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How Is the US Pricing Carbon? How Could We Price Carbon?

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Abstract

Economists have for decades recommended that carbon dioxide and other greenhouse gases be taxed—or otherwise priced—to provide incentives for their reduction. The United States does not have a federal carbon tax; however, many state and federal programs to reduce carbon emissions effectively price carbon—for example, through cap-and-trade systems or regulations. There are also programs that subsidize reductions in carbon emissions. At the 2022 meetings of the American Economic Association, the Society for Benefit-Cost Analysis brought together five well-known economists—Joe Aldy, Dallas Burtraw, Carolyn Fischer, Meredith Fowlie, and Rob Williams—to discuss how the United States does, in fact, price carbon and how it could price carbon. Maureen Cropper chaired the panel. This paper summarizes their remarks.

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1. Introduction

Economists have for decades recommended that carbon dioxide and other greenhouse gases be taxed to provide incentives for their reduction (Nordhaus 2019). The United States does not have a federal carbon tax; however, many state and federal programs to reduce carbon emissions effectively price carbon—for example, through cap-and-trade systems or regulations. There are also programs that subsidize reductions in carbon emissions. At the 2022 meetings of the American Economic Association, the Society for Benefit-Cost Analysis brought together five well-known economists—Joe Aldy, Dallas Burtraw, Carolyn Fischer, Meredith Fowlie, and Rob Williams—to discuss how the United States does, in fact, price carbon already and how it could do so more effectively. Maureen Cropper chaired the panel. This paper summarizes their remarks.

Meredith Fowlie (Section 2) discusses problems that a carbon tax would present if levied on the US energy sector. As Fowlie points out, setting a carbon tax equal to the social cost of carbon assumes that the prices of carbon-intensive goods reflect suppliers' marginal private costs. In many US states, however, regulated retail electricity and natural gas prices exceed marginal supply costs—in the case of electricity, sometimes by a factor of two to three. Electricity prices have risen to cover the costs of upgrading generation, transmission, and distribution systems and making the grid more resilient to extreme weather events. Adding a carbon tax to these prices would slow the pace of electrification for the clean energy transition and would burden low-income households. Fowlie discusses these issues and suggests that retail rate reform is needed.

Joe Aldy (Section 3) presents an overview of clean energy subsidies that the federal government has provided to reduce carbon emissions. These include investment and production tax credits for renewable energy sources, loan guarantees for renewable power, and state block grants to promote energy efficiency. Aldy discusses the limitations of these subsidies relative to a carbon tax. Whereas a carbon tax would provide a price signal throughout the economy that would tend to equalize marginal abatement costs, clean energy subsidies do not. And because of their limited lifetime, clean energy subsidies do not usually provide dynamic incentives for emissions reductions. Aldy discusses how specific clean energy subsidies could be redesigned to better mimic a carbon tax. He also suggests using formal program evaluation to improve the design of subsidies to reduce carbon emissions.

Dallas Burtraw (Section 4) reviews the barriers to implementing carbon pricing and notes nonetheless that it is important that we price carbon. Pricing carbon encourages cost-effective reductions in greenhouse gases (GHGs), rewards technological innovation to reduce carbon emissions, and helps coordinate activities to decarbonize the economy. To move in the direction of pricing carbon, Burtraw argues for formulating an industrial policy that mimics a carbon tax but is politically acceptable.

One way to do this is to couple regulatory standards with sector-specific subsidies. Tradable emissions performance standards, such as California's Low Carbon Fuel Standard, are an example. Burtraw discusses the extent to which tradable performance standards embody the attributes of a carbon tax.

Carolyn Fischer (Section 5) elaborates on how industries can be subsidized to reduce carbon emissions. Carbon taxes can be rebated to industries to overcome objections that emissions regulations give competitors in unregulated countries an advantage. Rebates can take several forms. In a cap-and-trade system, distributing permits free of charge is a common form of rebating. Rebates can also be given in proportion to output. Fischer notes that output-based rebates mute the pass-through of higher prices due to the cost of emissions reductions. This is generally inefficient compared with a carbon tax; however, if output prices are already distorted (e.g., because of monopoly power), then the efficiency loss may not be as great. Fischer also discusses intensity-based rebates—rebates proportional to reductions in emissions intensity—which have been used to encourage emissions reductions.

Rob Williams (Section 6) concludes by discussing the relationship between the types of carbon policies discussed by Aldy, Burtraw, and Fischer—policies that subsidize carbon reductions—and a federal carbon tax. If a federal carbon tax were levied, should such policies continue or be reduced in scope? A similar question arises with respect to subnational policies such as renewable portfolio standards and bans on natural gas connections in new construction. It is often assumed that these policies are complements to a carbon tax—and therefore should be kept in place. If, however, they are substitutes, the policies should be phased out when a carbon tax is levied. Williams argues that most other carbon reduction policies can be viewed as substitutes for a carbon tax. But a few are complements, and that group includes the utility rate reforms discussed by Fowlie.

2. How Are We Pricing Energy?

The primary source of US anthropogenic GHG emissions is fossil fuel combustion. An economy-wide carbon price would increase fossil fuel prices, thus incentivizing households and firms to reduce their energy consumption and/or switch to less carbon intensive energy sources.

A point of departure for any serious discussion about GHG pricing is asking: What is the right carbon price? In a scenario where the only market failure is the environmental externality, the carbon price should be set at a level that reflects the climate change damages caused—that is, the social cost of carbon. This textbook policy prescription assumes that, absent the carbon pricing policy, the prices of carbon-intensive goods (such as energy) reflect suppliers' marginal private cost. This is the outcome we should expect in competitive markets.

In the United States, however, retail prices of electricity and natural gas are often determined by a regulatory process, not set in a competitive market. In the case of natural gas and electricity, high infrastructure costs imply large economies of scale. To support the production and distribution of energy at an efficient scale, many natural gas and electric utilities are operated as regulated monopolies. The agencies charged with regulating the electricity prices that utilities can charge their customers routinely authorize retail energy prices that exceed marginal private costs so as to allow suppliers to recover their capital investments plus operating expenses (Borenstein and Bushnell, forthcoming; Davis and Hausman 2022).

The extent to which regulated retail electricity and natural gas prices exceed marginal supply costs has been increasing in the United States as capital investment spending in these sectors has been escalating. This escalation partly reflects efforts to upgrade aging transmission and distribution systems. It partly reflects the costs of climate change mitigation, including accelerated investments in renewable energy generation and grid integration. In some parts of the country, it also reflects the costs of climate change adaptation as electric utilities invest in making the grid more resilient to wildfires, rising temperatures, and other climate-related stressors.

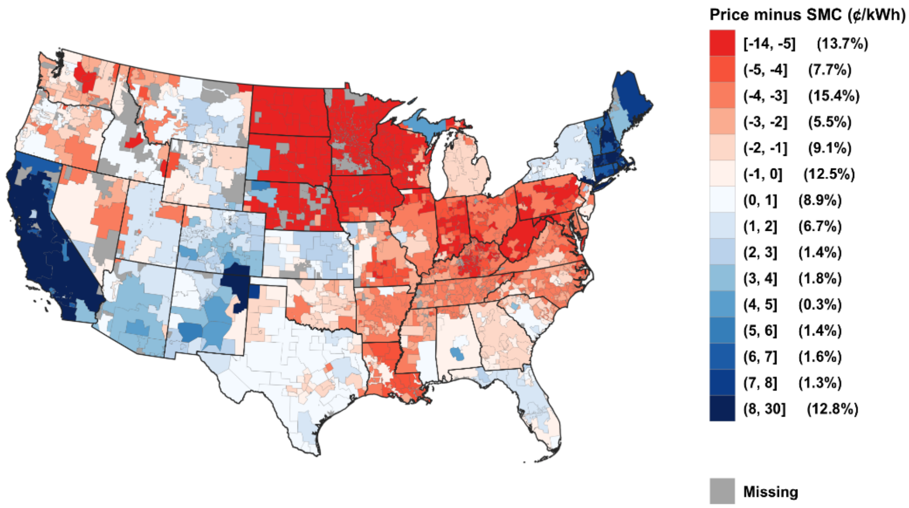
Escalating capital investment costs, together with a regulatory regime that recovers non-incremental costs in volumetric rates, is putting upward pressure on retail electricity and natural gas prices. Retail prices now exceed marginal costs by a substantial margin. A strict application of the textbook carbon pricing prescription would therefore result in retail energy prices that are too high. The current patterns and future trends in regulated residential electricity and natural gas prices have implications for carbon pricing policies going forward.

