Coal Power is Not Cheap Power

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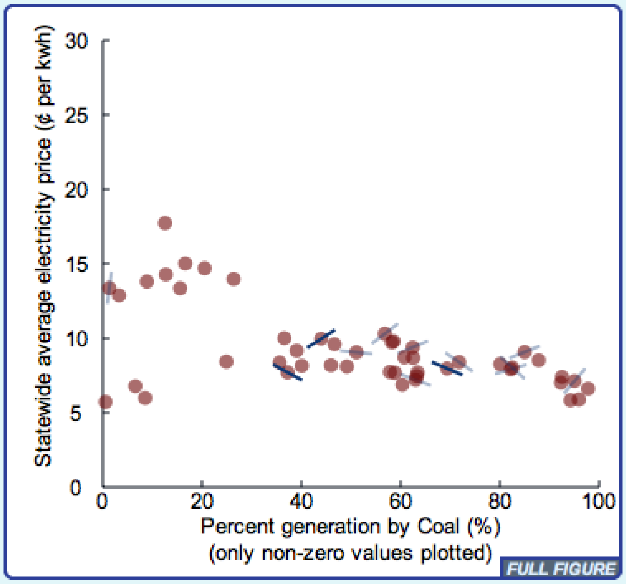
Coal power is not cheap power - An analysis of generation type and electricity prices in the United States (2011)

Abstract

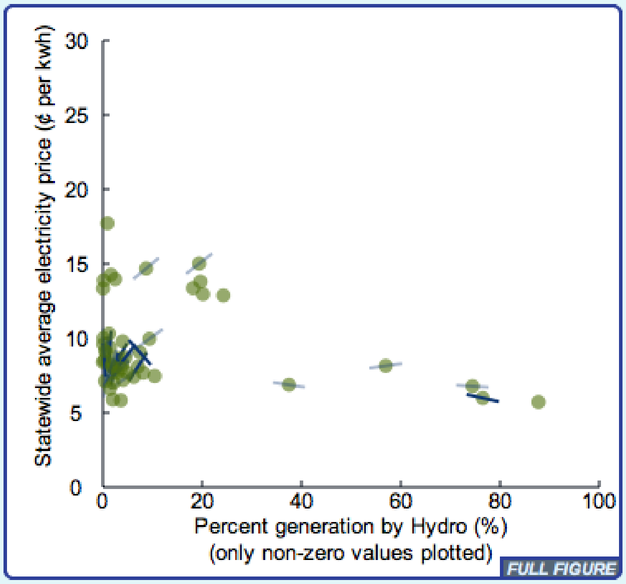
How can ratepayers and utilities best keep electricity prices affordable? Coal is often touted as a source of low-cost electricity, but some believe that coal's negative environmental impacts outweigh any such benefits. Our analysis examines three different aspects of the cost of coal: coal's impact on retail electricity prices, the estimated future cost of generating electricity with coal, and costs of coal generation not included in the retail price. By tracing changes in electricity prices in states that changed their energy portfolios we show that using more coal does not actually make power less expensive. States that reduced their use of coal-fired generators have not seen electricity prices rise, and states that increased coal use have not seen prices drop. Also, the estimated "levelized cost" of constructing and operating a new coal plant today is more expensive than generating the same amount of power from a new hydro or natural gas plant, and is comparable to the cost of wind power. Finally, the cost estimates for coal-generated power fail to factor in the "externalized costs" of pollution cleanup, medical bills, and environmental damages borne by the taxpayers and the public. When these costs are included, coal-fired power is more expensive than all the other generation types we examined.



States with the cheapest energy rely on unique resources and infrastructure

On average, US states that burn more coal pay less for elecricity (Figure 1). Some argue this shows that increasing coal-fired generation reduces electricity prices. However, a more detailed analysis of power prices over time in the U.S. shows this logic to be flawed.

Among the 48 coal-burning states, there is large variability in both generation portfolio and the price of electricity. In some cases, these two factors are correlated. Extensive use of coal is in fact significantly correlated with a low sticker price. Extensive use of hydropower is also significantly correlated with low prices (Figure 2). So states seeking to minimize electricity bills might seek to imitate the lowest-cost states: Idaho: 5.7 ¢/kwh, 87% hydropower, or Kentucky: 5.8 ¢/kwh, 94% coal power.



