# A Comprehensive Analysis of the Employment Impacts of the EPA's Clean Power Plan

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*Estimates made by the Environmental Protection Agency (EPA) of the likely employment effects of a proposed rule (the Clean Power Plan) mandating reductions in greenhouse gas emissions from existing power plants are incomplete. These estimates undercount both positive and negative influences on employment. This paper provides a comprehensive overview of the channels through which the mandated emissions reductions may lead to employment changes, both positive and negative. It finds that the Clean Power Plan is likely to lead to a net increase in employment of roughly 360,000 jobs by 2020, but that the net job creation falls relatively rapidly thereafter, with net employment gains of roughly 15,000 by 2030. Comparisons of the composition of employment in job-gaining versus job-losing industries are also made. The characteristics of employment in job-losing industries, as well as the likely geographic concentration of gross job losses in poorer states, are likely to lead to transition challenges for workers and communities in responding to the Clean Power Plan. This suggests the potential for a key role for federal assistance and complementary policies to aid these groups.*

## I. INTRODUCTION

In June of 2014, the Environmental Protection Agency (EPA) issued a proposed regulation to set emission limits that states must follow by developing plans to address greenhouse gas emissions from existing fossil fuel-fired electric generating units (EGUs).[1] The requirements within the Clean Power Plan (CPP) must be adopted by all EGUs by 2020.

This rule is the most substantive US regulatory undertaking aimed at mitigating global climate change. In 2007, the Supreme Court ruled that greenhouse gas emissions are covered by the 1970 Clean Air Act's definition of an air pollutant, and that the EPA must determine whether or not these emissions cause or contribute to air pollution that may be reasonably anticipated to endanger public health or welfare. Legislative efforts to mitigate greenhouse gas emissions passed the US House of Representatives in 2009, but failed to gain a vote in the Senate. Passage of such legislation to mitigate greenhouse gas emissions would

1 An electrical generating unit is a power plant. In the case of EGUs targeted by the Clean Power Plan, it is those power plants that use energy from burning coal to generate electricity.

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almost certainly have kept the EPA proposed rule from moving forward.

Although the economic, health, and environmental effects of the proposed rule are significant, this paper will focus on just one impact: potential effects on employment. Despite the fact that jobs and employment-growth are one of the smallest outcomes of the rule, its significant influence on this garners attention – as does the jobs-impact of most environmental legislation and rulemaking. In the regulatory impact analysis (RIA) that accompanied the release of the proposed rule, the EPA provided preliminary estimates of the direct impact of the rule on employment. This paper aims to build and to improve upon the EPA estimates and provide a comprehensive account of how the rule may affect US employment.  The key findings of this paper are:

- In the near-term (through 2020), the number of jobs supported by increased investments in renewables and efficiency investments is about 96,000 more than the number displaced by power plant retirements and reduced mining employment. By 2030, the gap between jobs supported and displaced is much smaller, but still positive (roughly 15,000).

- The net number of jobs supported in the near-term is larger (roughly 360,000) when taking indirect effects (supplier jobs, induced (re-spending or "Keynesian" effects), and public sector jobs supported through tax revenues) into account. But in the longer-term, the indirect effects actually reduce the net number of jobs supported to roughly 9,000.

- Higher electricity prices on a scale similar to those resulting from the CPP have the potential to reduce employment by between 25,000 and 150,000 if they are not anticipated. The assumption of price changes being unanticipated is only possible for the near-term (through 2020); in the medium and long-run any employment changes resulting from electricity price changes are unlikely.

- The labor force characteristics of jobs displaced and jobs supported following the CPP are quite different. Jobs displaced are more likely to be unionized, skew more towards male workers, and provide fewer low-wage and more middle-wage jobs than jobs supported, even though jobs supported are more likely to be filled by workers without a four-year college degree.

- Gross job losses are likely to be geographically concentrated, raising the challenge of ensuring a fair transition for workers in sectors likely to contract due to the CPP.

The first section of the paper describes the possible theoretical channels through which the proposed rule (referred to here as the CPP) may affect employment. Subsequent sections provide an empirical assessment of each channel, followed by a sum of the effects to provide an overall estimate of the employment changes spurred by the CPP. This estimate includes gross job gains, gross job losses, and net changes (the sum of gross positive and negative changes). Finally, the paper examines job quality differences between gross job gains and gross job losses.

## II. CHANNELS THROUGH WHICH THE CPP MAY IMPACT EMPLOYMENT

The CPP mandates emissions reductions on a state-by-state basis. By setting an overall state target, however, it leaves states many margins of adjustment along which to realize these emissions reductions. For example, states could mandate a share of overall electricity generation to come from non-emitting sources. Or they could provide incentives for business, utilities, and households to make investments in energy efficiency. There is even the possibility of states joining together to form a regional cap-and-trade system that only allows utilities to emit greenhouse gases after purchasing a marketable permit to do so. Given this flexibility in state response, there is great uncertainty in the precise economic outcomes that will be driven by the rule's implementation. For the purposes of this paper, I follow the economic modeling undertaken by the EPA in their regulatory impact analysis and translate their economic projections (include preliminary employment projections) into comprehensive measures of employment changes.

### ECONOMIC MARGINS OF ADJUSTMENT

The EPA's regulatory impact analysis identifies a number of margins of economic adjustment as likely to be most important to states to meet the emissions reduction guidelines. In the near term, electricity production from coal-fired electrical generating utilities will fall, and output by natural gas-fired power plants will increase. Construction of new electricity generation from renewables (mostly wind and solar) will be front-loaded during the first ten years of the rule, accelerating additions of renewable generating capacity. Solar and wind power will then replace some of the declines in coal-fired generation, particularly in the medium-term (more than five years out). Energy efficiency investments will also be accelerated by the rule. These efficiency investments in homes, businesses, and industry will allow electrical generation to fall significantly relative to baseline by 2030. Examples of such energy efficiency investments include the purchase of more efficient home appliances and the upgrade of insulation in residential homes; the optimization of heating, ventilation, air-conditioning systems, and electrical lighting in commercial buildings; and process optimization through modern instrumentation and control systems in the industrial sector.

Further, the sum of these effects is expected to raise electricity prices, particularly in the near-term. The efficiency investments will, however, sufficiently dampen the demand for electricity quantities to lower overall household electricity spending by the end of the period described in the EPA regulatory impact analysis on the rule.

### EMPLOYMENT MARGINS OF ADJUSTMENT

Employment changes will follow directly from these economic margins of adjustment. A number of channels will lead to employment reductions. For example, retirement of coal-generated electrical generating capacity will lead to losses in operations and maintenance employment at existing coal-fired power plants. These effects show up in both short- and longer-run horizons examined by the regulatory impact analysis. The switch from coal-fired generation will lead to a reduction in demand for coal, and subsequent significant declines in both the short and long-term for coal mining jobs. Increases in energy prices will spur employment responses, including demand-side reductions in spending, as households facing higher electricity bills (at least in the short-run) curtail spending on non-energy goods. There will also be supply-side reductions as the (slight) decline in real wages spurred by rising energy prices affects labor supply decisions. Finally, there may be responses related to international competitiveness, as higher domestic energy prices affect the cost of producing in the United States.

Conversely, a number of changes spurred by the CPP will lead to employment gains (or at least no losses) in both the near- and longer-term. For example, investments in energy efficiency lead to employment increases in all time horizons. Short-term investments in heat rate improvement of existing fossil-fuel power plants will spur employment in the near-term without reducing employment in the longer-term. Operations and maintenance jobs at natural gas power plants will rise slightly in all periods.

Some of these margins of economic adjustment to the CPP have different employment impacts depending on the time-horizon. For example, construction of new natural gas generation boosts employment in the short-run, but reduces employment in the longer-run, as jobs associated with planned natural gas EGU expansions are pulled forward in time by the rule. In the near-term, this implies increases in construction jobs for building this new capacity, but some of this comes at the expense of construction in the medium and longer-term. Similarly, construction of new renewable generation creates employment growth in the short-term, but reductions in medium and longer-term as these jobs are pulled forward relative to the non-CPP baseline.

Finally, each of these channels will in turn spur indirect effects. The indirect effects tracked in this paper will include: supplier jobs, induced (Keynesian) re-spending jobs, and public sector jobs supported through tax revenue. The sections that follow will provide an empirical estimate of the effect of each of these channels, including indirect channels.

## III. DIRECT EMPLOYMENT EFFECTS: TRANSLATING CHANGES BY ECONOMIC ACTIVITY INTO INDUSTRY CHANGES

This section will first report the estimates on direct employment effects contained in the EPA regulatory impact assessment, and will then assign these employment effects into specific industry codes that can be used as inputs into employment requirements matrices in order to undertake the analysis of indirect effects included in later sections of the report.

The regulatory impact assessment essentially provides four different estimates (or scenarios) for each of these flows in every year. The regulatory impact assessment estimates effects stemming from a "state-only" approach and a "regional" approach to meeting emissions targets. The Clean Power rule provides the option for states to collectively meet combined ("regional") emissions targets. This may alter the margins of adjustment for meeting emissions guidelines as compared to a single state-only approach. The regulatory impact analysis also provides two different options for the level and pace of emissions reductions that states must meet. One of the options is recommended by the EPA, the second is offered and public comment is invited. In what follows, I average the outcomes estimated by the regulatory impact analysis in the four different scenarios (two emissions guidelines that can be met by either single-state or regional action). Because the differences in outcomes stemming from the four different scenarios are quite small, this averaging approach does not compromise the overall findings.

The main driver of these direct effects on employment is simply the change in electricity generation: both overall and by type (summarized below in Table 1). Throughout this paper economic impacts (whether electrical generation, prices, or job-flows) of the CPP will be expressed relative to a baseline estimated by the EPA regarding the likely path of these variables if the CPP were not implemented. Relative to this non-CPP baseline projection for future electricity generation, the CPP leads to an 18.6 percent decline in coal-fired electricity generation by 2020, and a 26.1 percent decline by 2030. Renewables, conversely, rise by 6.4 percent by 2020 relative to the non-CPP baseline. By 2030, however, renewable generation is just 1.7 percent above the projected baseline. Natural gas generation rises by 14.6 percent relative to the non-CPP baseline by 2020, but by 2030 actually falls 5.7 percent. Besides the decline in coal-fired generation, the most striking finding in Table 1 is the decline in total generation, which is es-

