U.S. Energy & Climate Roadmap

Evidence-based Policies for Effective Action
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Inexpensive, reliable energy, largely sourced from fossil fuels, has driven U.S. economic growth and prosperity for more than a century. These gains have come with costs, however. Local environmental pollution causes people to lead sicker, shorter lives. Climate change, once thought to be a distant threat, has become a present danger to families and businesses from coastal Miami to the California mountains and the Alaskan Arctic. Policymakers cannot choose to ignore any one of these three policy areas, but instead must find ways to balance among them. Sustaining economic growth, protecting public health, and securing the future climate are together a defining challenge of this century: the Global Energy Challenge.

The United States, like all countries around the world, will navigate these three common challenges through the prism of its own particular history, values, and vision for the future. Increasingly, that includes an emphasis on addressing the significant, persistent racial and income disparities in exposure to environmental pollution with their roots in segregationist policies from the Jim Crow south to the South Side of Chicago. The path to addressing the Global Energy Challenge, and to addressing these long-standing inequities, runs through public policy. As the Biden administration and a new Congress take the reins in Washington, the policy choices they make could not be more important.

The American people will be best served by having these choices guided by the public interest and informed by the latest insights from economic, scientific, and public policy research. This book, a compilation of policy recommendations from affiliated scholars of the Energy Policy Institute at the University of Chicago (EPIC) is designed to help policymakers identify and implement practical policies to address the greatest challenge the country now faces. Each chapter is grounded in empirical research that has been galvanized by robust academic debate and channeled into practical policy applications through discussion with EPIC’s policy experts, rather than being developed only in Washington, DC policy circles or only in academic environments. The result is a constructive energy and climate agenda for U.S. policymakers.

The Global Energy Challenge

Preserving the indisputably enormous benefits of affordable energy will be a critical priority. Powered by access to cheap energy, the American economy is the world’s most diverse and productive. Historically, much of that energy has been derived from fossil fuels. For the last century, the United States has been a leader in the oil and gas industry, developing new technologies that have reshaped the market and ranked it among the world’s largest producers of oil and natural gas. Over the last twenty years, it has begun applying that innovative spirit to renewable energy generation. While renewable generation has grown steadily, supplying record levels of power in 2019, it still meets just 11 percent of U.S. energy needs. Policymakers will need to find a way to sustain the economic benefits that abundant fossil energy has provided while speeding the transition to more sustainable power sources.

For the millions of Americans who were brought up during an era of untrammeled fossil fuel consumption, the benefits of the transition to cleaner energy sources will be all too familiar. In the 1950s and 1960s, thick smog often blanketed U.S. cities. Power plants and factories emitted pollutants into the air with little or no regulation, while cars ran on fuel that left a wake of soot and airborne lead behind them. Since the 1970 Clean Air Act was passed, air pollution in Los Angeles has fallen by nearly 60 percent, extending average life expectancy in that city by more than a year, according to the Air Quality Life Index, a measure of the life expectancy impacts of long-term exposure to air pollution. In Philadelphia and Washington, DC, the effect of pollution reductions was even more significant, adding nearly three years to average life expectancy.

Yet, too many people continue to suffer from local pollution; research has demonstrated that predominantly Black and Hispanic communities face much higher rates of exposure to pollution, and exhibit higher rates of asthma, heart disease, and other pollution-linked illnesses. It has also shown that national air quality monitoring data do not capture the disproportionate exposure of communities of color to discrete sources of severe air pollution. Securing the benefits of clean air for all Americans is an overdue and essential element of the Global Energy Challenge in this country.

If air pollution has been the story of the last fifty years, climate change will be the story of the next fifty. By the middle of this century, business as usual scenarios project that average temperatures in the United States will rise by some 5°F over the historical average and the number...
of days with a high temperature over 95°F will increase by twenty-five for the average American. These are not just numbers on a thermometer. Higher temperatures—in particular, the increase in the number of days of extreme heat—will drive significant increases in mortality, crop loss, and energy consumption, and lead to other changes that together undermine well-being. Research also demonstrates that these effects will not be distributed equally: people in the northern parts of the United States will benefit from warmer winters but those in many parts of the South and Midwest will confront significant threats to their way of life. Today, for example, the Midwest’s corn and soybean belt covers 140 million acres of farmland. Recent research shows that, under a business as usual scenario, that land will become virtually unsuitable for growing those crops as soon as mid-century, and completely so by the end of the century.

Heat will not be the only challenge. By 2050, as many as 16.2 million American homes could be at substantial risk of flooding due to sea level rise and changing precipitation patterns. In 2020, in California alone, wildfires exacerbated by climate change burned an area larger than the state of Connecticut. From Native American coastal towns in Alaska and Louisiana to working class communities in increasingly fire-prone California, people are already beginning to abandon their homes in the face of rising climate challenges. It is not difficult to project future conversations about which parts of the Atlantic coastline the United States can afford to protect and which ones will have to let go. No administration, Democratic or Republican, can escape these costs, a large portion of which will fall on some of America’s most economically vulnerable and politically disenfranchised populations.

The scale and gathering speed of climate change makes finding the right policy balance among the needs for inexpensive and reliable energy, local environmental quality, and preventing disruptive climate change an urgent priority for the Biden administration. As if that weren’t challenging enough, there are many pressing demands on public resources in other domains, from educating the young to caring for the elderly, protecting U.S. national security, and the immediate urgency of the COVID pandemic’s health and economic repercussions. It is essential, therefore, that policy deliver the maximum bang for every buck, with energy and environmental policy being no exception.

Evidence-based Policy Solutions

This book is a compilation of policy proposals from EPIC faculty affiliates from the Booth School of Business, the Harris School of Public Policy, the UChicago Law School, and the College, informed by the best available evidence, that can help the United States navigate the Global Energy Challenge. Grounded in empirical research, the book offers specific, practical ideas on how to tackle a wide range of issues in climate and energy policy, from carbon pricing to fuel efficiency standards, oil and gas leasing, and coal mine reclamation. Though this one volume cannot be a comprehensive list of sensible policies in this wide-ranging policy space, it is a unique blend of ideas that all have their beginnings in the crucible of academia. Not content to let these ideas founder in academic journals and debates, each chapter’s authors worked with EPIC’s team of policy experts to turn them into concrete and actionable policy proposals.

The book’s opening section helps readers understand the likely effects of climate change in the United States and how best to think about their total costs. It begins with an overview of the effects that the United States can expect to experience from climate change in the coming decades and the repercussions that they will have across the country. Drawing on research from the Climate Impact Lab—a collaboration of experts from EPIC, the University of California, Berkeley, Rhodium Group and Rutgers University—Assistant Professor Amir Jina explores how climate change will affect core indicators of economic and public health both now and over time, noting in particular that these effects will not be felt equally across the country.

For policymakers, knowing the projected effects of climate change is only half the battle. Resources are finite and policymakers must choose how best to spend them, not only on fighting climate change but also on health, education, infrastructure, and all the many other demands on the public purse. Policymakers therefore need to understand the costs of climate damages to understand how best to address them. The second chapter in this section, therefore, explores the Social Cost of Carbon (SCC), which is an estimate of the monetary damages from the release of an additional ton of CO₂. The SCC is a critical tool for assessing the costs of climate change, and therefore the benefits of all policies to mitigate or adapt to it. EPIC Director Michael Greenstone and Tamma Carleton, an assistant professor at the University of California, Santa Barbara (and former EPIC postdoctoral scholar), describe how the SCC can be used in cost-benefit analyses for proposed climate and energy policies and provide several recommendations that would ensure the social cost of carbon reflects the advances in understanding about climate change over the past decade. These include using the latest climate modeling, applying a new valuation of climate damages, employing lower discount rates, and incorporating global, rather than only domestic, damage estimates of additional carbon emissions. Ultimately, they argue that a two-step process: the first step involves an immediate return to the Obama administration’s approach along with a more appropriate discount rate that together produce a SCC of $125 in 2020, and the second step is a comprehensive update that would return the SCC to resting on a foundation of frontier economics and climate science.

The balance of the book is organized under two broad themes. Chapters in Economy-wide Approaches start from the understanding that it is a fundamental policy failure that polluting industries do not pay a price for emitting carbon dioxide into the atmosphere. Chapters in this section offer guidance to policymakers on how to ensure that polluters pay for the damage they cause. Greenstone and Postdoctoral Scholar Ilian Neth offer a number of guiding principles for policymakers working to ensure polluters pay for the damage they cause—whether by imposing a carbon tax or implementing a cap-and-trade system.

If the United States takes steps to reduce emissions that substantially increase costs domestically, however, some fear it could push industrial production overseas, hurting the United States economically while making no net difference to the amount of carbon dioxide in the atmosphere. Border adjustment taxes (BATs) are an oft-proposed means to avoid simply exporting U.S. emissions, but they are difficult to administer, possibly violate international trade laws, and do not achieve significant emissions reductions. Professor of Law David Weisbach and his co-author, Samuel Kortum, Professor of Economics at Yale University, offer analysis to better understand the true scale of the problem that BATs are trying to solve and outline a combination of alternative taxes that will lead to deeper emissions cuts without the logistical and legal problems of traditional BATs.

Chapters in Sector-by-Sector Approaches dive into specific climate and energy sectors, offering policy ideas for tackling specific energy and environmental challenges.
Several chapters take up the myriad issues associated with producing and distributing electricity. Steve Ocasia, an Associate Professor at Tufts University and a Non-Resident Scholar at EPIC, notes the significant challenges that renewable energy poses for the current U.S. electrical grid. He argues that, by working primarily to develop and deploy utility-scale energy storage, the United States has been focusing on distributing electricity across time rather than across space. Building a truly national grid that could seamlessly transport and sell power generated anywhere in America would allow New York to buy solar power generated in Arizona, or Florida to use wind power from Oklahoma, smoothing prices nationwide and enabling the United States to take full advantage of its best sources of renewable power.

In the absence of a national policy, many states have used their own authority to encourage increased renewable energy production in their jurisdictions. Greenstone and Nath find that while these policies result in more renewable energy production and lower CO emissions, the high cost of installing, transporting, and backing up that power has meant that the carbon credits, stimulating innovation in clean energy and climate agendas available for the Biden administration and Congress.

Reducing carbon emissions is a critical priority, but policymakers are unlikely to lose sight of the traditional guiding priority of U.S. energy policy—ensuring sufficient, affordable supplies of energy for economic growth. Where that energy comes from, how it is produced, and what happens to the people and places that produce it are all important variables for the Biden administration to consider.

For decades, the overwhelming majority of U.S. energy production came from coal, a seemingly cheap, effectively inexhaustible fuel source. As Mark Templeton, Clinical Professor of Law, writes, however, the costs of coal are far higher than its price would suggest. Taking into account the economic cost of the environmental damage coal causes, using the social cost of carbon, reveals that it is in fact among the most expensive fuels there is. Templeton argues that the United States should move rapidly to ensure that coal pricing reflects its environmental damages and enforce the requirement that coal companies pay for the local environmental damage they have caused, while working to ensure that former coal communities have an economic stake in a clean energy future.

The dramatic expansion in fracking in recent decades has made available vast reserves of oil and natural gas, making the United States one of the world’s largest producers of both fuels. A significant percentage of that production, note Assistant Professor Thomas Covert and Professor Ryan Kellogg, takes place on federal lands, and producers of both fuels. A significant percentage of that production, note Assistant Professor Thomas Covert and Professor Ryan Kellogg, takes place on federal lands, and trading carbon-free energy for power generated from fossil fuels. Professor Robert Rosner and his co-author, Rebecca Lordan-Perrit, a Postdoctoral Scholar at the University of Basel, argue that nuclear power can and should be part of a carbon-free U.S. grid. Noting that modern nuclear facilities can ramp production up or down to backstop renewable energy sources, they offer recommendations on how the U.S. nuclear industry can overcome important obstacles and remain a critical energy source for decades to come.

Generating more clean energy is one way to reduce emissions. Another approach is simply to use less energy altogether. Assistant Professor Fionia Burlig notes, however, that policies designed to stimulate energy efficiency have often not achieved the energy reductions they promised. Burlig argues policymakers should rigorously assess which energy efficiency approaches really work and direct public support just to those approaches that have proved their value.

Like electricity generation, transportation is a critical source of carbon emissions and air pollution. Associate Professor Koichiro Ito argues that the best-known avenue for limiting vehicle emissions—fuel economy standards—incorporates a number of perverse incentives that limit the standards’ effectiveness. He outlines a series of concrete recommendations, from combining the car and light truck vehicle categories and eliminating attribute-based standards to making the credit market more transparent, that can make fuel economy standards a more effective means of reducing emissions.

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Effects & Costs of Climate Change

Climate change will have wide-ranging effects on the U.S. economy, with some communities seeing worse effects than others. Understanding the true costs of climate change can help policymakers choose how best to address it.
The changing climate has been understood for more than a century, when scientists identified CO₂ as one of several gases in the atmosphere that retain heat and keep the planet habitable for humans. To understand the consequences of this greenhouse effect as levels of CO₂ change, it is important to know not only what the trends of CO₂ have been in the past but also what they might be in the future. There is considerable uncertainty about what countries will do over the next 100 years, ranging from producing more emissions to gain the benefits of economic growth, to reducing emissions to limit the impacts of climate change. These alternate futures are captured in a set of scenarios, called Representative Concentration Pathways (RCPs) that correspond to different levels of radiative forcing, or warming, which could occur in the years to come.

Extended records about the climate paint a worrying picture of changes to date. Global average surface temperatures have risen by around 2°F since pre-industrial times and more than 1°F in the last few decades. (For scale, the global average temperature increase after the last ice age was about 11°F, an increase that took place gradually over thousands of years rather than in just decades.) In fact, according to the instrumental record of temperatures stretching back to the 1880s maintained by the National Oceanic and Atmospheric Administration (NOAA), nineteen of the twenty warmest years on record have occurred since the year 2000. The decade that has just ended is the warmest decade since records began. The research around the future climate. These range from a scenario of continued high emissions, spurred by a reliance on fossil fuels in a fast-growing global economy (RCP8.5), to a scenario of net zero emissions, where policymakers at all levels enact policies to remove carbon from the energy system, or at least prevent that carbon entering the atmosphere (RCP2.6).

The science of climate change poses four unique challenges for policymakers. First, the causes and the consequences of climate change are global. The main climate change culprit, CO₂, disperses throughout the atmosphere so emissions from anywhere can lead to consequences everywhere. Second, it is a long-term problem. Many of the gases that cause climate change will remain in the atmosphere and affect the climate for hundreds or thousands of years. Actions taken to reduce those emissions will provide benefits, but on a much longer timeframe than a typical election cycle. Third, as the science of climate change advances, it is apparent that there is potential for irreversible impacts. A point may arrive after which reducing emissions will not be sufficient to prevent or reverse many of the worst effects of climate change. Finally, while much is known about the causes and likely trajectory of climate change in the coming century, researchers are still racing to learn where certain impacts will be felt, how severely, and over what timeframe. Together, these four scientific issues suggest that the climate challenge will demand not one policy solution, but many.
historical record in Figure 2 shows the warming trend for the United States. It is worth noting that the United States is warming faster than the global average, as are many higher-latitude countries (i.e., countries further from the equator). Since the late 1970s, the United States has warmed between 0.29°F and 0.46°F per decade.

The question for policymakers is what these dramatic changes mean for the American people and the United States economy. Much of the science refers to global scales and far-off time horizons. Even expressing these findings for the whole of the United States provides an aggregate picture of climate change that may be difficult to apply in practice. With that said, however, scientists can make some concrete projections about local, relatively near-term changes to the U.S. climate and the consequences they may have for the economy.

Discussing climate change in terms of average temperature makes it hard to understand how much of a change Americans will actually feel. Figure 3 shows, for the whole of the United States, the change in the number of days at specific temperatures between 2015 and 2099. Figure 4 shows that the differences between hot and cool states shows that the changes between hot and cool states are shrinking even as all the states warm over time. Some of the coolest states, like Maine or Vermont, will warm to be similar to today’s Illinois, Indiana, or Virginia, while those three states will warm to be hotter than the states that currently have the hottest summer temperatures: Florida, Texas, and Louisiana. Today’s hottest states will far exceed their current summer temperatures; Texas and Louisiana, for example, will have summer temperatures at the end of the century similar to today’s Sudan or Saudi Arabia. Nearly half of the states in the United States will have summer temperatures hotter than today’s summers in India or Egypt.

Temperature rise is just one of the many environmental changes the United States can expect due to climate change. Changes are also expected in average precipitation levels, the frequency of extreme precipitation events, sea levels, and hurricane intensity, to name a few.4 Nor are these changes far off into the future. Over the past twenty years compared to 1960-1980, the average American has experienced 20 percent more extremely hot days (>95°F) per year, and a nearly 70 percent increase in extreme precipitation events.5 Hurricanes have also become more intense: in 2007-2017 compared to 1979-1989, while hurricanes of all intensity categories have become more frequent, the most extreme, Category 5, doubled in frequency.

The climate, in other words, is already changing.

Economic Impact

Understanding the damages due to climate change at both national and local scales is important for assessing the benefits that will accrue from any policy that limits climate change, as well as for informing policies to adapt. A recent increase in the volume of research into climate impacts has led to a new understanding of the relationship between climate and local economic outcomes, built on solid foundations in data. This has allowed researchers to empirically derive estimates of the climate’s influence on multiple sectors of the U.S. economy, project them into the future under various carbon emissions scenarios in high spatial detail, and then sum across outcomes to give a comprehensive estimate of damages that vary spatially. A discussion of some of these outcomes follows, but it is important to note that they do not cover all of the potential damages of climate change. Rather, they are a subset of outcomes that are likely to be major drivers of costs.6

Before discussing the economic implications of climate change for the U.S. economy in the future, it is important to understand some general features of how the economy and the climate are related. First, climate damages are often non-linear, meaning they can increase dramatically after a threshold level of warming is reached. Second, people are most affected by increases in extremes—that is, adding more very hot days has a greater impact than an increase in the average annual temperature.

4 The Intergovernmental Panel on Climate Change (IPCC, 2014) and the Fourth National Climate Assessment (Hayes et al., 2017) contain excellent summaries of these changes regionally and globally.
5 Houser et al., 2015

6 This discussion is drawn largely from the results in Hoisington, Kopp, (2017) and Rising, et al. (2020).
Non-linearities may mean, for example, that increases of 1°F in places with a low average temperature may have a different impact than an increase of 1°F somewhere warmer. Mortality rates, for example, are higher during both very cold and very hot temperatures, so a 1°F increase in a warmer location might increase mortality, while a 1°F increase in a colder location might decrease mortality. Non-linearities may take other forms. Temperatures above a certain value may damage growth in some crops, for instance, but below the threshold no negative effect is seen. These non-linearities lead to a few implications. Most importantly, a place’s current average climate matters. For instance, but below the threshold no negative effect is seen. These non-linearities discussed above. The damage curve gets steeper as temperatures increase, showing that damages get progressively worse as temperatures rise. Taken together, these effects could cost roughly 0.7 percent of gross domestic product per 1°F increase on average. Overall, climate change will harm the U.S. economy, even with modest amounts of warming, and damages will increase non-linearly with temperature. About two-thirds of these damages will be due to changes in mortality. When weighing policies to reduce emissions, the implications of Figure 5 are important. For example, under an average expected change of temperature associated with the high emissions scenario (between 7°F and 8°F), the U.S. economy would stand to lose between about 2 percent and 5 percent of GDP annually by the end of the century due to impacts in the six sectors that were analyzed.

Climate Change & Inequality

The aggregate picture masks substantial local differences in these impacts. Figure 6 shows damages at the county level as a proportion of that county’s income level in 2080-2099 under a high emissions scenario. As expected, the colder, more northerly parts of the United States have much lower damages than the rest of the country. In southern, coastal states, meanwhile, there is an overall high negative impact, as they experience higher temperatures and exposure to enhanced coastal damages from storms and sea level rise. Understanding the total damages expected in various locations, and the contributions made by energy, mortality, and other sectoral components, help to illustrate the adaptation challenge that the United States will face if it does not avoid the worst effects of climate change through mitigation. Adaptation policy at local levels will move expected damages off the trajectories that these results imply. What this map really shows is a future that can be avoided through either mitigation or adaptation. Neither policy choice is free, but doing nothing is also expensive. Economic assessments such as this provide information on the relative benefits of various climate policies in particular places.

The pattern of damages in Figure 6 also reveals another potential impact of climate change: an increase in inequality across the country. Figure 7 ranks counties by income level, and then plots damages in groups by income level, and then plots damages in groups together income deciles from poorest to wealthiest.

The pattern of damages is strongly correlated with income levels, and the poorest counties suffer the largest damages. Indeed, the poorest third of counties are projected to experience damages of between 2 and 20 percent of county income under a high emissions scenario. This aspect of climate impacts in the United States has the potential to substantially widen the income gap between rich and poor parts of the country, saddling those areas that may already have fewer resources to adapt with larger damages.
Climate change will affect the American people in different ways. The national aggregate results imply that the economy will start to exhibit losses no matter what the level of warming. No part of the country will be insulated. A hurricane in Florida or Texas still requires federal assistance, and a Midwestern heatwave with negative effects on agriculture will affect food prices in other parts of the country.

These results also imply, however, that limiting CO\textsubscript{2} emissions now would significantly reduce the overall losses by the end of the century. The projected 1-4 percent annual GDP decline under a high emissions scenario would drop to 0.1-1.5 percent in a medium emissions scenario. The differences in damages across sectors, locations, and income levels help to highlight that the effects of climate change will not be the same for everyone. Different sectors of the economy will be harmed in different places, but mitigation and adaptation policies will help avoid these often substantial and costly damages. Perhaps most important to remember is that climate change has the potential to dramatically increase inequality. The benefits of climate change mitigation have the potential to not only improve the U.S. economy on average, but also to protect and support the most vulnerable Americans.

![FIGURE 7](image)

**Income Distribution of Impacts across U.S. Counties**

25 Percent damage relative to county income

Note: Counties are arranged into deciles of county-level production/income and aggregate impacts as a percent of income are averaged across deciles. Boxplots denote median (white line), “likely” range (17 percentile-83 percentile, box), and 5 percentile-95 percentile (whiskers).

Source: Author’s calculation adapted from Hsiang et al., (2017).

[REFERENCES]


**FURTHER READING**

**Climate Change**

Estimating Economic Damage From Climate Change In The United States

Science

Unmitigated climate change will make the United States poorer and more unequal, with the poorest third of U.S. counties projected to sustain economic damages costing as much as 20 percent of their income if warming proceeds unabated.

Valuing the Global Mortality Consequences of Climate Change Accounting for Adaptation Costs and Benefits

National Bureau of Economic Research

Continuing a high emissions trajectory increases average global temperatures by around 4.8°C (8.6°F), raising global mortality risk in the United States by ten deaths per 100,000—about on par with the current fatality rate from auto accidents.
Heart of the Problem

All over the world, climate policies have the potential to provide large benefits by reducing the harms that result from carbon dioxide (CO$_2$) emissions. However, these policies can be costly, with some more expensive than others. The value of reducing such emissions is not $0, and it is not infinite. Some imaginable fuel economy standards, for example, would be very stringent, while others would be very lenient. What level of stringency is optimal, if a central goal of those standards is to reduce carbon dioxide emissions? To confront the challenge of climate change effectively, the public is best served by policies that have benefits in excess of costs, and that maximize net benefits.

A key tool in identifying such policies is the social cost of carbon (SCC), which represents the monetized damages associated with a one metric ton increase in CO$_2$ emissions. In principle, the SCC illustrates the dollar value of all the future damages associated with the change in climate due to the release of an additional ton of CO$_2$, including (but not limited to), mortality and other health effects from excess heat and natural disasters, depressed agricultural production, reductions in labor productivity, disruption of energy systems, increased risk of violent conflict, property damage from hurricanes and floods, and mass migration out of affected regions. The SCC therefore reflects how much society should be willing to pay to reduce carbon dioxide emissions by a ton.

With this information, policymakers can easily conduct cost-benefit analyses of regulations that reduce CO$_2$ emissions. The costs to the economy of lowering emissions (e.g., imposing fuel economy standards on car manufacturers) are naturally calculated in dollars. And with the SCC, the benefits of CO$_2$ emissions reductions are converted into dollars. The result is an apples-to-apples comparison of an individual regulation’s benefits and costs, both measured in dollars.

From the standpoint of law and practice, this conversion is extraordinarily helpful. In the United States, some legislation formally requires agencies to conduct cost-benefit analysis, and prevailing Executive Orders, supported by both Republican and Democratic presidents, require such an analysis for all major regulations, including those designed to reduce carbon emissions. Though the use of cost-benefit analysis is not without controversy, there is a strong argument in favor of conducting such an analysis, and giving serious consideration to it, if the goal is to ensure that regulations best promote the American people’s interests.

1 Livermore and Revesz, Reviving Rationality.

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**Updating the United States Government’s Social Cost of Carbon**

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Michael Greenstone, Milton Friedman Distinguished Service Professor in Economics; Director, EPIC; Director, Becker Friedman Institute

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This paper outlines a two-step process to return the United States government’s Social Cost of Carbon (SCC) to the frontier of economics and climate science. The first step is to implement the original 2009-2010 Inter-agency Working Group (IWG) framework, which includes global damages, using a discount rate of 2 percent. This can be done immediately and will result in an SCC for 2020 of $125. The second step is to reconvene a new IWG tasked with comprehensively updating the SCC over the course of several months. This would involve the integration of multiple recent advances in economics and science; we detail these advances here and provide recommendations on their integration into a new SCC estimation framework.
Following the Supreme Court’s decision in U.S. Environmental Protection Agency (EPA) vs. Massachusetts (2007), the U.S. government has been required to issue at least some regulations to reduce greenhouse gas emissions, but at the time of the decision it lacked a consistent SCC with which to inform its judgments. In 2009, therefore, President Barack Obama’s administration issued a temporary SCC and formed an Inter-agency Working Group (IWG) that was tasked with developing a robust SCC, based on the best available science and economics. The work was completed in 2010 and then successively updated, which ultimately produced a value of $52 per ton of CO2 in 2020. The same methods were used to develop a social cost of methane, another potent greenhouse gas, in 2016. Following a request from the Obama administration, the National Academies of Science, Engineering, and Medicine (NAS) released a report on how to bring the SCC closer to the frontier of climate science and economics in January 2017.

Not long after that report’s release, President Donald Trump’s administration disbanded the IWG and reduced the SCC to between $1 and $8 (see left panel of Figure 1), making changes in assumptions that did not follow the NAS recommendations and that were difficult to justify based on science and economics. In the past four years, the controversy and substantially lower SCC estimates used by the Trump administration have helped to pave the way for the rollback of environmental regulations. For example, as illustrated in Figure 2, the Trump administration’s 2017 reconsideration and substantial weakening of Obama-era fuel economy standards was merited, on cost-benefit grounds, with its lower SCC, but would not have been so justified with the IWG SCC. On February 26, 2021, the Biden administration announced an “interim” SCC of $52 for 2020, returning to the same framework developed by the IWG in 2010-2016.

Since its release in 2010, the SCC has played a central role in climate policy both domestically and internationally. For example, as of 2017 the federal government had used the SCC to assess the value of over eighty regulations with a combined $1 trillion in estimated gross benefits. At least eleven state governments have begun using an SCC to guide policy, most notably in Illinois and New York, where governments use the SCC to value “zero-emissions credits” paid to producers of clean energy. Meanwhile, several other countries, including Canada, France, Germany, Mexico, Norway, and the United Kingdom, have referred to the experience of the United States to implement their own SCC estimates, with some adopting estimates wholesale from the IWG. In many respects, the SCC is the “straw that stirs the drink” for most domestic climate policies, determining in some cases whether or not regulatory action can proceed. But the national SCC can also influence the direction of international climate negotiations: experience demonstrates that meaningful U.S. action can leverage large reductions in emissions from other countries that reduce the climate damages that Americans must contend with.

Rapid scientific and economic advances in the last decade mean that there is now an urgent need to update the SCC. The Obama-era SCC relied on the science and data available at the time, often making simplifying assumptions that are now understood to be invalid...
or unnecessary. Recognizing the likely advance of understanding, the IWG explicitly called for “update[s] over time to reflect increasing knowledge of the science and economics of climate impacts.” Despite some incremental changes, however, a wholesale update was never conducted. The consequence is that neither the Trump nor Obama SCC incorporates the explosion of data and research since 2010 that has dramatically expanded knowledge of the climate, economy, and the relationship between the two. A defining feature of the best new research is that it relies on large-scale data sets, rather than assumptions that are often unverifiable.

A number of these new, empirically grounded studies indicate that the underpinnings of the current SCC are no longer valid in terms of, for example, their projected impacts on mortality rates, energy demand, and agricultural productivity. The right panel of Figure 1 shows three of the sector-specific component or “partial” SCC estimates developed in recent years (yellow), as they compare to the same components of the federal SCC developed in 2013 (grey). New estimates for two of three recently studied SCC sectors (mortality and agriculture) indicate substantially larger damages from CO$_2$ suggesting that the SCC, as settled in 2013, is too low. Besides advancing understanding about the overall impacts of climate change, these data-driven updates to the SCC have uncovered large differences in the impacts of climate change both within and across countries that were invisible with previous approaches. The key finding is that climate change is projected to disproportionately harm today’s poorest populations, exacerbating concerns about environmental justice. These distributional findings are only visible with the detailed data that characterize the new wave of research. As just one example, even within a wealthy country like the United States, climate change is projected to cause economic damages in the poorest 5 percent of counties that are approximately nine times larger on average by the end of the century than in those in the richest 5 percent.

plainly, this new research makes it possible to assess who is most affected by climate policies—insight that is out of reach under the current SCC framework. Revising the U.S. SCC based on a new and more durable foundation would return the SCC to the frontier of understanding about the risks from climate change and lead to better policy that protects Americans against unnecessary climate risks. Moreover, such an update would undoubtedly influence policy abroad, which directly affects the well-being of Americans, since the climate is equally affected by emissions from Chicago, as those from Beijing, Paris, Mumbai, and Riyadh.

This chapter outlines a two-step approach to updating the U.S. SCC that returns it to the frontier of knowledge. The Biden administration can initiate the first step immediately; it simply involves implementing the IWG’s approach again with a discount rate of no higher than 2 percent, which reflects profound changes in international capital markets that make the current values difficult to justify. At a discount rate of 2 percent the SCC in 2020 is $125. The second step is for the Biden administration to launch a reconstituted IWG and task it with a comprehensive updating of the SCC. There are seven key “ingredients” that should go into such a process. The next section identifies each of them, explains what was done in the past, describes how understanding has advanced since 2009-2010, and make specific recommendations. The chapter’s final section details multiple pathways towards combining these ingredients to produce an updated SCC. Importantly, none of these pathways can be implemented immediately; a reconstituted IWG’s work could take several months.

### The Seven Key Ingredients for a Revised SCC

Calculating the SCC requires a model that accounts for the future growth of the economy, the relationship between emissions and climate change, the effect of climate change on the economy, and a number of other factors. Such models are referred to as Integrated Assessment Models (IAMs), since they combine scientific and economic models to evaluate the impacts of carbon emissions. The Obama-era IWG estimated the SCC using three existing IAMs—DICE, FUND, and PAGE—which were developed in the 1990s and have been widely used in the economic and scientific literature.

There are seven “ingredients” necessary to construct the SCC. The first four are often referred to as “modules” (see Figure 3): 1. A socioeconomic and emissions trajectory, which predicts how the global economy and CO$_2$ emissions will grow in the future; 2. A climate module, which measures the effect of emissions on the climate; 3. A damages module, which translates changes in climate to economic damages; and 4. A discounting module, which calculates the present value of future damages.

