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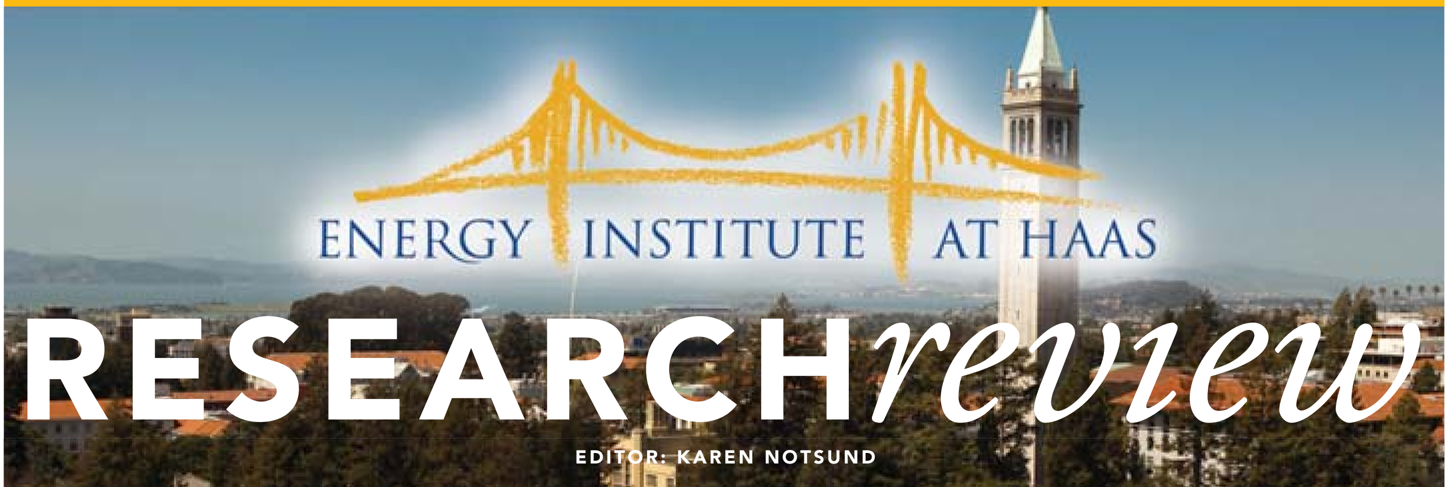

Cost Comparisons Between Renewable and Conventional Generation: It's Not as Simple as Some Would Like to Believe

Electricity from renewable sources is more expensive than conventional generation, but it reduces pollution. Analyzing the tradeoff between renewable and conventional energy sources is much more challenging than is often presumed because the value of electricity is extremely dependent on the time and location at which it is produced.

Likewise, the pollution benefits from renewable energy depend on what type of generation it displaces, which also depends on time and location. Without incorporating these factors, cost-benefit analyses of the alternatives are bound to be misleading. If governments are to implement reasoned renewable generation policy, it will be critical to understand the costs and benefits of these technologies in the context of the electricity systems in which they operate.

In his paper "The Private and Public Economics of Renewable Electricity Generation" (EI @ Haas Working Paper WP-221R), **Severin Borenstein** (University of California, Berkeley) studies the market and non-market valuation of electricity generation from renewable and conventional electricity generation, as well as the costs and subsidies that are available. Hydroelectric and geothermal generation are generally viewed as renewable, but they offer limited expansion opportunities and face environmental challenges apart from emissions. Borenstein focuses on the three broad categories of renewable energy that are considered closest to being scalable and cost competitive: wind, solar and biomass. The most significant potential barriers to greater adoption of solar, wind and biomass are cost of generation, cost of transmitting the power to where the demand is, and the value of the power generated. The lowest-cost wind power is usually generated in fairly remote locations, so the cost of infrastructure to transmit the power to demand sites can be significant. Some utility-scale solar generation suffers from the same need for substantial transmission investments.