**Table 1: Electricity Generation by Source, Baseline and Under CPP**

| | Total (MW) | | | | Share | | |
|---|---|---|---|---|---|---|---|
| | Baseline | Post-CPP | Change | % Change | Baseline | Post-CPP | P.p. change |
| **2020** | | | | | | | |
| Coal | 1,665 | 1,355 | 310 | -18.6% | 39.5% | 33.0% | -6.4% |
| Natural Gas | 1,159 | 1,328 | -169 | 14.6% | 27.5% | 32.4% | 4.9% |
| Nuclear | 817 | 817 | 0 | 0.0% | 19.4% | 19.9% | 0.6% |
| Hydro | 280 | 282 | -2 | 0.5% | 6.6% | 6.9% | 0.2% |
| Non-hydro renewables | 299 | 318 | -19 | 6.4% | 7.1% | 7.8% | 0.7% |
| Total | 4,220 | 4,100 | 120 | -2.8% | 100.0% | 100.0% | 0.0% |
| **2025** | | | | | | | |
| Coal | 1,702 | 1,315 | 387 | -22.7% | 38.7% | 32.1% | -6.6% |
| Natural Gas | 1,263 | 1,340 | -77 | 6.1% | 28.7% | 32.7% | 4.0% |
| Nuclear | 817 | 817 | 0 | 0.0% | 18.6% | 19.9% | 1.4% |
| Hydro | 280 | 282 | -2 | 0.6% | 6.4% | 6.9% | 0.5% |
| Non-hydro renewables | 335 | 344 | -9 | 2.7% | 7.6% | 8.4% | 0.8% |
| Total | 4,397 | 4,098 | 299 | -6.8% | 100.0% | 100.0% | 0.0% |
| **2030** | | | | | | | |
| Coal | 1,668 | 1,233 | 436 | -26.1% | 36.7% | 30.5% | -6.1% |
| Natural Gas | 1,455 | 1,372 | 83 | -5.7% | 32.0% | 34.0% | 2.0% |
| Nuclear | 797 | 797 | 1 | -0.1% | 17.5% | 19.7% | 2.2% |
| Hydro | 280 | 281 | -1 | 0.2% | 6.2% | 6.9% | 0.8% |
| Non-hydro renewables | 350 | 356 | -6 | 1.7% | 7.7% | 8.8% | 1.1% |
| Total | 4,550 | 4,038 | 513 | -11.3% | 100.0% | 100.0% | 0.0% |

Source: EPA Regulatory Impact Analysis of Clean Power rule (2014). Table 1's estimates average two options as well as state and regional compliance scenarios.

sentially a reflection of energy efficiency investments. Relative to the baseline, total generation falls 2.8 percent by 2020 and 11.3 percent by 2030.

The projected change in total electrical generation leads to corresponding changes in employment flows that are directly estimated by the EPA regulatory impact assessment. The directly estimated employment changes by category are summarized in an appendix in Table A1. Before presenting these findings on the direct employment flows, however, it is important to be specific about how these are expressed.

Again, each employment impact is relative to what would have occurred in the EPA's non-CPP baseline. Relative to this baseline, the EPA estimates a change in coal extraction in 2020, 2025, and 2030. In 2020, coal extraction employment is down 12,600 jobs relative to the no-CPP. This means that employment in coal mining is 12,600 lower than would otherwise be expected in that year because of the CPP. In 2025, coal extraction employment is down 15,300 relative to baseline. This does not mean that coal mining employment is 15,300 lower in 2025 than it was in 2020, but that the estimate is relative to that in a non-CPP world. Further, one cannot add the 2020 and 2025 estimates together and say that coal mining employment is reduced by 27,900 in 2025 due to the CPP. One can infer that the effect of the CPP on coal mining employment between 2020 and 2025 is a reduction of 2,700 (the difference between 15,300 and 12,600). Qualitatively, this means that the bulk of the effect of the CPP on coal mining extraction occurs before 2020, and that the rule's drag on coal extraction employment thereafter is less intense (though it does still grow).

### INDENTIFYING THE SPECIFIC INDUSTRIES AFFECTED BY THE EPA EMPLOYMENT ESTIMATES

Indirect employment effects associated with the direct employment consequences identified in the regulatory impact analysis will lean heavily on being able to use input-output (or employment requirements) matrices to identify supplier jobs associated with direct employment changes. This involves categorizing the direct employment losses identified in the CPP regulatory impact assessment into the 195 industrial sectors covered by the employment requirements matrices (ERM) that are available from the Bureau of Labor Statistics (BLS). The EPA analysis of employment changes by economic activity detailed in Table A1 can be translated into employment changes occurring in the industrial sectors in the ERM. The exact mapping of economic activity identified by the EPA employment estimates to an industrial classification is provided in Appendix C. The outcome of this mapping is summarized in Table 2, which presents employment changes by gaining and losing industries separately for each year as well as the net industry employment effects. I discuss the BLS ERM in greater detail in the next section.

## IV. INDIRECT EMPLOYMENT IMPACTS

By taking the EPA's direct estimates of first-round employment changes spurred by the CPP and calculating their indirect job impacts, this paper adds to the impact assessment of the CPP. In particular, because jobs in different industries can have very different levels of indirect employment associated with them, the EPA estimates on net job creation and displacement could be different or even change in sign from positive to negative when these indirect

**Table 2: Direct Employment Changes Estimated by the EPA, Mapped to Industrial Sectors**

| | Gains | | | Losses | | | Net | | |
|---|---|---|---|---|---|---|---|---|---|
| | 2020 | 2025 | 2030 | 2020 | 2025 | 2030 | 2020 | 2025 | 2030 |
| Oil and gas extraction | 5,050 | 2,700 | 0 | 0 | 0 | 2,000 | 5,050 | 2,700 | -2,000 |
| Coal mining | 0 | 0 | 0 | 12,600 | 15,300 | 17,300 | -12,600 | -15,300 | -17,300 |
| Electric power generation, transmission, and distribution | 0 | 0 | 0 | 11,663 | 20,425 | 24,300 | -11,663 | -20,425 | -24,300 |
| Construction | 16,160 | 3,203 | 1,313 | 0 | 0 | 0 | 16,160 | 3,203 | 1,313 |
| Plastics product manufacturing | 953 | 0 | 0 | 0 | 345 | 129 | 953 | -345 | -129 |
| Machine shops: hardware | 1,389 | 0 | 0 | 0 | 503 | 188 | 1,389 | -503 | -188 |
| Fabricated metal | 2,104 | 0 | 0 | 0 | 4,633 | 5,977 | 2,104 | -4,633 | -5,977 |
| HVAC equipment manufacturing | 20,573 | 17,269 | 17,440 | 0 | 0 | 0 | 20,573 | 17,269 | 17,440 |
| Engine, turbine, and power transmission equipment manufacturing | 12,970 | 0 | 0 | 0 | 5,107 | 8,048 | 12,970 | -5,107 | -8,048 |
| Machinery manufacturing | 2,937 | 0 | 0 | 0 | 1,064 | 398 | 2,937 | -1,064 | -398 |
| Communications equipment | 551 | 763 | 771 | 0 | 0 | 0 | 551 | 763 | 771 |
| Electric lighting manufacturing | 30,388 | 42,114 | 42,530 | 0 | 0 | 0 | 30,388 | 42,114 | 42,530 |
| Household appliance manufacturing | 2,624 | 3,637 | 3,673 | 0 | 0 | 0 | 2,624 | 3,637 | 3,673 |
| Electrical equipment manufacturing | 4,164 | 3,342 | 3,695 | 0 | 0 | 0 | 4,164 | 3,342 | 3,695 |
| Other electrical equipment and component manufacturing | 1,627 | 0 | 0 | 0 | 589 | 220 | 1,627 | -589 | -220 |
| Design services | 1,152 | 0 | 0 | 0 | 4,288 | 5,848 | 1,152 | -4,288 | -5,848 |
| Management, scientific, and technical consulting services | 8,113 | 0 | 0 | 0 | 0 | 0 | 8,113 | 0 | 0 |
| Scientific research and development services | 1,945 | 0 | 0 | 0 | 704 | 263 | 1,945 | -704 | -263 |
| Services to buildings and dwellings | 7,238 | 10,031 | 10,130 | 0 | 0 | 0 | 7,238 | 10,031 | 10,130 |
| Total | 119,938 | 83,059 | 79,552 | 24,263 | 52,959 | 64,672 | 95,675 | 30,100 | 14,880 |

Note: Following the mapping identified in Table A4 and based on the estimates of employment change by activity estimated in the EPA regulatory impact analysis.

effects are taken into account. In this section, I estimate three separate categories of indirect job impacts that are spurred by the first-round employment changes documented in the regulatory impact assessment: supplier jobs, induced (or re-spending) jobs, and public sector jobs. I label the total of these influences as the "employment multiplier." [2]

2 The employment multipliers for all 195 industries are available upon request.

### SUPPLIER JOBS, MATERIALS

Supplier jobs are generally the most intuitive category of indirect employment changes. Put simply, when jobs are lost in one industry sector, the sectors that provide inputs and materials also suffer losses. Take a concrete example: when coal mining activity shrinks, it leads to a reduction in demand for industries that provide inputs to coal mining, such as those that provide safety equipment, industrial equipment, and/or transportation equipment.

Supplier job estimates can be calculated directly from the BLS ERM. The ERM shows how many jobs are supported by $1 million in final demand in a given sector; jobs both in the sector directly satisfying the final demand as well as ones supplying inputs. For example, each $1 million in final demand for construction services supports jobs in the construction sector, but also supports jobs in concrete production, bulldozer manufacturing, and accounting services. The ERM tracks how many jobs in these supplier industries are supported by each $1 million in construction services purchased.

Because the ERM is set up in terms of dollar flows rather than job flows, translating the direct employment impacts identified by the CPP regulatory impact assessment into supplier jobs requires a small manipulation. Specifically, I take the ratio of jobs supported by a given amount of spending in a sector that are supplier jobs to direct jobs, and then multiply this by the number of direct jobs identified in the CPP regulatory impact assessment. The estimate for supplier jobs supported by each 100 direct jobs in a given sector is calculated using:

$$((ER_{total} - ER_{direct}) / ER_{direct}) * 100$$

**SUPPLIER JOBS, CAPITAL SERVICES**

One weakness of the BLS ERM is that it does not account for the depreciation of capital goods (plant and equipment and structures) that is caused by production. For very capital-intensive industries – and utilities and extraction are both notably capital-intensive – this could have non-trivial impacts on jobs supported.

To correct this, I estimate the number of jobs associated with producing the capital goods that would be needed to replace the amount of depreciation associated with 100 direct jobs in an industry. First, I estimate the value of capital services used in each industry's production. To do this, I use data from the BLS data series on multi-factor productivity (MFP), which provides data on the capital share of output (that is, the share of income generated by each industry that goes to pay owners of capital goods rather than workers). Combining industry output with the capital share provides an estimate of the amount of new capital goods that must be produced each period to replace this capital service flow. Essentially, capital-intensive industries will have to spend more money to replace capital services that are used up during production. Because I begin with a given number (100) of jobs (rather than output) in each industry, calculating industry output again requires a small manipulation of the data. The first expression in parentheses below shows how output (measured in dollars) per each 100 workers in a given industry can be calculated. This output measure is then multiplied by the capital share to give the expression for depreciation (or capital service inputs) associated with each industry.

$$(\$1,000,000/ER_{direct}) * 100 * \text{Capital share of output} = \text{Depreciation}$$

This measure of depreciation is then used to estimate industry capital demand. Based on ratios that approximately reflect the economy-wide division of aggregate capital investment to structures versus equipment, I assume that 40 percent of this total spending flows into construction to replace new structures and 60 percent flows into equipment manufacturing to replace machinery. From here, the formula for supplier jobs to replace the depreciation involved with every 100 direct jobs in a given industry is:

$$ER_{total\_equipment} * (Depreciation / \$1,000,000) * 0.6 + ER_{total\_structures} * (Depreciation / \$1,000,000) * 0.4$$

**INDUCED (OR RE-SPENDING) JOBS**

Another category of indirect jobs concerns those that are supported by the demand that relies on the wage and salary income of direct jobs. For example, each 100 jobs in construction also supports jobs in restaurants and diners where construction workers eat, grocery stores where they shop for food, and doctors' offices where they pay for medical services.