In addition, there are three cross-cutting modeling decisions that affect the entire process: 5. Whether to include global or instead only domestic climate damages; 6. How to value uncertainty; and 7. How to treat equity. Updating the SCC so that it is built on a foundation of frontier science and economics would require a newly constituted IWG to make decisions regarding each of these seven ingredients. However, the IWG need not start from scratch; some required updates are already clear. Due to significant advances in climate modeling and in climate impact analysis, as well as profound changes in global capital markets, it is essential to update the climate and damage modules and to change the rate of discounting. It is additionally essential to update the Trump administration’s U.S. SCC to reflect global, as opposed to domestic only damages, based on an overwhelming consensus amongst scientific and economic experts. Failing to account for these advances would leave any new SCC open to well-founded scientific criticism. It could...
also leave a new SCC vulnerable to legal invalidation; courts review agency decisions to ensure that they are not “arbitrary or capricious,” and if a new SCC were not based on scientific advances it could be challenged on exactly that ground. There are also valuable opportunities to update the other three ingredients, but to varying degrees the scientific and, for policy case for doing so is less urgent.

This chapter can be thought of as a “recipe,” outlining ways to bring the U.S. government’s SCC back up to the scientific frontier. This section briefly explains each of the seven key ingredients, describes how they were handled by the IWG in 2010, and makes recommendations to update each.

**Essential Updates to the SCC**

**Ingredient 1: Climate Module**

**Background:** The development of an SCC requires a climate model that converts carbon emissions into changes in the global climate. Specifically, these models must characterize the relationship between emissions and atmospheric CO₂ concentrations and the relationship between atmospheric CO₂ and changes in the climate, including both warming and sea level rise. All three IAMs used by the IWG included highly simplified climate models. A core input into each of these models was the Equilibrium Climate Sensitivity (ECS), which determines the total global warming realized from a doubling of atmospheric CO₂ concentrations. The ECS has a substantial impact on the SCC but its true value is not known with scientific certainty.

**2010 IWG Approach:** The IWG relied on the climate models within each IAM. However, to ensure that the ECS values used reflected the best available science at the time, the IWG harmonized the ECS across all models by using a probability distribution that reflected the likelihood of different possible climate outcomes at the end of the century according to the Intergovernmental Panel on Climate Change’s (IPCC) Fourth Assessment Report. This was the only component of each IAM’s climate model that the IWG calibrated to match scientific evidence.

**Progress:** Recent evidence makes clear that the IAMs used to calculate the IWG SCC, even with a harmonized ECS, are outdated, as they do not reflect a substantial body of new research quantifying multiple links in the causal chain from emissions to temperature change. In particular, DICE, FUND, and PAGE substantially underestimate the speed of temperature increase, relative to climate models that satisfy the NAS criteria for meeting scientific standards (Figure 4). For example, higher atmospheric CO₂ concentrations cause the oceans to warm and acidify, which makes them less effective at removing CO₂ from the atmosphere. The consequence is a positive feedback loop that accelerates warming. However, this dynamic is missing from both the DICE and PAGE climate modules.

The fact that existing IAMs do not reflect the well-developed climate science literature substantially influences the magnitude of the SCC. Importantly, the delay in projection of warming in the IAMs’ climate models means that resulting estimates of the SCC are likely to be too low. The delay pushes warming further into the future, which is discounted more heavily, as shown in the bottom panel of Figure 4. It is vital that an updated SCC relies on a climate model that accurately reflects the climate system’s functioning. Because any SCC calculation requires capturing the uncertainty surrounding the impact of CO₂ on temperature and other climate variables, however, it would be computationally infeasible to replace IAM climate models with state-of-the-art Earth system models that capture the physics, chemistry, and biology of the atmosphere, oceans and land at high spatial resolution. Therefore, a simple Earth system model that can conduct uncertainty analysis while also matching predictions from these more complex models is necessary.

**RECOMMENDATION**

The first part of our climate model recommendation is that IWG use the simple Earth system model FAIR to project changes in temperature.

The FAIR model satisfies all criteria set by the NAS for use in an SCC calculation. Importantly, this model generates projections of future warming that are consistent with comprehensive, state-of-the-art models and can be used to accurately characterize current best understanding of the uncertainty regarding the impact that an additional ton of CO₂ has on global mean surface temperature (GMST). Finally, FAIR is easily implemented and transparently documented, and is already being used in updates of the SCC.

The second part of our climate model recommendation is that the IWG use semi-empirical models to project changes in sea level based on changes in global mean surface temperature from FAIR.

A key limitation of FAIR and other simple climate models is that they do not represent the change in global mean sea level rise (GMSL) due to a marginal change in emissions. However, statistical methods can be used in combination with long historical records of both temperature and sea level to build a semi-empirical model of the relationship between GMSL and GMST. Such models are readily available and can enable the inclusion of marginal damages due both to warming and to projected changes in sea level. An important potential caveat is that available semi-empirical models of GMSL, in addition to more complex bottom-up models, may...
RECOMMENDATION

The third part of our climate model recommendation is that the damage function itself should relate total socioeconomic damages to changes in global mean surface temperature (and global mean sea level rise where appropriate).

Finally, a strength of simple climate models like FAIR is that they can project GMST, accounting for climatological uncertainty, both with and without a marginal increase in emissions, which is necessary to compute the social cost of one additional ton of CO2. However, they are not able to provide local climate projections at, for example, the county level. This introduces a challenge, as socioeconomic trajectories are available nationally and, as discussed below, recovering a valid damage function requires that climate impacts be estimated locally. It is possible, however, to use high spatial detail in socioeconomic and climatic conditions to estimate damages that are then calibrated to GMST (and GMSL, for sectors where sea level rise is an important driver of climate change impacts) in a second stage.38

Ingredient 2: Damages Module

Background: A “damage function” translates changes in the physical climate (e.g., temperature and sea level rise) into monetized impacts on the economy. In some IAMs, a single damage function is calibrated to represent all categories of climate impact (e.g., PAGE), while in others, separate damage functions are modeled for individual impact categories (e.g., FUND). In DICE, a single damage function is used, but it is calibrated based on individual sector-specific damage estimates.39

At least two problems have plagued the IAM damage functions. First, they are primarily derived from ad-hoc assumptions and simplified relationships, not large-scale empirical evidence. Further, the IAM damage functions have tended to treat the world as nearly homogeneous, dividing the globe into at most sixteen regions. This aggregation misses a great deal, especially because there are important non-linearities in the relationship between temperature and human well-being that are obscured by substantial aggregation. For example, a given increase in temperature will have very different impacts in Arizona than it will in northern Minnesota. For both of these reasons, these damage functions have been heavily criticized in recent years.39

2010 IWG Approach: When the IWG developed the first SCC in 2010, existing IAM damage functions were essentially the only feasible option. As a result, there were few if any alternatives and the IWG kept the damage functions originally included in DICE, FUND, and PAGE.

Progress: In the last dozen years, there have been great advances in computing power, access to data from around the world, and econometric methods designed to quantify climate change impacts. A result has been an explosion of empirical research that has significantly expanded scientists’ understanding of the economic impacts of climate change. Relative to 2009, there is almost an embarrassment of riches, with, for example, at least 110 empirical studies on climate change’s economic impacts published between 2010 and 2016 alone.38

How should one choose among all of these studies when developing an updated damage function? To make full use of scientific advances, any modern damage function must now meet three criteria:

1. Empirically derived and plausibly causal: Damage functions should be derived from empirical estimates that reflect plausibly causal impacts of weather events on socioeconomic outcomes.

Because the climate has remained stable throughout modern human history, it is difficult to isolate experimental variations in the long-run climate. However, a large and growing empirical literature leverages modern econometric methods to uncover causal impacts of short-term climate change.

2. Capture local-level non-linearities for the entire global population: Damage functions should be estimated with data that represent the entire global population (not just high-income, temperate regions). Further, damage functions should account for “non-linear” effects of climate variables at a local level.

Run weather events on a host of socioeconomic outcomes, from agricultural output to mortality rates to energy use. When combined with empirical estimates of differences in population’s responses to weather events (discussed in criterion three below), this literature provides a strong foundation for understanding the socioeconomic effects of weather, and its approach should be reflected in a new IWG’s damage function.

The damage functions from FUND, DICE, and PAGE used by the IWG do not meet this criterion. They are only loosely calibrated to empirical evidence and/or rely on outdated estimates that fail to isolate the role of changes in the climate from economic variables such as income and institutions. For example, the majority of the studies used in FUND’s sector-specific damage functions were published prior to 2000, and all likely suffer from the influence of unobserved factors that are correlated with temperature. Similarly, early versions of DICE utilized a damage function that was only loosely tied to empirical literature while the recent DICE update continues to rely on empirical papers that fail to identify plausibly causal effects.35

2. Capture local-level non-linearities for the entire global population: Damage functions should be estimated with data that represent the entire global population (not just high-income, temperate regions). Further, damage functions should account for “non-linear” effects of climate variables at a local level.

Dramatic reductions in computing costs and increased data availability have enabled researchers to identify the effects of climate change on social and economic conditions at local scale around the globe. This body of work has uncovered that many socioeconomic outcomes display a strongly non-linear relationship with climate variables—that is, the effects of climate change are not identical everywhere, but are instead sensitive to prior socioeconomic and climatic conditions.35 For example, both extreme cold and extreme heat increase mortality rates, while moderate temperatures have little


39 Nordhaus, “The DICE Model.”

30 Pindyck, “Climate Change Policy: What Do the Models Tell Us?;”

31 Carleton and Hsiang, “Social and Economic Impacts of Climate;”

Deschênes and Greenstone, “The Economic Impacts of Climate Change;”

32 Carleton and Hsiang, “Social and Economic Impacts of Climate;”

33 Carleton and Hsiang, “Social and Economic Impacts of Climate;”

Deschênes and Greenstone, “The Economic Impacts of Climate Change;”


35 Nordhaus and Molerë, “A Survey of Global Impacts of Climate Change;”

36 Carleton and Hsiang, “Social and Economic Impacts of Climate;”
Taiwan, and the United Kingdom. None of these locations that draws on multiple studies, but only one of these specific damage function is calibrated by an analysis from the United States. Based on an empirical analysis that only includes data from lower-income, hotter regions of the globe. For demographics, and region.

The existing IAMs’ damage functions fail to adequately reflect that people, firms, and governments make defensive investments that provide protection against climate-related risks, and that these investments are costly. As climate change unfolds, individuals, governments, and firms will make innumerable decisions and investments to respond to the gradually changing environment. Damage functions within DICE, FUND, and PAGE involve very different assumptions about such compensatory investments and their costs, the majority of which are not based on real-life observations of adaptation. 37

While further advances in data collection and computing power are needed to derive damage functions for all sectors in all countries at high spatial resolution, substantial improvements over the existing IAMs are feasible. Further, recent research has developed methods for estimating worldwide climate impacts by inferring damages in data-poor regions based on data-rich regions that have similar characteristics. 38

3. Inclusive of adaptation: Damage functions should reflect that people, firms, and governments make defensive investments that provide protection against climate-related risks, and that these investments are costly. As climate change unfolds, individuals, governments, and firms will make innumerable decisions and investments to respond to the gradually changing environment. Damage functions within DICE, FUND, and PAGE involve very different assumptions about such compensatory investments and their costs, the majority of which are not based on real-life observations of adaptation. 37

The damage function should include both the estimated benefits and costs of future adaptive investments. While earlier empirical studies failed to account for the benefits of adaptation, a growing literature covering multiple sectors is developing damage estimates that reflect the benefits of adaptation. 39

However, these compensatory investments are not free—any updated damage function should also account for costs of adaptation. 40 Some progress has been made to infer these costs from available data, 41 but this is an active area of research. Damage functions should capture adaptation costs wherever possible.

**RECOMMENDATION**

We recommend that the Biden administration replace all existing IAM damage functions with those that meet these three criteria.

Estimated damage functions that meet the above criteria lead to dramatically different understandings about the economic impacts of climate change, compared to the older damage functions. For example, one recent study found a mortality-only SCC estimate that is more than ten times larger than the total health impacts within the FUND IAM. 42 Further, its estimate of the loss from higher mortality rates in 2030 accounts for 49-135 percent of total damages across all sectors from the three leading IAMs. Another recent study derived an agricultural damage function that meets some aspects of the criteria above and found a substantial, positive, agriculture-only SCC, while FUND’s agricultural SCC is negative (see Figure 1). 43 In other words, by using more comprehensive techniques, this study overturned past findings that suggested that climate change would be beneficial to agriculture, instead finding that it would cause substantial damage. It is noteworthy that meeting these criteria does not always increase estimated damages. For example, one study quantifying the impacts of climate change on global energy expenditures found a small, energy-only SCC estimate of $2. This finding was attributable largely to net savings from reductions in heating and differences in the responsiveness of electricity demand to high temperatures in high- versus low-income regions of the world. 44 This estimate stands in stark contrast to the FUND model, where the energy-only SCC is $85 (6 of which is attributable to Chinese cooling demand only) and constitutes 40 percent of the total, all-sector SCC. 45

These examples demonstrate that research that meets the three criteria described here will fundamentally alter prior estimates of the economic impacts of climate change.

**Ingredient 3: Discount Module**

**Background** Along with a set of socioeconomic and emissions scenarios, discussed below, the climate and damages modules together translate a single additional ton of CO2 emissions into a trajectory of additional warming, and a stream of future damages. The final step in the SCC calculation is to express this stream of damages as a single present value, so that future costs and benefits can be directly compared to costs and benefits of actions taken today. Discounting is the process by which each year’s future values are reduced to enable comparison with current costs or benefits to society. The “discount rate” determines the magnitude of this reduction. Because CO2 emissions persist in the atmosphere and lead to long-lasting climatological shifts, small differences in the choice of discount rate can compound over time and lead to meaningful differences in the SCC.

There are two reasons for “discounting the future,” or more precisely for discounting future monetary amounts, whether benefits or costs. The first is that an additional dollar is worth more to a poor person than a wealthy one, which is referred to in technical terms as the declining marginal value of consumption. The relevance for the SCC 46 See, for example, Deschênes and Greenstone, “The Economic Impacts of Climate Change.”


48 Estimates of adaptation costs are essential when computing the total damages of climate change. In contrast, under a strict set of assumptions, the marginal benefits and marginal costs of additional adaptation cancel each other out in the calculation of the damages from a marginal ton of CO2 emissions, making adaptation cost estimates unnecessary for the SCC when these assumptions are taken.

49 See, for example, Carleton et al., “Valuing the Global Mortality Consequences.”

50 Id.

51 Moore et al., “New Science of Climate Change Impacts.”


53 Diaz, “Evaluating the Key Drivers.”
Another approach to updating damage functions guided by the three listed criteria is “top-down” in nature, relying on statistical relationships between GDP and climate variables (generally temperature) to quantify the impacts of climate change on aggregate growth in (or levels of) income. The idea is to use GDP as a wide-reaching measure of economic well-being such that individual socio-economic sectors do not need to be separately analyzed nor do their interactions need to be explicitly modeled. These top-down empirical analyses have recently been used to update SCCs.

For example, one recent study generated SCCs of about 400, nearly an order of magnitude larger than the Obama SCC.3

This is an important and rapidly evolving line of research. However, several critiques cause us to conclude that top-down empirical analysis is not currently ready for use in determining the SCC. First, GDP is an incomplete measure of economic well-being and of willingness to pay for reducing greenhouse gas emissions. For example, it misses non-market outcomes such as mortality and morbidity that are large in magnitude, and current top-down analyses omit the damages associated with flooding and sea level rise. However, a bottom-up approach that sums sector-specific damages may also be incomplete, as discussed in this chapter’s last section.

Second, there is a long history of skepticism about the ability of cross-country GDP regressions to provide reliable information on the determinants of growth.4 Many of these concerns boil down to questions of misspecification. Regression models can be designed to identify causal relationships between climate variables (generally temperature) to quantify the impacts of climate change on aggregate growth in (or levels of) income.

Third, it is unclear whether a change in temperature affects the level or growth rate of GDP. A test for growth effects of temperature shocks requires estimating a distributed lag model with many lags, but these models (which measure the effects of temperature on growth over time) are difficult to estimate with available data, leaving a good deal of uncertainty in the results. For example, one model was empirically unable to distinguish between growth and level effects,5 while another rejected evidence of growth effects6 and a third found evidence in support of growth effects (at the subnational level).7

Fourth, a paper in this literature notes that the estimated effects of temperature shocks on GDP growth rates appear implausibly large.8 “If an extra °C reduces growth by 1 percentage points, then it would take only eight years of sustained temperature differences to explain the overall cross-sectional relationship between temperature and income observed in the world today.” The magnitude of these effects along with concerns about whether there are plausible mechanisms through which temperature can affect economic growth (as opposed to the level of economic activity) together have led to some additional skepticism.

A top-down approach to damage function estimation has strong potential to inform the SCC, particularly because it is challenging to empirically ground the overlap, spillovers, and interactions among individual sectors of damages used in a bottom-up approach.9

Therefore, resolving the uncertainties in this expanding literature is an urgent line of inquiry. In the meantime, we believe that a bottom-up approach like that outlined in this chapter is a more promising avenue for determining an SCC grounded in real-world data.

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3. Hong et al., “Estimating Economic Damage from Climate Change in the United States.”

4. Note that this skepticism in the macro economics literature has applied both pure cross-sectional analyses (comparing country growth experiences to one another) and to growth regressions exploiting panel data (comparing GDP over time within a country). See Darulac (2009) for a detailed discussion.


7. Dell, Jones and Olken, “Temperature and Income.”


10. Burke et al. (2015) estimate a five-year distributed lag model that cannot reject zero growth effects is cumulative effect of −0.010 per °C with a 95% confidence interval of [−0.027, 0.008]. The authors conclude: “we cannot reject zero growth effects (cumulative effect of −0.010 per °C with a 95% confidence interval of [−0.027, 0.008].”


17. Giglio et al., “Climate Change and Long-run Discount Rates.”

18. Giglio et al., “Climate Change and Long-run Discount Rates.”


27. Giglio et al., “Climate Change and Long-run Discount Rates.”


32. Giglio et al., “Climate Change and Long-run Discount Rates.”

33. Giglio et al., “Climate Change and Long-run Discount Rates.”

34. Giglio et al., “Climate Change and Long-run Discount Rates.”

35. Giglio et al., “Climate Change and Long-run Discount Rates.”


37. Giglio et al., “Climate Change and Long-run Discount Rates.”

38. Giglio et al., “Climate Change and Long-run Discount Rates.”


40. Giglio et al., “Climate Change and Long-run Discount Rates.”

41. Giglio et al., “Climate Change and Long-run Discount Rates.”

42. Giglio et al., “Climate Change and Long-run Discount Rates.”

43. Giglio et al., “Climate Change and Long-run Discount Rates.”

44. Giglio et al., “Climate Change and Long-run Discount Rates.”

45. Giglio et al., “Climate Change and Long-run Discount Rates.”

46. Giglio et al., “Climate Change and Long-run Discount Rates.”

47. Giglio et al., “Climate Change and Long-run Discount Rates.”


49. Giglio et al., “Climate Change and Long-run Discount Rates.”

50. Giglio et al., “Climate Change and Long-run Discount Rates.”

51. Giglio et al., “Climate Change and Long-run Discount Rates.”

52. Giglio et al., “Climate Change and Long-run Discount Rates.”

53. Giglio et al., “Climate Change and Long-run Discount Rates.”

54. OMB, “Circular A-1.”

55. Gollner and Hammitt, “The Long-Run Discount Rate Controversy.”

56. Giglio et al., “Climate Change and Long-run Discount Rates.”


59. Giglio et al., “Climate Change and Long-run Discount Rates.”

60. A fixed rate below 2 percent does not contradict OMB Circular A-4, which along-lived benefit is in under consideration. If your rule will have important intergenerational benefits or costs you might consider a further sensitivity analysis using a lower but positive discount rate in addition to benefits using discount rates of 3 and 7 percent.” See OMB, “Circular A-4.”
due to the unique risk properties of climate change and uncertainty about future interest rates. Because discount rates reflect the returns to investments that mitigate climate change, Americans are best served by using an interest rate associated with investments that match the structure of payoffs from climate mitigation. Capital asset pricing models recommend lower discount rates in scenarios where investments (in this case CO₂ mitigation) pay off in “bad” states of the world—that is, if climate damages are likely to coincide with a slowing overall economic growth that could, for example, be due to “tipping points” or large-scale human responses to climate change, including mass migration. If on the other hand climate damages act as tax on the economy (i.e., total damages are larger when the economy grows faster), then higher discount rates like the average return faster), then higher discount rates like the average return
Additional Scientific Advances

Ingredient 5: Socioeconomic and Emissions Module

Background: To calculate the SSC, it is necessary to compare a baseline trajectory of economic growth and CO₂ emissions to a trajectory in which one more ton of CO₂ is released. All else equal, a higher baseline CO₂ emissions trajectory will result in a greater SCC. Because projected climate change damages are nonlinear, that is, an additional ton of CO₂ emissions is projected to cause more damages at higher atmospheric concentrations of CO₂. Baseline economic growth affects the SCC in a variety of competing ways. Richer economies consume more energy and generate higher emissions, such that marginal tons do more damage and populations have higher willingness-to-pay to avoid climate change, which increases the SCC. That said, richer countries are better prepared to invest in adaptations—such as increased air conditioning—that reduce the social costs of climate change. Changing population demographics can also alter the magnitude of future climate change damages by, for example, increasing the total population and raising the share of the population at higher risk of heat-induced mortality.

2010 IWG Approach: Since future emissions and economic growth are unknown, the IWG combined a range of five possible trajectories developed by the Stanford Energy Modeling Forum (EMF-22) with crude probabilistic assumptions. Four of these scenarios represent business-as-usual (BAU) trajectories, while the last assumes that aggressive climate policies dramatically reduce future emissions. The IWG calculated the SCC under all five scenarios and averaged the result, giving equal weight to each scenario.

Progress: In the past ten years, there has been only modest scientific progress in developing baseline scenarios due to the stubborn difficulties in making long-run population and economic growth projections. The IPCC and many researchers have moved towards using the Shared Socioeconomic Pathways (SSPs), built collaboratively by a group of climate researchers over the last several years, as benchmark scenarios. The SSPs may be a worthwhile update over the EMF-22 pathways, as the latter under-sample possible future scenarios. Moreover, the SSPs can be linked to the Representative Concentration Pathway (RCP) emissions scenarios, a standardized set of emissions trajectories used widely across the climate modeling community.

However, while the range of different modeling groups generating SSP and RCP scenarios captures some degree of model and parameter uncertainty, these scenarios do not systematically characterize uncertainty in emissions or socioeconomic projections. In recent years, economists have developed more sophisticated modeling techniques that rely on historical data to generate probabilistic economic projections and demographers have done the same for population. An alternative is to rely on expert elicitation techniques, that is, a process by which researchers synthesize the informed opinion of experts. The weakness of this technique is that it relies on a potentially unrepresentative sample of experts’ subjective judgments, while its strength is that those individuals may add information that is not captured by existing statistical approaches. As outlined by the NAS, empirically based projections can be combined with expert elicitation to formulate new socioeconomic and emissions projections that represent the many sources of uncertainty involved in generating long-run forecasts.

RECOMMENDATION

To generate socioeconomic and emissions projections, our recommendation is to rely either on a combination of the SSPs and the RCPs or on new probabilistic projections that combine statistical methods with expert elicitation.

The probabilities assigned to each projection should be chosen to best represent the most likely future global pathway.

Ingredient 6: Valuing Uncertainty about Climate Risk

Background and 2010 IWG: There are several sources of uncertainty in the calculation of the SCC. These include uncertainty about future economic growth, the sensitivity of the global climate to additional emissions, and the economic damages for a given level of climate change. Economic theory and empirical evidence (see, for instance, the general existence of the insurance industry) reveal that people dislike risk and are willing to pay to reduce their exposure to it. The IWG chose not to account for uncertainty in valuing climate damages but noted that this decision “demands further attention.”

Progress: Economic theory and empirical research decisively support the idea that people are risk-averse and value reducing uncertainty. In the last decade, advances in computing have enabled probabilistic climate change projections that capture multiple measures of uncertainty about the magnitude of climate damages. Thus, for the first time, it is possible to characterize these uncertainties and to incorporate them into the calculation of the SCC. For example, one recent study provided estimates of the total change in energy expenditures under climate change, accounting for both statistical and climatological uncertainty.

RECOMMENDATION

We recommend that the calculation of the SCC account for the considerable uncertainty from multiple sources about damages using standard economic tools for valuing this uncertainty.

Ingredient 7: Equity

Background: An additional dollar is worth more to a poor person than to a wealthy one. Applying this principle to the SCC would require “equity weighting” within

 damages. To use a domestic SCC would be to abandon this role of global leadership. It would also create an incentive for other nations to do the same, creating a risk of losing out on the benefits from potential foreign emissions reductions.

70. Riahi et al., “The Shared Socioeconomic Pathways.”
71. See, for example, Mäler et al., “An Econometric Model of International Long-run Growth Dynamics.”
72. Probabilistic projections describe the likelihood of experiencing a particular future condition. A weather forecast warning of a 60 percent chance of rain tomorrow, for example, is a probabilistic projection.
74. NASA, “Valuing Climate Damages.”
77. Colenna et al., “Valuing the Global Mortality Consequences of Climate Change.”
80. The application of standard methods of uncertainty valuation to empirically derived probabilistic damage estimates in a central feature of Pathway “C,” one of the recommended pathways for development of a new SCC described below.
81. Specifically, this should be done by accounting for risk aversion using standard parameterizations of the shape of the utility function (e.g., 1 – δ) from the existing literature to determine the “certainty-equivalent” value of damages under climate change (Traeger, “Why Uncertainty Matters”). A “certainty-equivalent” value is computed by determining the consumption less that society would accept as a certain outcome in place of the distribution of future uncertain outcomes.
However, OMB Circular A-4, which guides cost-benefit analysis across the U.S. government, has not been altered since its release and does not clearly allow for equity weighting within cost-benefit calculations. Therefore, conducting equity weighting would represent a significant departure from standard U.S. cost-benefit analysis. Further, it would have significant precedential implications far beyond climate regulations and environmental policy.

**RECOMMENDATION**

Though we believe there is a strong theoretical and empirical case for equity weighting, we recommend that it not be incorporated into the SCC until there is an overhaul of Circular A-4. Such a review would allow for a full consideration of the implications across multiple domains.

**Three Pathways Toward an Updated SCC**

Of the four ingredients that are essential to update in a new SCC, only two can be immediately implemented by the Biden administration upon inauguration: changes to the discount rate and the inclusion of global damages. A holistic update to the SCC that integrates substantial scientific progress in the other two essential ingredients—the climate model and damage function—will involve reworking the Inter-agency Working Group (IWG) to assess the costs and benefits of three distinct possible implementation pathways:

- **Pathway A:** Update the original IAMs (as much as possible)
- **Pathway B:** Build a new IAM (under the current Circular A-4)
- **Pathway C:** Build a new IAM (under an updated Circular A-4)

Each of these pathways will require an integration of research components that would entail several months of work.

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84. Standard parameterizations of utility function curvature (e.g., $\eta = 2$) can be used to calibrate equity weights.

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**Note:** Figure uses checkmarks to indicate whether bringing each SCC ingredient to the current scientific frontier is feasible within each of three possible pathways for a new SCC framework. Black checkmarks indicate a feasible update, while grey checkmarks indicate substantial implementation challenges. See text for a detailed discussion of each pathway.

**TABLE 1**

<table>
<thead>
<tr>
<th>Pathway</th>
<th>Pathway A</th>
<th>Pathway B</th>
<th>Pathway C</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Climate Module</strong></td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td><strong>Discount Module</strong></td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td><strong>damages Module</strong></td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td><strong>Socioeconomic and Emissions module</strong></td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td><strong>Uncertainty</strong></td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td><strong>Equity</strong></td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
</tbody>
</table>

**Recommended Update:**

We recommend the Biden administration immediately update the SCC by returning to the 2013 IWG’s approach, applying a 2 percent discount rate to reflect the profound changes in global capital markets in recent years. Simultaneously, we recommend that the Biden administration should reconvene the IWG to conduct a more holistic update, following Pathway B.

While the IWG should consider the pros and cons of all three pathways for a comprehensive SCC update, we believe Pathway B is the most feasible, transparent, and accommodating of evolving scientific research (Table 1).
Pathway A: Update Existing IAMs As Much As Possible

The first pathway closely mimics the structure used by the IWG in its original SCC calculation. This requires wherever possible updating each of the seven SCC ingredients within the three IAMs. One would then run each of the updated versions of these three models and produce new distributions of SCCs. An appeal of this pathway is that it is relatively straightforward to replace the existing climate models in each IAM with the FAIR model, including the construction of a semi-empirical model of global mean sea level rise. Moreover, this approach may be attractive because the Biden administration could rely on the original IAM model parameters when updated scientific evidence is not available or cannot objectively inform a key modeling decision. 80

The Achilles heel of Pathway A is that while the ultimate goal of the exercise is to estimate the damages from an additional ton of CO₂, there is not a compelling way to base this estimate on the latest evidence on climate change damages under this pathway. The challenges are both conceptual and practical. On the conceptual side, it is not straightforward to replace the existing damage functions with improved damage functions for any of the three IAMs. In the case of FUND, it is possible to subdivide the overall damage function into sector-specific functions that can roughly be mapped to the existing improved sectoral damage functions. 81 But the result would be an imperfect melding of new, scientifically robust analysis with older modeling assumptions that are only loosely tied to empirical evidence. The challenge of replacing the damage functions in DICE and PAGE is even greater, because their overall damage functions cannot readily be subdivided into categories that map to the empirically founded sectoral damage functions. The best case is that there would be some risk of double counting and then a mixing of the newer, empirically founded and the older, assumption-driven approaches with unclear weightings between the two. Overall, there is not a clear correspondence between empirically founded, sector-specific damage functions and IAM damage functions, which makes combining them conceptually complicated.

On the practical side, the nature of recent damage function estimates makes it challenging to replace components of the existing IAMs’ damage functions with the new, empirically founded sectoral damage functions for at least two reasons. 82 First, none of the existing IAMs have sufficient spatial resolution in socioeconomic projections to align population and income trajectories with new damage functions that reflect differences in climate change impacts at the local level (e.g., county). Second, adaptation is treated very differently in each model, 83 such that adjustments to incorporate real-world evidence on sector- and region-specific adaptation will require substantial changes to each model’s original structure.

In addition to these challenges, it will be difficult to fully follow the recommendations above with respect to both the valuation of uncertainty (Ingredient 6) and the treatment of equity (Ingredient 7). With respect to uncertainty, DICE is not designed to account for the many uncertain parameters in the SCC calculation, and FUND and PAGE can only enable valuation of uncertainty to the extent that sector-specific damage functions and their corresponding uncertainties can be integrated into the modeling framework; as discussed above, this is not a straightforward task. If equity weighting were pursued by the Biden administration, the low spatial resolution of all IAMs limits their ability to capture and value differences in the welfare effects of climate change. 84 Although Pathway A is feasible and was recommended by the NAS for use in the near-term, the integration of new, empirically founded sectoral damage functions into the existing IAMs has conceptual inconsistencies and is likely to be practically challenging. There is no near-term, off-the-shelf implementation available for Pathway A. Thus, Pathway A is a viable option, but it cannot fully accommodate one of the key advances in understanding about climate change that have taken place in the last decade.

Pathway B: Build a new IAM (under the current Circular A-4)

The second pathway is to build a new SCC framework that fully integrates scientific advances in each of the seven SCC ingredients. This is the approach recommended for longer-term implementation by the NAS. 85 As above in the case of Pathway A, such a new IAM framework is not available for immediate use. However, the Climate Impact Lab (CIL), 86 of which both authors are core members, is aiming to release such a framework in the first half of 2021. The CIL combines the SSP economic and population projections, high-resolution climate impact models, and recent efforts to better understand climate damage functions. For example, energy demand in FUND can be mapped directly to the energy demand damage functions derived in Rode et al. (2020), while the mortality damage function empirically derived in Carleton et al. (2020) covers only some of the causes of death forming mortality-related damages in FUND. Initial efforts to update the damage module within a single IAM (e.g., DICE, FUND) have each constituted a significant academic publication, given the challenges involved in conforming new, generally richer information to the existing IAM frameworks. For example, Moore et al. (2017) replace the agricultural damage function in FUND using a meta-analysis of the empirical agricultural impacts literature, and Bressler (2019) does the same by adding a mortality damage function on top of existing DICE damages. 88

In particular, in a new IAM built from empirical damage estimates, it is straightforward to integrate results from new studies updating sector-specific damages or providing estimates for previously unquantified sectors. Similar updates to other modules, such as the climate model, are also easily accommodated. Of course, any such revisions should be limited to changes that meet the damage function, climate model, or other corresponding criteria laid out above.