2.1. Retail Electricity Markets

As retail electricity rates increase across the United States, economists have been paying more attention to the retail pricing distortions associated with contemporary electricity rate regulation. Using detailed data from electric utilities across the country, Borenstein and Bushnell (forthcoming) systematically compare retail prices paid by households in different parts of the country against the economist's preferred efficiency benchmark: the social marginal cost (SMC) of electricity consumption. These SMC estimates capture not only the fuel costs of generating the electricity but also the estimated effects of air pollution–related damages and the social cost of carbon.

Figure 1 summarizes the results of this comparison. Red areas on this map represent regions where retail electricity prices are too low vis-à-vis the social marginal cost. In blue areas, households are paying a price above the social marginal cost.

Figure 1. Retail Electricity Prices Versus Social Marginal Cost



Source: Borenstein and Bushnell (forthcoming).

California is an important jurisdiction to analyze because it has been pushing the frontiers of climate change mitigation and adaptation investments in the power sector. Borenstein et al. (2021), investigating the state's retail electricity rates, find that California households are paying retail prices that are two to three times the SMC. This gap is widening as California prepares to invest billions in wildfire-related grid hardening, new transmission projects, distribution system upgrades, and public purpose programs.

Retail electricity prices that significantly exceed the social marginal cost raise two concerns. First, high electricity prices can slow the pace of electrification, which is expected to play a central role in the clean energy transition. Second, higher electricity prices place an economic burden on lower-income households, which spend a relatively large share of their income on electricity. The current approach to raising needed revenues in the electricity sector will undermine efforts to ensure that the clean energy transition is both just and equitable.

2.2. Natural Gas Markets

Building electrification has an important role to play in economy-wide decarbonization. As building owners switch from natural gas, natural gas utility financing will face a formidable challenge. Just like electric utilities, gas utilities operate as natural monopolies subject to price regulation: they routinely cover fixed costs by raising volumetric natural gas prices above the private marginal costs. On average, the retail price distortion in regulated natural gas markets is smaller than the aforementioned distortion in retail electricity markets (Borenstein and Bushnell 2022). However, this could change as building electrification efforts gain momentum (Davis and Hausman 2022).

A significant share of the nonincremental costs that are recovered in retail natural gas prices are sunk, legacy costs. Absent rate reform, an increase in building electrification will decrease demand for natural gas in the building sector, thus shifting the burden of legacy cost recovery onto a shrinking customer base. This could disproportionately impact low-income households, which spend a larger share of their income on natural gas and are potentially less capable of making capital investments in new electric appliances.

2.3. Retail Rate Reform

Under the current retail energy pricing regimes, state regulators are effectively taxing both electricity and natural gas to raise needed revenues for capital expenditures and investments, imposing a relatively regressive tax on lower-income households. Moreover, high retail electricity prices are slowing progress on electrification. These efficiency and distributional considerations have implications for carbon pricing policies. Thus, when we think about how to price carbon, interactions between carbon pricing and retail energy pricing warrant careful consideration.

3. Pricing Carbon Through Clean Energy Subsidies

Pricing carbon dioxide and other greenhouse gas emissions—explicitly through a carbon tax or implicitly through a market-based instrument like a cap-and-trade program—can promote cost-effective emissions abatement and, if the price equals the marginal social damage of emissions, maximize social welfare. In theory, policymakers could subsidize activities that deliver the equivalent socially optimal outcome as a tax on emission externalities (Baumol and Oates 1988). Realizing such an outcome depends on a strong set of assumptions about abatement technology, the firm, competition, and the nature of subsidy design. Baumol and Oates (1988, 213) note that “although it may be an interesting theoretical construct, it is virtually inconceivable that any such program would ever be adopted in practice. We will see that any plausible systems involve fundamental asymmetries between fees and subsidies.”

This section examines how the design and implementation of clean energy subsidies deviate from carbon pricing. Specifically, it focuses on technology- and industry-specific subsidy designs, their implications for coordinating emissions reductions across the economy, the dynamic incentives of subsidies, and the likelihood that any given clean energy project will claim multiple subsidies. It then suggests that institutionalizing program evaluation may enable policy reforms over time and considers the political economy lessons that subsidies have for carbon pricing politics and policy.

3.1. Clean Energy Subsidy Design

Subsidizing low- and zero-emitting clean energy technologies has been the most politically durable approach to national climate change policy in the United States. The major tax reform of 1986 established accelerated depreciation for renewable sources of electricity; the 1992 Energy Policy Act created the production tax credit for wind, geothermal, and other renewable power sources as well as the investment tax credit for solar; and subsequent laws—the Energy Policy Act of 2005, the Energy Independence and Security Act of 2007, the American Recovery and Reinvestment Act of 2009, the Consolidated Appropriations Act, 2016, the Inflation Reduction Act of 2022—have extended and expanded clean energy tax expenditures and grants (Metcalf 2010; Aldy 2013, Aldy 2022). Various pollution and clean energy markets created through regulation—including state renewable power standards, federal renewable fuel standards and fuel economy standards, and California's low-carbon fuel standard and zero-emission vehicle standard—implicitly subsidize the producers of low- and zero-carbon technologies by providing additional revenues from the sale of credits generated under the rules of these regulatory markets (Aldy 2020b).

Those policy practices deviate from the standard framing of carbon pricing as a technology- and industry-neutral incentive for emissions outcomes. Typically, clean energy subsidies are technology-specific and industry-specific. In many cases, the programs subsidize investment instead of output, although the latter may be more closely related to displacing the emissions externality. Tax expenditures are typically location independent, although the emissions displaced—by, for example, altering the mix of power-generating sources in an electricity market—are location dependent. Large clean energy projects often claim multiple subsidies, although some tax credits require the clean energy developer to have sufficient tax liability to monetize them (Metcalf 2010; Aldy 2013; Johnston 2019; Aldy et al. 2022b). Table 1 presents an illustrative set of clean energy subsidies.

Table 1. Clean Energy Policy Instruments in American Recovery and Reinvestment Act of 2009

Instrument	Example	Score
Cost-shared grants	Smart-grid grants support 100 projects with total investment costs in excess of $8 billion.	$3.4 billion
State block grants	Energy Efficiency and Conservation Block Grants support energy audits, energy efficiency retrofits, transportation programs, etc., by state, local, and tribal governments.	$2.7 billion
Tax credits	Tax filers can claim 30% of residential energy efficiency investments, up to $1,500.	$2.0 billion
Subsidized bonds	To finance renewable projects, government-owned utilities can issue no-interest Clean Renewable Energy Bonds that provide bondholders with tax credit in lieu of interest.	$1.6 billion
Loan guarantees	Section 1705 program provides loan guarantees for conventional and innovative renewable power projects and related manufacturing and transmission	$2.5 billion*
R&D	Competitive program promotes high-risk and high-reward energy innovation through Advanced Research Projects Agency–Energy (ARPA-E).	$400 million
Federal Infrastructure	General Services Agency finances federal facility retrofits through High Performance Green Buildings program.	$4.5 billion

Source: Aldy 2013, Appendix Table 1.

* The Recovery Act initially appropriated $6 billion for the §1705 program, but Congress rescinded $3.5 billion to finance the 2009 “cash-for-clunkers” program (Public Law 111-32) and the 2010 state fiscal aid bill (Public Law 111-226).

Consider the case of tax expenditures for renewable power. Historically, the US tax code has provided a production tax credit for qualifying renewable power sources—wind farms representing the largest technology class claiming this credit—at 1.5 cents per kilowatt-hour of output for the first 10 years a facility is in service.[1] It also provides an investment tax credit, valued at 30 percent of the qualifying investment expenditures, for solar power investments. Although both clean technologies deliver common, zero-carbon electricity, their marginal external benefits vary within and across technology types (Novan 2015; Callaway et al. 2018). Over 2009–2012, wind farms had the option to claim either the production tax credit or an investment grant equal to the 30 percent investment tax credit. The type of subsidy influenced power generation, with investment subsidy claimants producing about 10 percent less power than they would have under the output subsidy (Aldy et al. 2022b). Heterogeneity in output and marginal damages illustrates how such subsidies may fall short of the cost-effectiveness and efficiency associated with carbon pricing.

With modifications, existing clean energy subsidies could better approximate the incentive properties of carbon pricing, although some proposals focused on additional policy objectives may exacerbate the deviation from carbon pricing. For example, the US Senate Committee on Finance (2013) issued a staff proposal to reform energy tax credits so that they would be technology-neutral and performance-based. The proposal would replace the production tax credit with a clean electricity tax credit that pays out as a function of electricity output and the carbon intensity of a facility relative to other power-generating facilities. Metcalf (2021) proposes modifying the production tax credit in a similar way, making the subsidy a function of the social cost of carbon and the relative emissions intensity of the facility.

