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The Costs and Consequences of Clean Air Act Regulation of CO2 from Power Plants

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RESOURCES FOR THE FUTURE

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Abstract

U.S. climate policy is unfolding under the Clean Air Act. Mobile source and construction permitting regulations are in place. Most importantly, EPA and states will determine the form and stringency of the regulations for power plants. Various approaches would affect the cost of emitting greenhouse gases; these approaches create valuable assets, but they distribute the asset values differently among electricity producers, consumers, and the government. We compare a tradable performance standard with several cap and trade policies. Distributing asset values to producers and consumers has small effects on average electricity prices but imposes greater social cost than a revenue-raising policy.

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 provides the current regulatory framework for climate policy in the United States. In 2011, regulations were implemented for light duty vehicles that require a 5 percent improvement in efficiency per year and pre-construction permitting for new and modified stationary sources 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 generation, which is responsible for roughly one third of the nation's greenhouse gas emissions and nearly 40 percent of the nation's carbon dioxide (CO_2) 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 U.S. climate policy. However, the U.S. remains positioned to achieve domestic emissions reductions in 2020 as great as would have been achieved under that legislation (Burtraw and Woerman 2013a). These reductions could enable the U.S. to achieve President Obama's pledge of a 17 percent reduction from 2005 emissions levels by 2020 with respect to CO_2, although the prospect for other greenhouse gases is less promising. Achieving the 2020 pledge hinges on expected regulations for the power sector.

The regulation of greenhouse gases from power plants under the CAA can be cost effective, at least among the sources or sectors covered by the regulation. In 2013 President Obama directed the Environmental Protection Agency (EPA) to move forward with regulations that "to the greatest extent possible" allow the use of regulatory flexibility.[1] EPA guidelines will 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.

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

This paper surveys the major policy approaches the EPA and states are likely to consider. Each approach differs in the way it creates and allocates asset values, and we argue that this difference has important distributional and efficiency consequences. Using a simulation model of the U.S. electricity system, we compare policies that would reduce emissions sufficiently to take the nation past 16 percentage points of the 17 percentage point goal and within reach of the United States' 2020 target. A couple of key innovations make this modeling valuable. The model includes the first econometric estimates of the opportunity to improve emissions rates at existing coal-fired facilities, and it presents a full equilibrium accounting of the source of funds directed to various investments including energy efficiency and the effect on electricity prices, investment and system operation.

National cap-and-trade with a revenue-raising auction is the policy most familiar to economists 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 in fact do introduce a shadow price on emissions. All of the policies we consider create assets that have value to their owners, and the distinguishing feature among approaches is how the asset value is distributed to actors in the economy; this distribution has both efficiency and distributional consequences. We direct the value to five alternative uses: government, fossil-fired generators, consumers, energy-efficient end-use and renewable technologies.

We compare a cap-and-trade policy that directs auction revenue to government, which in fact might 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 exceed the standard to generate and sell credits to generators 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 that 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 keep the asset value in the industry by distributing it to producers or consumers, or as investments in technology, lead to very small changes in average electricity prices compared to one that allocates value to government. Under the tradable performance standard when all of the asset value is concentrated as a production subsidy to fossil-fuel generators, the increase in electricity price is less than one-tenth of the change under cap and trade with auction. 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, thereby lowering the electricity price. Allocating assets to consumers raises the electricity price by more than the standard because it distributes the asset value as a subsidy to all consumption without discriminating among types of production, thereby diminishing the value of the subsidy to the marginal fossil generators. Nonetheless, the change is only about one-third of cap and trade with auction.

The small change in electricity price may have political advantage but it also has economic disadvantage compared to a revenue-raising auction because the 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, an option we consider, which also leads to very small changes in electricity prices. These policies all lead to little incremental investment in renewable technology because existing state-level standards that establish a minimum quota continue to bind in most cases. However, additional mandates for investment in renewable energy also mitigate the increase in electricity prices compared to a revenue-raising auction. 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.

Decisions that will be made under the Clean Air Act involve a complex political economy at the national and subnational level. The national government will set goals but is expected to give discretion to states on how to achieve them. However, state decisions are not independent. A dilemma for EPA is the possibility of perverse outcomes because of the interaction of state policies within regional power markets, a point we discuss further in conclusion. In this paper we survey the bookend options of the policy framework that is taking shape. The tradeoffs 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.

The next section of the paper describes the policy framework of the Clean Air Act. Section 3 describes the model and baseline for the electricity sector. We then describe the policy scenarios and present a comparison of results before providing a concluding discussion.