An important additional benefit of a new SCC framework built from recent empirical damage estimates is that the different effects of climate change across socioeconomic groups can be explicitly described. Recent, local-level projections for multiple RCP emissions scenarios, and rich historical socioeconomic and climate datasets to estimate sector-specific, flexible, globally representative damage functions that capture differences across approximately 25,000 global regions and account for adaptation and its costs. It then applies the simple Earth system model FAIR and a wide range of valuation and discounting approaches to transform these damage functions into a full distribution of SCC estimates, accounting for multiple sources of uncertainty.

This approach has some strengths and weaknesses. A great appeal of this approach is that each of the seven SCC ingredients can be addressed, including the four essential updates. On the other hand, this pathway’s main weakness is that damage functions meeting the above criteria are not currently available for all sectors likely to be affected by climate change. Damage functions for some of these sectors are currently under development, both by the CIL and by other researchers, so this pathway will become more complete as science and economics advance. However, at least in the medium term, the resulting SCC will be based on an incomplete measure of climate damages. Although this is an important shortcoming, many of the most important areas of incomplete knowledge—such as catastrophic risks and interactions across regions and sectors—remain overly simplistic or completely absent in the IAMs themselves. 89 While an initial SCC built under this pathway will be incomplete, an important strength of this approach is that it can accommodate future advances in understanding. In particular, in a new IAM built from empirical damage estimates, it is straightforward to integrate results from new studies updating sector-specific damages or providing estimates for previously unquantified sectors. Similar updates to other modules, such as the climate model, are also easily accommodated. Of course, any such revisions should be limited to changes that meet the damage function, climate model, or other corresponding criteria laid out above.
estimates of sectoral damages have shown that climate change disproportionately affects today’s poorest populations. An SCC framework based on such studies will enable the Biden administration to evaluate and consider the distributional effects of climate policies for localities within and beyond the United States.

Our conclusion is that scientific and economic understanding has advanced enough that a revised SCC should be fully based on empirical evidence that meets modern standards. This will best serve the interests of the American people. While this approach may initially omit certain categories of damages, existing updated SCC results suggest that even partial accounting of sector-specific damages is likely to raise the existing U.S. SCC (see Figure 1), particularly if discount rates are updated and uncertainty is properly valued. Further, we think that the SCC’s political and legal durability would be enhanced by this approach, which is built to accommodate a scientific literature that will undoubtedly continue to evolve.

Pathway C: Build a new IAM (under an updated Circular A-4)

A third pathway constructs the same new SCC framework as described for Pathway B, only departing from Pathway B when valuing the sector-specific, empirically derived climate impacts that form the damage function. In particular, this approach builds a damage function that embeds discounting (Ingredient 3), the valuation of uncertainty (Ingredient 6), and the treatment of equity (Ingredient 7) into a single cohesive step. In so doing, this pathway directly contradicts some of the individual recommendations for these three ingredients listed above. If this pathway is taken by a future IWG, we recommend updating these ingredients as described below. All other aspects of this pathway follow Pathway B described above.

This pathway is based on the recognition that a simple economic principle—declining marginal value of consumption—underlies the motivation for discounting as well as the valuation of both equity and uncertainty. This principle is based on the straightforward observation that $100 is worth more to a person living in poverty than a wealthy person. In the climate setting, declining marginal value implies that one should attach a higher value to future and present impacts of climate change when they occur to populations experiencing lower incomes. It also means that when future incomes are uncertain, one has to account for the risk of severe damages occurring when average global income is very low, and thus when the value of an additional dollar is relatively high.

Therefore, an argument can be made for computing an SCC in which the damage function represents the difference in the “certainty-equivalent” value of consumption across all years, populations, and possible future states of the world with and without climate change. In this approach, the valuation of climate damages is conducted from the perspective of a person who does not know their circumstances in advance, so they account for all potential income levels (e.g., whether they earn $25,000 or $250,000 annually) and degrees of climate risk they might face (e.g., whether they live in Miami or Minneapolis). This calculation can be limited to those living in a particular country or applied to those living in any country.

Under this approach, discounting, uncertainty valuation, and accounting for equity implications are all incorporated into the construction of a single, certainty-equivalent damage function. To compute this damage function, estimates of possible local-level climate change damages and their associated probabilities are combined with evidence on how the marginal value of consumption declines as people become wealthier.

This approach, which is built to accommodate a scientific literature that will undoubtedly continue to evolve, can be limited to those living in a particular country or applied to those living in any country.

Such a calculation is possible only with updated damage estimates from the recent scientific literature, which can show effects down to the local level and fully capture economic, statistical, and climatological uncertainty. A paper implementing this pathway will be released by the CIL team in 2021.

The appeal of this approach is that it is the most intellectually coherent method for valuing the damages from climate change. However, it is not entirely clear that pursuing Pathway C would be consistent with Circular A-4; therefore, doing so would likely have implications for policies beyond climate and environmental regulation.

We therefore recommend Pathway B, which is the approach that will deliver a transparent, internally consistent, and scientifically robust set of SCC estimates that can accommodate evolving research and be implemented within the current legal framework. However, we believe that Pathway C should be carefully considered for adoption in the medium term.

Possible Approaches: Update original models or build new models (recommended)

FIGURE 7

Summary of the Recommendations Made for a Two-Step Process for Updating The U.S. Government’s Social Cost of Carbon

Closing Argument

This chapter details a recipe to return the SCC to the frontier of climate science and economics. There are seven key ingredients in this recipe. The chapter outlines recommendations for each of them, along with recommendations for how to pull them together to update the SCC.

We propose a two-step process that will return a seriousness of purpose to U.S. climate policy that the climate challenge demands. The first step involves an immediate update to the SCC that returns to the original IWG approach. Specifically, we propose that damage estimates again include global damages and that the 3 percent central discount rate be replaced with a 2 percent discount rate (left panel of Figure 7). These changes produce an SCC of $125 in 2020. The second step is to rework the IWG to conduct a comprehensive update by building a new SCC framework (right panel of Figure 7).

Following this recipe means that the SCC would reflect the substantial changes in understanding about climate change that have emerged over the last decade. Further, we believe that it would best serve the interests of the American people.

Note: Step 1 can be implemented immediately, while Step 2 requires a new IWG to conduct a holistic update to the SCC framework.


Economy-wide Approaches

This section offers guidance to policymakers on how to ensure that polluters pay the price of the damages caused by emitting carbon dioxide into the atmosphere.
Carbon pricing policies are widely recommended by economists and other experts as the most cost-effective approach to reducing emissions. These policies allow for the greatest environmental benefit at a given price by giving firms and consumers the option to choose the cheapest ways to reduce emissions, as well as to engage in emitting activities that benefit them more than the cost to society. While many countries around the world and several jurisdictions within the United States have priced carbon through either a carbon tax or an emissions trading system, existing federal U.S. climate policy instead consists of a piecemeal arrangement of regulations and mandates for specific actions and technologies. This approach has not been effective overall, with many existing policies achieving little environmental benefit at a relatively high cost. Putting a price on carbon is an alternative approach that ensures that society undertakes only the most cost-effective forms of carbon abatement and thereby minimizes the cost associated with urgently needed ambitious climate mitigation.

Heart of the Problem
Energy is essential to the modern world, heating homes, lighting offices, powering factories, and fueling cars. No country in the world has gotten rich without consuming large quantities of energy per capita. Today, that energy comes predominantly from coal, oil, and natural gas; these sources provide approximately 85 percent of global primary energy consumption and 81 percent in the United States. Fossil fuels dominate the energy landscape because they are reliable and cheap, a condition that is unlikely to change for the foreseeable future. This creates a challenge for policymakers facing competing priorities: how to mitigate the harms caused by burning fossil fuels, including climate change and air pollution, while continuing to reap the benefits of the energy the fuels have long provided. For the Biden administration, the challenge is even more specific: how to use American policy to address a global challenge without putting an undue burden on the U.S. economy.

Cheap, reliable fossil fuels play a primary role in powering the U.S. economy and appear on track to continue dominating the global energy system for decades to come. Though fossil fuel energy appears inexpensive to consumers, it creates severe harms to society that are not reflected in its price, from air pollution that damages health and shortens lifespans to carbon emissions that cause climate change that will become increasingly dangerous as the earth warms. As the world grows richer and energy demand increases, avoiding serious climate change damages will require emissions reductions on a massive scale. This underscores the critical importance of policy that makes ambitious mitigation goals attainable at a manageable cost.
Fossil Fuels Are Not On Track to Go Away

In the electricity sector, coal and natural gas provide both base load capacity, which produces a constant, steady stream of power, and dispatchable generation, which ramps up and down to meet fluctuating consumer demand. Both these sources do so at low prices. Electric costs about 3 cents per kilowatt hour (kWh) when produced by existing coal plants and just under 5 cents per kWh from new natural gas plants, making them the cheapest among currently available “baseload” options. While the costs of renewable sources have declined rapidly in recent years, their total cost to the grid remains higher than fossil fuels because they depend on backup generation or storage capacity (for more, see “Fueling Technology Deployment with a Clean Electricity Standard”, page 88). It is no surprise then that more, see “Fueling Technology Deployment with a Clean Electricity Standard”, page 88.

Meanwhile, the supply of fossil fuels is virtually limitless. Figure 1 shows that global proven reserves of oil, coal, and natural gas—defined as known deposits that are technically and economically recoverable at current market prices—account for many decades of production. More importantly, despite rising U.S. and global consumption, technological advances have actually increased reserves over the last twenty years. In the United States, for example, oil and gas reserves expanded for 62 percent of new electricity generation.

The current outlook in the transportation sector is similar. While electric vehicle (EV) sales have grown in recent years, they still account for under 2 percent of all new car sales. Internal combustion engines (ICE) remain the dominant technology with a substantial cost advantage. At current battery prices, the price of oil would have to rise to $180 per barrel to make an EV with 250 miles of driving range cost-competitive with traditional ICE-engine vehicles. Unless battery prices fall significantly or oil prices rise dramatically, gasoline and oil are in position to continue fueling the U.S. transportation sector for the foreseeable future.6

Despite these gains, recent estimates suggest that 3.5 billion people still lack access to reliable electricity and nearly 800 million have no access at all. As of 2018, the average person in India consumed less than a tenth of the electricity of the average American, the average person in China, just under a third.7 The extraordinary global progress of the last twenty years deserves celebration. Yet, there is little doubt that billions of people around the world will demand continued energy consumption growth in the next several decades. Under current policy and market trends, fossil fuels appear poised to be the primary source for meeting this growing demand.

Though continued technological improvements are never guaranteed, the best estimates suggest that, at least on the time scales that matter for restraining climate change, there are functionally unlimited global supplies of fossil fuels. Various experts place the range of possible resources at 3-4 times current proven reserves for oil, 7-60 times for natural gas, and 14-23 times for coal.8 If future technology allows people to tap into these reservoirs, global markets could have access to hundreds or even thousands of years of carbon-based energy. Energy use is plateauing in the United States and the rest of the wealthy world but global usage is growing rapidly, fueling historic improvements in human development. Between 2005 and 2019, global consumption of oil, coal, and natural gas rose by 16 percent, 20 percent, and 41 percent respectively, with increases concentrated in developing countries.9 The world’s poor and middle class have growing access to a wide variety of comforts and necessities—refrigerators, televisions, and cars—and the share of the world’s population living below the World Bank’s definition of extreme poverty ($1.90 per day) has fallen from 37 percent in 1990 to under 10 percent in 2015.10

Despite these improvements in fuel efficiency over recent decades, transportation remains a major source of emissions in the United States.

The Health and Climate Consequences of Fossil Fuels

Burning fossil fuels causes both local and global environmental damage with serious consequences for human welfare. Particulate matter air pollution, primarily driven by local fossil fuel combustion, has been linked to a wide range of social harms, including low infant birthweight, high infant mortality, chronic heart and lung conditions, reduced worker productivity, and diminished academic performance by school-age children.11 One study showed that early childhood exposure to air pollution reduces wages and labor force participation even at age thirty.12 While the United States has made considerable progress on reducing air pollution through the enforcement of the Clean Air Act and subsequent legislation, in 2018 11 percent of the U.S. population still faced exposure to annual pollution levels above the World Health Organization’s guideline of 10 micrograms per cubic meter. Globally, the consequences have been even more severe: particulate matter pollution reduced average life expectancy around the world in 2018 by about 1.9 years per person.13

![Image](https://example.com/image.jpg)
The economics of welfare

U.S. ENERGY & CLIMATE ROADMAP

...the shift in scale of... society about $51 in monetized climate change damages... Each ton of emissions costs... production alone totaled 33 billion metric tons in 2019... Global temperatures are on track to rise by 4.5°C (8.1°F) by 2100 under current policy. Global emissions from energy production alone totaled 33 billion metric tons in 2019 and have risen nearly 10 percent over the past decade. According to a review conducted by President Barack Obama’s administration, each ton of emissions costs society about $51 monetized climate change damages... While people in relatively poor and hot countries will be most vulnerable to the risks of climate change, the United States will not be immune. Climate change will affect a range of activities in the American economy, from sharply reducing the productivity of staple grain production in the Midwest to putting trillions of dollars of coastal property at risk from increased flooding and sea level rise. Moreover, the impacts of climate change in other countries will have spillover effects on American security and prosperity as exposure to extreme weather could intensify geopolitical conflicts and refugee crises. Slowing and reversing the rise of global carbon emissions will be essential to ensure human flourishing at home and abroad in the 21st century.

Maximizing Bang for the Buck

The problem facing the Biden administration is ultimately one of balancing the goals of inexpensive and reliable energy with the health and climate damages from fossil fuels. This critical endeavor, frequently referred to as the global energy challenge, requires all societies to make tradeoffs. Addressing these shared objectives is especially challenging because emissions from Peoria have the same impact on the U.S. climate and economy as those that originate in Chengdu, Moscow, Mumbai, and anywhere else on the planet. Thus, the United States will benefit most from climate policy that generates emissions reductions at home and abroad.

Figure 2 shows that mitigating the most serious consequences of climate change will involve an abrupt and significant change in the path of global emissions, requiring countries around the world to act swiftly on an enormous scale. To achieve such a dramatic change, policymakers will need to be laser-focused on achieving the most cost-effective policy possible, maximizing emissions reductions per dollar to ensure the greatest benefit to the climate at the lowest possible cost to firms, consumers, and taxpayers. There is widespread agreement among economists and other analysts that putting a price on carbon, either through a carbon tax or cap-and-trade market, will deliver the greatest carbon reductions at the lowest cost by allowing markets to identify the least expensive mechanisms to reduce emissions.

How We Got Here

Making firms and consumers pay for the harms associated with their actions is an old idea in economics, dating back to Arthur Pigou in 1920. Pigou found that people would engage in activities that generate excess harm to society if prices reflect only the costs to individuals and not those that individual choices impose on others. Pigovian taxes incorporate the social costs of an act—in this case, the act of emitting carbon dioxide—into the price.

When the government requires economic actors to pay a tax or purchase a permit for each unit of emissions they produce, it raises the price of emitting so that it incorporates its social costs. Raising the price, of course, makes emitting more expensive, creating a disincentive for forms of consumption and production that are relatively pollution-intensive. People may still choose actions that generate emissions, but they will choose to do so only if the benefit they gain outweighs the cost both to themselves and to society.

Increasing the price of emissions also ensures that businesses and consumers will take only the most cost-effective steps to reduce them. If abating a ton of emissions is too costly then they can choose to pay the tax or purchase a permit instead. In contrast to regulations that prescribe specific actions regardless of their cost, this allows consumers and firms the flexibility to choose inexpensive forms of abatement and forego costly ones. Thus, imposing a price on carbon emissions—through either a tax or an emissions trading scheme—tilts the market against high-emissions technologies and activities to align people’s choices with the broader social good. This is why it has widespread support among economists as the most cost-effective method to combat climate change.

Carbon pricing policies have been expanding rapidly around the world in recent years. The World Bank reports that, as of 2019, fifty-seven countries and localities have implemented or scheduled policies that cover about 20 percent of global emissions, a sharp increase from less than 5 percent coverage as recently as 2011. Figure 3 shows that the present set of policies consists of a mix of carbon taxes and emissions trading systems spread across a range of developed and developing countries. The average price of emitting a ton of carbon remains low, however. Even amongst jurisdictions with a policy in place, 51 percent of covered emissions are priced at under $10 per ton, far below the Obama administration’s $51 estimate of the climate damage caused by each ton of carbon emissions. Because most emissions in the world are not yet priced, the average cost of emitting a ton of carbon in the world is only $2.48 per ton, more than an order of magnitude smaller than the best estimates of the likely damage. Thus, while global carbon pricing policy has shown a promising ascent in recent years, it has a long road remaining to reach the necessary level of prevalence and stringency.

The United States has a long history of using market-based solutions to manage environmental problems. In 1982, the Environmental Protection Agency (EPA) implemented a program that reduced lead content in...
Subsequently, the landmark Clean Air Act Amendments of 1990 created two critical market-based policies that dramatically reduced the presence of harmful pollutants. First, the sulfur dioxide allowance trading program placed a national cap on acid rain-causing SO₂ emissions that mandated a 50 percent reduction by the year 2000. Second, the NOₓ Budget Program in eleven northeastern states and the District of Columbia implemented a cap-and-trade system that ultimately brought NOₓ emissions down by 74 percent between 1990 and 2006.14 These market-based systems to reduce pollution in the United States have been overwhelmingly successful. Analysis by the EPA found that the costs of reducing lead in gasoline were 20 percent lower because the policy allowed for trading. Similarly, the SO₂ Allowance Program and NOₓ Budget Program reduced costs by 15-30 percent and 40-47 percent, respectively, compared to traditional regulation, while still achieving their targeted pollution reductions.25

These programs reduce costs relative to technology-specific mandates in two ways. First, they allow firms the flexibility to choose and innovate solutions to achieve the cheapest reductions in their own emissions. Second, when the costs of reducing emissions differ substantially across firms, tradable permits or pollution taxes ensure that emissions will be reduced by those firms for whom it is least costly to do so, thereby maximizing the environmental benefit associated with a given economic cost.

Market-based programs to reduce carbon emissions have also been implemented in some parts of the United States, but lag behind those for other pollutants in both coverage and stringency. In 2009, ten northeastern states launched the Regional Greenhouse Gas Initiative (RGGI) and in 2012 California followed by implementing its own emissions cap-and-trade system.26 Together, the two programs now cover about 6 percent of U.S. emissions (California’s cap covers about 75 percent of its statewide emissions and RGGI covers about 15 percent of total emissions in participating states).27 While these policies have been in place, emissions have fallen from 2005 levels by about 30 percent in California and 45 percent in the RGGI states with permit prices remaining relatively low—about $6 for RGGI and $15 in California in 2019.28 Though it is not possible to separate the effect of these cap-and-trade programs on emissions from a multitude of other factors, such as competing policies and changes in fuel prices, it is evident from the low permit prices that the costs of compliance have not been high. The RGGI cap is scheduled to mandate a further 30 percent reduction in emissions by 2030 and California’s policy requires emissions to be 80 percent below 1990 levels by 2050. However, these increasingly aggressive targets will continue to apply to only a small proportion of U.S. emissions.

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The effort to establish a national U.S. carbon pricing policy has persisted for decades and shown sporadic bursts of momentum toward legislation. Senators John McCain and Joseph Lieberman first introduced legislation in 2003 to establish a national carbon cap-and-trade system. Though the bill did not pass, it garnered forty-three votes in the U.S. Senate, including six Republicans.29 Support for carbon pricing crested in 2008 when both presidential candidates supported a national emissions trading system to confront climate change. The push for legislation that year featured an ad campaign with bipartisan dims such as Newt Gingrich and Nancy Pelosi jointly calling for comprehensive climate policy.30 In 2009, the U.S. House of Representatives passed the American Clean Energy and Security Act (commonly known as the Waxman-Markey bill) to implement a cap-and-trade system with the goal of reducing U.S. emissions 83 percent by 2050 relative to 2005 levels. The bill stalled in the Senate amid the global financial crisis and recession, however, and interest waned. The 116th Congress showed signs of renewed interest in carbon pricing. Ten bills proposing either a gradually increasing carbon tax or a declining cap on emissions have been introduced, several of which were co-sponsored by Republicans.31 The path to a comprehensive, cost-effective approach to U.S. climate policy remains challenging, but open. Recent polling data suggests that a strong majority of Americans may be open to supporting a carbon tax, depending on the details of how the accompanying revenues are used.32

30 United States Senate, “Roll Call Vote 2020: Congress.”
31 Gingrich and Pelosi, “We’re Confident in Our Ad.”
32 Friends Committee on National Legislation, Bill Analysis: CONGRESS. GOV, FY 19-20.” Francis Rooney (R, FL-19) co-sponsored both bills. Bran Frappratek (R, NH-01) co-sponsored the first. The Market Choice Act would start with a $35 per ton carbon tax rising by 5 percent each year plus inflation. The Energy Innovation and Carbon Dividend Act would start with a $35 carbon tax, set to rise by $10 each year with adjustments determined by progress in meeting pre-specified emissions targets.
33 Energy Policy Institute at the University of Chicago, “New Pull.”
In the absence of a nationwide price on carbon, U.S. climate policy has fallen back on a series of costly sector- and technology-specific mandates that have been relatively ineffective at reducing emissions. Figure 4, shows estimates of the cost per ton abated for a range of proposed or implemented carbon reduction policies. While some policies, such as the Clean Power Plan, show a high level of emissions reductions per dollar spent, others, such as the Weatherization Assistance Program, cost several hundred dollars per ton reduced. The price society pays for a given unit of climate mitigation varies widely across programs, and frequently far exceeds conventional estimates of the climate change damage caused by each ton of emissions.

Figure 4 demonstrates that regulations that prescribe a specific mechanism for reducing emissions have been an unreliable path to carbon abatement. The Biden administration could instead adopt a cost-effective method of climate change mitigation by putting a price on carbon. This approach will ensure that firms and consumers choose only the lowest cost actions that reduce emissions, thereby maximizing the emissions reductions that can be achieved for a given economic price.

What To Do
Putting a price on carbon is a broadly recommended policy proposal that presents a variety of options for implementation. Rather than prescribe a particular approach, the balance of this chapter will outline principles that the Biden administration could use to guide its policy development process.

PRINCIPLE
Policies that achieve the largest carbon abatement per dollar spent will play an important role in making large-scale climate mitigation attainable.

The scale of the climate change problem requires the Biden administration to achieve enormous reductions in carbon emissions to prevent serious climate change damage during this century. Reaching an emissions target comparable to that of the Waxman-Markey legislation would require the United States to reduce over 4 billion tons of emissions per year by 2050. Given such ambitious goals for emissions reductions, if the range of abatement costs for future climate mitigation policies is as wide as that of the past policies shown in Figure 4, choosing more cost-effective policy options could save Americans hundreds of billions of dollars every year. This underscores the critical importance of prioritizing cost-effective policies for climate mitigation. By putting a price on carbon, the Biden administration can choose a climate policy that minimizes the cost per ton of emissions reduced and achieves the largest possible environmental benefit at a given price.

PRINCIPLE
Technology- and sector-specific mandates reduce the cost-effectiveness of a carbon price.

Carbon pricing minimizes costs by maximizing flexibility. When market participants can choose how to reduce emissions, they are free to choose the least costly response. Policies that mandate specific technologies and methods for reducing emissions restrict this flexibility, making it more expensive for people and companies to achieve the same emissions reductions.

In principle, Congress and regulators could identify and direct low-cost approaches to emissions abatement themselves, but the programs assessed in Figure 4 show that this approach has not been successful in practice. Furthermore, mandates applied simultaneously with an emissions cap achieve no additional environmental benefit beyond the target set by the cap. They simply direct how the cap should be achieved; they do not lower it. Since the total amount of emissions has been preset, any reductions achieved through the regulatory approach will free up permits for other firms and consumers to use and leave total emissions unchanged. Thus, the Biden administration could achieve the greatest net benefit by working with Congress to establish a carbon price as a replacement for, rather than a complement to, existing and proposed regulatory approaches to carbon abatement.

PRINCIPLE
Policymakers can choose between price (tax) and quantity (cap) instruments to balance environmental and economic goals.

The fifty-seven existing carbon pricing policies around the world consist of twenty-nine carbon taxes and twenty-eight emissions trading systems. Carbon taxes allow policymakers to choose the price polluters pay for each unit of emissions, whereas trading systems allow them to...
choose a cap on total emissions. Carbon taxes leave the total quantity of emissions to market forces while leaving the price of emissions fixed. Cap-and-trade systems allow markets to determine the price per unit of emissions while fixing the level of emissions.

In principle, if policymakers could perfectly predict how costly it would be for firms to reduce emissions, the two options could be calibrated to achieve the exact same outcome. In practice, policymakers can choose the policy instrument to prioritize between goals. Carbon taxes have the advantage of providing greater certainty to businesses about the costs of compliance and the return on investments made to reduce emissions. On the other hand, cap-and-trade systems deliver greater certainty about the environmental benefit the policy will achieve by guaranteeing that emissions stay below a certain level.

That said, the choice need not be binary. Many carbon pricing policies consist of a hybrid between cap-and-trade and a carbon tax. For instance, emissions trading systems frequently include price ceilings and price floors to provide firms with certainty that the cost per ton of emissions will fall within a certain range. These backstops are achieved by making extra permits available to prevent the price from rising past the ceiling or removing permits from circulation to prevent the price from falling beneath the floor, thus relaxing the precision of the emissions goal. Similarly, carbon taxes can be designed with flexibility to assure certain emissions goals. For example, policymakers can tie the level of the tax to emissions so as to adjust automatically to keep the long-run trajectory of emissions within a pre-specified range.

The Biden administration can choose among a broad range of options to implement carbon pricing programs that balance competing policy priorities.

**PRINCIPLE**

The Social Cost of Carbon is an appealing benchmark for the level of a carbon tax.

A Pigouvian tax, as noted above, is designed to ensure that the price of emitting carbon incorporates the social costs of those emissions. If a company or person chooses to emit once the social costs are reflected in the price, the benefits they accrue from it are, as evidenced by their choice, higher than the social cost. Market-based programs to reduce emissions, like carbon pricing, allow firms and consumers to determine for themselves the benefits they receive from an action that creates emissions.

Thus, it is critical that the level of the carbon price reflects the best available estimates of the harm to society caused by each unit of emissions, also known as the Social Cost of Carbon. A review by the Obama administration previously assessed the scientific evidence to provide an estimate of this measure, and the Biden administration may choose to update it to reflect recent advances in research (for more, see “Updating the United States Government’s Social Cost of Carbon,” page 20). 34

When the price of emissions matches the social cost, firms and consumers will undertake those actions for which the benefits outweigh the costs to society and forego those actions for which the costs to society are greater than the benefits for themselves. Thus, this approach maximizes the net benefits of climate mitigation.

**PRINCIPLE**

The environmental benefits from carbon pricing are unaffected by how the revenues are used. However, there is a strong case for devoting some of the revenue to energy research that the private sector would not undertake and to refunding some of the revenues to address the disproportionate impacts that would otherwise be borne by low-income households. Carbon pricing improves social welfare by making firms and consumers pay the full cost that their emissions impose on other people. It removes an implicit subsidy, or unpaid cost to society, for polluting activities and incentivizes a shift toward lower-emission forms of production and consumption. Thus, while a carbon tax or the auction of emissions permits creates a stream of government revenue, the environmental benefits of the carbon price do not depend on how that revenue is spent. Existing carbon pricing policies typically allocate government revenues in three ways: climate-related clean energy spending, general treasury funds, and directly paired tax cuts or rebates. Of the $283 billion in global carbon pricing revenues, 27 percent goes to “green” spending, 26 percent to general revenues, and 36 percent toward rebates and tax cuts. 35

In general, it is sensible for policymakers to view the decision of how to allocate the revenues from carbon pricing no differently than any other public finance decision over spending or taxation. However, there is a market failure that keeps basic research into clean energy below its optimum. Further, carbon pricing policies tend to be regressive. Consequently, there is a strong case for devoting some of the revenue to clean energy research that the private sector would not undertake and to refunding some of the revenues to address the disproportionate impacts that would otherwise be borne by low-income households. Recent polling evidence shows that rebating revenue and particularly funding renewable energy research raise public support for carbon pricing. 36

**PRINCIPLE**

International cooperation is critical to addressing the climate change threat and it is vital that a carbon pricing policy encourage climate action in other countries.

Climate change damages in each country in the world will be caused by emissions that come from all countries in the world. The United States accounts for about 5 percent of the world’s population and 15 percent of global carbon emissions. 37 Protecting Americans from the most harmful consequences of climate change requires major international cooperation.

There is a powerful opportunity for the Biden administration to align goals and harmonize policy mechanisms across countries. For example, the stringency of U.S. carbon pricing can be tied to the stringency of carbon policies undertaken by other major carbon polluters through multilateral or bilateral agreements. This will encourage other countries to reciprocate with their own climate mitigation policies and increase the ambition of their emissions reductions. In addition, border tariff adjustments can be used to ensure foreign and domestic firms are competing on equal terms. Further arrangements to coordinate policy can also be developed through continued international negotiation and cooperation.

**Closing Argument**

Climate change is a historic challenge to American society and the global community. Cheap, reliable fossil fuels have been the foundation of the energy system and are poised to remain so for decades to come. A serious effort to prevent the most damaging consequences of climate change will require enormous declines in emissions, underscoring the urgent need for policies that reduce pollution as cost-effectively as possible.

The existing piecemeal regulatory approach to carbon abatement has been neither effective nor efficient, generally reducing emissions at a relatively high cost per ton. Enacting a national, market-based framework to put a price on carbon can achieve ambitious climate change goals while minimizing the cost to the American economy. The most effective climate policy will be one that establishes a national carbon price and that incentivizes other countries to reduce their emissions as well.
In the absence of a uniform, global price on carbon, the most commonly proposed policy to address leakage is imposing what are known as “border adjustments.” Border adjustments are combinations of import tariffs and export rebates. The import tariff is a tax on emissions in the foreign country from production of the imported good. It ensures that imports face the same tax as goods produced domestically. The export rebate gives back any carbon taxes paid domestically, so that goods sold abroad face the same tax as other goods sold in the foreign country. Every major carbon-pricing proposal in the United States in recent years has included border adjustments in one version or another.

Research shows that carbon taxes paired with border adjustments can reduce leakage and modestly reduce carbon emissions. But, border adjustments pose serious legal and administrative problems, not least that they are difficult to calculate, easy to avoid, and possibly constitute an illegal trade barrier.

There is a different approach, however, that faces none of these drawbacks and at the same time is more effective at reducing emissions. The approach is to impose the carbon tax on domestic extraction of fossil fuels, rather than on domestic emissions, combined with border adjustments on imports and exports of energy, but not other goods. Rather than imposing the border adjustments at the same rate as the extraction tax, however, the border adjustments are imposed at a lower rate. The net result is a combination of a tax on domestic extraction and a tax on emissions from domestic production. This combination of taxes controls leakage effectively and legally and reduces emissions much more effectively than conventional approaches. Rather than devoting time to a hard-to-enforce, possibly illegal border adjustment system, the Biden administration should work with Congress to consider this new, targeted approach.

Heart of the Problem

Carbon pricing and leakage

Existing carbon pricing systems worldwide, and most proposals for carbon prices in the United States, impose a price on emissions wherever the smokestack or tailpipe is located. For example, if a steel plant is located in the United States, the steel producer would have to pay a tax on its emissions. The tax does not apply to emissions abroad: a Canadian steel producer would not be subject to a U.S. carbon tax even if the steel it produces is ultimately used in the United States. Similarly, a U.S. steel producer who exports its steel to Canada would pay the U.S. tax on the steel even though it is used abroad.