In contrast, the Inflation Reduction Act of 2022 includes multiple provisions in its extension of the production tax credit (and other clean energy subsidies) that condition the size of the subsidy on non-climate considerations. For example, the law authorizes large tax credits for facilities that satisfy prevailing wage and apprenticeship conditions set by the Department of Labor. The law also provides a bonus credit if construction of the facility surpasses a domestic content threshold.[2]

3.2. Coordinating Emissions Reduction Efforts

Technology- and industry-specific subsidies are unlikely to enable coordination among economic agents in cutting emissions across the economy. With an economy-wide carbon tax, in contrast, the price on emissions serves as an implicit coordination mechanism as the price is passed throughout the economy and influences investment and behavior by households and businesses alike. Such coordination is very difficult—and typically does not occur in practice—under clean energy subsidies. Consider

[1] The per kilowatt-hour subsidy has been adjusted for inflation over time and modified with various phasedown schedules as a function of the date a facility is placed into service.

[2] Refer to §13101 of P.L. 117-69.

electric vehicle (EV) subsidies, which effectively spur fuel switching from gasoline and diesel to the local source of electricity generation. If the local grid is low carbon, then displacing internal combustion engine vehicles with EVs can reduce carbon emissions. As Holland et al. (2016) show, however, in the case of Georgia's generous EV subsidies, the claimants initially drew from a coal-intensive power market that more than offset the carbon emissions savings from reduced gasoline demand.

This problem is not unique to clean energy subsidies. Industry-specific regulatory strategies can likewise suffer from lack of coordination. For example, Fowlie et al. (2012), comparing Clean Air Act regulations focused on cutting nitrogen oxides emissions in power plants and light-duty vehicles, find that power plant regulations resulted in marginal abatement costs double those on the regulated cars. More generally, the large deviations from social marginal cost pricing in electricity (with retail prices exceeding social marginal costs in many parts of the country) and natural gas and gasoline (with retail prices falling below social marginal costs in many places) can weaken incentives to electrify energy services (Borenstein and Bushnell forthcoming).

3.3. Dynamic Incentives of Subsidies

In addition to promoting contemporaneous coordination among agents, carbon pricing can also deliver dynamic incentives that facilitate coordination across time. In contrast, subsidies may fail in delivering such dynamic incentives. First, many subsidies operate over short time horizons because of sunset provisions in their authorizing legislation (Metcalf 2010). The uncertainty this creates may undermine incentives for innovation and the longer-term planning needed for novel technologies and large-scale energy projects. Second, technology-specific subsidies risk locking in the status quo technology, which may have adverse implications for next-generation clean energy technologies (Armitage 2022).

Clean energy subsidies may deliver some positive dynamics, to the extent that they expand the market for producers and thus increase incentives to drive down costs and increase efficiency over time. Failing to account for dynamic spillovers may result in large estimates of the costs per ton of carbon reduced through clean energy subsidies. For example, Marcantonini and Ellerman (2015) find that German solar subsidies reduced carbon dioxide at a cost of about €500 per metric ton. More recent work, however, shows that the ambitious solar subsidies contributed to a dramatic decline in solar panel costs, which enabled much larger take-up of solar power in the United States and beyond a decade later (Gerarden 2022; Gillingham and Stock 2018).

3.4. Multiple, Overlapping Subsidies

Clean energy subsidies operate within a complicated patchwork of energy and climate policies at the federal, state, local, and utility levels. The existing subsidies, regulations, and carbon pricing policies driving investment and operation decisions raise questions about whether any individual subsidy is marginal to those decisions. For example, consider the projects that received loan guarantees through the Department of Energy's §1705 program under the American Recovery and Reinvestment Act of 2009. Table 2 lists all recipients and notes the other tax expenditures, grants, subsidies, and carbon pricing policies from which these projects could secure economic value. All the projects receiving loan guarantees, which lowered the cost of financing their debt, were eligible for accelerated depreciation benefits under the tax code. The renewable electricity projects claimed §1603 grants, which paid them 30 percent of their investment costs. Many of the manufacturing projects received §48 clean energy manufacturing tax credits. Various projects received state tax credits, and the power-generating projects also generated and sold renewable electricity credits under state renewable portfolio standards. Some power generators sold electricity into markets covered by state carbon dioxide cap-and-trade programs, and other projects received other subsidies, such as agriculture biofuel subsidies.

Table 2. Additional subsidies for projects receiving Department of Energy §1705 loan guarantees, 2009–2011

Project	Description	LG	Acc. Dep.	1603	48C	RPS	State Tax Credits	Cap-and-Trade	Misc.
Abengoa Bioenergy	Biofuel plant	X	X						X
Abound Solar	Solar panel manufacturing facility	X	X		X	X			
Agua Caliente	PV solar power plant	X	X		X	X		X	
Alamosa Solar Generating Project	HCPV solar power plant	X	X	X		X			
Antelope Valley Solar Ranch	PV solar power project	X	X		X	X		X	
Beacon Power	Flywheel energy storage plant	X	X			X			X
Blue Mountain	Geothermal power plant	X	X			X			
California Valley Solar Ranch	PV solar plant	X	X	X		X		X	

Crescent Dunes	Concentrated solar plant	X	X		X	X	X	
Desert Sunlight	PV solar plant	X	X	X		X		X
Genesis Solar	Concentrated solar plant	X	X	X		X		X
Granite Reliable	Wind power plant	X	X	X		X		
Ivanpah	Concentrated solar plant	X	X	X		X		X
Kahuku	Wind power plant	X	X	X		X		
Mesquite Solar 1	PV solar plant	X	X	X		X		X
Mojave Solar	Concentrated solar plant	X	X	X		X		X
One Nevada Transmission Line	Transmission line	X	X			X		
Ormat Nevada	Geothermal power plants	X	X	X		X		X
Project Amp	Solar panels on buildings	X	X					
Project Liberty	Cellulosic ethanol plant	X	X		X			
Record Hill	Wind power project and transmission line	X	X	X		X		
Shepherds Flat	Wind power plant	X	X	X		X	X	
Solan (Solyndra)	Solar panel manufacturing facility	X	X			X		X
Solana	Concentrated solar plant	X	X	X		X		

SoloPower	Solar panel manufacturing facility	X	X			X	X
USG Oregon	Geothermal power plant	X	X	X		X	

Notes: Policies and programs that loan guarantee (LG) recipients participated in or were eligible to claim were accelerated depreciation (Acc. dep.); §1603 grant (1603); §48(c) tax credit (48C); state renewable portfolio standard credits (RPS); selling power into power markets subject to CO_2 cap-and-trade (cap-and-trade); other government subsidy programs (Misc.).

In sum, each of these projects claimed many subsidies. Because these subsidies vary by jurisdiction and type, suggesting that any given policymaker—a member of the Senate tax-writing committee, a state electricity regulator—may not fully appreciate the breadth of public policies supporting clean energy deployment. Extending existing subsidies and layering on new subsidies may be inframarginal and thus undermine the cost-effectiveness and the environmental benefits of clean energy spending.

3.5. Subsidy Program Evaluation and Climate Learning Agendas

How can the concerns that clean energy subsidies may be less efficient and less cost-effective than carbon pricing be addressed? Institutionalization of program evaluation could produce the information necessary for policy reform and improvement. This need is not unique to clean energy subsidies; reviewing policy performance could likewise improve the effectiveness of regulations and a carbon tax (Aldy 2014; Cropper et al. 2017; Aldy 2020a; Aldy et al. 2022a).

The Foundations for Evidence-Based Policy Making Act of 2018 provides a mechanism for institutionalizing policy evaluations. The law and associated implementation guidance from the Office of Management and Budget call for agencies to develop *learning agendas* that include rigorous *program evaluations* as critical components. These program evaluations can draw from causal inference methods common in the academic research literature and highlight how to simultaneously design a program and its evaluation strategy, including data collection and empirical methods (Aldy 2022).

Climate-oriented learning agendas could drive agencies to implement subsidy program evaluations, use the resulting evidence produced by such evaluations to inform policy updating, and enable more climate-focused strategic and budget planning by agencies. To guide the conduct of such evaluations, agencies can draw from their own guidance for economic analyses, including benefit-cost analysis, associated with regulatory impact assessments, as well as guidance from the Office of Management and Budget under regulatory review.

