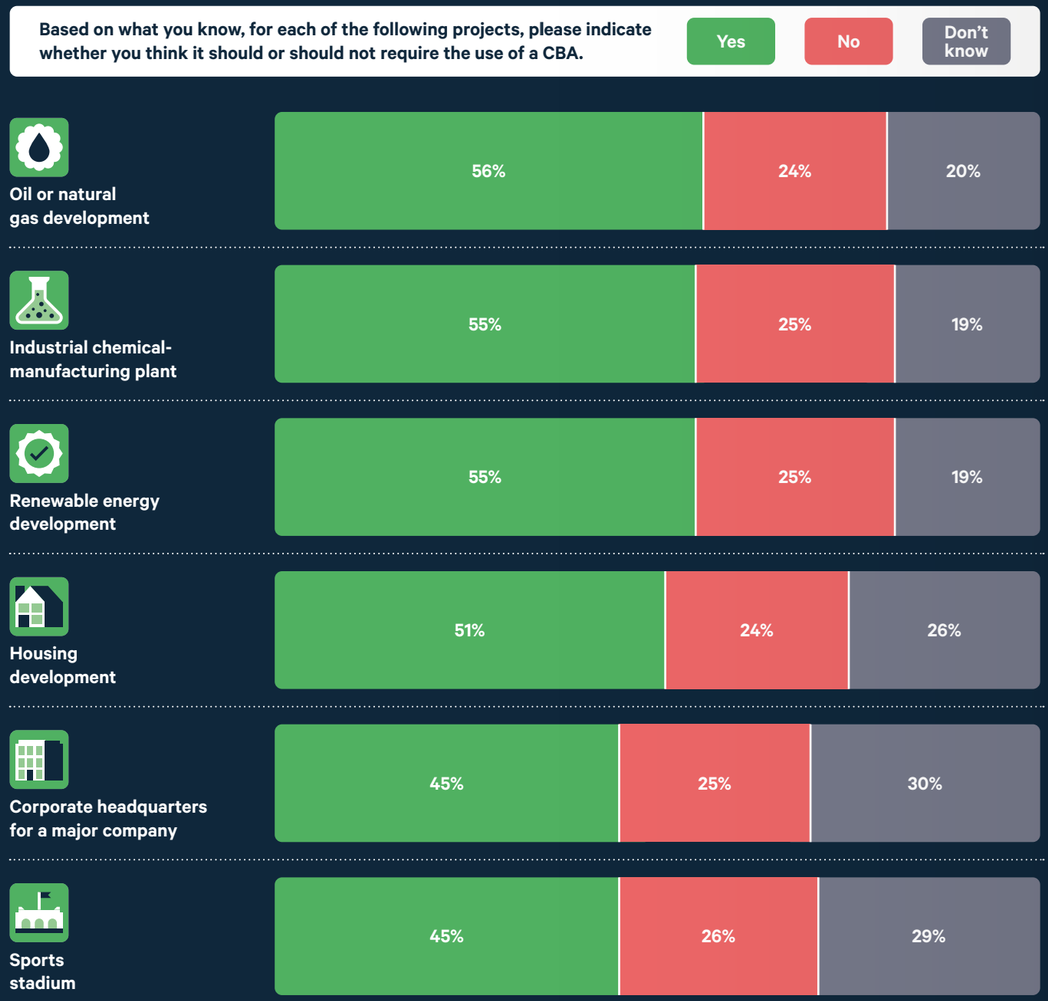
Transparency and Enforceability

Another challenge for CBPs lies in the inherent flexibility that DOE describes as a benefit of

Figure 01

Voters Favor Community Benefits Agreements for Energy and Industrial Development Projects

A Community Benefits Agreement (CBA) is a legally binding agreement between a project developer and a community where a project will be built. The CBA describes the benefits a project developer promises to give to a community in exchange for the community's support for the project.



Credit: Data for Progress. June 10–13, 2022, survey of 1,268 likely voters.

these documents. CBPs are considered flexible because they are not legally binding—and therefore are challenging to enforce.

DOE seeks to overcome the lack of enforceability by contractually obligating certain components of CBPs. However, the process is not transparent about how success is measured for the project and its CBP, how community members are engaged in determining what ultimately is written into DOE project plans, and how DOE makes decisions about funding for projects that do not meet the metrics of their CBPs. Without specific commitments that include quantifiable goals and timelines, public oversight, and accountability, equitable outcomes will be difficult to achieve.

Additionally, many components of a CBP are designed to convey benefits in later stages; for instance, permanent jobs, local tax revenue, and environmental remediation. Left unclear is how these post-development benefits can be enforced or guaranteed for the community through DOE's CBP process. Failure to deliver on the promised local benefits could generate real costs for a community without any legal recourse to pursue enforcement. Expending the time of community members in developing a CBP that does not get implemented may increase public distrust of developers, funders, and the government, which raises barriers for effective public engagement in the future.

Harm Reduction

Identifying the potential harms that may result from a project, and providing mechanisms to mitigate those harms, is important for building trust with a community. Hydrogen hubs could serve as an example of failure to acknowledge harms and potential impacts; DOE has acknowledged that a majority of hub development will be located in disadvantaged communities.

Community Benefits Agreements Can Offer Assurance of Implementation

Community Benefits Agreements (CBAs) are legally binding agreements that are publicly negotiated and aim to minimize negative impacts from development projects. CBAs improve upon the mechanisms of CBPs by creating a legally binding, mutually beneficial agreement between developers and residents. As legally binding agreements, CBAs in many cases give local leaders and community groups the power to challenge developers and halt construction or operations if residents believe that contractors are not upholding the established commitments to limit negative outcomes like pollution. CBAs thus can build long-term trust among communities that will then support and help accelerate the clean energy transformation.

Considering Design and Metrics for Community Benefits Agreements

Facilitating engagement and input from communities takes considerable time. Funders or government entities that require CBAs for project approval need to allow time for applicants to construct a representative community coalition, capacity building on the community side, and developers to understand and build trust with the community. Rushing this process could result in a CBA that is less representative and likely less beneficial for the overall community.

Critically, CBAs work best when the community participants represent the area's demographics. Effective community engagement involves extensive outreach and consultation in multiple sectors of the population. Ultimately, the development of a community-supported CBA may benefit from the formation of a local coalition that collectively bargains for community benefits and economic empowerment as part of the development agreement.

CBAs can include three categories of measures: risk mitigation and hazard management, enhanced public infrastructure, and community benefits related to economic outcomes and social services. CBAs often include monetary and nonmonetary contributions to the community that can be supplemented with overall tax revenue. However, relying on tax revenue instead of specific project commitments can be risky, as taxes can be contingent on a project's success and development timeline.

> **"Identifying the potential harms that may result from a project, and providing mechanisms to mitigate those harms, is important for building trust with a community."**

Policy Priorities for Community Benefits Plans

Advance Diversity, Equity, Inclusion, and Accessibility (DEIA)
Promote a robust DEIA plan for all aspects of each project.

Policy Priorities for Community Benefits Plans

Implement the Justice40 Initiative
Ensure that 40 percent of overall benefits go to disadvantaged communities.

> **“Upgrades that benefit only the development, and which do not provide any expansion of benefits or services to community members, should be explicitly stated as such.”**

Infrastructure, Risk Mitigation, and Hazard Management

CBA provisions can include measures to address and mitigate community concerns for safety and health risks associated with a development. For example, provisions might include installation of air-quality monitors with data available to the public; funding for third-party review and inspection of the facility; or other examples related to waste management, water quality, pipelines, and transportation infrastructure. The provisions would go alongside a detailed plan for what the developer will do in case agreed-upon expectations are not met.

Infrastructure upgrades, for example, should be evaluated to understand whether the proposed improvement and capacity expansion will serve only the development, or if it will provide a broader benefit to the community. Upgrades that benefit only the development, and which do not provide any expansion of benefits or services to community members, should be explicitly stated as such.

Community Benefits

In general, agreements for harm reduction should accompany agreements for local benefits that meet the principles of additionality, which means providing community benefits that are additional to what already exists or would exist with available public and private investment in the community, as opposed to replacing a community benefit that would be removed through the project's development with something of similar value.

Survey respondents polled by the nonprofit Data for Progress show substantial support for the mandatory use of CBAs for energy and industrial infrastructure projects, in addition to the construction of new housing, sports, and business centers (Figure 1).

Overall, the benefits portion of a CBA likely will rely on community outreach and engagement to inform what is included. CBA reviewers will want to understand whether the projected benefits for communities seem in proportion to the overall project investment. Examples of economic benefits that have been included in CBAs are living-wage requirements, local hiring and job-training programs, minority hiring minimums, funding for low-income and affordable housing, environmental-remediation requirements, and funding for community services and programs. Funding for these benefits can be administered by a community agency or foundation or directly distributed by the developer. CBAs also benefit from explicit discussion of whether any agreed-upon benefits will be funded through project-related tax revenue in the community or direct contributions.

CBAs can be further enhanced by clauses that address concerns around displacement-induced gentrification, loss of affordable housing, or the creation of jobs that do not include health or employment benefits.

Implementation and Enforcement

To ensure that a CBA represents the will of the community that is impacted by the development, legal counsel for community representatives may be funded by the developer or government, which can enable community representatives to participate in the drafting and reviewing of CBAs. Whether local governments can serve as official representatives for the community will vary across states and regions, depending on local regulations. Some states do not allow local governments to enter into development agreements; in those cases, CBAs could involve community organizations that can hold developers accountable.

If a developer fails to uphold the commitments in a CBA, community capacity and resources may not exist to navigate the legal process required for enforcement. These concerns can be considered within the CBA process itself and remediated through solutions such as establishing an escrow account where the developer deposits funds to cover all or a portion of the value of the CBA commitments, hiring a compliance monitor, or enabling legal representation and building capacity for communities to engage in forcing the developer to either abide by the agreement or terminate the project.

Finally, transfer of responsibility and shifts in the scale of the project as it progresses can be contemplated within a CBA, and mechanisms to address such occurrences can be explicitly documented. For example, transfer in ownership of a project to another entity could trigger payment into a CBA fund that is controlled by the community. Legal requirements could ensure that the funds are spent over a specified time period on the commitment as outlined in the CBA. The CBA also can contemplate shifts in project size with mechanisms that trigger commensurate shifts in fiscal commitments at specified thresholds for the project.

Overall, contemplating plausible scenarios and providing for automatic response within a CBA could avoid the need for renegotiation with developers and can help ensure that benefits are delivered.

PHOTO
Joe Holland / Unsplash

Conclusion

CBPs and CBAs represent valuable tools that help prevent environmental harms in frontline communities which otherwise could result from new energy infrastructure projects; these tools also can deliver meaningful benefits to communities that host new, large-scale, clean-energy infrastructure. The nonbinding nature of CBPs, and non-transparent nature of CBP implementation by DOE, makes this mechanism an imperfect solution for sharing project benefits among developers and community residents. The DOE CBP process could be improved by borrowing from the CBA model, wherein communities and developers are parties to a public, legally binding, specific agreement that centers community members in the crafting of benefits plans and enables the transparency, accountability, and enforcement of commitments for mitigating harm and delivering benefits.

CBAs have been implemented successfully across the United States to date. Resources for effectively developing CBAs, which also could apply to modified CBPs and be supported by DOE, are available at the All-In Cities initiative by the research institute PolicyLink. A related database and policy guide also have been constructed by the Sabin Center for Climate Change Law. States such as California have a long track record of successful CBAs, with examples that include the construction of a major Los Angeles sports arena in 2001 and the expansion of Los Angeles International Airport in 2005. These CBAs can serve as benchmarks for negotiations in energy-infrastructure developments, so communities and developers can avoid recreating the wheel. For further reading, papers published by ReImagine Appalachia and the World Resources Institute provide additional insights into best practices for developing CBPs and CBAs. ■

Suzanne Russo is a fellow and director of the Environmental Justice Initiative, and **Brandon Holmes** is a research analyst at Resources for the Future.

Resources for the Future Welcomes Carlos Martín

Carlos Martín joins Resources for the Future as the new vice president for research and policy engagement. Get to know him a little better through this Q&A that covers his reasons for joining the org and his plans for the future.

TEXT Elizabeth Wason

Stepping into the position of vice president for research and policy engagement at the start of this year, Carlos Martín joins Resources for the Future (RFF) as a welcome addition. We know Carlos well around RFF, as he's collaborated with RFF scholars for many years and participates regularly in RFF events. He grew his relationship with RFF by joining as a university fellow in 2023; his new role as an RFF vice president clinches his place at the organization.

Carlos has led research and policy engagement in the fields of climate mitigation and adaptation and disaster mitigation and recovery for more than 25 years. His work is well-known on decarbonization, adaptation, and environmental justice related to housing and building development policy. He comes to RFF most recently from Harvard University's Joint Center for Housing Studies, where he remains affiliated. Prior to that, he was a senior fellow at the Urban Institute, David Rubenstein Fellow at the Brookings Institution, and an assistant staff vice president at the National Association of Home Builders. He's also held positions at Arizona State University and the US Department of Housing and Urban Development.

