I. Introduction

Reducing greenhouse gas emissions in the United States is an essential part of a global strategy to slow climate change and prevent the worst damages projected to result from higher temperatures, higher sea levels, and more erratic weather. Climate legislation to reduce emissions of carbon dioxide (CO_2) and other greenhouse gases is (once again) stalled in the U.S. Congress. One important challenge in passing emission-reduction legislation is the variation in economic impacts that such a policy would have among states. States have different median incomes, income distributions, expenditure patterns, energy and transportation infrastructure, and policies to facilitate household efforts to conserve energy and switch to fossil-fuel alternatives.

Climate policies — taxes or permits to regulate the emission of CO_2 and other greenhouse gases into the atmosphere — work by changing relative prices. Because almost every consumer good sold in the United States uses fossil fuels in its production and delivery, the prices of nearly all goods would increase if a tax were set on these emissions, or if emissions permits were required. The more fossil fuel that is embodied in a good or service — the more "carbon-intensive" the product — the bigger the impact that carbon policy will have on its price. The prices of carbon-intensive products such as electricity and fuels for heating, cooking, and transportation would increase by a bigger percentage than those of most other goods: The more carbon emitted (on a per-dollar basis), the bigger the percentage price increase. Thus high-carbon-intensity goods would become more expensive *relative to* low-carbon-intensity goods.

This change in relative prices gives consumers an incentive to buy (and producers an incentive to make) fewer high-carbon-intensity products (like coal-generated electricity), and more low-carbon-intensity products (like wind-powered electricity). This is the main intended consequence of carbon policy. Carbon taxes and permits are a way to change the allocation of economic resources away from the products that cause the most emissions per dollar and toward the products that cause the least emissions. The result is to simultaneously lower national greenhouse gas emissions and restructure our economy to embrace low-carbon energy sources and cutting-edge energy technology. The latter would also mean more "green jobs" in fields related to "clean" energy and technology, along with job losses in the most carbon-intensive sectors.

The *allocational consequences* of climate policy depend on the size of the cap on emissions (the tighter the cap, the higher the price for which permits will be traded) or the size of the tax. Higher permit prices or taxes are a bigger incentive to change our buying habits and restructure our economy.

Climate policy may also have an additional, unintended, consequence: It may change the U.S. income distribution — all households may lose some income, but poorer households will bear the brunt of the impact unless careful measures are taken to counteract this effect. Carbon taxes and permits increase prices economy-wide. That's inflation; our "real" (inflation-adjusted) incomes won't buy as much as they used to. Worse, this drop in real income will be "regressive" — that is, it will have a much bigger effect on working- and middle-class households, who tend to spend bigger shares of their incomes on utilities, gasoline and carbon-intensive consumer goods. Richer households, in contrast, save or invest much of their income, and their spending includes more low-carbon-intensity goods and services; overall, higher prices on electricity and fuels will only mean a small percentage increase in wealthier households' expenses.

The good news is that policymakers who crafted recent carbon legislation were aware of these unintended distributional effects, and all of the climate bills that have been under serious discussion in Congress in 2010 include provisions to balance income losses with some benefit to households. One model under discussion is "cap and dividend," a well-known policy tool supported by many economists. A cap is set on total emissions; this cap gets a little smaller each year. Companies are required to purchase permits to emit greenhouse gases, and some portion of permit revenues is returned to households as an equal per capita rebate.[1] Companies will pass along to consumers the cost of the permits, thereby raising prices and creating a "carbon cost." These carbon costs are a bigger share of income for lower-income households than for wealthier households, but – because wealthier households have bigger budgets – the total carbon costs per household are bigger for the rich than for the middle class or for those just making ends meet. The net effect – rebates less carbon costs – is likely to be "progressive," with income gains for lower-income households and small income losses for higher-income households.

A simple example may be useful:

One family of four makes $100,000 each year, spends $10,000 on carbon-intensive products today and (hypothetically) would spend $11,000 on these goods with higher prices under the carbon policy. Their carbon costs are $1,000, or 1 percent of their income. If the carbon rebate is $200 per person, the household receives a total rebate of $800. For this family, the impact of the policy is a loss of $1,000 and a gain of $800, for a net loss of $200.

A second family of four makes $35,000 each year, spends $7,000 on carbon-intensive products today and would spend $7,700 on these goods with higher prices under the carbon policy. Their carbon costs are $700, or 2.5 percent of their income. If the carbon rebate is $200 per person, the household receives a total rebate of $800. For this family, the impact of the policy is a loss of $700 and a gain of $800, for a net gain of $100.

The *distributional consequences* of climate policy depend on the specific details of how tax or permit revenue will be used: How much of this revenue will be returned to households? Will it be returned on an equal per capita basis? What will happen to the rest of revenue? Will it be invested in fostering green job growth? The consequences can be progressive, regressive, or neutral, depending on policy design and political will.

The allocational and distributional consequences of climate policy will differ from state to state. Some states have already made great strides in energy efficiency, and use less carbon-intensive electricity, household fuels, and transportation systems; residents of these states will face lower carbon costs and may, as a result, have less incentive to make further emission reductions. Similarly, densely populated states with mild climates – not too hot, not too cold – have, by U.S. standards, relatively low greenhouse gas emissions per capita today, and as a result will have lower carbon costs and less incentive to further change.

Other states will find climate policy a big incentive to reduce emissions and shift toward a low-carbon-intensity energy and transportation infrastructure. The states with the biggest incentive to change have the highest greenhouse gas emissions today. Some have failed to plan for or lacked the means to invest in energy-efficient, low-carbon technologies; others face more permanent obstacles,

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[1] Rebates need not be equal, nor need revenue be returned as a rebate check. Other policies under discussion include increasing the earned income tax credit and offsetting income or payroll taxes.

such as very cold or very hot climates, and low population densities that necessitate high levels of transportation use.

Climate policy should neither exacerbate existing inequality among and within states, nor create new inequalities. Emission reductions may require us to change our lifestyles, but should not reduce our quality of life, or place new burdens on lower-income households. Good climate policy will balance strong incentives to shift the allocation of resources within our economy away from fossil fuels and toward more environmentally sound alternatives, with revenue redistribution to working- and middle-class families to keep living standards high in the new green economy.

Carbon policy: A primer

The fundamental goal of any carbon policy is to reduce emissions, but how that is accomplished can vary considerably. The simplest approach is **regulation** – the U.S. Environmental Protection Agency or another agency sets limits on emissions by mandating or banning certain technologies, or by imposing limits on the concentration of pollutants in factory effluents or minimum standards for ambient air quality. That is the status quo; the EPA is authorized by the Clean Air Act to regulate greenhouse gases, and under the Obama administration, it has begun to do so.

Another simple, more "market-based" approach is a **carbon tax** or **carbon fee**. Government starts by setting a "price" on carbon, which may be done by estimating the cumulative damages from climate change and their current-day value (the "social cost of carbon") or by estimating the per unit cost of eliminating emissions (the "marginal abatement cost"). The price then serves as the basis for a per-ton, per-barrel or per-gallon tax or fee, adjusted as needed to create the desired market incentives to reach target emissions reductions.

Finland adopted the first national carbon tax in 1990, and a few other countries have followed suit, including Denmark, the Netherlands, Norway, and Sweden. In North America, the largest-scale carbon tax is in British Columbia, which sets different rates by fuel type. Some U.S. cities and other local governments, such as Boulder, Colorado, and parts of Northern California, have carbon taxes; the first countywide tax was approved in May 2010 in Montgomery County, Maryland.[2]

The alternative to a tax is a cap on emissions, combined with a limited set of **permits** or **allowances**, which decline over time to meet a long-term emissions reduction target. That is the basis of **cap and trade**, which has been part of the successful efforts to control sulfur dioxide (one of the causes of acid rain) in the United States since the 1990s and has been embraced by the European Union to reduce greenhouse gas emissions.

Under cap and trade, permits may be auctioned off or given away by the government; the purchase of permits may be open to all, or limited to a narrower set of players. Once sold or given to private entities, permits could then be sold on a secondary market for derivatives. Some legislative proposals call for substantial giveaways of permits, especially in early years. With a tax, the price is fixed but the exact amount of emission reduction is uncertain; with a cap, the price can vary but the amount of emission reduction is fixed (assuming perfect enforcement), although some cap-and-trade plans include price floors and ceilings to limit price fluctuation.

Cap-and-trade systems also often allow **offsets**, which are investments to reduce emissions somewhere other than the permitted source. For example, a coal-fired power plant in West Virginia might invest in wind turbines in Colorado, or in a reforestation project in Brazil, and get credit for this emission reduction. Purchasing offsets would reduce businesses' need to purchase emission permits.

Finally, under a **cap and dividend** policy, some portion of revenue from permit sales (in principle, this could apply just as easily to revenue from carbon taxes or fees) is returned to the public in one or a combination of several ways: equal per capita annual rebate checks, increased Earned Income Tax Credits, reductions to payroll, income, or other taxes, or rebates on utility bills, among many other possibilities.

[2] National Center for Environmental Economics (ND), British Columbia Ministry of Finance (2010), McGowan (2010).

The Policy Context

Climate change legislation has long been on U.S. officials' agenda, but since the 1990s, political opposition has grown so strong that any bill to curb greenhouse gas emissions and put a price on carbon has been seen as a non-starter. The United States signed but never ratified the Kyoto Protocol, which President George W. Bush opposed, and under Bush's leadership, not only was climate legislation stalled, but the U.S. Environmental Protection Agency (EPA) refused to regulate greenhouse gas emissions under the 1990 Clean Air Act, until the U.S. Supreme Court mandated it in 2007.

In the absence of federal action, some states have taken the lead. California, already ahead of the nation on environmental policy, adopted the United States' first enforceable statewide greenhouse gas emissions target in 2006, A.B. 32, the Global Warming Solutions Act. Since then, 31 states have adopted statewide emission targets, and 36 states have drafted climate action plans (32 were complete as of 2009) (Pew 2009).[3] California battled for years with the EPA over state fuel efficiency standards it adopted in 2005 but couldn't implement without an EPA waiver; 13 states and the District of Columbia[4] have since expressed an intention to adopt the standards, but the EPA stalled and then denied the waiver in 2008. Shortly after taking office, President Barack Obama ordered the EPA to review the decision, and it was overturned in June 2009 (EPA 2009a).

Many states have also adopted energy efficiency legislation, and as of 2009, 29 plus the District of Columbia had renewable portfolio standards (RPS), which require a certain share of electricity to come from eligible renewable sources; another five had voluntary RPSs. Almost half the states have public funds to support energy efficiency and renewable energy projects, and 44 have at least one utility that offers "net metering," in which customers with solar panels or other generation capabilities can sell power back to the grid; 18 have it available statewide. Several states have required power plants to reduce or offset their CO_2 emissions, and 19 have energy efficiency resource standards, which set energy savings targets for utilities (Pew 2009).

Some of the most aggressive U.S. efforts to address climate change so far have involved regional initiatives, including three with greenhouse gas cap-and-trade systems. The most advanced is the Regional Greenhouse Gas Initiative, formed in December 2005, in which ten Northeastern and Mid-Atlantic states have set out to reduce CO_2 emissions from power plants by 10 percent by 2018; the first allowance auction was in September 2008 (RGGI 2010). In February 2007, another five states formed the Western Climate Initiative, which has since grown to include seven states and four Canadian provinces with a goal of cutting greenhouse gas emissions by 15 percent from 2005 to 2020; a cap-and-trade program is slated to begin in 2012 (WCI 2010).

In November 2007, six states and the Canadian province of Manitoba signed the Midwestern Greenhouse Gas Reduction Accord, which was originally intended to launch a regional cap-and-trade program in 2010; three more states and Ontario have since joined as "observers" (MGGRA website 2010). An advisory group issued proposed standards and rules in May 2010, with implementation to begin in 2011 at the soonest, but members also prefaced their recommendations by saying they "strongly prefer the implementation of an effective cap-and-trade program at the federal level in both countries, rather than a regional program" (MGGRA Advisory Group 2010).

[3] See Appendix C for a full listing of states' participation in state and regional initiatives.
[4] For ease of analysis, Washington, D.C., is included throughout this report as a 51st "state."

Also in May 2010, the three regional initiatives announced they were working together to share their experiences with cap-and-trade programs, "inform federal decision-making" on climate policy, and explore future collaboration (RGGI et al. 2010).

At the federal level, meanwhile, the EPA's stance toward greenhouse gas regulation has dramatically changed under the Obama administration, and the agency has begun to consider climate change in setting standards and rules, treating greenhouse gases as pollutants under various sections of the Clean Air Act and including a "social cost" for carbon in cost-benefit analyses.[5] Many critics – including strong opponents of any carbon cap or tax – have tried to stop the EPA from regulating greenhouse gases under the 1990 law (Broder 2010).

This is the context for the climate legislation debates on Capitol Hill: After a decade of delays, legislation seemed to be moving forward in both chambers of Congress until July 2010, but political opposition has been fierce. The three highest-profile carbon policies considered by the 111th U.S. Congress are the American Clean Energy and Security Act of 2009 (Waxman-Markey) in the House, and the Carbon Limits and Energy for America's Renewal (CLEAR) Act (Cantwell-Collins) and the American Power Act (Kerry-Lieberman) in the Senate.

All three bills target (roughly) the same emission reductions, 5 percent below 2005 levels by 2015, 17 percent by 2020, 42 percent by 2030, and 83 percent by 2050.[6] Each bill includes a cap-and-trade system with a price floor and a price ceiling on permits. The floors (lowest prices allowed) are $7 to $12 per metric ton (mT) CO_2 in 2020, rising to $12 to $16 in 2020; the ceilings (highest prices allowed) are $21 to $28 per (mT) CO_2 in 2012, rising to $32 to $41 in 2020.[7] But that's where the similarities end. Waxman-Markey and Kerry-Lieberman give away large shares of permits to industry (starting at 85 and 77 percent, respectively) and allow (with some restrictions) permits to be resold on secondary derivatives markets, while Cantwell-Collins auctions every permit and disallows such resales.

Both Waxman-Markey and Kerry-Lieberman would restrict the EPA's role in greenhouse gas regulation, barring it from treating CO_2 and other gases as pollutants under the Clean Air Act, but making it the enforcer of most of the standards set by the new law. Waxman-Markey also assigns new roles to the EPA, such as regulating black carbon[8] and setting emissions standards for uncapped stationary sources emitting more than 10,000 mT. In addition, both bills shut down state and regional cap-and-trade programs – Waxman-Markey from 2012 to 2017, Kerry-Lieberman permanently – and allow participants to exchange their permits or offsets for federal ones. Cantwell-Collins, meanwhile, does not change the EPA's or states' roles.

Perhaps most importantly, Cantwell-Collins rebates 75 percent of policy revenues to households on an equal per capita basis; Waxman-Markey also includes rebates, starting in 2030 at 28 percent of revenues and increasing to 55 percent in 2050; in Kerry-Lieberman, rebates begin in 2026, reaching

[5] The EPA's methodology, and the cost it has assigned to carbon (a central value of $21 per metric ton of CO_2), is flawed and controversial; see Ackerman and Stanton (2010) for our analysis.
[6] In this section we generalize across all three bills, often citing the maximum or minimum level or provision that would be acceptable under all three bills.
[7] These are in today's dollars; each bill also allows inflation adjustments in the floor and ceiling prices. Waxman-Markey allows 5 percent annual real growth in the ceiling price until 2014, with a more complex escalator thereafter; this calculation assumes 5 percent real growth continues through 2020.
[8] Better known as soot, black carbon is the product of incomplete burning of fossil fuels, biofuels and biomass, and is an important contributor to climate change (Ramanathan and Carmichael 2008).

58 percent of revenues in 2035 to 2050. Some of the remaining revenues under all three bills are returned to households indirectly via utilities' rebates to customers or job assistance to workers in the most affected industries.

Overview of Report

Section 2 of this report reviews the literature of economic models related to climate policy. Recent studies of green employment analyze two economic impacts of climate policy as they relate to employment gains and losses. Some share of tax or permit revenues may be spent on clean energy and green job growth investments, or on job retraining for workers in sectors most likely to lose jobs. In addition, as climate policy incentives change relative prices, jobs in low-carbon-intensity sectors will grow, while jobs in high-carbon-intensity sectors decline. Other recent studies estimate the direct impacts of the costs and benefits of carbon caps, trading systems, and taxes on U.S. households, across U.S. states and regions, and by income levels.

Section 3 presents a new model that analyzes the impacts to households by state and by income level. We examine the impacts on household incomes and economy-wide emissions reductions resulting from a wide range of carbon prices and shares of carbon-policy revenues returned to households. Detailed findings are presented for two scenarios: a carbon price of \$25/mT CO_2 in 2015 and a price of \$75/mT CO_2 in 2020.

Section 4 presents a variety of factors making states' residents more or less likely to experience high costs from climate policy, and more or less able to adjust to these costs while maintaining their quality of life and transitioning to a greener economy. Per capita emissions; energy efficiency policies; electricity, fuel, and transportation infrastructure; and spending habits all exhibit important differences from state to state.

Section 5 summarizes this report's findings and presents policy recommendations. States that consume high shares of electricity generated from coal may have some of the highest costs from climate policy. To soften the impact on the hardest-hit states, while retaining the incentive effect of the carbon price, policies such as the following can be applied: the return of a large share of policy revenues to households; state-level investments — directed to the states at risk of highest costs from climate policy — in energy efficiency and alternative transportation networks; and large-scale, rapid investments in building natural gas and renewable electricity generation to replace coal generation.

II. Recent Economic Studies of Climate Policy

Recent economic literature analyzes the impacts from climate policy in two areas, green employment and household direct costs. This section discusses this literature, with an emphasis on study findings regarding interstate differences in economic impacts. There is a broad consensus among most of the employment studies about the cost per "green job" created, and about the industries that will gain or lose the most from climate policy. There is also general agreement that a carbon price alone would be regressive, and would have widely differing effects on individual states; many policy options have been proposed to offset the regressivity of carbon prices and to promote interstate equity. Our own proposals are presented in Section III.

Green Jobs

Broadly defined, "green jobs" are jobs that contribute significantly to maintaining or improving environmental quality. Typically, green jobs are concentrated in sectors of the economy related to clean energy: energy efficiency, renewable energy sources, and alternative transportation (White and Walsh 2008). Green employment includes not only the engineers who develop new solar technologies and the construction workers who install them, but also the assembly workers who put the solar panels together.

According to recent economic literature on U.S. efforts to reduce carbon emissions, both green investments and cap-and-trade policies would have important implications for the domestic labor market. Green investments made with carbon-policy revenues are expected to create new jobs, both directly and indirectly, in industries like construction, transportation, utilities, and biofuels. Cap-and-trade policies, on the other hand, are expected to increase production costs for goods and services in emission-intensive industries, decreasing the quantities demanded for these goods and services; the result will be gains of "green jobs" in some industries, but some job losses in other sectors.

While green investments will generate jobs across all employment categories and skill levels, the majority will be concentrated among individuals with low to medium levels of education (Bivens et al. 2009a; Pollin, Heintz et al. 2009; Pollin, Wicks-Lim et al. 2009; White and Walsh 2008). Bivens et al. (2009a) find that the jobs supported by green investments are largely filled by high school graduates who have not attended college. Pollin, Wicks-Lim et al. (2009) reach similar conclusions: Of the net new jobs created through green investment, roughly 50 percent will be accessible to workers with high school diplomas or less education, of which roughly 70 percent will offer decent opportunities for promotion over time. In a subsequent study, Pollin, Heintz et al. (2009) find that each $1 million invested in green projects will yield four high-credentialed jobs requiring at least a bachelor's degree and paying on average $24 per hour; five mid-credentialed jobs requiring some college but not a bachelor's degree and paying on average $15 per hour; and eight low-credentialed jobs requiring a high school degree or less, and paying on average $12 per hour per (five of this last category of jobs have opportunities for advancement over time and improved earnings of $15 per hour).[9]

Several recent studies have quantified the impact of green investment on employment. One of these studies, produced by The Apollo Alliance (White and Walsh 2008), estimates a return on investment

[9] Wages reported in 2009 dollars. Conversion based on the CPI-U (Bureau of Labor Statistics 2010).

of one new job for every $10,000 of investment (per person-year of employment) in green projects.[10] Other studies (Bivens et al. 2009a; Pollin, Heintz et al. 2009) have projected the need for a much higher level of investment per job, with several studies reaching a similar conclusion: Approximately $90,000 of green investment will create one new job. Bivens et al. (2009a) estimate that $100 billion of new green investments, committed annually over the next decade, will generate 1.1 million net new jobs. This model (developed in Bivens et al. 2009b) first determines how the level of public investment will change for the overall economy and across industries as the United States adopts a cap-and-trade system. Next, the authors trace the effects of increased investment through the industry supply chain in an input-output framework. Merging this industrial data with household data on demographics and labor market characteristics, the authors identify the number and types of jobs that will result from a changing industrial mix. In calculating the number of jobs, the authors include both direct jobs created (e.g. workers directly hired for new construction projects) as well as indirect jobs (e.g. workers newly hired by industries that supply construction machinery).

Pollin and Heintz et al. (2009) focus on the direct, indirect, and induced employment effects of increased government spending, and find that clean energy investments of $150 billion per year will create 1.7 million new jobs in the United States. Based on the spending priorities outlined in the 2009 American Recovery and Reinvestment Act, the authors first determine the allocation of new investments to different types of clean energy projects — 40 percent energy efficiency retrofits, 20 percent mass transit, and 10 percent each to smart grid, wind power, solar power, and biomass fuels. Using an input-output model, they then estimate the direct and indirect employment effects resulting from increased demand for particular goods and services of specific industries. Finally, the authors assume that clean energy investments will result in an induced employment effect equal to 40 percent of the overall level of job creation.

The distribution of green jobs created will differ across regions and states. Using Current Population Survey data on recent shares of industry-level employment by region, Bivens et al. (2009a) conclude that 35 percent of new jobs created will be in the South, while the Northeast, Midwest, and West will each get roughly 20 percent. The distribution of these results by region is similar using the average of population share and GDP share to distribute green investment increases and fossil-fuel spending decreases. Pollin and Heintz et al. (2009) use an equally weighted average of each state's GDP share and population share to allocate jobs at the state level: California, Texas, and New York experience the greatest amount of job creation, while Wyoming, Alaska, and North Dakota experience the least (see Table 1).[11] When then job gains are compared to 2008 state unemployment rates, the District of Columbia, Oklahoma, and Mississippi would have the highest percentile decrease to their unemployment rates, while Rhode Island and Nevada would have the lowest.

[10] These estimates are the product of an input-output analysis originally performed for an earlier study (The Perryman Group 2003).

[11] See Appendix C for additional state green jobs data.