1 This chapter will, for the most part, discuss carbon taxes. The analysis would be the same if the United States were to impose a cap and trade system. That is, none of the differences between taxes and cap and trade systems affect the analysis here.
This structure raises the risk that a domestic steel producer could relocate abroad to a jurisdiction that has a lower, or even a zero, price on emissions and ship the steel into the United States, thereby avoiding the tax. Similarly, it raises the risk that domestic producers lose market share in foreign markets to competitors who do not face the same carbon price. Leakage—this shifting of emissions offshore—may make domestic carbon pricing futile because emissions reductions at home would be replaced by emissions increases abroad. Moreover, the steel producer is forced to operate in a less-preferred location and whatever benefits there were to the United States of having the steel produced domestically are lost. Leakage is likely concentrated in just a few industries: those that are energy intensive and trade exposed. Figure 1 provides a sense of which industries are prone to leakage. It plots industries in the Annex B countries that are energy intensive and trade exposed in terms of their percent trade exposure to the United States and energy intensity. As can be seen, most industries are very energy intensive. For each industry, the largest five countries of origin as well as the fraction of total imports that comes from those countries are shown. The table suggests that leakage may not be a problem. If the major competitors are located in countries with few emissions restrictions, leakage may not be a problem. If the major competitors of an EITE industry are in countries with few emissions restrictions, leakage may be more serious.

Table 1 shows U.S. imports, by origin, of the five most energy-intensive, trade-exposed industries. For each industry, it lists the five largest countries of origin as well as the fraction of total imports that comes from those countries. The models estimate leakage under this scenario to be between 8 percent and 20 percent. That means that for every hundred tons of emissions reductions from a carbon price in the United States, there is an increase of between eight and twenty tons in other parts of the world. This is modest in terms of the overall tax, but likely large in the case of particular industries.

### Border adjustments

The most commonly proposed solution to leakage is to impose border adjustments. To understand border adjustments, it is useful to think of there being three different places to impose a carbon price. Most carbon prices are imposed on emissions; that is on the smokestack. This tax can be thought of as a production tax because the tax is imposed on emissions from production. A second option is to impose an extraction tax on the mining of fossil fuels. Almost all fossil fuels that are extracted are eventually burned. Therefore, the carbon molecules can be taxed as they come out of the ground rather than when they are released into the atmosphere. Finally, it could be imposed as a consumption tax on the use of energy or goods produced with energy. Gasoline taxes work this way: consumers pay gasoline taxes at the pump.

In a closed economy, these three taxes would have the same effect. With minor exceptions, all fossil fuels that are extracted are used to produce energy for the production of goods or services, so extraction and production would be the same. Any resulting goods and services are consumed domestically, so production and consumption would be the same.

With trade, however, these taxes are no longer the same. Energy that is extracted in the United States might be exported, rather than used here. And producers in the United States might use energy that is imported. An extraction tax in these circumstances is no longer the same as a production tax. Similarly, goods that are produced here may be exported and consumers may buy imported goods. Production taxes are no longer the same as consumption taxes. The choice among the three taxes now means that policymakers are choosing different tax bases.

Border adjustments can be thought of as shifting among these tax bases. For example, consider an extraction tax with a border adjustment on energy. Any energy that is extracted here and used in production here would bear a tax, while any energy that is exported and used in production abroad would not because the extraction tax would be rebated on export. And any energy that is imported and used here in production would be taxed on import. Therefore, an extraction tax plus border adjustments is just a tax on the use of energy in domestic production.
The same logic holds for a tax on domestic production with border adjustments on goods. Any goods produced in the United States and consumed here would bear a tax. Exported goods would not because the production tax would be rebated at the border. And goods that are imported and consumed here would have a tax imposed at the border. Adding border adjustments to a tax on domestic production shifts it to a tax on domestic consumption. Border adjustments shift the tax downstream.

As mentioned, carbon prices around the world, as well as proposals for carbon prices in the United States, are for the most part imposed on emissions from domestic production. Modeling suggests that border adjustments to these taxes would be modestly effective at reducing leakage, perhaps by about a third. 4

Figure 2 shows a simulation of the effects of border adjustments on global emissions. The simulation, which will be returned to throughout this chapter, is of a model of the effects of carbon taxes and trade. The model assumes that one region of the world imposes a carbon price and the rest of the world does not and can be used to illustrate the set of carbon policies that are best for the people in the taxing region, taking into account their effects on the economy and global emissions.

The simulation of the model used here assumes that carbon prices are imposed in the Organization for Economic Cooperation and Development (OECD). It is calibrated to global trade and emissions data and uses available empirical estimates of parameters such as the responsiveness of energy supply to changes in prices. The model allows an arbitrary set of carbon prices (including border adjustments) to be imposed in the taxing region, so it can simulate the effects of different policies that policymakers might choose to apply.

The x-axis in Figure 2 is the marginal harm to the OECD from global emissions. It can be thought of as, roughly, the social cost of carbon measured as a percentage of the price of energy. A value of one means that the harms from a ton of CO2 are equal in dollar terms to the price of the carbon content of a unit of energy. (The same definition applies to all other figures so labeled.) The y-axis is global emissions measured in gigatons of CO2 (GtCO2).

The carbon prices in each case are the prices that the OECD would choose to maximize its welfare, conditional on the assumption that it has chosen to impose that particular policy. For example, the production tax line shows the emissions reductions that the OECD would achieve assuming that it has chosen to impose a production tax at a tax rate that is best for the OECD (taking into account leakage, harms from climate change, and other effects).

Baseline OECD emissions are 32.3 GtCO2. With marginal harm of two, emissions go down under the production tax by 1.7 GtCO2 to 30.6 GtCO2. Adding border adjustments allows the OECD to reduce global emissions by another 0.7 GtCO2 to 29.9 GtCO2, a real but modest improvement.

Though border adjustments produce some benefits in terms of emissions reductions, they are not without controversy. Critics argue that they constitute an illegal barrier to trade under World Trade Organization (WTO) rules because a border adjustment taxes the method of a good’s production rather than the carbon physically in the good. WTO law is unclear on whether border adjustments on methods of production are allowed, and if not, whether exceptions for environmentally motivated border taxes apply. While the majority view is that the WTO would not hold border adjustments on goods to be illegal, there is considerable uncertainty. Were U.S. policymakers to pursue this approach, it could take years to resolve these legal questions in Geneva with unknown trade repercussions.

Border adjustments on goods would also be incredibly difficult to impose in any accurate and comprehensive manner. There is no straightforward way to determine the emissions associated with an imported good. Imagine a shipload of automobiles arriving in Los Angeles. Each automobile will have parts from many different countries with the parts assembled in yet another set of countries. Those parts may have been produced using various technologies and fuel sources under a number of environmental regimes. And the mix of parts, countries, and fuel sources will be different for each type of vehicle and possibly for different model years of the same vehicle. A regulatory regime that purported to reflect the emissions generated by producing each car—let alone every other good passing through the port—would be impossibly complex, difficult to enforce, and expensive to maintain.

As a result, border adjustment proposals, including all bills in the 116th Congress, limit them to a narrow set of goods, most often raw materials such as steel and chemicals, excluding complex final goods such as automobiles. For similar reasons, they often limit border adjustment to imports from or exports to countries with a low or inadequate carbon price.

Yet, even these simplified versions pose significant implementation challenges. Raw materials of the same type are produced using a wide variety of production methods, and border adjustments would require new, complex systems to determine the emissions associated with each shipment. The rules would be difficult to impose in any accurate and comprehensive manner.

### Further Reading

**Carbon Taxes & Border Adjustments**

- *The Design of Border Adjustments for Carbon Prices*
  - National Tax Journal
  - Border adjustments levy a carbon fee on imports, while exports from a country with a carbon tax have their carbon price refunded at the border. As a result, domestic consumers pay the baked-in price of a carbon tax for goods produced domestically and on imports.

- *Optimal Unilateral Carbon Policy*
  - Working Paper
  - The central concern with imposing a unilateral climate policy is that it will lead to leakage. A model shows that there is an optimal policy that allows the taxing region to exploit international trade to expand the reach of its climate policy.
Border adjustments would also be prone to avoidance. For example, rather than shipping raw materials, exporters from low tax countries could ship final goods or partially finished goods. They could switch fuel sources, using clean sources of fuel for exports to the United States and dirty sources for their own use. They could also transship goods through countries with high carbon taxes (but no border adjustments), making the goods appear as if they were from the high-tax country rather than the low-tax country. In such a complex system, the opportunities for mischief are legion.

A crude system that is subject to avoidance would generate endless disputes. For example, importers would argue about the classification of goods or the method of attributing emissions to their production technology and fuel source. Policymakers would need to establish a robust bureaucracy, promulgating product categories, emissions attribution methods, rules to prevent avoidance, and methods of dispute resolution.

In short, despite their apparent political appeal, border adjustments have significant flaws. They only modestly adjust emissions and controls leakage much more effectively, raise the global price of energy while both production and consumption taxes—on the demand for energy—lower it. Policymakers can exploit this fact when designing a carbon tax system. To understand why extraction taxes raise the price of energy, suppose that the United States imposed a tax on domestic extraction. Energy extractors would receive their sales price minus the tax. Because extraction will be less profitable, they will extract less. A lower supply means prices go up. This effect will be mediated to some extent by an increase in extraction in other countries: a higher energy price makes foreign extractors want to extract more. Unless the increase in supply by foreign extractors completely offsets the domestic reduction, however, extraction taxes raise the global price of energy.

Compare that to the more typical carbon tax on emissions from domestic production. Producers’ cost of energy is the market price of energy plus the tax. They pay more for energy inputs and, therefore, will demand less. They will shift to cleaner technologies and sell fewer energy-intensive products. As a result, the price of energy goes down. This means that foreign producers see a lower cost for energy inputs. They expand production (partially offsetting the lower demand), resulting in traditional leakage.

Taxes on the consumption of goods produced with energy operate the same way. Consumers demand fewer energy-intensive goods and producers respond by adopting cleaner technology. The resulting lower demand for energy lowers its global price.

Figure 3 shows how extraction, production, and consumption taxes (i.e., production taxes with border adjustments) change the price of energy. A value of 1 indicates that the price of energy has not changed. As can be seen, extraction taxes increase the price of energy while production and consumption taxes reduce it.

**INSIGHT 1**

**Extraction, consumption, & production taxes affect energy prices—and leakage—differently**

Leakage arises because of changes in the price of energy seen by actors in different countries. For example, with conventional carbon prices, production shifts to regions without a carbon price because energy is less expensive there. Extraction taxes and production and consumption taxes, however, have opposite effects on the price of energy. Extraction taxes—taxes on the supply of energy—raise the global price of energy while both production and consumption taxes—on the demand for energy—lower it. Policymakers can exploit this fact when designing a carbon tax system.

Border adjustments would shift production taxes to consumption taxes, but both operate the same way on the price of energy because they are both taxes on the demand for energy. This means that border adjustments are not helpful in mitigating the core source of leakage, which is the reduction in the price of energy. They do not address the core problem.

**INSIGHT 2**

**Combining border adjustments can have complementary effects**

The second key insight is that border adjustments can be imposed at a lower rate than that of the underlying carbon tax, and that doing so effectively combines two different tax systems. If policymakers start with an extraction tax and impose border adjustments just on energy at a lower rate, the effect is to shift that portion of the extraction tax to production. Suppose for example, the United States were to impose an extraction tax at $100/ton of CO₂, and a border adjustment on imports and exports of energy at $60/ton. The border adjustment shifts $60 of the tax to production, leaving $40 on extraction. A similar effect arises with border adjustments to production taxes: a border adjustment at a lower rate than the production tax shifts that portion of the tax to consumption. As a result, we can use what we will call partial border adjustments to combine the various taxes whatever way is preferred.

These two insights can be combined to produce a simple and effective carbon price. By combining an extraction tax (which pushes energy prices up) with a partial border adjustment on energy, the United States (or a broader taxing coalition) can effectively combine taxes—an extraction tax and a production tax, a tax on supply and a tax on demand—that push the price of energy in opposite directions. By moderating the effects on the price of carbon, this combination controls leakage. Policymakers could also combine an extraction tax with a partial border tax on both energy and goods, effectively creating a combination of an extraction tax and a consumption tax. This combination similarly moderates the effects on the price of energy.

Figure 4 illustrates. It adds two taxes to those shown in Figure 2: an extraction tax combined with a production tax, and an extraction tax combined with a consumption tax. For example, the combination might be an extraction tax at $60 per ton and a production tax at $40 per ton. The hybrid taxes moderate the effects on the price of energy relative to an extraction tax alone. Energy prices go up...
with the hybrids rather than down (as they do under production and consumption taxes), but they go up less than under a pure extraction tax.

The effect of these hybrid taxes on emissions is dramatic. Figure 5 compares the emissions reductions with a traditional production tax, or production tax and border adjustments, with the hybrid taxes. A combination of extraction and production taxes reduces emissions by 6.2 GtCO₂, to 26.1 GtCO₂. The combination of extraction and consumption taxes reduce emissions by 7.3 GtCO₂, to 25 GtCO₂. The hybrids are much more effective at reducing emissions than the traditional production tax or a production tax plus border adjustments. This is because they operate to control the price of energy in ways that more traditional approaches cannot.

An alternative way to compare the taxes is to look at the relative costs of achieving a global emissions target for a group of countries, even those outside the taxing coalition, tends to be realistic and elusive. The final insight is that expanding the tax base to other countries, even those outside the taxing coalition, tends to be realistic and elusive.

To implement them, regulators only need to know the carbon content of imported or exported fuels, which is easy to calculate. And compared to overall imports and exports, the volumes are smaller and easier to track. They are legal because the border adjustment would be on the actual carbon crossing the border, not on the production process. Border adjustments on energy are not an unrealistic and elusive goal.

These first two insights on their own provide a solution to the leakage problem. The third and fourth insights show how to improve on this solution.

**INSIGHT 3**

Coalition size and composition influences effectiveness and cost

Expanding the taxing coalition reduces leakage and makes the tax more effective. Figure 7 illustrates. It shows each of the two hybrid taxes, for two cases: the prior case of the OECD as the taxing region and a new case adding China to the coalition. Adding China makes the taxes perform much better than with just the OECD as the taxing region. Emissions now go down by 10.6 GtCO₂ to 21.7 GtCO₂, with the extraction/production combination and by 11.2 GtCO₂, to 21.1 GtCO₂, with the extraction/consumption combination.

The cost differences between the two hybrid taxes are much smaller with China in the taxing coalition. The reason is that adding China adds more production than consumption to the tax base. There is, as a result, less (or no) benefit to adding border adjustments to goods (and, thereby shifting the tax base to consumption). In this group, an extraction tax with border adjustments only on energy does just as well (in terms of welfare) and would be far simpler to implement. This result confirms the conventional wisdom that expanding the number of countries in any taxing coalition is important, and suggests that Congress should work with the U.S. Trade Representative and the State Department to recruit partner countries and build a carbon pricing system that has the flexibility to absorb them.

**INSIGHT 4**

Broadening the carbon tax base increases its effectiveness

The final insight is that expanding the tax base to other countries, even those outside the taxing coalition, tends to further reduce emissions and leakage. The intuition is...
This approach has been suggested previously by Fischer and Fox (2012). Without a rebate on export, however, domestic producers may worry about their ability to compete in foreign markets. One way to do this is to impose border taxes on imports of goods but not rebate taxes on export. As discussed, this policy taxes both domestic production (regardless of where consumed) and domestic consumption (regardless of where produced). The tax base is broader and more effective. Without a rebate on export, however, domestic producers may worry about their ability to compete in foreign markets. One way to do this is to impose border taxes on imports of goods but not rebate taxes on export. As discussed, this policy taxes both domestic production (regardless of where consumed) and domestic consumption (regardless of where produced). The tax base is broader and more effective.

Figure 8 shows the effects of the last insight (returning to the assumption that the OECD is the taxing coalition). It illustrates what the model suggests is “optimal” policy: the combination of taxes and subsidies that maximizes domestic well-being. It combines an extraction tax, border adjustments (at a lower rate) on energy, a border adjustment on imports of goods, and a policy for the export of goods that expands exports through a combination of taxes and subsidies on exported goods. In terms of emissions reductions, it performs better than the simpler hybrids shown above, but not dramatically so.

In fact, the simulation results shown in this chapter indicate that an even more aggressive export policy is desirable. The United States should seek to expand, rather than just maintain, its export margin. It should do so through a policy of tax rebates and if necessary, subsidies, for exports so that it exports more with the carbon policy in place than without. Expanding exports in this way expands the carbon price and allows greater emissions reductions. It is the environmentally best policy and the policy that is best for the United States.

A better approach is to tax domestic extraction and to combine that with border adjustments (at a lower rate than the extraction tax) on energy and possibly goods or a subset of goods. It takes advantage of the offsetting effect on the price of energy from extraction taxes and either production or consumption taxes. This approach is simpler to administer, achieves much better outcomes, and is clearly legal.

Even better results can be reached by adding border adjustments on the import of goods and an export policy that retains or expands U.S. exports. Whether these additions are desirable depends on how much complexity and legal uncertainty they would introduce.

Reducing the possibility that high-emitting industries move overseas will be critical to ensuring the effectiveness of any carbon-pricing policy.

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Sector-by-Sector Approaches

Policy ideas to tackle specific energy and environmental challenges by sector.
Significantly expanding renewables generation is going to require moving power—to when it is needed with storage, and to where it is needed with transmission. While storage is an area of active research, a national grid that can transmit power from the Sun Belt and wind corridor to major cities is possible with existing technology. To decarbonize the economy, the regulatory and institutional dysfunction that have so far made the construction of such a grid impossible need urgent attention.

Heart of the Problem

The United States is endowed with vast energy resources of virtually all kinds. The challenge is that those resources are located far from where people live. The country’s existing energy transportation infrastructure is geared toward moving power as fuel and converting it to electricity near its location of final use. Over one third of the coal used for power generation, for example, comes from a single Wyoming county.1 It is extracted from surface mines and carried by rail cars to power plants across the country at great expense. Oil and gas make their way from underground and offshore deposits to refiners and consumers around the country in pipelines. The system transports the power as fuel, and local generators deliver it to consumers as electricity. This means that even though fuel resources are highly concentrated in specific locations, virtually every part of the country has sufficient electricity generation resources to meet its peak demand. As long as it is possible to move the fuel, this system keeps the lights on.

Just as some parts of the country have more fossil fuel deposits than others, renewable sources of energy are also unevenly distributed throughout the country. The key difference is that the wind and sun cannot be put on a rail car or in a pipeline to travel to consumers’ locations as fuel for local generators. It must be converted to electricity the moment it is harvested and transported over a transmission line. However, the transmission grid was not built to move a substantial fraction of the nation’s power from one remote county to the rest of the country, as the rail system can. And, until recently, there was little incentive for change.

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1 According to the 2018 Annual Coal report from the Energy Information Administration, Campbell County, WY produced over 300 million of the nation’s 750 million tons of coal.
Ten years ago, the principal challenge for reducing emissions from the power sector was technological: wind and solar technologies were not cost competitive with conventional fossil-based sources. The metric used for such comparisons is the levelized cost of energy (LCOE), which adds up all of the lifetime expenses of a plant, and divides by its output. In 2010, the unsubsidized LCOEs of conventional wind and solar generation were around $125 and $250 per megawatt-hour, respectively. Compared with $85 for combined-cycle gas generation, it was clear that renewables required substantial improvements before they might be competitive resources without significant subsidies. The technological progress over the last decade has been extraordinary. Renewables today are highly attractive investments, with LCOEs of $40 and $250 per megawatt-hour, respectively.1

With economical renewable generation technologies proliferating, the next challenge in decarbonizing the economy is to deliver power to where people are, when they need it. Prices begin to diverge across places when the system lacks transmission capacity. In the figure, there are generators willing to sell power for $54 per megawatt-hour in Arkansas, but the consumers in Michigan are unable to buy it at that price because there is not enough transmission capacity to deliver it. As a result, a more expensive generator in Michigan is fired up to serve local demand, costing consumers $165 per megawatt-hour. The difference in prices reflects a lost opportunity for low-cost generators to expand their output, and the inability of consumers to get the best possible price. This kind of problem occurs every day throughout the country because of the difficulties of moving electricity to where it is needed.

The day-to-day operations of the grid are in fact even more perverse. Prices typically determine the revenue that generators earn for their valuable output. But when generators are producing more power than the system can use, prices actually turn negative in order to discourage generators from producing more. A negative price means that consumers are being paid to use electricity, and generators are being fined for production. Everything is upside-down from how a market for a valuable commodity should work.

Nonetheless, generators do actually pay money to produce power (rather than getting paid for it) in these circumstances. Production subsidies for renewables provide revenues to wind and solar generators that are larger than the fines from the market, ensuring that those facilities continue producing even when there is no place for the power to go. This is not uncommon: in 2017, California’s wholesale market experienced negative prices 10 percent of the time. However, as in the figure above, prices were not negative everywhere; it was a local phenomenon. At the same time that some generators were being fined for producing, other generators were earning substantial revenues to serve local demand. The inability to connect renewable generators with population centers means that consumers in cities are paying higher prices while renewables generators are paying to produce power. This is not a problem that additional subsidies to renewable generators can fix.

In the absence of a national system that produces renewable energy where it is abundant and ships it to where the wind does not regularly blow, and solar panels where it is cloudy is not a cost-effective way of decarbonizing the grid.

The electrical grid is of central importance in decarbonizing the economy. Though electricity generation is responsible for 30 percent of total U.S. carbon emissions, the primary means of decarbonizing the transportation system (which accounts for 30 percent of emissions), industrial processes (20 percent), and residential use (10 percent) is through electrification. Successfully decarbonizing the other emitting sources through electrification depends on two key factors: emissions from the grid, and the price of electricity.

First, electrification only reduces emissions if the grid is green. The environmental benefits of replacing the entire petroleum-based transportation sector with electric vehicles would be substantially undermined if the United States continued to rely on coal and natural gas for large shares of overall power generation. In 2012, reliance on coal for electricity generation meant that environmental damages from charging electric cars were significantly larger than damages from internal combustion engines for all but a handful of congested urban areas.4 The shift away from coal in subsequent years was sufficiently large...
that by 2017 electric vehicles were cleaner than internal combustion engines for much of the country. Continued progress on this front requires not only more power from renewable sources, but also the capacity to deliver that power to consumers.

Second, even if the grid becomes completely green, the cost at which this is accomplished will be pivotal for decarbonizing the wider economy. Ultimately the decision to electrify cars, trucks, industrial processes and residential heating is made by households and firms. It is an easier switch to make when it saves consumers money. The cheaper green electricity is relative to the price of gasoline and natural gas, the more electrified other sectors will become. Sourcing renewable power from the places where it is most abundant will allow for lower decarbonization costs in population centers, and a more deeply decarbonized economy.

How We Got Here

In the early days of electrification, it was important to co-locate generation and users because power diminished quickly with distance when transmitted at the low voltages that were common at the turn of the 20th century. The interface between the industry and government was at the local level: many competing companies with their own wires created a tangled mess of public thoroughfares.

State and municipal governments took on the primary role of regulators when centralized power stations and alternating current became the dominant mode of power transmission. When a state regulator approves a $100 million capital project for the utility, it sets the price of electricity so that the utility will earn a competitive return—at 10 percent, or $10 million per year—to compensate the utility’s shareholders for financing the project. If the regulator approves a $1 billion capital project, a 10 percent rate of return earns shareholders $100 million per year in additional revenue from ratepayers. The incentive for shareholders is clear: the larger the capital project, the more profit they are able to reap. The end result is that utilities have strong incentives to generate power themselves with their own capital rather than buy it from someone else.

Early attempts by the federal government to introduce competition in electricity generation in the 1970s fell flat because the local utility was the only real potential customer, and they were not eager to encourage new entrants. The Public Utility Regulatory Policies Act of 1978 mandated that non-utility generators be paid at “avoided cost,” (i.e. paid at the rate it would cost them to generate it themselves) but selling power remained an unattractive proposition for new producers. The end result is that utilities have strong incentives to generate power themselves with their own capital rather than buy it from someone else. 

In the mid-1990s there was a renewed push to restructure the electricity sector. State legislatures around the country considered ways of injecting competition into the sector. Three main types of reforms came from this period: the introduction of retail competition so consumers could choose their provider; the divestiture of power plants to unregulated entities, and the introduction of wholesale electricity markets. Selling off the power plants helps mute the incentives to build capital projects as described above—utilities become buyers’ agents and are no longer actually producing the power sold to consumers. However, this reform was unevenly implemented. California, Illinois, Ohio, Texas, and several northeastern states passed restructuring legislation, but the California electricity crisis of 2000-2001 put an abrupt halt to further initiatives. Vertically integrated, investor-owned utilities remain dominant forces in much of the country.

One reform that did continue in spite of the California crisis was the expansion of wholesale electricity markets. Two-thirds of U.S. generation is now determined by these competitive auction mechanisms. While wholesale markets have reformed how electricity markets are determined by competitive bidding in auctions. Local utilities can no longer deny access to the transmission system, or treat their own generation assets preferentially because access to the transmission system is open and run by an independent system operator (ISO). Local utilities are also unable to impede the transmission of power across their service territory, which helps connect low-cost producers and population centers to the extent possible on today’s grid. Two-thirds of U.S. generation is now determined by these competitive auction mechanisms. Recent work has found these market-based rules for determining which power plants operate has reduced generation costs by $3–$5 billion per year.

Reforming incentives in the U.S. electricity sector has therefore been incomplete, both geographically and along the supply chain. The southeast and much of the west of the country operate in the same manner as they have for about eighty years. Where markets exist in the country’s interior, most local utilities continue to own generation based on rate of return regulation.

And while wholesale markets have reformulated the transmission system is operated, it has not systematically introduced market incentives to the construction of the transmission system itself. While the process for securing access to the grid and selling power competently has become somewhat easier, the incentives that guide the development of the transmission system itself are still a vestige of the old days of locally regulated utilities. Even in areas with wholesale electricity markets, the market stakeholders who help set priorities for capital projects, including new transmission lines, are incumbent...
transmission permitting to ease obstacles at the state level. The hammer is to encourage the upgrading and re-use of existing rights of way to develop a nationwide high voltage-direct current grid. Reserving the right to use the hammer is likely to make prospective opponents more amenable to the lighter touch.

THE HAMMER
Make FERC the primary venue for transmission project permitting, as it already is for oil and gas pipelines.

The federal government has been the primary permitting venue for interstate oil and gas pipelines since the Natural Gas Act of 1938. The process relies heavily on contracts between proposed buyers and sellers to demonstrate the need for new capacity—essentially a market test for economic viability to determine whether the project is in the public interest. This market test, combined with an environmental impact review and siting work, addresses all of the major roadblocks for potential projects in a single forum at the federal level. This streamlined process has enabled private investments to expand the U.S. network with about one thousand miles of new pipeline per year over the last two decades, and an additional one thousand miles per year of pipeline upgrades and conversions. 15

The regulatory structure for oil and gas pipelines provides a template that could be adopted for electricity transmission—it is only by historical accident that they are treated differently. The current process for transmission permitting gives state (and even county) authorities veto power over electricity transmission projects. Legislation that consolidates FERC’s permitting authority for energy transportation across modes of transportation—the federal government’s role in the permitting process. Once the DOE designates a new transmission corridor between wind and solar resources and population centers, states would have one year to consider permit requests at the state level before FERC would be empowered to take over permitting. This is a potentially weaker route than new legislation because a 2009 decision determined that the language of Section 216 of the Federal Power Act does not allow FERC to overrule a state permitting rejection—it only applies when states fail to act on a permitting request. 16 There is nonetheless room for FERC to assert its authority, even though it has been largely reluctant to take the lead to date.

THE FEATHER
Encourage the use of existing rights of way for new high-voltage transmission lines.

Even a streamlined permitting process runs into the unavoidable fact that virtually no one wants a transmission line in their backyard. Instead of fighting to use eminent domain to secure easements from unwilling property owners, the federal government may also use the Federal-Aid Highway Program to encourage creative use of existing rights of way such as waterways, railroads, and highways. Examples of this approach include the Cross Sound Cable, which connects Long Island, New York and New England with a high-voltage, direct current submarine cable, and the Neptune Cable, which similarly connects Long Island and New Jersey. Following in this approach is the Champlain Hudson Power Express, which if built, would connect hydropower from Quebec to New York City with a high-voltage direct current line that would run down the bed of Lake Champlain, along railroad tracks, and then down the bed of the Hudson River. In other words, by using land that has already been designated for public infrastructure use, the amount of new land required to build this line is minimized. Construction is set to begin in 2021.

The United States has nearly endless existing rights of way that could be utilized in a similar fashion. The Eastern

15 Potomax Economics, “2018 State of the Market report,” Figure A89.
16 This story is detailed in Gold, Superpower: The United States has nearly endless existing rights of way that could be utilized in a similar fashion. The Eastern

17 EIA, “U.S. Natural Gas Pipeline Projects”.
18 Pendentif Environmental Counsel v. FERC, 558 F.3d 304 (6th Cir. 2009).
seaboard could be connected via undersea cables that provide grid access to wind turbines sufficiently offshore as to be beyond the horizon from the shoreline. These paths are both out of sight, and under federal jurisdiction. In addition to rivers, there are highways, railroad beds, and pipelines already running from east to west. While these existing rights of way are generally not under federal jurisdiction, the Federal-Aid Highway Program provides the lion’s share of funding for the maintenance of the nation’s surface transportation network. Expanding the permitted usage of these existing rights of way to include transmission lines would greatly simplify the siting process. The federal government can encourage this process by either supplementing existing funding, or making some funding conditional upon expedited permitting in these corridors.

Upgrading existing transmission lines is another potentially low-resistance means of expanding renewable generation’s access to markets. This would appear to be a no-brainer, so it is unclear why it has not already happened. FERC and the Federal Trade Commission should conduct a close examination of the incentives facing existing transmission line owners and ISOs to determine whether market power concerns, perverse regulatory designs and/or across-state issues are impeding transmission upgrades and, if so, to recommend or implement policy changes.

FERC rulemaking has played a central role in the creation of wholesale electricity markets, and continues to guide their refinement. In recent years, this has focused on the design of capacity markets, which are payments to generation owners to cover the fixed costs of keeping power plants open and ensure sufficient capacity to meet peak demand. What is missing is a longer-term view toward what the grid itself should look like. Guidance from FERC can ensure that wholesale markets establish market-based practices that are transparent and promote competition in the expansion of the nation’s electrical grid.

Closing Argument

Every economist knows that demand curves slope downwards: if a good is more expensive, people will buy less of it. It is expensive to generate solar power that is available only part of the time. The more expensive it is to reduce greenhouse gas emissions, the more Americans will continue to pollute. Costs matter.

One of the cheapest things the government can do to encourage the growth of renewables generation is remove the regulatory obstacles that prevent generators from delivering power to consumers. Decarbonizing the grid will be hard enough. The least the Biden administration can do is not make it harder.

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Piedmont Environmental Council v. FERC. 558 F.3d 304 [4th Cir. 2009].


In the absence of a carbon price that forces fossil fuel generators to pay the full social costs of their production, a Clean Electricity Standard (CES) is a possible policy mechanism to drive deployment of existing clean energy technologies and create predictable market demand that encourages innovation. While such a policy has not yet been implemented in any jurisdiction in the United States, many states have implemented a somewhat related policy, Renewable Portfolio Standards (RPS), with a mixed record of success. A federal CES could build upon the lessons of these state-level programs and achieve the greatest environmental benefit at the lowest cost by making the standard geographically flexible and technology-neutral, linking the policy to carbon reduction programs in other sectors, and pairing the national mandate with complementary policies that facilitate grid integration and directly support technological innovation.

Heart of the Problem

Low carbon technologies account for a minority of U.S. electricity production and appear on track to grow only modestly under existing policy. As shown in Figure 2, less than 38 percent of U.S. electricity came from carbon-free sources in 2019. While the direct costs of renewable sources of power, such as wind and solar, have fallen dramatically in recent years, their continued growth remains uncertain due to the challenges of integrating them with the grid, particularly those arising from extensive transmission requirements and intermittent production.