Read on to get to know Carlos a little better and his reasons for joining RFF, how he thinks RFF work relates to this moment in history, and his vision for RFF research and policy engagement moving forward.

***Resources* magazine: How do you see this moment in history as unique for the work that RFF is doing?**

Carlos Martín: We're in an existentially critical moment in environmental policy and scholarship in our country. The courts are calling decades-old laws into question, while federal and state governments are rolling out their biggest investments in history for energy and climate. Environmental policy writ large—but especially global climate change—is a top national priority, if not *the* top policy, given the way it will shape so much of our economy and social prosperity for years to come. The case for rigorous evidence has never been stronger.

Why is RFF the right place for you at this point in your career and for your vision of the work that RFF will do in this critical moment?

Amid all the shifts in environmental policy occurring right now, the breadth of research topics, research methods, and researcher diversity has expanded. RFF was founded on the principle that you cannot develop sound environmental policy without considering economic and societal conditions and outcomes. Let's apply that analogy to the environmental research community: we need to reflect the demographic shifts that are occurring in our country and in professional workplaces. Along with continuing RFF's tradition of rigor and policy relevance, my vision for RFF is to smooth that professional transition. It's one I know will lead to amazing research insights, too.

What kinds of things have drawn you toward working in think tanks? Can you speak to your experience and fascination with the history of think tanks, particularly in the context of Washington, DC?

We work in a privileged space. We get to do cutting-edge research and communicate it to the very people who make decisions about the things we study and communities that are affected by those decisions. That level of relevance makes our work exciting—and it means that the stakes for accuracy, rigor, and review are that much higher.

I've quietly documented the history of the think-tank space as I've navigated my own career through it, so I've been able to compare institutions and how they deal with changes in the political and social landscapes. For example, RFF arose in what I call the "second wave" of DC think tanks coming out of the 1960s—one of the most prolific eras for environmental policy and civil rights legislation. That moment says as much about the role we must play now as it does about RFF's institutional legacy.

How did you get into the type of work that you do? What drives your passion for environmental issues?

My parents grew up on subsistence farms in Mexico with no electricity or running water. I spent summers there in my early childhood, developing a deep respect for the land and a profound sense of how the environment defined the financial and health outcomes of my family and the cohesion of our community. When I was born, my parents also unknowingly (and fortunately) moved my family out of the emissions plume of one of the most hazardous pollution sites in California. My family took seriously their role as occupants of the land they inhabited, so what drives me is ensuring that information and knowledge are uncovered, preserved, and shared to turn occupants into stewards.

What makes you excited to join RFF in this new capacity?

What doesn't excite me?! It's an amazing time to be working in our field, and RFF always has been a foundational institution in it. But RFF also has proven itself willing and able to change. RFF is fortunate to have an amazing team, including a crack team of researchers, research communicators, policy engagers, and project managers with whom I have worked or whom I've admired for decades. RFF is the right institution for this moment. I'm grateful and humbled to be part of it. ■

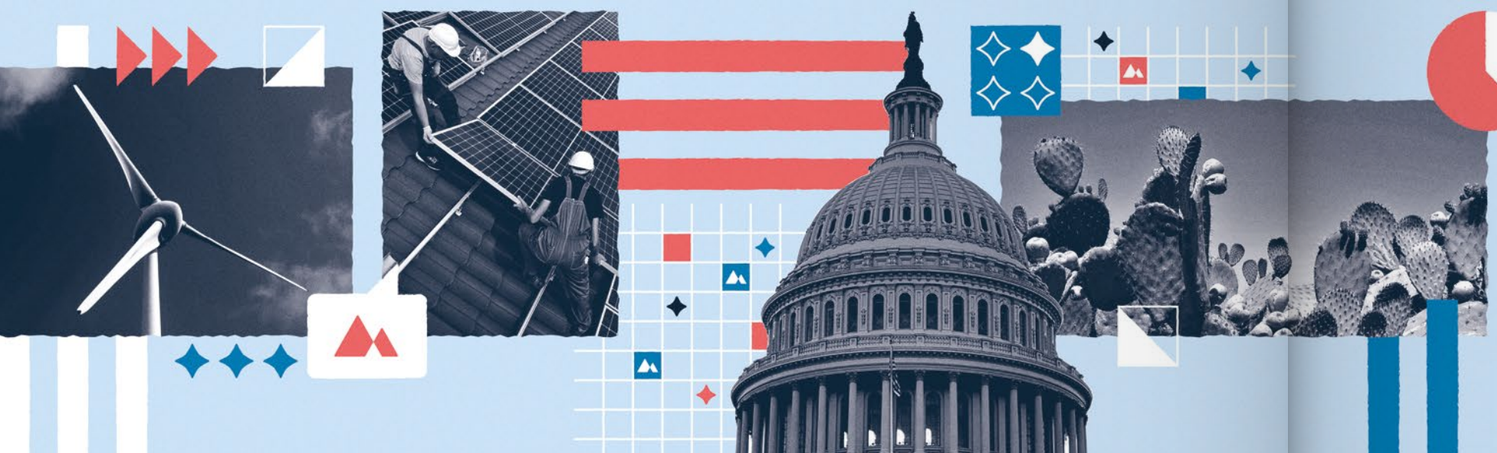
Get to Know Carlos

Carlos spends quality time with his 5-year-old dog, Oliver, whom he and his husband adopted from the DC Humane Rescue Alliance.

Carlos called Washington, DC, his home for 25 years before heading up to New England.

Carlos learns languages as a hobby—he's up to 9 in various levels of fluency.

Carlos loved growing up in the San Francisco Bay Area—El Cerrito to be exact!



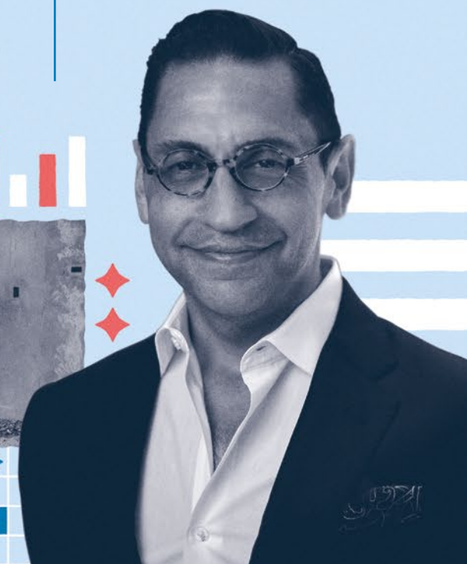


PHOTO
Dennis Degnan / Getty Images

> “The court is demoting everyone else—engineers; scientists; economists; Congress; and, ultimately, the general public—out of previously shared space for policymaking.”

Après *Chevron*, Judges Rule

The recent US Supreme Court decision in *Loper Bright Enterprises v. Raimondo*, which overturns a long-standing precedent called the *Chevron* deference, is representative of a broader transfer of regulatory power from government agencies to courts.

TEXT Alan Krupnick, Joshua Linn, and Nathan Richardson

In the case *Loper Bright Enterprises v. Raimondo* from the October 2023 term, a 6–3 majority of the Supreme Court overturned its 1984 *Chevron v. Natural Resources Defense Council* decision, under which administrative agencies (rather than judges) were empowered to make reasonable interpretations of ambiguous statutes. The *Chevron* decision had been the fulcrum of the balance of power between courts and administrative agencies. *Chevron*'s fall has prompted predictions that large portions of the administrative state are now at risk of judicial meddling or deconstruction, from protections for workers by the Occupational Safety and Health Administration to regulations on greenhouse gases by the US Environmental Protection Agency (EPA).

To be sure, the shift in power toward courts in *Loper Bright* is not new. The *Chevron* deference has been dead at the Supreme Court for a decade, and the court's antipathy toward administrative agencies has been well established by other changes in legal doctrine, most relevant being the “major questions doctrine” announced in *West Virginia v. EPA* in 2022. Policy wonks will be well familiar with this trend in light of the court's recent rejection of a series of environmental rules, including the Clean Power Plan.

But critics of *Loper Bright* are correct in the broader sense that the judicial aggrandizement it illustrates is a big problem, concentrating decisionmaking power in judges and other lawyers to the exclusion of other experts, such as scientists; engineers; and, yes, even economists. *Loper Bright* also sharply reduces the power of Congress relative to life-tenured judges, weakening democratic control over policy. We, as have others, refer to this shift away from democracy as the coming “juristocracy.”

Agencies get their power from statutes passed by Congress. EPA has specific powers and duties granted to it under statutes like the Clean Air Act. Much of the time, the limits of those powers are clear. But what if a dispute arises? General consensus acknowledges that purely legal disputes about agency power should be resolved by courts (a decision reached in *Marbury v. Madison*).

But in reality, few questions are purely legal. (And fewer still are *clearly* purely legal.) An example may help illustrate. Congress frequently makes broad and open delegations of power, such as when it tells EPA to set air-quality standards “requisite to protect the public health.” Implicit in this charge is that the agency will enlist doctors, scientists, and other experts to marshal scientific evidence to define a standard that offers such protection. Of course, not everyone will agree with whatever standards the agency sets. And beyond some point, the standards might be so restrictive (or so permissive) that they are not just unwise but violate the law, exceeding (or ignoring) the congressional delegation of power to the agency.

Who decides when that overstep has happened—when the merely controversial or ill-advised becomes illegal? Under the old *Chevron* rule, agencies operating within their expertise got some deference, though how much depended on the judge and changed over time. Certainly, if a statute were clear on its face, or an agency interpretation was unreasonable, a court could reject it. But in between, where scientific issues met legal

> **The result of this shift in legal doctrine is a profound concentration of power in one discipline (the law) and one small group of people (federal judges, and in particular the Supreme Court).**

considerations, agencies had some flexibility (and with that flexibility, accountability).

For Chief Justice John G. Roberts in *Loper Bright*, the question of who decides legality is much simpler: "[A]gencies have no special competence in resolving statutory ambiguities. Courts do." That sounds nice, but it's a superficial platitude. The law professor among us would give it low marks if the argument came from a student. Whether a standard is "requisite to protect the public health," like countless other delegations of power to agencies, is not a purely legal question. And even if we grant that some purely legal questions really could exist, Chief Justice Roberts doesn't address the obvious follow-up: Which questions qualify as purely legal? He says nothing about that meta-question, but the impact of *Loper Bright* is clear: judges, and judges alone, decide what constitutes legality.

The court's shift away from deference is but one of many tools it has deployed against agency power; perhaps even more important is the court's "major questions" doctrine, under which delegations of power to agencies that ordinarily would be legal may be invalidated by judges if those delegations fail to cross an extra-high bar of clarity.

The result of this shift in legal doctrine is a profound concentration of power in one discipline (the law) and one small group of people (federal judges, and in particular the Supreme Court). That shift bodes ill for both effective public policy and a logical division of powers.

It's worth illustrating this cautionary tale with a more in-depth (even if so far hypothetical) example. This year, EPA issued new greenhouse gas rules for light-duty vehicles (cars, SUVs, and small pickup trucks). The rule requires new vehicles to have lower average emission rates of greenhouse gases, accomplished either by increasing the fuel economy of gasoline cars or by increasing the share of zero-emission cars—mostly electric vehicles (EVs)—that manufacturers produce each year. The rule doesn't explicitly require any level of EV market share, but EPA does anticipate that the rule will lead to more EVs—an increase of somewhere between 9 and 14 percentage points relative to a baseline case without the rule.

The rule is a big deal, going a long way to achieving the Biden administration's economy-wide goals for greenhouse gas emissions and spurring automakers to invest billions of dollars in new technology. And EPA's legal authority to set this kind of national standard is well established. Section 202 of the Clean Air Act directs EPA to set "standards applicable to the emission of any air pollutant from … new motor vehicles … which in [the agency's] judgment cause, or contribute to, air pollution which may reasonably be anticipated to endanger public health or welfare." That's pretty broad and pretty clear authority, as federal regulatory statutes go, and EPA and the Department of Transportation have used this provision to set fuel economy standards for decades.

But the anti-administrative turn in the Supreme Court may allow these agency powers to be curtailed significantly. Opponents of the vehicle rule (who already have challenged it in court) claim that EPA is empowered to require only that pollution-producing internal-combustion vehicles get cleaner—not to push EV adoption. As industry lawyer Jeffrey Holmstead put it recently, "'The question is going to be, 'Did Congress clearly intend to give EPA authority to force a fundamental shift in the transportation sector?'"

The legal problem, under this view, isn't that EPA's rules are too strict; rather, the agency can't require manufacturers to meet standards for greenhouse gas emissions mainly by selling more EVs. What this argument ignores is that whether the standards dramatically (i.e., fundamentally) increase EV sales isn't a legal question—it's actually an engineering and economics question. How will the costs of producing EVs compare with the costs of making gasoline vehicles more efficient? How readily will consumers buy EVs? And what constitutes a "fundamental" shift in the marketplace such that the consideration becomes a "major question"? Is a 9–14 percent change in EV market share big or small? These aren't questions that judges are at all equipped to answer.