But is it possible to mimic Idaho or Kentucky to provide low cost electricity to consumers? Many states lack the hydropower resources that would allow them to imitate Idaho. Similarly, Kentucky is a state with large coal deposits, active coal mines, and an established infrastructure to transport and burn coal, which is not true of most states. Regional variations in price are impacted by local resources, population, and transmission costs.

More importantly, the correlation between coal or hydro and prices doesn't tell us whether increasing use of coal or hydro power can cause lower energy prices. This is an important question for states considering increasing their use of coal-generated power as a way to lower energy prices for their consumers, and for states seeking to lower their use of coal-generated power as a way to reduce environmental impacts. To address this question, we examined states that changed their generation portfolios between 1990 and 2009.

Using less coal does not increase electricity prices - Using more coal doesn't drop them

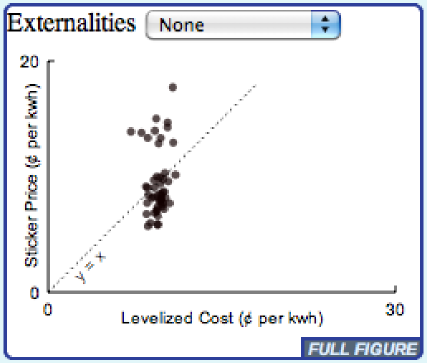
If using more coal meant lower prices, then those states that increased the proportion of their energy generated from coal should have seen reduced electricity prices. And states that reduced coal use should have seen their electricity become more expensive. This is not what has happened. In the 20 years between 1990 and 2009, even large changes in the percentage of electricity generated from coal had no consistent impact on consumer energy prices.

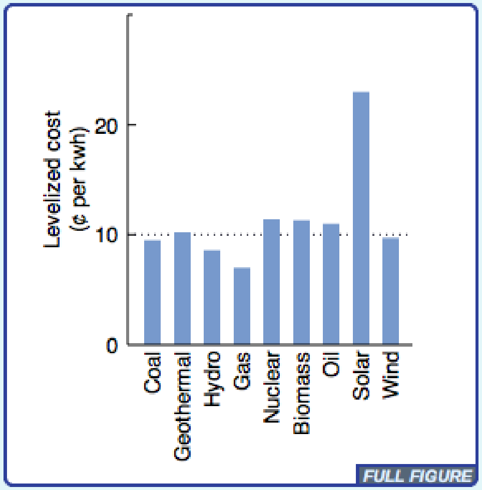
Out of all forty-eight coal-burning states, there were thirteen significant correlations, and these correlations were nearly evenly split between positive and negative correlations. [See statistics]. The most significant three correlations included South Carolina and Wisconsin, where more coal power was significantly correlated with less expensive energy. However in Arizona, the pattern was reversed. Here, more coal power was significantly correlated with more expensive energy. The 35 states showing no significant correlation between coal generation and price, included Florida, which reduced its use of coal by over 20%, and Colorado, which reduced coal use by nearly 30%. 17 states changed their coal use by more than 15% during the study period, so the lack of correlation cannot be explained by a lack of test cases. Taken as a whole, there is no relationship between increasing coal use and cheaper electricity.

Over the course of the study period, the percentage of coal use has decreased in the U.S, from 52.5% of generation in 1990, to 44.5% of generation in 2009. The inflation-adjusted price of electricity nationwide also dropped 1.2 cents in that time period, with no significant correlation between changes in coal use and changes in price.

The lack of a clear correlation means that there are other factors driving consumer electricity prices, and variations appear to be largely regional. If past trends continue to apply, states experiencing high energy prices will not solve the problem by burning more coal, and states seeking to move away from coal as a fuel for environmental reasons will not see prices rise.