Table 1: Net change to employment from $150 billion green investment

Highest net job gains		Lowest net job gains		Highest percentile decrease to unemployment rate		Lowest percentile decrease to unemployment rate	
California	174,927	Wyoming	3,522	Dist. Columbia	1.7%	Rhode Island	0.8%
Texas	152,760	Alaska	3,730	Oklahoma	1.6%	Nevada	0.8%
New York	109,441	North Dakota	4,257	Mississippi	1.5%	California	0.9%
Florida	94,725	Vermont	4,270	Maine	1.4%	Maryland	0.9%
Pennsylvania	71,667	Rhode Island	4,540	Louisiana	1.4%	Connecticut	0.9%
Illinois	69,624	South Dakota	5,272	Tennessee	1.3%	Arizona	0.9%
Ohio	67,356	Dist. Columbia	5,514	Alabama	1.3%	Washington	0.9%
Georgia	58,816	Delaware	5,726	Texas	1.3%	Hawaii	1.0%
Michigan	53,816	Montana	6,303	Arkansas	1.3%	New Hampshire	1.0%
North Carolina	51,210	Hawaii	7,146	Delaware	1.3%	Florida	1.0%

Source: Pollin, Heintz et al. (2009).

Entities covered by a cap-and-trade program are very likely to pass on the cost of permits and of emissions reductions to their customers, which will raise the price of carbon-intensive goods. As a result, these policies shift demand away from the goods and services offered in emission-intensive industries — like electricity, household fuels, and gasoline — and toward industries that require less energy or use alternative forms of energy — like many kinds of services (such as concerts, haircuts, or medical care).

The Congressional Budget Office (Arnold and Dahl 2010) reviewed several studies examining the employment effects of a shift of consumer demand toward less carbon-intensive goods and services. Ho et al. (2008) model the output and employment impacts of an economy-wide $10/mT CO_2 pricing policy on a variety of industries, allowing for variation in firms' output prices, input mixes, and capital allocations over time.[12] The authors employ a partial equilibrium analysis in the short run and a general equilibrium analysis in the medium and long run. Each analysis is disaggregated by industry and estimates of carbon intensity are determined using input-output tables. McKibbin et al. (2009) come to very similar results using a dynamic stochastic general equilibrium model of the world economy to measure the employment and output impacts of potential U.S. emissions policies. The model decomposes sectors by global region and by industry, and allows for short-run imperfections in macroeconomic dynamics.[13] The models employed by Ho et al. and McKibbin et al. make different assumptions about levels of emissions reduction and costs of alternative energy sources. To produce a set of results based on consistent assumptions, CBO scales the results of their meta-analysis to reflect a common price on CO_2 emission allowances of about $19/mT in 2015 and $31/mT in 2025.[14]

We averaged the Ho et al. (2008) and McKibbin et al. (2009) employment impacts, as scaled to the 2015 and 2025 prices by the CBO, and found that employment in the coal mining, oil and gas extraction and gas utilities; petroleum and coal production and refining; construction;

[12] Price reported in 2009 dollars. Conversion based on the CPI-U (Bureau of Labor Statistics 2010).
[13] Arnold and Dahl (2010) examine a third study by CRA International but ultimately dismiss its results because of rigidities placed on wages. In general, they write, "CBO believes that the economy is responsive and flexible overtime and would gradually adapt to constrains on emissions" (p. 6).
[14] Prices reported in 2009 dollars. Conversion based on the CPI-U. Source: http://http.bls.gov/pub/special.requests/cpi/cpiai.txt

transportation; and automobile industries would all decline under cap-and-trade systems, while employment in electric utilities and in services other than transportation will increase due to projected investment in new alternative-energy infrastructure (see Table 2). Job-loss projections are largest in the coal mining industry (approximately 12.5 percent in 2015 and 25 percent in 2025); coal is more carbon-intensive than any other fossil fuel and is largely mined domestically. Estimated losses in the oil- and gas-extraction industries are slightly smaller because oil is traded on an international market, and there may be substitution with coal and natural gas.

Table 2: National employment effects from $19/mT CO_2 in 2015 and $30/mT CO_2 in 2025

Economic sector	2015	2025
Coal mining	-12.5%	-25.0%
Oil and gas extraction and gas utilities	-11.0%	-24.5%
Petroleum and coal production refining	-6.0%	-9.0%
Electricity	5.0%	-0.5%
Construction, transportation, other manufacturing, and agricultural and related industries	-0.7%	-0.6%
Services other than transportation	0.2%	0.3%

Source: Authors' calculation; average of results from Ho et al. (2008) and McKibbin et al. (2009) as rescaled by Arnold and Dahl (2010).

We applied the CBO results to states using 2007 data for employment in each of these six economic sectors; Table 3 presents these results for 2015.[15] Net job gains would be highest in New York, Florida, and New Jersey, while net job losses would be highest in Texas, Louisiana, and Oklahoma. As a share of the civilian labor force, the District of Columbia, Hawaii, and Delaware would see the largest job gains, and Wyoming, West Virginia, and Louisiana would see the largest job losses.

Table 3: Job gains and losses from $19/mT CO_2 carbon price

Highest net job gains		Highest net job losses		Job gains as highest share of labor force		Job losses as highest share of labor force	
New York	6,716	Texas	-21,688	Dist. Columbia	0.2%	Wyoming	-1.1%
Florida	6,387	Louisiana	-6,475	Hawaii	0.1%	West Virginia	-0.4%
New Jersey	1,829	Oklahoma	-5,439	Delaware	0.1%	Louisiana	-0.3%
Massachusetts	1,542	Wyoming	-3,177	Vermont	0.1%	Oklahoma	-0.3%
Maryland	1,331	West Virginia	-3,084	Idaho	0.1%	Alaska	-0.3%
California	1,328	Kentucky	-2,920	South Dakota	0.1%	Texas	-0.2%
Georgia	1,292	Indiana	-2,390	Rhode Island	0.1%	Kentucky	-0.1%
Nebraska	1,021	Pennsylvania	-1,475	Nebraska	0.1%	North Dakota	-0.1%
Hawaii	931	Kansas	-1,424	New York	0.1%	New Mexico	-0.1%
Idaho	881	Colorado	-1,356	Florida	0.1%	Kansas	-0.1%

Source: CBO 2010 national values for 2015 and authors' calculations using data from the Bureau of Labor Statistics (2003; 2008b), Economic Census 2002 and 2007, and U.S. Energy Information Administration (2009b).

The CBO study also finds that industries that produce alternative forms of energy, such as wind, solar, and nuclear power, or the equipment to produce those forms of energy are likely to experience

[15] Employment data are from Economic Census 2007 (U.S. Census Bureau 2008a). These data are incomplete for several states and NAICS categories. Wherever 2007 data were unavailable, we substitute the 2002 share of sector employment (2002 employment data divided by the 2002 civilian labor force) multiplied by the 2007 civilian labor force.

an increase in employment. In addition, industries and sectors that do not use substantial amounts of carbon-based energy, directly or indirectly, will also experience an increase in employment. The electricity industry may see increases in employment if more labor is required to generate electricity using lower-emission technologies. This would impact employment in the portions of the construction industry that build new power plants, transmission lines, and local distribution networks.

The current distribution of investments in electricity generation show states' initiatives in green employment to date, and may also give some indication of the wealth or dearth of natural resources appropriate to these technologies. The largest states, California and Texas, dominate U.S. electricity generation in several categories (see Table 4). In addition, Washington, Oregon, and New York have significant investments in hydro-electric power; Illinois, Pennsylvania, and South Carolina in nuclear power; and Florida in natural gas. States with large investments in coal-based electricity generation, Texas, Pennsylvania, and Kentucky, are projected to suffer the highest job losses.

Table 4: Top ten generators of electricity by method, 2008 (million MWh)

Geothermal		Hydro-electric		Nuclear		Solar		Wind	
California	12.9	Washington	77.6	Illinois	95.2	California	0.7	Texas	16.2
Nevada	1.4	Oregon	33.8	Pennsylvania	78.7	Nevada	0.2	California	5.4
Utah	0.3	New York	26.7	South Carolina	51.8	Colorado	0.0	Minnesota	4.4
Hawaii	0.2	California	24.1	New York	43.2	Arizona	0.0	Iowa	4.1
Montana	0.1	Montana	10.0	Texas	40.7	New Jersey	0.0	Washington	3.7
Idaho	0.1	Idaho	9.4	North Carolina	39.8	North Carolina	0.0	Colorado	3.2
		Arizona	7.3	Alabama	39.0	Pennsylvania	0.0	Oregon	2.6
		Alabama	6.1	California	32.5	Massachusetts	0.0	Oklahoma	2.4
		Tennessee	5.6	New Jersey	32.2	Hawaii	0.0	Illinois	2.3
		Arkansas	4.7	Florida	32.1			Kansas	1.8

Coal		Natural Gas		Petroleum		Wood and Biomass		Other	
Texas	147.1	Texas	193.2	Florida	12.0	California	5.8	Texas	4.0
Ohio	130.7	California	120.0	Hawaii	8.7	Florida	4.3	Florida	2.8
Indiana	122.0	Florida	103.4	New York	3.7	Maine	3.9	Indiana	2.7
Pennsylvania	117.6	Louisiana	45.3	Kentucky	2.9	Alabama	3.4	California	2.6
Illinois	96.6	New York	43.9	Louisiana	2.3	Georgia	2.8	Louisiana	1.6
Kentucky	91.6	Arizona	38.8	Massachusetts	2.1	Louisiana	2.7	Pennsylvania	1.1
West Virginia	89.1	Oklahoma	33.8	California	1.7	Virginia	2.7	Connecticut	0.7
Georgia	85.5	Nevada	24.0	Ohio	1.4	Michigan	2.4	Maryland	0.6
North Carolina	75.8	Alabama	22.4	Virginia	1.2	Pennsylvania	2.1	Missouri	0.6
Alabama	74.6	Massachusetts	21.5	Texas	1.0	New York	2.1	Delaware	0.5

Source: U.S. Energy Information Administration (2010e).

Direct impacts of carbon policy

While scientific evidence and public concern warrant government action to tackle climate change, meaningful and effective policy will not be costless. Policies that limit carbon emissions will increase the price of energy-related consumption, and that means higher prices at the pump and higher monthly energy bills for U.S. households. Many of the proposed federal climate policies include plans to return some portion of carbon-tax or allowance-fee revenue to households. The economic theory behind carbon rebates is this: Consumers would face higher prices on carbon-intensive products (an incentive to purchase fewer of these goods) but also would have an increase in income. Their total purchase of all items — high and low carbon intensity — will change in response to both higher prices and higher income, and the purchase of any individual product may increase, decrease, or stay the same.

If rebates are high enough, most households' consumption of carbon-intensive products will decrease, but their overall consumption will not. The result is a carbon price that lowers U.S. greenhouse gas emissions without reducing our quality of life. Policies that do not rebate a significant portion of these revenues — or that allot benefits disproportionately to richer households — could lead to a decrease in the amount of goods and services consumed, especially for the poorest households, who spend the greatest proportion of total earnings on necessities like gasoline, electricity, and heat.

The design of U.S. climate policy, therefore, will have important distributional effects for households. Cap-and-trade and carbon tax policies (and derivations thereof) have emerged as attractive market-based instruments for reducing carbon emissions. Through a cap-and-trade policy, the government fixes the *quantity* of acceptable carbon emissions and distributes — either by auction or for free — tradable emissions allowances to firms. A carbon tax, on the other hand, enables the government to fix the *price* of carbon emissions by taxing fuels based on their carbon content. Cap-and-trade and a carbon tax are essentially different sides of the same coin — the government can either choose a quantity and the market will respond with a price, or it can set a price and the market will respond with a quantity; either option can be targeted to lead to the same result. Both kinds of policies generate revenues for the federal government — the former through the sale of allowances (to the extent that allowances are sold and not given away), the latter through tax revenues. Climate policy's ultimate impact on households will depend in large part on how the government distributes these revenues.

Several groups of economists have evaluated the distributional effects of current climate policy options. Boyce and Riddle (2009), for example, examine the state-level household impacts of a cap-and-dividend policy across income groups where carbon permits are auctioned at \$29/mT CO_2 in the year 2020.[16] Using data from the Consumer Expenditure Survey, Boyce and Riddle first estimate the carbon footprint of households by income decile.[17] Consistent with previous studies (Boyce and Riddle 2007; 2008; Metcalf 1999; Metcalf et al. 2008), they find that the lowest-income group has the smallest carbon footprint in absolute terms, but the highest carbon footprint as a percentage of income. Thus a cap on carbon emissions would be regressive. Boyce and Riddle argue that a cap-and-trade policy can be made progressive if permit auction proceeds are redistributed to the public on an equal per person basis. When 80 percent of carbon allowance revenues are refunded to households on an equal per capita basis, they find, each person receives a dividend of \$450 that results in net (the rebate less their higher costs) losses of 0.3 percent for the richest 10 percent of households and net income gains of 6.5 percent for the poorest 10 percent.[18]

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[16] Price reported in 2009 dollars. Conversion based on the CPI-U (Bureau of Labor Statistics 2010).
[17] Based on methodology developed in Boyce and Riddle (2007; 2008)
[18] Dividend reported in 2009 dollars. Conversion based on the CPI-U (Bureau of Labor Statistics 2010).

Since incomes, consumption patterns, and the carbon-intensity of electricity differ across states, Boyce and Riddle also consider interstate differences in the impacts of a cap-and-dividend policy. Using data on median incomes by decile and by state, they estimate regional carbon expenditures, adjusting for region-specific carbon consumption patterns, carbon intensity of electricity generation by state, and national carbon-intensity factors for household fuels (natural gas and fuel oil), gasoline, food, air transportation, public transportation, others goods, and other services. Based on a permit price of \$29/mT CO_2, they apply increased carbon costs and a per capita dividend of allowances, and determine the state-level net effects of a carbon cap by income bracket.[19] Again they find that the net impact has a strong progressive effect on household incomes. In 90 percent of the states, the poorest seven deciles experience a net benefit, and in every state, the poorest six deciles do so. The net benefit to the median household ranges from 0.2 percent of income in Indiana to 1.1 percent in Mississippi.

In a subsequent paper, Boyce and Riddle (2010) look at the potential impact of the Cantwell-Collins climate bill, which introduces a cap-and-dividend policy that limits the use of fossil fuels to reduce carbon emissions 83 percent by 2050 and recycles the majority of the proceeds from the sale of carbon permits to the public. Cantwell-Collins auctions all permits (no giveaways); refunds 75 percent of the auction proceeds to households; invests the remaining 25 percent in clean energy projects; and allows for no offsets, whereby polluters avoid using permits by taking alternative actions. Using the methodology and data developed in Boyce and Riddle (2007; 2008; 2009) the authors update their analysis to reflect a permit price of \$25/mT CO_2 in the year 2020 as specified by the Cantwell-Collins proposal.[20] According to their analysis, interstate differences are very small compared with differences across the income spectrum. Furthermore, the net benefit of the cap-and-dividend policy for the median household in each state is always positive; this means that working- and middle-class families are "made whole": The dividends households receive outweigh the additional costs incurred due to higher fossil-fuel prices. Nationwide, the median household experiences a net benefit of \$65 per person, and 70 percent of the population is "made whole" — with families in Oregon benefiting the most (\$101 per person) and families in Indiana benefiting the least (\$11 per person).

Burtraw et al. (2009) analyze the regional and distributional effects of increased carbon prices on household income and consumption given alternative means of distributing revenue from auctioned carbon permits priced at \$22/mT CO_2 in the year 2015.[21] They consider using auction revenues for five different purposes: To issue a taxable lump sum per capita rebate check; to issue a non-taxable lump sum per capita rebate check; to proportionally reduce income taxes across households; to proportionally reduce payroll taxes across households; and to expand the Earned Income Tax Credit (EITC) for low-income households so that each qualifying household earns a 50-percent larger credit. Burtraw et al. employ a partial equilibrium analysis that uses household level expenditure data on direct and indirect energy goods and services to predict spending on energy as a percentage of income by income group and by region. They find that both versions of the cap-and-dividend policy and expansion of the EITC reverse the regressive outcome of carbon costs. Reducing the income tax, on the other hand, amplifies the regressive nature of carbon pricing, while reducing the payroll tax preserves it.

[19] Price reported in 2009 dollars. Conversion based on the CPI-U (Bureau of Labor Statistics 2010).
[20] All Boyce and Riddle (2010) values in projected 2012 dollars.
[21] Price reported in 2009 dollars. Conversion based on the CPI-U (Bureau of Labor Statistics 2010).

When the results for the five policies are disaggregated at the regional level, Burtraw et al. find that across all regions, the average household consistently experiences a welfare loss. Households in the bottom deciles, on the other hand, only experience a welfare loss under the tax reduction policies. Under the dividend policies and the EITC policy, they experience a welfare gain. The variation in the impact on average households across regions is relatively small compared with the regional variation in the two poorest deciles. For example, under the taxable cap-and-dividend policy, the average household welfare loss across all regions ranges from 0.2 percent of income in the Northwest and California to 0.4 percent of income in the Plains. In the two poorest deciles, the differences are more pronounced, ranging from a welfare gain of 1.1 percent of income in the Northeast to a welfare gain of 3.8 percent of income in Texas. The results are similar but slightly muted under the non-taxable cap-and-dividend policy and the EITC policy. Under the reduction in income taxes and payroll taxes, regional variation for the average household welfare loss is again small, with average household welfare losses across all regions under 0.4 percent of income. Regional variation in welfare losses for the two poorest deciles is more pronounced — with the smallest welfare loss in California and the Northwest and the largest welfare loss in the Northeast.

The CBO assessed a version of the Waxman-Markey bill (CBO 2009) and estimated the household impact of a cap-and-trade program with a permit price of \$28/mT CO_2 on each quintile of the population according to income, looking specifically at 2020, eight years into the program.[22] Overall, the CBO finds, the distributional impact on household incomes will depend on how many carbon permits are sold (as opposed to given away), how the free permits are allocated, and how revenues from auctioned permits are used. (In 2020, 17 percent of the allowances would be sold, and 83 percent would be given away.) The net household impact reflects the additional costs that households incur due to higher prices of energy-related goods and the share of auction revenues that households receive in the form of benefit payments, rebates, tax decreases or credits, wages, and returns on their investments.

Using 2006 income and consumption data on households from the Current Population Survey, the Consumer Expenditure Survey, and the Internal Revenue Service's Statistics of Income Data, the CBO analysis estimates price increases for specific goods and services and distributes gross costs to households based on consumption expenditures. Next, it determines how much of the allowance revenue would be redistributed to each quintile based on stipulations in the bill. In 2020, it finds, 30 percent of the allowances would be directly redistributed to households — about 15 percent to low-income households through rebates and tax credits, and another 15 percent to electricity and natural gas providers, with instructions to pass the benefits on to residential customers.

The CBO argues that the allowance revenues received by businesses and governments would result in higher corporate profits. Ultimately, these profits would be passed on to households as a return on investment on the basis of stock ownership across income groups. As a result of the direct and indirect allowance revenues paid to consumers, the net annual economy-wide cost of the cap-and-trade program would be \$22 billion as of 2020 — or about \$175 per household. Since poorer households receive the bulk of the direct benefits, they experience a net benefit from the carbon cap, while households in all other income groups experience a net cost. Specifically, a household in the

[22] All CBO (2009) values in projected 2010 dollars. Note that the CBO assessment was based on the bill as reported by the House Committee on Energy and Commerce on May 21; the bill was substantially amended before final passage. The review stresses upfront that the gains and losses to different groups would vary from year to year because the distribution of allowances would change substantially over time: In the initial years, most allowances would be given for free to entities affected by the new cap, but by 2035, roughly 70 percent of the allowances would be auctioned, and a large share of the revenues would be returned to households on a per capita basis.

lowest quintile receives a net benefit of $40; one in the second quintile would incur a net cost of $40; one in the third quintile, $235; one in the fourth quintile, $340; and one the richest quintile, $245. On average, the net costs of this carbon policy would lower households' after-tax income by 0.2 percent.

Several economists also have performed distributional analyses of carbon taxes. In theory, cap-and-trade and carbon taxes can be gauged to achieve the same outcome, but in reality, policymakers cannot perfectly predict how markets will respond to an emissions cap or carbon price, and either one can miss its intended target price or emissions reduction. Metcalf et al. (2008) consider the distributional impacts of various carbon tax proposals on households across the income spectrum. Based on a tax of $30/mT CO_2 emissions, they calculate the increase in prices of various fuels and commodities for which fossil fuels are a major input and the resulting welfare effects across income groups based on data on consumer expenditures by income level.[23] Like a carbon cap, a tax on carbon is highly regressive in and of itself — Metcalf et al. find that those in the lowest income group face an average tax increase equal to 3.7 percent of their income. If the government returns tax revenues as a lump-sum per capita rebate to households, however, the net impact is moderately progressive. Households in the bottom 60 percent of the income distribution experience a decrease in taxes; those in the second-highest income quintile are made whole; and the richest 20 percent of households experience, at most, a 0.2-percent increase in taxes as a percentage of income.

Grainger and Kolstad (2009) also analyze the incidence of a price on carbon across income groups based on a tax of $17/mT CO_2 emissions, based on data from the 2003 Consumer Expenditure Survey. Using input-output analysis, they then estimate household-level emissions by quintile and calculate the associated tax burden of a price on carbon as a percentage of both annual income and lifetime income. Not surprisingly, they find that the carbon tax is regressive — the tax burden for the poorest households is 3.5 percent of annual income, while that for the richest households is only 1 percent of annual income. Grainger and Kolstad argue that the carbon tax can be made distributionally neutral if the tax revenues are at least partially recycled to consumers. Specifically, if the government returns tax revenues in the form of lump-sum payments to the bottom four deciles in the amounts of $139, $131, $122, and $89, respectively, each income group only experiences a tax burden equal to 1 percent of annual income.[24]

In another paper, Metcalf et al. (2007) also consider the regional impacts of a carbon tax on household incomes, and they reach similar conclusions to those found by economists who have analyzed the regional incidence of carbon caps. Based on a carbon tax of $16/mT CO_2, Metcalf et al. find that the tax burden does not vary much across regions — even though driving patterns and weather conditions differ quite a bit across the country. [25] The average tax burden as a percentage of income across all deciles ranges from 1.5 percent in the West-North-Central United States (which includes Iowa, Kansas, Minnesota, Missouri, Nebraska, North Dakota, and South Dakota) to 1.8 percent in the East-South-Central United States (which includes Alabama, Kentucky, Mississippi, and Tennessee).[26]

In a subsequent paper, Metcalf et al. (2009) discuss a carbon "tax swap" policy that provides a distributionally neutral approach to reducing emissions. The tax is $16/mT CO_2, and the swap is a

[23] Price reported in 2009 dollars. Conversion based on the CPI-U (Bureau of Labor Statistics 2010).
[24] Price and rebates reported in 2009 dollars. Conversion based on the CPI-U (Bureau of Labor Statistics 2010).
[25] Price reported in 2009 dollars. Conversion based on the CPI-U (Bureau of Labor Statistics 2010).
[26] For definitions of regions see Metcalf (2009).

reduction in payroll taxes funded by carbon tax revenues. Following the methodology in their 2008 paper, Metcalf et al. use the carbon tax revenue to fund a cut in taxes in order to offset the regressive impacts of the carbon tax. Each worker receives a reduction in taxes capped at the first $615 of payroll taxes. Since low-wage workers have lower payroll taxes, the tax cut as a percentage of original payroll taxes is greatest for the lowest-wage workers. Metcalf et al. also find that if the carbon tax revenues are extended to provide Social Security recipients with a lump-sum rebate, the tax reduction cap falls to $461, but the reform becomes progressive, because Social Security recipients tend to have lower income levels. Furthermore, the authors find that a lump-sum per capita redistribution of carbon tax revenues is the most progressive policy of all.[27]

While the U.S. carbon policy impact literature differs in smaller details, these studies all agree on several basic principles. All find carbon policy regressive without returns to households via rebate, EITC, or some other form of benefit directed to the lowest-income households; permit giveaways make policies more likely to be regressive even after rebates, as do plans to return revenues by reducing income taxes across the board. With rebates, even those directed only to working- and middle-class families, the highest-income households pay only very small shares of their income in carbon costs, ranging from roughly 0.1 percent of income (CBO 2009) to 0.5 percent of income (Burtraw et al. 2009).