> **Having different rules based on how much the judge cares about the outcome of a case is hardly good for the rule of law.**

This debate may sound familiar. Almost identical arguments were made against the Clean Power Plan, whose targets for emissions reductions for power plants were based on EPA assumptions that US states would shift away from coal and toward natural gas and renewable energy resources. The Supreme Court rejected exactly this kind of generation-shifting in *West Virginia v. EPA*, deeming it a "major question" over which Congress must *clearly* delegate authority to agencies.

EPA's authority to regulate cars is on firmer legal ground than its authority to regulate greenhouse gas emissions from existing power plants, but will that authority be strong enough to withstand a Supreme Court empowered by *Loper Bright* to ignore agency interpretations of law, science, economics, and the *West Virginia* decision to demand extreme clarity from Congress for major questions? There's no way to be sure, but a fundamental change in EPA's authority to regulate vehicles is plausible now in a way that it has never been before.

EPA goes to great lengths in its vehicle rule to claim broad legal authority, and to downplay the degree to which the rule pushes EV adoption, anticipating the kind of challenge described above. Those efforts show the degree to which the court's judicial aggrandizement empowers lawyers over other experts even within agencies, potentially leading to worse outcomes for the public. In the future, agencies may issue weaker rules—if the agencies regulate at all. Now that the vehicle rule has been finalized and challenged in court, judges alone will decide its fate. Agencies have substantially less discretion than they did before, and the limits of that discretion are decided exclusively by lawyers.

The court's decisions claim to be grounded in the separation of powers, protecting Congress and the general public from imperial and unaccountable agencies and "expert" bureaucrats. The court, in short, tells agencies (and everyone else) to stay out of the legal lane. But in reality, the court is demoting everyone else—engineers; scientists; economists; Congress; and, ultimately, the general public—out of previously shared space for policymaking. That type of exclusion could compromise effective policy, good government, and a logical division of powers.

And the problem isn't just one decision—*Chevron* was important, but the power balance between courts and agencies and their experts was reasonable before 1984, certainly more so than now. Instead, the suite of decisions (*Loper Bright* only one of them), and the thread of aggressive anti-administrativism that runs through those decisions, has upset the balance.

What can resolve these problems? Many, including President Joe Biden, have suggested Supreme Court reform. This solution is a larger topic that we will not go into here, other than to note that the *Loper Bright* and *West Virginia* cases are illustrations of the judicial aggrandizement that inspires many reformers.

Focusing on the specific question of maintaining a balance of judicial and administrative powers, a few options exist. First, Congress can reduce ambiguity in its laws. A pessimistic perspective would acknowledge that ambiguity helps useful bills pass even when legislators disagree on the details. Extreme partisanship and a proliferation of veto points already make it hard for Congress to act. What seems likely is that only large, single-party majorities in both the Senate and House could permit more specific language. But even in the case of a large majority, to reduce statutory ambiguity, Congress would need to obtain the scientific expertise that agencies already have.

Second, Congress could react by passing legislation that requires *Chevron*-style deference to agencies by courts, and that rejects the major questions doctrine. This kind of legislation seems even less likely to pass, and such a law might be rejected by the Supreme Court on constitutional grounds, anyway.

Third, perhaps the courts will find it necessary to rely on technical and scientific expertise, from agencies or elsewhere. Some legal scholars suggest that "deference is inevitable": judges may loudly claim exclusive domain, especially in high-profile cases, but in most cases, they will come to admit that they don't have all the answers. Having different rules based on how much the judge cares about the outcome of a case is hardly good for the rule of law, but perhaps is better than the juristocracy that's promised by the Supreme Court's recent decisions. ■

Alan Krupnick and **Joshua Linn** are senior fellows and **Nathan Richardson** is a university fellow at Resources for the Future. Linn also is a professor at the University of Maryland, and Richardson is an attorney and professor of law at Jacksonville University.

Modeling Deep Decarbonization in the Industrial Sector: Opportunities and Challenges for Modelers and Policymakers

Decarbonizing the industrial sector is a growing priority. To help produce models with high-quality data that inform policy, transparency and dialogue should be fostered among modeling colleagues, policymakers, and the modeling community.

TEXT Marc Hafstead and Lillian Anderson

PHOTO
ma li / Getty Images

Greenhouse gas emissions from the heavy-industry sector of the economy commonly are referred to as "hard to abate," especially in discussions about achieving deep decarbonization (i.e., completely, or nearly completely, eliminating emissions) across various industrial subsectors such as iron and steel or cement. These industrial emissions are hard to abate for a few reasons. First, industry subsectors tend to involve high-temperature, energy-intensive processes that are difficult to replicate with electrification or less energy-intensive processes, given the limitations of existing technologies. These subsectors also often produce carbon dioxide emissions as a byproduct of manufacturing (e.g., cement). Second, the technologies that are necessary to achieve deep decarbonization of these industries often are theoretical, unproven, or cost prohibitive. In the power and transportation sectors, on the other hand, low-carbon options have seen significant innovation over the past few decades and are relatively straightforward.

The complexities in decarbonizing these hard-to-abate industrial sectors also make it hard to predict how effective various policies can be in encouraging decarbonization and the implementation of advanced technologies. The current set of models that can predict changes in industrial energy demand and associated emissions over time are useful, but these models have limitations. Take an example of a model which suggests that a given policy would have little effect on future emissions. Does this result really mean that the policy is ineffective? Or does the result suggest that the model does not accurately reflect the mechanisms through which the policy could achieve emissions reductions?

Challenges in Modeling Industrial Decarbonization

Researchers at Resources for the Future (RFF) have done a deep dive into various approaches for industrial-sector modeling over the past year and a half. We published a report (with colleagues from our partner institution, the RFF-CMCC European Institute on Economics and the Environment) that reviews the strengths and weaknesses of existing approaches to industrial-sector modeling. We also hosted a private workshop that focused on identifying the challenges involved in modeling policies and pathways for deep decarbonization across energy-intensive industrial sectors.

Each energy-intensive subsector of industry—such as steel, cement, aluminum, chemicals, and pulp and paper—has its own unique approaches to decarbonization and faces its own unique challenges. Approaches to decarbonizing these sectors include switching sources of energy (i.e., replacing technologies and processes that are powered by fossil fuels with alternatives powered by electricity, green hydrogen, or biofuels), improving energy efficiency in production processes, developing new processes that emit less greenhouse gases, using materials more efficiently, implementing carbon capture and storage, reducing waste, and recycling products. Any of these methods alone in any given sector likely would not be enough for deep decarbonization, and each specific sector likely would need to use a combination of these approaches and use them to varying degrees. Any modeling framework to address deep decarbonization in industrial sectors therefore must be able to include a variety of options and approaches to decarbonization.

Further complicating industrial-sector modeling are data challenges. Attaining the appropriate data for modeling these sectors can be difficult. The availability and detail of data vary across countries, and how easily that data can be compared to the data from other countries, also can vary wildly. Even within the United States, it can be difficult to determine the precise production processes used (and related energy intensities) across different facilities, let alone make reasonable predictions of the uptake of decarbonizing technologies. Modeling the adoption of advanced technologies requires predicting the costs and performance of unproven technologies that don't currently exist at scale, which can force modelers to rely on probabilistic forecasts of energy-technology costs that often tend to be pessimistic.

PHOTO
Sean Justice / Getty Images

As we worked on our deep dive into industrial-sector decarbonization, we realized that perhaps the biggest challenge for industrial-sector modelers is that, despite the numerous teams working on these kinds of modeling frameworks, modelers often work in silos. Little to no collaboration or data sharing occurs between different modeling teams. Further, modelers often are detached from policymakers who are looking to develop new policy solutions for decarbonizing industrial sectors; in other words, modelers may be answering questions that are not as relevant to current policy discussions as they should be.

Fostering Collaboration

To foster collaboration among modeling teams, and between these groups and policymakers, RFF invited key modelers, policymakers, and other interested stakeholders to a private workshop in May 2023. The workshop followed the Chatham House Rule: participants were free to use information shared at the workshop as long as the source of the information remained anonymous. At the workshop, the group of participants agreed that sharing ideas more freely could help with some of the more difficult aspects of industrial-sector modeling; for example, how to approach international trade, integrate clean energy technologies into models, and solve other methodological or analytical problems.

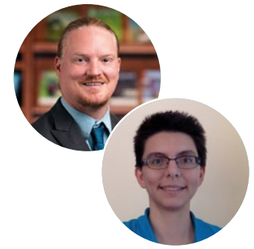
Another consensus was that sharing data between teams also could help address data availability issues. Because different teams have access to different databases and data sets, a process and a location for sharing that data between teams would be incredibly beneficial to all teams that model the industrial sector. Of course, this idea raises the question of how modelers can collaborate on data, and who would fund and maintain an industrial-sector database that could be used across different modeling platforms.

At the workshop, participants also identified modeling international trade as a tricky topic, especially as it relates to modeling unilateral climate policy or trade restrictions such as border adjustment mechanisms, which impose fees on imported products based on the greenhouse gas emissions associated with a given product. Participants posed some relevant questions. What's the better approach to model international trade: linking industrial-sector models with trade models, or accounting for trade within the industrial-sector model itself? Would we get the most accurate projections by using models for international trade that already exist—or should we develop new models for international trade that are specific to industrial subsectors, and then link these new models to industrial-sector models that are tailored to specific countries?

Finally, we identified a need for continued dialogue between policymakers and modeling teams. Policymakers need to know which models are or are not well suited to answer specific questions, and modelers need to know the types of policies that are under consideration and related questions that are being asked. Through continuing conversations, modeling teams can help policymakers and stakeholders understand the outcomes of different policy choices in terms of emissions, costs, impacts on various demographic groups, and equity among communities. This information can both improve decisions and facilitate consensus on the most effective policies across stakeholders and the general public.

In the coming years, RFF will host similar convenings with familiar and new participants to build a community of industrial-sector modelers that jointly share data, research agendas, and best practices; help each other address common challenges; and align their research to answer the most policy-relevant questions. This growing community can help policymakers develop policies for industrial decarbonization that are effective, efficient, and fair. ■

"Through continuing conversations, modeling teams can help policymakers and stakeholders understand the outcomes of different policy choices in terms of emissions, costs, impacts on various demographic groups, and equity among communities."



Marc Hafstead is a fellow and **Lillian Anderson** is a research associate at Resources for the Future.

NO. 217 | WINTER 2025 | *"A balance needs to be attained between methane and carbon dioxide."*

Should Climate Policy Focus More on Methane or Carbon Dioxide?

TEXT
Christian Azar,
Daniel Johansson,
and Thomas Sterner

ILLUSTRATION
James Round

Reducing greenhouse gas emissions will limit further increases in global temperature and reduce the negative effects of climate change. An important challenge is to find the most efficient balance in abating both methane and carbon dioxide.

Methane is a significantly stronger greenhouse gas than carbon dioxide. An important policy question is whether to direct more efforts toward reducing methane emissions or toward mitigating carbon dioxide emissions.

One kilogram of methane in the atmosphere is roughly 80 times more potent than a kilogram of carbon dioxide. Furthermore, methane adds water vapor to the stratosphere and ozone to the troposphere, so the resulting warming effect is roughly 120 times stronger than that of carbon dioxide. However, the atmospheric lifetime of methane is shorter (approximately a decade), while the lifetime of carbon dioxide in the atmosphere is much longer (Figure 1). In fact, after 100 years, around 40 percent of emitted carbon dioxide remains in the atmosphere. After 1,000 years, some 20 percent remains. The exact shares depend on the size of the cumulative historic emissions: the more we have emitted in the past, the higher the share of a pulse emission that will remain over time.

For climate policy to be efficient, the warming effects of carbon dioxide and methane have to be compared—or, more specifically, made comparable—on a common scale. This comparison is difficult, but the United Nations Framework Convention on Climate Change and others typically tackle it by using the so-called global warming potential (GWP) metric. The GWP shows the cumulative warming effect of an emission of 1 kilogram (kg) of methane over a specific time horizon, typically

"Methane adds water vapor to the stratosphere and ozone to the troposphere, so the resulting warming effect is roughly 120 times stronger than that of carbon dioxide."