The scale of induced jobs supported by each 100 direct jobs depends on the overall "re-spending multiplier." Bivens (2006) reviewed evidence on this multiplier and takes 0.5 as a conservative estimate of this effect. Induced jobs also depend on the relative wages of both direct and supplier industries. As an example, if automobile assembly jobs have wages that are 50 percent higher than the economy-wide average wage, this would lead to spending induced by each 100 jobs in that sector being 50 percent higher than the economy-wide average, making the induced spending multiplier this much higher. Further, if the supplier jobs supported by automobile assembly (steel, iron, glass, etc.) pay higher-than-average wages, then this will also increase the induced spending multiplier for the automobile assembly sector.

I index hourly wages by industry to establish an economy-wide average of one. From here, we can express the induced jobs supported by each 100 direct jobs in an industry as simply 100 times the index of average hourly wages in the industry times 0.5 (our re-spending multiplier). For supplier jobs, I multiply the (195 sector) vector of supplier jobs associated with a given 100 jobs in the direct industry by each industry's average hourly wage index, multiply by 0.5 (the re-spending multiplier) and then sum to estimate the induced spending from supplier jobs associated with direct employment in a given sector.

**PUBLIC SECTOR JOBS**

Finally, we can estimate the number of public sector jobs (federal, state, and local) associated with each 100 direct jobs in an industry. This measure differs across industries based on the relative wage of the industry. To generate the inputs for this calculation, I multiply each industry's hourly wage by 2,000 to express it as a full-time, full-year salary. For federal taxes, I multiply this by 0.2, and for state and local taxes, by 0.1. This provides a rough measure of the tax revenue supported by each job in an industry.

I then use Census data to obtain estimates of overall tax revenue and employment in federal, state, and local governments. Dividing total tax revenue by employment, I get a measure of how much tax revenue is required to support a public sector employee in federal versus state and local government employment. I then divide the tax revenue generated by each 100 jobs in a given industry by this per employee wage bill to get a measure of public sector employment generated.

**SUMMING UP THE INDIRECT EFFECTS OF CHANGING INDUSTRY EMPLOYMENT**

Table 3 below provides a summary of the indirect effects for each of the direct industry job flows estimated by the EPA. The largest multipliers, by a considerable margin, are in the oil and gas mining sector and the utilities sector. Large multipliers also are found in most of the manufacturing industries that receive considerable direct job flows, particularly the household appliance manufacturing sector. The net effect of the job multipliers is to increase the total net employment impact spurred by the direct spending flows that occur due to the CPP in the near-term. That is, in 2020, approximately 95,000 more jobs are generated directly through energy efficiency investments, heat rate investments, and the construction of new capacity than are displaced directly from coal plants retiring early and mining jobs being displaced. Further, 264,000 more jobs are generated when indirect effects are considered. However, by 2030 the estimated job gains are smaller than the direct employment flows would indicate. This is due largely to two influences: first, direct job creation in later years is expected to ebb because renewable and natural gas generation investments triggered by the CPP largely represent an acceleration of investments that would have occurred eventually even in the absence of the CPP; second, the employment multipliers of jobs in EGUs and coal mining are large, and these sectors are projected to shed jobs even in the medium- and longer-term horizons.

## V. PRICE EFFECTS ON EMPLOYMENT

There will also be job effects stemming from the rise in electricity prices projected to result from the new rule. On average across the four scenarios ("Option 1 and 2" and "State and Regional" approaches), the electricity price increase by 2020 will be 5 percent, and will decline to 2.7 and 2.9 percent in 2025 and 2030 respectively. Economic theory is far from settled on how the rise in a single price in the economy will affect economy-wide employment. In this section, I provide some broad parameters about the possible impacts, and then offer some evidence from simple regressions to assess the impact of electricity price changes on employment.

In order to establish some parameters to check the plausibility of regression results, assume first that the entire 5 percent increase in electricity prices leads to no reduction in demand from consumers. Multiply this 5 percent by electricity's share in the total economy (2.4 percent)[3] and this translates to a 0.12 percent decline in economy-wide demand for goods and services besides electricity. That is, by having to pay 5 percent more for electricity and not adjusting their demand at all, American households now have 0.12 percent less to spend on non-electricity goods and services. Given that economy-wide consumption spending in 2013 was roughly $11.5 trillion, this implies roughly a $14 billion decline in purchasing power. Given that each job in the US economy is associated with roughly $140,000 in gross domestic product, this $14 billion decline in purchasing power in turn translates into roughly 100,000 jobs that would be displaced by a demand reduction of this magnitude.[4]

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3 Electricity's share in the total economy is based on data from 2013 using data collected by the Bureau of Economic Analysis (BEA).

4 For translating changes in spending flows and gross domestic product (GDP) into jobs, see Bivens (2011).

**Table 3: Estimating Indirect Employment Effects from Changes in Industry Demand**

| | Direct Jobs | | | Indirect Effects per 100 Direct Jobs | | | | | | | Total Indirect Jobs | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Supplier Jobs | | Respending Jobs | | Public Jobs | | | | | |
| | 2020 | 2025 | 2030 | Materials | Capital Services | Direct | Indirect | Federal | State + Local | Total | 2020 | 2025 | 2030 |
| Oil and gas extraction | 5,050 | 2,700 | -2,000 | 271.9 | 200.0 | 29.0 | 158.6 | 4.2 | 9.9 | 673.5 | 34,013 | 18,185 | -13,470 |
| Coal mining | -12,600 | -15,300 | -17,300 | 89.7 | 61.9 | 60.7 | 48.6 | 2.4 | 5.8 | 269.0 | -33,895 | -41,158 | -46,538 |
| Electric power generation, transmission and distribution | -11,663 | -20,425 | -24,300 | 152.7 | 187.9 | 47.9 | 72.0 | 2.7 | 6.3 | 469.5 | -54,761 | -95,905 | -114,100 |
| Construction | 16,160 | 3,203 | 1,313 | 40.8 | 32.7 | 72.0 | 21.5 | 2.1 | 4.9 | 173.9 | 28,104 | 5,571 | 2,284 |
| Plastics product manufacturing | 953 | -345 | -129 | 99.6 | 24.6 | 55.9 | 50.7 | 2.4 | 5.6 | 238.8 | 2,275 | -824 | -308 |
| Machine shops: hardware | 1,389 | -503 | -188 | 54.7 | 19.8 | 43.0 | 28.5 | 1.6 | 3.8 | 151.4 | 2,103 | -762 | -285 |
| Fabricated metal | 2,104 | -4,633 | -5,977 | 101.7 | 18.8 | 47.1 | 52.4 | 2.2 | 5.2 | 227.5 | 4,787 | -10,541 | -13,598 |
| HVAC equipment manufacturing | 20,573 | 17,269 | 17,440 | 144.8 | 54.8 | 41.4 | 75.0 | 2.6 | 6.1 | 324.7 | 66,797 | 56,069 | 56,623 |
| Engine, turbine and power transmission equipment manufacturing | 12,970 | -5,107 | -8,048 | 166.2 | 64.5 | 53.3 | 85.9 | 3.1 | 7.3 | 380.4 | 49,333 | -19,426 | -30,613 |
| Machinery manufacturing | 2,937 | -1,064 | -398 | 148.7 | 29.7 | 63.6 | 76.0 | 3.1 | 7.3 | 328.4 | 9,645 | -3,494 | -1,306 |
| Communications equipment | 551 | 763 | 771 | 137.7 | 72.1 | 46.8 | 76.0 | 2.7 | 6.5 | 341.8 | 1,882 | 2,608 | 2,634 |
| Electric lighting manufacturing | 30,388 | 42,114 | 42,530 | 126.5 | 48.7 | 75.5 | 66.8 | 3.2 | 7.5 | 328.2 | 99,720 | 138,199 | 139,564 |
| Household appliance manufacturing | 2,624 | 3,637 | 3,673 | 198.1 | 75.3 | 65.5 | 102.0 | 3.7 | 8.8 | 453.5 | 11,903 | 16,495 | 16,658 |
| Electrical equipment manufacturing | 4,164 | 3,342 | 3,695 | 82.7 | 27.3 | 64.5 | 43.2 | 2.4 | 5.7 | 225.8 | 9,402 | 7,547 | 8,344 |
| Other electrical equipment and component manufacturing | 1,627 | -589 | -220 | 108.9 | 35.3 | 59.2 | 56.8 | 2.6 | 6.1 | 268.8 | 4,374 | -1,584 | -592 |
| Design services | 1,152 | -4,288 | -5,848 | 31.4 | 28.1 | 61.0 | 18.2 | 1.8 | 4.2 | 144.7 | 1,666 | -6,203 | -8,460 |
| Management, scientific and technical consulting services | 8,113 | 0 | 0 | 47.5 | 32.1 | 47.7 | 30.2 | 1.7 | 4.1 | 163.3 | 13,251 | 0 | 0 |
| Scientific research and development services | 1,945 | -704 | -263 | 80.7 | 48.7 | 46.6 | 48.3 | 2.1 | 5.0 | 231.4 | 4,499 | -1,630 | -609 |
| Services to buildings and dwellings | 7,238 | 10,031 | 10,130 | 16.7 | 12.3 | 85.2 | 9.3 | 2.1 | 5.0 | 130.6 | 9,455 | 13,104 | 13,233 |
| Total | 95,675 | 30,100 | 14,880 | | | | | | | | 264,554 | 76,252 | 9,462 |

Note: Direct jobs by industry from Table 2 and Table A4. Indirect effects estimated using method described in text.

But, of course, this assumption of no demand response is extremely strong, responsiveness of consumers to energy price increases (or the elasticity of demand for electricity) may be relatively low in the short-run, but is expected to be greater than zero and there is strong evidence that it rises sharply over time [see Maddala et al. (1997)].

If one made a strong assumption in the opposite direction, that a 5 percent increase in the price of electricity was met immediately by a 5 percent reduction in demand for electricity (implying an elasticity of demand of one), then there would be no overall demand effect stemming from reduced consumer spending; consumers would simply shift their spending away from electricity and towards other goods and services.

This thought experiment helps to establish some parameters for what a reasonable estimate of the employment response to an electricity price increase should be based simply on consumers' responses. Given that consumer spending is two-thirds of the US economy, the employment response due to changes in consumer spending is expected to be a large part of the total employment effects.[5] Any estimates of job declines that are much larger than the hig end of these rough benchmarks essentially need to be accompanied by a compelling theoretical reason for why they are so large, since the high end of mechanical effects of higher electricity prices "crowding-out" spending on other goods seems well-defined for price increases of 5 percent or less.

## VI. REGRESSION ANALYSIS

I undertake two methods of regression analysis to assess the impact of higher electricity prices on overall employment. First, I use a vector autoregression of total non-farm payroll employment on changes in electricity prices (following Killian, 2013). By ordering electricity prices first, and making the assumption that employment changes in a given month do not affect electricity price changes in that same month, the results can be interpreted as the causal effect of electricity price changes on employment. Second, I assemble a panel dataset of states from 1976 to 2013 to test how changes in electricity prices correlate with employment changes. For this set of regressions I follow Deschenes (2009).