For newly constructed plants, coal is not the cheapest option





Current consumer prices can't predict the cost of future electricity. When planning new generation facilities, the variable that best predicts cost is not the "sticker price" (price of electricity using existing generation facilities), but the "levelized cost" (expected price of electricity from a newly-constructed facility). The Energy Information Administration (EIA) publishes estimates of levelized costs for different power plants, looking at the expected cost of electricity per kilowatt hour from a power plant constructed today (coming online in 2016), averaged over 30 years. This price includes the cost of building, maintaining, and fueling a new plant over its lifetime, which is then annualized and adjusted for inflation to provide a comparative measure between different generation types. Most states current electricity prices are lower than these levelized costs (for an equivalent mix of generation), with the exceptions of Alaska, Hawaii, California, and the Northeastern US states (Figure 3).

Coal, in particular, is expected to be significantly more expensive than current prices indicate. A conventional coal plant built today would create electricity at 9.5 cents per kilowatt hour, more expensive than the electricity in current coal-reliant states (5.8-9.1 cents/kWh for states using more than 80% coal). This new coal plant would create electricity very close in price to a new wind plant (9.7 cents) and more expensive than a new plant using natural gas (7 cents) or hydropower (8.6 cents) (Figure 4).

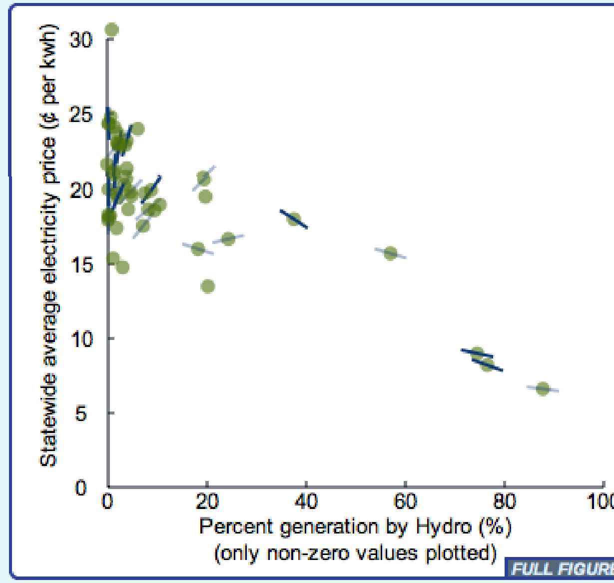
Costs borne by the public make coal the most expensive energy of all

Consumer prices don't reflect the other significant costs associated with generating power. These "externalized costs" are defined by economists as the real monetary costs of a product that are not reflected in the price paid by consumers. For electricity generation, these include the health impacts and taxpayer-borne cleanup costs of pollution, and the economic consequences of environmental damage, climate change, and other impacts of power generation. Instead of being part of the electric bill, these costs show up instead in tax payments, medical bills, and in reduced economic activity. Some of these impacts affect people who may receive none of the energy being generated. With externalities included, the average cost of electricity in the U.S. in 2009 was around 19 cents per kwh, with nearly half of that value (9 cents) due to externalized costs. Including externalized costs, the overall inflation-adjusted cost of electricity has dropped 2 cents between 1990 and 2009, reflecting a small shift to cleaner energy sources (lower externalized costs) in the past 20 years.

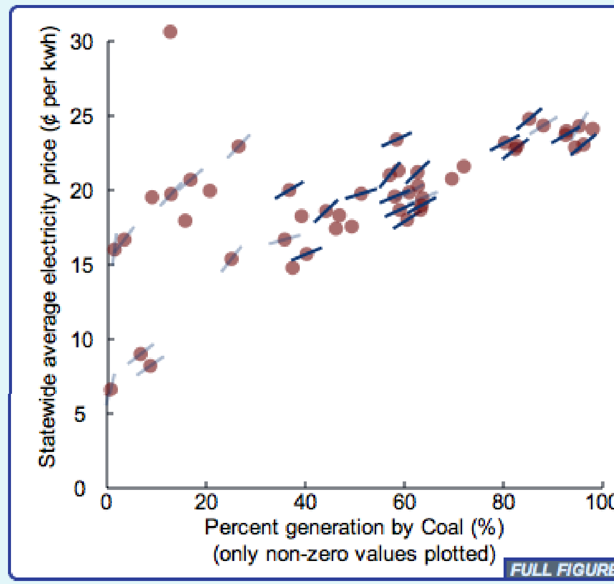
Energy sources vary widely in their externalized costs. Fossil fuels generally have the highest costs, with coal being the highest of all. For coal, externalized costs include health impacts from air pollutants like mercury and particulates, economic impacts from climate change and environmental degradation, and impacts to taxpayers from environmental cleanup and subsidies. These costs are often borne most heavily by residents in coal-dependent states, but are hidden from them as consumers.