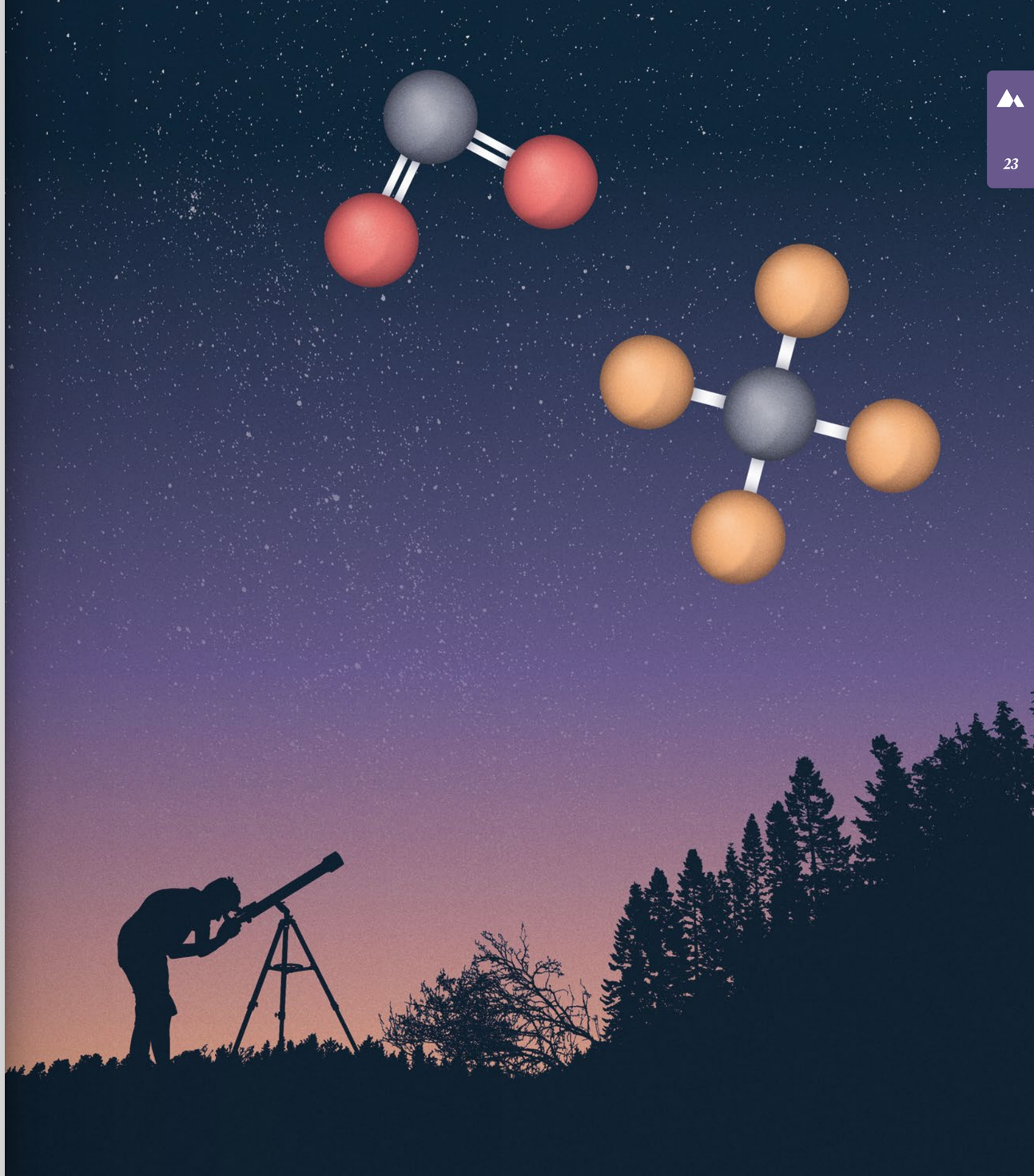
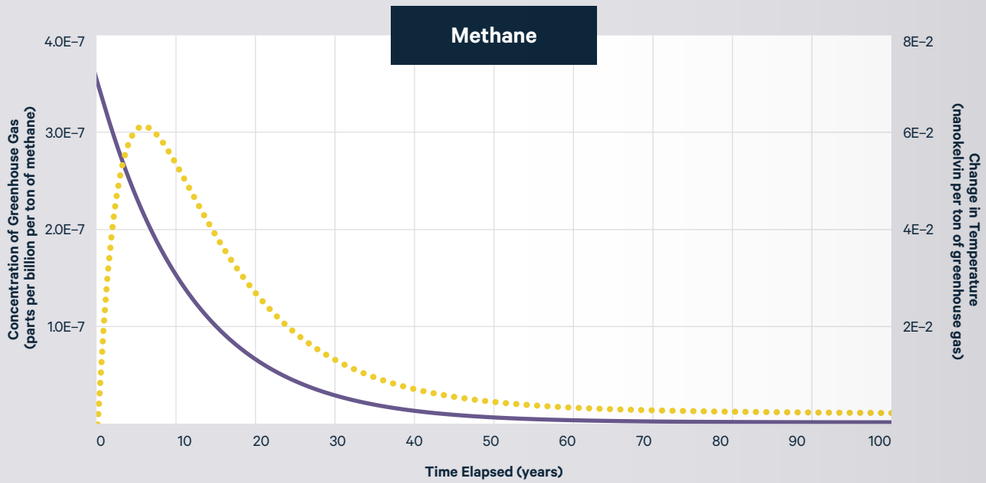


Figure 01
Change in Global Temperature and Concentration Due to a Pulse Emission of One Ton of Greenhouse Gas



100 years, and compares that value with the warming effect of an emission of 1 kg of carbon dioxide over that same horizon. Notably, effects in each year of the horizon are treated equally, and effects beyond the horizon are ignored. The GWP for methane evaluated after 100 years (i.e., GWP100) is about 27.

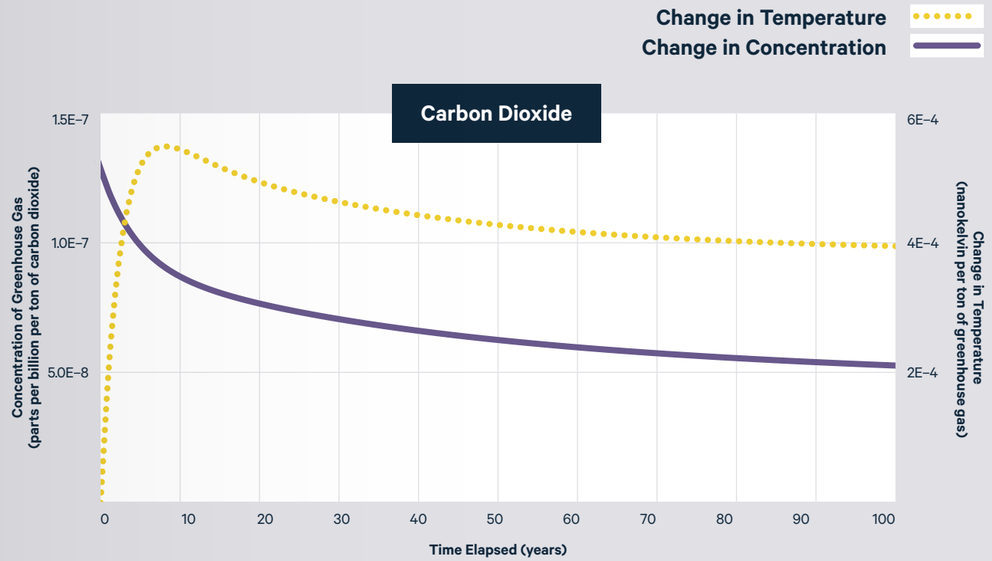
Critiques have been directed against this method of comparing greenhouse gases. One critique focuses on the fact that the GWP fails to consider certain key economic features. For example, the GWP does not consider discounting nor likely nonlinearities in damages.

Another critique points out that the GWP fails to portray important dynamic features. For instance, stabilizing the global temperature requires emissions of carbon dioxide to reach net zero, but stabilizing the temperature would be possible even if methane emissions continued at a constant rate in perpetuity. The GWP metric fails to convey this dynamic feature.

The trade-off between carbon dioxide and methane entails several dimensions, and opinions vary on the nature of the trade-off. Some analysts argue that GWP100 overvalues the climate impacts of methane; others say that GWP100 undervalues them; and yet others argue that the GWP is irrelevant or misleading, that we can have perpetual emissions of methane, and that virtually all abatement efforts should be directed toward carbon dioxide and other long-lived greenhouse gases.

In this article, we'll first delve deeper into the dynamic features of methane and carbon dioxide. Then, we'll further explore the arguments about how much effort should be put into reducing methane in relation to carbon dioxide. Finally, we'll present recent estimates of the social costs of methane and carbon dioxide. The ratio of the social cost of methane to the social cost of carbon can serve as a possible metric to guide the trade-offs in abatement efforts between these two important greenhouse gases. The approaches and problems discussed here are relevant not only for methane, but also for other climate forcers such as black carbon and contrails.

“The trade-off between carbon dioxide and methane entails several dimensions, and opinions vary on the nature of the trade-off.”



“The key reason why no single method exists to compare methane and carbon dioxide is that their respective lifetimes in the atmosphere are different.”

Basic Properties of Methane and Carbon Dioxide

The key reason why no single method exists to compare methane and carbon dioxide is that their respective lifetimes in the atmosphere are different.

Figure 1 shows the concentration and temperature responses associated with one unit emission of each respective greenhouse gas. The concentration immediately starts to fall after the pulse emission. The temperature response, in contrast, first lags behind the concentration response, then lingers for a longer period of time, which reflects the inertia of the climate system.

When evaluating the GWP of methane, a time horizon must be set over the cumulative warming from the methane emissions (known as the radiative forcing). According to the latest assessment by the Intergovernmental Panel on Climate Change, the GWP20 (i.e., the GWP over a time horizon of 20 years) is 80, GWP100 is 27, and GWP500 is just 7. That is, over longer time horizons, carbon dioxide becomes more important and methane relatively less so. Crucially, no value for the time horizon is objectively correct—subjective choices, laden with value judgments, must be made.

Comparing Sustained Emissions Rather than Emission Pulses

Let us now switch from analyzing emission *pulses* to constant *rates* of emissions. What happens to atmospheric concentrations of these greenhouse gases and the average global temperature under sustained emissions?

Figure 2 shows the increase in average global surface temperature with sustained emissions of 1 ton of methane per year for 500 years, compared to sustained emissions of 27 tons of carbon dioxide per year. The rationale for this comparison is that, according to the GWP100 metric, 1 ton of methane per year over 100 years warms the climate by about as much as 27 tons of carbon dioxide per year over the same period. These emissions are equivalent in terms of their GWP, but we see that the dynamics of the temperature responses are very different.

For methane, we see a fast initial response, but after a few decades, the temperature begins to plateau, eventually stabilizing over the long term, even as methane emissions continue at the same rate. The temperature increase associated with this sustained, constant level of methane emissions continues slowly for many hundreds of years before stabilizing due to the thermal inertia of the oceans and feedbacks from the carbon cycle.

For carbon dioxide, on the other hand, we get a roughly constant rate of temperature increase. After about 100 years, the temperature increases to the same level as in the scenario with methane (which might be expected, given that 27 kg of carbon dioxide should be equivalent to 1 kg of methane on a 100-year time horizon, as shown by Azar and Johansson in their 2012 paper). However, whereas the temperature continues to increase with sustained carbon dioxide emissions, that's not the case with sustained methane emissions.

Constant methane emissions eventually lead to a stable but elevated temperature because methane has a short lifetime in the atmosphere. After a few decades of sustained methane emissions, the added emissions are balanced out by the breakdown (oxidation) of methane. In essence, the more methane we have in the atmosphere (due to our emissions), the more (in absolute terms) is broken down (removed) from the atmosphere through chemical reactions, primarily with the hydroxyl radical.

Constant carbon dioxide emissions would lead to a sustained increase in global temperature because carbon dioxide has a long lifetime and accumulates in the atmosphere. Research has well established that each ton of carbon dioxide emissions yields a near-permanent elevated temperature (Figure 1), and a constant *rate* of carbon dioxide emissions yields a nearly constant *rate* of global temperature increase (Figure 2).

Thus, an important asymmetry emerges: constant carbon dioxide emissions yield a sustained rate of increase in the global temperature, whereas constant methane emissions lead to a near-stable temperature increase.

An important conclusion ensues for the debate concerning methane vs carbon dioxide emissions: To stabilize global temperature, emissions of carbon dioxide must eventually drop to zero. Not so for methane, for which constant emissions can be compatible with a stable global temperature.

Policy Positions on Methane vs Carbon Dioxide: Two Contrasting Schools of Thought

These observations have given rise to two fundamentally different positions in the debate over controlling emissions of methane vs emissions of carbon dioxide.

Policy Position 1
Give Methane a Higher Value

Some propose that we need to do much more to limit methane emissions, i.e., more than the warming potential suggested by GWP100. Related arguments typically focus on near-term consequences, such as the risk of passing tipping points in the short term or the need to quickly reduce the current rate of warming. Those who take this position tend to argue in favor of using GWP20 and suggest, for example, that mitigation efforts should focus on reducing methane emissions from shale gas, cattle, or agriculture.

The fundamental problem with this approach, however, is that choosing a 20-year time horizon implies a neglect of the warming impact from year 20 onward, as if what happens in the longer term would not matter.

An argument sometimes raised in defense of this position is that the 20-year time horizon should be used *only* when comparing the impacts of the two greenhouse gases, and that different time horizons should be used for different purposes. But this argument leads to considerable problems of inconsistency. Why should we take a long-term perspective when thinking about how carbon dioxide affects climate change, but consider a short time horizon when comparing greenhouse gases?

