Carbon Costs:
How a $15/ton CO2 cost could raise household electricity bills

By

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Abstract: *Climate change legislation is expected to raise the short-term cost of coal and natural gas used to generate electricity as well as raise the price of petroleum for transportation. Several recent studies have predicted climate change policies will produce a net economic gain over time through increased energy efficiency and new jobs created. Even so, policymakers are concerned about the immediate impact on consumers of such legislation. This paper estimates an added cost of $15/ton of carbon dioxide equivalent (CO2) carbon cap to average 2005 annual residential household electricity bills in U.S. states. Applying the MIT EPPA model to each state's 2005 coal and natural gas consumption, the authors find that a $15/ton CO2 cost leads average household electricity bills to increase by about 15%, but coal-rich states of North Dakota, Wyoming, and West Virginia see increases of 65-105%, while the average bills in the low-coal use states of Maine, Vermont, and Hawaii increase by 1% or less. The average household's annual electricity bills were found to rise by about 12% rise due to coal prices, and by about 3% due to an increase in natural gas prices. States with higher poverty rates were generally found to experience an above average rise in their average electricity bills, showing the potential for regressive impacts of electricity price increases in the absence of a compensating policy. Important factors in variability included the composition of each state's electricity mix, electricity price, and per capita electricity consumption.*

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I. Introduction

Opponents of climate change laws and treaties often cite potentially high economic costs. The Byrd-Hagel Resolution, passed by the US Senate in 1997, stated that the Senate would refuse to ratify the Kyoto Protocol or any international agreement that would " would result in serious harm to the economy of the United States," in part, because, "the level of required emission reductions could result in serious harm to the United States economy, including significant job loss, trade disadvantages, increased energy and consumer costs." More recently, on June 6, 2008, the U.S. Senate was unable to move past a filibuster to the Climate Security Act, also called the Lieberman-Warner bill. The main argument used by critics of the bill was that the economic costs would be too high. An outspoken opponent of climate change laws, Oklahoma Senator James Inhofe, was quoted in Time Magazine as saying, "Any action should not raise the cost of gasoline or energy to American families."

Most experts agree that the transition to cleaner fuels and electricity will most likely cause prices to rise in the short term. In the longer term, economies are expected to adapt and industries to change to accommodate higher energy prices. Many studies predict climate policies to result in new energy efficiency, technologies, and jobs, possibly producing a net gain to the economy, even before considering the benefits of avoided climatic disruption. Even so, reducing the uncertainty around the potential costs of climate policy could address concerns of opponents, and provide ideas for mitigating those costs.

This paper seeks to fill a niche in the climate policy literature by conducting a state-level, rather than national or multi-state, analysis of costs to household electricity bills. Previous work on the potential costs of climate policies generally use national or multi-state data to derive average costs for federal policies. In the absence of federal action on climate change, many states have begun to implement climate policies, with California and the northeastern states as leaders. The approach using national or multi-state regional data masks state-level heterogeneity. States vary in the composition of their electricity mix, their electricity market structure, and electricity pricing. This analysis lays the groundwork for future research at the utility level, since there are disparities between utilities within states as well.

This analysis may be helpful in designing an equitable carbon market system by predicting which consumers will be most affected by price increases from a carbon cap. An estimate of how much the average household spends on electricity in each state, and how much those prices could increase with carbon costs may help regional carbon capping systems determine how to apportion a carbon budget between states. The average household electricity price impacts as calculated in this paper may prove to be an important factor in comparing each state's baseline and future carbon budgets, and may be combined with other factors such as population and projected growth, industrial composition of the state, and other economic attributes.

The electricity sector is a major source of greenhouse gas emissions, and the primary target for emission reductions in many proposed greenhouse gas laws. Coal is the one of the most carbon intensive inputs to the economy. It is also the cheapest source of conventional electrical power. Coal comprises about 50% of US electricity supply. According to Green (2007), the carbon content of coal per energy unit is 1.9 Mt CO2/unit compared to .432 for crude oil, .054 for natural gas, and .009 for gasoline. The imposition of a carbon price is predicted to have the first and greatest impact on coal, due to its carbon intensity. The lower carbon intensity of natural gas is predicted to create price incentives for fuel substitution from coal to natural gas for electricity generation (Green 2007: Tables 1 and 2). This paper estimates the cost impact on the average consumer by state of a $15/ton carbon price affecting electricity generated by coal and natural gas, and compares the incidence of electricity prices on the average consumer by state using 2005 data.

Part II below provides background on electricity price regimes, and describes previous studies that looked at carbon price impacts at the national level. Part III describes the assumptions, methodology, results, and limitations of this study. Part IV lists policy implications for utilities and future studies that could expand on the findings presented here.

II. Electricity price increases resulting from climate policies

In traditional regulated state electricity systems, electricity is priced at the average cost. Pricing is determined by the cost-of-service of the regulated entity, which uses average costs (total costs divided by total sales). By contrast, electricity prices in deregulated markets is theoretically determined by the marginal costs, defined as the operations and maintenance (O&M) costs of the most expensive generating plant needed to supply the immediate demand for electricity. In competitive regions, electricity price is determined by the variable cost of the marginal generation facility.

By 2007, 17 states allowed "retail access" to their electricity grid. The EIA terms these deregulated states as "restructured."[3] Several states including California, Nevada, Montana, Arkansas, and Virginia had previously passed deregulating laws between 1998-2003, but had suspended retail access as of 2007.

States with no restructuring	States with restructuring
Alabama, Alaska, Arkansas, California, Colorado, Florida, Georgia, Hawaii, Idaho, Indiana, Iowa, Kansas, Kentucky, Louisiana, Minnesota, Mississippi, Missouri, Montana, Nebraska, Nevada, New Mexico, North Carolina, North Dakota, Oklahoma, South Carolina, South Dakota, Tennessee, Utah, Vermont,	Arizona, Connecticut, Delaware, Illinois, Maine, Maryland, Massachusetts, Michigan, New Hampshire, New Jersey, New York, Ohio, Oregon, Pennsylvania, Rhode Island, Texas, Virginia

[3] EIA Electricity Restructuring by State, http://www.eia.doe.gov/cneaf/electricity/page/restructuring/restructure_elect.html

Washington, West Virginia, Wisconsin, Wyoming	

Many electricity markets are moving away from state-owned, vertically integrated monopolies. Those markets are implementing regulatory changes to their pricing structure, and basing their electricity prices on factors such as performance goals rather than cost-of-service. Restructuring often entails separating the functions of generation, transmission, and retail, and creating new independent market monitors (P Joskow).[4] California's restructuring has created the Independent System Operator (ISO) to coordinate the state energy market.

Kammen (2008) notes that in practice electricity is priced through a combination of a firm's capital and operating costs, resource and equipment characteristics, and regulatory and financial constraints of firms. The major costs of traditional fossil fuel power plants are the cost of operating expenses of individual plant plus fuel cost. The cost structure for renewable energy power plants differs due to typically higher materials costs, but lower or non-existent fuel costs.

A common premise of studies of price impacts of climate policies, especially carbon taxes, is that the short-run burden of a carbon tax will be passed on to consumers (Bovenberg and Goulder, Hassett, Mathur, and Metcalf (2007), and Paltsev (2007)). Studies of potential carbon prices, such as a carbon tax, use either American tons or metric tonnes, and focus on either tons carbon (C) or tons carbon dioxide (CO2). In this paper, we will apply a $15/ton CO2 price. As noted by Metcalf (2007), a $15/ton CO2 tax may be converted to a $55/ton tax on carbon by multiplying by 44/12, the ratio in molecular weight between C and CO2.