Rooftop solar photovoltaics reduce the need for investment in high-voltage transmission lines, but there is controversy about whether solar PV reduces or increases the cost of the local distribution network. The cost of

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Climate Change Transportation Policies: Why Do Politicians Prefer Subsidies?

Economists agree that the preferred approach to addressing climate change is to price carbon either through a tax or a cap and trade program. Instead of efficiently pricing greenhouse gases, policy makers have favored approaches that implicitly or explicitly subsidize low carbon fuels. Given the inherent inefficiency of these alternatives, what explains the persistence of these policies in spite of their higher costs?

New research by **Stephen Holland** (University of North Carolina, Greensboro), **Jonathan Hughes** (University of Colorado, Boulder), **Christopher Knittel** (M.I.T.), and **Nathan Parker** (University of California, Davis) provides evidence that the answer lies in the political economy of climate change policy. In their EI @ Haas Working Paper WP-220 "Some Inconvenient Truths About Climate Change Policy: The Distributional Impacts of Transportation Policies" the researchers analyze the impacts of a cap and trade policy and three alternative policies that subsidize low carbon transportation fuels. While the alternatives to cap and trade are more expensive, policies that subsidize low carbon transportation fuels share a feature that makes them more amenable to adoption – the benefits are concentrated among a few "winners" and the losses are more dispersed among a number of "losers." With "winners" more clearly identified and positioned to gain significantly, their ability and incentive to influence policy is greater than that of a larger, less cohesive group of "losers" who each stand to lose a relatively small amount.

In their research, Holland, Hughes, Knittel and Parker simulate the U.S. market for transportation fuel in 2022. They construct a model of advanced biofuels and compare the outcomes under four different low carbon policies: 1) cap and trade, 2) ethanol subsidies, 3) renewable fuel standard (RFS), and 4) low carbon fuel standard (LCFS). Cap and trade legislation has been adopted by several states but has not been adopted nationally. The ethanol subsidies and RFS are policies in place at the national level to promote increased consumption of ethanol.

Federal ethanol subsidies have been quite generous historically. The national RFS mandates increasing annual levels of biofuel production. The LCFS is a California policy which requires the average greenhouse gas content of fuels to fall over time. In previous work, Holland, Hughes and Knittel have shown that a LCFS acts as an implicit subsidy for any fuel with a greenhouse gas content below the standard. For each policy, the model simulates prices, quantities, changes in farming activity and changes in private gains at the county level in the U.S.

Their analysis confirms that policies that subsidize low carbon fuels are quite costly compared to a cap and trade program. Average abatement costs of carbon range from $49 per metric ton of carbon dioxide equivalent (MTCO2e) under the LCFS to $82 per MTCO2e for subsidies, compared with only $20 per MTCO2e under cap and trade. The RFS, LCFS and ethanol subsidies all result in larger shifts in agricultural activity and land use compared to cap and trade. Accounting for environmental cost due to land use changes further increases the cost disparity among policies, adding an additional $0.89 to $5.77 per MTCO2e to the average abatement cost for the alternatives to cap and trade.

To identify distributional impacts, the researchers generate county-level estimates of producer and consumer surplus under each policy. These estimates suggest that gains and losses are distributed differently across the four policies. For example, they find that under a direct subsidies policy, 5 percent of the counties have annual gains of more than $1,250 per capita, only one county gains more than $6,600 per capita, and no county loses more than $100 per capita, when ignoring any climate change benefits from the policy. In contrast, under a cap and trade program, 5 percent of the counties gain more than $73, only one county gains more than $1,015 per capita, and no county loses more than $20 per capita.

Furthermore, compared to a cap and trade policy, the researchers find that under policies that subsidize low carbon fuels, the per capita gains are more concentrated. In other words, the gains under a cap and trade program are relatively small on a per capita basis and dispersed, while the gains under policies that subsidize low carbon fuels are larger on a per capita basis and more concentrated. Figure 1 shows the concentration of gains by county under each of the policies.