[27] Price and tax caps reported in 2009 dollars. Conversion based on the CPI-U (Bureau of Labor Statistics 2010).

III. Modeling Carbon Policy

Our model of carbon policy impacts follows that of Boyce and Riddle (2007; 2008; 2009; 2010) and Burtraw et al. (2009) in most respects, but results in somewhat greater interstate differences than found in most of the current literature.[28] We use a combination of Consumer Expenditure Survey and American Community Survey data for 2007 to estimate the incomes and expenditures of stylized four-person households by state and by income decile.[29] We follow the convention of treating the impacts of various kinds of carbon prices as functionally equivalent: Carbon costs may come from taxes or from higher prices passed along by companies required to purchase emission permits. We assume that all permits are sold – none are given away. All money values are in 2009 dollars.

Carbon emissions are estimated by applying a different carbon intensity to each of eight categories of expenditures: electricity, gasoline, household fuels (natural gas and fuel oil), air transportation, public transportation (buses, subways, trains, ferries, etc.), food, other goods, and other services; emissions intensities for electricity and household fuels vary by state. Total carbon emissions calculated in this away are approximately equal to total U.S. household carbon emissions for 2007.

We then apply a carbon price to expenditures per unit of CO_2, sum up the revenues generated from this price (and scale these revenues up to represent revenue collected from the whole economy, not just households; see Boyce and Riddle (2009)), and return part of these revenues to all U.S. households on an equal per capita basis. Expenditures in the model adjust dynamically to carbon prices and rebates based on estimates of the price and income elasticities for each category of consumption. It is important to note that while this model does incorporate interstate differences in carbon intensity, it cannot for lack of data include differences in price elasticities – or the responsiveness of consumer demand to a change in price – by state (a topic discussed in more detail in Section IV below). This limitation should be kept in mind when analyzing this model's results: Some states that seem to suffer the greatest costs according to the model in fact may be able to mitigate these costs by improving residents' responsiveness to carbon prices through public investment in energy-efficiency incentives for households and efforts to reduce the carbon intensity of electricity.

In response to the carbon price and rebates, households shift their expenditures away from high-carbon-intensity goods and services and toward low-carbon-intensity purchases. We compare carbon emissions before and after the policy is implemented, and also examine distributional effects – primarily the net dividend, or total rebate less total carbon costs – across states and across income brackets.

Some of the key differences between our methodology and those of Boyce and Riddle and Burtraw et al. regard the treatment of price elasticities and the market for electricity. We assume that consumers' response to price changes in electricity, gasoline, household fuels, and transportation services grows more elastic over time; that utilities choose to generate more of their electricity from existing lower-carbon-intensity sources; and that part of carbon revenues is spent to improve energy efficiency, with focused investment in states with the most carbon-intensive electricity.

[28] For a detailed model methodology see Appendix A. For full model results see Appendix B.
[29] Bureau of Labor Statistics (2009), http://www.bls.gov/cex/ and U.S. Census Bureau (2008b), http://www.census.gov/acs/www/Products/2007/.

The model contains several levers for parameters that change over time or are a function of policy decisions (for detailed citations and methodology see Appendix A):

- Default price elasticities are for the short run, but the model includes a long-run price elasticity scaling factor. Goods that are price-inelastic in the short run (changing their prices has little impact on how much they are consumed) tend to increase in elasticity as time passes and consumption changes become more feasible and more desirable. For our 2015 results, we increase these short-run price elasticities for electricity, fuels, and transportation by 50 percent; for 2020, we scale them up by 200 percent. Elasticities for food, other goods, and other services are left at their default, short-run values.
- U.S. electricity generation capacity is designed to be sufficient to meet peak demand, and therefore exceeds the capacity necessary for use on the average day. Utilities use the generators with cheapest marginal costs per kWh (often, hydro-electric energy, nuclear power, and some coal plants) around the year and around the clock, but leave generators with higher costs per kWh (often, natural gas-burning plants) idle until they are needed to meet seasonal, daily, or hourly increases in demand for electricity. Carbon prices will change the relative cost per kWh of different fuels, making some coal generation more expensive per kWh than some natural gas plants. This will lead utilities to use more gas and less coal, thereby decreasing the overall carbon intensity of electricity production. We assume a 0.06 percent decrease in the carbon intensity of electricity by state for each \$1/mT CO_2 of carbon price in all scenarios.
- Carbon policy revenue can be spent on energy efficiency investments with two effects. First, these investments bring jobs to the states in which they take place. We assume that a new job is created for every \$90,000 in energy efficiency investment. Second, these investments reduce the quantity of electricity consumed in each state and, therefore, reduce carbon emissions. We assume that energy efficiency investments would be allocated to states in proportion to their emissions from electricity; that each kWh saved by energy efficiency measures costs \$0.045; and that the maximum potential for such efficiency measures in any state is a 3-percent annual reduction in electricity CO_2 emissions (calculated from a 2012 starting point, so that the maximum reduction is 9 percent for 2015 and 24 percent for 2020).
- Carbon policy revenues can be returned to households as annual rebate checks. We assume equal per capita returns that can be varied based on the share of revenue returned to households.
- Finally, the carbon price (in 2009 dollars per mT CO_2) can be varied, or, alternatively, a target reduction to CO_2 emissions can be chosen.

Carbon Prices and Rebates to Households

Two key "policy levers" in this model are the carbon price and the share of total carbon policy revenues returned to households on an equal per capita basis. Figure 1 shows the impact of different carbon-price/share-returned-to-households pairings on economy-wide emission reductions and the share of U.S. households with positive net dividends (rebate greater than carbon costs). In this figure, each carbon price and percent returned pair is a point on the graph; the vertical axis indicates how much emissions reductions this pairing achieves, while the horizontal axis shows the share of U.S. households that receive a net benefit from the climate policy. Note that results shown in this graph are for 2015 (in 2009 dollars) and assume that efficiency investments come from a different source of revenue when 100 percent is returned to households.

Figure 1: Impacts from varying carbon price and share of carbon revenue returned to households

Sources: Authors' calculations.

The green values in this figure represent a $25/mT CO_2 carbon price with the share of total carbon revenues returned to households varying from 40 to 100 percent; the blue values represent a $100/mT CO_2 carbon price with varying shares returned. For both carbon prices, reductions from 2005 levels of CO_2 emissions vary little as the revenue share is changed — 4.9 to 5.4 percent and 13.1 to 14.9 percent, respectively. The size of the carbon price has little impact on the share of U.S. households with positive net dividends (both series of data have approximately the same horizontal values). Under either carbon price, however, the share of households with net gains is extremely responsive to changes in the share of revenue returned to households: When 100 percent of carbon policy revenue is returned, 94 percent of households receive positive net dividends; at 80 percent returned, 73 percent have net gains; at 60 percent returned, 44 percent have net gains; and at 20 percent returned, all households have net losses.[30]

In the red and purple values in Figure 1, the share of revenue returned to households is held steady at 60 percent and 80 percent, respectively, while the carbon price is varied. With 60 percent of revenue returned, the share of households with net gains ranges only from 43.0 to 43.4 percent; with 80 returned, this share ranges from 72.5 to 73.4 percent. At carbon prices from $25 to $50/mT, CO_2 emission reductions are roughly proportional to carbon price: For every $10/mT CO_2 there is a 2-percent reduction from 2005 CO_2 emissions. Prices lower than $25/mT result in a 3- to 4-percent reduction per $10/mT, and prices above $50/mT result in a 1-percent reduction per $10/mT.

A clear story emerges: Household gains and losses depend on the share of revenues that they receive back from taxes or allowance sales; emission reductions depend on the size of the carbon price. And perhaps more importantly: *Household gains and losses depend very little on the size of the carbon price*, and *emission reductions depend very little on the share of revenue returned to households.*

Of course, rebates to households need not be on a per capita basis as modeled here. Using carbon revenue to offset payroll taxes or increase the EITC would also have a progressive result, channeling rebates to households with the lowest incomes. Rebates to electricity users scaled to offset rate increases due to carbon pricing for low-income households — as proposed by Waxman-Markey and Kerry-Lieberman — could result in a progressive net outcome, but at the cost of undermining the intended incentive effects of higher electricity prices: Households that do not face higher prices are insulated from the policy incentive intended to reduce electricity consumption. Similarly, rebates that are tailored too closely to carbon costs on a state-by-state or household-by-household basis would tend to water down these policies' intended price incentives. Rebates to a specific sector, like electrical utilities, also would tend to lower some household bills while raising others: As rebated sectors contribute less to total emission reductions, other sectors will have to contribute more with still-higher prices.

Scenario Results for 2015 and 2020

Each scenario is gauged to meet emissions reduction goals set out in proposed legislation while minimizing the number of households with net losses after the rebate. In both scenarios, 85 percent of tax revenues are returned to households on an equal per capita basis, a rebate chosen to reduce the total share of U.S. households with net losses from the policy and reduce the number of states in which the median household experiences a net loss.

For 2015 we model $25/mT CO_2, the highest carbon price that falls under the price ceilings of Waxman-Markey, Cantwell-Collins, and Kerry-Lieberman.[31] An investment of $4.4 billion is made in energy efficiency, resulting in a nationwide reduction in CO_2 emissions from electricity of 6 percent, with the highest reductions — 9 percent — in North Dakota and Wyoming. In this scenario, CO_2 emissions from capped sources are reduced by 5.0 percent, or, if applied to just 85 percent of emission sources, a 4.25-percent decrease from total 2005 greenhouse gas emissions, which is similar to the assumptions in all three bills.

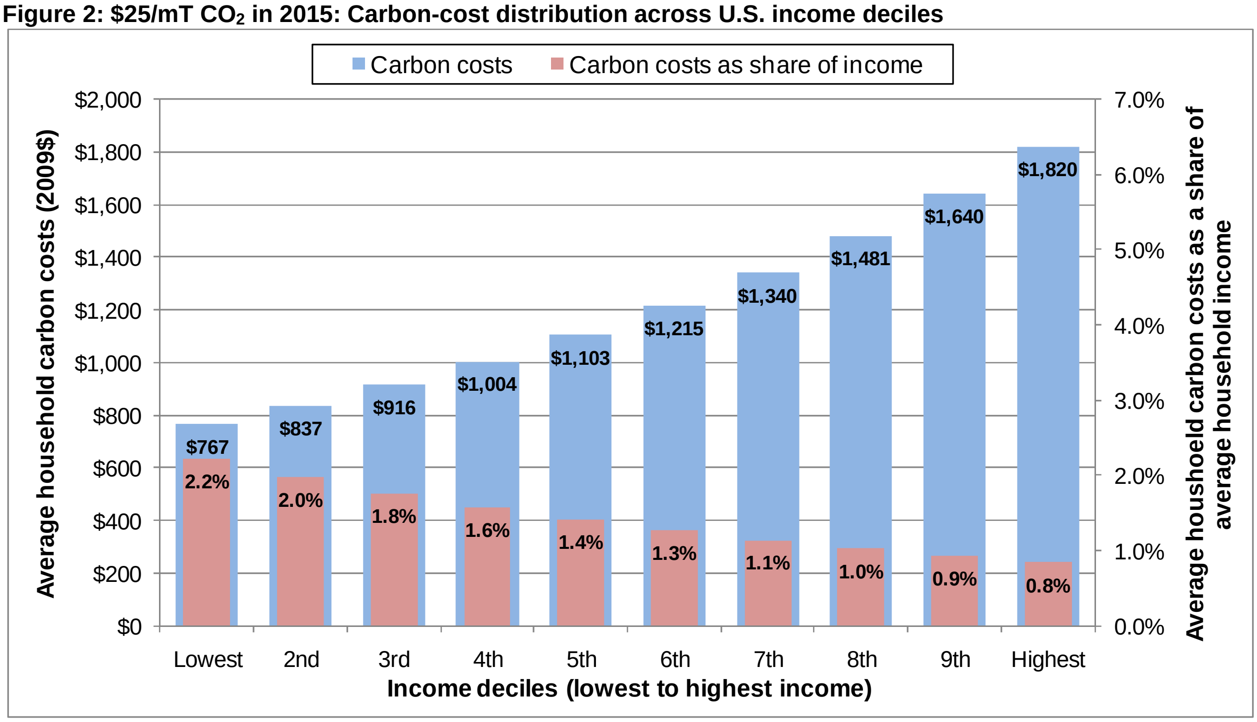
[30] The share of households with positive net dividends reported here in the text is for the $25/mT CO_2 case. Shares for the $100/mT CO_2 case are within 1 percentage point.
[31] The highest 2015 prices allowed under this bills are $32, $25, and $29/mT CO_2, respectively, based on $28, $21, and $25/mT CO_2 prices in 2012 and 5.0-5.5 percent annual increases, as specified in the indicated bills.

For 2020 we model a $75/mT CO_2 carbon price, with the goal of achieving the (approximately) 17-percent greenhouse gas emission reductions called for in these bills, by reducing CO_2 emissions from capped sources by 20 percent. An investment of $11.75 billion is made in energy efficiency, resulting in a nationwide reduction in CO_2 emissions from electricity of 15 percent, with the highest reduction – 24 percent – in North Dakota (Wyoming's reduction is 23 percent). The carbon price used in this scenario exceeds the price ceilings of Waxman-Markey, Cantwell-Collins, and Kerry-Lieberman; in these bills 2020 prices cannot exceed $41, $32, and $37/mT CO_2, respectively. According to this model, their prices are not sufficient to reduce carbon emissions to the levels called for in these bills. Put another way: You can't have both a fixed price ceiling and a fixed emissions cap; one or the other must be flexible. All three major pieces of legislation (Waxman-Markey, Cantwell-Collins and Kerry-Lieberman) have flexible caps that include a mechanism to release additional emission permits when the price ceiling is reached.[32]

2015: $25/mT CO_2, 85 percent of tax revenues rebated to households

Carbon costs are lowest for the poorest 10 percent of U.S. households (whose median income is $8,600 per capita, or $35,000 per four-person family), and higher for each succeeding decile (see Figure 2). On average, carbon costs are 137 percent higher for households in the top decile (whose median income is $217,000 per four-person family) than in the lowest decile. If none of the carbon revenues were returned to households, these carbon costs would be regressive: The lowest-income decile would pay 2.2 percent of their income, but the highest-income decile would pay only 0.8 percent.

Figure 2: $25/mT CO_2 in 2015: Carbon-cost distribution across U.S. income deciles



Sources: Authors' calculations.

[32] Each bill proposes a different mechanism; Waxman-Markey and Kerry-Lieberman would also allow sources to bank permits and to borrow against future allowances. Both also allow extensive use of offsets, domestic and international; Cantwell-Collins does not.

The U.S. median (by income) four-person household would pay $1,159, or 1.3 percent of its $87,000 income, in higher prices on goods and services in 2015. The median household in Wyoming would pay $1,601 in carbon costs, compared with the median household in Vermont, which would pay just $741 (see Table 5). As a share of income, carbon costs for the median household range from 2.1 percent in Kentucky to 0.8 percent in New York.

Table 5: $25/mT CO_2 in 2015: States with highest and lowest carbon costs

Median Household Carbon Costs (2009$)				...as a Share of Household Income			
Wyoming	$1,601	Vermont	$741	Kentucky	2.1%	New York	0.8%
North Dakota	$1,582	New York	$784	North Dakota	2.0%	Vermont	0.8%
Kentucky	$1,555	Maine	$842	Missouri	1.9%	Connecticut	0.9%
West Virginia	$1,542	Oregon	$894	Wyoming	1.9%	New Hampshire	0.9%
Indiana	$1,523	Washington	$897	Indiana	1.8%	New Jersey	1.0%
Missouri	$1,504	New Hampshire	$929	Tennessee	1.8%	Maine	1.0%
Virginia	$1,450	Rhode Island	$969	New Mexico	1.8%	Washington	1.0%
Kansas	$1,439	Connecticut	$985	Alabama	1.7%	Massachusetts	1.0%
Dist. Columbia	$1,429	California	$993	Texas	1.7%	California	1.0%
Minnesota	$1,428	Massachusetts	$1,065	Wisconsin	1.7%	Rhode Island	1.1%

Sources: Authors' calculations.

When 85 percent of total carbon revenues are returned to each decile of households on an equal per capita basis, each four-person household receives an annual rebate of $1,615. The U.S. median household receives a net dividend of $453, or 0.5 percent of its income. The median households in Vermont, New York, and Maine receive the highest net dividends: $871, $829, and $770, respectively; in these states the median households also have the highest net dividends as a share of income, 0.9 to 1.0 percent (see Table 6). The median households in Wyoming, North Dakota, and Kentucky receive the smallest net dividends: $11, $31, and $58, respectively.

Table 6: $25/mT CO_2 in 2015: States with highest and lowest net dividend

Median Household Net Dividend (2009$)				...as a Share of Household Income			
Vermont	$871	Wyoming	$11	Vermont	1.0%	Wyoming	0.0%
New York	$829	North Dakota	$31	Maine	0.9%	North Dakota	0.0%
Maine	$770	Kentucky	$58	New York	0.9%	West Virginia	0.1%
Oregon	$718	West Virginia	$70	Oregon	0.9%	Kentucky	0.1%
Washington	$715	Indiana	$89	Washington	0.8%	Indiana	0.1%
New Hampshire	$683	Missouri	$108	Rhode Island	0.7%	Missouri	0.1%
Rhode Island	$643	Virginia	$163	South Carolina	0.7%	Virginia	0.2%
Connecticut	$627	Kansas	$174	Montana	0.7%	Minnesota	0.2%
California	$619	Dist. Columbia	$183	Idaho	0.7%	Dist. Columbia	0.2%
Massachusetts	$547	Minnesota	$184	New Hampshire	0.7%	Kansas	0.2%

Sources: Authors' calculations.

In this scenario, carbon revenues total $143 billion, $21 billion of which is still available for other purposes after households are given their rebates. Energy efficiency investments absorb approximately $4 billion, leaving $17 billion available for further green investments. Energy efficiency investments are made in proportion to CO_2 emissions from electricity use; the states with the highest electricity emissions see the highest reductions in percentage terms, while states with low electricity emissions receive smaller investments; these investments range from $437 million in Texas to $1 million in Vermont (see

Table 7).

Assuming that one new job is created for every $90,000 green investment,[33] a total of 48,889 jobs would be created in fields related to energy efficiency. Texas gains the most, 4,854 jobs, and Vermont the fewest, 11. Netting these gains from the 2015 structural changes to employment from carbon policy (based on a $19/mT CO_2 carbon price),[34] six states switch from job losses to job gains: Arizona, Iowa, North Carolina, Ohio, Pennsylvania, and Tennessee. If one-quarter of the remaining carbon revenues were spent to generate additional green employment in the states with net job losses, all states would gain jobs from carbon policy. At the same time, these green investments — for example, retiring coal plants in favor of less carbon-intensive electricity generation — could further reduce disparities among states in the distribution of carbon costs.

Table 7: $25/mT CO_2 in 2015: Energy efficiency investments and jobs

Reduction in CO_2 electricity emissions		Energy efficiency investment (millions $)		Energy efficiency jobs gained		Structural changes to employment[a]		Net changes to employment	
North Dakota	9.0%	Texas	$437	Texas	4,854	New York	6,716	Florida	10,232
Wyoming	8.7%	Florida	$346	Florida	3,845	Florida	6,387	New York	8,332
Utah	8.2%	Ohio	$227	Ohio	2,526	New Jersey	1,829	Georgia	3,397
Indiana	8.2%	Georgia	$189	Georgia	2,105	Massachusetts	1,542	California	3,347
New Mexico	8.1%	California	$182	California	2,018	Maryland	1,331	New Jersey	2,719
Kentucky	8.0%	Illinois	$168	Illinois	1,863	California	1,328	Maryland	2,451
West Virginia	7.9%	Indiana	$163	Indiana	1,806	Georgia	1,292	Massachusetts	2,293
Iowa	7.8%	North Carolina	$162	North Carolina	1,795	Nebraska	1,021	Illinois	2,037
Missouri	7.7%	Pennsylvania	$160	Pennsylvania	1,778	Hawaii	931	Virginia	1,959
Wisconsin	7.3%	Virginia	$160	Virginia	1,777	Idaho	881	Missouri	1,822
Vermont	0.8%	Vermont	$1	Vermont	11	Texas	-21,688	Texas	-16,835
Washington	1.3%	Alaska	$6	Alaska	63	Louisiana	-6,475	Louisiana	-5,623
Oregon	1.8%	New Hampshire	$8	New Hampshire	85	Oklahoma	-5,439	Oklahoma	-4,809
New Hampshire	2.9%	Maine	$8	Maine	92	Wyoming	-3,177	Wyoming	-3,017
Connecticut	3.3%	Rhode Island	$10	Rhode Island	106	West Virginia	-3,084	West Virginia	-2,603
Maine	3.3%	South Dakota	$10	South Dakota	110	Kentucky	-2,920	Kentucky	-1,592
California	3.5%	Dist. Columbia	$12	Dist. Columbia	134	Indiana	-2,390	Alaska	-902
South Carolina	3.5%	Montana	$13	Montana	142	Pennsylvania	-1,475	Kansas	-870
Idaho	3.9%	Wyoming	$14	Wyoming	160	Kansas	-1,424	New Mexico	-839
New York	3.9%	Hawaii	$15	Hawaii	172	Colorado	-1,356	Arkansas	-635

Sources: Authors' calculations. Structural employment estimates based on Arnold and Dahl (2010). See Section II above for an explanation of calculations related to Arnold and Dahl's work.