Clean Air Act

There is considerable uncertainty about the structure of future regulations for existing power plants under the CAA, but there is the possibility that a market-based and reasonably cost effective approach will emerge. In *Mass v. EPA (2007)* the Supreme Court affirmed EPA's authority to regulate greenhouse gases. Subsequently the agency reached a formal finding of harm from these gases, which compelled the agency 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 they are based on measures that can be taken at individual facilities. The standards must reflect "the degree of emissions limitation achievable through the application of the best system of emissions 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 approaches(Wannier et al. 2011).

One approach would allow emissions rate averaging across sources, i.e. a tradable performance standard. 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 incentive for any action that reduces emissions. Although the 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 (tons/MWh) to calculate an emissions budget (tons) for each state, which 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 budget.

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 3.0 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 (2013b) incorporated the engineering estimates into simulation modeling to identify potential emissions reductions and their cost. This analysis suggests that nearly four times the emissions reductions would be possible if regulation encouraged switching from coal to natural gas compared to the estimates by Sargent & Lundy (2009), which are based on case studies of 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 mid-value of the social cost estimate is proximate to the marginal abatement cost of the technical measures already identified by EPA.

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 out to the year 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

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

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 from season to 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 are differentiated by quality and content. Coal, natural gas and biomass prices are differentiated by point of delivery and are modeled with price-responsive supply curves. Prices of oil and nuclear fuel as well as of 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 enough 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 co-fire with gas or, to a limited degree, with biomass.

Baseline: The *Baseline* includes all major environmental policies including allowance trading for SO_2 under Title IV of the Act, 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 peformance 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 U.S., 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 AEO 2012 forecasts with the exception of natural gas prices which is benchmarked to the updated AEO 2013 forecasts for both level and supply elasticity (EIA 2012; EIA 2013).

Policy Scenarios

We use this laboratory to analyze and compare 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 baseline, escalating linearly to 400 in 2020 and 650 in 2035. These targets would result in emissions reductions well past 16 percentage points relative to President Obama's 17 percent reduction pledge by 2020 at a marginal cost that would be proximate to the administration's estimate of the social cost of carbon. There is no banking or borrowing across years.

Cap and Trade with 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 the EPA could not introduce a revenue-raising policy, such an approach might be implemented by states (Morris 2013).

Tradable 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, which constitutes a production subsidy compared to the cap and trade with auction scenario. Generators surrender credits equal to their actual emissions rate multiplied by their annual generation, which constitutes 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. Benchmarks could be differentiated by technology or fuel, leading to different outcomes.

Cap and Trade with Allocation to Local Distribution Companies: California's existing cap-and-trade policy for the electricity sector, as well as the Waxman-Markey proposal (HR 2454) that passed the House of Representatives in June 2009, 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 electricity, these costs 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 were to use the revenue to reduce the fixed cost portion of electricity bills, then electricity prices would reflect the cost of the carbon constraint. However, it is unlikely all but the most sophisticated consumers differentiate between the fixed and variable portion of their bills and are likely to respond to changes in the bill rather than changes in the price (Borenstein 2009; Ito 2012). Consequently, in this scenario consumers are expected to behave as though electricity is less expensive than when auction revenues go to the government (Burtraw et al. 2010).

Cap and Trade with Allocation to Local Distribution Companies and Energy Efficiency Investments: The second existing cap-and-trade program in nine 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 2013). Actual decisions in RGGI are made by individual states. Across the nation, twenty states already have energy efficiency resource standards in place and 7 have similar goals (N.C.S.U.). Over two-thirds 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, who direct one-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 $40/MWh. (All values are 2010$.) In a sensitivity analysis we consider energy efficiency costs that are twice as expensive.

Results

Scenarios are compared for 2020 in Table 1, when emissions reductions of 400 million short tons are achieved compared to emissions of 2,073 in the *Baseline*.

When the asset value is directed to subsidize production under the performance standard or to subsidize consumption with allocation to LDCs the marginal abatement cost is about fifty percent greater than under cap and trade with auction. The distinction arises because these policies result in a small change in electricity price and in consumption and production compared to the cap and trade with auction. Consequently the carbon intensity of electricity generation must be less, as indicated in the third row of the table, which is achieved primarily from greater substitution from coal to gas resulting in greater marginal abatement cost. However, when half of the auction revenue is directed to investments in energy efficiency at our specified technology cost leading to reduced consumption and production, the resulting emissions intensity of supply is greater and the marginal abatement cost of emissions reductions from supply-side activities covered by the policies is twenty percent less than under the cap and trade with auction. We also consider a requirement to expand investment in renewables combined with allocation to LDCs and energy efficiency, which leads to the highest emissions intensity (across the fossil fleet) and the lowest marginal abatement cost.