The following studies all consider carbon prices in the range of $15/ton CO2:

Hassett, Mathur, and Metcalf (2007) considers the potential economic impact of a $15/ton carbon tax in three years: 1987, 1997, and 2003. They conclude that, assuming that the carbon tax is entirely passed forward to consumers, a $15/MMT CO2 carbon tax would raise consumer price of electricity 12.55% (equivalent to 1.78¢ per kilowatt hour) in 2003. The analysis of Hassett et al. concludes the amount of carbon tax paid varies little by region, and claims it is "distributionally neutral." However, the Consumer Expenditure Survey contains information on data by region, but does not collect data specific to states. We assume they compared the price impact of regions, not states.

Metcalf (2007) proposes a revenue neutral carbon tax paired with income tax deductions as an advantageous climate policy. He notes a major reason why economists promote a carbon tax as an efficient method of reducing emissions economy-wide: it equalizes the marginal costs of emissions abatement across disparate sectors of the economy. Also, he mentions that the price increases in gasoline resulting from a carbon price can induce

[4] Joskow, Paul. 2003. "Electricity Sector Restructuring and Competition: Lessons Learned," *Cuadernos de Economía (Latin American Journal of Economics)*, Instituto de Economía. Pontificia Universidad Católica de Chile., vol. 40(121), pages 548-558.

demand reductions. Assuming prices passed fully on to consumers, Metcalf predicts that the direct impact of $15/ton CO2 tax would result in an increase in gasoline prices by 13 cents per gallon, and an increase in natural gas price by 54 cents per thousand cubic feet. Metcalf does not specify the predicted impact on coal, but states that the average price of electricity would increase by 1.78 cents per kilowatt hour. He derives this number from the CO2 emission rate for a coal-fired power plant of 2,376 pounds per Mwh in 2004.

Green et al (2007) advocates for a carbon tax with an income tax reduction similar to Metcalf (2007), and prefers a tax over a cap and trade system. The authors use the results of a previous analysis by Bovenberg and Goulder (2000) to estimate price impacts of carbon tax. A $15 per ton CO2 tax would raise the price of coal-fired electricity by 1.63¢ per kilowatt-hour (kWh), or 20 per-cent at an average electricity price of 8.3¢ per kWh (Green). Their calculations show that a $10/ton carbon tax would increase price of coal by $18, and a $15/ton tax would raise gasoline prices 14 cents per gallon.

Paltsev et al (2007) conducts an economic analysis of bills introduced in Congress to limit GHG emissions. The paper discusses the Massachusetts Institute of Technology's (MIT) Emissions Prediction and Policy Analysis (EPPA) model. The paper begins by looking for a carbon tax rate that will achieve reductions equal to the stabilization targets of the bills being considered by Congress. Among the policies considered, one policy freezes the GHG emission level at 2008 levels. The EPPA model predicts this would generate a price of $18 per ton of CO2-e in 2015, and estimates that raising the price of $18/ton CO2 by 4% per year could achieve 550 ppmv by 2100. This policy option is appealing because it starts where we are today (2008), and achieves the reduction target through a relatively slowly escalating price signal. We do not advocate for this over a more aggressive emission reduction target, but rather wish to acknowledge the potential for political acceptability of this option.

Stavins (2007) also uses Paltsev's EPPA model, and calculates a carbon price of $18/ton in 2015 as a starting point for his analysis of a policy that he agrees is less aggressive but more politically feasible. Stavins utilizes Paltsev's EPPA model to derive prices for coal and natural gas using the same methodology as we do in Part III of this paper.

Burtraw (2008) gives Congressional testimony discussing electricity price changes at $15/ton. He derives a national average price of electricity of just over 8 cents/kwh, and estimates the price increase across eight regions. Burtraw finds that areas with the lowest current price have the highest percent of coal in their electricity mix, and therefore would see largest price increases. Those regions are KY, WV, and Western VA, followed by IN, and ND, SD, NE, and MN. After adding the additional price increase to each region's current prices, he concludes that even with the price increases, the regions with the lowest current prices would still have lower prices than elsewhere.

The academic literature on carbon taxes and regressivity notes that the degree of regressivity is significantly diminished when gasoline and electricity expenditures are divided by total expenditures, as opposed to annual income.[5] In the long run consumer

[5] Poterba (1991), Parry, Metcalf (1999) and others.

behavior does not change commensurately for sudden income shocks from job loss or personal economic upswings or downswings. For these reasons, most studies of the incidence of a carbon tax, starting with Poterba (1991), use lifetime expenditure, rather than income, as a more reliable indicator of longer-term consumer behavior. Unfortunately, the Consumer Expenditure Survey collects regional, but not state-level, expenditure data. This limits the potential for regressivity analysis below the regional level.

Table 1: Electricity and Gasoline Expenditures by Income Quintile

Quintile	Electricity	Gasoline	Income	Total Avg Expenditures	Electricity and gasoline expenditure as % of income	Electricity and gasoline expenditure as % of total expenditures
1	752	882	9676	19120	16.9%	8.5%
2	998	1485	25546	28921	9.7%	8.6%
3	1133	1997	42622	39098	7.3%	8%
4	1267	2518	67813	54354	5.6%	7%
5	1623	3182	147737	90469	3.3%	5.3%

Source: 2005 Bureau of Labor Statistics Consumer Expenditure Survey

Electricity and gasoline expenditures comprise a higher percentage of household wealth when measured as a percentage of income rather than as a percentage of total expenditures. For the lowest quintile, income is only about half of total average expenditure. One possible reason for this is that income in the lowest quintile may occur in the informal economy, and thus stated income is much less than expenditures. A second possible reason is that when people retire, their stated income usually drops, but their expenditures may not change as much if they are living off of savings or other assets. Total average expenditures are used as a proxy for lifetime household income.

III. Assumptions, methodologies, and results

Assumptions

For this study, we assume that a combination of climate policies leads to a $15/ton CO2 price that is added to the existing electricity price. We apply that price to each state's average electricity price in 2005 using MIT's EPPA model (Paltsev et al), focusing on the amount of coal consumed by residential customers in each state, and the amount of natural gas consumed in the electricity mix by residential customers.

The resulting increase in price represents a momentary, not dynamic, incidence on consumers. It is a policy snapshot, and does not account for changes made as a result of the price increase, or in anticipation of a carbon price. We recognize that utilities are predicted to respond to carbon prices through fuel switching from coal to natural gas, and increasing their mix of renewable energy. Consumer demand is expected to respond to price signals as well, but we do not include these actions in our results. Our data set focuses on the immediate price impact as a basis for comparison between consumers in states.

We chose $15/ ton CO2 as a carbon price for several reasons. As noted above, Paltev et al's EPPA model predicts $18/ton as a starting price in 2015 to freeze GHG emissions at 2008 levels. Burtraw's Congressional testimony refers to $15/ton CO2. Hassett et al and Metcalf use $15/ton CO2 in their analyses as well. In 2007 Senator Jeff Bingaman, Chairman of the Senate Energy & Natural Resources Committee, along with Senator Arlen Specter proposed a "safety valve" of $12/ton CO2 for a future national cap and trade system. Although higher and lower amounts appear in policy discussions, a $15/ton CO2 seems to be a reasonable number that is neither too high to appear unrealistic, nor too low to make a difference either economically or environmentally.