To test whether the simulation results translate into political incentives, the researchers match the estimates of county-level gains and losses with Congressional voting on H.R. 2454, better known as the Waxman-Markey cap and trade bill. One provision in Waxman-Markey was a new accounting of ethanol carbon emissions that would substantially weaken the RFS, thus making the cap and trade and RFS policies likely substitutes for one another. Their results show that the greater a district's RFS gains, the less likely the House member voted for

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The Case for Why Offsets Can Help

With the advancement of market-based environmental mechanisms, such as cap and trade programs, the increasing popularity of these mechanisms has served to highlight shortcomings in their implementation. A major challenge for regulators has been to reach the proper scope, over both geography and industrial sectors, in which market-based mechanisms are allowed to operate.

For example, in the climate policy arena, a large challenge has been to mitigate leakage of greenhouse gas (GHG) emissions from regions falling under a cap to those regions falling outside a cap. In addition to geographic issues, there are concerns about inconsistent regulations across polluting industries within a jurisdiction. Unfortunately, several factors conspire to limit the reach of cap-and-trade systems even within a single regulatory jurisdiction. The costs of monitoring and implementing allowance trading systems have largely limited their applications to large single-point sources to date. In many cases, important sources of emissions are not included in legislation establishing the regulatory authority. Other sources of emissions, such as those associated with land use, would be difficult to integrate into a cap-and-trade program under any circumstances. Lastly, some industries are more effective at deploying their political influence to deflect attempts to regulate their emissions as intensively as other industries.

In the face of these jurisdictional, economic, and political limitations to the broad application of cap-and-trade, offsets have emerged as an appealing tool for attempting to breach the regulatory barriers between regions and sectors. The primary distinction between offset programs and other forms of regulation are that offsets pay firms to reduce their emissions rather than raise the costs of continuing to emit. The payments allow the process to work as a voluntary program, bypassing jurisdictional issues by, in theory, providing incentives for firms to self regulate.

Although the fundamental need for offsets is rooted in the limits of regulatory jurisdiction, today's offsets programs are in fact motivated by a host of goals. A primary goal for many regulated industries is cost control. The prospect of a deep pool of offset projects providing a potentially low-cost supply of reductions creates an effective ceiling on allowance prices in a cap-and-trade system. To the extent that low-cost options for reducing emissions exist in sectors that are not directly regulated under a cap, an offset market allows for these "low-hanging fruit" to be harvested in place of more expensive reductions from the capped sector.

At the heart of most criticisms of offset programs is the concern that these offset programs are not in fact yielding the expected emissions reductions. Two fundamental attributes of offset programs may contribute to this problem. First, offset programs require a determination of an *emissions baseline* from which the attributable reductions can be measured. However, baselines by definition cannot be observed since they are a product of a "what if" exercise – what would emissions have been if the facility had not sold any offsets? Second, participation in an offset program is voluntary.

The combination of imperfect measurement and self-selection makes offset programs vulnerable to two classic regulatory problems: moral hazard and adverse selection. Moral hazard involves firms actively taking steps to inflate their baselines. Adverse selection involves paying too much to firms with already low emissions. **James Bushnell** (University of California, Davis) in his paper "Adverse Selection and Emissions Offsets" (EI @ Haas Working Paper WP-222) focuses on the phenomenon that offset sales will be particularly attractive to firms whose true baselines are lower than the regulators' estimates. These firms can essentially be paid for 'reductions' that would have happened anyway. In the jargon of offset policy, this problem is known as *non-additionality.* Bushnell develops a model of two polluting sectors, one which faces a cap on emissions and the other which does not. He uses the model to analyze the implications of imperfect information regarding the baseline emissions in both the capped and uncapped sectors and the impact on abatement costs and emissions levels when offset sales are allowed. Unlike other models of offset markets, regulators not only do not know whether a firm has a dirty or a clean baseline, regulators also may be wrong about the total amount of expected emissions from all uncapped firms.