Electricity price increases under cap and trade with auction by 9 percent on average across the nation. Under the other policies the change in electricity price ranges from less than one percent under the tradable performance standard to 33 percent under allocation to LDCs.

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 dollars in revenue. It is more than doubled under the next lowest cost scenario, which is the tradable performance standard and greater still across other scenarios. However, as viewed from within the electricity sector, producers and consumers combined are worst off under cap and trade with a revenue-raising auction.

These costs are strongly dominated by estimates of benefits. In the cap and trade with auction, benefits total $34 billion in 2020, ten times greater than costs. In that scenario, benefits come almost equally from the value of CO_2 reductions valued at the medium case value ($41 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.[3] When there is greater consumption and lower CO_2 emissions intensity under the tradable performance standard or with allocation to LDCs there is also a greater substitution away from coal generation, with associated greater SO_2 reduction benefits. On the other hand, there is a serendipitous outcome under the cap and trade with LDC allocation and energy efficiency spending because SO_2 benefits depend on where reductions occur.

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[3] In the eastern United States, the value is $30,000 per short ton of SO_2, and in the West, it is $8,600 (2009$).

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

	Baseline	*Cap and Trade: Auction*	*Tradable Perf. Standard*	*Cap and Trade: LDC*	*Cap and Trade: LDC + EE*
Marginal Abatement Cost ($/ton)	-	16.9	25.2	25.4	13.4
Electricity Price ($/MWh)	98.0	106.8	98.8	101.2	100.8
Emissions rate at fossil units (tons/MWh)	1,633	1,409	1,328	1,345	1,445
Total Social Cost (B$): Change from Baseline	-	-3.1	-7.0	-8.9	-10.5
Producer Surplus	-	0.3	-4.1	3.3	0.0
Consumer Surplus	-	-30.9	-2.0	-11.5	-8.4
Govt Revenues	-	27.6	-0.9	-0.7	-2.0
Total Benefits (B$)	-	34.0	37.2	36.4	36.1

We examine three other scenarios in sensitivity analysis. When we double the technology cost of energy efficiency we find only moderately greater marginal abatement cost or change in electricity price. Total social cost grows by 22 percent and benefits fall by 5 percent.

We also evaluate cap and trade with allocation to LDCs and investment in energy efficiency along with expanded requirement for generation with renewables, what might be called an all-of-the above approach. Twenty nine states plus the District of Columbia and two territories have standards requiring a percentage of all generation to come from renewable fuels (N.C.S.U.). In the *Baseline* these standards achieve 7 percent nationally by 2018 rising to 8 percent in 2035. Some of the standards are binding in most of the scenarios we consider so no major new investments in renewables are observed. In this scenario we imagine a national policy in addition to the existing state policies requiring that 5 percent of total electricity generation come from new renewable sources in 2018 increasing at 1 percent per year and reaching 22 percent in 2035. The renewable requirement is added to the previous scenario with allowance value directed to consumers and energy efficiency. This approach also leads to a small change in electricity price but it has greater resource costs because it forces investments that would not otherwise be chosen. The justification for such a policy would need to involve issues outside the model or beyond the model horizon. However, it also leads to substantial benefits resulting from reductions in SO_2 emissions, with total benefits roughly twice the other scenarios.

Conclusion

Most of the economics literature has approached the policy challenge of addressing climate change as a problem of design, while the political science literature describes it more as a problem of process (Keohane and Victor 2013). In the U.S. domestic policy arena, policy is not following a designed approach but instead carbon regulations are taking shape through existing policy. Under the Clean Air Act regulatory guidelines will be developed by the EPA and implementation plans will be developed by states. Because regulatory decisions will devolve to state authorities, we suspect that the influence of the regulated entities over the form of regulation is likely to be enhanced.

In simulation modeling, we find 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. If regulated entities have greater influence, then carbon asset value is more likely to be retained in the electricity sector, which would lead to a less efficient outcome. However, it is noteworthy that in every scenario we examine the net benefits of regulation are positive and large. The most inefficient policy outcome among those we compare would be no policy; in contrast, regulation under the Clean Air Act appears hugely beneficial.

A regulatory approach threatens additional inefficiency due to inconsistency of marginal abatement costs across sectors (Metcalf 2009). One way that regulation might address this is to align stringency according to a common metric such as the interagency estimate 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 examine 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 states as the jurisdiction of authority are incongruous with power pools. If the regulatory design differs among states within the same power pool it may have strategic implications with respect to incentives for system operation or new investment, a subject of ongoing analysis.