Methodologies and sources

We apply state-level electricity data from the US Department of Energy's Energy Information Agency (EIA) to a model developed by Paltsev et al's Emissions Prediction and Policy Analysis (EPPA) model of economic change to estimate the increase in electricity bills by state due to the imposition of a $15/ton price on CO2.

All EIA data is for 2005, using 2005 dollars, and included the statewide number of residential accounts, and the average annual household electricity bill. We used State Energy Profiles for the percentage coal and natural gas in their electricity mix. We used the residential consumption of natural gas. We multiplied the tonnage of coal in short tons by percent of residential customers. We consulted with the California Energy Commission for some data that was unavailable through EIA.

The chart below shows some of the variables in comparing states' energy use, electricity price, mix of coal, and population.

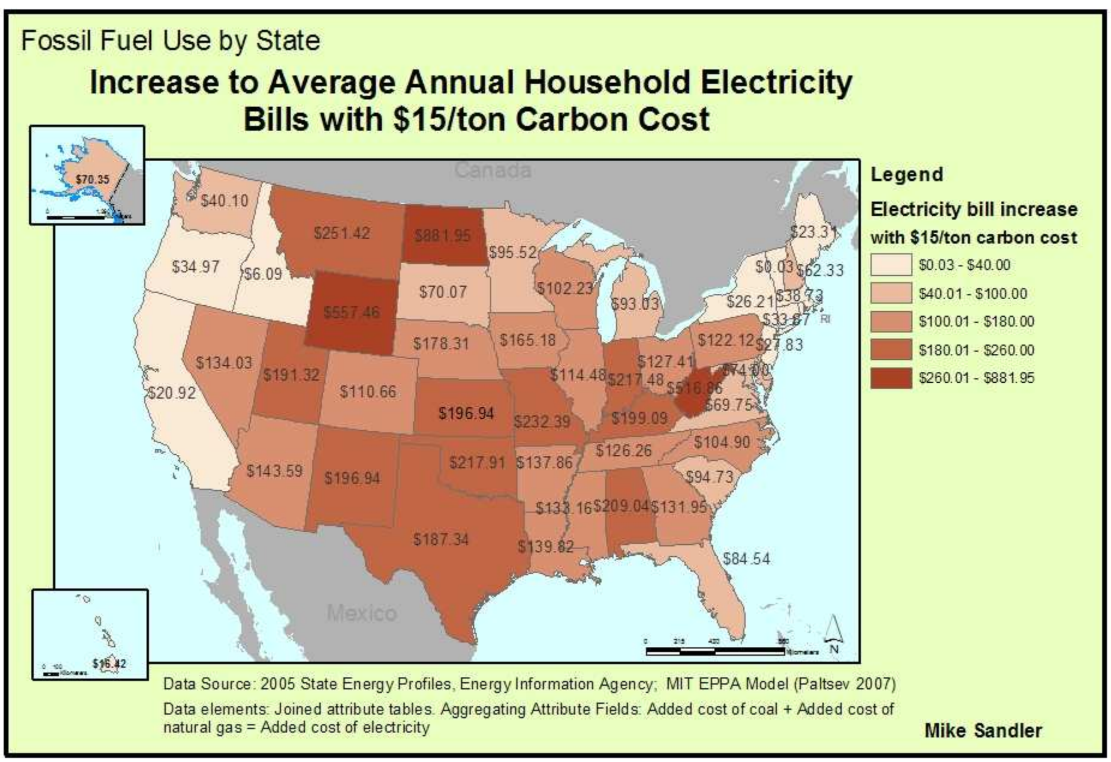
	U.S. Average by State	North Dakota	Hawaii	California	Pennsylvania
Annual electricity bill	1016	865	1658	858	1026
Annual electricity consumption per household (kwh)	11193	12376	8008	6859	10410
Average cost per kwh (cents)	9.49	6.99	20.7	12.51	9.86
Projected added costs to coal and natural gas to electricity bill	160.77	910	17.5	37.66	156.88
Million short tons of coal (residential)	7.52	8.89	0.711	2.25	19.9
Households	2,411,107	306,720	395,079	12,480,545	5,154,728

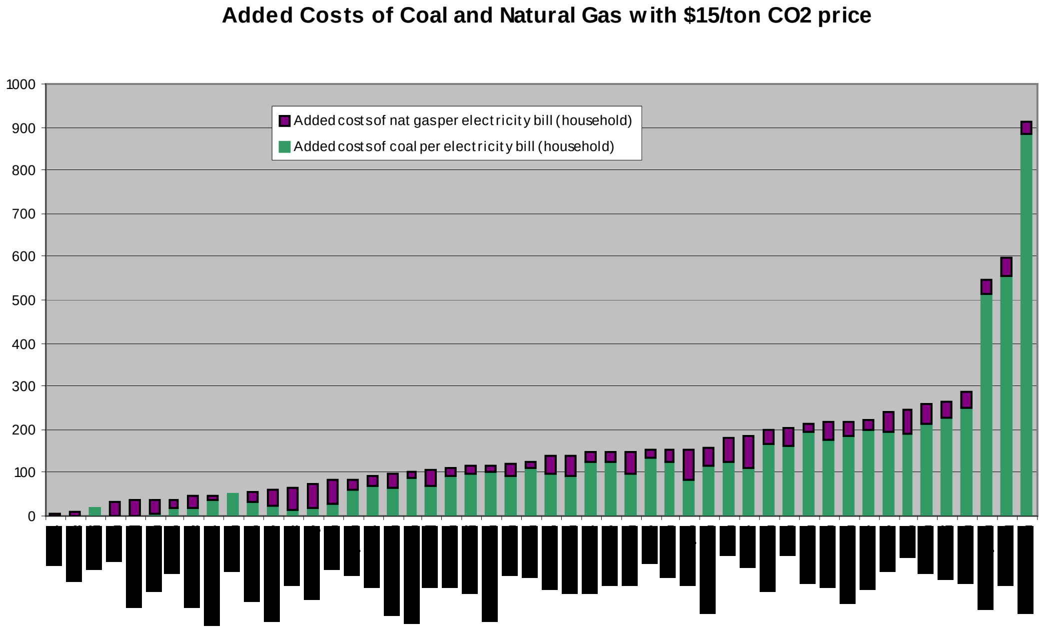
Paltsev's EPPA model uses a benchmark of $27/ton CO2e to derive an increased price per short ton of coal of $55.30/short ton for a total of $82/short ton. Following Paltsev's instructions on how to convert the benchmark to other carbon prices, the $15/ton is 55% of $27/short ton of coal benchmark, therefore we multiply .55 by EPPA's result of $55.30 to get added fuel cost of $30.42, and add this to base price of coal of $26.70 to get final result of $57.12, the cost of coal given a carbon price of $15/ton CO2.

For natural gas, the Paltsev EPPA model's benchmark of $27/ton CO2 derives an added price of $1.50/tcf into a base price of $11.05/tcf. The same 55% calculation gives an added price of $0.825/tcf or $825/mcf. If we used .5555, then the price would be $833/mcf. We split the difference and used $830/mcf as the added price of natural gas given a carbon price of $15/ton CO2.