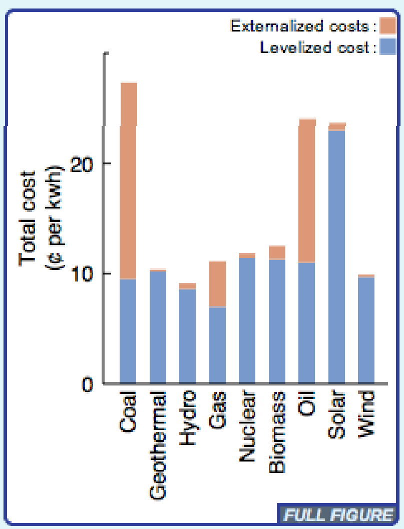
Epstein (2011) compiled these costs for coal in the US and found that they added between 9.45 cents and 26.83 cents per killowatt hour to the cost of coal-fired electricity, with the best estimate at 17.8 cents. Studies of externalities from other sources of power generation are less current and less thorough, but a broad study in Europe showed the lowest costs for wind, nuclear, and hydropower, with externalized costs ranging from 0.2 to 0.5 cents above the sticker price.

Taking into account these hidden costs to our existing power generation portfolio, some of the cheapest energy is found in states that rely heavily on hydropower (Figure 5) (low sticker price, low externalized costs), while states that rely heavily on coal see higher energy costs (low sticker price, high externalized costs) (Figure 6). The highest prices nationwide by any measure are in Hawaii, with the highest sticker price and large externalities from its primarily oil-fired power generation.



Analyzing changes in generation portfolios over time, we found that altering coal use did not affect the sticker price of electricity. However, if externalized costs are included in the calculation, the picture changes. Increasing coal use raises total costs and lowering coal use decreases them (Figure 6). In 30 states, greater coal use was significantly positively correlated with higher total electricity costs. [See statistics]. Nearly all these states actually reduced their coal use over time, seeing an associated reduction in total costs to consumers and the public.





Plans for new power generation should consider the actual total cost of the resulting electricity, including both levelized and externalized costs. In total cost a new coal plant would come in at 27.3 cents per kilowatt hour (9.5 cents levelized cost + 17.8 cents externalities), while a new hydro plant would come in at only 9.1 cents per kilowatt hour (8.6 cents levelized cost + 0.5 cents externalities), more than three times less (Figure 7). When states are seeking to build new power plants, the lowest total costs are found in wind, hydro, and geothermal plants - all renewable sources. Of the fossil fuels, natural gas is by far the lowest cost alternative.

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Methods and Analysis

Energy Prices and Generation Mix:

Data on yearly energy prices and generation mix in each state from 1990 to 2009 were acquired from the Energy Information Administration, which provides numbers for the "Average Price by State by Provider" and "Net Generation by State by Type." For the analyses in this study, all values were adjusted for inflation to 2009 dollars using the Consumer Price Index (CPI).

In our analysis, we lumped natural gas and other gases together into a single "Gas" category. We also lumped different types of biomass into a single "Biomass" category. We disregarded "Pumped Storage" as a generation type.

Externalized Costs Data Sources:

Externalized costs are difficult to calculate, and contain a fair amount of uncertainty. A 2011 study by Paul R. Epstein et al. estimated the externalized costs of coal-fired power to be an additional 17.8 cents per kilowatt hour above the price paid by the consumer. Epstein provided a low, best, and high estimate for each category, and we used the "best" or middle estimate for all our analyses. Some of these costs are coal-specific (like the costs of mountaintop removal mining), while others apply more broadly to other fossil fuels (like costs due to climate change impacts). However, no energy source is entirely free of externalized costs. To accurately compare coal with the other generation sources in our study, we attempted to create the best estimate of externalities for all generation types.

