DISCUSSION PAPER

January 2014 ■ RFF DP 14-01

The Costs and Consequences of Clean Air Act Regulation of CO_2 from Power Plants

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A version of this paper will be published in the *American Economic Review: Papers & Proceedings* 2014 (forthcoming).

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RESOURCES FOR THE FUTURE

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Abstract

US climate policy is unfolding under the Clean Air Act. Mobile source and construction permitting regulations are in place. Most important, the US Environmental Protection Agency (EPA) and the states will determine the form and stringency of the regulations for existing power plants. It is widely believed that flexible approaches could be suggested in EPA guidelines or proposed by states. Various approaches would create an implicit price on emitting greenhouse gases and create valuable assets that would be distributed differently among electricity producers, consumers, and the government. We compare a tradable performance standard with three variations on cap-and-trade policies that would distribute the asset value in different ways. Keeping the value within the electricity sector by distributing it to fossil-fueled producers or consumers or spending on energy efficiency has smaller effects on average electricity prices than a revenue-raising policy. These approaches impose greater social cost, but comparable net benefits in the sector.

Key Words: climate policy, efficiency, equity, Clean Air Act, coal, compliance flexibility, regulation

JEL Classification Numbers: Q54, Q58

Contents

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Introduction

The Clean Air Act (CAA) provides the current regulatory framework for climate policy in the United States. In 2011, the US Environmental Protection Agency (EPA) enacted regulations for light-duty vehicles that require a 5 percent improvement in fuel economy per year and implemented preconstruction permitting that, for the first time, requires best available technology to control greenhouse gas emissions. The next major category of emissions to be regulated is stationary sources, and the first of these will be electricity generators, which are responsible for roughly one-third of the nation's greenhouse gas emissions and nearly 40 percent of the nation's carbon dioxide (CO2) emissions.

Most observers perceive the failure to adopt comprehensive legislation (i.e., the Waxman-Markey bill, HR 2454) in the 111th Congress as a major undoing for US climate policy. However, the United States remains positioned to achieve domestic emissions reductions in 2020 as great as would have been achieved under that legislation (Burtraw and Woerman 2013b). This could enable the United States to achieve President Obama's pledge of a 17 percent reduction from 2005 emissions levels by 2020 for CO_2, although the prospect for reductions in other greenhouse gases is less promising. Achieving the 2020 pledge, however, hinges on the stringency of regulations for the power sector.

At stake now is not only the stringency of CAA regulations but also the form the regulations will take—and therefore their cost-effectiveness. In 2013, President Obama directed EPA to move forward with regulations that, "to the greatest extent possible," allow the use of regulatory flexibility—perhaps including market-based approaches.[1] EPA guidelines will

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[*] Burtraw is the Darius Gaskins Senior Fellow, Linn is a fellow, Palmer is a senior fellow, and Paul is a center fellow at Resources for the Future. This research was supported in part by Mistra's Indigo Program and RFF's Center for Climate and Electricity Policy. The authors appreciate comments from Gilbert Metcalf and assistance from Sophie Pan and Samantha Sekar. This paper was prepared for the 2014 meeting of the American Social Science Association. Direct correspondence to burtraw@rff.org.

[1] http://www.whitehouse.gov/the-press-office/2013/06/25/presidential-memorandum-power-sector-carbon-pollution-standards.

determine the stringency and flexibility of the regulation and influence the development of implementation plans by the states, all of which will be subject to court oversight.

This paper surveys the major policy approaches EPA and the states are likely to consider if markets are to be harnessed to achieve a cost-effective outcome. Each approach differs in the way it creates and allocates asset values, and this difference has important distributional and efficiency consequences. Using a simulation model of the US electricity system, we compare policies that would reduce emissions sufficiently to take the nation past 16 percentage points of the 17 percent goal and within reach of its 2020 target. Two innovations make this modeling valuable: the model includes the first econometric estimates of the costs of improving emissions rates at existing coal-fired facilities; and investments in energy efficiency are paid for with emissions allowance auction revenues, endogenously affecting electricity prices, generation investment and system operation, and yield demand reductions in a dynamic time frame.