Our numbers are reasonable given other studies that have used the EPPA model. Stavins (Table 3, pg 23) uses Paltsev's model to calculate a $25 allowance price on coal. He finds it adds $51.20 to the base price of $26.70 to coal for a total of $77.90, and $1.39/tcf as an added price to natural gas.

Results



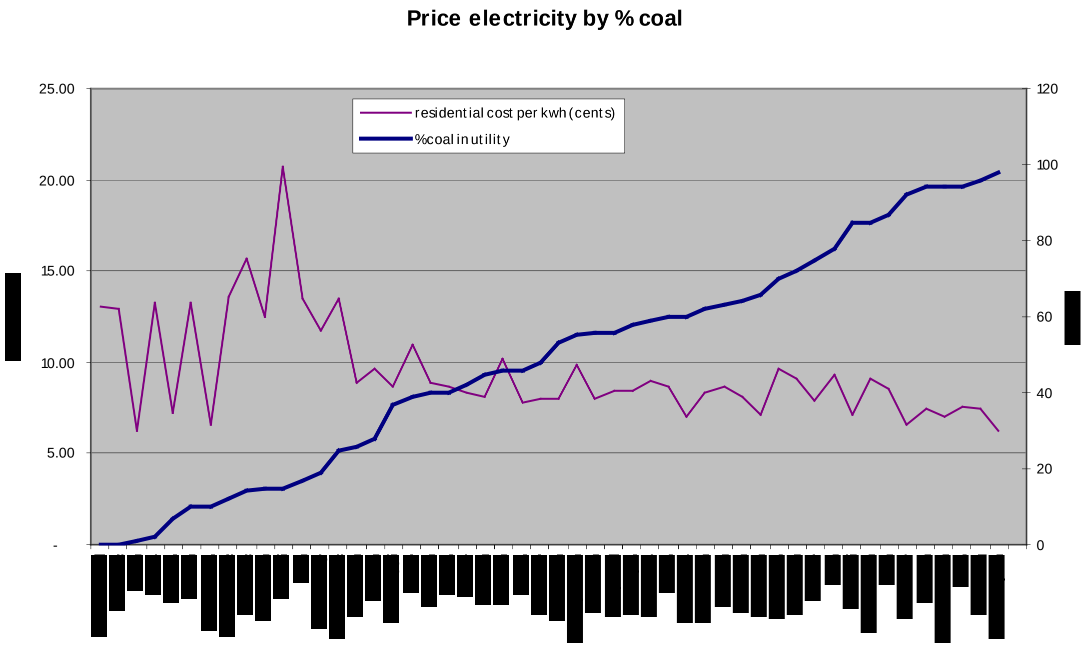


The chart above shows the added costs to coal and natural gas. In 40 states, the increase in the coal price is greater than the increase in the natural gas price. The three major coal states, North Dakota, Wyoming, and West Virginia show increases much greater than the national average of $160.

The chart below shows each state's electricity bill when sorted according to percent coal in the electricity mix before the $15 carbon price is added in. The rising purple line is the percent coal in the electricity mix, rising from 0% in Vermont toward 100% in West Virginia. The slope of the trend line of the annual electricity bill as the percent coal in the state's electricity mix increases is negative. This illustrates that as the percentage of coal increases, the price of electricity generally decreases, and consumers in low-price electricity states have less incentive to conserve energy.

Discussion

According to the EIA, electricity prices across states in 2005 were generally inversely correlated with the percent of coal in a state's electricity mix. The increasing blue line in the chart below is the percent of coal in a state's electricity mix, and the purple line is the average electricity price in each state. Hawaii had the highest price of electricity at over 20 cents/kwh. Wyoming had the lowest at 6 cents/kwh.

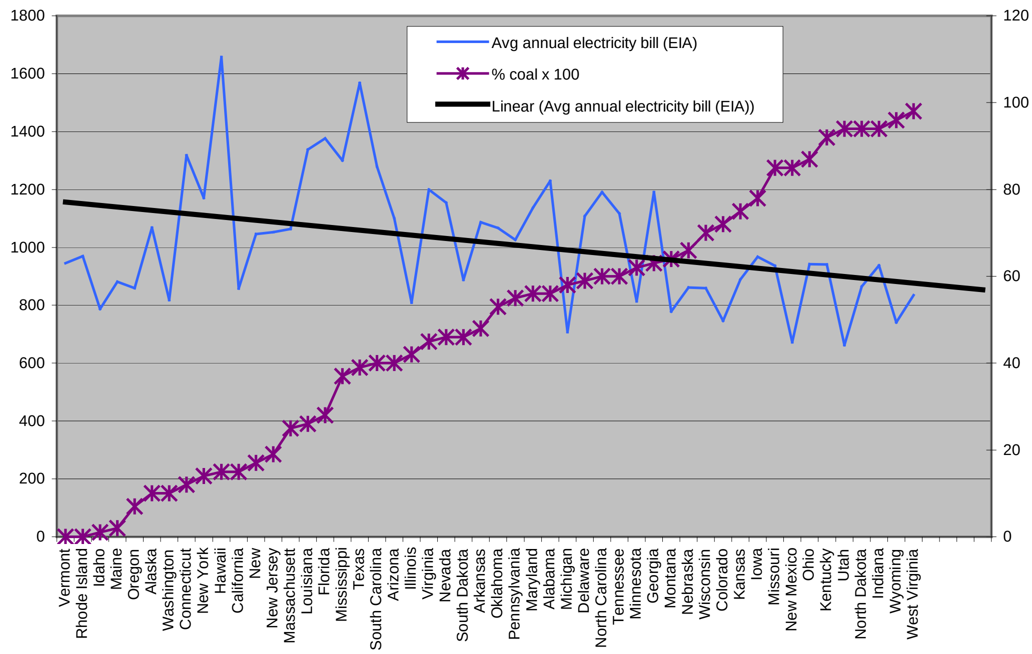


Since coal is the cheapest energy source, the fact that states with more coal had cheaper electricity should not come as a surprise, but it underlies the other findings.