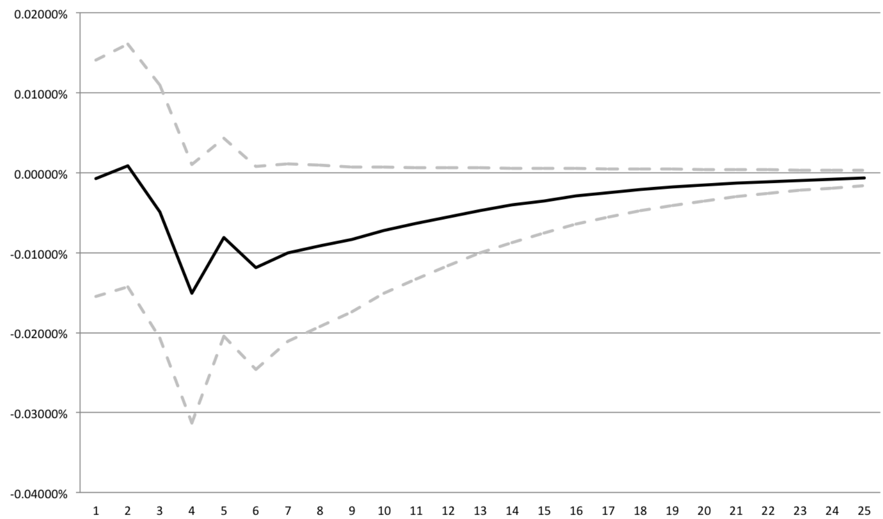
### VECTOR AUTOREGRESSION ESTIMATES

For the vector autoregression test, I use data on non-farm payroll employment and electricity price data from the consumer price index (CPI), both from the BLS. I run a vector autoregression with electricity prices ordered first. To assess the effect of higher electricity prices on employment, I simulate the effect of an electricity price shock. Figure 1 shows the results of this "impulse response function," showing how employment responds to a one standard deviation shock to electricity prices.

The data shows a clear pattern of a quick decline in employment that converges back towards zero effect. The magnitudes (0.015 percent) multiplied by the 2014 workforce of roughly

5 The labor supply effects of such an electricity price increase are likely to be considerably smaller. The 5 percent increase in electricity prices represents roughly a 0.12 percent reduction in real wages. Typical labor supply elasticities range from 0.1 to 0.3, so this implies a 0.0036 percent reduction in labor supply at most, or roughly 5,400 fewer jobs stemming from workers' voluntary labor supply decisions.

**Figure 1: VAR Impluse Response of Employment to 1 SD Shock to Electricity Prices**




Note: Impulse response estimated from VAR regression of monthly payroll employment and monthly electricity prices and their own-lags, with payroll employment ordered first. Ninety-five percent confidence interval shown in shaded lines. Data on monthly employment from the BLS Current Employment Statistics, and data on electricity prices from the Consumer Price Index from BLS.

140 million) suggest an employment decline of nearly 20,000 (0.015 percent, as indicated on the figure) after four months, and then a fade-out of more than 90 percent of the effect within a year (with the remaining negative effect no longer statistically significant). A one standard deviation shock to electricity prices in this data is 4 percent, so I multiply the employment decline from the impulse response function by 5/4 to estimate the employment impact of a 5 percent increase in electricity prices generated by the CPP, giving a final point estimate of 25,000 jobs displaced by higher electricity prices.

## STATE PANEL REGRESSIONS

The state/year panel results are summarized in Appendix Table A4. This table shows the results of a regression that uses the log of the level of state employment on the log of electricity prices across states. The employment data comes from the BLS, while state-level electricity price data comes from the State Energy Data Service (SEDS). This electricity price used is the average retail price for all end-users in each year between 1979 and 2012.

The preferred specification is shown in column 3 of Table A4 which controls for time and year fixed effects, state-level time-trends, and the unemployment gap (which is important to include as it seems to be absorbing some employment variation not controlled for in the state, year, and time-trend dummy variables). The data covers the period from 1979 to 2012. For this specification, the coefficient of employment on energy prices is -0.017. This implies that a 10 percent change in electricity prices reduces employment by 0.17 percent, or that a 5 percent increase in electricity prices (as forecast by the CPP regulatory impact assessment) will reduce employment by 0.085 percent, or just under 100,000 jobs.

As noted by Deschenes (2009), this is best interpreted as the short-run effect on employment of unanticipated increases in electricity prices. Electricity price changes that are fully anticipated and take some time before implementation should be expected to be significantly smaller.

Higher results are gained if the sample is cut off in 2008 (as is done in columns 4 to 7 of Table A4). Here, the coefficient estimates suggest job-losses of over 150,000 in the specification (column 6) that includes all other controls. It is unclear why including the latest five years of data changes the results to such a great extent, but it is regarded as more robust to proceed with including more data rather than less.

Finally, regressions that used state/industry cells as the unit of analysis are reported. The employment data let us examine 13 separate industrial sectors within states. Despite the larger sample size, the overall coefficient on state/industry employment in this larger panel never achieved statistical significance. Later sections focus just on manufacturing employment across states and do find significant and disproportionate job losses in this sector that are correlated with electricity price differences.

### COMBINING THE VAR AND STATE-PANEL REGRESSION RESULTS

The two different regression techniques provide results that span most of the plausible variation identified in the introduction to this section. The results range from 20,000 to 100,000 in the preferred specifications, with 150,000 in the panel regression with the time-period truncated in 2008.

Lacking any better alternative, I average the results provided by each method to establish the point estimate of the employment impact of higher energy prices. This gives a net increase of 75,000 jobs (the average of 25,000 and 125,000). Further, given the sharp fadeout of negative employment impacts in the vector autoregression, the interpretation of state panel regression results as measuring the responsiveness of employment to unanticipated short-run electricity price changes, and the evidence that the long-run elasticity of demand with respect to electricity prices is much larger than the short-run elasticity, I can only be confident about these negative price effects for the first year examined in the regulatory impact assessment - 2020.

## VII. TOTAL NET EMPLOYMENT IMPACTS

Table 4 provides the final tally on employment impacts, showing gross gains and gross losses by each employment channel: direct effects, indirect effects, and price effects.

The negative price effects are not large enough to swamp the positive net effect of tallying the direct and indirect job flows. The key driver of these positive net effects is the large increase in energy efficiency investments. These investments are large in direct scale (accounting for more than half of the total direct gross gains in 2020, and accounting for essentially all the gross gains in 2025 and 2030), and also tend to have higher-than-average employment multipliers as well. These energy efficiency investments also implicitly drive a large part of the generation response, as an overall decline in electricity use of roughly 11 percent is spurred by the rule relative to the baseline in 2035.

**Table 4: Summing Up Employment Effects of Each Channel**

| | Gains | | | Losses | | | Net | | |
|---|---|---|---|---|---|---|---|---|---|
| | 2020 | 2025 | 2030 | 2020 | 2025 | 2030 | 2020 | 2025 | 2030 |
| Direct | 119,938 | 83,059 | 79,552 | 24,263 | 52,959 | 64,672 | 95,675 | 30,100 | 14,880 |
| Indirect | 353,210 | 257,778 | 239,342 | 88,656 | 181,526 | 229,880 | 264,554 | 76,252 | 9,462 |
| Supplier | 136,504 | 99,634 | 92,687 | 29,117 | 62,884 | 80,644 | 107,387 | 36,750 | 12,042 |
| K-services | 60,433 | 41,848 | 36,268 | 29,713 | 54,273 | 68,722 | 30,720 | -12,424 | -32,453 |
| Induced, direct | 72,723 | 55,477 | 54,058 | 13,237 | 28,358 | 34,056 | 59,486 | 27,118 | 20,002 |
| Induced, indirect | 72,664 | 52,718 | 48,639 | 14,511 | 31,528 | 40,849 | 58,153 | 21,190 | 7,789 |
| Federal | 3,230 | 2,404 | 2,281 | 616 | 1,330 | 1,664 | 2,613 | 1,073 | 617 |
| State/Local | 7,656 | 5,697 | 5,408 | 1,461 | 3,154 | 3,944 | 6,195 | 2,544 | 1,463 |
| Direct +Indirect | 473,147 | 340,837 | 318,894 | 112,918 | 234,486 | 294,552 | 360,229 | 106,352 | 24,342 |
| Prices | 0 | 0 | 0 | -75,000 | 0 | 0 | -75,000 | 0 | 0 |
| Total | 473,147 | 340,837 | 318,894 | 37,918 | 234,486 | 294,552 | 285,229 | 106,352 | 24,342 |

Note: Summary of all previous effects by channel

In 2020, total net employment changes resulting from the rule total to an employment gain of 285,000 jobs. This net gain drops off rapidly in 2025 and 2030 but remains positive, assuming that price effects are no longer significantly impacting employment in 2025 and 2030.

### SENSITIVITY CHECK ON ENERGY EFFICIENCY JOBS AND FULL-TIME EQUIVALENTS

The EPA regulatory impact assessment's estimates of jobs supported by energy efficiency investments include a caution that these are not expressed as full-time equivalents, while the other direct job flows are. This could potentially bias the estimate of jobs supported through these investments upwards. My primary estimate of employment changes has not adjusted the overall numbers for this caution, mostly because the gap between total and full-time equivalent employment in sectors heavily represented in energy efficiency investments (mostly manufacturing and construction) is very small. However, I did experiment with adjusting the jobs supported by energy efficiency investments downward by the economy-wide ratio of full-time equivalents to overall employment, with the results shown in Appendix Table A5. This adjustment leads to a roughly 10 percent reduction in jobs supported by energy efficiency investments, which in turn leads to direct plus indirect job gains in 2020 falling to roughly 330,000 (down from 360,000 reported in earlier results), and to small net job losses in these categories by 2030 (less than 15,000).

It is worth noting that in a well-functioning economy (i.e., one without substantial degrees of economic slack and one no longer stuck in the liquidity trap that has characterized much of the past six years in the American economy), any significant impact on economy-wide employment – either positive or negative – would likely be met by a countervailing response from the Federal Reserve. In a sense, the job of the Fed is precisely to make sure that the economy-wide employment response to any shock like the CPP is zero. However, the Fed's countervailing response may be imperfect, and it is useful to know which direction the Fed will have to push the economy following the implementation of the CPP. And, as I note below, the geographic distribution of gains and losses means that even if the Fed fully sterilized the national employment impacts of the CPP, impacts that differ across regions would remain.

## VIII. COMPARISON OF JOB COMPOSITION OF GAINING VERSUS LOSING INDUSTRIES

In addition to changes in employment levels, policymakers may also be interested in changes in the composition of jobs spurred by labor market responses to the CPP. This section combines information from the BLS ERM and demographic and labor market data from the Current Population Survey (CPS) to predict the characteristics of workers that populate the jobs either displaced or created by the CPP.

I use the CPS to estimate the share of each industry's workforce by gender, race, educational attainment, union status, and wage-level. I then multiply these shares by the total number of jobs displaced or created by the CPP. I present the results separately for gaining and losing industries in Tables 5 and 6.