National cap and trade with a revenue-raising auction has been extensively studied, but the CAA precludes a federal auction of allowances. According to standard theory, regulatory approaches are less efficient than a price on carbon, partly because they fail to introduce a uniform price on emissions. However, actual policy rarely matches the standard theory even when an emissions price is used. Furthermore, flexible approaches that may be possible under the Clean Air Act in fact do introduce a shadow price on emissions and can be cost-effective, at least among the set of regulated entities. All of the policies we consider create assets that have value to their owners, and they direct asset values to four alternative groups or uses: government, owners of fossil-fired generators, electricity consumers, and end-use energy efficiency improvements.

We compare a cap-and-trade policy that directs auction revenue to government, and may in fact be implemented by state governments rather than the federal government, with a tradable performance standard that distributes the value to fossil-fuel-fired electricity generators. The standard sets a uniform emissions rate and allows generators that outperform the standard to generate and sell credits to those that do not meet the standard. The standard effectively allocates asset value to fossil-fuel generators. We compare allocation to government or to fossil generators with two other options, following the two existing state-level cap-and-trade programs, which may serve as templates for state implementation plans. One would direct auction revenue to electricity consumers through their local electricity distribution companies, and the other would direct it to investments in other technologies.

A key result is that the approaches that distribute asset values to fossil-fuel producers or consumers lead to very small changes in average electricity prices compared with one that allocates value to government. Under the tradable performance standard, all of the asset value is concentrated as a production subsidy to fossil-fuel generators. Fossil-fuel-fired generators almost always provide the marginal generation that determines the electricity price, and the production subsidy lowers the variable cost of fossil production; consequently, the electricity price increase is less than one-tenth of the change under cap and trade with auction. Alternatively, allocating assets to local distribution companies (LDCs), which would reduce consumers' bills, raises electricity prices by only one-quarter as much as cap and trade with auction. Allocating assets this way raises the electricity price by more than the standard, because it distributes the asset value as a subsidy to all consumption rather than directing most of the subsidy to the marginal fossil generators.

The small change in electricity price may have a political advantage, but it also has an economic disadvantage compared with a revenue-raising auction because lower electricity prices create less incentive for reducing electricity consumption or improving end-use energy efficiency; consequently, emissions reductions must come from electricity supply at incrementally greater cost. This might be remedied through directing auction revenue to investment in end-use energy efficiency as a way to harvest emissions reductions from investments on the demand side of the market, the fourth case we consider. In every case, the sum of producer and consumer surplus *within* the electricity sector is substantially greater if the asset value stays in the industry than if that value leaves the sector and goes to government.

The next section of the paper describes the policy framework of the Clean Air Act. The following section describes the model and baseline for the electricity sector. We then discuss the policy scenarios and present a comparison of results before providing our concluding thoughts.

Clean Air Act

Considerable uncertainty surrounds the structure of future regulations for existing power plants under the CAA, but it is possible that a market-based and reasonably cost-effective approach will emerge. In *Massachusetts v. EPA* (2007) the Supreme Court affirmed EPA's authority to regulate greenhouse gases. The agency subsequently reached a formal finding of harm from these gases, which compelled it to act to mitigate this harm. Regulation of existing stationary sources will unfold as standards of performance under Section 111(d). EPA first develops guidelines that states must address in developing implementation plans. The president called for final guidelines by June 2015 and for states to submit plans by June 2016. Legal challenges are certain, but the courts usually let EPA continue to implement air regulations in some form while they are under review. Because many emissions reduction measures involve low or no capital cost, regulations might be implemented quickly.

Performance standards do not require emitters to install a particular technology, but traditionally their stringency is based on measures that can be taken at individual facilities. The standards must reflect "the degree of emission limitation achievable through the application of the best system of emission reduction which … the Administrator determines has been adequately demonstrated." The phrase "best system of emission reduction" is understood to mean not a technology but a regulatory system, opening the way for flexible and market-based approaches (Wannier et al. 2011).

One approach, a tradable performance standard, would allow emissions rate averaging across sources. This approach would not be new; it was a key feature of the phaseout of lead in gasoline in the 1980s (Nichols 1997; Newell and Rogers 2003). A disadvantage of emissions rate averaging is that it does not inherently provide incentives for emissions reductions beyond the "fence line" of regulated sources, such as transmission line upgrades, increased use of nonemitting technologies, or end-use energy efficiency.