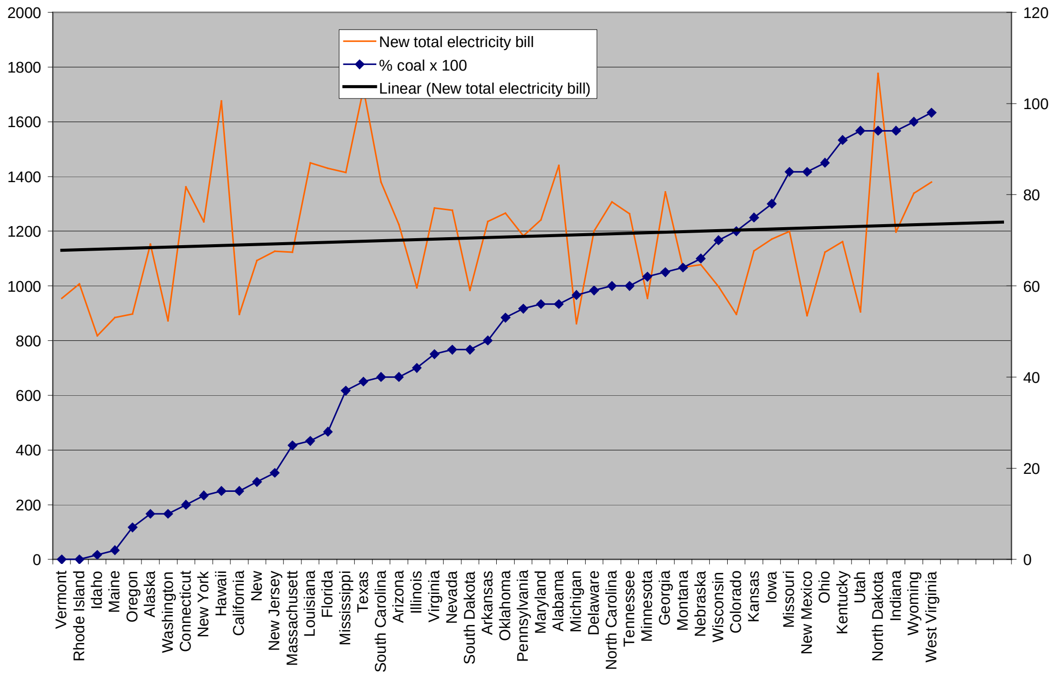
As mentioned above, the EPPA model yielded an added fuel cost for coal of $30.42/short ton of coal, and $830/mcf for natural gas. When these costs were added to the existing costs of coal and natural gas by state, the impacts differed according to the following variables:

- percent of coal or natural gas in the state's electricity mix
- electricity consumption per household
- existing price of coal or natural gas in that state

Nationally, the $15/ton carbon price would cause a 15.8% median increase to the average electricity bill, increasing the average annual bill from $1,016 to $1,177. The average electricity bill increased 17%. Fourty-seven states had increases under 40%. But the three largest price increases were WV, WY, and ND. The largest price increase was 105% for ND. The average increase per annual electricity bill per household was $160. For ND, the increase was $910, and of that increase, $881 was due to the new price of coal.



The next chart shows the electricity price and percent coal after a $15/ton CO_2 cost is added in. The slope of the trendline of electricity price as the percent coal in the electricity mix increases is slightly positive, showing that the new average electricity bills slightly increase for states with higher percentages of coal compared to states with lower percentages of coal.



The three highest coal states, ND, WY, and WV, show the highest increase in their average household electricity bill. Even so, when North Dakota, Wyoming and West Virginia are removed, the trendline is flat, not positive, but still a change from the negative trend line in the previous chart.

The electricity rates in both charts are not a smooth curve. This is due to existing characteristics of each state's energy market, consumer consumption, and regional factors contributing to energy mix.

No regional predictability: North Dakota vs. South Dakota

States vary considerably within a region. Our data shows dramatic differences in electricity mix and price impacts between neighboring states such as, for example, North Dakota and South Dakota; New York and Pennsylvania; Wyoming and Idaho; West Virginia and Florida. We conclude that regional analysis of the impacts of a carbon price on consumer electricity bills should be approached with caution.

For coal, the largest electricity bill increases were seen in North Dakota, Wyoming, and West Virginia. The largest increase in an electricity bill as a result of the coal price increase was 101% in North Dakota, an increase of $881 per household per year. According to the EIA's State Energy Profile of North Dakota, the state has a high heating demand in winter, which leads to North Dakota’s per capita energy consumption as fourth highest in the country.[6] North Dakota's energy mix is 94% coal. However, the State's Energy Profile puts residential consumption at 20%, with industry accounting for nearly one-half of the State’s total energy consumption, but according to the EIA's data

[6] EIA, North Dakota State Energy Profile. http://tonto.eia.doe.gov/state/state_energy_profiles.cfm?sid=ND

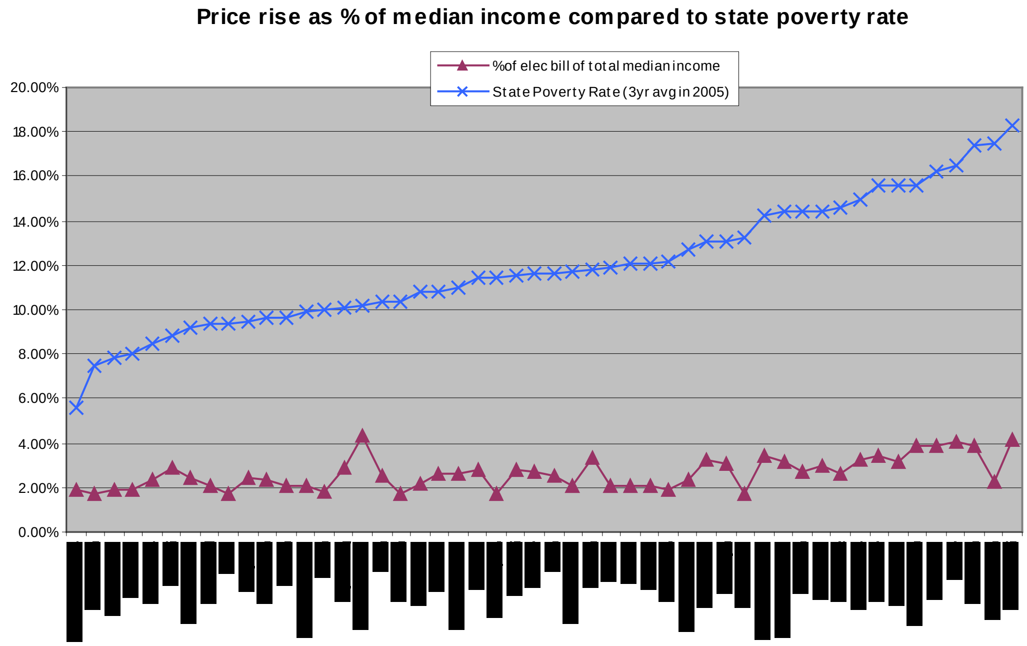
for electricity sales by sector, the residential sector is 35% of the total. In South Dakota, by contrast, hydroelectric power supplies almost half of the electricity consumed. Wyoming had a 75% price increase ($557/household/year), and a large aggregate price rise, but because the state's electricity use is 56% industrial and only 17% residential, as opposed to the average of 36% residential. Idaho, in contrast to Wyoming, uses very little coal because of its abundance of hydroelectric power. West Virginia had a price increase of 62%, or $516/household/year. A portion of these high coal-consumption-states' usage may be attributed to coal exports. Even so, half of states (25) had increases of less than 9% of their electricity bill and 39 states had increases of less than 17%. 29 states had a price increase of less than $100/household/year, and 46 states were under $230/household/year as a result of coal, with an average price increase of $129/household/year.

For natural gas, the largest price increases per household were seen in Illinois ($72/household/year), Michigan, Alaska, New Jersey, and Utah. Alaska has a high percent (56%) natural gas, and a high price (13.3 cents per Kwh). Half of the states bills showed increases of under $30 with the average state's electricity bill showing an increase of $31 per household, or 3.23% as a result of the natural gas price increase, and the maximum increase was 7.5% ($72) in Illinois.

When combining coal and natural gas, the three highest coal states had larger electricity bill increases than the highest natural gas states. Even so, the average Wyoming resident, where the average electricity bill nearly doubled after adding in a $15/ton carbon price, still paid less per month than residents of 11 other states. Those higher states include Connecticut, where coal comprises only 12% of the electricity mix and Hawaii, where coal is 15%. Those states currently pay some of the highest electricity bills. The average electricity bill in Texas and Hawaii is currently over twice that of Wyoming.