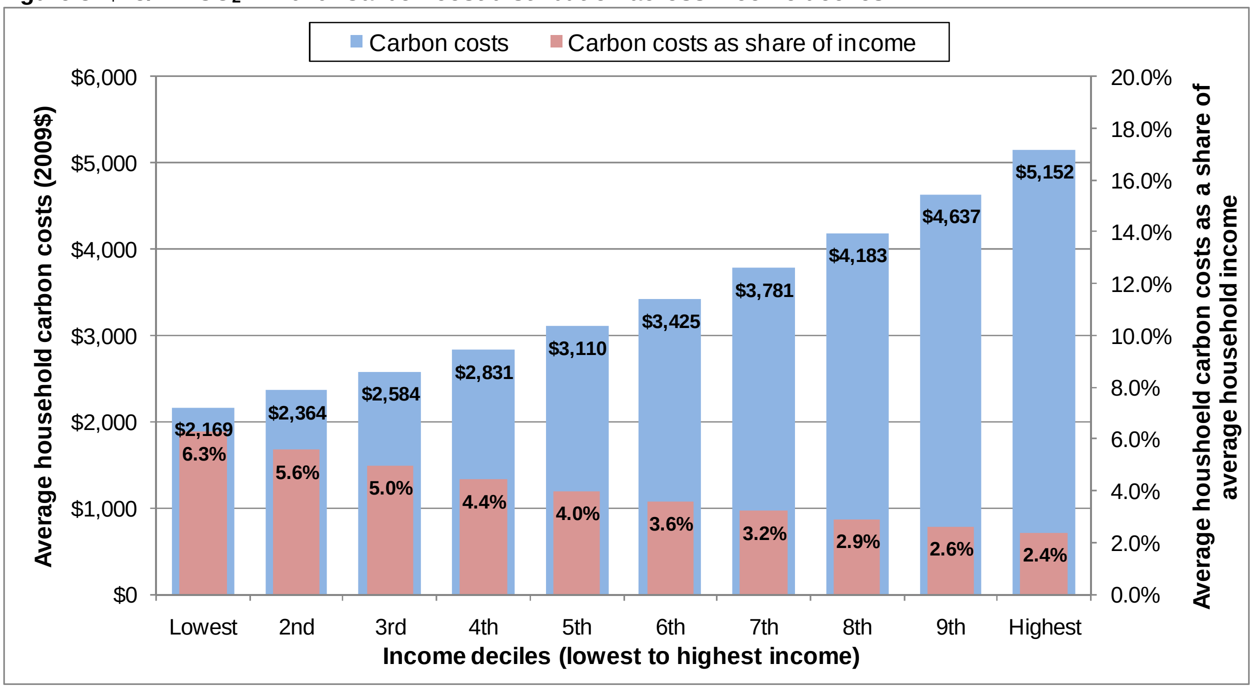
2020: $75/mT CO_2, 85 percent of tax revenues rebated to households

[33] See Section II above.

[34] Authors' calculations based on Arnold and Dahl (2010); see section II above.

With a higher carbon price but the same share of revenue returned to households on an equal per capita basis, the distributional effects change very little. Carbon costs are higher, but before receiving its rebates, the highest-income decile still pays 137 percent more, on average, than the lowest-income decile (see Figure 3). At a \$75/mT CO_2 price in 2020, the poorest households pay 6.3 percent of their income (before the rebate), while the richest households pay just 2.4 percent.

Figure 3: \$75/mT CO_2 in 2020: Carbon cost distribution across income deciles



Sources: Authors' calculations.

Before receiving rebates, the U.S. median household pays \$3,268 — or 3.8 percent of income — in carbon costs. Median four-person households in the same states still see the highest and lowest carbon costs: Wyoming with \$4,030 and Vermont with \$2,207 (see Table 8). Kentucky's median household pays 5.3 percent of its income; New York's pays 2.5 percent.

Table 8: \$75/mT CO_2 in 2020: States with highest and lowest carbon costs

Median Household Carbon Costs (2009$)				...as a Share of Household Income			
Wyoming	$4,030	Vermont	$2,207	Kentucky	5.3%	New York	2.5%
Virginia	$4,013	New York	$2,304	Tennessee	5.0%	Vermont	2.5%
North Dakota	$3,978	Maine	$2,478	North Dakota	5.0%	Connecticut	2.6%
Minnesota	$3,962	Oregon	$2,640	New Mexico	4.8%	New Hampshire	2.7%
Dist. Columbia	$3,945	Washington	$2,652	Texas	4.8%	New Jersey	2.9%
Indiana	$3,901	New Hampshire	$2,733	Missouri	4.8%	Massachusetts	3.0%
West Virginia	$3,900	Rhode Island	$2,813	Arkansas	4.8%	Maine	3.0%
Kansas	$3,900	Connecticut	$2,889	Alabama	4.8%	Washington	3.0%
Maryland	$3,880	California	$2,912	Mississippi	4.8%	California	3.0%
Missouri	$3,864	Massachusetts	$3,068	Indiana	4.7%	Rhode Island	3.1%

Sources: Authors' calculations.

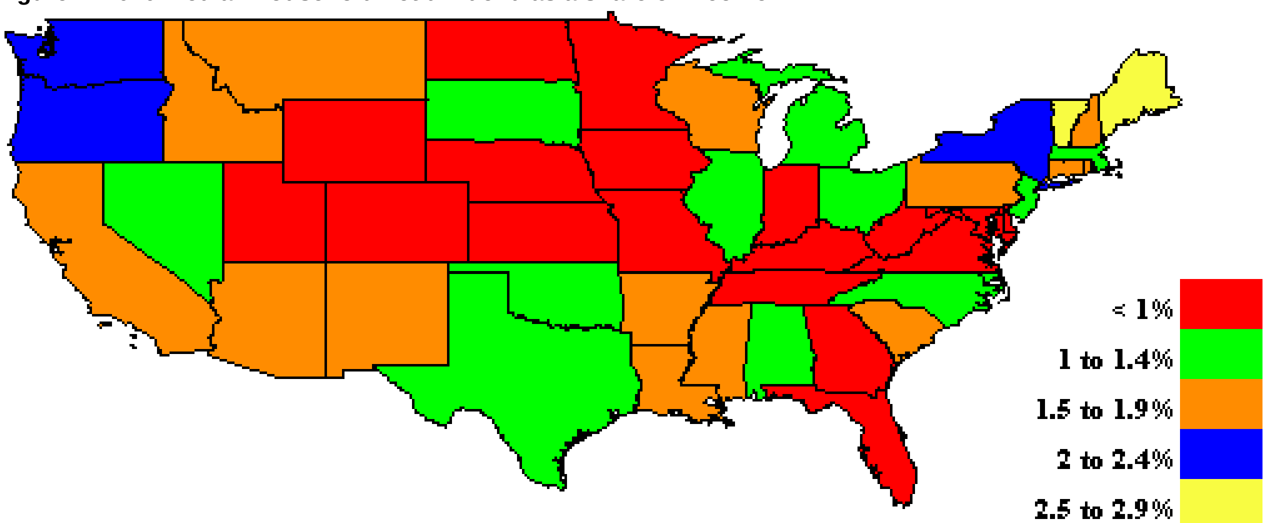
With a $75/mT CO_2 price, each four-person household gets an annual rebate check of $4,526. The U.S. median household receives a net dividend of $1,235, 1.4 percent of its income. Median households in all states receive positive net dividends, as do 80 percent of all U.S. households. Median households in Vermont, New York, and Maine still receive the highest net dividends, $2,296, $2,199, and $2,025 – or 2.6, 2.4, and 2.5 percent of income – respectively (see Table 9 and Figure 4). Median households in Wyoming and Virginia have the lowest net gains, $473 and $490, or a 0.5-percent increase to their income. In no state does the median household experience a net loss from climate policy.

Table 9: $75/mT CO_2 in 2020: States with highest and lowest net dividend

Median Household Net Dividend (2009$)				...as a Share of Household Income			
Vermont	$2,296	Wyoming	$473	Vermont	2.6%	Virginia	0.5%
New York	$2,199	Virginia	$490	Maine	2.5%	Minnesota	0.5%
Maine	$2,025	North Dakota	$525	New York	2.4%	Wyoming	0.5%
Oregon	$1,863	Minnesota	$541	Oregon	2.2%	Maryland	0.6%
Washington	$1,851	Dist. Columbia	$558	Washington	2.1%	Dist. Columbia	0.6%
New Hampshire	$1,769	Indiana	$602	Wisconsin	1.9%	West Virginia	0.6%
Rhode Island	$1,690	West Virginia	$603	Montana	1.9%	North Dakota	0.7%
Connecticut	$1,614	Kansas	$603	Rhode Island	1.8%	Kansas	0.7%
California	$1,591	Maryland	$623	Mississippi	1.8%	Indiana	0.7%
Massachusetts	$1,435	Missouri	$639	South Carolina	1.8%	Nebraska	0.8%

Sources: Authors' calculations.

Figure 4: 2020 median household net dividend as a share of income



Note: Values rounded to the nearest tenth of a percent. Median household net dividend as a share of income is 1.3 percent for Alaska, 1.0 for Hawaii, and 0.6 for the District of Columbia.

In the 2020 scenario, carbon revenues total $402 billion, $60 billion of which is still available for other purposes after households are given their rebates. Energy efficiency investments absorb approximately $12 billion, leaving $48 billion available for further green investments. If the energy efficiency investments are made in proportion to electricity emissions, they would range from $1,166 million in Texas to $3 million in Vermont (see Table 10).

At one new job for every $90,000 green investment, a total of 130,556 jobs would be created in fields related to energy efficiency, with Texas gaining the most, 12,961 jobs, and Vermont the fewest, 28. Netting these gains from the 2020 structural changes to employment from carbon policy (based on a $31/mT CO_2 carbon price),[35] 15 states switch from job losses to job gains: Alabama, Arizona, Arkansas, Colorado, Indiana, Iowa, Kansas, Kentucky, Mississippi, Montana, North Carolina, Ohio, Pennsylvania, Tennessee, and Utah. Spending just 4 percent of the remaining carbon revenue on additional green employment would offset job losses related to carbon policy in all states, while continuing to reduce disparities among states.

Table 10: $75/mT CO_2 in 2020: Energy efficiency investments and jobs

Reduction in CO_2 electricity emissions		Energy efficiency investment (millions $)		Energy efficiency jobs gained		Structural changes to employment[a]		Net changes to employment	
North Dakota	24.0%	Texas	$1,166	Texas	12,961	Florida	12,479	Florida	22,747
Wyoming	23.3%	Florida	$924	Florida	10,268	New York	12,301	New York	16,617
Utah	22.0%	Ohio	$607	Ohio	6,744	California	9,434	California	14,825
Indiana	21.9%	Georgia	$506	Georgia	5,621	New Jersey	4,562	Georgia	9,143
New Mexico	21.8%	California	$485	California	5,390	Massachusetts	3,819	Ohio	7,971
Kentucky	21.5%	Illinois	$448	Illinois	4,974	Georgia	3,522	Illinois	7,712
West Virginia	21.1%	Indiana	$434	Indiana	4,822	Maryland	2,945	New Jersey	6,937
Iowa	20.9%	North Carolina	$431	North Carolina	4,792	Illinois	2,738	North Carolina	6,700
Missouri	20.5%	Pennsylvania	$427	Pennsylvania	4,747	Washington	2,535	Michigan	6,633
Wisconsin	19.5%	Virginia	$427	Virginia	4,746	Minnesota	1,957	Virginia	6,339
Vermont	2.0%	Vermont	$3	Vermont	28	Texas	-44,280	Texas	-31,319
Washington	3.4%	Alaska	$15	Alaska	168	Louisiana	-13,538	Louisiana	-11,262
Oregon	4.7%	New Hampshire	$20	New Hampshire	226	Oklahoma	-11,665	Oklahoma	-9,983
New Hampshire	7.8%	Maine	$22	Maine	245	Wyoming	-6,844	Wyoming	-6,417
Connecticut	8.7%	Rhode Island	$25	Rhode Island	283	West Virginia	-6,168	West Virginia	-4,884
Maine	8.7%	South Dakota	$26	South Dakota	294	Kentucky	-4,338	New Mexico	-1,861
California	9.2%	Dist. Columbia	$32	Dist. Columbia	358	New Mexico	-3,077	Alaska	-1,846
South Carolina	9.3%	Montana	$34	Montana	380	Colorado	-2,660	Kentucky	-793
Idaho	10.3%	Wyoming	$38	Wyoming	427	Kansas	-2,060	North Dakota	-727
New York	10.4%	Hawaii	$41	Hawaii	459	Alaska	-2,014	Kansas	-581

Sources: Authors' calculations. Structural employment estimates based on Arnold and Dahl (2010). See Section 2 above for an explanation of calculations related to Arnold and Dahl's work.

35 Authors' calculations based on Arnold and Dahl (2010); see section II above.

IV. States and Energy Use

While our model includes different carbon intensities for electricity and households fuels for each state, it assumes that every state's household consumption will respond in more or less the same way to price and income changes. (In technical terms, price elasticities and income elasticities are the same for every state.) A more realistic assumption – which could not be modeled due to data limitations – would be that households' responsiveness to changes in prices and income depends on climate, geography, and the availability of alternatives.

Carbon policy – caps on greenhouse gas emissions, carbon prices or taxes, and fees for emission allowances – will increase the price of any consumer product that contains fossil fuel or was made with the use of fossil fuel (and some fossil fuel is used to produce nearly every good or service sold in the United States). When consumers face these higher prices, they will have to make a choice: Continue to purchase the same quantity at the higher price, or change their buying habits. When a carbon policies calls for a part of the revenue collected from carbon taxes or the auction of allowances to return to U.S. households, the rebate would increase households' incomes – a factor that can also influence their purchasing decisions. This section discusses state-by-state differences in fuel and electricity use and carbon emissions, and the factors that will make it more or less difficult for consumers to change their buying habits in response to changing prices and income.

A recent analysis of 2005 carbon emissions across U.S. states (Stanton et al. 2010) found that the per capita amount of carbon dioxide (CO_2) released into the atmosphere by transportation is strongly dependent on fuel use, which in turn varies in accordance with states' population density, share of workers using public transportation, and price of gasoline. Emissions from residential heating and cooking fuels depend almost exclusively on two factors: household fuel use per capita, and oil's share of heating fuel use; household fuel use per capita is, in turn, a function of income and climate. Residential electricity emissions (adjusted for interstate trade in electricity) depend on electricity use per capita and the share of electricity generated from coal. Electricity use varies as a function of climate and electricity prices. An interesting result from this study is that, when policy variables like gasoline or electricity prices and the share of travel by public transportation were taken into consideration, per capita transportation fuel and residential electricity consumption did not depend significantly on average state income: Factors like fuel and electricity prices and the existence of cleaner alternatives have a bigger effect on per capita emissions than average income does.

The study attributes some states' lower emissions per capita to the following factors:

- Driving less per person and having, on average, better fuel economy;
- Using less electricity per person at home;
- Having higher gasoline and electricity prices;
- Relying more on public transportation; and
- Using less oil for heating and less coal for electricity generation.

States with the lowest transportation and residential emissions – New York, the District of Columbia, Oregon, California, and Rhode Island – have some or all of these characteristics and offer ample opportunities for residents to reduce carbon-intensive fuel and electricity use. States with the highest emissions – Alaska, Wyoming, North Dakota, Louisiana, and Kentucky – lag behind; unless new policies fill this gap, residents of these states will have fewer opportunities and less public assistance toward low-cost adjustment to carbon policy.

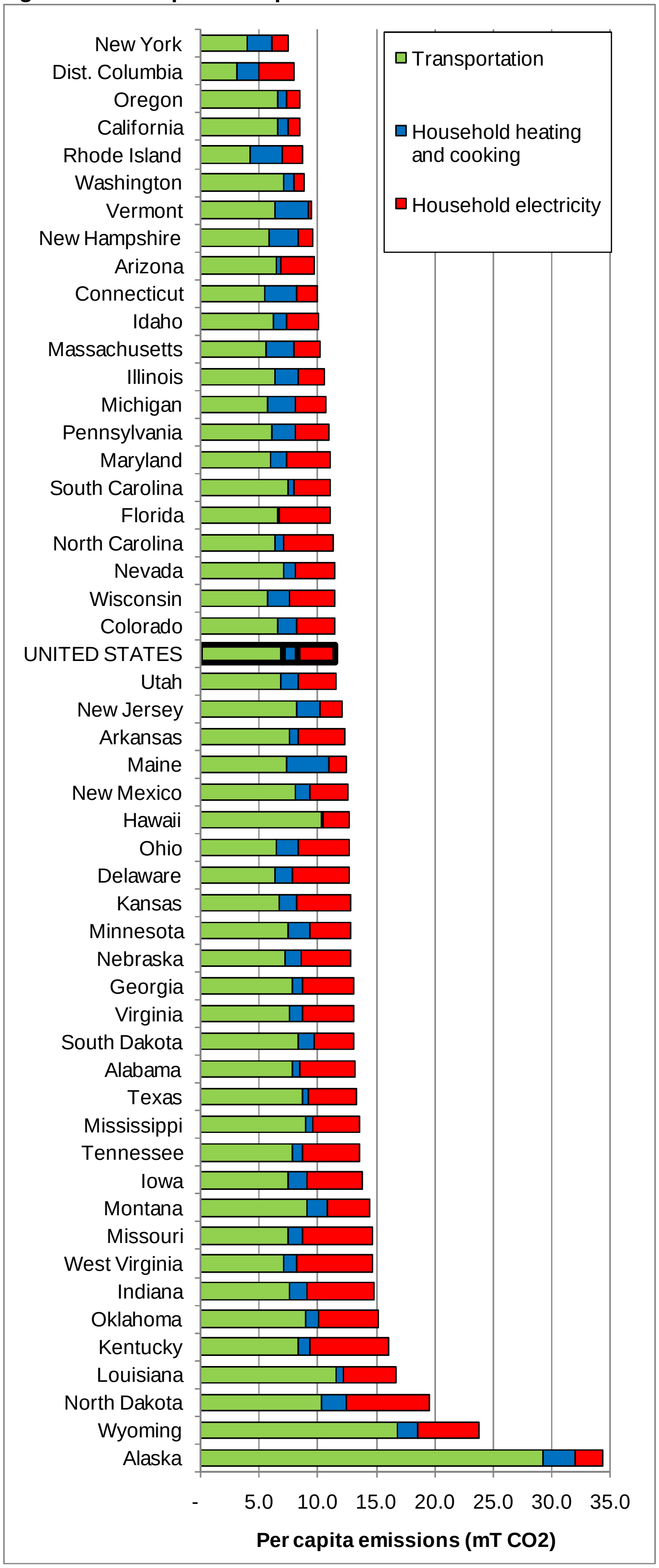
In 2005, annual U.S. emissions per capita were 21.2 metric tons (mT) of CO_2. A little more than half of that – 11.5 mT CO_2 – came from transportation fuel use, residential electricity use, and fuels for heating and cooking; the remainder came from fuel and electricity use by commercial establishments (offices, stores, restaurants) and government, 3.8 mT CO_2, and industry, 5.9 mT CO_2.[36] State-by-state differences in the economic impact of carbon policy depend on each state's per capita transportation and residential emissions, but less so on differences in commercial, government, and industrial emissions. Consumer purchases do result in commercial and industrial emissions, but there is only a very limited relationship between state consumption, and *in-state* commercial and industrial emissions: Residents of each state consume goods and services from around the country and around the world. Similarly, part of each state's government emissions includes those that result from policies and institutions of the nation as a whole, and not just the particular state in which federal activities occur.

Alaska's per capita residential and transportation emissions, 34.3 mT CO_2, are more than three times the U.S. average; New York has the lowest, just 7.5 mT CO_2 (see Figure 5).[37] On average, residents of states with the highest residential and transportation emissions per capita will face the biggest increases to their household budgets from carbon policy: The average Alaskan will pay more in carbon costs than the average New Yorker.

But the full story of how the economic impacts of carbon policy will vary by state isn't quite that simple. It stands to reason that when prices for fossil-fuel-intensive goods go up, both Alaskans and New Yorkers will try to adjust their spending to buy less gasoline, heating fuel and electricity, and more goods and services that require the least fossil fuel for their production and whose prices are thus least affected by a carbon price. How successful households are in changing their consumption patterns depends on a lot of factors, some specific to each family, but many dependent on conditions shared by residents within each state, such as climate, access to public transportation, and the types of fuels used to generate electricity.

[36] Unless another citation is given, all emissions reported in this section are for 2005, adjusted for trade in electricity between states, and based on Stanton et al. (2010).
[37] See Appendix C for additional state emissions data.

Figure 5: Per capita transportation and residential CO_2 emissions by U.S. state, 2005



Source: Stanton et al. (2010).

While every household will experience the impacts of carbon policy differently, there are clear patterns by state. Carbon permits or taxes will raise the prices of many goods and services, while rebate checks would raise incomes; if rebates are large enough, they can keep total expenditures steady even as the pattern of expenditures changes. Higher prices and higher incomes each have an effect on the kind and amount of purchases that each household makes – how big of an effect depends on qualities that economists call "elasticities." The responsiveness of purchases of a good to changes in its price is called the "price elasticity of demand." The responsiveness of purchases of a good to changes in incomes is called the "income elasticity of demand."[38]

Here's a classic example: If the price of insulin were to increase by 10 percent, few diabetics would change the amount of insulin that they purchase, and many would reduce some other purchases to make room for this bigger bite from their budget. Diabetics' demand for insulin is "inelastic" – small increases and decreases in the price don't have much of an effect on how much is purchased. In contrast, if the price of frozen waffles were to increase by 10 percent, many shoppers would buy fewer waffles, and might buy instead more bagels or breakfast cereal. Our demand for non-essential items, especially those with good substitutes, like waffles, tends to be very "price-elastic"; when prices change, so too does the amount we consume.

A high carbon price would raise the prices of gasoline, heating oil, and electricity, but most households' demand for these goods is very inelastic (Brons et al. 2008; Cooper 2003; Silk and Joutz 1997; Hughes et al. 2008): The prices change, but our buying habits stay the same. A carbon price would have a smaller impact on the prices of many other goods and services – the more fossil fuels used to make a good or provide a service, the greater the price impact from any carbon policy. For example, buying a plane ticket is far more "carbon intensive" than buying a ferry ticket; that is, there is a lot more carbon per dollar in plane rides than in ferry rides, and a carbon price would have a much bigger impact on the price (per dollar) of the former than the latter. Among those products for which demand is fairly elastic (more like waffles and less like insulin), a carbon price likely would cause consumers to buy more low-carbon-intensity products and services and fewer with high carbon intensities. But among products that are price-inelastic, such as gasoline, heating fuels, and electricity, a carbon price would have a much smaller impact on consumer purchases.