Bushnell suggests that sales of offsets by "non-additional" projects are not equally onerous under differing circumstances. Such a transaction can indicate adverse selection, but might instead reveal valuable information about the baseline emissions of the entire population of offset eligible projects. With these observations in mind, it is useful to consider the conditions under which offsets are likely to be the most beneficial. One such scenario is when the range of uncertainty about aggregate baseline emissions is large relative to the degree of variation in baseline emissions

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COST COMPARISONS BETWEEN RENEWABLE AND CONVENTIONAL GENERATION: IT'S NOT AS SIMPLE AS SOME WOULD LIKE TO BELIEVE CONTINUED FROM FRONT PAGE

of collecting and preparing the fuel relative to the energy it produces. All these factors illustrate that the cost of each renewable energy source can vary tremendously.

Many researchers and policy analysts have attempted to quantify these differences and have summarized their findings by presenting "levelized cost" estimates for the various generation technologies –a measure of the average cost of per kilowatt-hour over the lifetime of the source. Borenstein shows the astounding range of estimates and explains how subtle differences in assumptions about capital costs, inflation, tax treatment and other economic factors are the source of most variation in cost estimates.

Beyond the variation in cost estimates, previous research by Borenstein and many others has shown that the value of the power delivered from different generation sources also varies a lot. The value of power from intermittent resources, such as solar and wind, must account for the time at which it is produced. Because electricity is extremely costly to store, wholesale prices can vary by a factor of 10 or more within a day. Solar power is produced only during daylight hours and tends to peak in the middle of the day. In many areas, this is close to coincident with the highest electricity demand which usually occurs on summer afternoons. Thus, the average economic value of generation from solar is greater than if it produced the same quantity of power at a constant average rate over all hours of the day. Most wind generation in the U.S. has the opposite generation pattern, producing more power at night and at times of lower demand and prices. In addition, to cope with the minute-to-minute variability of intermittent resources, grid operators must contract for extra standby generation, the costs of which are spread across all the electricity in the market.

While a grid can handle very small shares of intermittent resources with little additional cost – in fact to a grid operator such supply variation looks almost the same as the fluctuations in demand – some grid engineers have argued that the cost will increase more than proportionally if intermittent resources constitute a significant share of generation. Ideal market pricing would reveal the value of a generator's production at every instant, but who lesale electricity markets are not set up to generate such fine-grained temporal price signals.

The value of power varies not just temporally, but also locationally due to transmission constraints. Complete locational pricing is difficult logistically due to the complex physics of power flows, but a number of areas of the U.S. do have what is known as "locational marginal pricing" that sends fairly efficient short-run price signals. The greater challenge is in the long run Borenstein argues, because the full cost of adding new transmission capacity can differ significantly from the direct infrastructure cost once one accounts for the resulting change in transmission capacity on all lines in the grid.

The pollution benefits of renewable energy are also more difficult to evaluate than it may at first seem. Incorporating emissions reduction requires knowing which fossil-fuel generation the renewable generation displaces. Solar power that reduces coal-fired generation lowers greenhouse gas emissions by about twice as much on average as if it reduces natural-gas-fired generation. A number of studies have attempted to identify the generation that is displaced in the short run by an additional unit of power from wind or solar, which is challenging in itself. Still, Borenstein argues that the more important and much more difficult question is the long-run displacement as new generation is built and old plants retire over the many-decades life of new renewable generation.

Accounting for the pollution benefits of renewables is made so difficult, Borenstein argues, because most governments have attempted to do so by subsidizing "green power" rather than charging "brown power" for the pollution it creates. Charging directly for the pollution emitted eliminates the need for the difficult and imprecise estimation of which generation is displaced by each unit of power from a renewable source. Subsidizing green power is also less efficient than taxing brown power because it keeps the price of power below its true social cost, causing over-consumption of electricity and disincentives for energy efficiency.