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Clean energy sources face an uphill climb in electricity markets for a number of reasons, starting with competition from cheap fossil fuels. For example, the levelized costs of electricity (or LCOE, the total value of lifetime capital, came from nuclear power plants, with hydropower, wind, and solar electricity accounting for only 7 percent, 7 percent, and 2 percent respectively.

Various projections suggest that these patterns may continue in the long run, inhibiting the urgent task of reducing CO₂ emissions to avoid the most serious consequences of climate change. For example, Figure 2 shows the U.S. Energy Information Administration (EIA) reference scenario for the coming decades, which suggests that the share of carbon-free electricity will remain under 50 percent by 2030, and climb to only 53 percent by 2050. While the EIA scenarios are not firm predictions, the balance of forecasts from other industry analysts suggests a similar outlook. Thus, despite rapid renewable growth in recent years, low-carbon power sources risk plateauing under current policy as fossil fuels continue to provide a large share of future U.S. power generation.

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operations, and fuel costs divided by expected power produced) from existing coal-fired power plants is $3.1 cents per kilowatt hour (kWh). The LCOE for a new combined cycle natural gas power plant is 4.6 cents per kWh. Critically, however, these market costs do not account for the harm that pollution inflicts on others. External damages from greenhouse gas emissions and air pollution add more than 10 cents per kWh to the market cost of coal power and about 3.5 cents for natural gas (see Figure 1). The implicit subsidy fossil fuels receive from operating in a policy environment that does not reflect the true price of their emissions helps them out-compete cleaner energy sources, even when this may not be best for society. [For more information on how best to incorporate these costs, see “Placing the United States Government’s Social Cost of Carbon,” page 20.]

Until the full costs of fossil fuels are reflected in their price, renewable energy will be competing at an uneven playing field. To be sure, these technologies have made enormous progress toward reducing costs in recent years, but key obstacles continue to inhibit their widespread adoption. By one measure, the direct costs of producing electricity have fallen by nearly 86 percent for solar photovoltaic (PV) and 49 percent for wind since 2009, nearing parity with coal and natural gas. However, the indirect costs of integrating these intermittant resources into the grid remains an unresolved challenge. Solar and wind electricity have capacity factors (average power generated divided by maximum possible supply over the course of a year) of about 25 percent and 35 percent, respectively, compared with about 85 percent for a natural gas combined cycle plant, creating a perpetual need to back them up with more stable sources of supply.

The need for backup power costs add considerably to the full cost of renewables. According to Lazar, power from natural gas “peaker” plants that can ramp production up and down on short notice is 18 cents per kWh, adding considerably to the full cost of wind and solar. In addition, some grid operators in the United States have started making substantial “capacity payments” to fossil fuel electricity generators—paying them not for producing electricity but rather to keep idle capacity available to protect against unpredictable supply shortages from renewable facilities. While quantifying the precise costs of intermittency remains challenging, Figure 1 displays estimates of the LCOEs of providing a steady supply of power by combining wind and solar with natural gas or battery backups, illustrating the magnitude of the challenge that continues to face renewable sources.

Elevated transmission costs also play an important role in impeding the growth of renewable energy. Because the ideal geography for wind and solar power installations is frequently far away from cities, and because those installations require substantial physical space, the costs of bringing their power to market exceed those of fossil fuels. A review by the Lawrence Berkeley National Laboratory found that excess transmission costs add about 1.5 cents per kWh to the cost of wind generation. A separate analysis by the Edison Electric Institute, an electricity industry group, highlighted that nearly 65 percent of a representative sample of U.S. transmission investments over a ten-year period were primarily directed toward integrating renewables, suggesting that these sources account for a disproportionate share of transmission costs. Because the additional costs of transmission and grid integration are not included in traditional comparisons across energy sources, the progress of carbon-free power risks stalling even as the costs of solar panels and wind turbines continue to decline.

While some clean energy technologies have improved greatly in recent years, others have not, and the pace of innovation lags behind what is necessary to mitigate the most serious consequences of climate change. The costs of lithium ion batteries, which could facilitate the integration of variable renewable production by storing electricity to align supply and demand, have fallen, but remain prohibitively high for utility-scale use. Many experts believe that even the minimum technologically feasible cost of lithium ion batteries would be several times too high to be useful for large-scale grid integration, and alternative technologies remain far from broad commercialization. Incorporating carbon capture and sequestration (CCS) into fossil fuel plants is another potential pathway toward reliable low carbon power, but the United States still does not have a single operational CCS plant generating electricity and capturing CO₂ emissions. (The Petra Nova plant in Texas completed a three-year demonstration project that began in 2016, but was placed in reserve shutdown status as of May 2020.) Only one such CCS plant, the Boundary Dam plant in Canada, exists anywhere in the world.

In sum, low carbon power sources comprise less than 40 percent of current U.S. electricity generation and do not appear on track to drive the reductions in carbon emissions needed to mitigate climate change. The Biden administration must act decisively to enable the transition toward a cleaner U.S. grid and develop the clean energy technologies of the future.

Two broad categories of policy levers exist to promote these goals: direct investment in research and development (R&D) of new technologies, and market signals that will encourage the private sector to innovate on its own. The federal government, through the Department of Energy (DOE) and other agencies, is already active in funding research and development in energy technologies, though it can and should do more. A national Clean Electricity Standard, meanwhile, is an important pathway to establishing market signals. By credibly signaling to investors and firms that there will be market demand for innovations in cheaper, more reliable clean energy technologies, policy can put in place the profit motive to drive investment.

How We Got Here

A Clean Electricity Standard would require carbon-free or low carbon sources to supply a given proportion of electricity generation. To date, no jurisdiction in the United States has implemented such a standard that includes the full range of carbon-free technologies. Some informative parallels can be drawn, however, from the most-similar existing policies: state-level Renewable Portfolio Standards (RPS), which have been implemented by 30 states and the District of Columbia over the past three decades. These policies mandate that a certain proportion of electricity in a state be generated by sources designated as renewable. Electricity producers that demonstrate generation from a qualifying source receive a certification called a Renewable Energy Credit (REC) for each unit of electricity produced. Electricity retailers must then purchase RECs equal to the required proportion of their sales to achieve compliance. If at the end of the compliance period (typically each year), they have not purchased enough RECs to meet the required standard, they must pay a fine called an “Alternative Compliance Payment” for each unit they fall short.

10. Edison Electric Institute, Transmission Projects.
11. Peterson, “To Combat Climate Change.”
13. Folger, Carbon capture and sequestration.
18. Edison Electric Institute, Transmission Projects.
19. Peterson, “To Combat Climate Change.”
22. In vertically integrated non-restructured states retailers may also use RECs generated by their own renewable generating units. Alternative Compliance Payment fines are typically large – on the order of $50 per MWh.
Renewable energy from variable sources like wind and solar needs to be backed up to ensure the lights stay on whatever the weather.

Because REC’s are tradable across technologies, and to some extent across jurisdictions, this approach allows market forces to select the lowest cost sources and locations for renewable production. Electricity suppliers trying to minimize their cost of compliance will purchase the lowest price RECs available for sale, driving competition amongst generators, technologies, and regions to offer the lowest prices.

The technologies covered by existing RPS policies vary across states, but often exclude a number of carbon-free electricity sources that do not meet the criteria to be considered “renewable.” While all states include wind and solar, for example, many do not include hydropower or geothermal. No states included nuclear or carbon capture and sequestration (CCS) in their original RPS programs. To date, only Ohio has added nuclear and only four states (Massachusetts, Michigan, Ohio, and Utah) have added CCS to their list of eligible sources.

In addition, many states do not establish a level playing field among included technologies. In some cases, regulators set higher standards for particular technologies, essentially mandating a larger market share for popular technologies. Thirteen states, for example, have specific mandates for the proportion of the RPS that must be met using solar generation. Many others use REC multipliers to assign more than one unit of credit for each unit of power from favored technologies or producers. For example, Delaware gives extra REC credits to plants that use components manufactured in Delaware. While these technology-specific mandates arise for a variety of state-specific reasons, one common justification is the belief that certain technologies offer greater opportunities to benefit from learning-by-doing. Each of these additional restrictions and exclusions, however, serves to distort the market away from the lowest cost allocation of technologies and raise the cost of complying with the policy.

Existing state-level RPS policies allow for a limited degree of trade across regions. Electricity retailers can purchase RECs from out-of-state generators within a geographic region to comply with their state’s requirement. Some REC regions cover geographic regions—for example, the M-RETS tracking system covers states from the upper Midwest to the South, stretching from North Dakota to Arkansas—allowing producers to comply with policies while locating where renewable resources are abundant and low-cost. Other RPS programs, however, such as those in Michigan, Nevada, North Carolina, and Texas, restrict REC regions to their home state, and some states, such as Illinois and Ohio, require special permission from regulators to approve out-of-state REC purchases. Such restrictions raise costs by narrowing the available range of options for producers to comply with clean energy mandates.

Not only do existing RPS policies limit technologies and markets in ways that could raise costs, they have also generally resulted in only modest increases in the share of renewables in a given state. Though the headline numbers for renewable generation in the early years of RPS mandates appeared substantial, many of the requirements could be met by preexisting capacity. One study found that seven years after the adoption of RPS policies, renewables were required to raise their market share by only 2.2 percentage points of total generation, and twelve years after by only 5.0 percentage points.

In the coming years, however, many RPS mandates are set to rise considerably. For example, the New Jersey and Vermont RPS mandates require that 40 percent of the electricity produced by 2030 be from renewable sources. These policies raise the cost of compliance far above what states are presently experiencing. On the other hand, aggressive targets well outside the range of today’s state-level mandates could cause costs to consumers to increase dramatically if broad reliance on intermittent power sources places unexpected or unmanageable strains on the grid.

Policy Recommendations

The objective of effective U.S. climate policy is to achieve major reductions in emissions while minimizing the economic burden placed on American firms and consumers. Implementing a national market price on carbon emissions is the most efficient method to achieve this goal (see “Put a Price on It: The How and Why of Pricing Carbon,” page 50). In the event that political constraints make such an approach unavailable to the Biden administration, however, a national Clean Electricity Standard is challenging. The specific details of a potential national policy matter a great deal, and could differ substantially from existing state-level mandates. Years of future technological innovation could reduce the costs of compliance far below what states are presently experiencing. On the other hand, aggressive targets well outside the range of today’s state-level mandates could cause costs to consumers to increase dramatically if broad reliance on intermittent power sources places unexpected or unmanageable strains on the grid.

Using these findings to project the effects of a long-term national Clean Electricity Standard is challenging. The specific details of a potential national policy matter a great deal, and could differ substantially from existing state-level mandates. Years of future technological innovation could reduce the costs of compliance far below what states are presently experiencing. On the other hand, aggressive targets well outside the range of today’s state-level mandates could cause costs to consumers to increase dramatically if broad reliance on intermittent power sources places unexpected or unmanageable strains on the grid.

Policy Recommendations

The objective of effective U.S. climate policy is to achieve major reductions in emissions while minimizing the economic burden placed on American firms and consumers. Implementing a national market price on carbon emissions is the most efficient method to achieve this goal (see “Put a Price on It: The How and Why of Pricing Carbon,” page 50). In the event that political constraints make such an approach unavailable to the Biden administration, however, a national Clean
Electricity Standard is a viable alternative to harness market forces, incentivize firms to innovate, and reduce U.S. emissions substantially over time. The following are principles and proposals that the Biden administration and Congress could use to develop such a policy.

**PRINCIPLE**

Allow the broadest possible range of technologies and geography to qualify for compliance.

Existing state-level RPS policies have been expensive to consumers, in part because they place undue restrictions on the type and location of clean electricity generation included in the policy. A national CES policy could reduce costs by allowing electricity retailers to purchase credits from low-cost generation across a broad range of technologies and without geographic restrictions. This means including options that have been largely excluded from state-level programs, such as nuclear energy and carbon capture and sequestration. It also means allowing credits generated by those companies to be traded in an integrated national market, reducing barriers that prevent low-carbon producers from locating in the most advantageous possible places and thereby reducing overall costs.

Credits earned under a national CES program could be referred to as Clean Energy Credits (CECs) instead of Renewable Energy Credits (RECs) to be consistent with this broader definition of allowable technologies.

**PROPOSAL**

Specify clear standards for certifying new technologies to promote innovation.

Achieving the emissions reductions necessary to prevent dangerous levels of climate change is an immense challenge that will unfold over a period of decades. Thus, it is critical not to limit the bounds of policy to technologies that exist today, but instead to create a flexible legal framework that can incorporate the innovations of scientists and entrepreneurs tomorrow. Any policy that certifies only a static list of technologies for compliance will exclude inventors working on technologies that might not commercialize until 2030, 2040, or 2050—technologies that could radically transform the market.

To avoid this restriction on future innovation, a national Clean Electricity Standard could articulate clear standards, including emissions benchmark measurements and broader public health and safety certifications, to qualify as an approved low-carbon source of power. While an initial list of approved power sources must be specified in the law, regulators at the Department of Energy could be empowered to apply the standards outlined in the law to decide whether other technologies or power sources merit additional inclusion. These regulators would be charged with certifying new technologies for inclusion in the decades to come, as well as with periodically reviewing approved technologies to ensure they are delivering as designed (for example, whether carbon capture and sequestration technologies are successfully preventing carbon emissions).

**PROPOSAL**

Set up a centralized exchange for CEC trading to promote transparency and efficiency.

Realizing the full efficiency benefits of a technology-neutral and geographically inclusive national CES will require a transparent and efficient market on which CECs can be traded. Retailers purchasing CECs must be able to easily observe the range of available offers from clean electricity generators in order to purchase the lowest-cost option, and producers must have access to a national pool of potential buyers. Establishing a centralized exchange through FERC where generators can post CEC bid prices and retailers can choose which credits to purchase will ensure price transparency, facilitate monitoring of trade and compliance, and ensure that the aggregate costs of the policy are minimized.

**PROPOSAL**

Allow CECs to be traded with credits issued for compliance under EPAs Light-Duty Vehicle GHG Standards.

Given that the electricity sector accounts for only 27 percent of U.S. emissions, a Clean Electricity Standard will be just one element of U.S. climate policy. By harmonizing carbon-trading regimes across multiple sectors, policymakers can increase the total percentage of emissions being addressed in a single system. This approach can also reduce total costs to the economy, as companies will buy the cheapest emissions credits available and thereby direct investment toward the lowest-cost forms of carbon abatement, regardless of sector.

Under existing state level policies, RECs certify that a unit of electricity was produced with zero emissions. Similarly, the Environmental Protection Agency (EPA) administers a system for vehicle manufacturers to acquire and trade credits for compliance with tailpipe greenhouse gas (GHG) emissions standards (see “Four Proposals to Improve the Design of Fuel Economy Standards,” page 122). Making permits tradable across the two programs—EPA’s tailpipe GHG program and the national CES—would allow emissions reductions to be achieved wherever costs were lowest between the two sectors.

One difficulty with allowing permits to be traded across regimes is the difference in units, since CECs are measured in units of electricity generated rather than GHG emissions. To resolve this discrepancy, regulators could assign each CEC a value for the emissions it abates. Specifically, they could multiply the amount of electricity a generator produces by the average emissions intensity of traditional generation sources displaced by the CES in the state of production. For example, if average the emissions intensity from non-CECS sources is one metric ton per MWH, then each MWH of CEC would be worth one metric ton of CO2 when traded for a permit in the tailpipe emissions market.

**PROPOSAL**

Award CECs for carbon reductions that do not involve electricity generation.

Hydropower is one of the most common renewable energy sources in the United States but is not always included in RPS policies. Vehicles are just one of many sectors that could be integrated with a Clean Electricity Standard. Policymakers could also empower regulators to issue credits for other provable methods of reducing emissions outside of the electricity sector. For example, technologies that successfully demonstrate the ability to capture and durably sequester carbon could be eligible for CECs. These may include direct air capture, agricultural processes that increase soil absorption of carbon, forest expansion, and carbon mineralization. This certification process could be administered by DOE in consultation with relevant scientific experts from the EPA.

As above, the amount of CEC credits to be awarded can be determined by measuring the existing emissions intensity from traditional electricity sources. If the emissions intensity of those sources is one metric ton per MWH, DOE would award one metric ton of carbon removal with one MWH worth of CEC credits.

**PROPOSAL**

Empower FERC to site interstate transmission lines in “National Interest Electric Transmission Corridors” to improve integration of renewables.

Renewable energy relies heavily on the availability of extensive transmission infrastructure to bring electricity from areas with abundant sun or wind resources (such as the desert Southwest or the southern plains) to cities, where demand is high. Obtaining regulatory approval for long distance, interstate transmission lines, however, remains virtually impossible due to...
More generally, establishing an effective approach to federal siting authority for long distance transmission lines can determine the success of the siting process for interstate natural gas pipelines. FERC has served as the primary siting authority for natural gas pipelines since passage of the Natural Gas Act of 1938. The process for siting pipelines, potential builders must acquire approval from FERC affirming that the project constitutes a necessary public objective, which grants the pipeline owner eminent domain authority over the proposed path. Under eminent domain, private property owners along the proposed path for building are entitled to “just compensation” for their losses under the Fifth Amendment. Under the original 2005 law designating FERC’s eminent domain authority over NIETCs, such compensation in the case of transmission lines can either be negotiated directly between the property holder and the construction permit holder, or be determined by a federal or state court.

**PRINCIPLE**

Invest heavily in government research and development of new energy technologies.

There are two ways free markets fall short in the energy sector. First, as described above, a market with unpriced emissions is unfairly tilted against clean technologies because polluting technologies do not have to pay for all the costs they impose on others. A national CES indirectly addresses part of this issue by giving clean technologies credit for zero-emissions production and creating demand to incentivize innovation. However, this still leaves a second market failure that applies to emerging technologies—innovators get only a small portion of the benefits to society they create with their innovations, so the incentive to develop better technologies is below the level that would be best for society.

Thus, even with a national CES encouraging the private sector to develop better clean energy technologies, government support for energy R&D remains critical. U.S. investment in energy R&D has fallen by nearly two-thirds over the past few decades, and currently stands at only about 0.4 percent of GDP—for far below the level recommended by most economists. The low carbon technologies essential for meeting U.S. climate goals make up a minority of electricity production and face major obstacles to further growth. Major investments to enable future breakthroughs of carbon-free electricity production and grid integration technologies such as advanced batteries are necessary to make ambitious CES targets achievable. The Biden administration could drive progress in this area by substantially raising funding to the Department of Energy and its Advanced Research Projects Agency (ARPA-E) to support all stages of this innovation process, from basic science to demonstration and commercialization. A number of other analysts and researchers have provided detailed recommendations and specific proposals to execute these objectives.

**Closing Argument**

Low carbon technologies play a relatively minor role in current U.S. electricity production, and continue to face significant challenges to substantial growth in the coming decades. A national Clean Electricity Standard would level the playing field between clean and dirty sources, mandate decarbonization of the power sector, and encourage innovation in clean energy technologies, though it has the disadvantage of being less efficient than policies that price carbon directly. While CES policies with broad technology inclusion remain largely untested in the United States, the mixed track record of somewhat related state-level Renewable Portfolio Standards offers policymakers some experience to draw on. If the Biden administration chooses to implement a national CES policy, policymakers could maximize the benefits of this approach by making the standard flexible and technology neutral, linking it to carbon reduction policies in other sectors, and pairing it with complementary policies that facilitate grid integration and directly support technological innovation.
The emission of greenhouse gases—primarily carbon dioxide (CO₂)—resulting from electricity generation, ground transport, and industrial use (including process heat) needs to be eliminated as soon as technically, economically and politically feasible to avoid the most serious consequences of climate change. Technology already exists to produce and distribute low- or zero-carbon fuels.

In the absence of technological breakthroughs in grid-scale electric storage, renewable power by itself cannot reliably meet U.S. electricity needs, even before ground transportation and other high-demand sectors have been fully electrified. Supplementary power will be needed to provide the necessary stability to a decarbonized energy system, and by definition it cannot come from fossil fuels.1 If the United States is committed to decarbonizing, it will need to accept a substantial continued role for nuclear power in the energy system in order to avoid the current contribution of approximately 20 percent—through 2050. However, current optimistic projections show that nuclear’s share will drop to approximately 12 percent by 2050. Thus, it appears that a modest return to nuclear power in the United States will continue to decline as operating licenses for most of the existing nuclear power plants in the United States reach the end of their operating licenses. By 2050, most of the existing nuclear power plants will have reached the end of their operating licenses.

1. The high initial cost of building new nuclear power plants in the United States, a key reason for the non-competitive levelized cost of electricity (LCOE) for both existing and new nuclear power plants;
2. The continued political stalemate regarding the disposal of used nuclear fuel; and
3. The poor public perception of nuclear power, fed by a lack of confidence in the safety of nuclear power plants and of the proposed permanent storage of nuclear waste.

Without confronting these three issues, nuclear power in the United States will continue to decline as operating plants reach the end of their operating licenses. By 2050, most of the existing nuclear power plants in the United States will have reached the end of their operating licenses.

Heart of the Problem

Nuclear power in the United States suffers from three serious challenges that currently limit its contribution to decarbonizing the electric power sector:

1. The high initial cost of building new nuclear power plants in the United States, a key reason for the non-competitive levelized cost of electricity (LCOE) for both existing and new nuclear power plants;
2. The continued political stalemate regarding the disposal of used nuclear fuel; and
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States will be shut down, assuming that the Nuclear Regulatory Commission does not grant any further operating license extensions. 3 If these plants are replaced with natural gas-fired facilities, as many are slated to be, it will all but ensure that the country cannot achieve the carbon emissions reductions necessary to avoid the worst effects of climate change.

Solving Nuclear is Central to Decarbonizing the Economy

Increasing the share of U.S. electricity stemming from renewable resources will mean that grid operators and utilities will be more exposed to the risk of reductions or interruptions in supply from variable sources like wind and solar power. Today, operators largely manage that risk through contracts with fossil fuel plants known as “peakers” that can ramp production up or down based on demand. If the United States is to pursue a decarbonized future, that option will not be available long-term.

Technological solutions like carbon capture and storage (CCS) for fossil fuel plants or grid-scale battery storage for renewable generation could help address this challenge, but neither is technically ready or economically competitive enough for deployment at the scale necessary to support a decarbonized electricity system. Importing power from our neighbors—such as Canada—is a third potential avenue for meeting demand during lulls in available energy supply. In the case illustrated in Figure 3, the discrepancy is entirely due to large scale distribution grid. To compensate for this gap, grid storage would need to provide approximately 100 gigawatts (GW) of electricity continuously over periods of around twelve hours.

While this illustrates the scale of a potential intermittent supply problem, the experience of electricity consumers in California during 2020 tells us that utilities already face such difficulties even in less extreme conditions. California has closed not only its two nuclear plant sites but also a number of natural gas-fired generation plants, replacing the resulting shortfall in generation capacity with renewable generation sources. The heat wave of late August 2020 in California has shown that even much more modest supply deficits than hypothesized in Figure 3 (e.g., on the order of 10 GW) can lead to substantial brownouts and blackouts in the absence of grid storage or the ability to import power from neighboring states.

Storage capability at the scale required to deal with weather events such as the one shown in Figure 3 is not currently within the reach of available technologies, for two distinct reasons. First, the scale of the requisite energy storage capacity—over 1 terawatt hour (TWh)—is well beyond what is currently available. In fact, in 2018 there were only 86 megawatts (MW) of installed battery capacity in the United States. 4 Though installed capacity has been expanding over the past decade, it will clearly be some time before there are facilities of the scale needed to address that kind of gap.

Second, the economics argue against this storage solution. An optimistic capital cost projection for battery storage is $100/kilowatt hour (kWh) by 2040, 5 which suggests that the capital costs alone for utility-scale lithium battery storage sufficient to deal with a 100 GW supply deficit over ten hours (similar to the polar vortex event referenced in Figure 3) would amount to approximately $1 trillion. This cost in principle should be very high if the power it provided to the grid was available at a competitive price, but that is unlikely to be the case. Unlike nuclear power plants, which can generate revenue and recoup capital costs through regular daily use, grid storage facilities can only earn revenue when they are operating. Because large disruptions on the scale of the polar vortex are currently rare, 6 the full supply capacity of such a grid storage facility would only be used sporadically. This necessarily implies an extremely high cost of electricity.

Presume, for instance, that the functional lifetime of a storage system is twenty years, and there is one 1 TWh generation insufficiency event per year. In order to recoup its investment (thus, not even accounting for operational costs and profit), such a storage system would need to charge an electricity cost of $5/kWh, to be compared with the maximum LACE of carbon-free generation currently estimated to be $0.049/kWh (solar photovoltaics), $0.083/kWh (onshore wind), and $0.093/kWh for nuclear power. 7 This argument strongly suggests that utility-scale grid storage is best used to handle much more frequent, much smaller, and more geographically compact supply insufficiencies that can be handled by smaller, more affordable, local storage facilities.

It should also be noted that the polar vortex illustrated in Figure 3 was an extreme shock both because of its severity and because it extended over a spatial scale of continental dimensions. It covered the entire northeast quadrant of the United States, stretching from Chicago to Washington, D.C., to Maine. While transferring renewable power from other areas of the country on a national grid could address some of that insufficiency, Figure 3 suggests it is highly unlikely that strategy could cope with a disruption on this scale.

Extreme supply insufficiencies of the kind illustrated in Figure 3 should therefore be dealt with by deploying large generation resources. A fleet of modern nuclear power plants for forty years of operations initially. Subsequently, the NRC may grant twenty-year extensions—and indeed has granted one twenty-year extension to many operating reactors—and may grant one additional twenty-year extension, for a total of a operating license period of eighty years, but only a few second extensions have been granted to date. See U.S. NRC, “Status of Subsequent License Renewal Applications.”

Notes: Net Load = Gross Load minus wind and solar. Positive supply gap = potential battery discharge cycle or dispatchable renewable resources. A fleet of modern nuclear power plants for forty years of operations initially. Subsequently, the NRC may grant twenty-year extensions—and indeed has granted one twenty-year extension to many operating reactors—and may grant one additional twenty-year extension, for a total of a operating license period of eighty years, but only a few second extensions have been granted to date. See U.S. NRC, “Status of Subsequent License Renewal Applications.”

8 The probability of occurrence of events such as the polar vortex event of 2019 remains unknown. Extant climate models suggest that the probability of extreme weather events will increase with time over the next few decades, but the science remains uncertain (cf. Mann, et al., “Projected changes in persistent extreme summer weather events,” 2018). In other words, tail events will become more common, but scientists are uncertain about the specifics of their frequency.

9 U.S. EIA, “Levelized Cost and Levelized Avoided Cost of New Generation Resources.” All estimates for new generation sources in 2002 are in 2019 $/kWh. Note that decreasing the probability or scale of such supply insufficiency events simply increases the associated cost of electricity from grid storage.

3 The Nuclear Regulatory Commission (NRC) licenses nuclear power plants for forty years of operations initially. Subsequently, the NRC may grant twenty-year extensions—and indeed has granted one twenty-year extension to many operating reactors—and may grant one additional twenty-year extension, for a total of a operating license period of eighty years, but only a few second extensions have been granted to date. See U.S. NRC, “Status of Subsequent License Renewal Applications.”

4 Currently operating commercial nuclear power plants in the United States can ramp to a limited extent, but are not designed to do so effectively. The more limitations are contaminations by Xe-135 (“xenon poisoning”) and uneven burnup within the core. However, naval nuclear reactors are designed to ramp significantly, and commercial reactor designs such as molten salt reactors (MSRs) can be designed to avoid xenon poisoning.


6 U.S. EIA, “Battery Storage in the United States.”

7 Cole & Frazier, “Cost Projections for Utility-Scale Battery Storage.”
power plants capable of dispatching 100 GW, and a grid able to shift this supply around the country would secure the energy supply, even during such extreme weather events. Modern nuclear plant designs are capable of ramping production up and down on the basis of demand, and thus can—unlike most existing plants—be readily used as peakers. Furthermore, such plants may be used for ancillary zero-carbon emission power needs (such as powering desalination plants10 or providing process heat11), and could be temporarily dispatched to resolve grid power insufficiencies in emergencies. Thus, modern nuclear power plant designs have the advantage over large-scale grid storage of being able to earn revenue when not dealing with grid power deficiencies.

The preceding discussion assumes that the United States has transitioned to a fully decarbonized electricity sector, but it must be noted that the Department of Energy’s (DOE) current (2020) reference case12 for 2050 does not project full decarbonization of the grid by mid-century. As illustrated by Figure 1, these projections show that fossil-fuel-powered generation would only decrease to 49 percent of the total power generated, from its 2019 contribution of 61 percent, assuming a continued decline of nuclear power in the United States. Whatever the target date for full decarbonization of the electricity sector might be, a grid fully powered by renewables will still need ancillary infrastructure in place—either grid storage or fully dispatchable power—to deal with the kind of serious long-term power supply deficits illustrated in Figure 3. It is in this context that nuclear power can play an important role.

**How We Got Here**

Federal policymaking on nuclear power has varied substantially with time. Strong federal support for nuclear research and development throughout the 1950s established the first civilian nuclear research facilities in the country as well as the first functioning nuclear power plants.

While nuclear power capacity and generation continued to grow through the 1960s and 1970s,13 driven in large part by investment by utilities, federal support for the industry waned substantially following the Three Mile Island and Chernobyl nuclear plant accidents in 1979 and 1986, respectively, leading to substantial cuts in federal support for nuclear power research and development (R&D).

The drop in federal support was driven in no small part by rising public opposition to the nuclear industry. Accidents like Three Mile Island raised public fears of inadequate oversight of power plant operations by the Nuclear Regulatory Commission (NRC), stoking both local and national resistance to the industry. In 1989, local opponents succeeded in shuttering a brand new fully functional plant in Shoreham, NY, before it had ever been operated. Public concerns about nuclear waste disposal, meanwhile, have thwarted plans to open a used fuel repository in Yucca Mountain, NV for decades.

While both Democratic and Republican administrations continued relatively modest R&D support, mostly in the direction of new reactor designs, construction of new nuclear power plants ceased almost entirely after 1996, leaving a twenty-year gap during which no new nuclear plants were put on-line (Figure 4).

Not only has that resulted in an aging nuclear fleet, but also in a serious delay of U.S. industrial capacity to construct new nuclear power plants. It is only within the last decade that federal efforts aimed at supporting the design and construction of small modular nuclear power plants has led to efforts to address these critical deficiencies. As a result, the cost overruns encountered by Westinghouse and its collaborators building four gigawatt-scale nuclear power plants in Georgia and South Carolina should not have been a surprise—these efforts were effectively “first-of-a-kind” projects, with the attendant risk premium, given the relative inexperience of the contractors working on these plants.

The net result of these dynamics is that the actual cost of nuclear power based on gigawatt-scale plants is well above the LACE estimates provided by the EIA. Without concerted action now, the United States risks taking nuclear power off the table as a significant electric power source into the latter part of this century.

Furthermore, if the United States remains on its present course to exit nuclear, but still aims to decarbonize by mid-century or earlier, it will face the rising risk of extensive power shortages during extreme weather events such as the polar vortex instability, extremes that in global climate models suggest are likely to increase in both frequency and severity. Since such power shortages are not likely to be politically acceptable, the United States will need to continue to rely heavily on fossil fuel-based backup power—unless it makes a substantial effort to introduce new nuclear power plants.14 Thus, if the United States does not change course, it is almost certain that it will fail to achieve significant decarbonization by mid-century—an unthinkable result given the threat of climate change.

**What To Do**

Each of the three critical issues nuclear power faces (cost of construction and competitiveness, the handling of spent fuel, and public concerns about safety) can and should be addressed. By doing so, the United States can achieve a technologically plausible path towards complete decarbonization of its electricity sector by the end of this century—and possibly even by mid-century if policymakers address these issues expeditiously.