The broad summary of differences in job composition between gaining and losing industries can be summarized briefly: losing industries tend to have fewer workers with a four-year college degree (19.8 percent versus 29.8 percent) and yet have fewer low-wage and more middle-wage jobs. This is likely in part because jobs in losing industries are significantly more unionized than in gaining industries (19.8 percent versus 9.0 percent). Jobs in both gaining and losing industries have higher shares of male workers and white workers than economy-wide averages.

**Table 5: Composition of Jobs in Gaining Industries**

| | Jobs Gained | | | | | Percentage of Jobs Gained | | | | | Economy-Wide Average (%) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Direct | Supplier | Direct + Supplier | K-Input | Total | Direct (%) | Supplier (%) | Direct + Supplier (%) | K-Input (%) | Total (%) | |
| Totals | 119,938 | 136,504 | 256,441 | 59,969 | 316,410 | 37.9 | 43.1 | 81.0 | 19.0 | 100.0 | 100.0 |
| Gender | | | | | | | | | | | |
| Male | 87,464 | 99,434 | 186,898 | 51,464 | 238,363 | 72.9 | 72.8 | 72.9 | 85.8 | 75.3 | 51.5 |
| Female | 32,474 | 37,069 | 69,543 | 8,504 | 78,047 | 27.1 | 27.2 | 27.1 | 14.2 | 24.7 | 48.5 |
| Race | | | | | | | | | | | |
| Non-Hispanic white | 84,543 | 99,750 | 184,293 | 39,743 | 224,036 | 70.5 | 73.1 | 71.9 | 66.3 | 70.8 | 66.2% |
| Non-Hispanic black | 9,259 | 11,067 | 20,326 | 3,313 | 23,639 | 7.7 | 8.1 | 7.9 | 5.5 | 7.5 | 10.9 |
| Hispanic | 17,808 | 15,792 | 33,600 | 13,714 | 47,314 | 14.8 | 11.6 | 13.1 | 22.9 | 15.0 | 15.8 |
| Asian (including Pacific islander) | 6,700 | 8,048 | 14,748 | 2,330 | 17,078 | 5.6 | 5.9 | 5.8 | 3.9 | 5.4 | 5.3 |
| Other | 1,627 | 1,848 | 3,475 | 869 | 4,344 | 1.4 | 1.4 | 1.4 | 1.4 | 1.4 | 1.7 |

### Table 5: Composition of Jobs in Gaining Industries (continued)

| | Jobs Gained | | | | | Percentage of Jobs Gained | | | | | Economy-Wide Average (%) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Direct | Supplier | Direct + Supplier | K-Input | Total | Direct (%) | Supplier (%) | Direct + Supplier (%) | K-Input (%) | Total (%) | |
| **Age** | | | | | | | | | | | |
| Less than 25 years | 9,135 | 9,367 | 18,502 | 5,701 | 24,203 | 7.6 | 6.9 | 7.2 | 9.5 | 7.6 | 14.6 |
| 25–54 | 89,897 | 101,761 | 191,658 | 45,875 | 237,533 | 75.0 | 74.5 | 74.7 | 76.5 | 75.1 | 70.0 |
| 55 years and older | 20,905 | 25,376 | 46,281 | 8,392 | 54,673 | 17.4 | 18.6 | 18.0 | 14.0 | 17.3 | 15.4 |
| **Union Status** | | | | | | | | | | | |
| Covered | 9,847 | 11,034 | 20,880 | 7,739 | 28,619 | 8.2 | 8.1 | 8.1 | 12.9 | 9.0 | 10.7 |
| Not covered | 110,091 | 125,470 | 235,561 | 52,230 | 287,791 | 91.8 | 91.9 | 91.9 | 87.1 | 91.0 | 89.3 |
| **Education** | | | | | | | | | | | |
| Less than high school | 11,201 | 8,911 | 20,112 | 9,923 | 30,035 | 9.3 | 6.5 | 7.8 | 16.5 | 9.5 | 9.7% |
| High school only | 38,404 | 43,819 | 82,223 | 22,706 | 104,929 | 32.0 | 32.1 | 32.1 | 37.9 | 33.2 | 28.2 |
| Some college | 32,686 | 38,874 | 71,560 | 15,536 | 87,096 | 27.3 | 28.5 | 27.9 | 25.9 | 27.5 | 29.8 |
| Bachelor's only | 25,780 | 30,394 | 56,173 | 8,811 | 64,984 | 21.5 | 22.3 | 21.9 | 14.7 | 20.5 | 21.4 |
| Advanced degree | 11,867 | 14,506 | 26,373 | 2,993 | 29,366 | 9.9 | 10.6 | 10.3 | 5.0 | 9.3 | 11.0 |
| **Wage Quintile** | | | | | | | | | | | |
| First (lowest) | 10,609 | 9,311 | 19,921 | 5,360 | 25,281 | 8.8 | 6.8 | 7.8 | 8.9 | 8.0 | 20.50 |
| Second | 19,151 | 19,837 | 38,989 | 10,796 | 49,785 | 16.0 | 14.5 | 15.2 | 18.0 | 15.7 | 19.6 |
| Third | 26,581 | 30,669 | 57,251 | 14,156 | 71,407 | 22.2 | 22.5 | 22.3 | 23.6 | 22.6 | 20.0 |
| Fourth | 31,151 | 37,126 | 68,277 | 15,496 | 83,774 | 26.0 | 27.2 | 26.6 | 25.8 | 26.5 | 20.0 |
| Fifth (highest) | 32,444 | 39,560 | 72,004 | 14,160 | 86,164 | 27.1 | 29.0 | 28.1 | 23.6 | 27.2 | 20.0 |

Note: Job estimates do not include spending effects. Employment shares for each industry represent pooled data from 2009–2012.
Source: Author's analysis of Current Population Survey Outgoing Rotation Group microdata and BLS employment requirements matrices, as described in text.

## Table 6: Composition of Jobs in Losing Industries

| | Jobs Gained | | | | | Percentage of Jobs Gained | | | | | Economy-Wide Average (%) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Direct | Supplier | Direct + Supplier | K-Input | Total | Direct (%) | Supplier (%) | Direct + Supplier (%) | K-Input (%) | Total (%) | |
| Totals | 24,263 | 29,117 | 53,379 | 29,115 | 82,494 | 29.4 | 35.3 | 64.7 | 35.3 | 100.0 | 100.0 |
| Gender | | | | | | | | | | | |
| Male | 21,034 | 24,665 | 45,699 | 24,986 | 70,685 | 86.7 | 84.7 | 85.6 | 85.8 | 85.7 | 51.5 |
| Female | 3,229 | 4,452 | 7,681 | 4,129 | 11,809 | 13.3 | 15.3 | 14.4 | 14.2 | 14.3 | 48.5 |
| Race | | | | | | | | | | | |
| Non-Hispanic white | 20,907 | 24,521 | 45,428 | 19,295 | 64,724 | 86.2 | 84.2 | 85.1 | 66.3 | 78.5 | 66.2 |
| Non-Hispanic black | 1,210 | 1,748 | 2,958 | 1,608 | 4,566 | 5.0 | 6.0 | 5.5 | 5.5 | 5.5 | 10.9 |
| Hispanic | 1,315 | 1,842 | 3,158 | 6,658 | 9,816 | 5.4 | 6.3 | 5.9 | 22.9 | 11.9 | 15.8 |
| Asian (including Pacific islander) | 224 | 342 | 566 | 1,131 | 1,697 | 0.9 | 1.2 | 1.1 | 3.9 | 2.1 | 5.3 |
| Other | 606 | 664 | 1,270 | 422 | 1,691 | 2.5 | 2.3 | 2.4 | 1.4 | 2.1 | 1.7 |
| Age | | | | | | | | | | | |
| Less than 25 years | 1,760 | 1,978 | 3,738 | 2,768 | 6,506 | 7.3 | 6.8 | 7.0 | 9.5 | 7.9 | 14.6 |
| 25–54 | 17,941 | 21,668 | 39,609 | 22,273 | 61,881 | 73.9 | 74.4 | 74.2 | 76.5 | 75.0 | 70.0 |
| 55 years and older | 4,562 | 5,471 | 10,032 | 4,074 | 14,107 | 18.8 | 18.8 | 18.8 | 14.0 | 17.1 | 15.4 |
| Union Status | | | | | | | | | | | |
| Covered | 5,559 | 7,025 | 12,585 | 3,757 | 16,342 | 22.9 | 24.1 | 23.6 | 12.9 | 19.8 | 10.7 |
| Not covered | 18,703 | 22,091 | 40,795 | 25,358 | 66,153 | 77.1 | 75.9 | 76.4 | 87.1 | 80.2 | 89.3 |
| Education | | | | | | | | | | | |
| Less than high school | 1,140 | 1,185 | 2,325 | 4,818 | 7,143 | 4.7 | 4.1 | 4.4 | 16.5 | 8.7 | 9.7 |
| High school only | 10,817 | 11,815 | 22,632 | 11,024 | 33,656 | 44.6 | 40.6 | 42.4 | 37.9 | 40.8 | 28.2 |
| Some college | 7,539 | 9,409 | 16,949 | 7,543 | 24,492 | 31.1 | 32.3 | 31.8 | 25.9 | 29.7 | 29.8 |
| Bachelor's only | 3,509 | 4,937 | 8,447 | 4,278 | 12,724 | 14.5 | 17.0 | 15.8 | 14.7 | 15.4 | 21.4 |
| Advanced degree | 1,257 | 1,770 | 3,027 | 1,453 | 4,480 | 5.2 | 6.1 | 5.7 | 5.0 | 5.4 | 11.0 |

**Table 6: Composition of Jobs in Losing Industries (continued)**

| | Jobs Gained | | | | | Percentage of Jobs Gained | | | | | Economy-Wide Average (%) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Direct | Supplier | Direct + Supplier | K-Input | Total | Direct (%) | Supplier (%) | Direct + Supplier (%) | K-Input (%) | Total (%) | |
| Wage Quintile | | | | | | | | | | | |
| First (lowest) | 714 | 853 | 1,567 | 2,602 | 4,169 | 2.9 | 2.9 | 2.9 | 8.9 | 5.1 | 20.5 |
| Second | 1,944 | 2,317 | 4,261 | 5,241 | 9,503 | 8.0 | 8.0 | 8.0 | 18.0 | 11.5 | 19.6 |
| Third | 4,032 | 4,804 | 8,836 | 6,873 | 15,709 | 16.6 | 16.5 | 16.6 | 23.6 | 19.0 | 20.0 |
| Fourth | 9,072 | 10,291 | 19,363 | 7,524 | 26,887 | 37.4 | 35.3 | 36.3 | 25.8 | 32.6 | 20.0 |
| Fifth (highest) | 8,502 | 10,851 | 19,352 | 6,875 | 26,227 | 35.0 | 37.3 | 36.3 | 23.6 | 31.8 | 20.0 |

Note: Job estimates do not include spending effects. Employment shares for each industry represent pooled data from 2009–2012.
Source: Author's analysis of Current Population Survey Outgoing Rotation Group microdata and BLS employment requirements matrices, as described in text.