In contrast, an emissions cap-and-trade program could provide incentives for any action that reduces emissions. Although EPA has indicated it will not introduce a national cap-and-trade program, cap and trade could emerge under the CAA by other means. For example, EPA or states might use modeling to predict electricity production (MWh), which can be multiplied by a performance standard (lbs./MWh) to calculate an emissions budget (tons) for each state, and this would accommodate trading. This approach also would not be new; it was the approach used to launch the regional nitrogen oxides (NO_x) trading program among eastern states in 2003. States might choose to auction tradable emissions allowances or even to use an emissions tax sufficient to achieve their emissions budgets.

Determination of stringency will be a central issue. EPA initiated the rulemaking in 2008–09 by identifying cost-effective engineering opportunities for emissions rate improvements at existing coal plants that could reduce national emissions by to 1.5 to 3 percent without changing the utilization of these facilities (Sargent & Lundy 2009; Burtraw et al. 2011). States, however, must consider multiple criteria in identifying the best system, including emissions reductions and costs, which together imply cost-effectiveness.[2] EPA could use cost-effectiveness as the basis for determining stringency by directing states to identify all abatement options that could be taken by fossil generators at or below some marginal abatement cost. Burtraw and Woerman (2013d) find that taking this approach to encourage fuel switching can result in four times the emissions reduction at the same marginal cost as regulations that only encourage efficiency improvements at existing coal plants. Alternatively, to determine stringency, EPA might cite the recently revised interagency estimate of the social cost of carbon as justification for determining the stringency of emissions reductions (Interagency Working Group on Social Cost of Carbon 2013). Coincidentally, the midvalue of the social cost estimate is proximate but greater than the marginal abatement cost of the technical measures already identified by EPA (Burtraw and Woerman (2013d).

Model

We use the Haiku electricity market simulation model to characterize the response of the electricity system to climate policies that might unfold under the Clean Air Act (Paul et al. 2009a). Haiku is a highly parameterized partial equilibrium model that solves for investment in and operation of the electricity system in 22 linked regions of the contiguous United States, from 2013 to 2035. Each simulation year is represented by three seasons (spring and fall are combined) and four times of day. Supply is represented using 58 model plants in each region, including various types of renewables, nuclear, natural gas, and coal-fired power plants. Demand is modeled for three customer classes (residential, industrial, and commercial) in a partial adjustment framework that captures the dynamics of the long-run demand responses to short-run changes in price, income, or weather (Houthakker et al. 1974; Paul et al. 2009b). Price formation is determined by cost-of-service regulation or by competition in different regions corresponding to current regulatory practice. The retail price of electricity does not vary by time of day in any region, though all customers face prices that vary by season.

Operation of the electricity system minimizes short-run variable costs of generation. Coal boilers are differentiated by their installed controls to reduce conventional pollutants, and coal types by quality and sulfur content. Coal, natural gas, and biomass prices are differentiated by

[2] The statute also cites other environmental outcomes and gives states the discretion to consider the remaining useful life of facilities.

point of delivery and are modeled with price-responsive supply curves. Prices of oil and nuclear fuel, capital, and labor do not respond to demand but do vary over the modeling horizon.

Investment and retirement are determined endogenously for an intertemporally consistent (forward-looking) equilibrium, based on the capacity-related costs of providing service and the discounted value of future revenue streams. Each region must have capacity sufficient to meet a reserve requirement. The reserve price reflects the scarcity value of capacity and is set just high enough to retain sufficient capacity to cover the required reserve margin in each time block. Investment and operation include pollution control decisions to comply with regulatory constraints for NO_x, sulfur dioxide (SO_2), mercury, hydrochloric acid, and particulate matter, including equilibria in emissions allowance markets where relevant.

Existing coal-fired facilities have opportunities to make endogenous investments to improve their efficiency based on unit-specific econometric estimates of abatement costs (Linn et al. 2013) that are similar to estimates from the engineering case studies (Sargent & Lundy 2009). Facilities also have the opportunity to cofire with gas or, to a limited degree, with biomass.