**POLICY**

**High cost of building new nuclear power plants and obstacles to competitiveness**

The high cost of building new nuclear plants can be dealt with by a concerted focus on the obstacles faced by the nuclear industry in the United States, such as designs that do not account for modern manufacturing technology; broken or non-existent supply chains for important system components; lack of sufficiently trained workforce; a nuclear regulatory regime with the

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12 U.S. DOE, Annual Energy Outlook
13 U.S. EIA, “Nuclear explained.”
14 It is important to note here that modern nuclear power plants, including small modular nuclear reactors, can be designed to function as peaking power plants, an ability that current gigawatt-scale nuclear power plants do not have.
dual focus on safety and security; 21 and a significant risk premium in financial markets. 22 There are a number of steps that the Biden administration can take to address these issues. The DOE should strengthen its R&D programs in advanced reactor designs, as well as its collaborative programs with industry in transitioning new reactor designs to construction of test reactors and ultimately to commercial products. NRC and the Federal Emergency Management Agency (FEMA) should revisit regulations governing the operations of new reactor designs, including in particular the nature of Emergency Planning Zones (EPZs) and the impact that new design features (such as fully below-grade reactor vessels) have on these EPZs. The persistent degradation of the NRC’s licensing capabilities for designs other than light water reactors—driven by consistent reductions in its budget 23 —needs to be reversed so that its technical capabilities for granting design and operating licenses for advanced nuclear plant designs can be restored. These changes can be effective in encouraging private industry to adopt new designs (of which small modular reactors—SMRs—are an example).

Modular designs in particular take advantage of highly automated—assembly line-based—manufacturing pioneered in other high-technology industries such as the airframe industry, which has been shown to be effective in restraining manufacturing and construction costs. The current effort to build the first DOE-supported, Nucleardesigned, modern SMR at Idaho National Laboratory is the first (necessary) step in this direction. Finally, to help staff these manufacturing facilities and build the new reactors, DOE could strengthen its partnership with industry and the nation’s technical colleges to train a new generation of nuclear workers focused on plant construction. But, focusing on design, manufacturing, and construction is not enough. 24 Regulatory reforms are also needed. For example, current Environmental Protection Agency (EPA) and NRC regulations set stringent limits on exposure to extremely low levels of radiation, which can considerably complicate the operation of nuclear facilities, raising operating costs. These constraints, especially the concept of limiting radiation exposure to “as low as reasonably achievable” (ALARA), are poorly grounded in science, because studies focusing on the biological effects of very low exposure levels have proven to be extremely difficult to carry out reliably. Thus, the cognizant federal agencies (especially the EPA) should launch a concerted research effort to finally settle the question of the biological effects at extremely low dosage levels, an effort that would establish scientifically informed regulations in this domain and provide clarity for workers, the industry, and the public. 25 The non-competitive status of even existing nuclear power plants in the United States is the result of two policy failures. The first is the failure to price the damages caused by fossil fuel-based power production (most notably climate change and air pollution), which is a major factor in the current low LCOE of natural gas-powered electricity production. The second is the continued subsidization of non-hydroelectric renewables (e.g., wind and solar) without accounting for the costs of dealing with supply fluctuations from those sources. It is revealing that in Sweden, where nuclear power competes with hydroelectric power and other renewables (and where fossil fuels play no role in electricity generation), nuclear power and hydro show comparable generation costs, and lower generation costs than other carbon-free generation technology. 26 Thus, this issue can be resolved by (i) Congress, if it were to pass legislation that allowed for pricing carbon emissions appropriately (as discussed in “Put a Price on It: The How and Why of Pricing Carbon,” page 50); (ii) the states, by eliminating renewable energy credits (RECs, which explicitly disadvantage nuclear power), and transitioning to clean energy standards (CES) and zero emissions credits (ZECs), both of which incentivize carbon-free electricity generation irrespective of technology; and (iii) state utility commissions, by accounting explicitly 27 for the costs of dealing with [non-hydropower] renewable power supply fluctuations. A competitive market relies on the pricing of all externalities, including both carbon emissions and renewable intermittency. 28 Without placing an appropriate price on carbon emissions and the costs of managing intermittency 29 like contracts with peaker plants, fossil fuel-based technologies and renewables, respectively, gain a cost advantage over nuclear. Hence, the low LCOE of natural gas-powerelectricity production and non-dispatchable renewables does not properly represent their true costs to the electricity sector. This deficiency can be remedied if the Biden administration supports the passage of legislation that prices all such externalities. While nuclear power’s role for a decarbonized energy sector would serve primarily to support grid demand during an extreme weather, such nuclear power plants could also serve alternate energy needs (such as desalination of sea water or providing process heat) that are interruptible, so that they are able to earn revenue while they are not needed to support large-scale grid power insufficiencies. For this reason, the cost of nuclear power will compare quite favorably with the cost of providing comparable backup power via grid storage, viz., grid-scale batteries, which earn no revenue when not used to deal with grid power insufficiencies.

POLICY

Safely disposing of nuclear waste

The Biden administration should revive the sensible roadmap for resolving the nuclear waste problem.

21. The ultimate fate of the Shoreham nuclear power plant in Long Island, NY—which was completed but never put into operation, and led to the bankruptcy of its operator, LILCO—is illustrative of the corrosive effects of mixing regulatory uncertainty with public opposition (for more, see Weisbock, A Chronicle of The Shoreham Plant).
22. Petti et al., “Future of Nuclear Energy”.
24. Indeed, such streamlined manufacturing processes have been credited with bringing down the costs of renewables, including solar panels and windmills.
25. Petti et al., “Future of Nuclear Energy”.
27. With the elimination of the tax on nuclear power production, Vattenfall estimates its nuclear generation costs to be SEK 0.019/kWh ($0.022/Wh) in 2020. World Nuclear Association, “Nuclear Power in Sweden.” See also Hong & Breake, “Costs of replacing nuclear.”
28. There is considerable variability in how utilities allocate the costs of grid storage; in some cases, such costs are borne by the supplier (i.e., the wind or solar power generator); in other cases, such costs are incorporated into transmission costs. In the latter case, the result is to effectively hide from the consumer the additional costs associated with the variability of renewable energy production.
29. Though some would argue that the risk of a nuclear accident is also an externality, this risk has been internalized through regulatory oversight and multiple insurance premia mandated by The Price-Anderson Nuclear Industries Indemnity Act (1957).
30. Pricing the intermittency externality is of course related to the costs incurred by dealing with renewable power imbalances, e.g., the costs associated with grid storage and/or carbon-free “peaker” plants.
outlined by the Blue Ribbon Commission on America’s Nuclear Future in 2012. The principal components of that roadmap include the creation of a new federally chartered corporation (a “fedcorp”) with the unique charge to deal with nuclear waste disposition, and establish a new body to set standards and field public concerns. Establishing this fedcorp would be a clear opportunity for the Biden administration to change public attitudes regarding nuclear power.

U.S. friends and allies have laid a path Washington can follow in this regard. In Canada, Finland and Sweden, initial efforts at dealing with the nuclear waste issue confronted opposition similar to that in the United States. But a clear turn towards total transparency—including consent-based siting that allows local communities a veto power over siting decisions—transformed their public relations problem. Their approach was similar to what the Blue Ribbon Commission recommended, but unfortunately has not been implemented in the United States. Implementing the findings of the 2012 Commission is important opportunity for the Biden administration.

Closing Argument

Significant changes in the U.S. electric power sector take an enormous effort to accomplish, in terms of time, money, and political focus; the electric power sector does not turn on a dime. If the United States postpones decisions regarding nuclear power until mid-century, hoping for the technological miracles that will usher in renewable energy, it will be too late to avoid the worst effects of climate change. Building new nuclear power plants in sufficient numbers to replace the burning of fossil fuels will depend on tackling a series of overreliance on renewable energy. This is an agency widely mistrusted as a result of its past failures to deal with nuclear waste disposition, and establish a new body to set standards and field public concerns.

For the United States, nuclear power’s public relations problem can be addressed—as it has been in Canada, Finland, Sweden and Switzerland—by increasing the transparency of the decision processes concerning nuclear power. In the United States, public skepticism regarding nuclear power has centered on the question of safety of nuclear power plants, and on the safety of ultimate disposal of the associated waste. The NRC’s licensing process, followed in detail for the planned NuScale modular reactor in Idaho, is widely regarded as the gold standard for regulatory practice worldwide. This process has given regulators considerable opportunity to question the adequacy of NuScale’s safety provisions, and to insist that this vendor respond satisfactorily before issuing design approval. However, there has been essentially no progress on dealing with civilian nuclear waste—in particular, there has been no progress in confronting the lack of public confidence in DOE’s ability to deal with its mandated role in securing civilian nuclear waste. The aforementioned Blue Ribbon Commission’s recommendation of a new fedcorp whose sole responsibility would be to deal with civilian nuclear waste would go a long way to address this difficulty. It would lift this responsibility out of the DOE, utilities will have little choice but to continue to dispatch fossil fuel-based backup power, in all likelihood vitiating the effort to decarbonize the energy sector. This point is understood not only by Canada, Finland and Sweden, but also by countries that are among the largest current users of fossil fuels, such as China and India, and the latter are implementing ambitious plans for expanding their nuclear power plant fleets during the balance of this century. If the United States is to successfully decarbonize its economy, it needs to turn to the technology that is here, proven, and ready to deploy: nuclear energy.

REFERENCES

Mann, Michael E., Stefan Bahmoff, Kai Kernhuber, Byron A. Steinman, Sonny K. Miller, Stefan Petz, and Dan Coumo. “Projected changes in power output of summer wind and solar: The role of nuclear storage capacity and the restructuring of the national grid needed to allow large power transfers on the continental scale, as described on the text. Furthermore, large blackouts related to renewable source failures have also already occurred, perhaps most prominently in the UK as the result of a failure of a large offshore wind farm in August 2019 (BBC, “UK power cut”). The recent (August 2020) power outages in California have further illustrated the problems encountered when grid operators are insufficiently equipped to deal with extreme weather events (and associated heightened power demand) in a power supply environment that relies heavily on renewables and access to out-of-state power supply, their approach was similar to what the Blue Ribbon Commission recommended, but unfortunately has not been implemented in the United States. Implementing the findings of the 2012 Commission is important opportunity for the Biden administration.

Public safety concerns

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However, new research suggests that energy efficiency substantially underdelivers on its promises to reduce energy consumption, putting global climate goals at risk. In a series of empirical studies comparing projected energy savings from energy efficiency retrofits to real-life energy use after they were installed, economists have demonstrated that energy efficiency savings fall short of expectations. In the largest American residential energy efficiency program, the Weatherization Assistance Program (WAP), retrofits delivered less than 40 percent of expected savings, ultimately rendering the costs of the program substantially higher than its societal benefits. These disappointing savings results have also been found in other energy efficiency retrofit programs outside of the residential sector.

What does this mean for future energy efficiency policy? Though existing energy efficiency retrofit programs do not live up to expectations, there are still avenues for these kinds of policies to play an important role in addressing climate change. The next administration should consider two core policy recommendations for reforming energy efficiency policy in the United States. First, setting energy prices correctly will incentivize customers to invest in the appropriate level of energy efficiency on their own, without requiring additional subsidies. Second, rigorous ex post evaluation should be built into energy efficiency programs, in order to direct spending to projects that do deliver energy savings at low cost.

The American economy consumes more than 100 quadrillion British thermal units (Btu) of energy every year, or approximately 305 million Btu per person, for lighting, telecommunications, transportation, and industrial production and other everyday uses. For comparison, this is triple China’s per capita consumption (98 million Btu), and approximately double that of Germany (170 million Btu) and Japan (150 million Btu). U.S. energy consumption has grown rapidly over time: in 1950, total primary energy consumption in the United

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1 Fowlie, Greenstone, and Catherine Wolfram, “Do Energy Efficiency Investments Deliver?”
2 Burlig, Knittel, Rapson, Reguant, and Wolfram, “Machine Learning from Schools about Energy Efficiency.”
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4 Burlig, Knittel, Rapson, Reguant, and Wolfram, “Machine Learning from Schools about Energy Efficiency.”
6 U.S. EIA, “Frequently Asked Questions.”
7 U.S. EIA, “Energy Intensity.”

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SECTOR-BY-SECTOR APPROACHES

Making Energy Efficiency Work

Fiona Burlig, Assistant Professor, Harris School of Public Policy

*Thanks to Garrison Schlauch for excellent research assistance.

Energy efficiency is often touted as a win-win approach to the global climate problem. Customers that install energy efficient appliances win by reducing their electricity bills enough to cover the cost of the new appliance, and the planet wins as reducing electricity consumption means lower greenhouse gas (GHG) emissions. Policymakers have therefore made energy efficiency a cornerstone of climate policy. In order to meet the Paris Agreement’s target of limiting average warming in 2100 to no more than 2°C, the International Energy Agency estimates that energy efficiency will be required to deliver nearly 30 percent of global emissions reductions. In the United States, the Department of Energy (DOE) alone spent $14.5 billion on a wide range of energy efficiency investments from 2000 to 2019, including early stage research funding, technology evaluation, compliance monitoring, and retrofit programs.

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Heart of the Problem

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1 International Energy Agency, “CO₂ Emissions Reductions by Measure.”
2 Gallagher and Anadon, “DOE Budget Authority for Energy Research, Development.”
3 Fowlie, Greenstone, and Catherine Wolfram, “Do Energy Efficiency Investments Deliver?”
4 Burlig, Knittel, Rapson, Reguant, and Wolfram, “Machine Learning from Schools about Energy Efficiency.”
6 U.S. EIA, “Frequently Asked Questions.”
7 U.S. EIA, “Energy Intensity.”

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FIGURE 1 - CHAPTER IN A CHART

Energy Efficiency Delivers Lower than Expected Savings

<table>
<thead>
<tr>
<th>Realization Rate (Realized savings / expected savings)</th>
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<tbody>
<tr>
<td>Air conditioning, CA</td>
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<tr>
<td>Public schools, CA</td>
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<tr>
<td>Home weatherization, WI</td>
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<td>Home weatherization, IL</td>
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<td>Refrigeration, Mexico</td>
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<td>Air conditioning, Mexico</td>
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energy efficiency will need to account for eight gigatons of energy reductions relative to present policy, or nearly 30 percent of all reductions, to meet the 2°C target.**

**Energy efficiency does not work as well as expected**

If energy efficiency upgrades are as effective as they seem, it suggests that customers are leaving money on the table. The McKinsey analysis, for example, reports that more than 1.2 gigatons of CO₂ (equivalent) savings could be attained at negative cost—that is, the efficiency investments would more than pay for themselves. The fact that consumers have not made these investments yet suggests that there may be an “energy efficiency gap” between how much energy efficiency consumers have invested in and the level of investment that would make them privately better off. Potential explanations for this gap have included market failures such as lack of consumer information about available energy efficiency policies or products, as well as behavioral biases that cause consumers to make mistakes, such as inattentiveness (failing to consider the benefits of action), short-sightedness (overweighting the present relative to how much they would value the future in the status quo).

However, a large body of research has substantiated an alternative explanation: energy efficiency upgrades are not nearly as cost-effective as engineering projections suggest. Figure 1 shows realization rates from nine empirical evaluations of energy efficiency programs in the United States and Mexico. A realization rate compares realized savings caused by an energy efficiency upgrade, measured in the field, with the expected energy savings, typically derived from an engineering model. A realization rate of one implies that the energy efficiency upgrade delivered 100 percent of expected energy savings; a realization rate of zero implies that the upgrade delivered no savings. While the majority of this research focuses on residential retrofits such as installing insulation or energy-efficient appliances, one study demonstrates similar results in public schools in California. In all of these studies, the estimated realization rate is below one. Even the most optimistic study only finds a realization rate of 0.6: energy efficiency upgrades delivered only 63 percent of expected savings.

The remainder of the studies are even less optimistic, with estimates ranging from 0.6 (in California schools) to zero (on insulation and housing upgrades, and on air conditioning, both in Mexico). Several studies of the flagship U.S. residential energy efficiency program, WAP, have likewise found low realization rates across a large body of research has substantiated an alternative explanation: energy efficiency upgrades are not nearly as cost-effective as engineering projections suggest. Figure 1 shows realization rates from nine empirical evaluations of energy efficiency programs in the United States and Mexico. A realization rate compares realized savings caused by an energy efficiency upgrade, measured in the field, with the expected energy savings, typically derived from an engineering model. A realization rate of one implies that the energy efficiency upgrade delivered 100 percent of expected energy savings; a realization rate of zero implies that the upgrade delivered no savings. While the majority of this research focuses on residential retrofits such as installing insulation or energy-efficient appliances, one study demonstrates similar results in public schools in California. In all of these studies, the estimated realization rate is below one. Even the most optimistic study only finds a realization rate of 0.6: energy efficiency upgrades delivered only 63 percent of expected savings.

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In the wake of the 1973 energy crisis sparked by the Arab oil embargo, in 1979 Congress passed the Energy Policy and Conservation Act (PL. 94–163) to expand federal energy policy. This included increasing energy production and reserves to mitigate future supply chain disruptions and fostering energy conservation through fuel economy and energy efficiency standards for home appliances. The following year, the Energy Conservation and Production Act (PL. 94–385) established energy standards for new buildings, provided grants, low-interest loans, and loan guarantees to improve energy conservation in existing buildings; provided oversight, proposals, and state funding to improve electric utility rate design; and created financial incentives for domestic energy production.

Together, these acts created several energy efficiency programs under DOE, including WAP and the State Energy Conservation Program, which later became known as the State Energy Program (SEP).

WAP provides funding to states for home weatherization, and was designed in part to reduce energy costs for low-income households, for whom energy expenditures often make up a large fraction of total spending. One study found, for instance, that low-income households with electric heat spend 12 percent of annual income on electricity. An average household with electric heat, by contrast, spends just 3 percent of its total expenditure on energy. For the tens of millions of Americans living below the poverty line, home weatherization investments could have a meaningful impact on their household’s bottom line. However, it is critical that these programs actually deliver real energy savings to low-income households.

WAP initially focused on measures thought to produce the most energy savings per dollar spent, such as air sealing and insulation improvements. These measures eventually expanded to include sealing damaged doors, windows, pipes, and ducts; tuning, fixing, and installing heating and cooling units; and addressing potential gas leaks and electrical hazards. Under the American Recovery and Reinvestment Act (ARRA), WAP’s scale and scope increased dramatically, funding increased from $450 million in 2009 to nearly $5 billion in 2011-12. Eligibility was extended to all owner-occupied households at or below 200 percent of the poverty line. Over 7 million households have been provided weatherization assistance through the program since its inception in 1976. As noted above, however, recent research has shown WAP’s effectiveness to be vastly overstated, finding that the program’s costs outweigh its benefits. Like many energy efficiency programs, WAP uses engineers’ estimates of a technology’s energy-saving potential to estimate savings prior to determining which upgradess to install. These estimates can overstate savings threefold, with upfront weatherization costs typically double actual savings. Even after accounting for the societal benefits of emissions reductions derived from installing more energy efficiency upgrades, WAP’s average annual rate of return is approximately 7.8 percent. These findings highlight the need to base resource allocation decisions on rigorous evaluations of real-world energy efficiency programs rather than engineering projections alone, by using existing empirical analyses where possible, conducting ongoing evaluations as new technologies are deployed, and revising funding guidelines in line with these real-world results.

The SEP provides funding and technical assistance to U.S. states and territories to promote energy efficiency. These funds are used in over eighteen project areas, including energy standards and audits, retrofits, grants and low-interest loans, and loan guarantees to improve energy conservation in existing buildings; provided oversight, proposals, and state funding to improve electric utility rate design; and created financial incentives for domestic energy production. Together, these acts created several energy efficiency programs under DOE, including WAP and the State Energy Conservation Program, which later became known as the State Energy Program (SEP).
and loans, and education and training. As it did for WAP, ARRA significantly increased SEP’s funding. From just $53 million in 2008, SEP was afforded $3.1 billion for 2009-11. This grant also came without fund-matching requirements, allowing states to receive support without having to first raise money themselves. A 2015 review by Oak Ridge National Laboratory found SEP cost-effectively reduces energy consumption, increases renewable power generation, and avoids carbon emissions. These estimates, however, are also based on engineering estimates, which as noted above significantly overstate the cost effectiveness benefits of WAP. The findings should therefore be interpreted with caution.

In addition to funding programs designed to retrofit private homes, like WAP, the federal government itself is also a major participant in energy efficiency programs. In 1973, the Federal Energy Management Program was established as part of the DOE to encourage the federal government to adopt more energy-efficient practices, such as improving utility management, adopting renewable energy technologies, and conserving energy. The federal government’s experience has been fairly similar to those of state agencies and private homeowners, however, as energy efficiency upgrades have not delivered cost savings in the expected timeframe. In 2011, the General Services Administration (GSA) published a national study comparing the environmental performance and financial metrics of twenty-two representative green buildings in its portfolio to commercial and GSA baselines. Although the green buildings did use 25 percent less energy, GSA spent an estimated $172 million to achieve these reductions, with guaranteed savings amounting to just $10.8 million in the first year. Even after ignoring potential operating and replacement costs and assuming that future years would produce similar levels of savings, this investment would take sixteen years to pay off. This is a significantly lower payoff compared to gains typically achieved through investing in other energy efficiency endeavors, namely research and development. Ultimately, across a suite of federal programs, there is clearly room for improvement in the effectiveness of energy efficiency investments.

What To Do
Current energy efficiency programs in the United States have been shown to be expensive and relatively ineffective. The remainder of this chapter lays out two principles aimed at improving the existing suite of American energy efficiency programs to ensure that future policies generate tangible benefits at a reasonable cost.

### PRINCIPLE
Correctly setting energy prices empowers consumers to make the best decisions

The vast majority of Americans currently face energy prices that are below the true cost of energy consumption. When a household uses a kilowatt hour (kWh) of electricity, it does not pay the full cost that the production of that kWh imposes on society, because damage caused by energy-related global and local pollution is not reflected in the electricity price. This leads consumers to overuse energy relative to a scenario in which consumers actually paid for the pollution damages caused by electricity generation. In other words, without a price on pollution, the United States is implicitly subsidizing the use of fossil fuel energy. It also means that consumers will underinvest in energy-efficient technologies, compared to a world with higher energy prices that reflect the true cost of electricity use, because there is less financial pressure to do so.

The textbook economics approach to closing the gap between the energy price a consumer pays and the true cost of that energy is a price on pollution (including carbon pollution), in the form of a pollution tax or other carbon pollution, in the form of a pollution tax or other.

### POLICY
Energy efficiency programs should be subject to rigorous ex post evaluation

Unless and until energy prices reflect the true cost of energy use, policymakers should continue to promote energy efficiency through other approaches. As noted above, the biggest challenge facing existing energy efficiency programs in the United States is that they are extremely costly but do not appear to deliver promised energy savings or climate benefits. Across a variety of contexts and programs, research in this setting demonstrates two common themes, both of which highlight the importance of ex post evaluation in energy efficiency programs.

First, engineering projections for energy efficiency upgrades have been found to be overly optimistic. Though current energy efficiency programs typically do require upgrades to pass a cost-benefit test of some kind, these metrics only use expected savings to determine which measures are eligible for installation. These expected savings metrics are often based on laboratory, rather than real-world conditions, which leave them susceptible to producing unrealistically high expected savings estimates. In contrast, ex post analysis has shown that energy efficiency upgrades deliver far lower savings than promised up front. For every 100 kWh in expected savings, large-scale North American energy efficiency retrofit programs provided substantially fewer information, see “Put a Price on It: The How and Why of Pricing Carbon”, page 50. If Congress were to impose such a price, it would be more costly for an average household or firm to use energy, so consumers would find ways to reduce their overall energy use either by lowering consumption of energy services, or by turning to more efficient technology. Without such a price on carbon or other pollutants, consumers are missing an important incentive for energy conservation. As a result, government subsidies for energy efficiency continue to be a useful policy tool—provided that these subsidies are targeted towards cost-effective upgrades.

### FURTHER READING

**Energy Efficiency Policies**

[Machine Learning from Schools about Energy Efficiency]

**Energy efficiency improvements lowered electricity consumption on average by 3 percent, but the energy savings was only 24 percent of what was projected before officials invested in the upgrades.**

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34. Oak Ridge National Laboratory, National Evaluation of the State Energy Program.
35. Ibid.
38. Rosenthal and Bushnell, “Are Electricity Prices Wrong? Make a Right?”
savings: between 60% and 78% kWh, with WAP delivering approximately 24 kWh. Applying these realized savings estimates in place of engineering expectations, many energy efficiency retrofits that appeared to pass a cost-benefit test would no longer do so. Regulators should therefore require that proposed programs that are similar or identical to past initiatives use real-world results, rather than engineering estimates, in any cost-benefit analysis prior to launch. All ongoing programs should also be reviewed regularly and have a mechanism to accommodate new evidence. Measures that pass a cost-benefit review on the basis of realized savings should continue to be funded, measures that fail to do so should be excluded or amended in line with those findings.

For new technologies, where possible, state and federal agencies planning to implement new approaches should begin with small-scale trials to generate rigorous evidence. Where this is not feasible, existing energy efficiency programs can be used to begin with, but should be replaced by real-world analysis as part of a regular review process. Importantly, these ex post analyses must be rigorous and conducted independently. Randomized controlled trial evidence should be the standard. A second reason for ex post evaluation of energy efficiency programs is that these analyses can go beyond simply identifying a difference between anticipated and real-world energy savings in energy efficiency programs to identifying the design flaws that account for these gaps. One important step in this process is identifying which of a program’s individual energy efficiency measures, if any, are capable of efficiently reducing energy use in the real world. For instance, a home weatherization program could fail short of expectations because the insulation technology underperformed, because the program failed to attract sufficient participation, the type of properties enrolled in the program were disproportionately energy efficient to begin with, or a host of other reasons. Ex post evaluations can tease out the specific components that contributed to program failure to improve future implementation or program design. Ex post analysis can also identify implementation challenges that impede energy efficiency programs from delivering low-cost savings. In WAP, new evidence reveals that differences among contractors can explain up to 43% of the difference between expected and realized savings. More effective contractor selection processes and incentives also have the potential to substantially improve energy efficiency retrofit programs. As an example, a new study finds that in California’s low-income Energy Savings Assistance (ESA) program, when contractors were paid on a per-retrofit basis, they intentionally misreported program data and replaced relatively new appliances, rather than only the older, inefficient ones officially covered by the program. This lead an otherwise successful program to fail a cost-benefit test. Had only the old refrigerators been replaced, the program would have been cost-effective, because these replacements delivered large energy savings. By contrast, replacing newer refrigerators generated little in terms of savings. After this study was released, ESA contractors were required to provide photographic evidence that they were only replacing qualified refrigerators, which should make the program substantially more cost-effective. As state and federal agencies approve spending plans under WAP and other energy efficiency programs, they should bear in mind the clear importance of using careful monitoring and evaluation to update existing energy efficiency programs. These examples demonstrate the benefits of evaluating energy efficiency programs: ensuring that these policies are re-evaluated using the best available evidence will allow policymakers to identify and eliminate wasteful program spending. The Biden administration and incoming Congress are likely to face historic demands on the federal purse. Rigorously evaluating proposed and ongoing spending will ensure that every penny spent on these programs is delivering real energy savings at low cost. Where they are not, it offers policymakers the opportunity to devote those resources to areas where they are more likely to have a positive return on investment.

One promising place to redirect funding from underperforming efficiency programs is research and development and basic science in the energy sector. Because the benefits to society of innovation tend to be higher than the narrow, private benefits the innovation accrues to the inventor, private firms under-invest in innovation. There is therefore a clear and beneficial role for federal spending in this area.

**Closing Argument**

Energy efficiency appears to be an attractive solution to America’s energy challenge, with its dual promises of reduced local and global pollutants and lower energy bills. However, existing U.S. energy efficiency programs have failed to make good on these promises. Energy efficiency programs in the United States have substantially over-promised and under-delivered, with some, such as WAP, ultimately proving to have a negative return on taxpayers’ investment. That said, there are ample opportunities to improve U.S. energy efficiency spending. In an ideal world, Congress would pass pollution pricing—such as a carbon tax—and obviate the need for federal subsidies for energy efficiency retrofits. In the absence of pollution pricing, energy efficiency retrofit subsidies can improve overall well-being, but must be targeted towards cost-effective investments. To do so, DOE and, where relevant, state program administrators, should require retrofit programs to incorporate data from rigorous ex post evaluation to determine which energy efficiency measures to invest in, and uncover potential flaws in program design. These evaluations should be conducted by independent evaluators using state of the art methods such as randomized controlled trials. Before applying new measures or technologies, these measures should first be piloted with a small sample of real consumers before being deployed at scale. When piloting is not possible, programs should begin with a combination of existing evidence on similar technologies and engineering estimates, and conduct ex post analysis after deployment. This approach would help to prevent costly, ineffective investments; help the government discover which energy efficiency retrofits deliver cost-effective energy savings and greenhouse gas reductions; and identify implementation failures that undermine program effectiveness. This approach to energy efficiency will help the United States reduce carbon emissions and mitigate climate change, while enabling it to maintain high standards of living supported by the American energy system.

40 Davis, Martinez, and Taborda, “How Effective Is Energy-Efficient Housing?”
41 Burlig et al., “Machine Learning from Schools about Energy Efficiency”
42 Fowlie, Greenstone, and Wolfram, “Do Energy Efficiency Investments Deliver?”
43 In response to this research on WAP, its proponents claimed that a negative cost-benefit calculation should not be sufficient reason to suggest the program be reformed, because the program was also providing benefits to low-income households. However, this logic is flawed: it would have been much cheaper to simply provide these low-income households with the per-household costs of the program in cash, if the goal were poverty alleviation.
45 Christensen et al., “Decomposing the Wedge.”
To meet the challenge of climate change, U.S. transportation emissions will need to fall significantly. Policymakers can take several steps to address structural flaws in the standards and increase their effectiveness. These include eliminating footprint-based standards and the distinction between cars and light trucks, both of which tend to incentivize larger vehicles; easing trading for compliance credits, which will make the compliance market more attractive and efficient; and making it more difficult for auto companies to manipulate vehicle performance data.

Heart of the Problem

The transportation sector is the largest source of energy-related greenhouse gas (GHG) emissions in the United States. Indeed, while the United States has made significant progress in reducing emissions since the first standards were promulgated in the 1970s, they have not achieved the level of emissions reductions expected. Consumer trends have favored light trucks, especially SUVs, and larger cars in general—vehicles that get lower fuel efficiency overall—undermining the effectiveness of the standards. Moreover, the fuel efficiency gains achieved have come at a higher price than could have been achieved through other policies.

Four Proposals to Improve the Design of Fuel Economy Standards

Koichiro Ito, Associate Professor, Harris School of Public Policy

The United States is a nation of drivers. From the road trip to the school run, cars and trucks play an outsized role in American culture and daily life. All this driving, however, makes transportation one of the country’s most important sources of air pollution and greenhouse gas emissions. Fuel efficiency and tailpipe emissions standards are well-known tools intended to reduce the environmental impact of U.S. vehicles. While they have had a significant effect on emissions since the first standards were promulgated, they have not achieved the level of emissions reductions expected. Consumer trends have favored light trucks, especially SUVs, and larger cars in general—vehicles that get lower fuel efficiency overall—undermining the effectiveness of the standards. Moreover, the fuel efficiency gains achieved have come at a higher price than could have been achieved through other policies.

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If the United States is to make significant progress in reducing its overall carbon emissions, it must finally address transportation in a meaningful way. To do this, it must implement policies capable of sharply reducing GHG emissions from passenger cars and light trucks, which account for nearly 60 percent of U.S. transportation emissions, as well as medium- and heavy-duty trucks, which account for an additional 23 percent of transportation’s total.

To date, the single most important U.S. policy regulating fuel consumption and GHG emissions in the transportation sector has been fuel economy standards. Created by Congress in 1975 and modified a number of times in the decades since, these standards regulate the amount of fuel that cars and light trucks sold in the United States consume per mile of travel. As the standards tighten periodically (reducing the targeted amount of fuel consumed per mile of travel), the goal is that overall fuel consumption—and therefore emissions—will also be reduced.