To promote learning about the overall climate policy agenda, cross-agency comparisons of program performance could be issued on a periodic basis. Such compilations could present a common set of performance metrics—the costs or expenditures per ton of carbon dioxide emissions avoided, for example, or the Gini coefficient on the distribution of the benefits of a subsidy program—for clean energy subsidy programs. Such a compilation could also account for the overlapping nature of subsidies and indicate where marginal changes in federal clean energy programs and tax expenditures could improve cost-effectiveness, environmental benefits, and the distribution of outcomes. A federal government scorecard on these metrics across government programs and agencies, issued on an annual basis—akin to the annual report to Congress on the benefits and costs of federal regulations—could inform policymakers and the public about the implementation of subsidies and track progress toward the ambitious decarbonization goals of the Inflation Reduction Act of 2022.

3.6. Political Economy of Clean Energy Subsidies

Clean energy subsidies represent the vast majority of what could be considered federal climate change policy in the United States over the past three decades. Although such instruments may fall short in several dimensions, compared with carbon pricing policies, the political revealed preference for subsidies over carbon pricing indicates the potential to draw lessons for future climate policy design. Identifying the various factors contributing to the durability of clean energy subsidies could inform carbon pricing policy design to enhance its political salience.

To the extent that subsidies continue to play a major role in US energy and climate policy, there are opportunities for drawing from economic insights to improve their design and enhance social welfare and cost-effectiveness. With more data and the tools for extracting signals from the new information, it has become more feasible, at least technically, to tailor subsidies to pollution externalities. Such efforts to incorporate the best design elements from carbon pricing could also inform the design and implementation of other non-pricing policies, such as regulatory standards. The intersection of economics and politics represents an area that is potentially ripe for future research.

4. Using Tradable Emissions Performance Standards to Price Carbon

Economic ideas about regulating pollution have influenced environmental policy at all levels for 50 years, but the singular idea of pricing pollution, and specifically carbon dioxide emissions, has been slow to gain traction. One must observe that embedding carbon prices set at the marginal social cost of carbon as the core of climate policy is politically unavailable. The high barriers to carbon pricing, and indeed climate policy stringency, need to be the strategic focus of climate policy, and this new focus should motivate economists to reimagine their potential influence on climate policy. At this historic juncture, the key is to infuse the *attributes* of economic approaches into a policy portfolio that addresses the climate crisis immediately while also creating conditions that allow a moderate and growing role for carbon pricing.

4.1. Insights about Current Policies

The conventional framework of economic thinking would design the optimal climate policy to involve comprehensive global coverage that sets emissions at a level that equates the marginal cost of emissions reductions with the marginal benefits identified by the marginal social cost of carbon. The policy design would use incentive-based instruments to solve the asymmetric information problem and to achieve cost-effectiveness.

Let us assume that we know the social cost of carbon. Does it determine the right price of carbon, and how and when it should be introduced in the economy? The economic literature is conflicted on this, suggesting adjustments in one direction or the other. The tax interaction effect, infrastructure inertia, the need for technological change, and climate risk management often suggest that the right price should be set at a value that is different—alternatively lower or higher—than the social cost of carbon. This dynamism in economic science clouds the pathway for policymakers.

In any event, a carbon price proximate to the social cost of carbon and adequate to achieve climate goals is evidently politically unachievable. It is sufficient just to note that unfair competition from firms in unregulated jurisdictions would cause leakage of economic activity and make prices set at such levels unsustainable. Other barriers to implementing a strong carbon price include distributional effects, the presence and influence of losing coalitions and the logic of collective action (Olson 1971), the timing of technology development, and institutional and legal structures. Importantly, there is the dilemma of dynamic inconsistency in setting and maintaining a high carbon price that is subject to political renegotiation over political cycles. If the carbon price is subject to regular renegotiation, it cannot adequately shape expectations—necessary to launch a wave of private sector investments to achieve climate goals.

Paradoxically, although carbon pricing does not offer a silver bullet to the climate crisis, carbon pricing is important. Pricing introduces cost-effectiveness, rewards innovation, and coordinates resource allocation in the economy, all of which will become increasingly important as emissions reductions become more stringent. Perhaps most usefully, pricing indicates commitment. This was evident in a 2019 remark about climate policy by Chancellor Angela Merkel of Germany, a country with many policies other than carbon pricing at the time and where a great deal has been spent to address climate change: Merkel said that she had come to recognize there was no substitute for talking about a carbon price when signaling the government's long-term commitment to climate policy.

4.2. Implications for Future Carbon Pricing

Hence, we are between a rock and a hard spot. Carbon pricing faces many barriers and cannot have a role at the center of US climate policy at present; nonetheless, pricing at a moderate level at least is essential for making long-term progress.

How do we begin? To quote Marcus Aurelius: "The impediment to action advances action. What stands in the way becomes the way." We must be consciously aware of the barriers to carbon pricing, and consciously address these barriers if we want to achieve the goal. To do otherwise is like having an army proceed without any awareness of the terrain that it is walking on.

An informative example is the finding that in most jurisdictions where we have seen its emergence, carbon pricing was preceded by a green industrial policy, such as feed-in tariffs or renewable portfolio standards in the power sector, that helped build a winning coalition that ultimately supported carbon pricing (Meckling et al. 2015). One can generalize this idea in a policy-sequencing framework that prioritizes the barriers to future and more stringent climate policy to guide current policy choices, with the goal of overcoming these barriers over time (Pahle et al. 2018; Meckling et al. 2017). The policy-sequencing perspective suggests a departure from the straightforward implementation of a carbon price and instead looks at a strategic approach to policy formation that moves into the realm of industrial policy. How do we build industrial policy to be as efficient as possible and take advantage of economic ideas?

One way to think about this is to realize that a carbon price is equivalent to a coupled performance standard and consumption tax (Pollitt et al. 2020), an idea related to Joe Aldy's remarks (Section 3, above) about how one can use a variety of instruments to mimic where a carbon price would take us. It is particularly useful to imagine sector-specific policy coupling of regulatory standards that impose shadow prices with sector-specific subsidies, such as rate reform to promote electrification, electric vehicle subsidies, output-based free allocation of emissions allowances to mitigate leakage, and tradable performance standards.

4.3. Tradable Performance Standards

Successful climate policy requires a broad social transformation because the way we consume fossil fuels touches so many human and economic interactions. Acknowledging that a single carbon price could in principle influence all these facets, one must consider an array of policies in an industrial policy framework. Table 3 uses the example of tradable performance standards to examine the degree to which they employ the attributes of carbon pricing.

Table 3. Attributes of Carbon Pricing in Tradable Performance Standards

	Pricing	Tradable Performance Standards
Solving Asymmetric Information	✓	✓
Cost effectiveness	✓	?
Input substitution	✓	✓
Process changes	✓	✓
Output substitution	✓	-
Innovation	✓	✓✓

Tradable performance standards are like carbon pricing in solving the asymmetric information problem between regulators and firms, and they provide strong incentives for input substitution and process changes to reduce the emissions intensity of production. However, tradable performance standards fail with respect to output substitution—that is, promoting a substitution in consumption behavior away from the regulated product. For the exact same reason, they are politically relevant and for many years have been the one surviving type of policy: they suppress the change in product prices and do not lead to the internalization of the social cost of a pollutant, as would a pollution price. Specifically, tradable performance standards do not affect consumers in the same way as a pollution price, and they do not directly harm competitiveness on an international basis and indeed may help if they promote efficiency in industry.

The comparison of a carbon price and a tradable performance standard on the metric of cost-effectiveness is unclear. A tradable performance standard is cost-effective within the set of regulated sources, but the set of sources can be narrow at the industry level. Its cost-effectiveness could improve if it were implemented at the sectoral level or even across sectors.

On the other hand, tradable performance standards can exceed carbon pricing in providing an incentive for innovation within the domain to which the standards apply. One example is the California Low Carbon Fuel Standard (LCFS), which required a 10 percent reduction in the greenhouse gas emissions per unit of energy in transportation fuels by 2022, and a 20 percent reduction by 2030. The carbon intensity of fuels in the California program is measured on a life-cycle basis, encompassing emissions associated with extraction, transportation of feedstock, refining, and use of the fuel.