For our base estimate, we used the ExternE study from 2001. This Europe-wide study has the most comprehensive externalities assessment we have found, with estimates across 15 countries and 9 different energy generation types. To convert these numbers to a base estimate in this study we assumed a normal distribution for the ranges in the original data and then took an average across all counties for each generation type. The ExternE study contained no analysis for geothermal energy, which we set equal to wind at 0.19 cents per kilowatt hour. From these averages, we converted from Euros to 2001 US dollars and scaled for inflation to 2009 US dollars.

Although they cover an array of energy sources, the analyses in ExternE were conducted in the 1990s and lack the most up-to-date estimates of climate change and other externalities found in the Epstein study, as well as the costs of mountaintop removal mining (which are US specific).

Externalized Costs Best Estimate Calculation:

To combine these analyses we used the number from the Epstein study for coal, and scaled the ExternE estimates for other generation types according to the relevant elements of the Epstein study. Without scaling we would underestimate externalities in other generation types, since the more recent Epstein coal analysis takes more factors into account than ExternE's older analysis.

To perform this scaling we divided Epstein's analysis into three pieces: coal-specific, fossil-fuel general, and subsidies. Into coal-specific we placed "public health burden in Appalachia" and "abandoned mine lands", which together accounted for 4.8 cents/kwh. Subsidies accounted for 0.16 cents/kwh. Into fossil-fuel general we placed everything else, which included a variety of costs, with the highest being "emission of air pollutants from combustion" at 9.31 cents/kwh and "climate change total" at 3.51 cents/kwh.

Epstein's coal number of 17.8 cents/kwh was used directly as our best estimate for coal externalities. The fossil-fuel general category was used to scale the ExternE results for oil and natural gas. Both these fuels incur externalized costs from drilling and transport, air pollution from combustion, and climate change from the CO2 released. Per kilowatt hour these factors might be smaller for oil and natural gas than for coal, because it takes a larger mass of coal to get a single kilowatt hour of electricity. However, determining how much smaller is difficult. To account for the difference, we assumed that the ratio of coal impacts to oil or gas impacts is equal to the ratio of these impacts found in the ExternE study.

In ExternE, coal and oil externalities were both calculated at 6.27 cents/kwh (2009 US dollars). So oil is equal to 100% of coal, and Epstein's full 12.88 cents/kwh for air pollution and climate change costs were assigned to oil generation. Natural gas, however, was calculated at 1.98 cents/kwh, only 32% of coal's 6.27 cents in the ExternE study. Therefore 32% of the 12.88 cents/kwh for "mining/transport," "air pollution," and "climate change" was assigned to natural gas generation (4.07). Subsidies were not included in the scaling because the original ExternE study already incorporated subsidies.

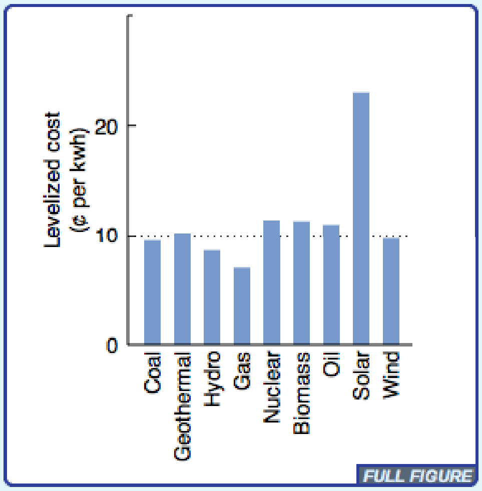
There are inevitable uncertainties and inaccuracies in the externality calculations, both in the original data and in the assumptions we made to combine them. However, the resulting numbers represent our best estimate– far better than assuming that externalities are in all cases 0. The relative magnitudes of coal, oil, and gas externalities are broadly similar to other studies, and nuclear externalities would only matter if ExternE had under-estimated this number by an order of magnitude.