Correlation with state poverty rate shows potential regressivity

States with higher poverty rates exhibited a higher percent of income spent on electricity after the $15/ton carbon price is added in (rising from 2-4%). The rise in the average household electricity bill as a percent of state median income is greater in states with a higher poverty rate. Using the poverty rate as a proxy for the number of low-income residents in a state supports the contention that residents in low-income states will be more affected by rising electricity prices.



Sensitivity Analysis

Prior to adding in the projected addition due to a $15/ton CO2 carbon price, average annual state electricity bills in 2005 ranged from $661 in Utah to $1657 in Hawaii. The sensitivity analysis below shows how the EPPA model price change varies for a $5/ton and $25/ton carbon cost.

Results with $5/ton

Following the methodology above, a $5/ton carbon cost leads to an increase of $10.23/short ton of coal.[7]

For natural gas, the Paltsev EPPA model's benchmark of $27/ton CO2 derives an added cost of $1.50/tcf. Following the same methodology, 18.5% of $1.50 gives an added cost of $277.50/mcf.

Using these numbers, the range of state electricity bills rises to $743 to $1663. Hawaii is still highest, and Utah is still lowest.

Results with $15/ton

[7] Using Paltsev's EPPA model benchmark of $27/ton CO2e resulting in an increased price per short ton of coal of $55.30/short ton, $5/ton is 18.5% of 27, and 18.5% of $55.30 is $10.23/short ton of coal, the added amount from a $5/ton CO2 cost.

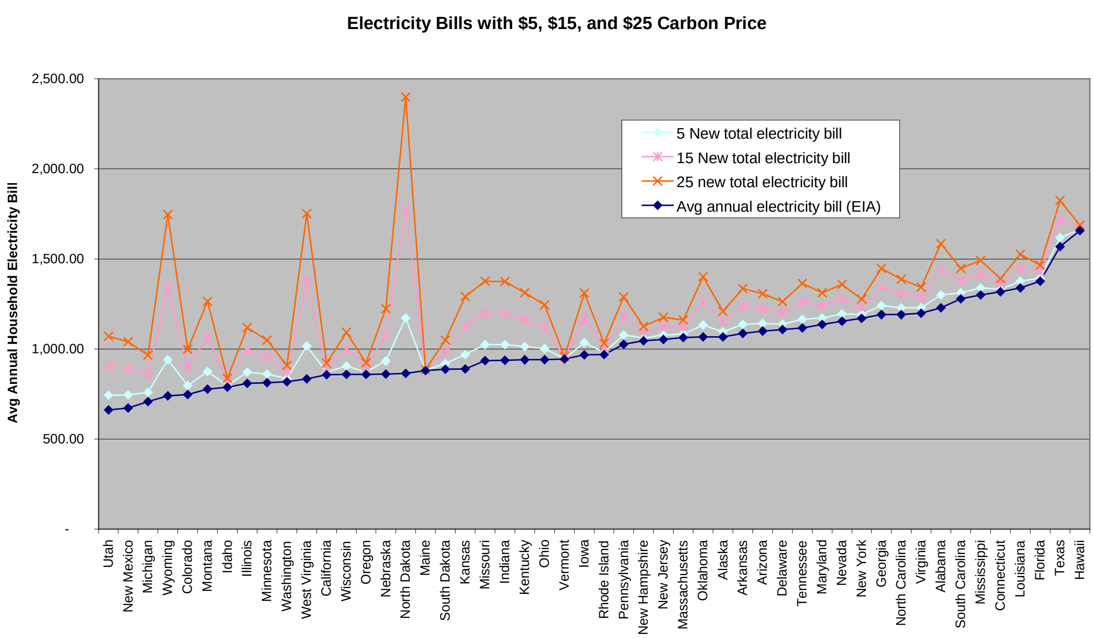
The $15/ton results are reported in the main results section of this paper. The range of electricity bills becomes $817 to $1,776. Idaho becomes the state with the lowest average household electricity bill, and North Dakota becomes the state with the highest.

Results with $25/ton

Following the EPPA benchmark conversion described above, $25 is 92.6% of 27, and 92.6% of $55.30 is $51.21/short ton of coal. For natural gas, 92.6% of $1.50 results in an added cost of $1,389/mcf.

The range of state average electricity bills is now $837 (Idaho) to $2398 (North Dakota). The second highest is Texas at $1,824. The largest movers by percent increase to $25/ton are: North Dakota, Wyoming West Virginia, Montana, Utah.

The chart below shows the estimated average residential electricity bills resulting from a $5/ton, $15/ton, and $25/ton carbon cost.



Caveats

Limitations with this analysis:

This analysis was performed using state-level data. We recognize that there are significant differences in the electricity mix between utilities within states. The data used in this study is not specific to a particular utility's service area. This is an area for future research. Some utilities serve multiple states. The average state electricity bill can conceal differences between pricing regimes in different utilities in a single state. Some consumers living near a state border, may find their electricity bill is more similar to the neighboring state than their own.

We do not assess whether a $15/ton carbon cost is sufficient to change consumer behavior, or what carbon price is needed to achieve a given reduction. We do not consider price elasticity of demand over time, and do not consider what actions would be taken given a $15/ton carbon cost.

We use data that focus on the average consumer in each state. Demographics and consumer use can vary widely within regions within states. The composition of the electricity mix can vary widely due to geography within states.

As mentioned above, this analysis does not look at actions a utility may take to alter the impact of prices on consumers such as fuel switching. It also does not consider actions that consumers may take in advance of the imposition of a carbon price, nor does it consider the increased price's effect on demand over time. If this were the only caveat, we could say we found larger price increases than could actually be expected.

However, our analysis does not reflect the indirect price increases from higher energy costs for other goods and services in the economy. For simplicity, we will assume those indirect price increases offset the price reductions from efficiency and fuel switching.

The carbon cost was applied to 2005 data retroactively. Although a carbon cost is likely to be phased in over time, these results can be interpreted as short term costs assuming reaction delays from producers or consumers, perhaps during the first year of such a program.

We looked at residential prices, and residential energy usage. We did not take into account the difference between residential and industrial and commercial prices. In all cases we surveyed, residential prices were greater than industrial or commercial prices. This implies that residential customers may subsidize industrial and commercial customers by paying more than just the increase in the residential portion that we analyzed. Therefore, our estimates are conservative, since the subsidy would raise residential prices even more.

We did not look at indirect costs to consumers if electricity prices increase. Other goods and services will become more expensive as well, so the cost to consumers will be greater than simply the rise in electricity bills.

Hurricane Katrina occurred in August of 2005, disrupting natural gas prices for several months, and changing the energy use of Louisiana, Texas, Alabama, and much of the nation that was served by the natural gas pipelines in the Gulf of Mexico. Our analysis does not look at changes in state's electricity mix that have occurred since 2005 such as new renewable energy generation or Renewable Portfolio Standards.