The LCFS has been criticized in the economics literature for not achieving emissions reductions comparable to a carbon price set at the same level as the LCFS credit price (Holland et al. 2009). However, it has had an interesting effect in driving innovation. At its inception more than 15 years ago, policymakers anticipated that cellulosic ethanol and hydrogen (along with corn ethanol) would be fuels that benefited strongly. It has turned out that cellulosic ethanol and hydrogen have fallen off the list of top benefactors. Instead, other fuels have emerged as important, including renewable diesel, biodiesel, and electricity, and the contribution of corn ethanol has been limited by the blend wall constraint associated with vehicle engine designs. The LCFS has influenced a breadth of technologies, reaching across the refining, agriculture, and electricity sectors, as would a carbon tax. The life-cycle carbon intensity of ethanol, as evaluated by the California Air Resources Board, has fallen by a third over the course of the program as the fuel competes with others to improve its score and grow its value in the program. Biodiesel carbon intensity has decreased by 41 percent over the past decade. The program has also harvested substantial funds for investment in electric vehicle charging infrastructure (Yeh et al. 2021).

Furthermore, the LCFS has driven innovation in these industries with a potency that exceeds what would be realized from a carbon price with a comparable effect on gasoline prices at the pump. For achieving a 10 percent improvement in emissions intensity, the incentive for reducing emissions intensity was 10 times greater under the LCFS than under the carbon price. Around 2020, when the first phase of the LCFS was complete, the value of an LCFS credit was about $200 per ton; the value of a carbon emissions allowance in California's emissions trading program was then about $20 per ton. However, the effects of these policies on retail gasoline prices were roughly comparable, at about 20 cents per gallon (Yeh et al. 2021).

A classic challenge for industrial policy is how to avoid its obvious traps—the lemons problem and the lock-in of subsidized technologies. This challenge should not be discounted, and addressing it requires a lengthier discussion than can be afforded here; however, it is useful to note that tradable performance standards have inherent properties that lessen these concerns. For instance, performance standards applied across increasingly broad technology, industry, or sector categories can achieve technology neutrality that approaches that of carbon pricing. The price of credits and the transfers that occur within a tradable performance standard framework tend to fall as its technology goal is achieved, automatically reducing the cross-subsidy that flows to new technologies.

To summarize, one can observe that the industrial policy approach is not as efficient as first-best economic policy, and regulatory approaches would not be selected according to conventional economic criteria. But regulatory approaches, often in the form of tradable performance standards, account for most of the emissions reductions we have seen to date for greenhouse gases and indeed for all pollutants. Looking forward now for how to address the climate crisis, and paraphrasing French Ambassador Laurence Tubiana in the leadup to the 2015 Paris climate meetings, it has become less important to articulate further where we want to end up, and more important to articulate the path that can take us there. Carbon pricing is an important part of that policy pathway, but a rich policy portfolio is necessary to ensure progress along the path. Tradable performance standards appear to offer a valuable step forward.

5. Pricing Carbon in Industrial Sectors: The Role of Rebates

Pricing carbon in energy-intensive industries is particularly fraught because of intense competitive pressures from abroad as well as the political prominence of many of these industries at home. To date, no system of carbon pricing fully prices the emissions embodied in industrial goods: industry is granted free allocations, exemptions, or rebates, and prices are often kept relatively low. This section briefly explores why and how carbon pricing with targeted rebating can support climate action.

The use of emissions revenues is an intrinsic part of environmental policy. Although economic efficiency may be enhanced by recycling revenues to offset other taxes or budgetary needs (Goulder and Parry 2008), earmarking revenues to affected firms or households has been shown to increase political support for taxes, including carbon pricing (Baranzini and Carattini 2017; Kallbekken et al. 2011). In practice, for carbon pricing systems covering industrial emitters, whether because of trade and competitiveness concerns or lobbying prowess, offering some form of rebating has become the norm.

Rebating can take many forms. The primary motive may be to compensate affected stakeholders or to enhance climate action beyond the incentive effects of the carbon price. The methods or basis for rebating may or may not be conditioned on firms' behavior. Table 4 shows four broad categories of rebating, depending on the associated motivations and methods, which are subsequently discussed in turn.

Table 4. Motivations and Methods for Rebating Environmental Revenues

		Form of Rebating	
		Lump-sum or Discretionary	*Conditional and Automated*
Motivation	*Compensation*	Table	Table
	Climate Action	Table	Table

5.1. Grandparenting

The earliest cap-and-trade schemes, such as the Acid Rain Program in the United States and the first phase of the European Union's Emissions Trading System (EU ETS), used "grandparenting," under which firms are granted allowances in a predetermined manner based on some historical measure of emissions. These lump-sum distributions are intended to compensate firms for lost profits without distorting incentives for emissions reduction on the margin. Of course, to the extent firms can pass on embodied costs, much less than 100 percent free allocation is needed. Goulder et al. (2010) found that allocating roughly 15 percent of emissions for free would be sufficient to replace forgone profits in a US carbon pricing scheme. In a survey of EU firms, Martin et al. (2014) indicated that 14 to 25 percent free allocation would prevent offshoring.

In practice, however, few grandparenting schemes are truly unconditional. Invariably, there are provisions for new entrants or for significant changes in production capacity or utilization. Furthermore, over time, through different phases of the emissions pricing system, the allocation rules are updated.

5.2. Output-Based Rebating

Output-based rebating (OBR) makes the updates explicit and in proportion to production. An emissions price remains to signal abatement, and it is combined with a rebate that acts as a production subsidy, in effect signaling that emissions reductions should not be achieved by reducing output. OBR comes in many forms, all of which—when the policy is revenue neutral—offset the cost of reducing embodied emissions, on average. A tradable performance standard implements this explicitly: covered firms sell (buy) credits if they emit below (above) the standard emissions intensity, and the trading equilibrium ensures that the average emissions intensity equals the freely allocated standard. Tradable intensity standards for CO_2 emissions are being used in some Canadian provinces with federal or provincial output-based pricing systems and in China's national ETS.[3] Many more standard cap-and-trade systems use output-based allocation of emissions allowances for leakage-prone sectors, including those of New Zealand and California, and arguably the more recent phases of the EU ETS. Finally, OBR can also be combined with an emissions tax, as in Sweden, where NO_x emissions tax revenues are rebated to covered entities in proportion to their power generation.

The implicit output subsidy in OBR mutes the emissions price pass-through, which comes with an efficiency cost. Consumers have less motive to conserve or find alternatives, meaning the playing field is not level for competing low-carbon goods. As

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[3] These systems are, however, complicated by benchmarks that are differentiated by sources. See Goulder et al. (2022).

a consequence, to meet the same emissions target, higher carbon prices or costly overlapping polices are needed.

That said, the literature has identified multiple situations in which passing along the full cost of embodied carbon may not be efficient because of second-best situations (Fischer and Fox 2011; Fischer 2019). First and foremost in most minds is carbon leakage, where exposure to international trade competition limits firms' ability to pass on emissions costs without losing market share to foreign competitors that face lighter regulation (Fischer and Fox 2007; Böhringer et al. 2012). Incomplete regulatory coverage more generally is a reason for OBR to avoid shifting production toward unregulated firms (Holland 2012; Bernard et al. 2007).

Tax interactions may also raise concerns about fully passing on carbon costs. Higher product prices erode real wages and can thereby discourage labor supply in a market that is already distorted by labor taxes (Parry 2003). Thus, if the revenues are not used to lower other distorting taxes, using them to keep prices from rising can lower regulatory costs (Goulder et al. 2016).

In other cases, the product prices themselves may already be distorted by imperfect competition or preexisting regulations. As Fowlie (Section 2) points out, Borenstein and Bushnell (forthcoming) indicate that in many US states, retail electricity prices already exceed the social marginal cost of generation.

Since rebates typically are much larger than the abatement costs undertaken in response to a carbon price, the distributional effects of OBR are also quite different from emissions pricing policies that fully pass through embodied carbon costs. As a consequence, lump-sum policies are redistributing a relatively large amount of revenue. A "cap-and-dividend" approach, by which each household gets an equal share, tends to be progressive, in a vertical equality sense, since poorer households on average spend less on energy. However, such averages mask a great deal of heterogeneity within income classes, and thus many poor households may still be worse off. For example, the yellow jacket protests in France were in part touched off by a rural-urban divide on the implications of a CO_2 tax package. By avoiding large energy or product price increases, OBR avoids large swings in circumstances that lead to greater problems of horizontal equity (Fischer and Pizer 2019).

In addition to other market failures, political failures can provide a rationale for rebating policies that otherwise seem distorting. A broad-based carbon price that is low may be efficient in the sense of equalizing marginal abatement costs, but it is not efficient in the sense of reflecting marginal social costs. If rebating helps achieve acceptance of better-aligned prices, it can improve efficiency. Multiple surveys have found that voters tend to prefer policies that do not obviously raise prices, like renewable energy subsidies or performance standards, over policies that do, like carbon taxes (Newport 2018; Bedsted et al. 2015).