Yet, despite some important progress, it is difficult to argue that the current approach matches the challenge of climate change. A major programmatic reform introduced in 2011 by President Barack Obama’s administration sought to directly target GHG emissions from cars along with setting more stringent fuel economy targets. It has delivered significantly lower fuel savings than hoped thus far due to low oil prices and surging sales of inefficient vehicles.
Real-world data illustrate the problem. First, annual sales of light trucks are far higher than the agencies expected when the rules were first written and fuel savings were calculated. Using a revised definition of light truck, regulators expected the market share of light trucks to fall from 38.9 percent in 2012 to 36.4 percent in 2018. Instead, the truck share has actually risen every year since 2012, reaching 39.1 percent of the market in 2018. Second, in part as a result of this shift toward trucks and away from cars, vehicles have gotten larger than agencies projected. The fleet-wide average footprint (defined as the rectangle formed where all four wheels touch the ground) increased over the course of the last several years, reaching 50.4 square feet in 2018. This trend was the opposite of what regulators expected; they projected that average footprint would decline from 48.6 square feet in 2012 to 47.9 square feet by 2018. It is worth noting that a portion of this increase was driven by an increase within the car category, which appears to support the academic literature touting footprint-based standards, such as those currently in place in the United States, to increased vehicle size. Together, these trends have directly undermined efficiency and fuel savings. For example, according to the Environmental Protection Agency’s (EPA) most recent evaluation of automakers’ performance under the current standards, the model year 2018 fleet of passenger vehicles sold in the United States achieved efficiency of 35.1 miles per gallon (mpg) in GHG-equivalent terms, including all credits and bonuses. While this reflects notable improvement from the 2012 level of 30.1 mpg, it is well short of the originally projected 2018 level of 38.3 mpg. Critically, this variance is not the result of technological barriers. Rather, as EPA noted in one recent report, it was due to the fact that “the industry-wide truck fraction of the fleet is higher than projected in the rulemaking analyses.”

Some recent research suggests that these shortfalls have caused the program to deliver fuel savings that are more than one-third smaller than originally projected in the most recent model years. Despite more than four decades of regulation, aggregate transportation GHG emissions are not declining in any significant way. Instead, they have increased by 36 percent since 1980, and total, annual transportation emissions in 2018 and 2019 were among the highest in U.S. history. In addition to these shortfalls, whatever fuel and emissions savings the standards do produce are expensive when compared to other policies. According to one analysis, for example, the cost per gallon saved through a fuel economy standard is three to six times higher than a gasoline tax. Another study compared fuel economy standards to fuel taxes and confirmed that taxes were the lower-cost way to achieve the same fuel use reductions. This finding held even in light of the possibility that some consumers would not fully take fuel prices into account when purchasing new vehicles, and was actually bolstered after taking into account differences in vehicle longevity and on-road fuel economy.

In practice, however, fuel economy standards are a more popular policy than a carbon tax or a gasoline tax. Ostensibly, this is because the cost of the fuel economy standard is difficult for a typical consumer to observe, whereas the cost of a tax is more transparent. The result is that political opposition to the tax is much higher. This is true even though the fuel economy standards are likely to impose higher costs—both on automakers and consumers—than fuel taxes. The result is that these standards are likely to remain the primary option to regulate fuel consumption from cars and trucks for the foreseeable future.

There have been three major milestones in U.S. fuel economy policy: (1) their introduction in 1975; (2) a set of major structural changes enacted into law in 2007; and (3) a major program overhaul in 2011 following Massachusetts v. EPA. Each of these milestones resulted in consequential policy changes that will shape U.S. policy in the transportation sector over the coming decades and are, therefore, of high importance to the Biden administration.

The United States enacted its first fuel economy regime as part of the Energy Policy and Conservation Act of 1975 (EPCA). Implemented in the wake of the 1973-74 oil embargo, which rocked the global market as oil prices tripled, EPCA established Corporate Average Fuel Economy Standards (CAFE) for all cars sold in the United States.

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referred to as the National Program, and its initial set of standards covered model years 2012-25.14 Fuel economy regulation has by any measure produced important economic, energy, and environmental benefits in the United States. Indeed, the benefits in the form of reduction in criteria pollutants, GHG emissions, and petroleum use are estimated to be in the billions of dollars.15 The efficiency of the entire, on-road U.S. passenger car fleet stood at just 14 mpg in 1977, the year before the first U.S. standards came into effect; in 2018 it stood at 27.7 mpg.16 Light truck fleet efficiency increased from 11.2 mpg to 20 mpg over the same period.17 Though technological development and competition played important roles, it is difficult to deny that policies targeting fossil fuel consumption in transportation have been central to the per-vehicle reductions in fuel use and GHG emissions in today’s fleet.

At the same time, the current approach to vehicle regulation—attribute-based efficiency standards with separate schedules for cars and light trucks—is highly inefficient and unnecessarily costly. It is therefore also unlikely to be adequate as a means to achieve the substantial reductions in transportation-related GHG emissions needed to reduce the odds of disruptive climate change. Redesigning key elements of the standards can increase the net benefits of the policy and better achieve the goals of reducing fuel usage and GHG emissions.

What To Do
There are appealing opportunities to help CAFE get more bang for the buck by redesigning the regulation. Policymakers should begin by tackling four critical priorities.


16. ORNL, Transportation Energy Data Book. 17. 14
that the fuel economy target has declining “steps.” When a vehicle reaches a certain weight threshold, the required fuel efficiency drops.

The figure shows that automakers have strong incentives near the edge of each step to increase car weight to move up to the next weight category. Moving up to the next weight category substantially lowers the fuel economy target. This implies that automakers can comply with the fuel economy regulation without making costly investments to actually improve the fuel economy of their cars.

Figure 4 shows that Japanese automakers did indeed respond to that incentive. The tall spikes in the figure show that many more cars than one would otherwise expect cluster at the low end of each step, indicating that car companies increased the weight of those models to be able to reach the next weight category with a lower fuel economy target.

Figure 5 shows the same analysis over a second time period, in which Japanese regulators raised fuel efficiency standards while maintaining a step-wise reduction in standards as vehicle weight rose. Sure enough, automakers responded to the implicit incentives of the standards there. Companies selling in the United States took advantage of the attribute-based regulation in this country to shift sales from passenger cars to light trucks.

Based on data from NHTSA, the fleet-average mpg in 1979 were 18 mpg for light trucks and 19 mpg for domestic passenger cars. In 2019, these numbers were 29 mpg for light trucks and 41 mpg for domestic passenger cars. That is, although both vehicle categories experienced increases in fuel economy over the last forty years, fuel economy for light trucks did not improve as fast as it did in passenger cars.

Incentivizing larger vehicles has consequences beyond fuel economy. One of the most consequential is an increase in mortality from traffic accidents. In the event of a traffic accident, heavier automobiles are safer for the occupants of the vehicle but more dangerous for pedestrians or the occupants of other vehicles. An increase in vehicle weight of 1,000 pounds is associated with a 0.09 percentage point increase in the probability that the vehicle is associated with a fatality, compared to a mean probability of 0.19 percent. Overall, researchers estimate that this policy-induced weight increase resulted in a 3.4 percent increase in fatality in traffic accidents.

In addition to the social costs of higher fatality rates, this research also calculates the economic cost of this attribute-based fuel economy regulation. The attribute-based fuel economy regulation was 3.5 times more costly than an efficient fuel economy regulation without attribute basing to produce the same amount of fuel economy improvement in the society.

POLICY
Eliminate the distinction between cars and light trucks.

A second important form of attribute-based regulation in U.S. fuel economy policy is the substantially different fuel economy targets for passenger vehicles and light trucks. For example, the fuel economy targets in 2012 were 32.7 mpg for passenger cars and 25.3 mpg for light trucks.

The light truck category has existed since 1979. Figure 6 shows that the rise in the market share of light trucks, which includes SUVs, coincides with this timing. The light truck share was approximately 20 percent in 1979 but was more than 72 percent in 2019 in the U.S. auto market. Like Japanese automakers, which made heavier vehicles in response to the implicit incentives of the standards there, companies selling in the United States took advantage of the attribute-based regulation in this country to shift sales from passenger cars to light trucks.

There is no economic rationale that can justify less stringent fuel economy regulation for SUVs than other passenger cars. The Biden administration should therefore seek to eliminate the distinction between the two vehicle types for the purposes of setting fuel economy standards.

The Energy Policy and Conservation Act (EPCA), which first established fuel economy standards, empowered NHTSA to set separate standards for passenger cars and light trucks. The law is less clear, however, on whether the standards need to be different. The Biden administration therefore has two options. First, it can work with Congress to amend EPCA to eliminate the distinction between the two vehicle types under the law and create a single standard for all passenger vehicles. Or, second, the Department of Transportation can take advantage of the existing ambiguity in the law to establish separate but identical fuel economy standards for both vehicle types, de facto eliminating the distinction between them.

POLICY
Stimulate trading of compliance credits.

The National Program included a notable innovation: compliance trading. Each year, automakers are assessed on whether their fleet efficiency (GHG or fuel economy) has met its target based on the mix of vehicles it sells. If fleet efficiency outperforms the target, then the
automaker receives credits for the surplus. If instead its fleet efficiency does not meet the target, then the automaker must either buy credits or rely on prior year surpluses to fill the requirement. The credits and trading for GHG emissions are managed by EPA. NHTSA manages fuel economy credit trading.

The balance of this discussion focuses on the EPA credit system, as it is the more important regulation under the current rules.

Under the current regulations, EPA credits can be traded across manufacturers. Trading improves the market by allowing each automaker to specialize in what it’s best at without compromising on the overall fuel standards for the fleet. The costs of improving fuel economy vary widely across automakers. Some automakers have relative expertise in producing and marketing fuel-efficient vehicles, whereas for other automakers it can be much harder. With compliance trading, investments are made where the cost of improvement is lowest, achieving the targeted aggregate level of fuel economy at lowest total cost.

Similarly the current standards allow automakers to bank and borrow credits across years. This compliance trading across years creates a similar benefit to compliance trading across firms. Automakers can smooth year-to-year fluctuations in demand driven by macroeconomic shocks, changes in gasoline prices, and other factors. The banking and borrowing also provides stability for the permit market, helping to avoid permit price spikes and crashes, and mitigating concerns about market power in permit markets.

Figures 7 and 8 illustrate how a trading system can help smooth differences between firms and over time. Figure 7 shows that many automakers generated large surpluses from 2012–15—that is, they easily met the fleet-wide fuel economy standards, earning credits for coming in well under the requirement. In 2016, however, many automakers fell short of the standard, requiring them to apply their own credits from the past or buy credits from other automakers. This shows an example of why the credit trading system is important. Because automakers can trade their credits between the past and future, and between firms, they were able to smooth the marginal compliance cost across years and across firms. If the compliance trading did not exist, the marginal compliance costs would have been much higher in 2016.

Figure 8 shows the total annual stock of credits by manufacturer. Figure 9 shows the total annual stock of credits across automakers.

which are more reliant on trucks, have relatively fewer credits. In theory, the differences between automakers should create the perfect conditions for trading to begin to sprout up in a major way. Rather than seek expensive emissions reductions in their truck fleets, automakers with deficits could seek out more efficient firms and buy their credits to comply.

However, to date, trading between firms has been held back partly because there is no real platform for trades or transparent price discovery. Trades occur on a one-to-one basis, and the transaction details are kept secret. As a result, trading has been relatively modest, equal to just 7 percent of available credits in model year 2018.

Classic economic theory implies that it is important to reduce transaction costs to make compliance trading practical. To make it easier for companies to trade their credits, Congress should work with regulators, industry leadership, and environmental groups to create a transparent auction market mechanism, similar to the ones being used in wholesale electricity markets. Automakers would use the market to submit their selling and purchasing bids on compliance credits, making compliance trading more transparent and efficient. For example, EPA does not currently disclose information about the credit prices of traded credits, which makes it difficult for automakers to decide to use the compliance trading. More transparent information about the market outcomes should improve the use of this important market.

POLICY

Prevent automakers from manipulating their fuel economy ratings.

For fuel economy regulations to be effective, the fuel economy data reported by automakers must be accurate. A series of recent scandals revealed, however, that automakers often manipulate their fuel economy data to meet fuel economy standards. Recent studies show that on-road fuel economy ratings are in fact significantly worse than official ratings. One study found that official fuel economy ratings were overstated by 30 percent to 90 percent compared to actual, on-road fuel economy ratings in recent years, and such mis-reporting is both common across automakers and getting worse over time.

The Biden administration can take three critical steps to prevent automakers from manipulating their fuel economy ratings. First, DOT should work with EPA and automakers to design a fuel efficiency test cycle that better reflects real-world driving conditions. Doing so
would not only ameliorate the wide and growing disparity illustrated in Figure 11, but also make it easier to attribute any remaining disparities to causes other than simple misalignment between the test and the real world. Second, the administration should work with Congress to amend the law governing fuel efficiency standards to require either EPA or DOT to oversee fuel economy testing directly. Currently, automakers test fuel economy to require either EPA or DOT to oversee fuel economy and should be significant enough to create an incentive for automakers not to manipulate their ratings. The penalty to existing penalties automakers must pay for failing to meet their fleetwide fuel economy standards. The penalty should be significant enough to create an incentive for automakers not to manipulate their ratings. The penalty would be in addition on-road performance. This penalty would be in addition to any remaining disparities to causes other than simple misalignment between the test and the real world.

Closing Argument
Fuel efficiency regulations are not perfect policies for reducing emissions, but there are steps that policymakers can and should take to make them more effective. Decoupling standards from vehicle size and type will eliminate implicit incentives for automakers to build bigger vehicles. Establishing a formal, transparent market to trade emissions credits will help the industry reduce emissions at the lowest possible cost. And, promulgating new rules to bring emissions testing under the direct supervision of regulators rather than car companies themselves, and imposing tough penalties for violations, will deter cheating and increase trust in the system. Short of imposing a carbon tax, these are the next-best steps that policymakers can pursue to cut vehicle emissions without imposing undue hardship on automakers and consumers.

REFERENCES


FIGURE 11
Gap between On-Road and Official Fuel Consumption per Firm

Source: Reynaert and Sallee (2020).
Coal has been an essential fuel for American economic development since the 19th century. Even today, it is responsible for approximately 25 percent of U.S. electricity generation.1 U.S. coal mines generate approximately 45,000 direct jobs2 and approximately $1 billion of tax revenues annually.3 Every state in the country has a coal mine or coal-fired power plant, or is connected to an electric grid that transmits power derived from the combustion of coal. Despite continuing competition from natural gas, the U.S. Energy Information Agency (EIA) projects that coal combustion will still provide 700 billion kilowatt hours (kWh) in 2050 in direct electricity production, meaning that, under current trends, coal will still be a significant source of energy in this country for decades to come.4

However, the environmental, public health and economic damages from coal mining and coal combustion justify accelerating coal’s exit.5 To address the problems of climate change and other forms of air pollution, the Biden administration can apply the social costs of carbon, methane, particulate matter, and other air pollutants to inform decisions about how much federal land to lease for coal mining and the acceptable level of emissions from coal-fired power plants.

In addition, to protect the communities near existing mines, the Biden administration can revise protections for waters around mines and ensure that land surrounding retired mines is restored to a useful and safe condition. It can also promulgate regulations and create incentives to rectify both legacy land contamination and current threats to groundwater from coal combustion byproducts, commonly known as coal ash. Cleanup projects at former mines and current coal ash ponds can employ current and former workers in these industries to help smooth the financial transitions away from mining for them, their families, and their communities.

The climate impacts of coal usage are severe. In its 2020 Annual Energy Outlook, EIA estimates that on current trends coal will provide approximately 875 billion kWh of electric power in 2020 and approximately 700 billion kWh in 2050, an approximately 1 percent decline per year.6

Reference:

2. Federal Reserve Bank of St. Louis, “All Employees, Coal Mining.” For specific examples of the significance of coal tax revenues on individual communities, see Moret et al., “The Risk of Fiscal Collapse in Coal-Reliant Communities.”
3. Headwaters Economics, “Coal Extraction,” Table 1.
4. U.S. EIA estimated that coal will provide approximately 875 billion kWh of electric power in 2020 and approximately 700 billion kWh in 2050, an approximately 1 percent decline per year. Annual Energy Outlook 2020, Table 8.
5. See Hendryx & Ahern, “Relations Between Health Indicators,” 669. They find that “high levels of coal production were associated with worse adjusted health status and with higher rates of cardiopulmonary disease, chronic obstructive pulmonary disease, hypertension, lung disease, and kidney disease.”
States will produce approximately 875 million metric tons (MMmt) of carbon dioxide emissions in 2020 (equal to about 58 percent of total U.S. electricity emissions), declining to a still-significant 661 MMmt by 2050. Using estimates of the social cost of carbon from President Barack Obama’s administration’s Intergovernmental Working Group, and applying a 3 percent discount rate, the total monetized damages from carbon emissions caused by coal to 2050 are more than $966 billion—enough to fund the Environmental Protection Agency (EPA) at historical levels for more than a century.19 Read more about the IWG and the social cost of carbon in “Updating the United States Government’s Social Cost of Carbon,” page 50.

Coal mining and combustion are significant sources of other air pollutants that cause public health and environmental problems as well. In 2017, for example, coal combustion for electric power generation was responsible for approximately 45 percent of emissions of sulfur dioxide20 and nitrogen oxide,21 which cause acid rain and serious respiratory diseases.22 EPA estimated that the net present value and serious respiratory diseases.23 EPA estimated that the net present value of the benefits of 4,200 to $35,168 (June 21, 2010).

Problems include lack of impermeable liners, insufficient groundwater monitoring systems, and improper construction and maintenance. See 80 Fed. Reg. at 37,528-28.


Id. at 1,121.

Earthjustice comment at 4, citing 2014 Risk Assessment at 5-5 to 5-4, tbl. 5-3. For details on the negative health effects, see Earthjustice comment at 26 to 29, citing many U.S. EPA reports.

2012 Risk Assessment at 5-5 to 5-4, tbl. 5-3. For details on the negative health effects, see Earthjustice comment at 26 to 29, citing many U.S. EPA reports.

26 Earthjusticecomment at 4, citing 2012 Risk Assessment at 5-5 to 5-4.

27 For details on the negative health effects, see Earthjustice comment at 26 to 29, citing many U.S. EPA reports.

28 Appalachian Voices, “Mountaintop.”

29 Earthjustice comment at 3 (citing EPA, Annual Energy Outlook 2020, Table 13).

30 U.S. EIA, Annual Energy Outlook 2020, Table 18.


33 EPA, “Inventory of U.S. Greenhouse Gas” Table 9-14 and Table 9-4.

34 i.e., the future benefits minus future costs, discounted to the present to account for the time value of money

majority of this total was due to the benefits of 4,200 to 13,000 fewer premature deaths in the United States from lower levels of particulate emissions.14

Coal pollution is not confined to the air. Burning coal leaves behind coal ash, which contains toxic materials and heavy metals including arsenic, lead, and mercury,15 and which can pollute groundwater and surface waters when not disposed of properly.16

Coal-fired power plants in the United States generate approximately 10 million tons of coal ash waste each year,17 which is stored at more than 742 coal ash surface impoundments and 286 coal ash landfills in forty-seven states.18 A survey published in 2019 found that more than 90 percent of coal plants had unsafe levels of one or more coal ash constituents in the groundwater beneath them and that the majority had unsafe levels of at least four toxics found in coal ash in their groundwater.19 In more than a dozen cases, the contamination was so significant that companies were forced to provide alternative sources of drinking water, pay compensation, or both.20 EPA itself... has documented 157 sites in thirty-two states where coal ash management has caused damage to human health and the environment,21 and has determined that, “containment from coal ash in unlined impoundments results in unacceptable risks of developing lung cancer from exposure to arsenic and unacceptable risks of developing non-cancer illnesses from exposure to arsenic, lithium, molybdenum and thallium.”22

Environmental damage from coal mining can also affect public health. Perhaps the most graphic example is mountaintop removal mining, in which miners dynamite the tops off mountains and move the top layer of rock into valleys below in order to recover the coal. In Central Appalachia alone, mountaintop removal has destroyed more than 500 mountains and 2,000 miles of stream channels—roughly the length of the entire Mississippi River.23 According to the Congressional Research Service, the EPA has found that, “The cumulative effects of such surface coal mining operations include deforestation, which has been linked to harm in aquatic communities; accelerated sediment and nutrient transport; and increased algal production, as well as possible human health impacts.”24 Studies conducted in the Appalachian region show that health disparities, including higher cancer mortality rates, higher cardiovascular disease mortality rates, and higher rates of birth defects are concentrated in areas where mountaintop removal is practiced.25

Left un-reclaimed, coal mines cause lasting harm to air, water and land, and present environmental hazards. Air pollution occurs in the form of dust blown by wind26 and emissions from spontaneous combustion27 and mine fires.28 Abandoned mines harm water resources by emitting acid drainage that affects water quality and wildlife.29 Two decades ago, EPA named contaminated water seeping from abandoned coal mine areas, especially from acid mine drainage, as “the most severe water pollution problem in the coal fields of the Appalachian Mountains of the eastern United States.”30 A more recent study reports that acid mine drainage pollutes more than 9,000 miles of streams.31 Drainage from abandoned coal mines can also contain other contaminants—including manganese, selenium and sediments—endangering rivers, especially in the northern Appalachian coal region.32

This is not just an eastern problem, however. A recent study of western states shows that of the total area mined for coal since 1977 in that region, 37 percent remains un-reclaimed.33 While operators and the federal government state that land is still being mined or used for supporting operations,34 some researchers contend that some of that land is actually available for reclamation, but the state governments are not forcing mining operators to begin the reclamation process.35 Moreover, a recent spat of bankruptcies among top coal mining companies in the region has raised significant concerns as to whether sufficient funds will be available to reclaim these lands when operations cease at these sites.36

How We Got Here

As noted above, coal is expected to remain an important power source in the United States until at least mid-century, in large part because it is a relatively cheap and abundant source of energy. It is cheap, however, because the market price of coal does not account for coal’s full costs, measured in terms of the climate and health impacts of air and water pollution, ash disposal, and land reclamation. Failure to consider these social costs has also led the federal government to continue to lease coal from public lands when incorporating these costs would likely have led to ending—or at least significantly reducing—such leasing.


36 Bian et al, “Environmental Issues from Coal Mining,” 207.


38 Western Organization of Resource Councils, Planning for Coal’s Decline.

39 OSûBâ recorded twenty-two percentage points, or approximately 82,000 acres, as “active mining areas,” and seventeen percentage points, or approximately 68,000 acres, as “long-term mining and reclamation facilities.” Id. at 10-11.

40 Id. at 20-24.

41 Id. at 10, 31.
Donald Trump ran on a platform to support coal and other fossil fuels. Once in office, he issued a Presidential Executive Order on Promoting Energy Independence and Economic Growth, which disbanded the IWG and revoked its guidance to federal agencies. As a result, federal agencies in the past two years have taken positions that vary from arguing that they do not have a legal obligation to consider social costs to using much lower social cost values than those of the IWG.

In June 2019, the EPA replaced the Clean Power Plan with the Affordable Clean Energy (ACE) Rule, which among other things changed how the social cost of carbon was calculated. It required the government to take into account only climate damages in the United States (rather than globally) and applied a much higher discount rate (the rate at which future costs are discounted when calculating present value). Taken together, these changes dramatically reduced the official value of the social cost of carbon.

These changes depart from scientifically and economically appropriate methods for monetizing damages caused by CO₂ emissions. According to an amicus brief filed in litigation against the rule in the U.S. Court of Appeals for the D.C. Circuit, “EPA undervalued significantly the economic impacts caused by CO₂ emissions by applying inappropriately high discount rates that none of current market conditions, economic theory, or relevant government directives support.” In addition, by focusing solely on damages to the United States rather than the entire world, EPA “failed to account fully for impacts on U.S. citizens and businesses, misrepresented underlying climate models, failed to consider reciprocity benefits of using a global value, and was wrong as a matter of law.” These errors left “EPA well outside the bounds of reasonable economic methods for monetizing benefits from CO₂ emissions reductions.”

The net effect of the Trump administration’s policies has been to reduce the compliance costs faced by coal-fired power plants, making the plants more economical and encouraging them to run more often or for longer than they would have otherwise. A 2019 study from Harvard University’s Center for Climate, Health and the Global Environment documents the climate impacts of the “emissions rebound effect” while the ACE Rule reduces emission rates at individual coal plants, it is expected to increase the number of operating coal plants and coal-fired electricity generation, leading to overall higher CO₂ emissions compared to no policy. In the long term, longer lives for these coal plants will lead to more air pollution and higher environmental and public health damages than would have been the case otherwise.

Water

Beginning in 2009, the Obama administration launched an effort to update portions of the 1977 Surface Mining Control and Reclamation Act (SMCRA) to protect approximately 6,000 miles of streams and 52,000 acres of forests from mining waste dumped by coal companies in the process of mountaintop removal. The Stream Protection Rule, which the Department of Interior’s Office of Surface Mining Reclamation and Enforcement (OSMRE) promulgated on December 19, 2016, placed new limits on the dumping of waste and debris by coal companies. The Rule also required regulators and companies to complete baseline assessments of nearby ecosystems prior to mining, to monitor affected streams during mining, and to develop restoration plans for waterways in order to return them to their pre-mining state.

Less than a month after President Trump’s inauguration, the 116th Congress under the authority of the Congressional Review Act repudiated the Stream Protection Rule. Now, coal mining companies need only comply with the less-stringent requirements that the Department of Interior established in 1983. According to OSMRE’s 2016 Final Regulatory Impact Analysis, just those annualized environmental and health benefits that could be quantified were worth approximately $110 million in 2020, compared to annual costs to industry of approximately $81 million.

Air Pollution

When Barack Obama became president in 2009, he began working with Congress on a number of environmental initiatives. The legislation with the most direct relevance for coal was the comprehensive Waxman-Manley American Clean Energy and Security Act, which would have, among other things, imposed a price on carbon. Though it passed the House of Representatives—the first comprehensive climate policy to do so—it failed to pass the Senate.

Faced with the defeat of Waxman-Manley, the Obama administration focused on regulatory approaches instead. It conceived an Interagency Working Group (IWG), to calculate the first government-wide social cost of carbon and provide guidance to federal agencies on its use (see “Updating the United States Government’s Social Cost of Carbon,” page 20). The social cost of carbon showed that the true costs of coal use were significantly higher than the sticker price of coal would suggest.

The Obama administration’s furthest-reaching effort was a set of rules designed to limit carbon dioxide emissions from the power sector, which was then the largest contributor to U.S. greenhouse gas emissions. The Clean Power Plan drew on existing authority from the 1970 Clean Air Act and the U.S. Supreme Court decision in Massachusetts v. EPA to impose emission limits on power plants. If enacted, carbon emissions from existing coal-fired power plants would have been 32 percent lower in 2030, 60 percent lower in 2040, and 90 percent lower in 2050. EPA calculated the discounted net present value of the benefits of the Clean Power Plan to be between $25 billion and $45 billion in 2050. The proposed rules faced almost immediate legal challenge, however, and were still under the presidency in January 2017.
For mines closed after SMRCA came into effect, the law requires coal mining companies to return mining sites to “a condition capable of supporting the uses which it was capable of supporting prior to any mining, or higher or better uses following mining.” SMRCA mandates that companies pay to reclaim sites themselves, but it gives them significant flexibility in how they will pay for those reclaims. Under the law, companies are allowed to “self bond” for their future reclamation responsibilities, meaning that they promise to pay for those costs in the future based on their own credit rather than raising bonds up front to ensure sufficient financial resources to reclaim the site if the company does not do so itself. GAO estimated in 2017 that a total of $1.2 billion of coal mining assurances were held as self-bonds, including $425.9 million in Wyoming, accounting for 21 percent of the state’s total bonding.

Often, however, companies attempt to shed financial responsibility for reclaiming their sites when they encounter financial difficulty, liquidating those financial obligations along with others. As the coal industry has faced rising competition from natural gas in recent years, this has become more common. Over the past decade, more than fifty coal companies in the United States have declared bankruptcy; in 2019 alone, eight coal companies filed for bankruptcy. The lack of sufficient bonding can put state regulators at risk. If a company does not do so itself.

Land

The Abandoned Mine Land (AML) fund, established as part of the SMRCA, requires companies to pay into a government-run fund to clean up former mining sites. SMRCA requires “all operators of coal mining operations” to pay a reclamation fee to the AML fund based on the lesser of a fee per ton of coal mined or a fee on the value of the coal in the mine. The AML disburse those funds to states for purposes including but not limited to: public health, safety and property from adverse effects of coal mining practices; and restoring land and water resources and the environment that have been degraded by the adverse effects of coal mining practices. However, the fund can only pay to address sites abandoned or un-reclaimed as of August 3, 1977, the date of SMRCA’s enactment, and the fund has far less money than it needs even for those sites. As of 2019, the fund had $3.3 billion in assets to cover an estimated $110.7 billion in costs, and it received only approximately $150 million in new fees in fiscal year 2019.

For example, “Ohio’s bond pool guarantees $150 million in new fees in fiscal year 2019. Many states attempted to solve the problem through creation of ‘bond pools’ that could be used to cover those costs in the future based on their own credit rather than raising bonds up front to ensure sufficient financial resources to reclaim the site if the company does not do so itself.” GAO estimated in 2017 that a total of $1.2 billion of coal mining assurances were held as self-bonds, including $425.9 million in Wyoming, accounting for 21 percent of the state’s total bonding. Often, however, companies attempt to shed financial responsibility for reclaiming their sites when they encounter financial difficulty, liquidating those financial obligations along with others. As the coal industry has faced rising competition from natural gas in recent years, this has become more common. Over the past decade, more than fifty coal companies in the United States have declared bankruptcy; in 2019 alone, eight coal companies filed for bankruptcy. The lack of sufficient bonding can put state regulators at risk. If a company does not do so itself.

Coal ash, a byproduct from burning coal, is one of the most common types of industrial waste in the United States. In 2008, a massive coal ash spill from a Duke Energy power plant in Kingston, Tennessee released 5.4 million cubic yards of wet coal ash, illustrating the potentially catastrophic risks of this waste. The spill flooded over 300 acres of nearby land, led to an unprecedented fish kill in the Tennessee River and its tributaries, contaminated local waterways with arsenic, lead, and beryllium, and endangered workers tasked with the mass cleanup effort. In the context of the disaster, under the authority of the 1976 Resource Conservation and Recovery Act and 1970 Clean Water Act President Obama’s EPA promulgated the Coal Ash Rule in 2015. The rule imposed obligations for groundwater monitoring of coal ash.

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Despite EPA’s finding that unlined impoundments presented the “greatest risks to human health and the environment.”

When environmentalists challenged the 2015 rule on the grounds that it was not sufficiently stringent, the U.S. Court of Appeals for the D.C. Circuit held that EPA had acted arbitrarily and capriciously in limiting the scope of regulations. It remanded the rule, finding the agency had not sufficiently addressed the risk of unlined coal ash impoundments and erroneously exempted “legacy ponds,” essentially older, inactive dumps, from regulation. 87 A 2018 Coal Ash Rule issued by the Trump administration, which rolled back regulatory oversight, 88 was likewise remanded by the D.C. Circuit in line with its opinion on the 2015 rule. 89

Many of these sites may never be fully protected. In a recent report, Daniel Raimi of the University of Michigan and Resources for the Future observed, “A 2009 study estimates that closing all the nation’s 135 ‘wet’ ash impoundments would cost roughly $3 billion over ten years, and billions more will likely be needed for long-term monitoring and remediation.” Generally speaking, he continued, “no local, state, or federal policy ensures adequate funding for decommissioning. In these locations, plant owners may not be adequately saving for decommissioning, potentially exposing shareholders, ratepayers, and/or taxpayers to unanticipated costs in the coming years.” 90

What To Do

The Biden administration, working in conjunction with Congress, can take several important steps to speed this transition. Those changes, along with the full range of social costs of electricity generation. These figures, including the social costs of carbon and of other air pollutants, should be based on the best available science, incorporate global costs and benefits, and use discount rates that reflect current market conditions and the nature of the problem (e.g., intergenerational effects in the case of greenhouse gas emissions).