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 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 to anticipate and avoid strategic behavior in the decisions of state governments.

References

ACEEE 2013. State Energy Efficiency Scorecard. Washington DC, American Council for an Energy-Efficient Economy.

Borenstein, S. 2009. To What Electricity Price Do Consumers Respond? Residential Demand Elasticity under Increasing-Block Pricing. Paper presented at NBER., Summer Institute. July 2009, Cambridge, MA. http://www.nber.org/~confer/2009/SI2009/EEE/Borenstein.pdf.

Burtraw, D., A. Fraas and N. Richardson 2011. Greenhouse Gas Regulations under the Clean Air Act: A Guide for Economists. Review of Environmental Economics and Policy 5(2): 293-313.

Burtraw, D. and S. Sekar 2013 Journal of Environmental Studies and Sciences DOI: 10.1007/s13412-013-0151-y

Burtraw, D., M. Walls and J. Blonz 2010. Distributional Impacts of Carbon Pricing Policies in the Electricity Sector. U.S. Energy Tax Polic. G. E. Metcalf. Cambridge, Cambridge University Press.

Burtraw, D. and M. Woerman 2013a. Economic Ideas for a Complex Climate Policy Regime. Energy Economics forthcoming.

Burtraw, D. and M. Woerman 2013b. Technology Flexibility and Stringency for Greenhouse Gas Regulations. Washington DC, Resources for the Future. Discussion Paper 13-24.

EIA 2012. Annual Energy Outlook 2012. Washington DC, Energy Information Administration.

EIA 2013. Annual Energy Outlook 2013. Washington DC, Energy Information Administration.

EPA 2011. Regulatory Impact Analysis for the Final Mercury and Air Toxics Standards, U.S. Environmental Protection Agency.

Houthakker, H. S., P. K. Verleger and D. P. Sheehan 1974. Dynamic Demand Analysis for Gasoline and Residential Electricity. American Journal of Agricultural Economics 56: 412-418.

Interagency Working Group on Social Cost of Carbon, U. S. G. 2013. Technical Support Document: Technical Update of the Social Cost of Carbon for Regulatory Impact Analysis under Executive Order 12866. Washington, DC: U.S. Government.

Ito, K. 2012. Do Consumers Respond to Marginal or Average Price? Evidence from Nonlinear Electricity Pricing. University of California, Berkeley, Energy Institute at Haas Working Paper 210R.

Keohane, R. O. and D. G. Victor 2013. The Transnational Politics of Energy. Daedalus 142(1): 97-109.

Linn, J., E. Mastrangelo and D. Burtraw 2013. Regulating Greenhouse Gases from Coal Power Plants under the Clean Air Act. Discussion Paper 13-05.

Metcalf, G. E. 2009. Market-Based Policy Options to Control U.S. Greenhouse Gas Emissions. Journal of Economic Perspectives 12(2): 5-27.

Morris, A. 2013. Recommendations to the U.S. Environmental Protection Agency: Why EPA Should Offer a Price-Based Standard for Carbon Pollution from Existing Power Plants. Washington DC, Brookings.

N.C.S.U. Database of State Incentives for Renewables and Efficiency. http://www.dsireusa.org/rpsdata/ (Accessed December 27, 2013).

Newell, R. G. and K. Rogers 2003. The Market-based Lead Phasedown Washington DC, Resources for the Future.

Nichols, A. L. 1997. Lead in Gasoline. Economic Analyses at E.P.A.: Assessing Regulatory Impact. R. D. Morgenstern. Washington DC, Resources for the Future: 49-86.

Paul, A., D. Burtraw and K. Palmer 2009a. Haiku Documentation: R.F.F.'s Electricity Market Model version 2.0 Washington DC, Resources for the Future.

Paul, A., E. Myers and K. Palmer 2009b. A Partial Adjustment Model of U.S. Electricity Demand by Region, Season, and Sector. Resources for the Future Discussion Paper 08-50.

Sargent & Lundy, L. L. C. 2009. Coal-Fired Power plant Heat Rate Reductions. L. L. C. Sargent & Lundy.

Wannier, G. E., J. A. Schwartz, N. Richardson, M. A. Livermore, M. B. Gerrard and D. Burtraw 2011. Prevailing Academic View on Compliance Flexibility under Section 111 of the Clean Air Act. Washington DC, Resources for the Future.