5.3. Green Funds

Whereas most rebating schemes have been targeted to protect industrial competitiveness, some newer mechanisms seek to deepen reductions as well. Several schemes have used modest emissions revenues to subsidize the adoption of abatement technologies, as for marine emissions in Norway or water pollution in France (Hagem et al. 2020). For climate policy, "cap-and-invest" programs are gaining traction, as in the Climate Commitment Act passed in Washington State. In such programs, carbon revenues are earmarked for complementary projects and activities that would reduce emissions or promote resilience, often outside the sectors covered by the emissions pricing program. Such schemes can be considered discretionary, since the allocation process is not automated, and the grants may be disbursed in lump-sum fashion or through an application process. Like earmarking through OBR or clean energy standards, such climate policy bundles are found to improve political acceptability (Bergquist et al. 2020).

5.4. Intensity-Based Rebates

More recently, an automated form of rebating based on firm performance has emerged in practice. To allow for higher carbon prices, some jurisdictions have offered a rebate of emissions tax payments to firms according to their ability to meet or make progress toward an intensity-based performance standard.[4] Such schemes combine a price on emissions with a subsidy to intensity reduction, meaning the same emissions reductions can be achieved with a lower carbon price—in contrast to the higher price required by OBR (Böhringer et al. 2022). The rebate also addresses competitiveness concerns by offsetting embodied carbon costs, similarly to OBR. However, when a firm's own emissions payments are refunded, the rebate functions in part as a subsidy to emissions, which unravels some of the carbon price incentive. The net effect on the opportunity cost of emissions to the firm can then be heterogeneous, depending on the firm's initial circumstances, since dirtier firms have more to gain from reducing their effective emissions tax rate, and thus receive larger subsidies. An inefficient allocation of abatement and production in the market can in theory even backfire: emissions-based rebating, despite conditioning on intensity performance, could actually raise total emissions (Fischer et al. 2022).

Intensity-based rebating mechanisms hold promise by offering greater emissions reductions for a given, politically feasible carbon price while avoiding threats to competitiveness. However, although discounts on emissions payments may seem intuitive, policymakers should explore alternative formulations that are likely to be less distorting. One idea is to condition output-based rebates on additional intensity reductions.

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[4] British Columbia has the CleanBC Industrial Incentive Program, and the government of the United Kingdom enters into voluntary agreements for reducing Climate Levy payments.

5.5. Design Considerations

In summary, experience indicates that addressing concerns about product price impacts can make room for stronger carbon pricing, particularly in industrial sectors. Although conditional rebating mechanisms can be distorting, they may be helpful and even improve efficiency in the transition by mitigating the competitiveness, distributional, and political effects that otherwise impede ambition. Benchmarks can also focus attention on the technological opportunities and challenges. Intensity-based rebating further leverages benchmarks as goals to amplify incentives for reductions without raising the carbon price. However, it remains important that benchmarks and the basis for rebating be well designed, to avoid introducing yet other distortions. Finally, it is worth recalling that rebating to covered firms is but one of several potential uses of carbon revenues, and less than full rebating may be needed to address industry concerns. The more rebates are targeted to polluters, the fewer revenues are available to reduce other distorting taxes, address distributional concerns, support innovation, or invest in adaptation infrastructure.

6. National Carbon Pricing and Subnational Policy: Complements or Substitutes?

Subnational climate policies do not exist in a vacuum: they interact with national policy. Are these policies complements or substitutes to national-level carbon pricing? And how does national-level policy (either carbon pricing or other options) affect state and local governments' incentives for subnational policy?

The United States has very little explicit carbon pricing at either the national or subnational levels.[5] Far more common are policies that aren't explicit prices, and in most cases don't directly target carbon, but have the effect (and often the goal) of reducing carbon emissions. At the federal level, these include tax credits for renewable energy, electric vehicle tax credits, vehicle fuel economy standards, other efficiency standards, and the renewable fuel standard. Similar policies are common at the subnational level, such as renewable portfolio standards, low-carbon fuel standards, renewable energy subsidies, subsidies for electric or hybrid vehicles, and bans on natural gas connections in new construction. The general pattern at both levels is similar: policies are narrow (covering only certain sectors, and often with

[5] The most notable exceptions are California's cap-and-trade program and the Regional Greenhouse Gas Initiative (RGGI) cap-and-trade program covering electric power generation in northeastern states. One might also consider the carbon capture tax credit under Section 45Q as a very narrow-based carbon price. And federal and state motor fuel taxes function as carbon prices, though they aren't labeled as such.

incomplete coverage even within those sectors) and are typically regulations or subsidies.

The rationale for these policies is primarily political, not economic. Narrow nonprice policies are typically less (often much less) cost-effective than broad-based pricing policies.[6] The few exceptions are primarily policies that target market failures other than carbon emissions, such as local air pollution or technology spillovers. But in general, narrow nonprice policies miss many low-cost opportunities to cut emissions and thus rely more on higher-cost reductions, whereas broad-based carbon pricing can fully exploit the low-cost reductions. And as policy gets more ambitious (cutting emissions by more) and widens in scale (moving from the local to regional or national level), the cost advantage of broad carbon pricing grows.

These narrow nonprice policies are often referred to as "complementary policies" to a carbon price.[7] But in an economic sense, the vast majority of such policies are substitutes to a carbon price: implementing a broad-based carbon price (or increasing the price if one already exists) reduces the optimal stringency of those other policies. One intuition for this result is that a carbon price by itself provides an incentive for any emissions reductions that cost less per ton than the price, and thus any additional reductions from a nonprice policy layered on top must have a marginal cost higher than the carbon price: the carbon price effectively cherry-picks the low-cost emissions cuts. Thus, as the carbon price rises, the additional emissions cuts from any given set of nonprice policies get smaller, and the average cost of those cuts rises. An alternative intuition recognizes that with a carbon price in place, any emissions cuts from other policies lower the revenue from the carbon price, and losing that revenue is a cost.[8] Consequently, the narrow nonprice policies are generally substitutes to a broad-based carbon price: raising the price lowers the optimal level of those other policies. And they're inferior substitutes: going from a collection of narrow nonprice policies to a broad carbon price will generally lower costs substantially.

An obvious exception can arise when the carbon price doesn't cover all emissions and the additional policy cuts emissions that the price misses. In that case, the carbon price misses some low-cost reductions (that the other policy can then pick up), and cutting those other emissions won't reduce carbon price revenue.[9] And if there is leakage (raising the carbon price cuts emissions covered by the price but increases

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[6] See Gillingham and Stock (2018) for a survey of cost estimates.

[7] "Complementary policy" in this context is rarely defined explicitly, but the term is widely used for any policy other than a carbon price that would lower carbon emissions.

[8] See Williams (2019) for a more detailed explanation of these points (including a graphical exposition) and further discussion of which existing policies would be efficient to eliminate in the presence of a federal carbon price.

[9] Although the other policy isn't a substitute in this case, it isn't necessarily a complement, either. If emissions in two sectors are independent—that is, if emissions cuts in one have no effect on emissions in the other—then raising the carbon price in one sector has no effect on optimal policy stringency in the other.

uncovered emissions), then the gains from an additional policy targeting those uncovered emissions increase.

More generally, the critical question is whether the carbon price ameliorates or exacerbates the distortion the other policy addresses: if the carbon price exacerbates another distortion, a policy addressing that other distortion will generally be a complement. Such cases include the example just mentioned (a policy addressing emissions from a sector missed by a narrow carbon price), or its geographic analogue (carbon policy in one state or region can easily be a complement to a carbon price covering a different state or region). But note that the opportunities for this type of complementary policy shrink as the carbon price gets broader, in either a sectoral (covering a wider range of economic sectors) or a geographic (more states or regions) sense. With a broad federal carbon price that is sufficiently high, it would be efficient to suspend or eliminate or suspend many existing state and federal policies.

So what policies could be genuine economic complements to a broad federal carbon price? Policies addressing technology spillovers are one possibility, if the presence of a carbon price increases the magnitude of the spillover externality. Note, though, that many green-technology policies target deployment of current low-carbon technologies rather than research and development, and those technology-deployment policies are almost certainly substitutes to a carbon price. Another possible complement would be a policy encouraging lighter on-road vehicles: electric vehicles are generally heavier than the gasoline-powered vehicles they replace, and heavier vehicles impose larger accident externalities on other road users, so decarbonizing road transportation could exacerbate those other externalities.[10]

Changes in energy price regulation are a third possible complement: imposing a carbon price could exacerbate the distortions from the way local utilities price electricity and natural gas, thus increasing the gains from regulatory reform.[11] A fourth would be relaxing local zoning rules to allow more density: carbon pricing will generally encourage density (increasing density generally lowers carbon emissions), making existing limits on density more binding, so carbon pricing could increase the value of relaxing those rules.[12] And there are likely other examples. In general, it seems that more research on this question—what policies would be genuine economic complements to a broad carbon price—would be valuable.