Policy Position 2
Methane Is Not (So) Important for Climate Stabilization

> **Constant carbon dioxide emissions yield a sustained rate of increase in the global temperature, whereas constant methane emissions lead to a near-stable temperature increase.**

> **If the current level of methane emissions is kept constant, then the global temperature eventually would increase by about 1˚C above the pre-industrial level, in addition to the contribution from carbon dioxide.**

A second school of thought argues that GWP100 gives an excessively high value for methane. This argument builds on the dynamic factors mentioned above, that sustained (constant) emissions eventually result in a stable temperature response. The most vulgar version of this argument says that we do not need to reduce methane emissions at all, because constant methane emissions do not produce additional warming above the equilibrium temperature.

However, this argument is irrelevant. The fact remains that every time we emit methane, the global temperature becomes higher than it would have been otherwise.

If the current level of methane emissions is kept constant, then the global temperature eventually would increase by about 1°C above the preindustrial level, in addition to the contribution from carbon dioxide. This increase in temperature would make it essentially impossible to achieve the Paris Agreement target of limiting the increase in global temperature to 1.5–2.0°C.

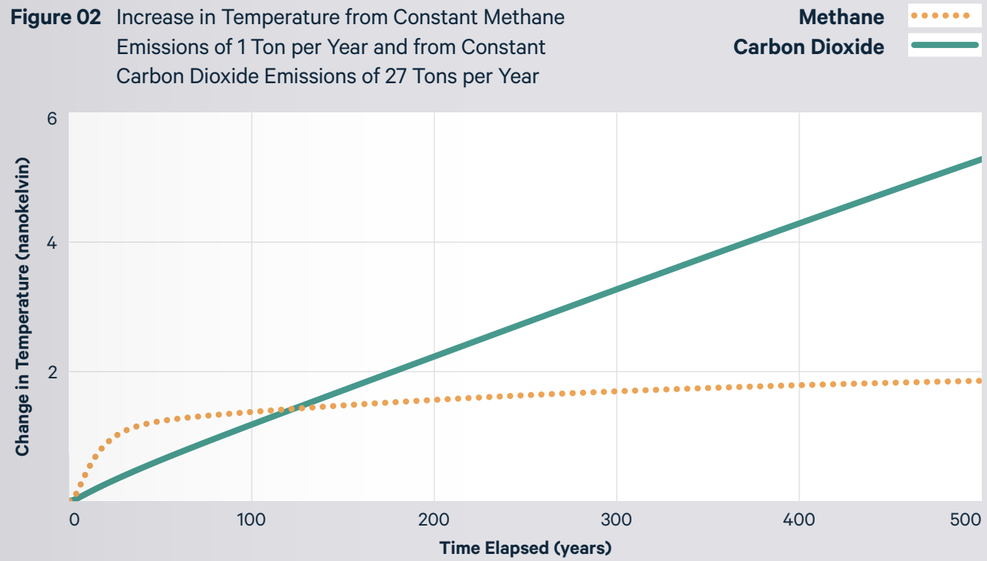
Furthermore, whereas reducing carbon dioxide emissions only *implies* a reduction in the rate of increase in global temperature (which is why carbon dioxide emissions eventually must drop to net zero), reducing methane emissions will in fact *reduce* the global temperature (in terms of the contribution from methane emissions alone to the global temperature response). This reduction in global temperature will in turn reduce the pressure to abate carbon dioxide—and reduce the associated abatement cost for a given level of climate stabilization.

In fact, reducing methane emissions will help achieve climate targets. A balance thus needs to be attained between methane and carbon dioxide. For that purpose, we turn now to economic metrics.

Social Costs of Methane and Carbon Dioxide

An alternative approach to comparing the relative warming impacts of

Figure 02 Increase in Temperature from Constant Methane Emissions of 1 Ton per Year and from Constant Carbon Dioxide Emissions of 27 Tons per Year



“Emissions of carbon dioxide from the combustion of fossil fuels are the dominant driver of climate change, while emissions of methane (whether from agriculture or fossil fuels) also play an important role.”

methane and carbon dioxide is to compare the marginal economic damage of emissions of these two gases. The common terminology that describes this economic damage is the “social cost of methane” and the “social cost of carbon dioxide.” (Often with the latter, people skip the “dioxide,” saying instead, “social cost of carbon.”) The ratio between these two quantified social costs (abbreviated as the SCM/SCC ratio) may be used as a metric to compare the relative importance of methane (or any other greenhouse gas) to carbon dioxide in creating the economic costs that result from climate change.

The social cost of any greenhouse gas is measured as the marginal damage of one unit emission of that particular gas, integrated over time. Here, the marginal damage is the additional amount of damage in economic terms (discounted over time) that is caused by one additional unit of emission.

Economists have tried to estimate the social cost of carbon for more than three decades. This research was pioneered in 1992 by William Nordhaus and William Cline in their respective work. Despite this long period of research, estimates of the social cost of carbon still span a wide range, quantified in rough terms from $10 to $1,000 per ton of carbon dioxide. The most important parameters that produce this wide range are the discount rate, damage function, and future temperature pathway. The US Environmental Protection Agency—building on work published in 2022 by the Social Cost of Carbon Initiative, a collaboration between Resources for the Future and the University of California, Berkeley—estimates a value of $190, following specific guidelines that were suggested in a 2017 report from the National Academies of Sciences, Engineering, and Medicine.

Efforts to estimate the social cost of methane have intensified lately (as with work from the Social Cost of Carbon Initiative in 2022 and our own work in 2023). In part, these efforts have been motivated by the increased recognition that multiplying the social cost of carbon by the GWP value for methane does not necessarily give an appropriate estimate of the social cost of methane.

In our recent work, we estimate the social cost of methane and social cost of carbon. Our estimate of the social cost of methane is $4,000 per ton, with the social cost of carbon estimated as $192 per ton of carbon dioxide. The ratio of these two costs is 21, a somewhat lower value than the GWP100 of 27.

We find a higher estimate than Nordhaus for the social cost of carbon. The reason is that we use both a lower discount rate and a higher damage function. The lower discount rate is taken from a survey of economists and philosophers. A high discount rate implies that the lives of people in the future are worth less, just because they live in the future. The higher damage function comes from a recent meta-analysis of the costs of climate change. Our estimate of the social cost of carbon is roughly the same as that obtained by the Social Cost of Carbon Initiative, although our estimate of the social cost of methane is about twice as high.

Second, the SCM/SCC ratio varies with the discount rate. The lower the discount rate, the lower the ratio. The ratio drops because a lower discount rate increases the social cost of carbon much more than it increases the social cost of methane, given that carbon dioxide is much more long-lived in the atmosphere (Figure 1). When we use the higher discounting parameters from Nordhaus in our analysis (which entails a significantly higher discount rate), the SCM/SCC ratio increases to 33. This use of higher discount rates, which favors the present over the more distant future, is analogous to shorter time horizons in the GWP calculation.

A higher ratio implies that methane contributes relatively more to the costs of climate change, but a higher discount rate also means a drop in the social costs of both carbon and methane.

Our paper demonstrates a relationship between the SCM/SCC ratio and the time horizon of the GWP. Assuming that the background temperature pathway continues at close to current levels, we find that the difference between the discount rate and economic growth rate is inversely proportional to the time horizon. Thus, a discount rate of 1 percent above the growth rate yields an SCM/SCC ratio approximately equal to GWP100.

We also find that the social cost of carbon is sensitive to the background temperature. When we run our model with a business-as-usual emissions scenario that leads to a 3.7°C temperature increase by the year 2100, our estimate of the social cost of carbon increases to $1,200 per ton of carbon dioxide. This increase in the social cost of carbon stems entirely from the higher marginal damages that occur when the background temperature is higher.

The social cost of methane also increases, by about a factor of two. This increase for methane is less than the increase in the estimate of the social cost of carbon because methane is short-lived and hence less affected by a long-term temperature pathway. The combined changes in the social costs of methane and carbon, in turn, means that the SCM/SCC ratio drops from 21 to around 7. Hence, with a higher background temperature, the social cost of carbon increases by several times, the social cost of methane doubles, and the effect of methane on climate change is significantly *lower* relative to carbon dioxide.

An interesting corollary here is that estimates for the social cost of carbon (in an optimizing framework, in contrast to predetermined temperature pathways) also depend on assumptions about the availability of negative emissions technologies (e.g., bioenergy with carbon capture and storage). When such technologies are available and cost-effective, the optimal temperature pathway may become significantly lower in the very far future, which would exert downward pressure on the social cost of carbon.

For instance, if we exclude the option of net-negative carbon dioxide emissions in our model, the estimate of the social cost of carbon increases from $192 to $318 per ton of carbon dioxide. The impact on the social cost of methane is much smaller (less than 10 percent), and the SCM/SCC ratio drops from 21 to 13.

Notably, for optimization models, the choice of whether to consider net-negative emissions in the long term significantly affects the optimal valuation of methane emissions vs carbon dioxide emissions.

Conclusions

Emissions of carbon dioxide from the combustion of fossil fuels are the dominant driver of climate change, while emissions of methane (whether from agriculture or fossil fuels) also play an important role. To meet the targets of the Paris Agreement, climate policies need to regulate both carbon dioxide and methane emissions. A key question is how much to value the mitigation of carbon dioxide emissions vs reductions in methane emissions.

Comparisons between methane and carbon dioxide are tricky and context dependent, with several pitfalls. Those who say that methane emissions do not have to be abated rely on the fact that methane emissions indeed can be sustained at a constant level even while maintaining a stable global temperature. However, every ton of methane emitted does increase the global temperature above what would otherwise be the case.

On the other hand, some say that methane should be given higher priority in efforts to mitigate climate change (in line with GWP20) because of the urgent nature of the climate problem. This argument risks downplaying the fact that climate change is quintessentially a long-run problem, a feature which is critical to take into account when considering carbon dioxide.

In this article, we have discussed two approaches to valuing the climate benefits of reducing methane vs carbon dioxide: calculating the GWP of these gases (an approach based on physics), and calculating a ratio of the social costs of the two greenhouse gases (a combined method based on physics and economics). Although different in many aspects, these two metrics are conceptually related. From an economics viewpoint, the most natural expression of the importance of each respective greenhouse gas probably is given by the SCM/SCC ratio, which leverages information about the relative impacts of greenhouse gases on society and welfare, not just the relative impacts on global temperature. On the other hand, policymakers should note potential complications associated with the uncertainty of variables such as discount rates and temperature trajectories. ■

Christian Azar is a professor and **Daniel Johansson** is an associate professor at Chalmers University of Technology, Sweden. **Thomas Sterner** is a university fellow at Resources for the Future and a professor at the University of Gothenburg.

Finding a Balanced Perspective on Climate Solutions

Resources magazine recently spoke with Kate Barnes, Senior Program Officer for Climate Solutions at the MacArthur Foundation. Below are excerpts from the conversation, which ranged across topics like mining for critical minerals, centering equity in the search for climate solutions, and what gives her hope in the face of the climate crisis.

Supporter Spotlight

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

R*esources* magazine: Tell us about your personal interest in nature and the environment. How did those interests develop?

Kate Barnes: I grew up on an apple orchard in a farming town in Indiana. I spent a lot of time outside as a child, playing and working in our orchard and on our friends' farms. We gathered apples, raised goats, and grew a lot of our own produce. My parents worked in medicine, and by the time I reached college, I knew that I wanted to study biology. But then I had an opportunity to support a research study in the Caribbean, looking at coral and fish diversity following a major bleaching event. That experience drew me to the environment instead of medicine.

What excites you about working on climate issues at MacArthur, and the work you support at Resources for the Future (RFF)?

The climate crisis is an existential threat. So many aspects of our society have to change for us to solve this crisis, and achieving those changes feels impossible and overwhelming at the individual level. One of the reasons I love this work is because I get to support other people who care a whole, whole lot about solutions. It gives me a sense of community and hope that I might not have, otherwise. I like supporting RFF because the quality of the research it produces gives me confidence that I, and the communities that I care about, understand the most important dimensions of the crisis and the solutions.

Can you talk a bit about MacArthur's environment and climate priorities? The foundation has been sunsetting its specific effort toward advancing strategies that mitigate climate change—what MacArthur calls its "Climate Solutions" strategy. How are those priorities evolving?

We have a focus on the United States and the energy sector with our climate work, so our thought partnership with RFF is based on those themes. Climate Solutions began in 2014, and it was conceived as a time-limited area of work that was meant to reduce emissions and ensure that the Earth stays below a 2°C temperature increase. The Climate Solutions strategy will wind down by 2026, and we may develop a new strategy around climate. But we'll continue to focus on the whole spectrum of capital that can be deployed to address the climate crisis, including our investment portfolio.

> **"One of the reasons I love this work is because I get to support other people who care a whole, whole lot about solutions."**

PHOTOS
Courtesy of Kate Barnes

What do you see as the value of the independent and nonpartisan research that RFF provides?