In the interactive figure, the viewer can use the "Externalities" menu to toggle between our "Best Estimate" (calculated as described here), "ExternE Average" (ExternE data with no input from the Epstein study), or remove externalities entirely by selecting "None."

Levelized Costs:

Levelized costs are an attempt to calculate future energy prices for a not-yet-built plant of a given energy type. Levelized costs take into account the expected costs of power plant construction, maintenance, transmission, as well as fuel costs over a designated period of time. The levelized costs of future power plants are nearly always higher than the costs from already-built generation capacity of a given type. These numbers have a significant amount of uncertainty, particularly for fuel costs, but are the most relevant numbers to look at when planning future generation capacity.

The Energy Information Administration (EIA) publishes estimates of levelized costs for different types of power plants, looking at the expected 30-year cost per kilowatt hour from a power plant constructed today (coming online in 2016). This cost is then annualized and adjusted for inflation to provide a comparative measure between different generation types. While levelized cost does take into account subsidies received by different sources of energy generation, it doesn't account for externalities.



FULL FIGURE

For our analysis, we simplified the EIAs numbers slightly to allow us to compare them to current generation portfolios (Figure 4).

Coal:

"Advanced Coal" (10.9 cents/kWh) and "Advanced Coal with CCS" (13.6 cents/kWh) were ignored since there are only two of the former in the US and none of the latter. Therefore these types of facilities don't represent significant options at the present time, particularly in the case of CCS which has never been tested on large scale at a coal facility. In our analysis "Coal" is the same as "Conventional Coal" (9.5 cents/kWh) in the EIA's table.

Gas:

The EIA lists a number of different types of natural gas plants. We ignored ACT and ACG since these technologies are not in widespread use. Our estimate based on utility profiles is that US natural gas plants are approximately 75% CCC plants and 25% CCT plants. Scaling the costs with those numbers, we arrived at an approximate levelized cost for natural gas of 7 cents per kWh.

Oil:

No value for petroleum generation is given by the EIA, so we were forced to estimate one. We assumed it to be 11 cents/kWh, on the grounds that an oil-fired plant likely costs slightly more than a coal-fired plant. It may be that the EIA did not include this number because of the volatility of oil prices, which would add considerable uncertainty.

Even if this number is significantly inaccurate, it does not change our conclusions.

Wind:

"Offshore Wind" was ignored as representing a negligible part of current wind generation, and the conventional wind number of 9.7 cents/kWh was used.

Solar:

In 2009, photovoltaic solar represented around 3/4 of total solar capacity, while thermal solar accounted for the remaining 1/4. We used a weighted average of these two types of solar capacity to arrive at a general levelized cost for solar energy of 23 cents/kWh.

Geothermal, Hydro, Nuclear, and Biomass:

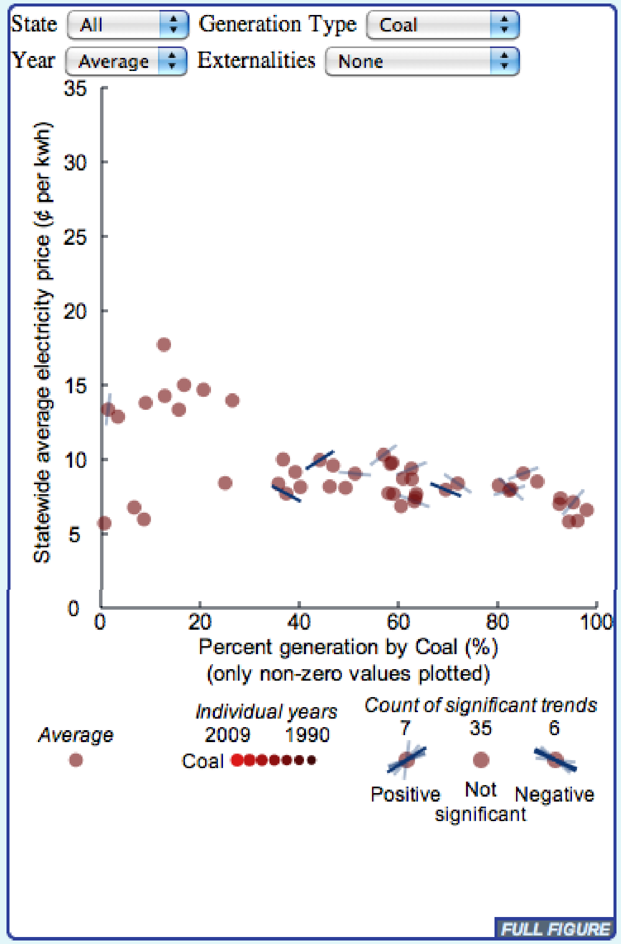
These values were all taken straight from the EIA tables.