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[10] See Shaffer et al. (2021).

[11] See Meredith Fowlie's discussion in Section 2 (above), or for more detail, Borenstein and Bushnell (forthcoming).

[12] See Weil (2012) for further discussion of this issue and other local policies that could complement a federal carbon price. The argument that relaxing zoning rules is complementary to a carbon price presumes that those local zoning rules are distortionary, or at least that they would become distortionary in the presence of a carbon price. If not (e.g., if they're efficiently targeting negative externalities associated with higher density), then it could be important to keep them in place, and indeed, imposing carbon pricing could raise the value of keeping them.

It's also important to consider the incentives federal climate policy creates for subnational governments' policy decisions, even for policies primarily targeting narrower local externalities.[13] Ideally, these incentives would align so that subnational governments have an incentive to make policy decisions that are in the nation's best interest. But that is by no means guaranteed, and alignment depends strongly on policy design at the national level. Nonprice climate policy at the national level creates a substantial disincentive for subnational policy that would lower carbon emissions (even if that subnational policy primarily targets a local externality) because the local jurisdiction bears the full cost of emissions reductions beyond what the national policy achieves. In contrast, a national carbon tax provides much more incentive for local policy because the national price leaves emitters in the state indifferent at the margin (further carbon reductions have a cost but also reduce the amount paid in carbon taxes). Whether this aligns incentives between levels of government or creates too much or too little incentive for subnational policy depends on the subnational distribution of the federal carbon tax revenue and the damage from carbon emissions, but in general, it will come much closer to aligning incentives than a national nonprice policy. National-level cap-and-trade creates somewhat similar (but not identical) incentives to a tax.[14] Having an incentive for overly stringent subnational policy appears to be slightly more likely under national cap-and-trade than under a national tax.

In summary, existing US climate policy at both national and subnational levels consists primarily of relatively narrow nonprice policies. Although such policies are often described as complementary to a broad-based national carbon price, they are substitutes in an economic sense: imposing (or raising) a national carbon price would reduce the optimal stringency of these policies. If we have a sufficiently high and broad federal carbon price, it would be efficient to repeal or suspend many of these policies while keeping those primarily aimed at externalities not addressed by the carbon price (perhaps modifying them to target those other externalities more precisely). Subnational governments may well have an incentive to relax or repeal those policies in the presence of a federal carbon price, but incentives won't necessarily align perfectly between levels of government.

One might argue that any discussion of relaxing or eliminating existing climate policies is premature (or perhaps even dangerous), even if such policies are inferior substitutes for a national carbon price. The US doesn't have a federal carbon price. It seems unlikely that a US federal carbon price will become politically feasible in the near term, and even if it does, the price would probably be below the marginal damage from carbon emissions. But it's still well worth considering these issues. Political

[13] Williams (2012) analyzes the incentives for environmental policy in a one-shot simultaneous-move game with national and subnational governments. The discussion of these issues here draws heavily on the analysis in that paper.

[14] The equilibrium is different under cap-and-trade (even if the policy is otherwise equivalent to a carbon tax) because strategies are quantities rather than prices, analogous to Cournot versus Bertrand competition.

feasibility is hard to predict and can change quickly, and it's worth thinking through potential policy changes ahead of time, rather than rushing the analysis if and when it becomes relevant. Considering other policy changes could also boost the political feasibility of a carbon price: some political stakeholders might well oppose a carbon price on its own but support a package that would impose a carbon price and eliminate some other (more costly) policies.

One open question is whether federal policy should explicitly preempt subnational policy (and if so, in which cases). The answer in general is probably no: the cases in which national policy makes it efficient to repeal subnational policies will line up reasonably well with cases in which subnational governments have an incentive to repeal those policies. Nevertheless, careful research on this issue would be valuable. And in general, we need more research on how national and subnational policies interact, what that implies for optimal policy, and how those interactions shape incentives for subnational policy.

7. References

Aldy, Joseph E. 2013. Policy Monitor: A Preliminary Assessment of the American Recovery and Reinvestment Act's Clean Energy Package. *Review of Environmental Economics and Policy* 7(1): 136-155.

Aldy, Joseph E. 2014. Learning from Experience: An Assessment of the Retrospective Reviews of Agency Rules and the Evidence for Improving the Design and Implementation of Regulatory Policy. Report prepared for the Administrative Conference of the United States.

Aldy, Joseph E. 2020a. Carbon Tax Review and Updating: Institutionalizing an Act-Learn-Act Approach to US Climate Policy. *Review of Environmental Economics and Policy* 14(1): 76-94.

Aldy, Joseph E. 2020b. Pricing Pollution through Market-based Instruments. In Konisky, David. (Ed.) *Handbook of US Environmental Policy*: 202-216. Northampton, MA: Edward Elgar Publishing.

Aldy, Joseph E. 2022. Learning How to Build Back Better through Clean Energy Policy Evaluation. Harvard Kennedy School Faculty Working Paper Series.

Aldy, Joseph E., Maximilian Auffhammer, Maureen Cropper, Arthur Fraas, and Richard Morgenstern. 2022a. Looking Back at Fifty Years of the Clean Air Act. *Journal of Economic Literature* 60(1): 179-232.

Aldy, Joseph E., Todd D. Gerarden, and Richard L. Sweeney. 2022b. Investment versus Output Subsidies: Implications of Alternative Incentives for Wind Energy. *Journal of the Association of Environmental and Resource Economists*. Forthcoming.

Armitage, Sarah. 2022. Technology Adoption and the Timing of Environmental Policy: Evidence from Efficient Lighting. Harvard University Working Paper, April 25 Draft.

Baranzini, Andrea and Stefano Carattini. 2017. Effectiveness, Earmarking and Labeling: Testing the Acceptability of Carbon Taxes with Survey Data, *Environmental Economics and Policy Studies* 19(1): 197 -227.

Baumol, William J. and Wallace E. Oates. 1988. *The Theory of Environmental Policy*. Cambridge: Cambridge University Press.

Bedsted, Bjorn, Yves Mathieu, and Christian Leyrit (Eds.). 2015. World Wide Views on Climate and Energy: Results Report. Danish Board of Technology Foundation, Missions Publiques and the French National Commission for Public Debate, September 2015. Available at **http://climateandenergy.wwviews.org/results/**.

Bergquist, Parrish, Matto Mildenberger, and Leah C. Stokes. 2020. Combining Climate, Economic, and Social Policy Builds Public Support for Climate Action in the US. *Environmental Research Letters* 15: 054019.

Bernard, Alain L., Carolyn Fischer, and Alan K. Fox. 2007. Is There a Rationale for Output-Based Rebating of Environmental Levies? *Resource & Energy Economics* 29(2): 83-101.

Böhringer, Christoph, Jared Carbone, and Thomas Rutherford. 2012. Unilateral Climate Policy Design: Efficiency and Equity Implications of Alternative Instruments to Reduce Carbon Leakage. *Energy Economics* 34: S208-S217.

Böhringer, Christoph, Carolyn Fischer, and Nicholas Rivers. 2022. Intensity-Based Rebating of Emissions Pricing Revenues. Resources for the Future Working Paper 21-37.

Borenstein, Severin and James Bushnell. Forthcoming. Do Two Electricity Pricing Wrongs Make a Right? Cost Recovery, Externalities, and Efficiency. *American Economic Journal: Economic Policy*.

Borenstein, Severin and James B. Bushnell. 2022. Headwinds and Tailwinds: Implications of Inefficient Retail Energy Pricing for Energy Substitution. *Environmental and Energy Policy and the Economy* 3: 37-70.

Borenstein, Severin, James Bushnell, Frank A. Wolak, and Matthew Zaragoza-Watkins. 2019. Expecting the Unexpected: Emissions Uncertainty and Environmental Market Design. *American Economic Review* 109 (11): 3953-3977.

Borenstein, Severin, Meredith Fowlie, and James Sallee. 2021. Designing Electricity Rates for An Equitable Energy Transition. Energy Institute Working Paper 314.

Callaway, Duncan S., Meredith Fowlie, and Gavin McCormick. 2018. Location, Location, Location: The Variable Value of Renewable Energy and Demand-Side Efficiency Resources. *Journal of the Association of Environmental and Resource Economists* 5(1): 39-75.