Electricity Imports and Exports and California

We do not account for cross-border transmission (imports and exports), except for California. Since the EIA data we used does not account for interstate commerce of electricity, it initially showed only 1% coal in California's electricity mix. According to the California Energy Commission, coal represented 15% of the state's electricity mix. Almost all the coal used by California electricity consumers is combusted at out-of-state powerplants, and the electricity is imported from neighboring states. This occurs at several large powerplants located in Utah, Nevada, and Arizona, and it was difficult to find exact data for the tonnage of coal used. Therefore, for California, we added only the coal used by the Intermountain Power Plant in Utah, but did not subtract it from Utah. As a result, California's coal price impact is probably underestimated, and the surrounding states' coal price impact is probably overestimated in our results.

California passed a bill, SB1368, that sets an emissions performance standard for major utilities and limits the future procurement of coal-powered electricity. The performance standard is set at a limit that may not be met by existing coal powerplants, but future plants that incorporate carbon sequestration may meet it. This law will have the effect of reducing the coal in California's electricity mix as current interstate coal contracts expire.

More specific explanations:

Although there are many cases where state level analysis is more accurate than regional analysis, there are some regional characteristics that partly explain some of the results above.

The chart below shows the difference in percentage of coal in various regions in 1999.[8]

Region:	% of electricity from coal in 1999:
New England	16.3
Middle Atlantic	35.8
East North Central	72.0
West North Central	73.9
South Atlantic	55.5
East South Central	68.0
West South Central	40.1
Mountain	67.5
Pacific Contiguous	4.2
Pacific Noncontiguous	11.7

Several state's results, including New England states, California, Oregon, and Washington follow from this regional data.

[8] EIA, Percent of Electricity Generated at U.S. Electric Plants by Fuel Type and Census Division, 1998 and 1999. http://www.eia.doe.gov/cneaf/electricity/page/co2_report/co2report.html#table_3

Distillate fuel oil and kerosene use differs by region. In 2001, the northeast U.S. used 0.6 quadrillion btus of distillate fuel oil and kerosene, while all other parts of the country combined used only 0.16 quad btus.[9] Our analysis did not look at distillate fuel oil and kerosene.

Additionally, demand differs in various states. Climate is a factor. The National Weather Service's Climate Prediction Center measures annual temperature differences between cities as they relate to energy demand in heating degree days (HDD) and cooling degree days (CDD).[10] HDD and CDD are calculated by measuring the mean of the high and low temperatures for the day multiplying the degrees away from 18 degrees C or 64 degrees F for that day times the number of days per year.

The chart below shows the heating degree days and cooling degree days as calculated by the National Weather Service for 2005.

	2005-6 Heating Degree Days	2005 Cooling Degree Days	Total HDD+CDD
New England	6007	642	6649
Middle Atlantic	5257	990	6247
East North Central	5801	960	6761
West North Central	5809	1094	6903
South Atlantic	2632	2081	4713
East South Central	3285	1696	4981
West South Central	1888	2636	4524
Mountain	4641	1457	6098
Pacific	3071	728	3799

Some regions experience a climate that requires higher energy use than other regions. The Pacific Region in particular benefits from a mild climate, allowing the region to use less energy for heating and cooling of buildings.

Another demand side input that plays a role in differences between states is the energy efficiency required by building codes. The Alliance to Save Energy tracks energy efficient building codes by state.[11]

The particulars of each state's regulatory environment may play a role in determining how states are affected by a carbon price. A chart in Part II of this paper shows which states are deregulated. The three states with the largest impact on coal, North Dakota, Wyoming, and West Virginia, are not deregulated.

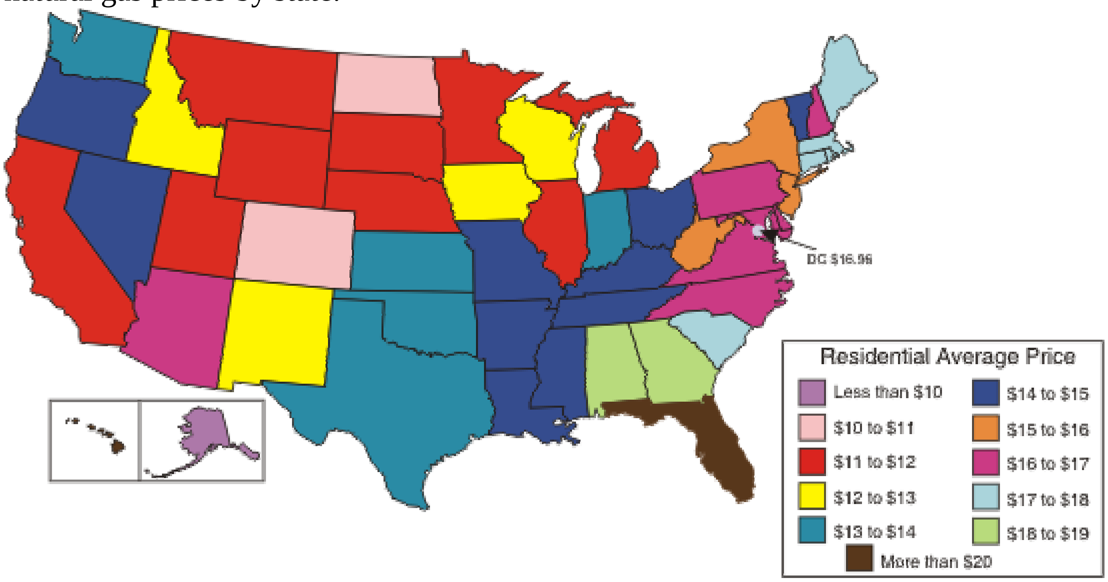
[9] EIA, Table 2.4 Household Energy Consumption by Census Region, Selected Years, 1978-2001 http://www.eia.doe.gov/emeu/aer/txt/stb0204.xls
[10] National Weather Service's Climate Prediction Center - Heating and Cooling Degree Days Data http://www.cpc.noaa.gov/products/analysis_monitoring/cdus/degree_days/
[11] Alliance to Save Energy, http://www.ase.org/content/article/detail/2603

The following chart shows some of the differences between deregulated and not deregulated states. Deregulated states are generally lower in coal, have a higher price of electricity, and a higher electricity bill, but would be predicted to have a lower added cost with a carbon price.

	residential cost per kwh (cents)	% coal	Avg annual electricity bill (EIA)	Added costs of coal and nat gas
Deregulated States	10.63	36	1051.43	100.15
Not Deregulated States	8.84	55	996.56	194.87

The added costs of a carbon price to not deregulated states decrease from $194 to $144 if the three top coal states are removed. Even so, deregulated states have less coal, and would face lower added costs than not deregulated states.