Renewable generation will continue to improve and will likely take on increasing importance as the impacts of climate change become more pronounced. It will be critical to be able to construct comparable estimates of the costs and benefits of different energy options. That will require careful incorporation of many factors beyond the simple levelized cost estimates that are often referenced. EI@HAAS

Severin Borenstein, " *The Private and Public Economics of Renewable Electricity Generation,*" EI @ Haas WP-221R, December 2011.

CLIMATE CHANGE TRANSPORTATION POLICIES: WHY DO POLITICIANS PREFER SUBSIDIES?

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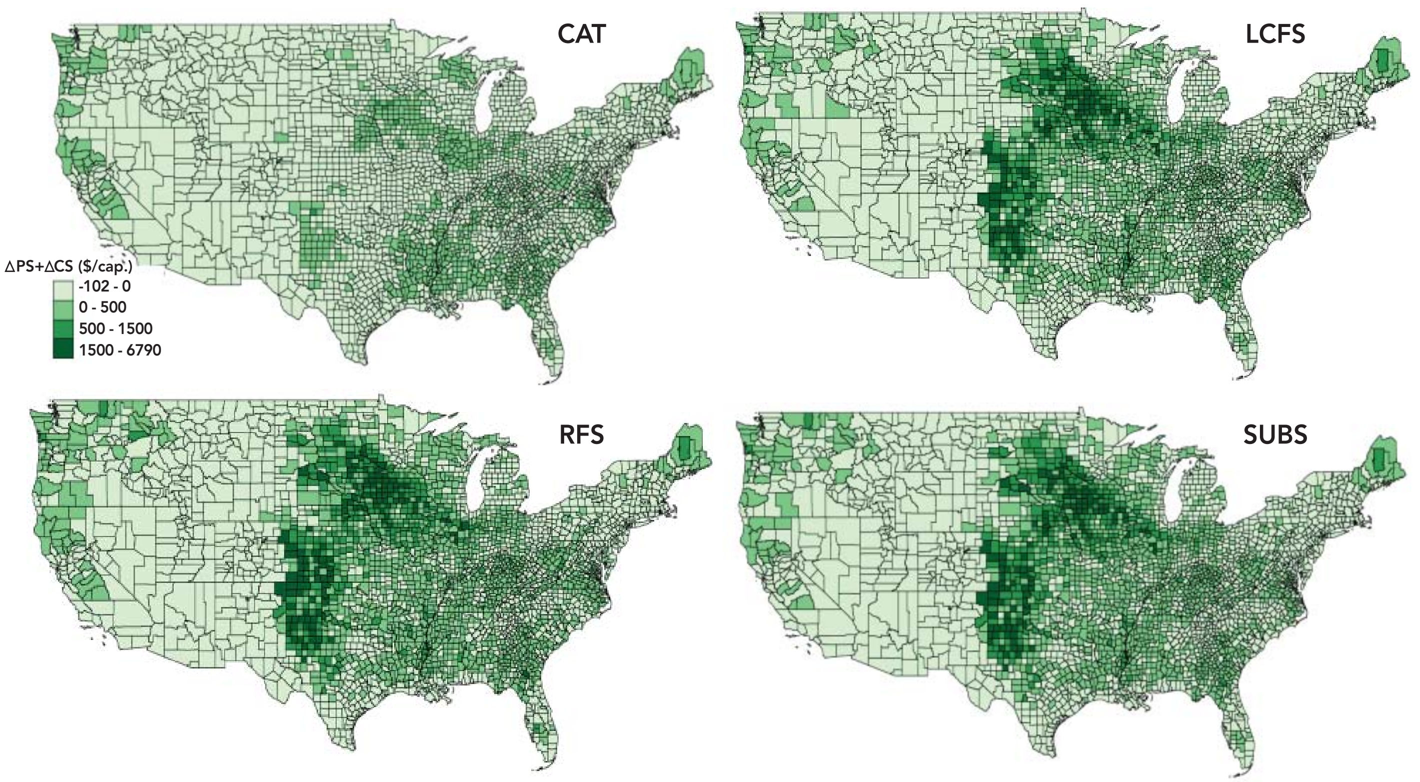
FIGURE 1: COUNTY-LEVEL GAINS AND LOSSES UNDER ALTERNATIVE LOW-CARBON POLICIES: CAP-AND-TRADE, LCFS, 2022 RFS AND SUBSIDIES.