To forecast the impacts of carbon policy on a state-by-state basis, it is therefore important to understand what can make demand for some high-carbon-intensity products more or less price-elastic. In general terms, our use of energy products requires that we make big investments, both public and private, in equipment specific to particular energy sources. For example, consumers can't change their gasoline purchases without changing their means of transportation to work, school, and shopping: this means buying a fuel-efficient car; switching to public transportation; or making an important lifestyle change by walking, riding a bike, forming a car pool, changing jobs, or moving. (The big exception is leisure travel. People can change their transportation-fuel use by not going on summer road trips or flying to far-off vacation spots.) We have the power to make some of these changes as individuals or families, if we want to, but other changes depend on the availability of more fuel-efficient products, or products that use alternative (non-fossil) fuels, or depend on public infrastructure: bike paths or cyclist-friendly roads,[39] public transportation networks, or charging stations for electric cars.

[38] The own-price elasticity of demand is the percentage change in the quantity consumed of a particular good or service caused by a 1-percent change in its price; it is normally a negative value. The income elasticity of demand is the percentage change in consumption of a particular good or service caused by a 1-percent change in the consumer's income.
[39] Other bike-friendly public measures include relatively low speed limits and timing of traffic signals to make cycling convenient; measures that workplaces can take include locking facilities (racks or lockers) and showers.

Because of public investments, residents of some states will find it easier and cheaper to respond to a carbon price by changing their buying habits, while residents of other states will have little choice but to continue the same, inelastic purchase of high-carbon-intensity fuels and electricity, at least in the short run. In the long run, however, all states have the potential to reduce greenhouse gas emissions and green their economies. Consumers' demand for gasoline, heating fuels and electricity will become more elastic with each year of carbon policy as investments in fuel-efficient cars, furnaces, appliances and insulation become more cost-effective, and public policy makes more low-carbon-intensity options available by retiring coal plants, expanding public transportation networks, and creating incentives for households to improve their energy efficiency.

In the sections that follow, we give an overview of states' investments in energy efficiency, and the use, availability, and carbon intensity of electricity, household fuels, and means of transportation. Households' price elasticity of demand in response to carbon prices will depend in great part on state-specific infrastructure, as well as climate and geography.

Energy Efficiency

The efficiency of energy use varies greatly from state to state. With better energy efficiency, a state's residents can achieve the same benefits of heating, cooling, home appliances, electronics and lighting, and transportation but have lower energy use and emissions per capita. States that have made larger investments in renewable energy, public transportation, and conservation measures are likely to find that their residents have a more elastic response to a carbon price, and therefore experience less of an economic impact from climate policy.

The American Council for an Energy-Efficient Economy (ACEEE) publishes an annual scorecard of states' levels of energy efficiency. Research from ACEEE also points to further untapped potential in U.S. energy efficiency: 23 percent more efficient energy use, with benefits more than paying for the cost of implementation, and the potential for a net gain of 500,000 to 1,500,000 green jobs by 2030 (Laitner and McKinney 2008). Another report estimates that energy efficiency in the multifamily housing sector could improve by 30 percent, and that making these improvements would eliminate 50 to 100 million mT CO_2 each year (Stone et al. 2009).

In ACEEE's most recent scorecard (2009), California ranks highest in overall energy efficiency, followed by Massachusetts, Connecticut, Oregon, and New York (see Table 11).[40] Wyoming received ACEEE's lowest score for 2009 – 1 out of 50 possible points, followed by Mississippi, North Dakota, Alabama, and Nebraska. ACEEE also drew attention to six states that had the biggest improvements in energy efficiency from 2008 to 2009: Delaware, Maine, Tennessee, Colorado, South Dakota, and Washington D.C.

[40] See Appendix C for additional state energy efficiency data.

Table 11: Top 10 States by Energy Efficiency, 2009

State	Utility and Public Benefits Programs and Policies	Transportation Policies	Building Codes	Combined Heat & Power	State Government Initiatives	Appliance Standards	TOTAL SCORE
California	18.5	6.0	7.0	5.0	5.0	3.0	44.5
Massachusetts	17.0	4.0	7.0	4.0	5.0	2.0	39.0
Connecticut	17.0	5.0	4.0	5.0	4.5	2.0	37.5
Oregon	14.0	5.0	6.0	5.0	4.5	2.0	36.5
New York	14.0	5.0	4.5	5.0	5.0	1.0	34.5
Vermont	19.0	4.0	3.5	2.0	4.0	1.0	33.5
Washington	14.0	6.0	6.0	3.0	2.0	2.0	33.0
Minnesota	16.5	2.0	5.0	3.0	4.0	0.0	30.5
Rhode Island	13.0	4.0	5.5	1.0	2.0	2.0	27.5
Maine	8.5	4.0	5.5	4.0	4.0	0.0	26.0

Source: ACEEE (2009) Energy Efficiency Scorecard.

ACEEE bases its rankings on six categories contributing to the efficient use of energy:

Efficiency in *utility and public benefits programs and policies* is based on electricity and gas program spending as a share of state revenues, public-electricity savings, energy efficiency resource standards, utility incentives, and the removal of utility disincentives. Vermont receives the highest score in this category, followed closely by California, Connecticut, Massachusetts, and Minnesota. Five states get a zero score in this category, which is worth 20 points: Alaska, Alabama, Mississippi, West Virginia, and Louisiana.

The *transportation policy* score — based on vehicle greenhouse gas emissions standards, policies to reduce vehicle miles traveled, state transit funding, and high-efficiency-vehicle consumer incentives — contributes another possible eight points to the final efficiency score. California and Washington tie for the highest score, 6; Connecticut, Maryland, New Jersey, New York, and Oregon tie for third place. Twenty-three states score zero in this category.

Building efficiency codes contribute another possible seven points to the final score. States are rated on their compliance efforts and the stringency of residential and commercial codes. California and Massachusetts get the maximum score; Oregon, Washington, Pennsylvania, and the District of Columbia tie for third place. Five states get a zero score: Alabama, Mississippi, North Dakota, South Dakota, and Wyoming.

The score for *state government initiatives,* worth seven points, is based on financial and information incentives; energy research, development and deployment; and “lead-by-example” building requirements and state-vehicle-fleet efficiency. California, Pennsylvania, and New York get the top score, followed by Connecticut and Oregon. Four states get a zero: Arkansas, Georgia, North Dakota, and Wyoming.

State policies encouraging *combined heat and power* systems that simultaneously generate electricity and heat buildings are worth another five points. Seven states tie for first place: California, Connecticut, Illinois, New York, Ohio, Oregon, and Texas; tying for last place were Georgia, Iowa, Louisiana, Virginia, and Wyoming.

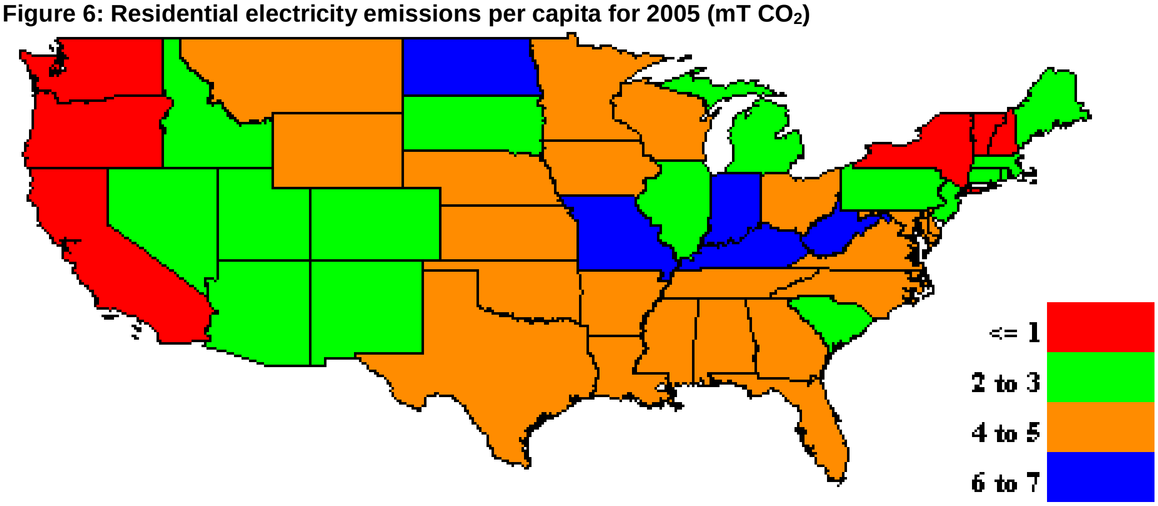
A final three possible points come from an *appliance and efficiency standards* score, which is based primarily on new state standards enacted since 2002. California is a clear winner, followed by Connecticut, Maryland, Massachusetts, Oregon, Rhode Island, and Washington. Thirty-eight states received a score of zero in this category.

In states that have embraced energy efficiency – California, Connecticut, Massachusetts, New York, Oregon – consumers will have a leg up in responding to a carbon price elastically, by consuming less gasoline, heating fuel, electricity, and other high-carbon-intensity goods and services, and more of the low-carbon-intensity goods and services that they enjoy. States like Delaware, Maine, Tennessee, Colorado, South Dakota, and Washington, D.C., are making great strides towards catching up with their most energy-efficient neighbors. Others – Alabama, Mississippi, Nebraska, North Dakota, and Wyoming top this list – lag behind, and therefore lack the flexibility that would allow their residents to switch to public transportation, or seek out public energy-conservation assistance. Unless these states catch up, their residents will find it more difficult to avoid the economic impacts of carbon prices.

Electricity

U.S. electricity consumption resulted in the release of 2.5 billion mT CO_2 into the atmosphere in 2008 – 43 percent of total U.S. CO_2 emissions (see Figure 6).[41] Carbon policy will mean bigger electricity bills, especially in states that use a lot of electricity per person, and states where the electricity consumed (some produced in state and some imported) is very carbon-intensive. Consuming less electricity – conservation – is an important focus of energy-efficiency investment; in many states, programs exist to make new, energy efficient appliances less expensive, to improve insulation thereby reducing air-conditioner use, and to offset the costs of rooftop solar panels.

Figure 6: Residential electricity emissions per capita for 2005 (mT CO_2)



Note: Values rounded to the nearest whole number. Per capita residential electricity emissions, in mT CO_2, are 2.3 for Alaska, 2.2for Hawaii, and 2.9 for the District of Columbia.

Per capita electricity use ranges from 31.3 megawatt-hours (MWh) in Wyoming to just 9.2 in Vermont (see Table 12); average U.S. per capita electricity consumption is 12.3 MWh.[42] Emissions

[41] U.S. Energy Information Administration (2009a; 2010c), http://www.eia.doe.gov/oiaf/1605/ggrpt/carbon.html and http://www.eia.doe.gov/cneaf/electricity/epa/epat3p9.html. See Appendix C for additional state electricity data.
[42] U.S. Energy Information Administration (2010d), http://www.eia.doe.gov/oiaf/1605/state/state_emissions.html .

from electricity generation account for 74.4 percent of West Virginia's total CO_2 emissions, but just 0.1 percent of Vermont's. Energy efficiency may be an important part of the explanation of these differences: Among the ten states with the lowest electricity consumption per capita, seven are in the ACEEE's 2009 top ten for energy efficiency.

Table 12: States with highest and lowest electricity consumption per capita, 2008 (MWh)

Highest per capita		Lowest per capita	
Wyoming	31.3	California	7.3
Kentucky	21.9	New York	7.4
Dist. Columbia	20.0	Rhode Island	7.4
North Dakota	19.4	Hawaii	8.1
Alabama	19.2	New Hampshire	8.3
West Virginia	18.9	Massachusetts	8.6
South Carolina	18.0	Connecticut	8.8
Louisiana	17.8	Maine	8.9
Indiana	16.8	Alaska	9.2
Tennessee	16.8	Vermont	9.2

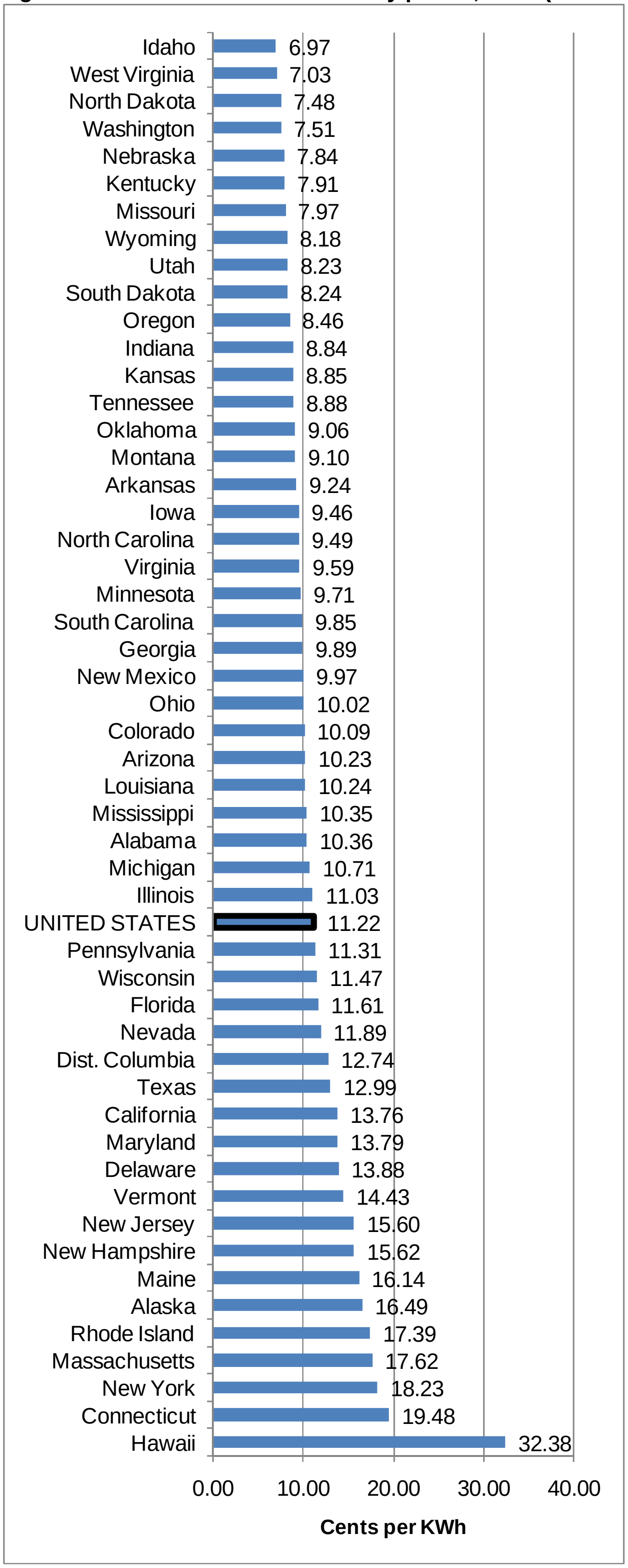
Sources: U.S. Energy Information Administration (2010b) state data tables, http://www.eia.doe.gov/cneaf/electricity/epa/epa_sprdshts.html; U.S. Census Bureau (2009) ACS 2008 data, http://factfinder.census.gov/home/saff/main.html?_lang=en; and Hodges and Rahmani (2009), http://edis.ifas.ufl.edu/fe796.

Another important factor affecting per capita consumption of electricity is the residential retail price; electricity prices range from 6.97 cents per kilowatt-hour (kWh) in Idaho to 19.48 in Connecticut, with Hawaii as an extreme outlier at 32.38 (see Figure 7).[43] Nine out of the ten states with the lowest per capita electricity consumption (California is the exception) are among those with the ten highest electricity prices. There is a similar, although somewhat weaker, correlation between states with the highest per capita electricity use and low electricity prices.

Climate can also have an effect on electricity use and can be a key cause of demand inelasticity for electricity: Consumers in hot climates may pay higher prices without reducing their demand for electricity – to do otherwise would require them to go without air conditioning. Few of the hottest states are among those with the highest electricity consumption per capita (just Alabama and Louisiana), but none of the hottest states are among those with the lowest consumption. Figure 8 reports "cooling degree days" for each state – each day's difference between a comfortable temperature and the actual temperature, summed up for an entire year.

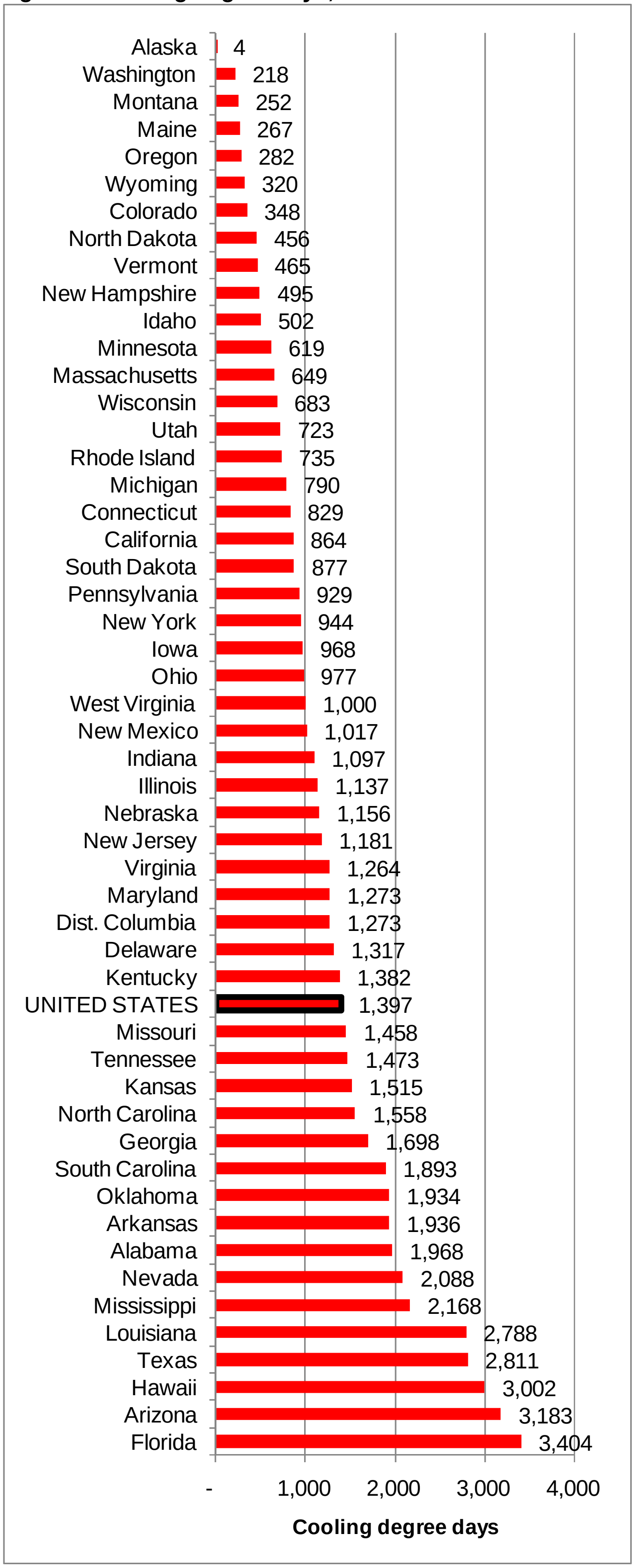
[43] Prices reported in 2009 dollars. Conversion based on the CPI-U, Bureau of Labor Statistics (2010), ftp://ftp.bls.gov/pub/special.requests/cpi/cpiai.txt.

Figure 7: Residential retail electricity prices, 2008 (cents/kWh)



Sources: U.S. Energy Information Administration (2010b) state data tables. Prices reported in 2009 dollars. Conversion based on the historical CPI-U, Bureau of Labor Statistics (2010).

Figure 8: Cooling degree days, 2005



Source: National Climatic Data Center (2007), http://www.ncdc.noaa.gov/oa/documentlibrary/hcs/cdd.200501-200612.pdf.

Two more states in ACEEE's top ten – Oregon and Washington – are examples of a second key factor in explaining the distribution of U.S. emissions from electricity, the carbon intensity of in-state electricity generation. Methods of electricity generation differ in the metric tons of CO_2 emitted per megawatt-hour produced. In 2007, burning biomass – usually wood industry and agricultural residues – for electricity generation in the United States resulted in, on average, 1.08 mT CO_2 per MWh; coal, 0.98; petroleum, 0.84; and natural gas and propane, 0.46 (Hodges and Rahmani 2009).

U.S. states use all of these fuels to generate electricity, plus nuclear power and renewables – geothermal, hydro-electric, solar, and wind – which do not directly create greenhouse gas emissions. States' mix of production methods results in very different average state carbon intensities of electricity generation, from 1.02 mT CO_2 per MWh in North Dakota, where 91 percent of electricity is generated from coal, to 0.09 mT CO_2 per MWh in Vermont, where 72 percent comes from nuclear and 22 percent from hydro-electric power (see Table 13 and Table 14).[44]

Table 13: Carbon intensity of in-state electricity generation, 2007 (mT CO_2/MWh)

Highest intensity		Lowest intensity	
North Dakota	1.02	Vermont	0.09
Wyoming	0.99	Washington	0.13
Kentucky	0.96	Idaho	0.18
Indiana	0.95	Oregon	0.21
Delaware	0.92	California	0.31
West Virginia	0.90	Connecticut	0.33
New Mexico	0.88	New Jersey	0.33
Utah	0.88	New Hampshire	0.36
Missouri	0.85	New York	0.37
Ohio	0.84	Rhode Island	0.42

Sources: U.S. Energy Information Administration (2010b) state data tables, U.S. Census Bureau (2009) ACS 2008 data, http://factfinder.census.gov/home/saff/main.html?_lang=en; and Hodges and Rahmani (2009), http://edis.ifas.ufl.edu/fe796.

[44] The average carbon intensity of coal generation in the U.S. is 0.98 mT CO_2/MWh, but different generation facilities have different intensities. North Dakota and Wyoming's carbon intensity of coal generation is higher than the national average because of the carbon intensity of the specific coal plants located in these states.