## IX. SPECIFIC CHALLENGES POSED TO TRANSITION FROM LOSING INDUSTRIES

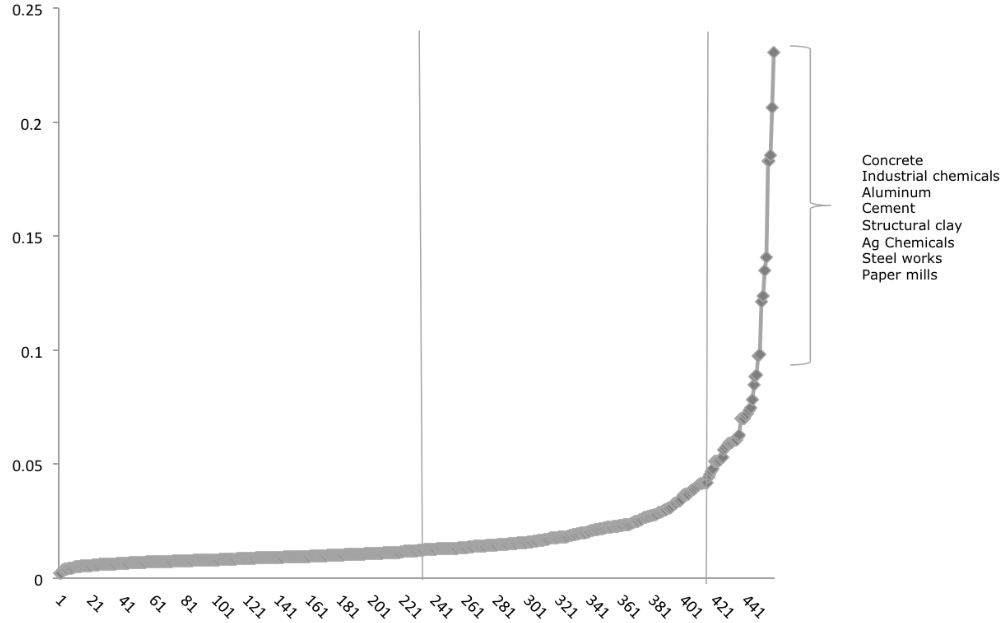
These indicators of job quality highlight some key of the challenges in managing the labor market transitions that are likely to result from the CPP. Specifically, workers displaced by the CPP tend to have less formal credentials than economy-wide averages and also skew older. Both of these characteristics correlate with lower re-employment probabilities and lower quality jobs when alternative employment is secured (Sum et al. 2011). Further, because jobs in losing industries pay higher-than-average wages even for a workforce that has fewer formal educational credentials, the expected wage-loss from displacement from these industries is expected to be higher.

Another transition issue comes from the disproportionate impact of job losses due to price effects on energy intensive, trade-exposed industries. As Figure 2 shows, there are a small number of manufacturing industries that have significantly higher energy cost shares than others, and so these industries may see a significant decline in their international competitive position if domestic policy (i.e., the CPP) made electricity significantly more expensive for them relative to the global competition.

I first examine whether or not manufacturing overall bears a disproportionate share of job losses stemming from price increases. Appendix Table A6 shows the results of the state/panel regressions examined earlier, but now with manufacturing employment as the dependent variable. In the preferred specification (column 2), the coefficient on electricity prices is larger than for overall employment (0.03 versus 0.017) and is statistically significant. Applying this coefficient result to the expected price change resulting from the CPP implies manufacturing job-loss of roughly 20,000, or about a fifth of the entire predicted job losses due to higher prices. Manufacturing employment is far below 10 percent of total employment, so this is clearly a disproportionate effect.

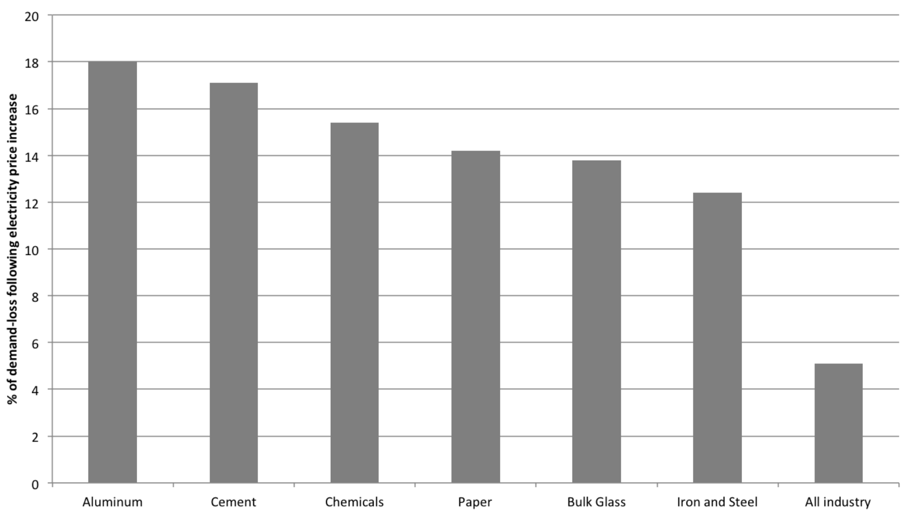
While manufacturing overall bears a disproportionate burden from price increases, this still leaves open the question of how much of this

**Figure 2: Energy Cost Shares Highly Skewed - Even in Manufacturing: Energy Costs as Percent of Gross Output**




Note: 445 NAICS manufacturing industries ranked in order of ascending energy cost shares. Vertical lines reading from left represent median and 90th percentile of energy cost intensity. Data on energy cost shares from the National Bureau of Economic Research (NBER) Productivity Database.

**Figure 3: Trade-Exposed, Energy-Intensive Industries and Rising Cost of Emissions: Share of Demand-Loss Stemming from Increased Electricity Prices Accounted for by Rising Net Imports**



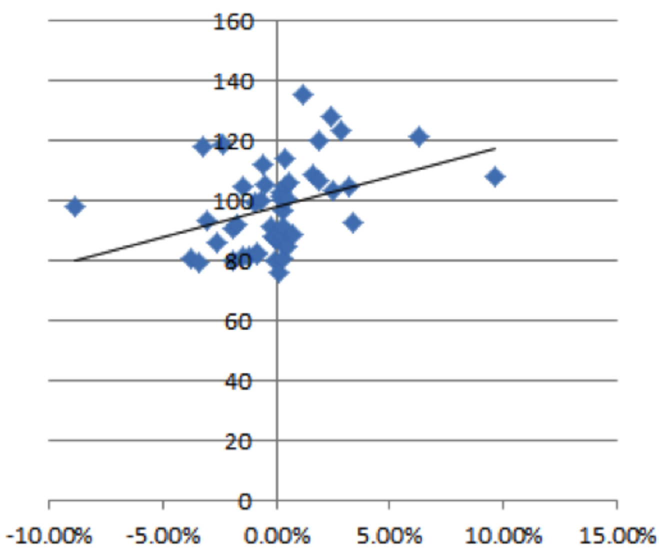

Note: Estimates taken directly from Aldy and Pizer (2014).

burden stems from eroded international competitiveness. Aldy and Pizer (2014) recently studied how much of output and employment declines stemming from increasing energy prices are the result of declining international competitiveness. Their results for overall manufacturing, as well as for some particularly energy-intensive sectors, are shown in Figure 3. For particularly energy-intensive industries, about one fifth of the entire output and employment decline stemming from higher energy prices is due to an eroded position in international markets.

Figure 4 highlights another concern related to transition challenges posed by the CPP. The drivers of job displacements in our analysis are the closure of coal-fired EGUs and the reduction in coal mining. The figure below adds together state employment in mining and a rough estimate of state employment in coal-fired EGUs and divides by total employment in the state, to gain a measure that can be thought of as potential exposure to job losses from the CPP.[6] It then plots this measure of potential exposure to job losses against each state's average per capita personal income. The key finding is that potential exposure to job displacements caused by the CPP seems likely to occur disproportionately in poorer states, which could hence have greater trouble finding resources to deal with the needed transitions. Because of this issue, and because the benefits of mitigating carbon emissions are national (indeed, global), this seems like a strong basis for federal policymakers to act to provide relief for states and communities that will have the largest necessary adjustments stemming from the CPP.

6 For the estimate of employment in EGUs by state, I allocate nation-wide employment in coal-fired plants by each state's share of national coal-fired electrical generation, using data from the Energy Information Association (EIA).

**Figure 4: State PCI vs Disproportionate Share of Direct Employment Losses**




**Note: PCI stands for Pulverized Coal Injection.**

## TRANSITION POLICIES

The President's Fiscal Year (FY) 2016 budget proposal included support for managing the transition to the CPP. This – so far unapproved – proposal included a new $4 billion fund to encourage states to make faster and deeper cuts to emissions from power plants, and an additional $2 billion tax credit for power plants that capture their carbon dioxide. These recommended financial supports indicate that the Administration acknowledges that a key downside to addressing greenhouse gas mitigation through regulation rather than legislation is that it has the potential to create market distortions that may require additional intervention. A legislative solution would have provided the opportunity to bundle job-creating investments and transition assistance as a combined policy package that raised the cost of fossil fuel energy production and triggered displacements from "dirty" to "clean" power. The regulatory approach does not offer that same opportunity. The legislative defeat of greenhouse gas mitigation approaches in 2009 made the regulatory track the only available option, and so it is vital that policymakers concerned about jobs and incomes take steps to blunt any economic harm caused by job displacements spurred by the CPP.

There are many such steps that could be taken. Possibly the most important includes ensuring the viability of the health and pensions funds of coal companies. Many retirees rely on this income and they should not be punished for policy changes that make company pension obligations untenable. Currently the United Mine Workers (UMW) multi-employer pension fund is roughly $1 billion short of being in actuarial balance, driven predominantly by the rapid shrinkage of the current workforce relative to retirees. Another significant blow to the level of the current workforce could be disastrous for the pension fund. The Obama Administration's FY2016 budget includes transfers to the UMW pension fund through the Pension Benefits Guaranty Corporation to insure the solvency of the plan. The FY2016 budget also boosts transfers to health plans administered by the UMW to insure their viability.

Another set of tools would aim to ameliorate the decline in industrial competitiveness that could accompany the rule. For example, if other countries undertook measures to raise the price of carbon emissions, this would stem the competitiveness loss. Signing international agreements that raise the cost of greenhouse gas emissions would be an effective policy tool to mitigate the negative effects of labor market transitions stemming from the rule (and would further make the rule more effective in stopping global emissions by stopping carbon-intensive production from simply "leaking" abroad to other countries that do not regulate or price emissions). Until such an international agreement is reached, the US could unilaterally impose a "border-adjustment" tariff based on the carbon-intensity of the production of imports. Such a tariff would make the global reduction in emissions stemming from the rule larger, would blunt the employment dislocation in the US caused by the rule, and is in fact necessary for preserving the principle of non-discrimination in trade relationships.

# X. CONCLUSION

The Clean Power Plan is the largest US undertaking to date aimed at mitigating the effects of global climate change. Given the vast importance of global climate change, this means that the impact of the CPP on economic, health, and environmental outcomes is likely to be quite large – and this is indeed what the EPA's own impact analysis of the rule shows. Yet much debate about the CPP (and indeed about nearly all environmental regulations) has focused on the narrower issue of employment changes spurred by the rule. Economic theory suggests that such employment changes are likely to be modest (see Goodstein 1997 and Bivens 2011). This paper offers a comprehensive account of the economic channels through which the rule's effects could alter US employment. It finds that these effects are relatively modest in the near-term, and are more likely to provide a small net boost in employment by 2020. After this, the net impacts of the rule on employment converge quickly to zero – becoming almost completely insignificant by 2030.