RFF's value comes down to the fact that there are real tensions within the solutions to climate change. MacArthur's strategy aims to center equity, which means having honest conversations about trade-offs: Take transition minerals like lithium, cobalt, and nickel, which are needed to electrify society and move away from fossil fuels. Mining could provide a lot of jobs, but the sector has a record of harms to the environment and human rights. Given that a lot of new sources of critical minerals in the United States are near or on Indigenous lands, the sector will have to improve how it works. How can we transition away from fossil fuels without repeating those harms?

I know I can rely on the work that RFF is doing on these issues. The topic of mineral mining is relatively new to me, so I'm having to educate myself about it to make informed decisions related to our funding. I trust RFF's analysis and research to help me gain a balanced perspective on these tensions.

Finally, what makes RFF special? What do you think sets RFF apart from other organizations?

The high caliber of the research that RFF conducts stands out, and the fact that RFF uses that research to inform policy is important to us at the MacArthur Foundation. We also appreciate that almost every aspect of RFF's research includes a robust environmental economics component, which we feel is unique. A lot of information out there focuses strictly on science or on a particular bit of policy. RFF does a really good job of making sure to involve economic analysis and connect its work to policy engagement.

Four Ways You Can Support RFF

1 Give through our website

Visit **www.rff.org/donate** to make a one-time donation, or to set up a monthly recurring donation.

2 Give through the mail

Send your check to Resources for the Future | 1616 P Street NW, Suite 600 | Washington, DC 20036

3 Give through a donor-advised fund

Donate through a DAF account at a community foundation or financial institution to support RFF while receiving favorable tax benefits.

4 Give through a will, trust, or gift plan

Include RFF in your estate plans to provide meaningful, long-lasting support.

Discover other ways to give at **rff.org/waystogive** or contact Ryan Sabot at **rsabot@rff.org**

Celebrating the Life and Career of Ray Kopp

Ray Kopp started at Resources for the Future in 1977, holding multiple positions at the organization, including fellow, director, and vice president. He passed away in August 2024, which compels colleagues to celebrate Ray's life from many angles.

TEXT Kristin Hayes, Billy Pizer, Paul Portney, and V. Kerry Smith

This article celebrates the life and legacy of Dr. Ray Kopp, with whom I shared an office wall for much of my tenure at Resources for the Future (RFF). When I first started working for Ray in late 2010, our respective offices were on opposite sides of the building—and when we undertook a big renovation and shuffled everyone's offices around, my primary request was "be closer to Ray."

Ray epitomized many of the things that are great about RFF: a commitment to doing work that matters, a willingness to push intellectual boundaries, a firm belief in excellence. And Ray played as hard as he worked; he brought that same desire for excellence to his rich life outside the office, whether prepping for car races, cooking, tending to bonsai, or making toys for his grandchildren.

I encourage you to read about Ray's accomplishments in the sections below—and through those words, I think you'll see that many people benefited from being closer to Ray. I found him creative, inspiring, organized, diligent, and endlessly empowering. He was an introvert who nonetheless could talk your ear off about subjects of mutual interest. He was fundamentally private, but nonetheless drew people to him and inspired them in ways that always impressed me.

I miss Ray profoundly, and I'm grateful for the opportunity to introduce this article about someone who gave RFF so much.

INTRODUCTION BY Kristin Hayes

> I believe he has been one of the drivers that steered Resources for the Future into the position it is today. Ray was at the heart of doing research inspired by deep engagement with policymakers and stakeholders.

Ray as Mentor and Leader

Ray was exceptionally good at *not* being the center of attention. He loved to give credit to others, compliment the attributes of people around him, and lead from behind.

AS REMEMBERED BY Billy Pizer

Ray leaves a legacy as a scholar, collaborator, and one of the architects of RFF being a truly enjoyable place to work. You'll hear more about his contributions in those areas later in this article. But where I want to focus my remarks is on Ray's impressive ability to identify and cultivate opportunities to improve policymaking by applying economic research—and, through his leadership, define a successful trajectory for RFF. I'll give four examples that make the point.

When I arrived at RFF in 1996, I had been researching and writing about how two prominent economic ideas for regulating greenhouse gases—carbon taxes and cap-and-trade programs—behaved differently. And, perhaps more importantly, how these approaches could be combined to deliver even better "economic" results. By which I mean, I had an equation that defined what was good for society, and playing with combinations of carbon taxes and emissions trading could provide better outcomes than either strategy alone. This was literally all academic, however. I had written journal articles and given talks to economics departments. But Ray and another colleague, Dick Morgenstern, saw in this research something I did not: A way to connect all this to the policy world.

In 1997, Ray, Dick, and I wrote an article we called, "Something for Everyone: A Climate Policy that Both Environmentalists and Industry Can Live With." That blog post described how environmentalists valued certainty about the emissions reductions that could be associated with a cap on emissions. Industry and business cared about having some certainty about the cost of such a policy or regulation. We proposed mashing them together in the same way my research had suggested, but without the equations, math, and complexity of academic writing. We later called the policy a "safety valve."

Folks may recognize some version of the safety-valve idea as a component of multiple trading programs—including California, the Regional Greenhouse Gas Initiative, and the EU Emissions Trading System. But in 1997, the idea was totally new. What Ray was doing, early on, was making research accessible and relevant to policy in a way that 28-year-old me was just beginning to understand. Under Ray's leadership, RFF's Weathervane website did this same thing across a range of climate topics for nearly 15 years.

The second example is Ray's co-leadership (with me) of the Climate Policy Forum, an 18-month project in 2006–2007 that brought together business leaders from 23 companies to provide detailed and thoughtful policy options for climate legislation. I was certainly older by that point and understood more about policy issues. In particular, I had a keen idea of the kinds of topics we wanted to cover. Think of me as the "back end" of the effort, managing analysis. Ray was the front end, thinking about who needed to be at the table, how the convening of business leaders needed to be executed, and how the topical analysis and writing needed to be presented.

The result was threefold. Over the course of 18 months, we provided a forum for business leaders across major sectors—electricity, fossil energy, transport, agriculture, heavy industry—to meet one another and learn about the various facets of climate policy. The Climate Policy Forum helped these leaders understand their own issues and questions, target RFF research and expertise to answer those questions, and move the business conversation forward about climate policy.

We also produced a lot of ideas, ranging from economy-wide policy options to sector-specific options. We wrote about offsets and agriculture. We wrote about domestic policies that were tied to international negotiations. And we answered basic questions about the pace, timing, and cost of emissions reductions that were necessary to hit different targets. Finally, we produced a collection of short briefs—the report itself was a collection of 15 of these briefs—that were easy to digest and a resource for stakeholders and students for more than a decade.

Another example is something I learned about only two years ago, when Ray shared a "thank-you note" from a Senate Appropriations Committee staffer. Back in 2016, Ray had written a memo for the committee staff—something RFF researchers increasingly are asked to do—on how to design a subsidy mechanism for the nuclear power industry. The question was simple: What options are available for the federal government to keep nuclear power plants financially viable, and how much would those options likely cost? In typical fashion, Ray produced a seven-page memo, outlining options that drew from available data. Moreover, the memo highlighted how an auction mechanism could minimize the necessary payment by incentivizing generators to reveal what they really needed to survive.

Nothing further happened on this in 2016. But in 2021, Congress passed the Bipartisan Infrastructure Law, which included the Civil Nuclear Credit Program. This program allows operators of commercial US nuclear reactors to competitively bid on credits that help support their continued operations. As a Senate staffer put it in his note to Ray, "Your original analysis was used throughout the entire process for this."

My most recent example comes from Ray's work over the past three years with Senate staff on climate and trade issues. In a rare area of bipartisan interest, both Democrats and Republicans in the Senate have been interested in how to tackle the challenge of reducing greenhouse gas emissions in traded industrial goods, even as many of our global competitors are not doing so. This is tricky stuff—both understanding how much carbon is emitted to create various products in various countries, and thinking through the design of a system that can tackle the problem. A lot of options are on the table, with a lot of consequences stemming from those options.

Ray spent the last two years of his life leading RFF's work in this area, producing ideas and analyzing their consequences, following direct engagement with Senate staff. These efforts build on research that Ray organized on climate and trade for probably a decade or more, including collaborations with European and Japanese colleagues and numerous reports and publications. Like his work on nuclear subsidies, this work with the Senate has yielded public and private appreciation. But what was more gratifying was seeing Ray's efforts materialize in better-informed legislative proposals and, hopefully someday, successful efforts to reduce industrial emissions dramatically.

These kinds of activities at RFF over the nearly three decades that I've known Ray are not just his own direct efforts. Thanks to Ray's leadership over many years; his mentorship of young scholars (like me, 28 years ago); his steering of the organization as a vice president, program director, and staff director; and his incredible knack for seeing how to write and talk in ways that engage stakeholders and policymakers—I believe he has been one of the drivers that steered RFF into the position it is today. Ray was at the heart of doing research inspired by deep engagement with policymakers and stakeholders. And thanks to him, RFF increasingly succeeded in our unique contribution of relevant, independent, honest, and trusted research that answers the questions those policymakers and stakeholders care about. ■

Kristin Hayes is senior director for research and policy engagement, **Billy Pizer** is president and CEO, **Paul Portney** is a senior advisor and former president and CEO, and **V. Kerry Smith** is a university fellow at Resources for the Future.

Fun at Work

Ray created good culture at RFF by bringing good times, and he literally helped build a great RFF community through great hiring.

AS REMEMBERED BY Paul Portney

PHOTO
Courtesy of John Mullahy and Paul Portney

Billy Pizer has spoken to the seriousness with which Ray immersed himself in the process of designing public policy regarding climate change. And Kerry Smith will point out the high quality and significant impact of Ray Kopp's economic research throughout Ray's career at RFF, along with important participation in natural resource damage assessments.

I want to take a different tack. Ray was a terrific researcher and a model for those wishing to see their research have an impact on public policy. And during his 40+ years at RFF, he also helped create an atmosphere in which doing research on environmental and natural resource issues was not only rewarding but also—dare it be said?—fun!

He didn't do this by being an office cutup or practical joker. In fact, Ray was reserved, remarkably disciplined, and managed his time as well as anyone I've ever worked with. That said, he always made sure to allow time in his schedule for fun, and he always tried to include his colleagues in the action.

This social savvy may have been something as simple as hosting a midsummer pool party at Linda's and his home in Great Falls or encouraging us all to go out for drinks together at the end of the workweek. But the fun took more ambitious forms, as well. For instance, Ray made sure that RFF had a team in Washington's traditional summer Softball on the Mall league, where we interacted with teams from congressional offices, government agencies, and other nonprofit organizations. (See above, with Ray shirtless in the top row.) Those softball games may have been his first involvement with the people involved in the public policy process!

As another example, in 1982, Ray and others at RFF hired a new research assistant, John Mullahy, who not only was very technically gifted but also shared our interest in college basketball and, particularly, the annual NCAA tournament. Ray knew the office pool was a source of great entertainment across RFF and tasked John with running it, at which John excelled. When interviewing research assistant applicants in subsequent years—only after questioning them about their undergraduate education, technical skills, and other relevant qualifications—Ray might casually ask, "By the way, do you have any experience with NCAA tournament pools?"

Permit me a final and epic example. One spring in the mid-1980s, Ray and I were talking about our love for Delaware's Atlantic beaches. Ray said, "Why don't we rent a big beach house there for a weekend and invite everyone we work with to come?" And that's what we did. Members of the administrative staff, research assistants, and junior and senior researchers came for sun, swimming, beach football, and the occasional adult beverage. I would say more, but we took an unspoken vow that, like Las Vegas, what happens in Dewey Beach stays in Dewey Beach! Long before the term "team building" took hold in organizational behavior, this was a definitive example, never to be forgotten by any who attended.

Many would argue that Ray's stellar research record and his dedicated involvement in the policy process must overshadow the contributions I've identified above. I'm not so sure. While sometimes exhilarating and exciting, research can be frustrating and disappointing. Papers are rejected for publication, grant applications are turned down, and other things go wrong. Similarly, even the most diligent efforts to shape public policy often go awry. Elections bring in new officials who may have no interest in the areas where their predecessors paid attention. Coalitions built over periods of years can fall apart suddenly and for what seem to be ephemeral reasons. In times like these, it's easy to throw in the towel. Unless, of course, one is lucky enough to work in an environment with smart and supportive colleagues, excellent role models, and people who make work … fun.

Before he retired, Ray and his wife Linda bought land atop a ridge in the Shenandoah mountains and subsequently designed and built a home there. Whenever Ray and I talked, texted, or emailed, I always started out by asking him, "How are things are up there on Mount Olympus?" It dawns on me now that Ray was Olympian in his talents as a researcher, policy advocate, and colleague. Thank you, Ray, for always having made it easy—and, yes, fun—to come to work on Monday.

Ray's Research Legacy

Ray's legacy of research involves phenomenal contributions to the field—though what people may remember the most is the great integrity he brought to his work.

AS REMEMBERED BY V. Kerry Smith

Good research addresses important questions and provides clear answers. *Great* research meets these standards and does more: great research changes the way people think.