Table 14: Share of electricity generated in U.S. and selected states by method, 2008

Geothermal		Hydro-electric		Nuclear		Solar		Wind	
United States	**0.36%**	**United States**	**6.2%**	**United States**	**19.6%**	**United States**	**0.02%**	**United States**	**1.3%**
California	6.19%	Idaho	78.2%	Vermont	71.8%	Nevada	0.44%	Minnesota	8.0%
Nevada	3.94%	Washington	70.1%	South Carolina	51.3%	California	0.32%	Iowa	7.7%
Hawaii	2.06%	Oregon	57.6%	Connecticut	50.8%	Colorado	0.03%	Colorado	6.0%
Idaho	0.71%	South Dakota	42.3%	New Jersey	50.6%	Arizona	0.01%	North Dakota	5.2%
Utah	0.55%	Montana	33.7%	Illinois	47.7%	New Jersey	0.00%	New Mexico	4.4%
Montana	0.38%	Maine	26.1%	New Hampshire	40.9%	North Carolina	0.00%	Oregon	4.4%
		Vermont	21.9%	Virginia	38.4%	Massachusetts	0.00%	Texas	4.0%
		New York	19.0%	Pennsylvania	35.4%	Hawaii	0.00%	Kansas	3.8%
		Alaska	17.3%	North Carolina	31.8%	Pennsylvania	0.00%	Washington	3.3%
		California	11.6%	Maryland	31.0%			Oklahoma	3.1%

Coal		Natural Gas		Petroleum		Wood and Biomass		Other	
United States	**48.2%**	**United States**	**21.4%**	**United States**	**1.1%**	**United States**	**1.3%**	**United States**	**0.4%**
West Virginia	97.8%	Rhode Island	97.4%	Dist. Columbia	100%	Maine	23.0%	Delaware	6.5%
Indiana	94.2%	Nevada	68.3%	Hawaii	76.2%	Vermont	6.1%	Connecticut	2.4%
Wyoming	94.2%	Alaska	59.1%	Alaska	14.4%	New Hampshire	5.1%	Indiana	2.1%
Kentucky	93.6%	California	57.7%	Florida	5.5%	Idaho	3.8%	Maine	1.8%
North Dakota	90.6%	Massachusetts	50.6%	Massachusetts	5.0%	Virginia	3.7%	Hawaii	1.7%
Ohio	85.2%	Louisiana	49.0%	Maine	3.1%	Massachusetts	2.9%	Louisiana	1.7%
Utah	81.6%	Texas	47.7%	Kentucky	2.9%	Louisiana	2.9%	Maryland	1.3%
Missouri	80.8%	Florida	47.1%	Delaware	2.9%	Mississippi	2.9%	Florida	1.3%
Iowa	76.1%	Oklahoma	44.2%	New York	2.7%	California	2.8%	California	1.2%
New Mexico	73.0%	Maine	43.2%	Louisiana	2.5%	Arkansas	2.7%	Texas	1.0%

Source: U.S. Energy Information Administration (2010b) state data tables, http://www.eia.doe.gov/cneaf/electricity/epa/epa_sprdshts.html.

Twenty-seven percent of U.S. electricity comes from carbon-free generation methods.[45] Washington, with the second-lowest carbon intensity of electricity generation, produces 70 percent of its electricity from hydro-electric power, 8 percent from nuclear power, and 3 percent from wind. Rhode Island, with the tenth-lowest carbon intensity, produces 97 percent from relatively low-carbon-intensity natural gas.

But electricity consumption per capita and the carbon intensity of electricity generated within each state can only go so far in explaining states' per capita carbon emissions from electricity use. The third key factor is the carbon intensity of electricity imported from other states. One-tenth of all electricity generated in the United States crossed state lines in 2008.[46]

[45] No method of electricity generation is truly "carbon-free" over its entire life cycle; all methods result in greenhouse gas emissions in the construction of the power plant, and nuclear power entails additional emissions in mining and processing uranium. It is common to refer to non-combustion power plants as "carbon-free," since they do not release carbon dioxide in the process of generation itself.

[46] U.S. Energy Information Administration (2010a) state data tables. Our approach to interstate electricity transactions is oversimplified in two important ways, both forced on us by data limitations. First, most states are included in multi-state power pools, within which electricity frequently flows back and forth across state boundaries. Even a state that is, on

The state exporting the most electricity in 2008, Pennsylvania, generated 53 percent from coal, 35 percent from nuclear, and 8 percent from natural gas, for a carbon intensity of electricity of 0.58 mT CO_2/MWh (see Table 15 and Figure 9). Some of the other big electricity exporters have much higher carbon intensities: West Virginia, 0.90 mT CO_2/MWh; Wyoming, 0.99; North Dakota, 1.02; and Utah, 0.88. California's relatively low carbon intensity, 0.31 mT CO_2/MWh, describes only its in-state generation, not the 43 percent of its electricity consumption that it imports from neighboring states. A carbon price would increase electricity prices in proportion to the total carbon intensity of electricity consumption (imports and in-state generation combined); state investments in alternative energy sources for electricity generation can only dampen carbon price effects if they account for a significant proportion of electricity consumed in the state.

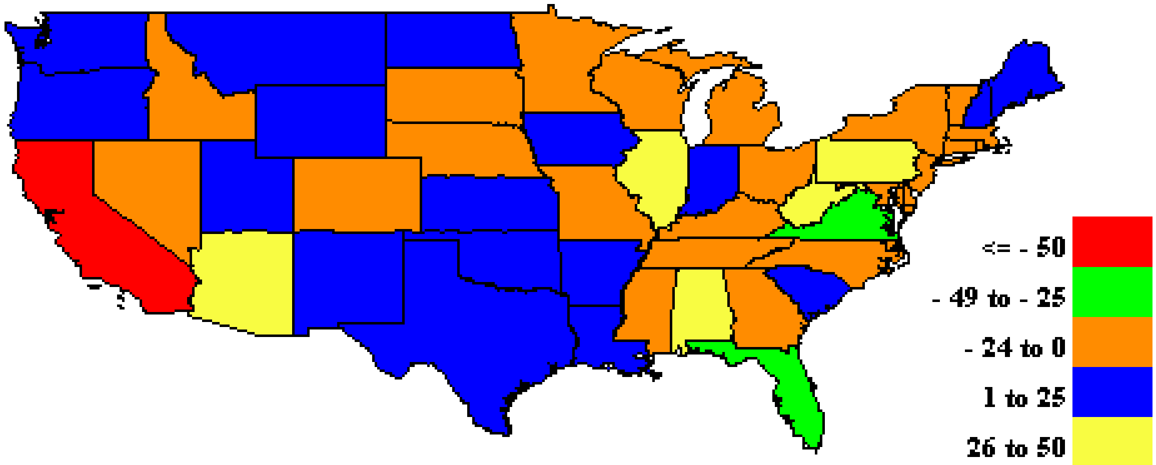
Table 15: Top ten exporters and importers of electricity (million MWh)

Exports		Imports	
Pennsylvania	50.1	California	80.6
West Virginia	47.9	Virginia	44.6
Alabama	41.8	Florida	28.1
Illinois	35.2	New Jersey	23.1
Arizona	31.4	Tennessee	22.4
Wyoming	25.2	Ohio	21.1
Texas	17.9	Maryland	20.6
North Dakota	17.1	Minnesota	19.4
Utah	13.8	Massachusetts	17.6
Washington	12.6	New York	17.5

Source: Authors' calculations from U.S. Energy Information Administration (2010b) state data tables; see Stanton et al. (2009) for methodology.

balance, self-sufficient or exporting electricity may have imports from nearby states, offset by equal or greater exports. Data on electricity imports and exports in this article refer only to net interstate flows, not to actual gross flows in both directions. Second, interstate exports differ greatly in their carbon intensity, ranging from carbon-free hydro-electric and nuclear power to coal-fired electricity. Unfortunately, there is no way to track who received the exports of electricity with different carbon intensities; we have therefore applied the national average carbon intensity of exported electricity throughout the country.

Figure 9: Electricity exports and imports (million MWh, exports are positive, imports are negative)



Note: Values rounded to the nearest whole number. Electricity exports and imports, in million MWh, are 0 for Alaska and Hawaii, and -11.8 for the District of Columbia.

Interstate trade in electricity is reflected in both the carbon intensity of electricity use and the share of electricity use from coal generation, and there is a very close – 94 percent – correlation in the state-by-state variation of these two factors. West Virginia's coal share of electricity use is 98 percent, and its carbon intensity of electricity use (here, measured as emissions per $1,000 of electricity sales) is 18.0 mT CO_2/$1000; in Maine these figures are 2 percent and 3.6 mT CO_2/$1000 (see Table 16 and Figure 10).[47]

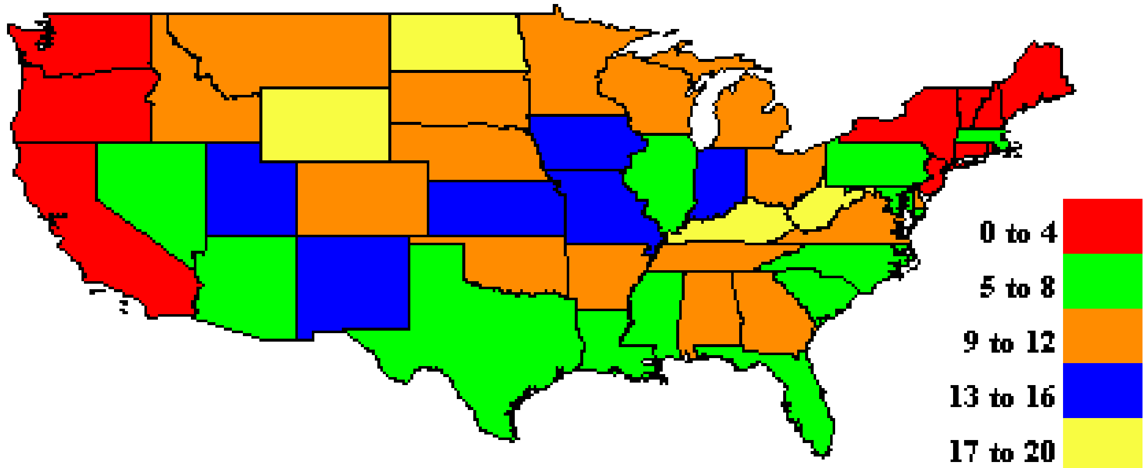
Table 16: States with highest and lowest carbon intensity of electricity (including imports) (mT CO_2/$1,000) and share of electricity use from coal generation (including imports)

Highest intensity		Lowest intensity		Highest coal share		Lowest coal share	
Wyoming	19.7	Vermont	0.8	West Virginia	97.6%	Maine	1.7%
Kentucky	18.8	Washington	2.5	Wyoming	95.1%	Vermont	7.8%
West Virginia	18.0	New Hampshire	2.7	North Dakota	94.8%	Oregon	9.3%
North Dakota	17.7	Connecticut	3.2	Utah	94.2%	Alaska	9.5%
Indiana	16.3	New York	3.3	Indiana	94.2%	Washington	10.3%
Utah	16.2	Oregon	3.3	Kentucky	90.7%	Hawaii	14.8%
Missouri	14.7	California	3.5	Missouri	85.3%	Connecticut	16.3%
Iowa	13.7	Maine	3.6	New Mexico	85.2%	New Hampshire	16.6%
Kansas	12.8	New Jersey	4.4	Ohio	84.4%	California	19.1%
New Mexico	12.7	Hawaii	4.4	Iowa	76.6%	New York	19.8%

Sources: Stanton et al. (2010) and authors' calculations.

[47] Stanton et al. (2010) and authors' calculations.

Figure 10: Carbon intensity of electricity (including imports) (mT CO2/2009$)



Note: Values rounded to the nearest whole number. Carbon intensity of electricity (including imports), in mT CO_2/2009$, is 9.6 for Alaska, 4.4 for Hawaii, and 10.3 for the District of Columbia.

When carbon intensity of electricity generation and carbon intensity of electricity use are compared, most states change rank by a few places, but a few states stand out. Idaho – where 78 percent of electricity generation is hydro-electric and 55 percent of electricity is imported – ranks eighth lowest in carbon intensity by generation but only 25 lowest by use. Virginia rises eight places in this ranking, Wisconsin seven places, and Maryland and Nevada, four places each. Several states move in the other direction, with lower carbon intensities by use than by generation: Florida, Georgia, and Mississippi all stand out among states that import electricity that is less carbon-intensive than what they produce in-state.[48]

In the short run, demand for electricity is very inelastic; it can be difficult for households to substitute consumption of electricity for consumption of some lower-carbon intensity good or service. In the longer run, however, households can conserve electricity by buying energy-efficient appliances or adding insulation to prevent the escape of air-conditioned air. The lion's share of reductions will depend on utilities – and the state regulations that control them – to change the carbon intensity of electricity. Utilities, or regional power pools, may choose differently which generation facilities to run more often (in the extreme, around the clock and around the year), and which to reserve for times of higher demand (in the extreme, some facilities may be used only for a few hours of peak demand per year). In addition, many coal plants can be retired as natural gas and renewable electricity generation is built. States can also improve the elasticity of households and businesses' electricity purchases by creating programs that provide financial support and other assistance toward energy efficiency.

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[48] Stanton et al. (2010); U.S. Energy Information Administration (2010a) state data tables; U.S. Census Bureau (2009) ACS 2008 data, http://factfinder.census.gov/home/saff/main.html?_lang=en; Hodges and Rahmani (2009); and authors' calculations.

Home Heating and Cooking

Residential "direct" fuel use – fuels that are combusted in the home for space heating, water heating, and some appliances (e.g., stoves, ovens, and dryers that run on propane or natural gas) – was responsible for the release of 343 million mT CO_2 in 2007 – 5.7 percent of total U.S. CO_2 emissions.[49] Carbon policy will make these fuels more expensive; to avoid paying high prices, consumers must keep their homes cooler in winter, improve home insulation, or purchase more fuel-efficient heating fuels and heating systems.

Household fuel use's share of total emissions ranges from 0.3 percent in Hawaii to 25 percent in the District of Columbia.[50] Ten other states have emission shares from household fuels of 10 percent or greater: Vermont (24.0), Rhode Island (21.3), Connecticut (20.6), Maine (20.3), New York (18.0), Massachusetts (16.8), New Hampshire (14.7), New Jersey (12.1), Minnesota (11.3), and Idaho (10.0). In these states, heating bills are a large part of a household's annual budget. A high carbon price could be a motivation to switch to a lower carbon-intensity heating fuel, despite the expense of a new furnace and heat delivery system.

To state the obvious, colder states use more heating fuel than warmer states. Per capita non-electricity fuel use expressed in British Thermal Units (Btu), a measure of heating energy, gives an approximate picture of this relationship (non-electricity Btus include fuel used for water heating and cooking, but don't include electricity used for heating). U.S. average non-electricity fuel use was 22.6 Btu per capita in 2007; state averages ranged from 1.3 in Hawaii to 49.9 Btu per capita in Alaska (see Table 17).[51]

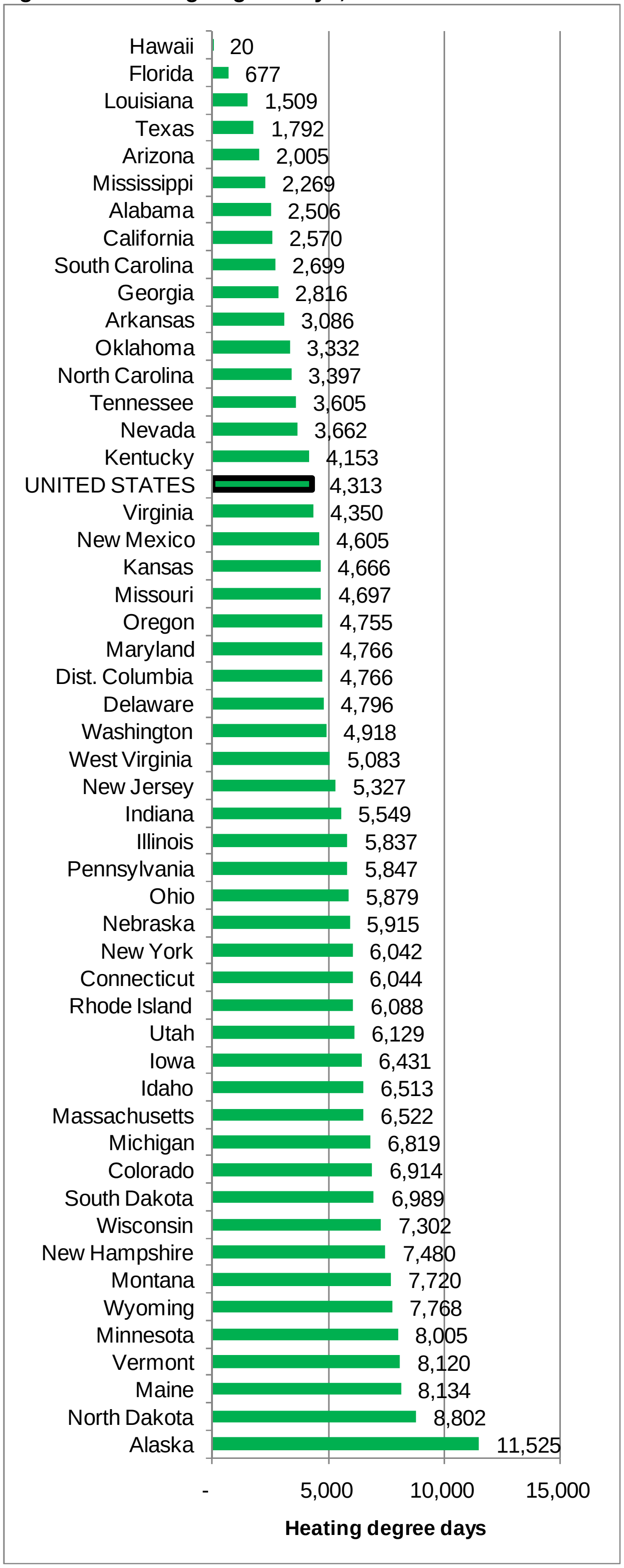
Table 17: Per capita non-electricity fuel use, 2007 (million Btu)

Highest per capita		Lowest per capita	
Alaska	49.9	Hawaii	1.3
Maine	45.8	Florida	1.9
Michigan	40.7	Arizona	9.5
Vermont	40.0	South Carolina	9.7
Illinois	38.8	Louisiana	10.2
Connecticut	38.7	Texas	11.1
Rhode Island	37.0	Alabama	11.7
Massachusetts	36.6	Mississippi	12.2
Wyoming	36.1	North Carolina	13.2
New York	35.3	Tennessee	14.5

Sources: U.S. Energy Information Administration (2009c), http://www.eia.doe.gov/emeu/states/_seds.html; and U.S. Census Bureau (2006) ACS 2005 data.

[49] U.S. Energy Information Administration (2010d), http://www.eia.doe.gov/oiaf/1605/state/state_emissions.html. See Appendix C for additional state household fuel use data.
[50] Authors' calculation for the District of Columbia based on total *positive* emissions. The EIA (ibid.) reports significant *negative* industrial emissions for D.C. EIA definition of negative emissions is unclear; see U.S. Energy Information Administration (2009e) , Chapter 2, for a possible explanation regarding the production of biofuels.
[51] U.S. Energy Information Administration (2009c); and U.S. Census Bureau (2006) ACS 2005 data.

Figure 11: Heating degree days, 2005



Source: National Climatic Data Center (2007).

Non-electricity fuel use corresponds very closely to the extent of cold weather. U.S. heating degree days — a measure of how much heating is required over the course of a year to maintain buildings at a comfortable temperature — range from 20 in Hawaii to 11,525 in Alaska (see Figure 11).[52] Residents of states with the highest heating degree days will tend to have an inelastic demand for heating fuel — using less just isn't an option for most families. The 11 states with the highest emissions from household fuel use have heating degrees days that range from 5,327 to 8,134. Several states with high per capita non-electricity fuel use and high heating degree days, however, do not have correspondingly high household heating and cooking shares of total CO_2 emissions. Alaska is a clear example; it ranks highest among all states in per capita non-electricity fuel use and heating degree days, but 31 states have a greater share of their emissions originating in the use of household fuels. Because its transportation emissions are so high, Alaska's household fuels account for just 4.2 percent of its CO_2 emissions.

The amount of greenhouse gases released per Btu differs by fuel, and fuel choice is a second important factor determining the scale of emissions from household fuels. The combustion of fuel oil emits 78.8 mT CO_2 per billion Btu; natural gas, 66.9; and propane, 62.3.[53] On average, across the United States, 74 percent of non-electricity fuel use (in Btu) comes from natural gas, 11 percent from oil, and 7 percent each from propane and wood.[54] Oil is the predominant home heating fuel in only a handful of states in New England; propane heating predominates only in Hawaii (see Table 18).

Table 18: Top ten states by share of non-electricity residential energy consumption in Btus, 2007

Oil		Natural gas		Propane		Wood	
Maine	71.8%	Illinois	91.0%	Hawaii	68.8%	Arizona	23.5%
Connecticut	57.8%	California	90.1%	Florida	42.0%	South Carolina	16.2%
New Hampshire	54.2%	Utah	89.4%	North Dakota	25.6%	Alabama	15.9%
Vermont	52.3%	Dist. Columbia	86.7%	Vermont	24.5%	Mississippi	14.2%
Rhode Island	45.3%	Colorado	86.3%	South Dakota	24.2%	Oregon	13.7%
Massachusetts	40.9%	Louisiana	85.4%	Montana	23.1%	Tennessee	12.5%
New York	26.6%	Ohio	84.4%	New Hampshire	20.4%	Washington	12.2%
Alaska	26.6%	Oklahoma	83.9%	Wyoming	19.6%	North Carolina	11.9%
Pennsylvania	26.5%	Michigan	83.7%	Mississippi	19.2%	Nevada	11.0%
Delaware	20.0%	Texas	83.5%	North Carolina	18.6%	Kentucky	10.6%

Source: U.S. Energy Information Administration (2009c).

The price of fuels, together with their availability, can also be an additional determining factor in household fuel use. Fuels vary widely in their price per unit of heat energy, but not all fuels are available in all areas, and switching from one fuel to another is likely to require the purchase and installation of new heating equipment — an expensive investment for most households. On average, across U.S. states, the highest-priced heating "fuel" was electricity, at $32 per million Btu in 2009; prices of other fuels cover a broad spectrum: $26 per million Btu for propane, $20 for fuel oil, $13 for natural gas, and $9 for wood.[55]

[52] National Climatic Data Center (2007).
[53] U.S. Energy Information Administration (2010f), emission factors for 2006.
[54] U.S. Energy Information Administration (2009c) .
[55] Prices reported in 2009 dollars. Conversion based on the CPI-U, Bureau of Labor Statistics (2010), and on U.S. Energy Information Administration (2009c).

There is a 4-to-1 variation in natural gas and electricity prices across states, 2-to-1 in propane and wood prices, and just 1.2-to-1 in oil prices (see Table 19). States with the highest prices for household fuel include both those with the lowest heating needs – Hawaii and Florida – and some of those with the highest – several states in New England. The states with the highest number of heating degree days, Alaska and North Dakota, face relatively low prices for natural gas, the dominant fuel used in both states, and also have low shares of their total CO_2 emissions coming from household fuel use – 4.2 and 2.1 percent, respectively.