Baseline

To compare with the policy scenarios, we define a baseline that reflects all major environmental policies, including allowance trading for SO_2 under Title IV of the CAA, the Regional Greenhouse Gas Initiative and California's CO_2 cap-and-trade programs, the federal renewable energy production and investment tax credits, and all of the state renewable portfolio standards and renewable tax credit programs. The baseline also includes the Mercury and Air Toxics Standards, which have been finalized by EPA and fully take effect in 2016 in our model, and the Clean Air Interstate Rule for SO_2 and NO_x in the eastern United States, which remains in effect while its replacement, the Cross-State Air Pollution Rule, is reviewed by the Supreme Court. Demand and input prices are calibrated to Annual Energy Outlook (AEO) 2012 forecasts, with the exception of natural gas prices, which are benchmarked to the updated AEO 2013 forecasts for both level and supply elasticity (EIA 2012; EIA 2013).

Policy Scenarios

We analyze policy scenarios that are calibrated to achieve the same CO_2 emissions trajectory through 2035 in the electricity sector. The constraint achieves a reduction of 367 million short tons in 2018 from the baseline, escalating linearly to 400 in 2020 and 650 in 2035. These targets would result in emissions reductions close to President Obama's 17 percent reduction pledge at a marginal cost that would be proximate to but less than the administration's estimate of the social cost of carbon. There is no banking or borrowing across years. We compare four scenarios that differ according to whether asset values are granted to government, owners of fossil-fuel generators, or electricity consumers or are invested in end-use energy efficiency.

Emissions Cap and Trade with Revenue-Raising Auction

A national emissions cap-and-trade policy is implemented with auction revenues accruing to the government. Given certainty, the outcome is equivalent to an emissions tax. Although EPA could not introduce a revenue-raising policy, such an approach might be implemented by states (Morris 2013). Regardless, setting a sector-wide price on emissions, as in this scenario, serves as a useful comparison for the other policies.

Tradable Emissions Rate Performance Standard

Each source is assigned a compliance obligation, which we refer to as its benchmark emissions rate and is denominated in tons of CO_2 per megawatt hour of generation, serving as an intensity standard for the regulated sources. Credits are denominated as a ton of CO_2. Generators earn credits equal to the benchmark emissions rate multiplied by their annual generation, and this mode of crediting constitutes a production subsidy compared with the cap and trade with auction scenario. Generators surrender credits equal to their actual emissions rate multiplied by their annual generation, which mimics the imposition of an emissions price like that present in the cap and trade with auction scenario. The net compliance obligation stems from the difference between the benchmark and actual emissions rates. We implement a uniform national emissions rate benchmark for all fossil-fired generators sufficient to achieve the emissions target.[3]

Emissions Cap and Trade with Allocation to Local Distribution Companies

California's existing cap-and-trade policy for the electricity sector and the Waxman-Markey proposal (HR 2454) that passed the House of Representatives in June 2009 both include variations of cap and trade with the allowance value allocated to local distribution companies (LDCs). These companies are regulated retail providers that distribute energy to homes and businesses and are responsible for billing consumers for all the costs of delivered energy. For

[3] See Burtraw and Woerman (2013c) for conisdieration of emissions rate benchmarks that differ by fuel or geography.

electricity, these include the costs associated with generation, transmission, and distribution. In this scenario, auction revenue is distributed to LDCs in proportion to their share of consumption. (This approach is included in our baseline in California.)

As regulated entities, LDCs are assumed to act as trustees for consumers. An important question is how LDCs use these revenues to consumers' benefit. If LDCs used the revenue to reduce the fixed-cost portion of electricity bills, then electricity prices would reflect the cost of the carbon constraint. However, most consumers likely do not differentiate between the fixed and variable portions of their bills and respond to changes in the overall bill rather than changes in the price (Borenstein 2009; Ito 2012). Consequently, in this scenario, consumers are expected to behave as if electricity is less expensive than when auction revenues go to the government (Burtraw et al. 2010).