Cropper, Maureen, Arthur Fraas, and Richard Morgenstern. 2017. Looking Backward to Move Regulations Forward. *Science* 355: 1375-1376.

Davis, Lucas and Catherine Hausman. 2022. Who Will Pay for Legacy Utility Costs? *Journal of the Association of Environmental and Resource Economists* 9(6):1047-1085.

Fischer, Carolyn. 2019. Market-Based Clean Performance Standards as Building Blocks for Carbon Pricing. Hamilton Project Report (October). Washington, DC: Brookings Institution. Available at **https://www.brookings.edu/research/market-based-clean-performance-standards-as-building-blocks-for-carbon-pricing/**.

Fischer, Carolyn and Alan K. Fox. 2007. Output-Based Allocation of Emissions Permits for Mitigating Tax and Trade Interactions. *Land Economics* 83(4): 575 -599.

Fischer, Carolyn and Alan K. Fox. 2011. The Role of Trade and Competitiveness Measures in US Climate Policy. *American Economic Review Papers & Proceedings* 101(3) (May): 258-262.

Fischer, Carolyn and William Pizer. 2019. Horizontal Equity Effects in Energy Regulation. *Journal of the Association of Environmental and Resource Economists* 6(S1) (March): S209-S237.

Fischer, Carolyn, Christoph Böhringer, and Nicholas Rivers. 2022. Rebating Emission Pricing Revenues with Heterogeneous Firms. Unpublished manuscript.

Fowlie, Meredith, Christopher R. Knittel, and Catherine Wolfram. 2012. Sacred Cars? Cost-Effective Regulation of Stationary and Nonstationary Pollution Sources. *American Economic Journal: Economic Policy* 4(1): 98-126.

Gerarden, Todd. 2022. Demanding Innovation: The Impact of Consumer Subsidies on Solar Panel Production Costs. *Management Science*. Forthcoming.

Gillingham, Kenneth and James H. Stock. 2018. “The Cost of Reducing Greenhouse Gas Emissions,” *Journal of Economic Perspectives* 32(4): 53-72.

Goulder, Lawrence H. and Ian W. H. Parry. 2008. “Instrument Choice in Environmental Policy,” *Review of Environmental Economics and Policy* 2008(2:2): 152-174.

Goulder, Lawrence H., Marc A.C. Hafstead, and Michael Dworsky. 2010. Impacts of Alternative Emissions Allowance Allocation Methods under a Federal Cap-and-Trade Program. *Journal of Environmental Economics and Management*, 60 (3): 161–181.

Goulder, Lawrence H., Marc A. C. Hafstead, and Roberton C. Williams III. 2016. "General Equilibrium Impacts of a Federal Clean Energy Standard. *American Economic Journal: Economic Policy* 8(2): 186-218.

Goulder, Lawrence H., Xianling Long, Jieyi Lu, and Richard D. Morgenstern. 2022. China's Unconventional Nationwide CO2 Emissions Trading System: Cost-Effectiveness and Distributional Impacts. *Journal of Environmental Economics and Management* 111: 102561. Available at **https://doi.org/10.1016/j.jeem.2021.102561**.

Hagem, Cathrine, Michael Hoel, and Thomas Sterner. 2020. Refunding Emission Payments: Output-Based versus Expenditure-Based Refunding. *Environmental and Resource Economics* 77 (3): 641–667.

Holland, Stephen. 2012. Emissions Taxes versus Intensity Standards: Second-Best Environmental Policies with Incomplete Regulation. *Journal of Environmental Economics and Management* 63(3): 375-387.

Holland, Stephen P., Jonathan E. Hughes, and Christopher R. Knittel. 2009. Greenhouse Gas Reductions under Low Carbon Fuel Standards? *American Economic Journal: Economic Policy* 1(1): 106-46. doi: 10.1257/pol.1.1.106.

Holland, Stephen P., Erin T. Mansur, Nicholas Z. Muller, and Andrew J. Yates. 2016. Are There Environmental Benefits from Driving Electric Vehicles? The Importance of Local Factors. *American Economic Review* 106(12): 3700-3729.

Johnston, Sarah. 2019. Nonrefundable Tax Credits versus Grants: The Impact of Subsidy Form on the Effectiveness of Subsidies for Renewable Energy. *Journal of the Association of Environmental and Resource Economists*, *6*(3), 433-460.

Kallbekken, Steffen, Stephan Kroll, and Todd L. Cherry. 2011. Do You Not Like Pigou, or Do You Not Understand Him? Tax Aversion and Revenue Recycling in the Lab. *Journal of Environmental Economics and Management* 62(1): 53-64.

Marcantonini, Claudio and A. Denny Ellerman. 2015. The Implicit Carbon Price of Renewable Energy Incentives in Germany. *Energy Journal* 36(4): 205-239.

Martin, Ralf, Mirabelle Muûls, Laure B. de Preux, and Ulrich J. Wagner. 2014. Industry Compensation under Relocation Risk: A Firm-Level Analysis of the EU Emissions Trading Scheme. *American Economic Review*, 104 (8): 2482-2508

Meckling, Jonas, Nina Kelsey, Eric Biber, and John Zysman. 2015. Winning Coalitions for Climate Policy. *Science* 349(6253): 1170-1171.

Meckling, Jonas, Thomas Sterner, and Gernot Wagner. 2017. Policy Sequencing toward Decarbonization. *Nature Energy* 2(12): 918-922. doi:10.1038/s41560-017-0025-8.

Metcalf, Gilbert E. 2010. Investment in Energy Infrastructure and the Tax Code. *Tax Policy and the Economy* 24: 1-34.

Metcalf, Gilbert E. 2021. "Supporting Low-Carbon Energy through a New Generation of Tax Credits." Policy Brief, Climate Policy Lab, Tufts University. Available at **https://sites.tufts.edu/cierp/files/2021/09/CPL_Policy_Brief_US_Tax-Credits.pdf**. Accessed May 30, 2022.

Newport, Frank. 2018. Americans Want Government to Do More on Environment. Gallup News, Washington, DC.

Nordhaus, William D. 2019. Climate Change: The Ultimate Challenge for Economists. *American Economic Review* 109(6): 1991-2014.

Novan, Kevin. 2015. Valuing the Wind: Renewable Energy Policies and Air Pollution Avoided. *American Economic Journal: Economic Policy* 7(3): 291-326.

Olson, Mancur. 1971. *The Logic of Collective Action*. Cambridge, MA: Harvard University Press.

Pahle, Michael, Dallas Burtraw, Christian Flachsland, Nina Kelsey, Eric Biber, Jonas Meckling, Ottmar Edenhofer, and John Zysman. 2018. Sequencing to Ratchet Up Climate Policy Stringency. *Nature Climate Change* 8: 861-867.

Parry, Ian W. H. 2003. Fiscal Interactions and the Case for Carbon Taxes over Grandfathered Carbon Permits. *Oxford Review of Economic Policy* 19(3): 385-399.

Pollitt, Hector, Karsten Neuhoff, and Xinru Lin. 2020. The Impact of Implementing a Consumption Charge on Carbon-Intensive Materials in Europe. *Climate Policy* 20 (sup1): S74-S89. doi:10.1080/14693062.2019.1605969.

Shaffer, Blake, Maximilian Auffhammer, and Constantine Samaras. 2021. Make Electric Vehicles Lighter to Maximize Climate and Safety Benefits. *Nature* 598: 254-256.

US Senate Committee on Finance. 2013. Summary of Staff Discussion Draft: Energy Tax Reform. Available at **http://www.finance.senate.gov/imo/media/doc/121813%20Energy%20Tax%20Reform%20Discussion%20Draft%20Summary1.pdf** (accessed May 30, 2022).

Weil, Gabriel. 2012. Subnational Climate Mitigation Policy: A Framework for Analysis. *Colorado Journal of International Environmental Law & Policy* 23: 285-307.

Williams III, Roberton C. 2012. Growing State-Federal Conflicts in Environmental Policy: The Role of Market-Based Regulation. *Journal of Public Economics* 96(11-12): 1092-1099.

Williams III, Roberton C. 2019. How to Change U.S. Climate Policy after There Is a Price on Carbon. Hamilton Project Policy Proposal 2019-15, Brookings Institution, Washington DC.

Yeh, Sonia, Dallas Burtraw, Thomas Sterner, and David Greene. 2021. Tradable Performance Standards in the Transportation Sector. *Energy Economics* 102: 105490. doi: **https://doi.org/10.1016/j.eneco.2021.105490**.