While the effect of the rule on employment levels is small (and positive), the concentration of job dislocations and the composition of jobs in the losing industries suggest that policymakers should consider complementary policies in order to adjust and to blunt some of the less desirable outcomes of the rule. The clearest virtue to addressing climate change and greenhouse gas emissions through legislation is precisely that such complementary policies can be bundled together with the mechanisms that reduce emissions. This virtue does not accompany the current efforts to limit greenhouse gas emissions through regulation. While a regulatory approach can be effective in achieving the primary target of reducing greenhouse gas emissions, it needs to be complemented with policies that will ensure groups of workers and communities bearing a disproportionate burden of adjustment are fairly compensated for this.

# XI. APPENDIX

## EPA ESTIMATES OF JOB-CHANGES BY ACTIVITY

Appendix Table 1 reports directly the EPA estimates of employment change by activity spurred by the CPP. It breaks out these employment changes by three different employment flows: (1) Operations and maintenance (O&M) employment in the electrical power generating sector, (2) construction of new EGUs and heat rate improvements to existing EGUs and energy efficiency investments, and (3) extraction of fossil fuels. As with Table 1 in the main text, the employment flows shown below in Appendix Table 1 average the four different estimates provided in the regulatory impact analysis (State versus Regional and Option 1 versus Option 2).

Appendix Table 1 provides the averaged estimates for each employment flow (O&M, construction, and extraction) in each year examined by the regulatory impact analysis (2020, 2025, and 2030). In 2020, construction of natural gas generating capacity increases, as does renewable generation, heat-rate improvement investments, and energy efficiency investments. The sum of this short-run construction activity is 123,000 additional jobs relative to baseline. In later years, however, this pulling forward of natural gas and renewable construction actually depresses construction jobs (relative to baseline) in 2025 and 2030. Energy efficiency investments, conversely, continue to grow through 2030, though at a slower pace.

The large negative impact of the CPP on coal-sector employment is obvious in O&M employment. O&M employment in coal-fired EGUs falls by nearly 20,000 by 2020, and stays about that depressed relative to baseline all the way through 2030. This is obviously consistent with the significant decline in coal-fired generation identified in Table 1. In the near-term natural gas O&M employment rises, while O&M employment in oil and gas plants falls. Over longer horizons, O&M employment in all fossil fuel generation (including natural gas) falls relative to baseline. In 2020, the sum total of O&M employment losses is just under 20,000, and this rises to roughly 24,000 jobs by 2030.

Losses in coal extraction are large and significant in all three years – 12,600 in 2020 rising to 17,300 by 2030. Natural gas extraction actually rises slightly in the near-term – up by 5,050 in 2020 but by 2030 is lower than baseline by 2,000 jobs. Again, the CPP pulls forward natural gas related jobs and leaves them lower in later years.

**Appendix Table 1: Direct Employment Changes Estimated by EPA RIA Relative to Baseline Under CPP, by Generating Source and Job Type**

| | Construction | O&M | Extraction | Total |
|---|---|---|---|---|
| 2020 | | | | |
| Coal | 0 | -19,400 | -12,600 | -32,000 |
| Natural Gas | 6,775 | 1,825 | 5,050 | 11,450 |
| Oil and Gas | 0 | -2,200 | 0 | |
| Nuclear | 0 | 0 | 0 | 0 |
| Hydro | 0 | 0 | 0 | 0 |
| Non-Hydro Renewable | 15,875 | 0 | 0 | 15,875 |
| Energy Efficiency | 67,900 | 0 | 0 | 67,900 |
| Heat-rate improvements | 32,450 | 0 | 0 | 32,450 |
| Total | 123,000 | -19,775 | -7,550 | 95,675 |
| 2025 | | | | |
| Coal | 0 | -17,800 | -15,300 | -33,100 |
| Natural Gas | -25,225 | -725 | 2,700 | -25,150 |
| Oil and Gas | 0 | -1,900 | 0 | |
| Nuclear | 0 | 0 | 0 | 0 |
| Hydro | 0 | 0 | 0 | 0 |
| Non-Hydro Renewable | -5,750 | 0 | 0 | -5,750 |
| Energy Efficiency | 94,100 | 0 | 0 | 94,100 |
| Heat-rate improvements | 0 | 0 | 0 | 0 |
| Total | 63,125 | -20,425 | -12,600 | 30,100 |
| 2030 | | | | |
| Coal | 0 | -18,950 | -17,300 | -36,250 |
| Natural Gas | -34,400 | -3,300 | -2,000 | -41,750 |
| Oil and Gas | 0 | -2,050 | 0 | |
| Nuclear | 0 | 0 | 0 | 0 |
| Hydro | 0 | 0 | 0 | 0 |
| Non-Hydro Renewable | -2,150 | 0 | 0 | -2,150 |
| Energy Efficiency | 95,030 | 0 | 0 | 95,030 |
| Heat-rate improvements | 0 | 0 | 0 | 0 |
| Total | 58,480 | -24,300 | -19,300 | 14,880 |
| Source: EPA RIA of CPP (2014). | | | | |

## CONSISTENCY CHECK ON EPA EMPLOYMENT ESTIMATES

The information provided in the regulatory impact analysis and summarized in Tables 1 and 2 allows us to undertake a quick consistency check to see if the numbers seem to be in concordance with what employment and generation estimates from other sources indicate. Specifically, from Table 1, we see that coal-fired generation falls by nearly 20 percent by 2020. Coal EGU O&M employment falls by 19,400 according to Appendix Table 1.

Appendix Table 2 combines data from the Bureau of Labor Statistics (BLS) Current Employment Statistics (CES) and the Energy Information Agency (EIA) to provide a consistency check on these estimates. The BLS CES data indicate that all fossil fuel generated electrical utility employment in 2013 was 100,000. The EIA data indicate that coal-fired EGUs generate a little over two-thirds of all fossil fuel generated electricity in 2013. So, if employment fell in strict proportion to generation, this would imply that a 20 percent reduction in coal-fired generation should only see employment losses of roughly 12,000-14,000 jobs. The fact that the CPP regulatory impact analysis instead forecasts nearly 20,000 jobs declining due to the 20 percent reduction in coal-fired generation implies that coal-fired EGUs – or at least those coal-fired EGUs that are likely to close in response to the CPP – are more labor-intensive than other fossil-fuel generated EGUs.

This same logic holds in reverse for the short-term changes in natural gas generation. The regulatory impact analysis indicates that natural gas-fired EGU generation increases by 15 percent by 2020. EIA estimates indicate that natural gas is roughly a third of all fossil-fuel generated electricity, so, if employment rose in proportion to generation, this would imply an increase in natural gas O&M employment of roughly 5,000 in 2020. The fact that the CPP regulatory impact analysis only forecasts a 2,000 increase in natural gas O&M jobs indicates that natural gas – or least the natural gas generation that increases due to the CPP – is less labor intensive than overall fossil fuel generation.

This implicit finding that coal-fired EGU generation is more labor intensive is largely in line with other data. The EIA data shows that levelized costs for fixed O&M (which is largely dominated by labor costs) is higher in coal-fired EGUs than (most) natural gas EGUs. And Wei et al. (2009) show that while fixed O&M employment in both coal and natural gas-fired plants is low compared to other forms of generation, coal O&M employment (per unit of generation) is higher than natural gas.

In short, the data on generation and direct employment impacts from the CPP regulatory impact analysis seem to be roughly plausible (the employment losses/gains are clearly the same order of magnitude and quite close to overall generation losses/gains) and the implicit relative rankings of labor intensity match other data.

**Appendix Table 2: Employment Changes by Generation**

| | 2013 Generation, EIA (%) | Actual 2013 employment (BLS), thousands | Actual 2013 employment (BLS), % share of total |
|---|---|---|---|
| Total Fossil Fuels | 67.7 | 100.2 | 60.8 |
| Coal | 43.4 | | |
| Natural Gas | 23.6 | | |
| Other Fossil Fuels | 0.7 | | |
| All non-Fossil Fuel | 32.3 | 64.7 | 39.2 |
| Nuclear | 20.0 | | |
| Hydro | 8.0 | | |
| Non-Hydro Renewable | 4.2 | | |

## MAPPING EPA EMPLOYMENT ESTIMATES INTO SPECIFIC INDUSTRIES

Appendix Table 3 maps the employment changes by economic activity identified above in Appendix Table 1 into specific industries that I can use to identify indirect impacts. Many of the employment changes identified in Appendix Table 1 are quite straightforward to slot into ERM industries. Coal mining job losses enter into sector 7 – Coal Mining. Natural gas extraction gains (in 2020) and subsequent losses (in 2025 and 2030) enter into sector 8 – Oil and Gas mining. O&M employment changes (both positive and negative) unfortunately (for the sake of precision) all have to enter the same sector, 12 – Electric power utilities.

Slightly more complex decisions must be made to determine which industries are the direct recipients of employment flows due to other effects. Energy efficiency, for example, is not the name of a single industry sector in the ERM. To apportion changes due to energy efficiency investments, I used the data provided by EPRI (2014). EPRI (2014) estimates the areas with the highest potential for achieving energy efficiency savings in the residential, commercial, and industry sector. I used the EPRI estimates of possible potential savings as weights to apportion the spending flow of investments in energy efficiency. For example, in their estimates for the residential sector, EPRI (2014) highlights the highest potential savings coming from the following categories: space cooling, electronics, water heating, lighting, household appliances. They have similar mappings into sectors for the commercial and industrial sectors. These categories match tightly to existing ERM categories, and I assume that these flows will be proportional to the amount of energy savings achieved through these investments estimated by the EPRI report. So, for example, if lighting accounts for 15 percent of energy savings in the residential sector, I apportion 15 percent of employment gains spurred by energy efficiency investments into the sector in the ERM that best approximates this (electrical lighting equipment).

For apportioning employment flows stemming from investments in electricity generation from renewable sources, I drew on estimates from Pollin et al. (2009), who undertake a detailed analysis of job-creation stemming from clean energy production, and provide a mapping of industrial spending associated with investment in renewable energy, based on surveys with industry professionals. I used these mappings to assign direct employment flows stemming from renewable generation construction. Both solar and wind generation requires construction employment as the single largest input. The remaining inputs constitute a mix of manufactured goods and technical services, as shown in Table 4.

For apportioning employment flows to ERM industry that occur due to construction of natural gas capacity, I assume that a third of such flows go to construction jobs, a third to manufacturing of transmission equipment, and a sixth each to design services and fabricated metals.

Finally, for heat-rate improvements at existing EGUs, I assign the employment flows equally between EGU O&M jobs, ventilation and cooling equipment, power transmission equipment, and scientific and technical services.