Emissions Cap and Trade with Allocation to LDCs and Energy Efficiency

The other existing cap-and-trade program in 9 northeastern states (RGGI) involves an auction with the major portion of revenue (63 percent in 2011) directed to investments in end-use energy efficiency and a smaller portion (21 percent) returned to LDCs to benefit consumers (Burtraw and Sekar 2013a). Actual decisions in RGGI are made by individual states. Across the nation, 20 states already have energy efficiency resource standards in place, and 7 have similar goals (NCSU 2013). Over two-thirds of states have funded programs promoting energy efficiency (ACEEE 2013). These policies may emerge as an important part of state implementation plans. In this scenario, we model national emissions cap and trade with emissions allowances distributed to LDCs, which direct half of the revenue to investments in end-use energy efficiency and return the remainder to consumers. Energy efficiency expenditures are allocated to consumers based on consumption shares. About 22 percent of the lifetime energy savings associated with an investment in efficiency is realized in the first year. We assume first-year cost of energy savings of $180/MWh, with lifetime reductions persisting and decaying based on the partial-adjustment structure of the Haiku demand system. The lifetime undiscounted cost is $40/MWh. In comparison, Arimura et al. (2012) find a lifetime undiscounted cost under previous utility-sponsored programs of $32/MWh. (All values are in 2010$.)

Results

Table 1 compares scenarios for 2020, when emissions reductions of 400 million short tons are achieved compared with emissions of 2,073 million short tons in the baseline.

Under the cap-and-trade policy with a revenue-raising auction, the national average electricity price increases by 9 percent. Under the other policies, the change in electricity price ranges from less than 1 percent under the tradable performance standard to 2 percent under allocation to LDCs. Under the tradable performance standard, the asset value is used to subsidize production. In particular, the benchmark emissions rate is above the observed emissions rate for most natural gas units, providing a valuable net subsidy to production that reduces the variable cost of generation, leading to lower costs for the generator on the margin that is setting electricity price. Consequently, given the relatively greater level of electricity production, the marginal abatement cost is about 50 percent greater than under cap and trade with auction. Because production is greater, the carbon intensity of electricity generation must be less, as indicated in the third row of the table. This is achieved primarily by greater substitution from coal to gas.

When the asset value is used to subsidize consumers through their LDCs, the electricity price increase is substantially less than with the revenue-raising auction, but consumption and the marginal abatement cost are greater. However, the subsidy to consumers differs importantly from the subsidy to fossil generators, which reduces the variable cost of generation. In equilibrium (accounting for the subsidy to consumers), the price increase is a bit greater under the consumption subsidy than with the generator subsidy (i.e., the tradable performance standard). Perhaps surprisingly, producers as a group fare better when the asset value is directed to consumers through their LDCs, because this results in a higher electricity price, whereas consumers fare better when the asset value is directed to fossil generators, because this has the greatest effect on variable cost of the marginal electricity generator, leading to a lower electricity price.

When half of the auction revenue is directed to investments in energy efficiency, however, electricity consumption and generation are reduced more substantially. This enables the emissions intensity of supply to be greatest across the scenarios we examine, because in this case, less generation emits the same amount of CO_2. The marginal abatement cost is least in this scenario.

Total social cost is measured in a partial equilibrium framework and includes changes in producer and consumer surplus within the electricity sector plus changes in government revenue. The total social cost is least under cap and trade with auction, which results in $28 billion in auction revenue. The cost is more than doubled under the tradable performance standard and the auction with allocation to LDCs. The cost for the scenario with investment in energy efficiency leads to a large shift in the demand curve. Consequently, the partial equilibrium welfare changes we measure are not well defined and not reported. Nonetheless, we can conclude that producers and consumers combined are worst off under cap and trade with a revenue-raising auction and best off when the asset value stays within the sector. It is noteworthy, however, that the change in natural gas use under various scenarios would raise gas prices outside of the electricity sector.

Table 1. Key Results for Year 2020 (2010$)

	Baseline	*Cap and trade: auction*	*Tradable perform. standard*	*Cap and trade: LDC*	*Cap and trade: LDC + EE*
Recipient of asset value:		(government)	(producers)	(consumers)	(consumers)
Marginal abatement cost ($/ton)	—	18	27	21	12
Electricity price ($/MWh)	98	107	99	100	100
Emissions rate at fossil units (lbs. CO_2/MWh)	1,637	1,415	1,332	1,345	1,466
Total consumption (TWh)	3,821	3,631	3,764	3,753	3,545
Delivered natural gas price ($/mmBtu)	4.3	5.0	5.5	5.3	4.6
Total welfare change: cost (B$)	—	–3	–7	–7	n/a
Producer surplus	—	*2*	*–4*	*0*	—
Consumer surplus	—	*–33*	*–2*	*–8*	—
Government revenues	—	*28*	*–1*	*0*	—
Total welfare change: benefits (B$)	—	34	38	37	34
CO_2 benefits	—	*16*	*16*	*16*	*16*
SO_2 benefits	—	*17*	*22*	*21*	*17*

Note: The cost for the scenario with investment in energy efficiency leads to a large shift in the demand curve. Consequently, the partial equilibrium welfare changes we measure are not well defined and not reported.