Further reading:

- Updated Capital Cost Estimates for Electricity Generation Plants (EIA, 2010)
- Assumptions to the Annual Energy Outlook 2010 (EIA)
- Annual Energy Outlook 2011 (EIA)

Statistics:

All of our statistical results are accessible via the interactive at right. As we conducted our analyses, we replicated them in this figure, which is directly linked to our database. For instructions about how to use this interactive figure, see our [interactive figure section](#).



To detect significant correlations between changes in generation portfolio and electricity prices, we tested the significance of simple linear regression associating price in a given state and a given year (Y-axis) with the percentage of electricity generated by a give source (X-axis). For example, we tested whether the percentage of coal could predict price in the state of CO. Each datapoint corresponded to a year. Our statistics were computed using a custom JavaScript library available [here](#).

To segregate significant correlations from those more likely to have arisen coincidentally we applied a cutoff of $p<0.05$. In many cases, we were applying a number of statistical tests in parallel, which increases the likelihood of coincidentally "significant" correlations (multiple testing problem). To highlight correlations that were so strong that they remain significant in light of the multiple testing problem, we corrected our significance tests by dividing by the number of tests (Bonferroni correction). States that never used a given generation type were not counted in the number of tests (e.g. we only counted 48 tests for coal generation, since two states and DC did not use any coal in any of the years we examined).

The Bonferroni correction is appropriate for filtering out individual states that have significant correlations and for making inferences about the states that do exhibit a significant correlation. However, this correction is conservative and most probably underestimates the number of states that did exhibit significant correlations. Our results primarily emphasize the lack of correlation, in which case the Boneferroni correction is not conservative, since it increases the false negatives (correlations are rejected despite being meaningfully significant.) Therefore, the interactive figure reports the uncorrected $p<0.05$ significant results, but highlights the Bonferrroni corrected significant correlations.

Looking at the correlation between coal use and consumer electricity prices, when a weaker $p<0.05$ threshold for significance was applied, the relationship between coal use and electricity prices depended on the state [(Figure 1)](#). Seven of thirteen significant correlations show rising prices with increased coal burning, the other six show the opposite. The remaining 35 coal-burning states show no correlation between coal generation and price. This latter category includes states such as Florida and Colorado, which reduced their use of coal by over 20% and for which correlations should have been readily apparent, had they existed. Results using the stronger (Boneferroni corrected) significance cutoff led to similar conclusions. Finally, when externalities were considered in the analysis of coal use and total costs, the number of positive correlations was 30, with no significant negative correlation [(Figure 5)](#). In other words, for 30/48 states, higher percentage of coal use resulted in higher total costs.

In addition to the statistics presented in this report, we explored a number of avenues that did not yield usefully different results. In particular:

- We looked at correlations between annual change in %generation for a given energy source and annual change in price, for all states and all years. The correlation between price without externalities and % coal generation was not significant (i.e. more coal did not reduce cost), while the correlation between price with externalities and % coal generation was significant and positive (i.e. more coal increases cost). We excluded this from the study because the results were similar to those from the simpler approach here but much more complex to explain.
- We considered the relationships described here using an "Energy Inflation" adjustment instead of CPI inflation adjustment. This adjustment was defined so that the US average electricity price was constant. Though this seemed to reduce noise in some of the relationships, and slightly increased the number of significant correlations, the results were not substantially different either.
- We explored possible multi-variable correlations between generation portfolio and electricity price. This analysis did not reveal any new relationships missed by our simple 2D linear regression analysis.

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