Ray's research over 30 years ago changed the way that the social costs of environmental policy were defined and measured. His 1990 paper with Michael Hazilla in the *Journal of Political Economy* assures that, when the US Environmental Protection Agency conducts benefit-cost analyses for regulatory impact analyses, the analyses must explain why the general equilibrium effects of any proposed policy can be overlooked.

Over a decade before that 1990 paper, Ray was a leader in using programming methods to distinguish between technical efficiency and allocative efficiency for electric power plants. Technical efficiency measures whether a power plant is using the best possible practices in producing its outputs; the measurement is defined within the structure of neoclassical production models. Allocative efficiency gauges whether the incremental contributions of each pair of inputs to production matches their relative costs.

Ray's research on this topic began in graduate school. I asked Ray to explain an abstract paper on frontier production functions (the basis for defining technical and allocative efficiency measures). His explanation was clear and became a major article in one of the most important journals in economics, the *Quarterly Journal of Economics*, in 1981. That paper and his subsequent research on the topic led to many other contributions. Some of these novel contributions were collaborations with prominent economists who at the time were defining the theory of index numbers. Indeed, one of these coauthors told me how Ray worked out the details of their paper on the back of a coaster during a break between technical sessions at an international conference on production modeling. The resulting paper from 1982 is one of the most highly cited articles in a leading econometrics journal.

Skills in applied economic theory and measurement usually are not good predictors of comparable interdisciplinary talent. But this rule of thumb does not apply to Ray. He led every major natural resource damage assessment for three decades—while advancing major research programs at RFF. The assessments for state and federal litigation that involved *Exxon Valdez*, Montrose Chemical Corporation, and Deepwater Horizon required someone who could listen to and integrate the ideas of a wide array of social scientists while mediating the concerns of these scientists with the practical needs of the lawyers who managed the cases. Everyone involved—researchers and lawyers—respected Ray's quiet, thoughtful demeanor.

Ray ensured successful outcomes and research that met the highest standards. The Internet Age sometimes causes us to forget research legacies. In Ray's case, we should not. ■

AS REMEMBERED BY
Kristin Hayes

I'd like to close with one more personal anecdote.

On August 19, 2019, I was sitting in my RFF office when my mother called and told me that my father had passed away earlier that day. He had been sick for some time, and I knew the end was coming—but when it actually did, I found I couldn't fathom what to do next. I sat immobilized in my office, and then finally texted Ray (in the office next door): "I need help." Ray came over, gave me a big hug, and got me up, which was exactly what I needed in that moment.

Ray died on August 19, 2024; this time, it was Billy Pizer who came into my office to give me a hug and share in the sadness. We spend so much of our lives with our colleagues, and it's a privilege to work with ones—both present and past—who approach their lives with as much commitment and caring as my RFF colleagues do.

More Memories of Ray

People from around the world have shared their own anecdotes about Ray Kopp, which have been posted on the Resources.org website in fond memory of our colleague.

NO. 217 | WINTER 2025 | *"Natural gas is a different footprint."*

The Future of Fossil Fuels in a Decarbonized United States

IN CONVERSATION
Daniel Raimi and Susan F. Tierney

PHOTO
Getty Images for Unsplash+

Podcast host Daniel Raimi talks with Susan F. Tierney, a senior advisor at Analysis Group and chair of the board of directors at Resources for the Future, about the energy transition as an avenue toward a new world of decarbonization. Tierney discusses the challenges of meeting climate goals while maintaining energy security, the importance of making energy accessible to all citizens, and how to support communities and states that historically have depended on the coal and oil and gas industries for jobs and public revenue.

Daniel Raimi: Let's talk about the future of fossil fuels. Our conversation comes in the context of a report you coauthored from the National Academies of Sciences, Engineering, and Medicine, which is called *Accelerating Decarbonization in the United States*. To get us started: It might not be intuitive to people why it makes sense to talk about the future of fossil fuels in a report that's all about decarbonization. Why did you and your coauthors choose to dedicate a whole chapter to this topic?

Susan Tierney: I'm really glad you asked that question. It is not intuitive, and it was not obvious to the committee that it was something that we needed to look at. I was somebody who thought it was really important that we examine it.

We looked at a lot of different topics that were cross-cutting in the area of decarbonization. By that, I mean, What are some of the public health issues? What are some of the energy justice issues? The report also has chapters on public engagement, industry, buildings, the electric sector, and so forth.

The through line of almost everything in every chapter is, What happens with fossil fuels? My thought was that, if we didn't call out the fossil fuels sector, it would almost be an obvious tone deafness to our report.

Decarbonization of the US economy—that topic makes people imagine that we are zeroing out fossil fuels in the economy. Our report focused on what's happening in the next decade, and it's clearly not the case that we will zero out fossil fuels during the next decade in the United States. There's a lot of uncertainty about what happens after that, and even though coal production and coal use are certainly diminishing and have been for decades, the outlook for oil and gas is different.

Modeling shows that, even with changes over the next decade that are associated with energy use in buildings, the direct use of fossil fuels, electric vehicles, and so forth, there's still a lot of uncertainty about what happens with fossil fuels beyond that. I'm really glad that we looked at the topic.

One of the issues that you and your coauthors talk about is the challenge of balancing climate goals and energy-security goals. Can you talk about whether you agree that there's a tension in this balance, and what recommendations you give for this tricky balance of achieving climate goals while ensuring energy security and energy affordability?

I do think there's a lot of interesting tensions and trade-offs. I'll answer by broadening what we mean by energy security. Of course, energy security is about our national-security interests and our energy relationships with other parts of the world, but I think energy security also is about keeping the lights on and ensuring that people have access to safe and affordable energy. Let me talk about those various things associated with fossil fuels and energy security, broadly writ.

Liquefied natural gas exports from the United States have increased significantly since Russia invaded Ukraine and threatened gas supply in Europe. The projections of US exports of liquefied natural gas are such that they offset reductions in natural gas consumption in the United States in the power sector or the buildings sector, for example, so we do see an important role for the United States being the world's leading exporter of natural gas.

Natural gas also is important for energy security in our electric system. As coal plants retire, those resources that are dispatchable (or that can provide power around the clock, like natural gas–fired generation) will be important for balancing the output of solar and wind projects. Even if we are going to add new battery storage and other kinds of storage, we have the expectation of extreme weather events, during which we'll need to ride out long periods when there may not be a lot of wind or solar.

Certainly, one of the concerns that we know about in buildings is that, in cold-weather climates, heat pumps provide an efficient electric source of heating—but issues with cold-weather performance can arise in some parts of the country, where you would expect to see some people using other kinds of fossil fuels, like propane or natural gas, as back-up systems.

Resources Radio, a podcast produced by the *Resources* editorial team and Resources for the Future (RFF), has released more than 300 episodes on a weekly basis. For every episode, one of the hosts—Daniel Raimi, Kristin Hayes, or Margaret Walls—speaks with a guest about a new or interesting idea that's related to topics like energy policy, environmental policy, climate impacts, and environmental justice.

This interview was originally released on March 26, 2024. The transcript of this conversation has been edited for length and clarity.

“Of course, energy security is about our national-security interests and our energy relationships with other parts of the world, but I think energy security also is about keeping the lights on and ensuring that people have access to safe and affordable energy.”

There's a lot of ways in which these show up as tensions. But I think these are less tensions, literally, than they are uncertainties around what's going to happen with commodity prices for fossil fuels, what's going to happen with policy, changes in technology, unforeseen events—and those unforeseen things and volatile conditions contribute to variation in the forecasts for the future of oil and gas, in particular.

Let me just mention a small handful of these uncertainties: the technological uncertainty around hydrogen, how it will develop, what form it will take; the role of carbon capture and utilization, how fast and how deep a role it will play in industrial and power-generation facilities; the ability to repurpose natural gas and oil pipelines should there be changes to those flows of fossil energy. Those are uncertainties that one would expect to see playing out with decarbonization futures. They're tensions, and they're unknowns, and they make a very interesting set of challenges for the United States in the next decade.

One of the issues that the report focuses on is at the more local and regional scales in the United States. You all talk about how transitioning away from fossil fuels entirely, or just reducing fossil fuel production and use, can create big challenges for workers in communities that depend heavily on the fossil fuels sector. Can you talk about some of those risks and some related recommendations that come out of the report?

It's no surprise that our fossil resources are located in certain parts of the country. It's no surprise that the economy in these parts of the country developed around extraction, production, delivery, and consumption of fossil fuels. There's a whole political economy associated with fossil industries, and we spend some time in the report trying to characterize what those footprints look like.

In the area of coal, which has been changing over decades, the famous and legacy mining industry in West Virginia and Kentucky clearly has been in decline for many years, as it has been in Pennsylvania. Coal production in Wyoming and other parts of the Rocky Mountains is very strong and has been hit less compared to the Appalachian region—but coal is in decline in a lot of places, and different communities in the Rockies are experiencing this, as well.

Natural gas is a different footprint. Let me give a big shout-out to Texas and Pennsylvania, which are the two places that lead the country in gas production and oil production, because the two resources often are colocated. The development of shale gas in the eastern part of the United States is newer than production in the gas and oil regions down in the Gulf and the Lower Plains States.

But those economies really have developed around fossil fuels; fossil fuels are part of the culture and vernacular. Depending on the size of the state and the diversity of the economy, fossil jobs can play an outsized role.

For example, we most often think about Louisiana, Texas, Oklahoma, Pennsylvania, and Ohio as oil-and-gas country—but in fact, Wyoming has more fossil jobs as a percentage of total jobs than those economies. The same is true in North Dakota and Alaska. The fossil dependency of those communities is very high in places that are new, compared to the long legacy development of oil and gas production, say, in Texas and other parts of the South.

When we think about public revenues associated with oil and gas and coal production, it's in royalty payments or severance taxes. Your own research, Daniel, shows that changes or reductions in production and extraction of these fossil fuels is hitting public-revenue streams in places like North Dakota, Wyoming, and New Mexico, as a percentage of total state general revenues. Some states have done better than others in planning for that and in trying to diversify away from just fossil fuels, but it's a big deal.

Let's talk about some examples of what happens to communities when fossil fuel extraction related to fossil use in, say, power plants is changing. I think of coal-production communities as the exemplar here. We know that, over decades, we've seen mine closures and tens of thousands of job losses in those

communities. When jobs are lost, and coal mines are closed in those communities, less revenue streams are going through those communities. That means less funding for schools, hospitals, and tax bases. There's lower demand for people buying in shops. All those activities and induced impacts that are directly and indirectly associated with loss of jobs in coal communities—those are at risk, which makes it so that, in many places, we've seen a real existential risk for these communities.

We do talk in detail about these kinds of community impacts in our chapter on fossil fuels in the National Academies report. We discuss the impacts in different ways in our chapter on employment, but we put a microscope on community impacts in the fossil chapter itself.

Let me just mention two of our recommendations about things that have been happening in Washington, DC, to address these issues.

We are aware of the Interagency Working Group on Coal and Power Plant Communities and Economic Revitalization. That's a big mouthful for the name of a working group. The group has focused predominantly on things related to coal—both mining and power production—and we have suggested that the work be expanded to incorporate oil and gas communities as well, because we think it's important to have an eye on the outlook for production in those communities, the possible changes ahead, and what might be needed to address community impacts.

We members of the Committee on Accelerating Decarbonization have recommended that Congress authorize a multiyear authorization and appropriation, so that funding for transition offices will be available in each state that would be affected by these fossil transitions (whether coal, oil, gas, or multiples of these) to plan, look at lessons learned, and consider best practices about

“When jobs are lost, and coal mines are closed in those communities, less revenue streams are going through those communities. That means less funding for schools, hospitals, and tax bases.”

PHOTO
Coal production and use have been on the decline for decades. In a clean energy transition, the implications of declining fossil fuels (e.g., for the workforce and energy security) are important to consider.
krblokhin / Getty Images

The more that communities can become aware of the expectation that there is going to be a closure and begin to plan for it—in terms of how they will diversify their workforce and their industrial activities, if they can, and try to think about other forms of tax revenue—that's important.

assistance with economic development and attracting new businesses into areas that have been seeing a decline in fossil fuel production. We think that's an important thing to do, and we note elements in the Inflation Reduction Act that are important for implementation.

An example would be the Energy Infrastructure Reinvestment Program from the US Department of Energy, through which $5 billion in appropriations has been made available for loans that can go to retooling, repowering, repurposing, and replacing energy infrastructure that no longer operates in part because of these transitions.

Let me ask you about another section of the report in which you and your coauthors recommend that utilities and service providers, such as for electricity and natural gas, begin to plan for the transition. Can you talk about why the committee thought that was important, and can you say a little more about what it means for a utility or a service provider to actually plan for a transition?

Great question, and I'll talk about a couple threads that run through our analysis and discussion. For example, we know that when facilities close—whether a sports arena, a mine, a nuclear plant—there are big disruptions. We know this from the long history of big facilities that employ a lot of people and are important to the tax base of communities. The more that communities can become aware of the expectation that there is going to be a closure and begin to plan for it—in terms of how they will diversify their workforce and their industrial activities, if they can, and try to think about other forms of tax revenue—that's important.