Waxman-Markey. In that same spirit, the results also show that the greater a district's gains under cap and trade, the more likely the House member voted for Waxman-Markey. The results remain significant even after controlling for measures of a House member's political ideology, state and district-level carbon emission from sources other than transportation, and current corn production.

Holland, Hughes, Knittel and Parker also investigate whether there is a relationship between a district's gains and campaign contributions from organizations favoring one policy versus another. In particular, they match campaign contributions from organizations that either supported or opposed Waxman-Markey with estimates of a district's gains or losses from the RFS and cap and trade. They find that the greater a district's gain from the RFS, the more money the district's House Member received from organizations opposing Waxman-Markey. Similarly, when they match voting behavior with financial contributions, they find that contributions from groups who support Waxman-Markey are associated with an increase in the probability of voting for Waxman-Markey and that greater contributions from groups opposing Waxman-Markey are associated with a decrease in the probability of voting for Waxman-Markey.

Taken together these results strongly support the private-interest theory of regulation. This theory characterizes the regulatory process as one in which well-organized groups benefit at the expense of more dispersed groups.

The research finds that regulation with more concentrated private benefits – the RFS – is preferred by politicians over a cap and trade program which would offer larger social benefits but with less concentrated private benefits. The pattern of campaign contributions around the vote on Waxman-Markey is consistent with political interest groups effectively influencing carbon regulation to benefit their constituents.

While it may be inconvenient, this research shows both the benefits and the distribution of those benefits determine the adoption of climate legislation. **EI@HAAS**

Stephen P. Holland, Jonathan E. Hughes, Christopher R. Knittel, and Nathan C. Parker, "*Some Inconvenient Truths About Climate Change Policy: The Distributional Impacts of Transportation Policies,*" EI @ Haas WP-220, August 2011.

THE CASE FOR WHY OFFSETS CAN HELP

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within a population of eligible projects. In the face of such large uncertainty in the uncapped sector, the optimal policy is likely to be one that sets emissions limits as tightly as possible in the capped sector, while simultaneously encouraging offset sales – additional or not – from the uncapped sector. This strategy of "plan for the worst, hope for the best" would allow the stringency of the cap in the capped sector to adjust automatically to the emergence of surprisingly low emissions from the uncapped sector. Of course, this strategy depends on regulators being able to reach enough emissions under the cap to be able to reach emissions targets with abatement from the capped sector alone.

To date the primary bulwark against additionality concerns has been a review process that has been simultaneously criticized as too onerous to allow for substantial investment and also inadequate in weeding out non-additional projects. Implementing a programmatic rather than project-specific review process can offer several potential benefits. First, a programmatic approach can greatly lower the transaction costs of review and certification relative to the value of offsets produced. Second, such an approach can help access a broader array of activities including energy efficiency and prevention of deforestation that have largely been absent from cap-and-trade programs. Last, a program review can focus on risks, at an industry level, of the "bad" form of adverse selection while being less concerned with correlated, coincidental reductions. For example, investments in building efficiency may very well prove to be economic in the absence of offset programs, and therefore not truly additional. Even if that were the case, increased efficiency in one building is unlikely to imply worse efficiency in others. **EI@HAAS**

James Bushnell, "*Adverse Selection and Emissions Offsets*," EI @ Haas WP-222, September 2011.