Table 19: Top ten highest and lowest states by price per unit of heating energy, 2007 ($/million Btu)

Natural gas		Oil		LPQ		Electricity	
Hawaii	34.0	Washington	23.1	Hawaii	47.0	Hawaii	73.2
Florida	19.7	California	21.4	Rhode Island	37.2	Connecticut	58.0
Alabama	18.4	Nevada	21.3	New Jersey	33.6	New York	51.8
Georgia	17.7	New Jersey	21.3	Florida	33.5	Maine	50.1
Massachusetts	17.4	Vermont	21.2	Massachusetts	32.2	Massachusetts	49.2
Arizona	17.4	Arizona	21.1	Maryland	31.6	Alaska	46.0
South Carolina	17.2	Maryland	20.9	Maine	31.4	New Hampshire	45.1
New Hampshire	17.1	Hawaii	20.8	Alaska	31.1	California	43.7
Rhode Island	16.6	Rhode Island	20.8	Dist. of Col.	30.7	Vermont	42.9
Vermont	16.5	New York	20.7	California	30.7	New Jersey	42.9
Natural gas		**Oil**		**LPQ**		**Electricity**	
Wyoming	8.8	Oregon	18.7	Iowa	19.6	Idaho	19.3
Alaska	8.9	Georgia	18.7	North Dakota	19.8	West Virginia	20.4
Colorado	9.0	North Carolina	18.8	Nebraska	19.9	Washington	22.0
North Dakota	9.0	Alaska	18.8	South Dakota	20.0	North Dakota	22.2
Utah	9.2	Virginia	18.9	Kansas	21.3	Kentucky	22.3
Montana	10.1	New Hampshire	18.9	Montana	21.4	Nebraska	23.0
South Dakota	10.8	South Carolina	19.0	Missouri	21.5	Missouri	23.3
Illinois	11.0	Florida	19.1	Illinois	21.7	Wyoming	23.5
Michigan	11.2	Delaware	19.3	Wisconsin	21.8	Tennessee	23.8
Minnesota	11.3	Montana	19.3	Minnesota	22.1	South Dakota	24.5

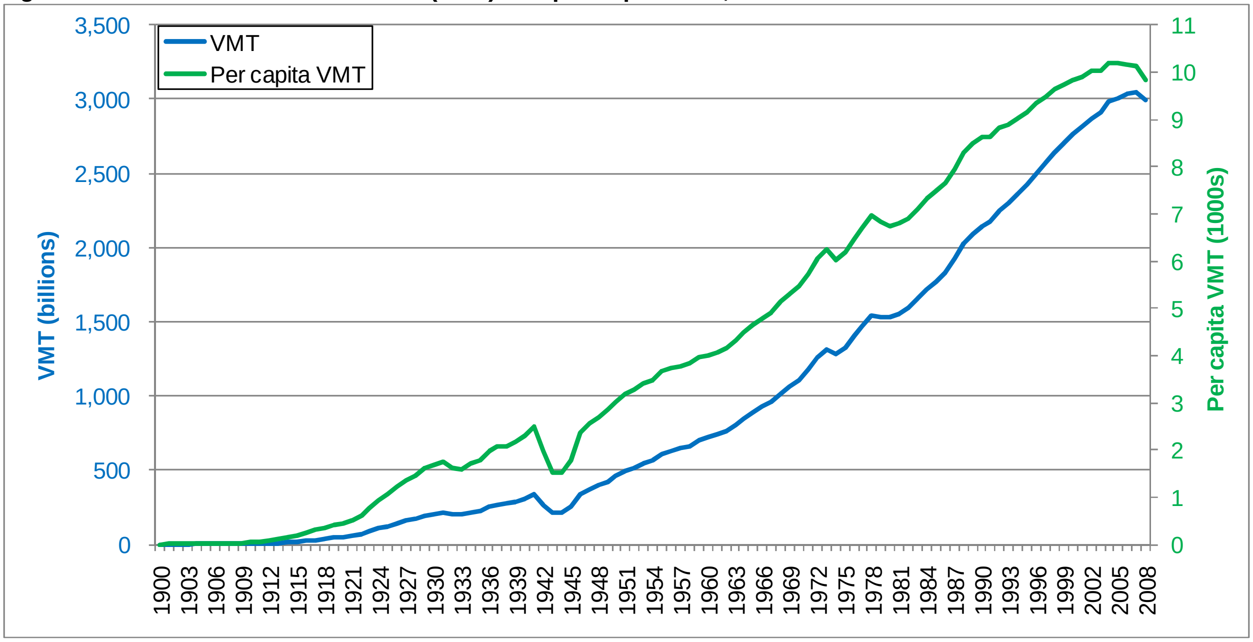
Source: U.S. Energy Information Administration (2009c). Prices reported in 2009 dollars. Conversion based on the historical CPI-U, Bureau of Labor Statistics (2010).

Demand for heating and cooking fuels is inelastic – in part, fuel use depends on the size of each family's home – a 3,000-square-foot house requires a lot more heating that 800 square-foot unit, and even without moving to a new home, investing in a new heating system can be very expensive (and is not an option for most renters). Fuel use per capita is determined by climate, and fuel choice is often determined by availability. Government incentives to subsidize insulation, other weatherization, and fuel-efficient heating equipment, and to improve access to lower-carbon-intensity fuels, are essential to help households reduce their emissions.

Transportation

U.S. transportation by households, industry, and government caused the release of 2.0 billion mT CO_2, 34 percent of total CO_2 emissions, in 2007.[56] Transportation's share of total CO_2 emissions ranges from 59 percent in Idaho to 11 percent in West Virginia. Average U.S. transportation fuel consumption was 562 gallons per capita in 2008.[57] U.S. average fuel economy for cars and light trucks was 13.1 miles per gallon (mpg) in 1975, reached a peak of 22 mpg in 1987 and has since fallen to 20.2 mpg in 2007.[58]

Figure 12: U.S. vehicle miles of travel (VMT) and per capita VMT, 1900-2008



Sources: Federal Highway Administration (2010), http://www.fhwa.dot.gov/policyinformation/statistics/2008/vmt421.cfm; population data from the U.S. Census Bureau, http://www.census.gov/population/www/censusdata/files/table-2.pdf for 1900 to 1990, the 2000 U.S. Census for 2000, and 2008 ACS for 2008; population for years in between these data were estimated based on a linear trend.

In part the decline in fuel efficiency is the result of an enormous shift in car sales toward trucks, SUVs, and large minivans – from 19 percent of cars and light truck sales in 1975 to 49 percent in 2007. Average U.S. vehicle miles have grown from 1 mile per person per year in 1900 to 1,000 miles in 1925; 3,000 in 1950; 6,200 in 1975, and 9,800 today (see Figure 12).[59]

Wyoming has, by far, the highest annual per capita transportation fuel consumption, 1,311 gallons, while the District of Columbia has the lowest. Fuel consumption depends directly on vehicles' fuel efficiency and the number of miles traveled, and indirectly on population density and the availability and use of means of transportation other than private cars. In the United States, demand for gasoline has historically been very inelastic (Brons et al. 2008; Hughes et al. 2008),though responses to the OPEC oil price spikes of the 1970s included conservation measures such as car-pooling and an increase in average fuel efficiency.

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[56] U.S. Energy Information Administration (2010d). See Appendix C for additional state transportation data.
[57] Federal Highway Administration (2009b).
[58] 2007 is the last year for which the EPA reports data (EPA 2007).
[59] Sources: Federal Highway Administration (2010); population data from the U.S. Census Bureau, http://www.census.gov/population/www/censusdata/files/table-2.pdf for 1900 to 1990, the 2000 U.S. Census for 2000, and 2008 ACS for 2008; population for years in between these data were estimated based on a linear trend.

Table 20: States with highest and lowest transportation fuel consumption, 2008 (gallons per capita)

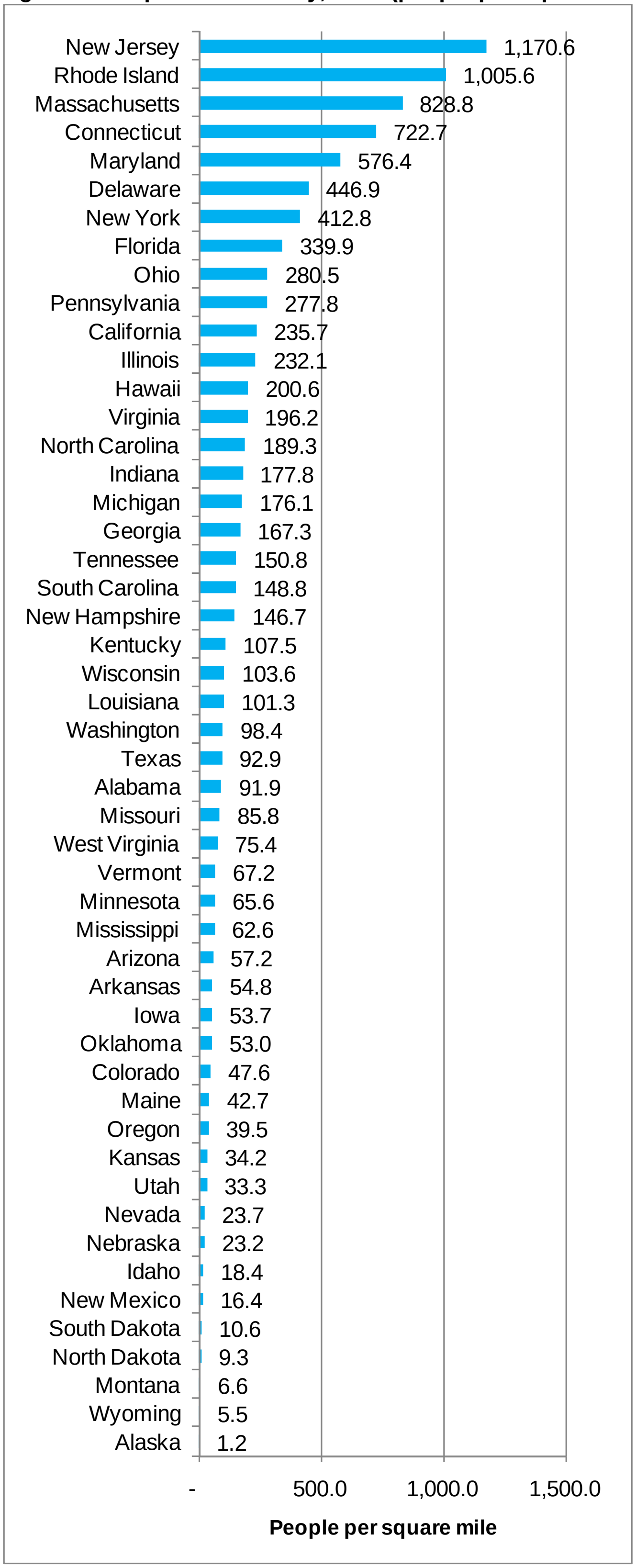
Highest per capita		Lowest per capita	
Wyoming	1,311	Dist. Columbia	215
North Dakota	835	New York	354
Mississippi	754	Hawaii	377
South Dakota	748	Rhode Island	431
Alaska	738	Massachusetts	483
Montana	736	California	483
Oklahoma	733	Illinois	489
Iowa	717	Washington	493
South Carolina	709	Connecticut	502
Alabama	705	Pennsylvania	509

Sources: Federal Highway Administration (2009b) and ACS 2008.

One important factor contributing to inelasticity in demand for gasoline is population density. Overall, U.S. population density is 86 people per square mile, but state density ranges from 1 person per mile in Alaska to 1,171 in New Jersey and 9,639 in the District of Columbia (see Figure 13).[60] Population density gives a basic measure of how close together people live and how far it is necessary to travel to get to work, school, and shopping. In states where people are more spread out, it is difficult for consumers to respond to gasoline price increases by driving less. Policies to change local population densities are, of necessity, long-term in nature: reducing transportation needs with policies designed to combat urban sprawl, or improving alternative transportation with trains or bike trails. Households' desire to use less gasoline today can be thwarted by a lack of foresight in public expenditures.

[60] U.S. Census Bureau (ND; 2009).

Figure 13: Population density, 2008 (people per square mile)



Sources: U.S. Census Bureau (ND; 2009).

Only 5.0 percent of the U.S. working population commutes via public transportation (excluding taxis); another 2.8 percent walk, and 0.6 percent bike.[61] In the District of Columbia, half of all workers take public transportation, walk or bike (see Table 21). In New York State, it is just over one-third. But in many states, those using alternative transportation are just a small share of the workforce. Population density does not explain all of this variation. In Alaska, the least dense state, a high proportion of people living close together in small settlements gives it the second-highest share of people walking to work. Community planning and the availability of public transportation, and safe walking and bike routes, have an important role to play.

Table 21: Workers travelling via public transportation, biking, or walking, 2008

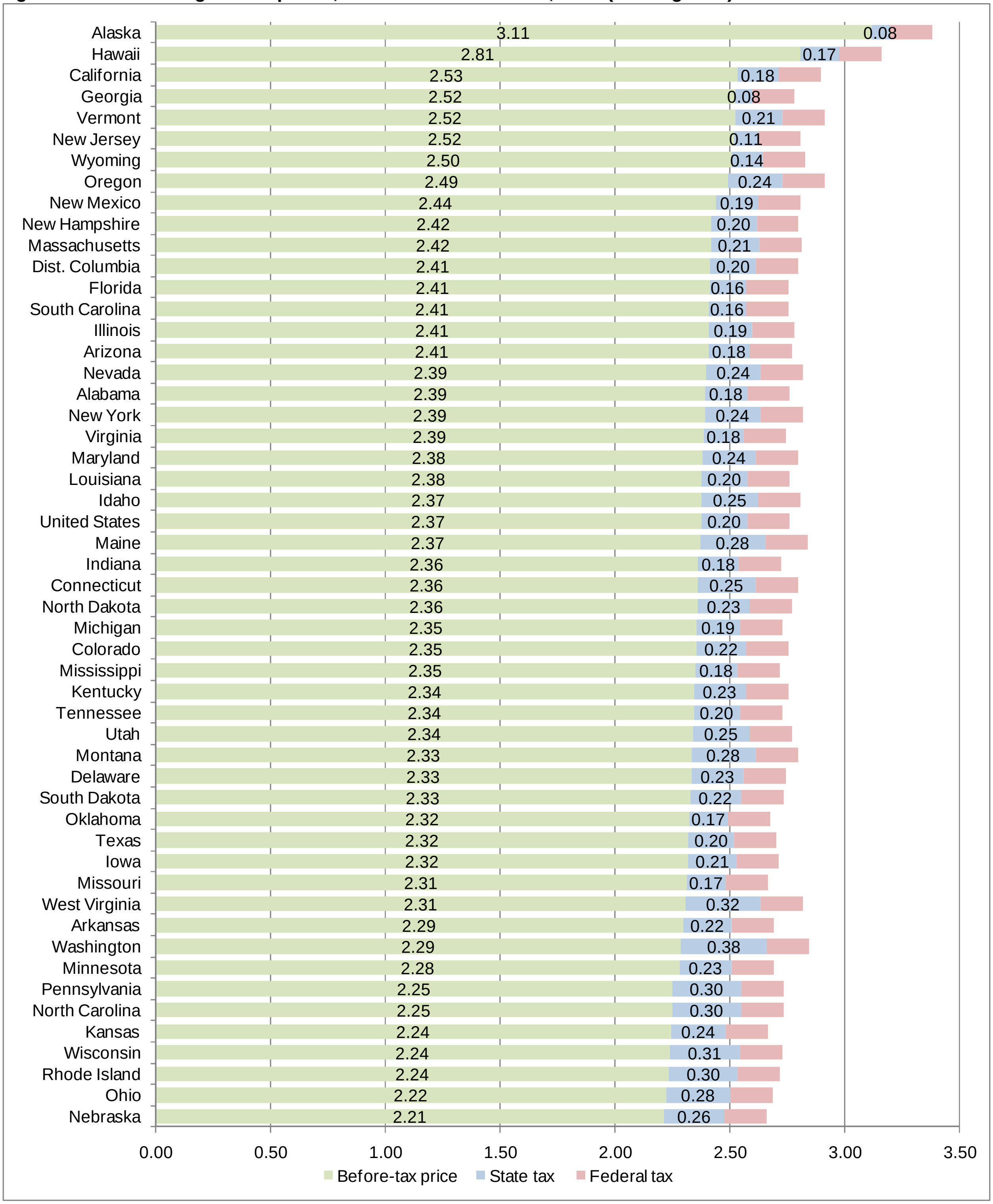
Public transportation, highest share		Bike or walk, highest share		Public transportation, lowest share		Bike or walk, lowest share	
Dist. Columbia	35.7%	Dist. Columbia	14.4%	Mississippi	0.36%	Alabama	1.39%
New York	26.7%	Alaska	8.0%	Oklahoma	0.40%	Tennessee	1.54%
New Jersey	10.3%	Vermont	7.0%	Arkansas	0.43%	Georgia	1.67%
Massachusetts	8.9%	Montana	6.9%	Kansas	0.51%	North Carolina	1.96%
Illinois	8.7%	New York	6.8%	Alabama	0.52%	Mississippi	1.98%
Maryland	8.5%	Oregon	6.0%	South Dakota	0.54%	Texas	1.99%
Hawaii	5.9%	Massachusetts	5.3%	North Dakota	0.63%	South Carolina	2.07%
Washington	5.5%	Hawaii	5.2%	South Carolina	0.69%	Florida	2.12%
Pennsylvania	5.3%	South Dakota	5.2%	Nebraska	0.72%	Arkansas	2.17%
California	5.3%	Wyoming	4.9%	Maine	0.73%	Missouri	2.22%

Source: U.S. Census Bureau (2009).

A final factor differentiating states is their gasoline prices. In 2009, the average price of gasoline was $1.89 per gallon, with a low of $1.76 in Arkansas and a high of $2.61 in Alaska.[62] Over the past 25 years, with few exceptions, state gasoline prices stay in the same rank ordering even as the whole set of prices experiences swings up and down: Alaska, the District of Columbia, and Hawaii have the highest prices; Arkansas, Kansas, and Tennessee have the lowest. Hawaii and the District of Columbia have some of the lowest fuel use per capita, but Alaska has one of the highest: Low population density makes gasoline demand more inelastic, so that even with such high prices (and a relatively low average income), Alaskans still consume a great deal of transportation fuel.[63]

[61] U.S. Census Bureau (2009).
[62] U.S. Energy Information Administration (2009d), http://tonto.eia.doe.gov/dnav/pet/pet_pri_allmg_a_EPM0_PTA_cpgal_a.htm, and CPI-U (Bureau of Labor Statistics 2010). EIA did not report a 2009 gasoline price for the District of Columbia. Its 2008 price was $2.80 per gallon.
[63] U.S. Energy Information Administration (2009d) and CPI-U (Bureau of Labor Statistics 2010).

Figure 14: Before-tax gasoline prices, state and federal taxes, 2008 (2008$/gallon)



Sources: U.S. Energy Information Administration (2009d), Federal Highway Administration (2009a; 2009c) Prices are in 2008 dollars to preserve relationship to taxes.

Gasoline taxes explain neither the difference in gasoline prices among states nor the difference in states' gasoline consumption per capita. Some of the states with the highest gasoline taxes have both high gasoline prices and high fuel consumption (see Figure 14 above). Alaska has the lowest state gasoline tax, $0.08 per gallon, and Washington has the highest, $0.375 per gallon; in addition, there is a $0.184 per gallon federal tax that applies in all states. Overall, the before-tax span in gasoline prices across states – $0.897 – is three times larger than the span in state gasoline taxes.

When a carbon price is placed on highly inelastic, high-emissions-intensity products like gasoline, there is little change in the consumption of those products, so something else must give. This could mean reduced consumption of other goods and services to stay within the household budget, or spending out of savings or on credit. Government policies to make public transportation and fuel-efficient vehicles more affordable can make demand for gasoline more elastic, and soften these economic impacts.

V. Conclusions and Policy Recommendations

Our model tracks the CO_2 emissions resulting from all categories of consumer spending, and estimates the impacts of a carbon price on those emissions. Nonetheless, when it comes to understanding interstate differences in the impacts of a carbon price and dividend, it's all about electricity — and almost all about the use of coal to generate electricity.

Based on these model results, in round numbers, the U.S. totals for household emissions, prior to a carbon price, are approximately 30 percent from electricity, 25 percent from gasoline, and 45 percent from everything else. Of these three categories, electricity emissions are by far the most variable from state to state. Interstate variations in other categories play a minor role by comparison. (In addition, emissions from electricity make up a large share of the household emissions from the purchase of goods and services. Unlike direct electricity emissions, the carbon intensity of goods and services does not decrease with green investments and higher long-run price elasticities in our model. This omission tends to dampen overall emission reductions and, therefore, leads us to estimate the need for higher carbon prices to achieve any given emission reduction.)

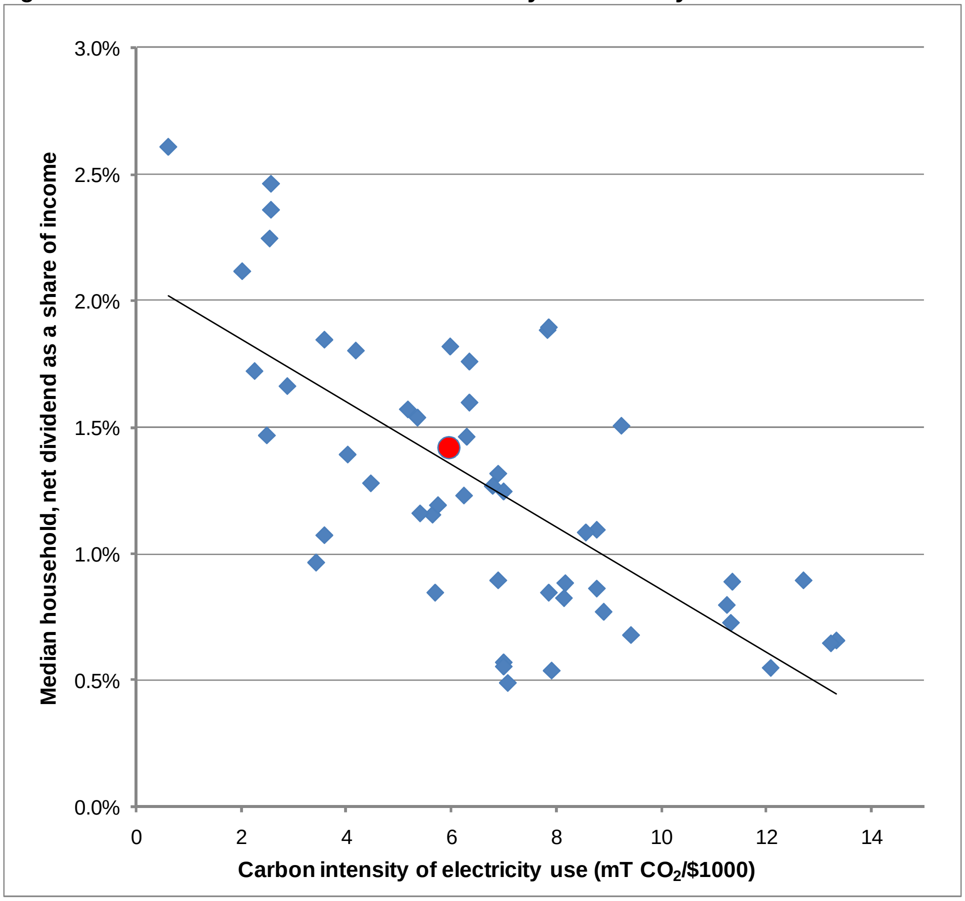
Ground transportation uses the same technology everywhere in the country (aside from the limited areas where public transportation is important). Gasoline emissions differ because states with low population density and limited urban development have greater transportation needs than high-density urban states. At the high and low ends of the national spectrum, Wyoming has six times the per capita transportation emissions of the District of Columbia. The second-highest state, North Dakota, has less than 2.5 times the per capita transportation emissions of the second-lowest, New York (see Table 20). Per capita transportation emissions in most states differ by 2 to 1 or less.