These costs are strongly dominated by estimates of benefits. In the cap and trade with auction, benefits total $34 billion in 2020, 10 times the size of costs. In that scenario, benefits come almost equally from CO_2 reductions valued at the medium case value ($42 per short ton) of the social cost of carbon (Interagency Working Group on Social Cost of Carbon 2013) and from reductions in SO_2. To evaluate the benefits of reductions in SO_2 , we rely on average benefit per ton estimates used in EPA (2011) for eastern and western parts of the country.[4] The CO_2 benefits are the same across the policy scenarios because the same emissions reductions are achieved. However, greater consumption and a lower CO_2 emissions rate across the fossil fleet result in less coal generation and more gas generation. Consequently, SO_2 emissions are reduced, causing an increase in overall benefits.

Conclusion

Much of the economics literature has approached the policy challenge of addressing climate change as a problem of designing an efficient system, often not recognizing the institutional constraints and political economy of diverse interest groups that affect the outcome, while the political science literature describes the challenge more as a problem of process and coalition formation (Keohane and Victor 2013). In the US domestic policy arena, policy is taking shape through the existing institution of the Clean Air Act with a process that involves many stakeholders at the federal and state levels. Nonetheless, the relevant portion of the act offers an opportunity for a low-cost outcome, especially compared with traditional, prescriptive approaches to regulation. These regulatory decisions will devolve to state authorities; consequently, we suspect that the influence of the regulated entities and state energy regulators over the form of regulation is likely to be enhanced. Their influence may be to capture for the electricity sector the asset value that is created by introducing a constraint on carbon emissions by directing that value either to CO_2-emitting producers or to consumers. In this paper, we have evaluated bookend options that could emerge.

In simulation modeling, we found producers and consumers together fare much better when the value of assets created by introducing a (shadow) price on carbon is kept within the electricity sector than if the value accrues to government, even though the latter approach would have lower social cost. However, in every scenario we examined, the net benefits of regulation

[4] In the eastern United States, the value is $30,492 per short ton of SO_2, and in the West, it is $8,741 (2010$).

are positive and large. Moreover, net benefits are similar across the policies because the approaches with greater social cost serendipitously yield greater ancillary reductions in SO_2 emissions. The most inefficient policy outcome among those we compared would be no policy; in contrast, regulation under the Clean Air Act appears hugely beneficial.

A regulatory approach threatens additional inefficiency because of inconsistency of marginal abatement costs across sectors (Metcalf 2009). One way regulation might address this is by aligning stringency according to a common metric such as the interagency estimate of the social cost of carbon. One important result in this paper is that the observed marginal abatement cost can vary substantially depending on the form of the regulation, and efforts to coordinate the stringency of regulation across sectors should take this into account.

Another form of inefficiency may stem from the coordination problem among states. In this analysis, we examined alternative forms of a uniform policy implemented by all states. However, if states retain a great degree of discretion, they may not all choose the same approach. Coordination problems may result because state borders are incongruous with power pools, which loosely define markets. If the regulatory design differs among states within the same power pool, this may have strategic implications with respect to incentives for system operation or new investment, a subject of ongoing analysis. A dilemma for EPA is the possibility of perverse outcomes because of the interaction of state policies within regional power markets. Full deference to the states in the design of policy may not be consistent with a low-cost outcome. Some policy coordination from EPA may be required. In this sense, the trade-offs that must be considered and the way this regulation takes shape may be a microcosm of the "bottom-up" policy context at the international level.

On the other hand, if conflicts are avoided, state actions can capture a major share of the potential cost-effectiveness of first-best policy instruments, and states may build coalitions and institutional infrastructure to enable greater emissions mitigation. Economists have a huge opportunity to influence the outcome by suggesting that the regulations create proper incentives for abatement and by helping develop a program design that anticipates and avoids strategic behavior in the decisions of state governments.

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