• Use the social cost of carbon and other social costs when making permitting, leasing, and other decisions. The Obama administration’s Intergency Working Group on the Social Cost of Carbon may have stated only that officials should consider the social cost of carbon in rulemakings, but the same logic applies to individual permitting and leasing decisions: government officials should understand the full costs of their decisions and incorporate those into their decision-making. Thus, if the programmatic review of federal coal leasing recommended above does not foreclose future leasing, the Biden administration could require officials to consider the full range of social costs when assessing whether to proceed with an individual lease. Officials can give significant weight to those cost-benefit analyses, approving those that are net beneficial and rejecting those that are net negative.

POLICY

To address problems related to water pollution and land contamination from coal mining and coal ash, the administration and legislators could:

• Protect waters from mountain top removal mining. While the Congressional Review Act forbids administrative agencies such as EPA from promulgating “substantially similar” rules to those that Congress has nullified under the Act, such as the Stream Protection Rule, EPA can promulgate a new regulation that uses other approaches to protecting mountain streams. Even better, if politically feasible, would be the new administration to work with the new Congress to pass new legislation that achieves these objectives.

• Eliminate self-bonding. Rather than attempting to reform the self-bonding program, the administration could propose legislation to eliminate the self-bonding option. Under such a law, companies would still need to provide financial assurance, but the law would require them to do so through third-party instruments like bonds or insurance instruments. Financial markets would then use their skills and expertise to assess the potential liabilities and risks, charge

the companies appropriately, and provide the necessary funds for reclamation if a company failed to fulfill its obligations.

• Change the bankruptcy code to make shedding environmental liabilities more difficult. The Biden administration could promote legislation to make it more difficult for companies to shed their environmental liabilities in bankruptcy. The bankruptcy code could instead give privity to public interest claims—past and present—over those of unsecured creditors. Such a change would increase the amount of funds available for reclamation and coal ash cleanup, should mining or power generation companies go bankrupt.

• Provide more funds for reclamation of abandoned lands. To meet the billions of dollars of unmet need for both historical mines and mines that have just shuttered or are about to shutter, Congress should urgently consider shoring up the Abandoned Mine Land fund, and expanding the use of the Abandoned Mine Land fund to mines that shut down after August 3, 1977, the date of SMCRA’s enactment. The Biden administration could work with Congress to increase the amount of funds available for cleaning up abandoned mines, which could be through increasing taxes on mined coal or increased general appropriations. At minimum, Congress should consider allowing for disposal of coal ash only at sites that have sufficient liners and other technologies to protect groundwater, and requiring the relocation of coal ash that is in unlined pits. EPA could also require more extensive and more frequent groundwater monitoring, characterization of groundwater flow, and assessments of actual and potential impacts to surface waters under various scenarios. The Biden administration could eliminate the loopholes that allow existing operations to seek exemptions to stay open and tighten disposal of associated hazardous wastes with coal ash. Finally, the Biden administration should consider developing a Superfund-type program to address legacy sites for which there are no financially responsible parties to cover the costs.

• To assist in a transition away from coal for coal-workers, the Biden administration and legislators should prioritize hiring coal workers for these cleanups. As the United States transitions away from coal mining and coal combustion, workers in those industries need jobs. There may be few other jobs in the near future in the communities in which these facilities reside, and many of these workers have a long and proud connection to the industry. The new administration could support tax credits for companies that hire and retain current and unemployed former coal workers for these positions. According to a July 2020 report by the Western Organization of Resource Councils, surface mining reclamation employment could employ 4,800 full-time equivalent jobs per year, or 65 percent of the current surface mining workforce in the western coal mining region of Colorado, Montana, North Dakota and Wyoming. 50

Closing Argument

On current trends, the EIA predicts that significant amounts of coal will continue to be mined from public and private lands in the years to come, and it will remain a major source of electric power in this country. Staying the course, though, will lead to billions of dollars of public health and environmental damages.

The Biden administration can help to accelerate the country’s transition away from coal mining and coal-fired power generation. Regulators should consider the full social costs of coal use when deciding whether to approve new coal mines on federal lands and how much pollution should be allowed from coal-fired power plants. Environmental officials should develop a new and improved approach for regulating emissions from existing coal-fired power plants. The Biden administration can act on its own—and in conjunction with Congress when necessary—to restore protections to mountain ecosystems, to ensure sufficient funds are available and are spent on reclaiming former mining sites, and to address water and land contamination from coal ash ponds. Those who have worked for years in these industries should have the opportunity to continue working in their communities.

The public health and environmental benefits of reducing CO2 emissions and other air pollutants and of protecting our streams and lands outweigh the benefits of continuing the status quo. With the policy changes recommended above, mining companies and electric power generators companies would no longer be able to shift the burdens of their operations to the environment or people. The Biden administration has a great opportunity to build on technological innovations and market forces to ensure a strong, just and cost-effective transition to a clean energy economy.

REFERENCES


Federal Reserve Bank of St. Louis. FRB Economic Data, “All Employees, Coal Mining.” https://fred.stlouisfed.org/series/CB50232200001


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At the same time, current BLM leases fail to induce timely resource development by allowing firms to acquire leases for minuscule initial prices and then effectively tie up land, without development, for as long as ten years. Moreover, the BLM’s bonding practices, ostensibly designed to ensure that companies restore the surrounding environment when a well is exhausted, have not been revised in some fifty years, leaving them outdated and unequal to the task.

There are a number of changes the Biden administration could pursue to ensure that BLM meets its statutory responsibilities. Specifically, it could raise the federal royalty rate to substantially increase taxpayers’ returns, reduce the standard lease term to speed the rate at which resources are developed, and increase federal bonding requirements to better protect the environment. Each of these steps would also bring federal onshore oil and gas leasing policy into better alignment with that used by state agencies.

HEART OF THE PROBLEM

While the majority of U.S. oil and gas production comes from privately owned mineral resources, federal lands contribute a non-trivial share of U.S. hydrocarbon production. While the largest single federal oil and gas resource is the offshore Gulf of Mexico, considerable volumes of oil and gas are produced from onshore resources managed by BLM. In 2019, for example, 0.8 million barrels (mmbbl) of oil and 9.1 billion cubic feet (bcf) of natural gas were produced per day from onshore federal land, equal to 6 percent of total U.S. oil production and 8 percent of total U.S. natural gas production. At the average prices prevailing in 2019, these produced resources were collectively worth $25 billion during 2019.

Note: The average royalty rate in each state is the average of the lowest and highest royalties used in state auctions. Primary terms are identical for all auctions in each state except TX, which sometimes uses three years. The minimum reserve price is the lowest reserve observed in each state’s auctions. The highest reserve observed in NM is $1,875/acre, and the highest reserve observed in TX is $5,000/acre.

Sources: Louisiana Department of Natural Resources; North Dakota Department of Trust Lands; New Mexico State Land Office; Texas General Land Office; Bureau of Land Management.


BLM is directed by statute to generate a market-based return to taxpayers—especially when compared to leases used in markets for state-owned and privately owned resources.4 A mineral lease is a contract that specifies, among other things: a primary term that dictates the length of time a lease will be in effect; an up-front payment called the bonus paid to the government at the start of the term; a royalty that dictates the share of oil and gas production revenue that flows to the government; and annual delay rental payments.5

A lease term together allow firms to sit on land for a decade in “option” or “corridor” status and avoid the cost or, for instance, $60,000 to plug and abandon a well.6

Law of averages also depends on the policy that governs whether, where, and when oil and gas resources are developed. This leasing process is a critical stage that governs the extent to which the local environment is protected. This chapter documents several ways in which current federal oil and gas leasing policy fails to deliver both statutorily required “market based” financial returns and necessary environmental protections to mineral owners—in this case, U.S. taxpayers—especially when compared to leases used in markets for state-owned and privately owned resources.

A lease term together allow firms to sit on land for a decade in “option” or “corridor” status and avoid the cost or, for instance, $60,000 to plug and abandon a well.6

5 Each of these leases has an at-risk state-managed mineral leasing program in which the state decides whether to lease and at what price. BLM oil and gas leases require a 10-year primary term, a 12.5 percent (one-eighth) royalty, and a reserve price of $2/acre. Figure 1 compares these terms to those used by four major oil and gas producing states—Louisiana, New Mexico, North Dakota, and Texas—when they lease their state-owned minerals. Relative to the BLM, all four states use a shorter primary term and a larger royalty. While the auction reserve prices in Louisiana and North Dakota are comparable to those used by BLM, New Mexico and Texas impose substantially higher reserve prices on bidders for their state-owned resources.

The differences between BLM and state oil and gas leasing policies reduce the revenue that the federal treasury receives from its oil and gas resources, and at the same time fail to expedite resource development. The low BLM royalty substantially curtails the value that the federal treasury can recover from the public’s oil and gas resources, and the low reserve price and long primary term together allow firms to sit on land for a decade in exchange for a negligible up-front payment and similarly small annual delay rental payments.

BLM’s oil and gas policies also affect the potential for damage to the environment and who pays for environmental liabilities. Once an oil or gas well is drilled, the well will produce oil and gas for many years, gradually depleting the underground reserves. Eventually, the well will reach the end of its economic life once production revenues are too low to cover the well’s ongoing operating cost. At that point, the well is “shut in” to turn off production. However, a shut-in well poses hazards that can harm people’s health and damage the environment. For instance, even after it is shut in the wellbore can remain filled, up to the surface, with oil, gas, and brines from the underground formation. These fluids may contain heavy metals or chemicals potentially linked to cancers and developmental problems.7 Should these fluids leak, they will harm the environment around the well and potentially affect surface or groundwater resources downstream. To prevent such damage, shut-in wells must be decommissioned by a process known as plugging and abandonment (P&A). An important role for mineral policy is to ensure that firms properly decommission their wells at the end of their economic life. The BLM and all oil and gas producing states mandate that operating firms P&A their wells at the end of their economic life. However, BLM makes it relatively easy for firms to avoid the cost of doing so by declaring bankruptcy—thereby leaving taxpayers to foot the bill for their “orphaned” wells. Current regulations address this well-known “judgment-proof problem” by requiring firms to post a bond, prior to drilling the well, which covers the expected decommissioning liability. However, relative to other oil and gas producing states, BLM’s required bond amounts are low and insufficient to cover P&A costs. The end result is that federal taxpayers are exposed to these costs instead.

Oil and gas will play significant roles in the U.S. and global economies for decades to come, and during that time the United States is likely to remain one of the world’s most important producers. The Biden administration should take urgent steps to ensure that taxpayers are receiving a fair return for these vital public resources, and that both current and future generations do not suffer preventable environmental harm from them.

How We Got Here

BLM’s mineral leasing program is part of its “multiple-use and sustained yield mission,” as mandated by the Federal Land Policy and Management Act (FLPMA) of 1976. The FLPMA defines “multiple use” as “management of the public lands and their various resource values so that they are utilized in the combination that will best meet the present and future needs of the American people.” Per the FLPMA, multiple uses include:

- Protecting “the quality of scientific, scenic, historical, ecological, environmental, air and atmospheric, water resource, and archeological values”;
- Ensuring that “the United States receive fair market value of the use of public lands and their resources”; and
- Managing public lands “in a manner which recognizes the Nation’s need for domestic sources of minerals, food, timber, and fiber.”

BLM is therefore statutorily obligated with the challenge of balancing at least three objectives that have the potential to conflict with one another: developing the country’s natural resources, ensuring fair value for taxpayers, and preserving the natural environment.

BLM’s oil and gas leasing process touches on each of the following dimensions: BLM’s governance of the public lands and their various resource values; the extent to which the public lands sustain multiple uses; the extent to which the local environment is protected; and the extent to which the policies produce a fair return to federal taxpayers.8


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<th>Bond Required for One Well</th>
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Sources: Louisiana Department of Natural Resources; North Dakota Department of Trust Lands; New Mexico State Land Office; Texas General Land Office; Bureau of Land Management.


4 BLM is directed by statute to generate a market-based return to taxpayers. See C.B.O., “Increasing Federal Income from Crude Oil and Natural Gas,” and the Federal Land Policy and Management Act (FLPMA) of 1976.

these three land management objectives. In order to do
velop oil and gas on federal lands, the BLM enters
nto mineral lease contracts with oil and gas companies.
ese leases are similar in structure to those used by
both private mineral owners and state agencies
ponsible for managing state-owned minerals. First,
royal and gas leases encourage resource development
by granting specialized oil and gas firms the right
to drill wells that explore for, develop, and produce
underground hydrocarbon reserves. Leases ubiquitously
include a habendum clause that gives the firm only
a finite time period, known as the primary term, to
 commence production. If the firm fails to develop the
leases by the end of the primary term, it loses the
lease and all development rights. Second, leases collect
revenue for taxpayers by charging firms an up-front cash
bonus (due at lease signing) and by collecting a royalty
share of all revenue generated by the sale of oil and gas
production. Finally, drilling permitting policies endeavor
to protect the environment by requiring firms to post
a bond prior to drilling. 9 Bond is only returned to
the firm when the drilled well is safely plugged and
abandoned—and the well site fully remediated—at the
end of the well’s productive lifetime.

The BLM’s leasing procedures and policies for setting
parameters such as the royalty, primary term length,
minimum bonus bid, and bond amount are governed by
the FLPMA and the Mineral Leasing Act (MLA) of 1920,
which was last amended in 1987. 7 The MLA requires
the BLM to award oil and gas development leases through
competitive auctions, in which firms submit bids for
the cash bonus but other lease terms such as the royalty
and primary term are pre-specified by the BLM. The
statutory minimum bid requirement is $2 per acre. In the
event a parcel fails to win a minimum bid, the MLA then
prescribes a “non-competitive” award process in which a
lease may be granted to a firm for a nominal fee, on a first-
come, first-served basis.

In either case, the awardee obtains a mineral lease in which
the primary term is specified by the MLA to be ten years.
Each year prior to drilling, the MLA then specifies that the
lessee pay a minimum rental fee of $1.50 per acre for the
first five years, and at least $2 per acre thereafter. Should
the firm commence production of oil and gas, the MLA
specifies a minimum royalty rate of 12.5 percent. While
neither the FLPMA nor the MLA explicitly requires that
firms post performance bonds prior to drilling, the House
Committee report for the FLPMA recommends that BLM
require performance bonds that guarantee reclamation. 10
The BLM currently sets its royalty rate and minimum
bid at the statutory minima specified in the MLA. The
net result of these regulatory decisions and the other
prescriptions in the FLPMA and MLA statutes is that BLM’s
current leasing policies put little weight on two of the
three land management objectives under its multiple use

8 Private oil and gas leases do not typically require that a bond be held
by the private mineral owner. Instead, the relevant state’s oil and gas
bonding policy applies.
9 The discussion of BLM’s statutory authority versus regulatory
discretion is sourced from B.O. “Increasing Federal Income from
Crude Oil and Natural Gas,” 60.
10 Schwartz, “Federal Land Policy and Management Act (FLPMA) of 1976,”
292-293.

What To Do

There are a number of steps that BLM can take itself,
under current legislation, to better align its terms with
those in private and state-level leasing, and to better
achieve the three land management goals it is tasked
with under federal law. The Biden administration can
also pursue improvements by working with Congress on
amendments to existing legislation.

POrICY

Increase the federal onshore royalty rate.

The royalty rate in any oil and gas lease (federal, state,
or private) dictates the share of all oil and gas revenue
that must be paid to the resource owner rather than be
taken by the lessee firm. The BLM currently imposes a
12.5 percent royalty—the statutory minimum—on all
of its oil and gas leases. This royalty rate falls well below
that used in major oil producing states for leases on
state-owned land. Texas, for instance, imposes royalties
of 20-25 percent on its state-owned oil and gas leases
(Figure 1). This rate is aligned with the 20-25 percent
royalties that are commonly used in private oil and gas
leasing. BLM gets as little as half as much as state or
private landowners for every dollar’s worth of oil and gas
produced from its lands.

While the direct effect of increasing the royalty rate is
to increase the government’s payments from all oil and gas
produced, setting the royalty rate too high can actually
reduce both drilling activity and revenues. Because the
royalty is essentially a tax on firms’ revenues, higher
royalties will discourage the drilling and completion of
ewells. An excessive royalty might mean no drilling and no
royalty revenue at all. Moreover, when leases are awarded,
firms will consider future royalty payments when they
make their bonus bids. If the royalty is high, that will
make leases less attractive to firms and consequently
lower their up-front bids.

The royalty rate that delivers the greatest value to taxpayers
is therefore not 100 percent, but it is not 0 percent either.
When, as is common, lease auctions do not attract a large
number of bidders and the cash bonus is therefore low,
the royalty essentially resurces owner receive value for their
resources rather than losing it to the extraction firm. Bonus
bids alone do a poor job of capturing value for the mineral

11 These statistics were compiled by the authors based on BLM lease
auction data available at https://www.energynet.com/page/
Government_Sale_Results_Previus. Because BLM auctions are
typically open outcry (whether in person or online) there are no formal
data on the number of bidders. Preumably, leases sold for only the $1/acre
minimum bid received only that single bid.
deliver less value to taxpayers than do similarly tasked development over taxpayer value, however, is out of line with that of other major oil and gas producing states. Royalties in Louisiana, New Mexico, North Dakota, and Texas are as high as 50 percent, depending on the size of the firm’s oil and gas sales and take allowable cost deductions for the purpose of royalty valuation. To value oil, for instance, firms can choose to use the price at the first arm’s-length transaction for the oil or use an approved benchmark price such as the New York Mercantile Exchange (NYMEX) price for West Texas Intermediate crude at Cushing, OK. Firms can also elect to take allowable deductions based on actual transportation costs or on price differentials (based in turn on published prices or private exchange agreements), as well as on crude quality differences and some processing costs. All of these choices and more allow firms to select terms that are most favorable to them, at the expense of U.S. taxpayers. Firms are quite sophisticated in how they manage the value received by taxpayers from federally owned oil and gas. Such a low rate is consistent with a desire to emphasize resource development rather than taxpayer value. For instance, one recent study estimated that the probability a lease is drilled would increase by 60 percent if New Mexico’s royalty were zeroed out. BLM’s prioritization of resource development over taxpayer value, however, is out of line with that of other major oil and gas producing states. Royalties in Louisiana, New Mexico, North Dakota, and Texas are at minimum 16.67 percent and can be as high as 25 percent. There is no obvious reason why BLM should deliver less value to taxpayers than do similarly tasked development rather than taxpayer value. For instance, firms can choose to use the price at the first arm’s-length transaction for the oil or use an approved benchmark price such as the New York Mercantile Exchange (NYMEX) price for West Texas Intermediate crude at Cushing, OK. Firms can also elect to take allowable deductions based on actual transportation costs or on price differentials (based in turn on published prices or private exchange agreements), as well as on crude quality differences and some processing costs. All of these choices and more allow firms to select terms that are most favorable to them, at the expense of U.S. taxpayers. Enforcing this web of rules also requires careful audits to ensure that reported arm’s-length transactions are legitimate, increasing the cost of the system for firms and for the government alike. ONRR instead could pursue a simpler and less administratively burdensome approach to royalty valuation: use a liquidly traded, transparent price index—such as West Texas Intermediate or Brent for oil, or Henry Hub for natural gas—as the benchmark for all produced oil and gas. The benefit of such an index is that daily prices can be independently verified by third parties, and the markets are sufficiently deep that they would be extraneously difficult to manipulate. Universal use of an index would also obviate any need to verify transaction records or litigate whether a buyer and seller are truly arm’s-length.

Additionally, ONRR could eliminate deductions for transportation costs, price differentials, or product quality. Although these deductions do increase the value to firms of acquiring a mineral lease in the first place, enforcement requires costly audits, and even after auditing firms will still have some incentive to manipulate them. If deductions are eliminated, potential drilling partners may bid less in certain mineral lease auctions, but the winners of those auctions will end up paying more in royalties.

**POLICY: Increase the rate of tract development by shortening primary terms, increasing minimum bids, and eliminating non-competitive leasing.**

BLM’s standard primary term of ten years gives firms a remarkably long time to hold a lease before developing it. While such a long lead-time might be appropriate for large, offshore deepwater developments that require long construction times, it is excessive for onshore resources that can be developed more quickly. It is also out of line with primary terms used by major oil producing states. As illustrated in Figure 5, the longest primary term used by Louisiana, New Mexico, North Dakota, and Texas when leasing state oil and gas parcels is five years. Three and five year terms are also common in private oil and gas leasing markets. Short primary terms are valuable for two reasons. First, they promote timely resource development, one of BLM’s core objectives. Second, they increase the present value of the revenues earned by the resource owner, despite the fact that short primary terms may lead firms to make lower bids during lease auctions. A recent paper shows that primary terms create value for the resource owner by accelerating drilling, countering the incentive to delay drilling that is induced by the royalty. That is, the royalty and primary term work together as complementary tools by which the resource owner can earn value from its reserves while not inducing the firm to excessively delay resource development.

The ability of firms to obtain a federal oil and gas lease and not develop it for a long period of time, or perhaps not develop it at all, is exacerbated by the low minimum bid of $2 per acre that BLM uses in its auctions, along with the low annual rental payments of $1.50 or $2 per acre. Even in the least desirable, most outlying “wildcat” areas in the earliest days of shale plays, state auctions had minimum bids of $100 per acre or more. In active shale plays today, minimum bids of thousands of dollars per acre are not uncommon. Given the BLM’s low minimum bid, and given the fact that many tracts are leased at the minimum, it is easy for a firm interested in developing a position in an outlying area to acquire a long-term option at near zero cost. If BLM could be sure that the acquiring firm was indeed going to be the best user of the lease for a decade into the future, this situation could be reasonable. However, when a firm wins such a position at the minimum bid, it means that there are currently no other interested parties. When and if such land ever becomes productive, it is quite likely that more than a single firm will have an active interest in it, and there is no guarantee that the firm who bid early, at the minimum bid of $2 per acre, is the best user. BLM’s policy therefore not only deprives the public of value for the land in the initial lease, but it also means that it may not ever be developed as productively—and profitably for the public purse—as possible.

In addition, BLM’s reserve prices are not actually imposed as binding reserve prices in practice. Instead, auctioned parcels that fail to receive a qualifying bid are transferred to BLM’s “non-competitive” leasing program, where they can be leased to firms for no up-front fee at all. In state auctions, in contrast, parcels that do not receive minimum bids revert back to private or state ownership, and are available for future auction at corresponding market terms. Recent research comparing the outcomes of auctions to a similar “non-competitive” leasing market for state minerals in Texas shows that revenues and production from auctions, even those that will be delayed until a future date, can be much higher than that from non-competitive and informal transactions.


Ordin, “Investment and Taxation,” 32, estimates that the probability of drilling would increase from 6 to 34 percent, a 4 percent of royalties were set to zero, a 60 percent increase.


For instance, Kellogg, “The Effect of Uncertainty on Investment,” 1710, finds that firms can mobilize to drill conventional onshore wells in Texas with three months of a significant change in the oil price. Newell, Froist, and Vining, “‘Trophy Hunting’ vs. Manufacturing Energy,” 69, and Newell, and Froist, “The Unconventional Oil Supply Boom,” finds that most of the response of unconventional drilling to price changes comes in the first two calendar quarters of the price change.


14 Although these deductions do increase the value to firms of acquiring a mineral lease in the first place, enforcement requires costly audits, and even after auditing firms will still have some incentive to manipulate them. If deductions are eliminated, potential drilling partners may bid less in certain mineral lease auctions, but the winners of those auctions will end up paying more in royalties.

15 BLM’s royalty rate of 12.5 percent therefore falls well below the rate that would maximize the value received by taxpayers from federally owned oil and gas. Such a low rate is consistent with a desire to emphasize resource development rather than taxpayer value. For instance, one recent study estimated that the probability a lease is drilled would increase by 60 percent if New Mexico’s royalty were zeroed out. BLM’s prioritization of resource development over taxpayer value, however, is out of line with that of other major oil and gas producing states. Royalties in Louisiana, New Mexico, North Dakota, and Texas are at minimum 16.67 percent and can be as high as 25 percent. There is no obvious reason why BLM should deliver less value to taxpayers than do similarly tasked state agencies.

16 Herrnstadt, Kellogg, and Lewis, “Bidding and Drilling,” 32; Ordin, “Investment and Taxation,” 32, estimates that the probability of drilling would increase from 6 to 34 percent, a 4 percent of royalties were set to zero, a 60 percent increase.

For instance, Kellogg, “The Effect of Uncertainty on Investment,” 1710, finds that firms can mobilize to drill conventional onshore wells in Texas with three months of a significant change in the oil price. Newell, Froist, and Vining, “‘Trophy Hunting’ vs. Manufacturing Energy,” 69, and Newell, and Froist, “The Unconventional Oil Supply Boom,” finds that most of the response of unconventional drilling to price changes comes in the first two calendar quarters of the price change.

20 Covert, and Sweeney, “Relinquishing Riches.”
Both federal and state governments require operating firms to decommission wells at the end of their economic life. Because the process is costly, however, firms have an incentive to avoid this obligation. One way they can do so is to transfer a well’s ownership to a poorly capitalized firm that lacks the money required to cover the decommissioning cost. Once the well reaches the end of its economic life, the firm can then declare bankruptcy rather than pay for decommissioning. The ability to avoid environmental liabilities via bankruptcy is an example of the judgment-proof problem, by which firms that can avail themselves of bankruptcy protection have an incentive to take excessive risks. 21

A well that is abandoned by a bankrupt firm then becomes classified as “orphaned” and either remains unplugged—posing an ongoing environmental hazard—or is decommissioned at the public’s expense. Data collected from state agencies indicate that the problem of orphaned wells is widespread. As of 2018, there were 56,600 documented orphaned wells in the United States, and likely hundreds of thousands of additional undocumented orphaned wells. 22 Assuming a minimum cost of $24,000 per well, decommissioning these documented and undocumented wells would cost billions of dollars. Using public funds, states are plugging them at a glacial pace: only 3,956 orphaned wells were reported plugged in 2018. 23

To help prevent orphaned wells, many states and the federal government require oil and gas operators to post a bond—or pay an insurance firm to post a surety bond on their behalf—prior to drilling. The firms only recover the bond once the well is properly decommissioned.

In principle, this bonding requirement can solve the judgment-proof problem, but only if the required bond amount is commensurate with wells’ decommissioning costs. However, BLM’s requirement that firms only post a single, $25,000 bond for each state in which they operate, regardless of the number of wells they operate, effectively requires firms to post a bond sufficient to cover the decommissioning of just one well, at best. Moreover, and as shown in Figure 2, the BLM bonding requirement is substantially weaker than that used in other major oil-producing states. For instance, $25,000 per operator is the smallest bond that the State of Texas requires, and operators of multiple wells pay substantially more.

BLM’s weak bonding policy gives firms both an incentive and an opportunity to escape environmental liabilities via bankruptcy, leaving taxpayers to foot the bill for well decommissioning—or to suffer the health and environmental consequences of orphaned wells. Evidence indicates that firms act on this incentive. Texas’s bonding requirement was not always as high as that shown in Figure 2. Prior to 2001, operators in Texas were able to avoid bonding requirements by paying small annual fees. Starting in 2001, however, Texas required all operators in the state to post bond amounts equal to those shown in Figure 2 (poorly capitalized operators could pay risk-rated premiums to an insurer to post a surety bond on their behalf). These new requirements dramatically changed the distribution of operating firms in Texas and substantially improved environmental performance. 24 Many small operators with poor environmental records left the industry, selling their wells to larger firms. Orphaned wells decreased by a remarkable 70 percent, and violations of state water protection rules dropped by 25 percent.

By following Texas’s lead and strengthening its bonding requirements, BLM could also achieve these benefits on federal lands. BLM can increase its bond requirement by administrative rulemaking, without requiring new statutory authority.

**Closing Argument**

The federal resources managed by the BLM are an important source of U.S. oil and gas production. In 2019, 800,000 barrels of oil and 9.1 billion cubic feet of natural gas were produced per day from federally owned onshore land, collectively worth $25 billion over the course of the year. BLM is entrusted with ensuring that these valuable resources are developed expeditiously, while simultaneously capturing fair market value for the resource owners—U.S. taxpayers—and safeguarding the environment.

While the resources governed by BLM are federally owned, development and extraction is performed by private firms, which have the incentive to avoid environmental liabilities via bankruptcy. BLM’s weak bonding policy gives firms both an incentive and an opportunity to escape environmental liabilities via bankruptcy, leaving taxpayers to foot the bill for well decommissioning—or to suffer the health and environmental consequences of orphaned wells. Evidence indicates that firms act on this incentive. Texas’s bonding requirement was not always as high as that shown in Figure 2. Prior to 2001, operators in Texas were able to avoid bonding requirements by paying small annual fees. Starting in 2001, however, Texas required all operators in the state to post bond amounts equal to those shown in Figure 2 (poorly capitalized operators could pay risk-rated premiums to an insurer to post a surety bond on their behalf). These new requirements dramatically changed the distribution of operating firms in Texas and substantially improved environmental performance. 24 Many small operators with poor environmental records left the industry, selling their wells to larger firms. Orphaned wells decreased by a remarkable 70 percent, and violations of state water protection rules dropped by 25 percent. By following Texas’s lead and strengthening its bonding requirements, BLM could also achieve these benefits on federal lands. BLM can increase its bond requirement by administrative rulemaking, without requiring new statutory authority.

**FURTHER READING**

- **Relinquishing Riches: Auctions vs. Informal Negotiations in Texas Oil and Gas Leasing**
  - National Bureau of Economic Research
  - Oil and gas extraction leases allocated via centralized auctions pay the owners of such extraction rights 67 percent more and produce 44 percent more output than informally negotiated leases.

- **The Economics of Time-Limited Development Options: The Case of Oil and Gas Leases**
  - National Bureau of Economic Research
  - Primary terms can benefit the landowner and increase the total value that the landowner and firm receive together because they accelerate drilling activities.

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21 Raimi, Nerurkar, and Bordoff, “Green Stimulus for Oil and Gas Workers,” 12.
23 Raimi, Nerurkar, and Bordoff, “Green Stimulus,” 12; IOGCC, “Idle and Orphaned,” 44.
24 IOGCC, “Idle and Orphaned,” 5.
25 Boomhower, “Drilling Like There’s No Tomorrow.”
firms. The lease contracts that govern the relationship between BLM and these firms are the key policy lever with which BLM can fulfill its mission, since lease terms can profoundly influence firms’ incentives to drill, the division of revenue between firms and the government, and firms’ incentives to protect the environment.

Across the board, the terms of BLM oil and gas leases favor oil and gas production companies over U.S. taxpayers. They allow firms to capture the lion’s share of oil and gas resources’ value, while at the same time letting them avoid liability for environmental harm. Relative to benchmarks from state-level agencies that manage state-owned resources, BLM leases have low royalties and are at essentially no cost. Finally, while the BLM requires firms to post bonds as a guarantee that the surface environment will ultimately be restored, the size of the bond amounts up to the point that they credibly cover the proper wells’ plugging and abandonment at the end of their useful life. Adopting a stronger bonding requirement will protect taxpayers from footing the bill for decommissioning costs and protect public health from the hazards imposed by abandoned wells.

REFERENCES


Rauni, Daniel, Neelash Nerurkar, and Jason Bordoff. “Green Stimulus for Oil and Gas Workers: Considering a Major Federal Effort to Plug Orphaned and Abandoned Wells.” Joint Report by the Columbia SIPA Center on Global Energy Policy and Resources for the Future (July 2020).


EPIC produces data-driven research that advances society’s understanding of the global energy challenge and translates research insights into real-world impacts through strategic outreach and training for the next generation of global energy leaders.

**Confronting the Global Energy Challenge**

Energy powers the modern world, fueling innovation and improving people’s lives. But humanity’s energy usage is also generating levels of pollution that are substantially shortening people’s lives and causing disruptive climate change. Finding a way to supply the energy needed for human development without risking health or the environment is one of the most important challenges the world faces: the global energy challenge.

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The **Climate Impact Lab** is a first-of-its-kind, multidisciplinary effort working to measure the real-world costs of climate change at a local level. It is also developing the world’s first empirically-derived estimate of the global social cost of carbon, which can be used by governments around the world to set climate policy.

The **Air Quality Life Index (AQLI)** is an air quality metric that converts particulate air pollution measurements into perhaps the most important factor that exists—their impact on life expectancy. The Index allows users to zoom in on any district in the world to see the effects of that district’s air pollution levels on residents’ lifespans.

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