Take the case of a nuclear plant that's going to close and which has provided hundreds of good-paying jobs in a community and served an important role in the tax base of its host community. Of necessity, there is a multiyear period of visibility before the plant actually closes and gets decommissioned. That occasionally happens with some power plants that might be burning coal, too, such that the owner of the power plant has identified that it's going to close in five years when another set of replacement facilities are up and operating. Sometimes there's runway for visibility, but often there's not.

We know that a whole lot of facilities in the fossil industry are not regulated from a price point of view, and therefore there are fewer opportunities to see the decisions of an owner, or even require those disclosures in US Securities and Exchange Commission statements, that are specific to a certain plant or mine. There's a huge risk that there's no transparency whatsoever for a large number of facilities.

We thought a lot about related solutions, though not a lot of strategies are available. One idea we had was that, to the extent a facility receives federal funding or federal permitting in one way or another, an insertion could be put into the funding or the permit to identify that, *x* months in advance of a closure (it could be two years or whatever is appropriate for the size of the facility and the size of the investment), some kind of public disclosure gets associated with the anticipated closure. This transparency can help a workforce begin to plan. We also thought of other important ways in which a community can try to take responsibility for coming up with some other solutions—perhaps not with the owner of that facility, but through other economic-development means, as well.

We identified a special case associated with planning for transitions: the regulation of a group of local gas-distribution companies, which provide gas service to buildings. They provide, for the most part, the investment, maintenance, and operations of the pipes between the interstate system and individual buildings. They are regulated by states from a rate point of view and from a safety point of view.

If we think about a situation of potentially less throughput going through those local pipes, there could be circumstances in which customers are dropping out of the system, because they are adding heat pumps, and they're no longer going to need gas that moves through that local pipeline. Or there could be a theoretical expansion of a gas pipeline system into a new area. Yet, in the larger community, the expectation is that a decarbonization policy will preclude any additions to the gas pipeline system; rather, attention should be paid to which areas of the system should not be expanded, to make sure that we're addressing both safe pipeline systems and decarbonization.

Having state regulators keep an eye out for this type of planning actually is complicated. Here's the essence of the issue: As long as anybody is being served by these local pipes, or a local offshoot of one of the main branches of the pipeline system, service to everybody on that circuit of the pipe has to be maintained, and the pipe has to be operated at safe pressures. You can't just assume that the local gas company can say, "Okay, there's going to be less use, so we don't need to invest in that pipe." In fact, the system has to be maintained. Thinking about how to be strategic about that continued investment for maintaining the safety of pipeline systems, while one is thinking about a transition in the system as a whole, is really important going forward.

Political challenges accompany many of the recommendations that have been suggested in this report. I'm curious if you can talk about those challenges from the perspective of utilities that might resist some of the efforts that we're talking about here, or any other political "flags" that come to mind.

The National Academies committee was asked explicitly not to render an opinion about whether we thought decarbonization was going to happen or not from a political perspective; rather, we were assigned to answer the question of what's involved and required in decarbonizing the economy. That's how we approached it.

But if you think about the situation today, there's actually not one single answer to the question of how utilities feel about this transition.

For one thing, "utilities" really is a phrase that represents a whole lot of different kinds of regulated firms. You can imagine that electric utilities might actually think the transition is a great opportunity, if they expect to sell more electricity, given that buildings will be heated with electricity and vehicles are going to run on electricity. In fact, we see a real change in outlook that varies across electric companies.

We also could point to examples of, for example, publicly owned electric companies that may own a coal-fired power plant, but they are not ready to retire that plant, in part because they don't have any shareholders on whom any underappreciated investment can be written off. "Electric utilities" are not a homogeneous group, but I would call out a sea change among some members of the electric industry who see that kind of opportunity in this transition.

The same is not the case for gas utilities. In the case of gas utilities, I would include interstate pipelines, whose only business is to invest in and operate and earn a return on investment in pipes; companies that own storage facilities; and local gas pipeline companies. If they don't have an affiliate that's an electric company that itself might be seeing an upside, then these companies are worried (if they're paying attention) about what this uncertain outlook is going to mean for them. We do see either opposition or not-yet-focused attention on addressing fossil transitions among gas utilities, similar to what we see for the electricity sector.

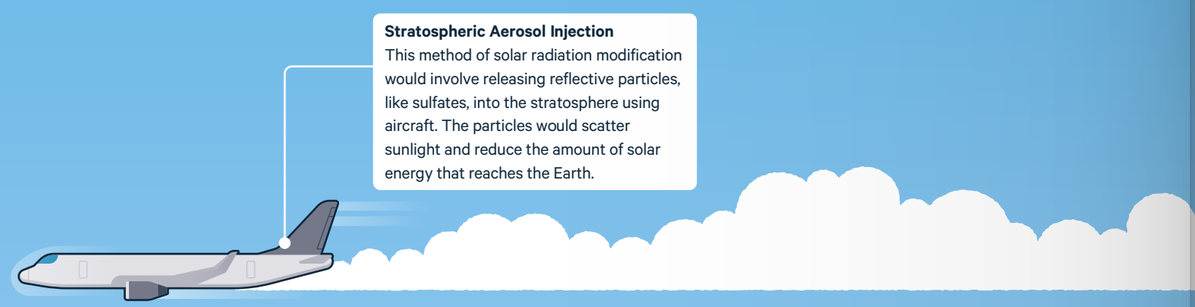
If I could point out one takeaway from today's conversation, it would be that all utilities are not the same.

I often make the same point about oil companies. "Big Oil" is a term that people like to use, but there are lots of "Little Oils" in there, too.

Exactly.

I wish we had more time to talk, because there's so much richness in this chapter of the report and the report itself. I hope some of our listeners will be able to take a deep dive into the report, which will be much deserved. ■

Daniel Raimi is a fellow and **Susan F. Tierney** is chair of the board of directors at Resources for the Future.



Injecting Reality Into Debates About Solar Radiation Modification

Notes from a recent workshop on mitigating the effects of climate change through the global geoengineering strategy of solar radiation modification.

TEXT Joseph E. Aldy, Milan Elkerbout, Tyler Felgenhauer, and Billy Pizer

ILLUSTRATION James Round

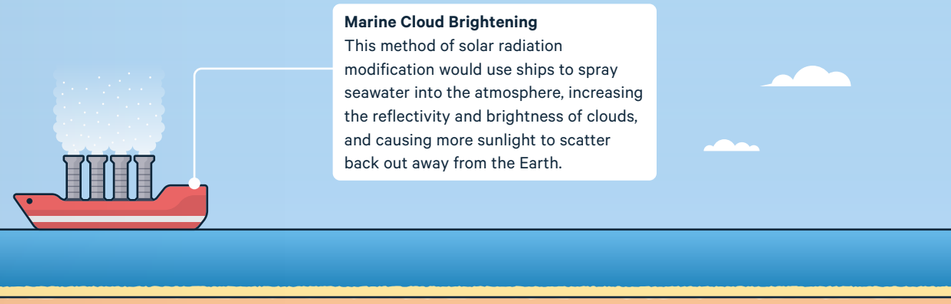
Cutting global greenhouse gas emissions enough to deliver on the temperature goals of the Paris Agreement is an increasingly daunting prospect. With climate change impacts occurring around the world, policymakers, stakeholders, and the public are exploring ways to reduce the human suffering of a warming planet. Solar radiation modification (SRM), also known as solar geoengineering, has received growing attention as a potential additional approach to mitigate the risks of a changing climate.

On September 19–20, 2024, Resources for the Future and the Harvard Solar Geoengineering Research Program at the Salata Institute for Climate and Sustainability organized the third annual conference on SRM and the social sciences. Taking part in the conversation were 47 participants in person, with several dozen more joining online. Presenters and moderators came from 12 countries, with strong Global South representation. Here, we summarize some of the major themes that arose. Interested readers can check out the full suite of videos and presentations on the webpage of the event.

This year's workshop focused on gaining a better understanding of cooperative and noncooperative approaches to the governance and deployment of SRM. Cooperative approaches, with a globally agreed-upon strategy, appear relatively more attractive but raise the question of how such an agreement would arise and under what conditions. Noncooperative approaches, such as unilateral deployment by a single country or small group of countries, raise questions about national capacities and the potential strategic responses of other nations. The technical and scientific dimensions of SRM have important implications that can inform social-science analyses of its governance and use, both cooperatively and noncooperatively. For example, SRM typically is viewed as a relatively quick way to respond to climate change. But data may be necessary from a decade or more of SRM deployment before a scientific assessment could identify and distinguish the cooling effect of a global SRM intervention against the backdrop of climate change and natural climatic variability. Such a lengthy time between action and evidence of impact raises questions about the ability of politicians, who typically want a quick demonstration of success, to stick with the intervention.

Assuming policymakers do stick with an initial intervention, the deployment ultimately would need to continue for decades to avoid serious risks. An oft-envisioned scenario is a long-duration SRM intervention, coupled first with eliminating net emissions of greenhouse gases from anthropogenic activities, and then shifting to a strategy of achieving negative emissions which would reduce atmospheric concentrations of greenhouse gases. The SRM intervention would be scaled back in tandem with efforts to mitigate the underlying drivers of climate change, avoiding the worst warming that would result from peak concentrations of greenhouse gases. If an intensive intervention halted unexpectedly for an extended period, however, the Earth would rapidly heat back up to a level that matches the background level of greenhouse gas concentrations, creating a "termination shock" that has adverse consequences.

Stratospheric aerosol injection (SAI) is the technology that's most often discussed in the context of SRM, but the use cases depend on who could eventually deploy it. In particular, the engineering, logistical, and technical characteristics of SAI likely limit the number of actors or countries that could deploy this technology or even undertake relevant research. As the capacities for SAI overlap with the capacities common to countries which are powerful in terms of their military and



industry, interactions with the geopolitics of the day seem a given under most scenarios.

"Capacity to deploy" is not binary, either: Some parties may develop capacities that are limited to certain types of intervention, or to certain regions. Because long lead times are involved with related technologies (e.g., specialized high-altitude aircraft) and supply chains, capacities among rival countries may change over time.

A well-designed SAI intervention would be expected to bring global benefits on average, but uneven effects would be likely, and a poorly designed intervention could be bad. For example, an actor that's motivated to use SRM to counter the melting of Arctic sea ice also would need to commit to an Antarctic program to avoid negative global climate perturbations. Even a well-designed and globally balanced SAI intervention, while bringing benefits in the form of slowed or stabilized temperature, could result in some regions around the world experiencing changed precipitation patterns that are worse than under future climate change.

While the governance of SRM appears challenging, some useful analogues exist and could inspire further social science research. The construction of hydropower dams often is a unilateral (and not necessarily well-coordinated) policy choice with significant trans-boundary impacts on water supply and biodiversity. If SRM is seen as a potential "great power" capability, international agreements such as the Partial Test Ban Treaty could be seen as a useful analogue. Neither is the composition of the atmosphere unchartered territory for international diplomacy: in addition to the United Nations Framework Convention on Climate Change, we have the Montreal Protocol on ozone-depleting substances and the treaty on preventing hostile environmental modification that's commonly known as ENMOD.

Despite a focus on global interventions, the governance of SRM—and future research—should reflect that not all forms of SRM need to be global in scale or several decades in duration. In fact, a greater exploration of smaller types of intervention, which may be linked to mitigating particularly harmful local climate impacts, might benefit the SRM debate as a whole. Work already is underway that explores the preservation of the Great Barrier Reef through the geoengineering technique of marine cloud brightening. Other use cases might address regional, episodic weather events—droughts, heat waves, cyclones, and the like. Indeed, the strongest demand for SRM could occur in these sub-global, but still trans-boundary, cases. These examples also imply that SRM should not always be read as SAI, even if most related research has focused on SAI to date.

Central to any debate on SRM governance should be the topic of justice, along with the role of and impact on the Global South. Beyond the need to avoid exacerbating the existing inequities of climate change, countries in the Global South should be part of the conversation from a procedural perspective. Local expertise in related technologies, consequences, economics, and modeling is necessary to meaningfully engage in SRM deliberations. It will be important that researchers in the Global South—who have essential local context knowledge—are brought into the SRM space and able to shape the evolution of this geoengineering strategy.

More broadly, an indispensable element of any SRM policy is observational data on the state of the atmosphere that's high quality and shared globally, whether globally coordinated or not. Without good measurement of the impacts, shifts in public perception and government policy will be that much more unpredictable. Moreover, the communication of outlandish narratives should not be discounted. The politicization of Atlantic hurricanes in 2024 is a warning sign for how amenable SRM could be to political distortion and misinformation.

These were just some of the themes that we took away from our recent research workshop. One of our key interests continues to be a consideration of what eventually might drive the emergence of coordinated and uncoordinated deployment scenarios, and what can be done to facilitate more socially beneficial outcomes. Meanwhile, we look forward to continued convenings with members of the social science community who are interested in SRM, and hearing even more from them about their specific interests. ■

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