The variation in natural gas prices around the country also plays a role in describing how states would be affected by a carbon price. The following map shows the variation in natural gas prices by state.[12]



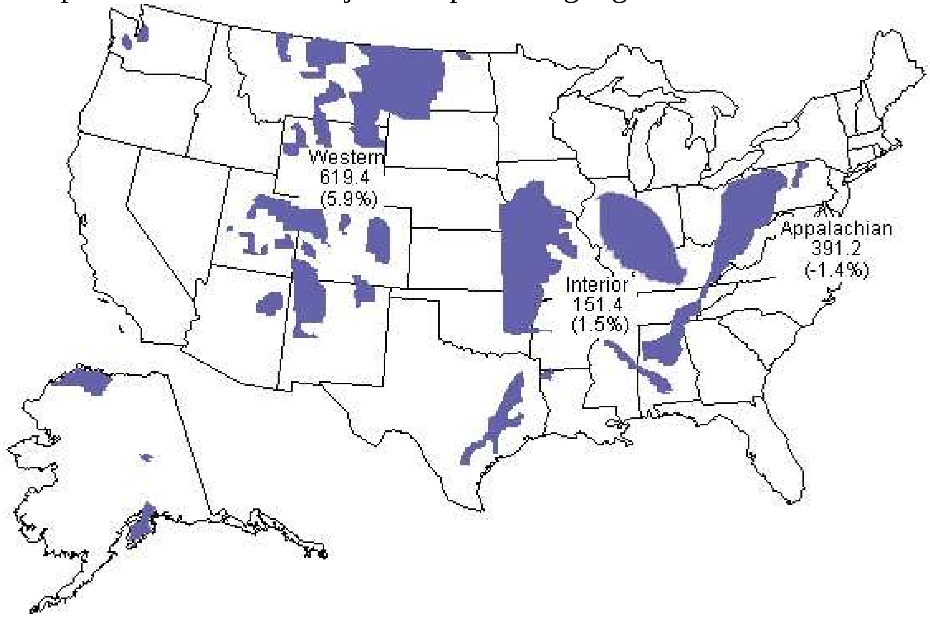
This map shows there is little regional coherence or predictability in natural gas prices.

Coal prices also vary by state. The national average coal price for utility plants in 2005 was $31.22/short ton. Other industrial plants paid an average of $47.63/short ton. North Dakota's coal price for utility plants in 2005 was only $10.99/short ton, while the average price reported in New England was $65/short ton, and Massachussetts reported the

[12] EIA http://www.eia.doe.gov/neic/brochure/oil_gas/rngp/index.html

highest price at over $71/short ton. Several other states did not report their coal price. The coal price for utility plants increased 9.7% between 2005 and 2006.[13]

The map below shows the major coal producing regions in the U.S.[14]



The three top coal users, North Dakota, Wyoming, and West Virginia, are all identifiable on this map of coal producing regions. However, some states with coal reserves are not as affected by the carbon price. For example, Illinois has large coal reserves, but only 42% coal in their electricity mix, in this case, due to the state's nuclear powerplants.

The map below shows the estimated per capita fossil fuel carbon emissions by state for the year 2000.[15] The map also shows Wyoming, North Dakota, and West Virginia as the three highest emitters per capita.

Even with a near doubling in its average annual electricity bill, the average Wyoming resident would still pay less than 11 other states.

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[13] EIA, Average Price of Coal Delivered to End Use Sector by Census Division and State http://www.eia.doe.gov/cneaf/coal/page/acr/table34.html

[14] EIA Annual Coal Report, http://www.eia.doe.gov/cneaf/coal/page/acr/acr_sum.html

[15] Blasing, T. J., Christine Broniak and Gregg Marland "State-By-State Carbon Dioxide Emissions from Fossil Fuel Use in the United States 1960–2000" *in Mitigation and Adaptation Strategies for Global Change* Volume 10, Number 4 / October, 2005 http://www.springerlink.com/content/7x1650vq1g133406/fulltext.pdf

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Per capita fossil fuel carbon emissions, to the nearest whole number, by state for year 2000.

IV. Policy implications of results

The goal of this paper is to compare the rise in average household electricity bills between states due to a $15/ton carbon price. Our analysis is a snapshot using 2005 data, which ignores actions that may be taken to reduce costs to consumers and businesses.

Our state level analysis of the projected increase in electricity prices shows that some states will face a greater burden than others. Consumers in some states will see a much greater increase that the $160 average increase in their annual household electricity bill, up to $900 per year, but in other states the increase will be negligible. The three states with the greatest exposure to a carbon price are North Dakota, Wyoming, and West Virginia, due to their reliance on coal for electricity, and the in-state availability of coal. Those three states are major suppliers of coal to the rest of the nation. The low cost of coal, and therefore electricity, in those states has not provided incentives for end use energy efficiency, resulting in high per capita energy use.

The state-level analysis shows the potential flaws in using national and multi-state regions to generalize about impacts of a carbon price on electricity bills. National data overlooks whether a state's electricity market is deregulated, and the composition of the state's energy mix. Neighboring states often exhibited major differences in electricity prices, per capita electricity consumption, and amount of coal used.

In some cases, neighboring states will face an order of magnitude disparity in price impact. The major factors in the price discrepancy between states include: percentage of coal or natural gas in the state's electricity mix, whether the state has deregulated its electricity market, the fossil fuel resources of the state, the renewable, hydroelectric, or other energy resources of the state, the price of coal or natural gas, per capita energy use, building codes, geography, climate, and more. The implication of the disparities between neighboring states is that Federal climate policy should consider impacts at the state level, not just at the regional or national level. Similarly, in evaluating regional emissions permit trading systems, state level price differences could result in unbalanced state level outcomes.

We also found that States with higher poverty rates exhibited a higher percent of income spent on electricity after the $15/ton carbon price is added in, supporting the contention that low-income residents (and states) will be more affected by rising electricity prices. When this result is placed next to the three top coal states, we believe a carbon price may have the biggest impact on the rural poor.

Increasing average annual household electricity bills also lead to the following policy implications. Coal-rich states may not continue to have lower electricity bills than low-coal states. Utilities may find more consumer support for end-use energy efficiency investments, especially in states with high per capita consumption, which often correlate with high-coal states. State regulators may need to justify their state-level regulatory pricing systems, if a national carbon price brings more scrutiny to disparities between electricity bills across borders.

These results may also be helpful to the designers of multi-state carbon capping systems such as the Western Climate Initiative (WCI) or the Regional Greenhouse Gas Initiative (RGGI). Those systems must determine an equitable method of apportionment of allowances under a multi-state cap. Our analysis provides an estimate for predicting how consumers in neighboring states will be most affected by price increases from a carbon cap. An estimate of how much the average household spends on electricity in each state, and how much those prices could increase with carbon costs may help regional carbon capping systems determine how to apportion a carbon budget between states. The average household electricity price impacts as calculated in this paper may prove to be an important factor in comparing each state's baseline and future carbon budgets, and may be combined with other factors such as population and projected growth, industrial composition of the state, and other economic attributes.

Future studies

Further analysis at the utility level could provide more specific predictions about winners and losers in a regional emissions permit trading system and within states.

This study looked at electricity prices. A future study could perform a similar analysis for the transportation sector. Two possibilities for assessing the price impacts from the transportation sector are gasoline prices and vehicles mile traveled (VMT). Although gasoline prices would follow the electricity sector's approach more closely, the recent price increases in gasoline prices since 2005 might make such a study less relevant to 2008 or 2010. Vehicle miles traveled varies across states, and could provide a basis for state-by-state analysis of the impact of a carbon price. These issues may be picked up in future studies.

Once the cost impacts on consumers is assessed, an additional area of study becomes how to compensate consumers, or ameliorate the economic impacts of consumers so that the price signal achieves the desired changes in behavior without compromising the political support for carbon emission reduction. Future studies could assess the state level outcomes of providing consumer compensation. Three potential methods of consumer compensation are carbon dividends from emission permit revenues, carbon tax rebates and dividends, or carbon shares allocated directly to consumers that would be sold to fuel and energy companies. Future studies could assess the effectiveness of these methods in addressing the cost impacts on consumers shown in the current study.

Appendices:

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