**Appendix Table 3: Indirect Employment Impacts by Economic Activity**

| ERM Industry Code | ERM Industry label | Job-Change | | |
|---|---|---|---|---|
| | | 2020 | 2025 | 2030 |
| EGU O&M plus Fuel Extraction | | | | |
| 7 | Oil and gas extraction | 5,050 | 2,700 | -2,000 |
| 8 | Coal mining | -12,600 | -15,300 | -17,300 |
| 12 | Electric power generation, transmission and distribution | -19,775 | -20,425 | -24,300 |
| | Total | -27,325 | -33,025 | -43,600 |
| Energy Efficiency Investments | | | | |
| 15 | Construction | 9,480 | 13,138 | 13,267 |
| 67 | HVAC equipment manufacturing | 12,461 | 17,269 | 17,440 |
| 69 | Engine, turbine, and power transmission equipment manufacturing | 2,384 | 3,303 | 3,336 |
| 72 | Communications equipment | 551 | 763 | 771 |
| 77 | Electric lighting manufacturing | 30,388 | 42,114 | 42,530 |
| 78 | Household appliance manufacturing | 2,624 | 3,637 | 3,673 |
| 79 | Electrical equipment manufacturing | 2,775 | 3,845 | 3,883 |
| 136 | Services to buildings and dwellings | 7,238 | 10,031 | 10,130 |
| | Total | 67,900 | 94,100 | 95,030 |
| Renewable generation investments | | | | |
| 15 | Construction | 4,445 | -1,610 | -602 |
| 44 | Plastics product manufacturing | 953 | -345 | -129 |
| 61 | Machine shops: hardware | 1,389 | -503 | -188 |
| 63 | Fabricated metal | 953 | -345 | -129 |
| 69 | Engine, turbine, and power transmission equipment manufacturing | 238 | -86 | -32 |
| 70 | Machinery manufacturing | 2,937 | -1,064 | -398 |
| 79 | Electrical equipment manufacturing | 1,389 | -503 | -188 |
| 80 | Other electrical equipment and component manufacturing | 1,627 | -589 | -220 |
| 126 | Scientific research and development services | 1,945 | -704 | -263 |
| | Total | 15,875 | -5,750 | -2,150 |

**Appendix Table 3: Indirect Employment Impacts by Economic Activity (continued)**

| ERM Industry Code | ERM Industry label | Job-Change | | |
|---|---|---|---|---|
| | | 2020 | 2025 | 2030 |
| Heat Rate Improvement Investments | | | | |
| 12 | Electric power generation, transmission and distribution | 8,113 | 0 | 0 |
| 67 | HVAC equipment manufacturing | 8,113 | 0 | 0 |
| 69 | Engine, turbine, and power transmission equipment manufacturing | 8,113 | 0 | 0 |
| 125 | Management, scientific, and technical consulting services | 8,113 | 0 | 0 |
| | Total | 32,450 | 0 | 0 |
| Natural Gas Generation Construction | | | | |
| 15 | Construction | 2,236 | -8,324 | -11,352 |
| 63 | Fabricated metal | 1,152 | -4,288 | -5,848 |
| 69 | Engine, turbine, and power transmission equipment manufacturing | 2,236 | -8,324 | -11,352 |
| 123 | Design services | 1,152 | -4,288 | -5,848 |
| | Total | 6,775 | -25,225 | -34,400 |

## STATE BY YEAR PANEL REGRESSIONS OF ELECTRCITY PRICES AND EMPLOYMENT

Appendix Table 4 shows the results of a panel regression with the log of state employment as the dependent variable and the log of end-user electricity prices (and other relevant controls) as the independent variables.

Column 1 shows the results from this regression with year and state fixed effects included. Column 2 also includes a state-specific time-trend. Column 3 also includes a measure of the unemployment gap – the difference between the unemployment rate in a state in a given year and the average unemployment rate for that state over the entire sample period.

I note that higher results are gained if one cuts off the sample in 2008 (as is done in columns 4-7), with the coefficient estimates suggesting job-losses of over 150,000 in the specification (column 6) that includes all other controls. It is unclear why including the latest five years of data changes the results so much, but I prefer including more data rather than less.

Finally, I also ran regressions that used state/industry cells as the unit of analysis. The employment data allow us to examine 13 separate industrial sectors within states. Despite the larger sample size, the overall coefficient on state/industry employment in this larger panel never achieved statistical significance. Later sections look just at manufacturing employment across states and do find significant and disproportionate job losses in this sector that are correlated with electricity price differences.

## Appendix Table 4: Regression Coefficients from State/year Panel

| | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) |
|---|---|---|---|---|---|---|---|---|---|
| State/year panel | -0.014** (.008) | -0.038*** (.0054) | -0.017*** (.0044) | -0.017* (.009) | -0.049*** (.0055) | -0.026*** (.0047) | | | |
| State/industry/year panel | | | | | | | -0.049 (.042) | -0.044 (.058) | -0.024 (.058) |
| Predicted employment effect, short-run | 81,453 | 221,088 | 98,908 | 98,908 | 285,087 | 151,270 | - | - | - |
| Quadratic in year | yes | yes | yes | yes | yes | yes | yes | yes | yes |
| Year fixed effecs | yes | yes | yes | yes | yes | yes | yes | yes | yes |
| State fixed effects | yes | yes | yes | yes | yes | yes | yes | yes | yes |
| State-specific time trend | no | yes | yes | no | yes | yes | no | yes | yes |
| Industry fixed effect | - | - | - | - | - | - | yes | yes | yes |
| Industry-specific time trend | - | - | - | - | - | - | no | yes | yes |
| Unemployment gap | no | no | yes | no | no | yes | no | no | yes |
| Years | 1979-2012 | 1979-2012 | 1979-2012 | 1979-2008 | 1979-2008 | 1979-2008 | 1990-2012 | 1990-2012 | 1990-2012 |
| Obs | 1,734 | 1,734 | 1,734 | 1,474 | 1,474 | 1,474 | 14,292 | 14,292 | 14,292 |

***, **, * denotes statistical significance at 1, 5, and 10 percent confidence levels, respectively. Standard errors in parentheses.
Note: Following method of Deschenes (2009), dependent variable is log of state employment. Independent variable of interest is log of end-use electricity prices by state. Employment data from the Current Employment Statistics of the BLS. Electricity price data from the State Energy Data System (SEDS) from the Energy Information Agency (EIA).

## Appendix Table 5: Sensitivity Check - Assuming Energy Efficiency Employment Figures Expressed in FTES

| | Gains, EE Adj for FT | | | Losses | | | Net | | | Multiplier | Net | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 2020 | 2025 | 2030 | 2020 | 2025 | 2030 | 2020 | 2025 | 2030 | | 2020 | 2025 | 2030 |
| Oil and gas extraction | 5,050 | 2,700 | 0 | 0 | 0 | 2,000 | 5,050 | 2,700 | -2,000 | 673.5 | 39,063 | 20,885 | -15,470 |
| Coal mining | 0 | 0 | 0 | 12,600 | 15,300 | 17,300 | -12,600 | -15,300 | -17,300 | 269.0 | -46,495 | -56,458 | -63,838 |
| Electric power generation, transmission, and distribution | 0 | 0 | 0 | 11,663 | 20,425 | 24,300 | -11,663 | -20,425 | -24,300 | 459.5 | -66,423 | -116,330 | -138,400 |
| Construction | 15,213 | 1,890 | -13 | 0 | 0 | 0 | 15,213 | 1,890 | -13 | 173.9 | 41,668 | 5,176 | -36 |
| Plastics product manufacturing | 953 | 0 | 0 | 0 | 345 | 129 | 953 | -345 | -129 | 238.8 | 3,227 | -1,169 | -437 |
| Maching shops: hardware | 1,389 | 0 | 0 | 0 | 503 | 188 | 1,389 | -503 | -188 | 151.4 | 3,492 | -1,265 | -473 |
| Fabricated metal | 2,104 | 0 | 0 | 0 | 4,633 | 5,977 | 2,104 | -4,633 | -5,977 | 227.5 | 6,891 | -15,174 | -19,575 |
| HVAC equipment manufacturing | 19,327 | 15,542 | 15,696 | 0 | 0 | 0 | 19,327 | 15,542 | 15,696 | 324.7 | 82,079 | 66,004 | 66,657 |
| Engine, turbine, and power transmission equipment manufacturing | 12,732 | -330 | -334 | 0 | 5,107 | 8,048 | 12,732 | -5,438 | -8,382 | 330.4 | 61,158 | -26,120 | -40,264 |
| Machinery manufacturing | 2,937 | 0 | 0 | 0 | 1,064 | 398 | 2,937 | -1,064 | -398 | 328.4 | 12,582 | -4,557 | -1,704 |
| Communications equipment | 496 | 687 | 694 | 0 | 0 | 0 | 496 | 687 | 694 | 341.8 | 2,189 | 3,034 | 3,064 |
| Electric lighting manufactruing | 27,349 | 37,902 | 38,277 | 0 | 0 | 0 | 27,349 | 37,902 | 38,277 | 328.2 | 117,098 | 162,281 | 163,885 |
| Household appliance manufacturing | 2,362 | 3,273 | 3,306 | 0 | 0 | 0 | 2,362 | 3,273 | 3,306 | 453.5 | 13,074 | 18,119 | 18,298 |
| Electrical equipment manufacturing | 3,886 | 2,958 | 3,307 | 0 | 0 | 0 | 3,886 | 2,958 | 3,307 | 225.8 | 12,662 | 9,636 | 10,774 |
| Other electrical equipment and component manufacturing | 1,627 | 0 | 0 | 0 | 589 | 220 | 1,627 | -589 | -220 | 268.8 | 6,001 | -2,174 | -813 |
| Design services | 1,152 | 0 | 0 | 0 | 4,288 | 5,848 | 1,152 | -4,288 | -5,848 | 144.7 | 2,818 | -10,492 | -14,308 |
| Management, scientific, and consulting services | 8,113 | 0 | 0 | 0 | 0 | 0 | 8,113 | 0 | 0 | 163.3 | 21,362 | 0 | 0 |
| Scientific research and development services | 1,945 | 0 | 0 | 0 | 704 | 263 | 1,945 | -704 | -263 | 231.4 | 6,444 | -2,334 | -873 |
| Services to buildings and dwellings | 6,514 | 9,028 | 9,117 | 0 | 0 | 0 | 6,514 | 9,028 | 9,117 | 130.6 | 15,024 | 20,821 | 21,027 |
| Total | 113,148 | 73,649 | 70,049 | 24,263 | 52,959 | 64,672 | 88,885 | 20,690 | 5,377 | | 333,915 | 69,885 | 12,486 |

**Appendix Table 6: Manufacturing Employment Regressions**

| | (10) | (12) |
|---|---|---|
| State/industry/year panel | -0.15*** | -.03* |
| | (.04) | (.02) |
| Predicted employment effect, short-run | 97,500 | 19,500 |
| Quadratic in year | yes | yes |
| Year fixed effecs | yes | yes |
| State fixed effects | yes | yes |
| State-specific time trend | no | yes |
| Industry fixed effect | yes | yes |
| Industry-specific time trend | no | yes |
| Unemployment gap | no | yes |
| Years | 1990-2012 | 1990-2012 |
| Obs | 1184 | 1184 |

***, **, * denotes statistical significance at 1, 5, and 10 percent confidence levels, respectively. Standard errors in parentheses.
Note: Following method of Deschenes (2009), dependent variable is log of state (manufacturing) employment. Independent variable is log of end-use electricity prices by state. Employment data from the Current Employment Statistics of the BLS. Electricity price data from the State Energy Data System (SEDS) from the Energy Information Agency (EIA).

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