The indirect emissions caused by purchases of food, other non-energy goods, and services are even more uniform across the country; the highest-emitting state has less than twice the per capita emissions of the lowest. This is not surprising: Food, clothing, health care, entertainment, and other non-energy goods and services are produced with the same technology, and with similar carbon emissions, regardless of where they are consumed.

Electricity is different: It can be produced by burning coal, with the highest emissions intensity; by burning natural gas, with roughly half the emissions from coal; or by hydro-power, nuclear power, wind, or other renewable technologies, with no direct emissions. States differ widely in technology choices and carbon-intensity: At the extremes, electricity used in Wyoming has more than 24 times the carbon emissions per dollar of Vermont (see Table 16). The average intensity of the top ten states is five times the intensity of the lowest ten. (Other household fuel use also varies widely by state, driven in large part by local heating requirements, as seen in Table 17 — but the total emissions are small, and opportunities for changing fuels are limited, in comparison with electricity.)

As a result, the impacts of a carbon price and dividend on a state are closely related to the carbon intensity of electricity, as shown in Figure 15 (showing impacts for our 2020 scenario; the large round dot is the national average). The lower the carbon intensity of the state's electricity, the better the state's households will fare under this carbon policy.

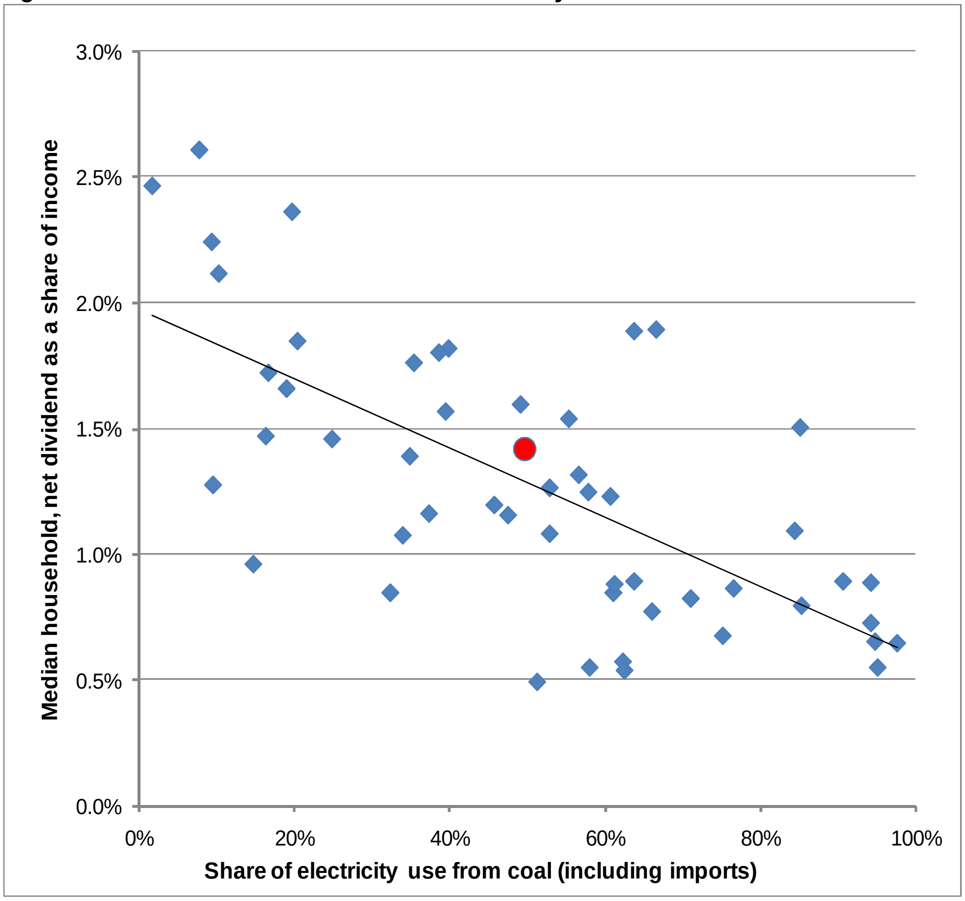
Figure 15: Net dividend versus carbon intensity of electricity use



Sources: Authors' calculations.

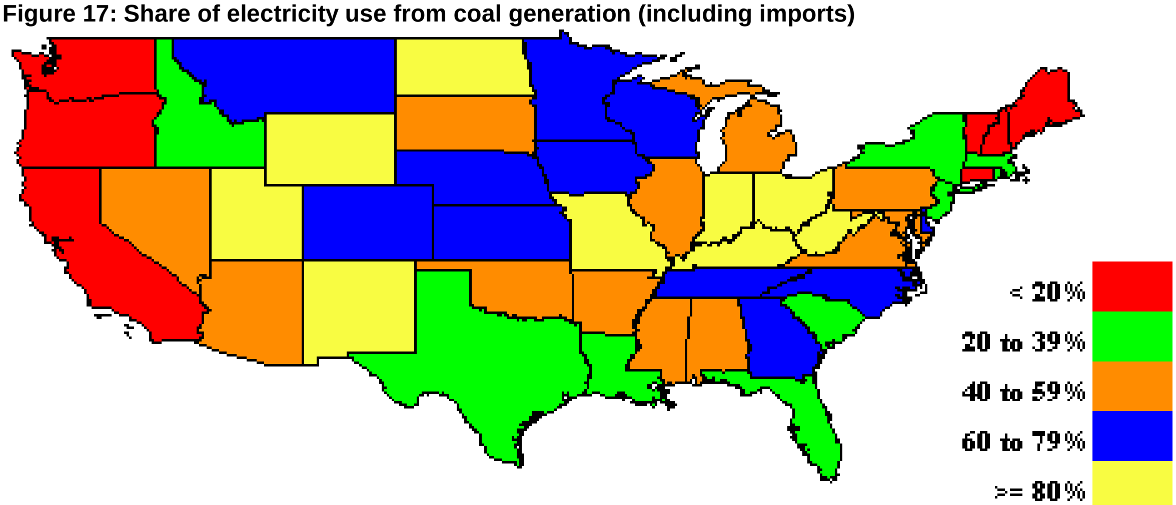
While other factors also affect the carbon intensity of electricity, the share of electricity from coal is the most important factor, as shown in Figure 16 (again for our 2020 scenario). The more coal your state uses, the smaller your dividend will be. In terms of reducing emissions in the short run, and prospering under a dividend system, nothing is as important as reducing the use of coal-burning electricity, regardless of whether a state generates it in state, or buys it from a neighboring state.

Figure 16: Net dividend versus share of electricity use from coal



Sources: Authors' calculations.

Figure 17: Share of electricity use from coal generation (including imports)



Note: Values rounded to the nearest whole percent. Share of electricity use from coal (including imports) is 9.5 percent for Alaska, 14.8 for Hawaii, and 62.4 for the District of Columbia.

Market Mechanisms Are Not Enough

The effects of a carbon price, as analyzed in our model, can do part of the job of reducing emissions – but price signals alone, at the levels contemplated in recent legislative proposals, won't reach targets such as a 20 percent drop in emissions by 2020. Additional policies are needed to complement market mechanisms and to accelerate the shift away from coal.

While our model assumptions about utilities choosing low-carbon generation among existing plants and the scale of effective investment in energy efficiency are at the high end of a realistic range, our assumptions regarding the change in price elasticity over time omit a key factor – the variation in price elasticities among states. Households in states that have already invested in (or have well-developed plans to invest in) energy efficiency, alternative transportation, and retiring coal plants by building natural gas and renewable electricity generation will have much better opportunities to substitute low-carbon-intensity electricity, fuels, and other products for high-carbon-intensity ones. This ease of substitution will tend to lower carbon costs below those estimated in our model.

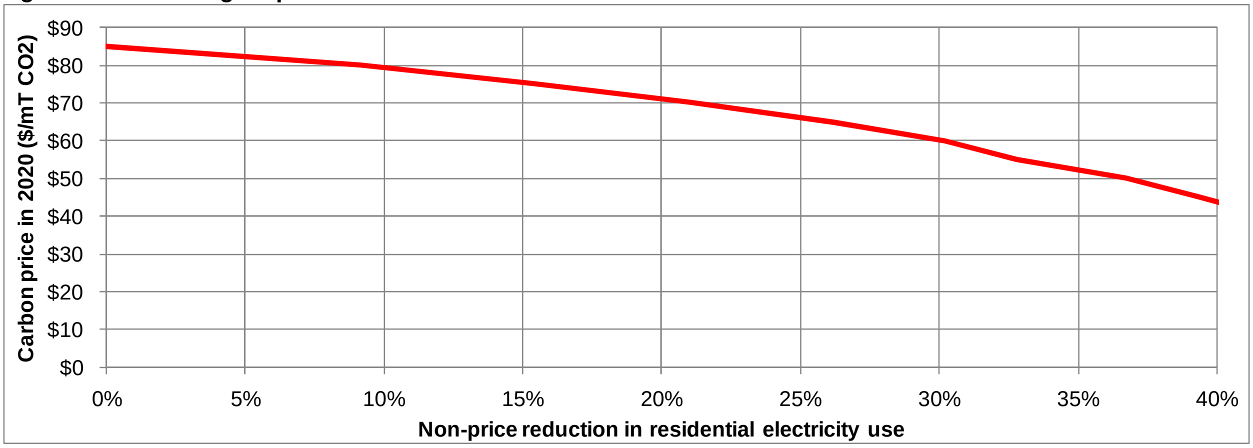
Some states lag behind in implementing these measures, but all states can move towards a green economy while creating jobs and lowering their households' impacts from climate policy. Indeed, states that have yet to make significant investments in energy efficiency and alternatives may see the biggest difference in their short and long-run price elasticities for electricity and fuels: As these states embrace green investment, they are likely to find measures that are "low-hanging fruit," or easy, low- and even no-cost measures that can make a big difference in reducing greenhouse gas emissions.

In the long run, a price on carbon provides an incentive for investment in new, low-carbon sources of electricity generation, such as wind power and other renewables. But by 2015 or even 2020, most of the electricity used in the United States will be produced by plants that exist today. With the existing power plants in place, the adoption of a price on carbon emissions has two effects on electricity supply and demand: It causes reductions in consumer purchases of electricity, and it leads utilities, or power pools, to make more intensive use of existing sources of low-carbon power. Neither of these is a large effect, because in the short run neither producers nor consumers are sufficiently sensitive to price changes.

Our model includes one additional mechanism beyond price impacts: the adoption of efficiency measures, which are assumed to reduce U.S. average residential electricity consumption by 5.8 percent in 2015, and 15.4 percent by 2020. Without any efficiency measures, achieving a 20-percent reduction in overall emissions by 2020 would require a carbon price of \$85/mT CO_2, rather than the \$75 in our 2020 scenario shown above.[64] There is a trade-off between the required carbon price and the non-price reductions in emissions (which could be achieved by efficiency measures, or by the introduction of new wind power or other renewable energy), as shown in Figure 18. To stay within the price bands prescribed in recent legislative proposals, with upper limits at \$32 to \$41/mT CO_2, non-price measures would have to reduce electricity emissions by more than 42 percent – almost triple the amount assumed in our \$75/mT CO_2 in 2020 scenario.

[64] Calculations in this paragraph are based on additional runs of the same model (not shown in this report).

Figure 18: Achieving 20-percent reduction from 2005 emissions in 2020



Sources: Authors' calculations.

In short, getting to the target of a 20-percent reduction in emissions by 2020 requires either a carbon price roughly twice as high as the proposed upper limits, if the job is to be done by price incentives alone – or vigorous adoption of non-price measures, such as efficiency and much-expanded renewable energy. Recent analyses of the U.S. electricity system have found that it is possible to achieve rapid reduction in emissions at a modest cost (Keith et al. 2010); our $75/mT CO_2 in 2020 scenario does not represent the limits of what is possible. It is clear, however, that the problem requires a concerted attack on all fronts, combining price incentives and non-price programs to reduce emissions.

Nuclear Power: Too Clean to Meter?

If carbon emissions from energy production are the problem, is nuclear power the solution? After all, nuclear reactors split uranium atoms to generate heat; no fossil fuels are used on site, and no CO_2 is released into the air from the power plant itself. Plenty of voices can be now heard advocating construction of nuclear plants in order to save the environment. The Obama administration supports new loans and incentives for nuclear power, as does the Kerry-Lieberman climate and energy bill.[65]

It's not quite that simple. The nuclear power life cycle includes many steps, from mining and enriching uranium, building the reactor, operating the plant, processing and disposing of the spent fuel, through, someday, decommissioning the plant when it can no longer be used. Many of these stages are quite energy-intensive, so there are life-cycle greenhouse gas emissions from nuclear power. The best available data show the life-cycle emissions from nuclear power to be much lower than from fossil fuel-burning power plants, but equal to or higher than the emissions from renewable energy, such as solar, wind, and hydro-power.

A comprehensive literature review screened the available studies on greenhouse gas emissions from nuclear power, identifying 19 studies that met several criteria for reliability (Sovacool 2008). Table

[65] Waxman-Markey is noticeably silent on nuclear power, but an EPA analysis identified it as a key source of clean energy under Waxman-Markey and envisioned a substantial increase in nuclear generation capacity (EPA 2009b).

22 shows the average carbon emissions across these studies for the five major stages of the nuclear life cycle, in kilograms of CO_2-equivalent (CO_2-e) per megawatt-hour (MWh).[66]

Table 22: Carbon emissions for five major stages of the nuclear life cycle

kg CO_2-e/KWh	Stage	Description
25	Front end	Mining, milling, conversion, enrichment, fabrication ,and transportation of uranium
8	Construction	All material and energy inputs for building the facility
12	Operation	Energy needed for maintenance and operation of facility
9	Back end	Spent fuel processing, conditioning, storage, and disposal
12	Decommissioning	Deconstruction of facility, land reclamation at reactor and mines
66	**Total, all stages**	

Source: Sovacool (2008).

The same literature review reported estimates of life-cycle emissions from renewable electricity generation ranging from 9 to 41 kg CO_2-e per MWh, with wind and hydropower at 9 to10, and photovoltaics at 32. Fossil fuel-burning plants, in contrast, ranged from about 440 kg CO_2-e per MWh for natural gas combined cycle turbines, up to 1,050 for some coal plants. Thus nuclear power has much lower life-cycle greenhouse gas emissions than fossil fuels, but higher than leading renewable technologies.

There are a number of uncertainties in estimating emissions from the nuclear fuel cycle. The quality of uranium ore makes a big difference; mining and processing ore with lower concentrations of uranium uses more energy per MWh of electricity. The choice of enrichment technology is also important; much of the world uses gas centrifuges, which require much less energy than the gas diffusion technology used in the United States. Finally, the end of the nuclear life cycle, encompassing the disposal of spent fuel and other radioactive waste, along with decommissioning of retired reactors (parts of which are by then radioactive), remains a subject of guesswork, with the siting, design, and construction of a final waste repository still an unsolved problem.

With all this in mind, how does nuclear power measure up to the alternatives? On grounds of greenhouse gas emissions alone, nuclear power looks like a big improvement over fossil fuels, with about 15 percent of the emissions (per MWh) of efficient natural gas-burning plants. On the other hand, wind and hydro-power have about 15 percent of the emissions of nuclear plants; photovoltaics may have half the emissions of nuclear power.[67]

Meanwhile, there are a host of other questions about nuclear power, which would have to be answered if it were to become a bigger part of our energy system. The safety concerns, from the era of the Three Mile Island and Chernobyl accidents, may be the least of the current problems; improvements in U.S. reactor operations have led to fewer outages and more reliable performance in recent years. Reactors remain staggeringly complex systems, in which the myriad possible pathways

[66] CO_2-equivalent is a measure of all greenhouse gases given in terms of their impact on climate change; all greenhouse gases are scaled to their equivalence in CO_2 terms. Not all 19 studies made estimates for all stages; these are the unweighted averages for all studies that included the stage in question.
[67] Another study estimates that under typical U.S. conditions, nuclear power and photovoltaics currently have similar emissions per MWh, but notes reasons to expect future reductions in photovoltaic life-cycle emissions (Fthenakis and Kim 2007).

to failure cannot all be anticipated and planned for in advance, but for now, they appear to be under control. New reactor designs may allow for safer operations in future plants.

Safety, however, is not cheap; the price of making a reactor reasonably safe drove construction costs far up into the billions of dollars, bankrupting some of the original investors and raising the price of electricity from nuclear plants. It is vitally important to avoid the temptation to make nuclear power more affordable by cutting corners on safety — as the recent Deepwater Horizon oil rig explosion in the Gulf of Mexico has amply demonstrated, expensive environmental and safety regulations are adopted for very good reasons.

Nuclear power plants are also thirsty: Huge volumes of cooling water are required to keep temperatures under control. Heat waves and droughts have forced cutbacks in nuclear power production, in both the United States and Europe, in recent years. All thermal power plants, whether fossil fuel-burning or nuclear, require cooling water, but nuclear power requires the most of all. According to a U.S. Department of Energy study, nuclear plants with closed-loop cooling (recycling water within the plant instead of using it once and then returning it to its source) consume 720 gallons of water per MWh of net power produced; the comparable figures are 310 to 520 gallons per MWh for several types of coal plants, and 190 gallons per MWh for natural gas combined-cycle plants.[68]

Investing in a technology that needs a lot of cooling water seems less than ideal in a world in which climate change is making many areas hotter and drier. The hottest days of the summer are the times of peak electricity demand, when every air conditioner is turned on — not a time when major power plants should be going off-line.

Finally, the nuclear waste problem won't go away. The federal government has promised to build a permanent disposal site, but has failed to do so; as a result, ever-growing numbers of spent fuel rods are being stored in ponds near nuclear reactors around the country. Some of the wastes produced by nuclear power will be dangerous for thousands, if not tens of thousands, of years — an environmental hazard that is even longer-lived than the climate crisis. Until this problem is solved, and the cost of the solution is known, nuclear power can't be a dependable answer to our energy needs today.

Another Way To Achieve Equity

Household carbon costs differ greatly from state to state, and even after receiving part of the climate policy revenues as a rebate, net dividends are still negative for a small percentage of households. When we modeled 75 or 80 percent of revenues returned to all households on an equal per capita basis, we found that the median household in several states had a net loss. For this reason, in the scenarios discussed above, we offer the policy prescription of 85 percent of revenues rebated to households on an equal per capita basis. This plan emphasizes the need for directing a large share of revenues back to households.

But this is not the only way to achieve the objective of reducing net impacts to most households while simultaneously lowering greenhouse gas emissions and preventing climate change. In our model, the states with the biggest losses or smallest gains from climate policy share two qualities:

[68] Gerdes and Nichols (2008, rev. 2009).

They have made little progress to date in energy efficiency and building alternative transportation networks, and they consume electricity generated almost exclusively from coal.

The greater households' price elasticity for electricity, gasoline, and household fuels, the smaller their economic impacts from a carbon price, but households' purchasing decisions can only take them so far. The set of available choices is just as important as the decisions that they make, and public policy has a big role to play in easing households' transition to energy conservation, and in making available alternative transportation and low-carbon-intensity electricity. States that have not yet begun to invest in the green economy have a lot catching up to do, but may also have a lot of low- and no-cost energy efficiency measures still at their disposal.

Use of electricity generated from coal is, by far, the most important factor determining households' carbon costs. Building lower-carbon-intensity natural gas and renewable-power generation, and retiring coal plants, is essential to reducing impacts for the states with the highest costs from climate policy. In 2007, coal miners represented 0.05 percent (i.e., 5/100^{ths} of 1 percent) of the U.S. labor force; they were a larger, though still small, share of the labor force in the three states with the highest carbon costs in our model: 0.3 percent in North Dakota, 0.2 percent in Kentucky, and 2.2 percent in Wyoming.[69] As the occupation that is most directly affected by climate policy, coal miners have a uniquely strong claim to compensation – either alternative, good jobs, or adequately funded retirement. Since there are relatively few coal miners nationwide, this will not be an overwhelming burden on the economy; much of it can be included in plans for green jobs and investment in energy efficiency (which, in our model, is targeted to the coal-intensive states).

A recent study from Synapse Energy Economics found that coal could be entirely phased out of U.S. electricity generation by 2050, and nuclear power cut back by 30 percent at the same time, through a combination of efficiency measures and large-scale investment in wind power and other renewables (Keith et al. 2010). The Synapse scenario reduces electricity sector CO_2 emissions by 83 percent below 2005 levels by 2050, similar to the goals for that year in recent legislative proposals.[70] By 2020, Synapse's scenario costs $9.6 billion more than business as usual – less than our assumed spending on efficiency – and reduces emissions by about 20 percent. While costing moderate amounts in the early years, the scenario saves money for the country as a whole in 2040, with rapidly growing savings thereafter. Of course, such a transition away from coal would eliminate the economic burden of carbon costs on coal-dependent states, as well as taking a giant step toward protecting the climate.

The costs of a climate policy will be unequal across U.S. states. Because some states have far higher per capita greenhouse gas emissions than others, this inequality is necessary to make price incentives work and emission reductions succeed. This is why carbon pricing must be paired with other policy measures to ensure that all households receive the help they need to prevent emissions reductions from being a burden. Rebates from tax or permit revenue, or measures like reducing payroll taxes or increasing the EITC, make climate policy a net benefit for most households. States using a high share of electricity generated from coal, and states that have a lot of untapped potential for energy efficiency improvements, will need the most help; we recommend that a significant share of climate policy revenues be targeted toward these states. Eliminating coal generation and

[69] U.S. Census Bureau (2003; 2008a) and Bureau of Labor Statistics (2003).
[70] This electricity sector reduction may not be enough to achieve a similar overall reduction in U.S. emissions, since it is more difficult to reduce emissions in other sectors, such as transportation.

improving energy efficiency will mean new green jobs in every state, and great strides toward the cutting-edge low-carbon-intensity economy of the future.