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Assessment of the Economy-wide Employment Impacts of EPA's Proposed Clean Power Plan

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EXECUTIVE SUMMARY

This document presents an economy-wide assessment of the employment impacts associated with the U.S. Environmental Protection Agency's (EPA's) proposed Clean Power Plan. This analysis expands upon the employment analysis included in EPA's regulatory impact analysis (RIA) for the proposed Plan, as it captures several indirect effects not included in the EPA analysis. These include the employment impacts associated with changes in electricity and other energy prices (both positive and negative, depending on the year), the productivity impacts associated with heat rate improvements at power plants, households and businesses re-directing expenditures to other uses because of increased demand-side energy efficiency, expenditures crowded out by energy efficiency expenditures, and changes in investments for air pollution control devices. Based on these effects and those captured in EPA's RIA for the proposed rule, this analysis estimates a net gain of 74,000 jobs in 2020, and projects that these annual employment gains will increase to 196,000 to 273,000 jobs between 2025 and 2040. These results represent a 0.1-0.2 percent increase in civilian employment.

CHAPTER 1 | INTRODUCTION

On June 2, 2014, the U.S. Environmental Protection Agency issued a proposed rule for the Agency's Clean Power Plan. Under this proposal, EPA would establish state-specific CO_2 emission rate goals for the electric power sector and would also establish guidelines for the development, submission, and implementation of state plans to meet these goals. The proposal identifies four illustrative building blocks that EPA used to set the emission rate targets for each state, based upon existing measures for reducing CO_2 emissions. These building blocks include:

- Improvements in individual electricity generating units' (EGUs') emission rates;
- Re-dispatch from affected steam power plans to affected natural gas combined cycle units;
- Expanded use of low- or zero-carbon generating capacity (e.g., renewables); and
- Expanded use of demand side energy efficiency.

EPA identifies these building blocks to illustrate potential approaches that states may use to meet the state-specific carbon intensity targets included in the Clean Power Plan. In practice, states may use whatever approach they deem most appropriate.

With the U.S. economy still recovering from the Great Recession, policymakers and the public are keenly interested in the employment impacts associated with environmental and other regulations. Evaluating these employment impacts in the context of a particular rulemaking is a challenge, however, as various countervailing factors may influence a rule's employment impacts. For example, environmental regulations increase abatement costs for polluting facilities, which may put upward pressure on prices and result in reduced sales, leading regulated firms to lay off workers. Offsetting this effect (at least partially), the installation of new abatement capital and compliance with environmental regulations requires additional labor, creating potential job gains. The issue is further complicated by the myriad other factors that affect employment.

EPA's regulatory impact analysis (RIA) for the proposed Clean Power Plan generates estimates of the rule's employment impacts, distinguishing between supply-side employment impacts for the power and fuel production sectors and demand-side effects associated with energy efficiency activities. The former reflects changes in labor demand associated with heat rate improvements, construction of new electricity generating units, changes in fuel use, and reductions in electricity generation due to demand-side energy efficiency activities, while the latter reflects the labor associated with energy efficiency expenditures projected to result from the rule. To estimate supply-side effects, the RIA uses a bottom-up engineering approach that combines data from EPA's cost analysis with data on labor productivity within the power and fuel extraction sectors. For demand-side employment impacts, EPA estimates the relationship between expenditures and employment in the energy efficiency sector and applies this to the energy efficiency expenditures expected under the rule. Applying these methods, EPA estimates an employment loss of 77,900 job years on the supply side in 2025 and gains of 112,000 job years on the demand side.[1]

While EPA's analysis provides a reasonable first approximation of the proposed rule's employment effects, its focus on direct employment impacts does not capture various indirect employment impacts that may be of interest to policymakers and the public. To provide a broader perspective on the rule's employment impacts, this document provides an ***economy-wide*** assessment of the rule's impact on employment. In broad terms, this analysis captures the employment impacts of the rule not only for directly affected industries (similar to EPA) but also for industries that may be indirectly affected by the rule. For example, changes in electricity prices associated with the rule affect production costs for manufacturers across the economy, potentially impacting their output and employment. To assess the proposed rule's employment impacts on an economy-wide scale, this analysis relies upon the Long-term Interindustry Forecasting Tool (LIFT), a macro-econometric model developed and maintained by the Interindustry Forecasting Project (Inforum) at the University of Maryland.[2]

Our analysis of the proposed Clean Power Plan's employment impacts proceeds as follows:

- ***Approach***: In Chapter 2, we provide a detailed description of the methods employed in this analysis. This discussion identifies the overall structure of the analysis, describes the positive and negative employment impacts of the proposed rule as captured in this study, summarizes the macro-econometric model that we applied to estimate the proposed rule's employment impacts, and documents the derivation of the data inputs that we incorporated into the macro-econometric model.
- ***Results:*** Based on the methods described in the previous chapter, Chapter 3 presents the results of the analysis. In addition to the estimated employment impacts of the rule, these results include estimated changes in GDP, consumption, and investment over time.
- ***Conclusions***: To conclude, Chapter 4 discusses the implications of our results and highlights the insights that may be gained from our economy-wide methodology relative to more narrowly focused approaches.

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[1] See U.S. EPA (2014b), Tables 6-5 and 6-6.

[2] A preliminary draft of this analysis was submitted to the docket for the proposed Clean Power Plan. This update to that analysis reflects comments received from two independent peer reviewers.

CHAPTER 2 | APPROACH

The approach applied in this analysis was designed to provide as comprehensive a view as possible of the employment impacts associated with the proposed Clean Power Plan. In addition to estimating the direct employment impacts associated with the rule, we designed the analysis to account for the various indirect pathways through which the rule may affect employment. Because the power sector is closely linked with virtually every sector of the economy, capturing these indirect effects is important for developing a full understanding of how the Clean Power Plan is likely to affect employment. A narrow focus on only the rule's direct employment impacts or on impacts for the power sector alone may not only yield employment impact estimates of the incorrect magnitude, but may also yield estimates of the wrong sign.

To capture the full range of employment impacts associated with the Clean Power Plan, we applied the *LIFT* macro-econometric model of the U.S. economy. *LIFT* is a 97-sector dynamic representation of the U.S. national economy. The model combines an inter-industry input / output (I-O) formulation with extensive use of regression analysis to employ a "bottom-up" approach to macroeconomic modeling. That is, the model works like the actual economy, building macroeconomic totals from details of industry activity, rather than distributing predetermined macroeconomic quantities among industries. *LIFT* also captures interactions between industries across the economy, enabling the model to gauge how changes in prices, investment, or productivity in one industry cascade across the economy. In the context of the Clean Power Plan, this is an important feature for understanding how the rule's direct impacts for the electric power sector affect other industries.

As a starting point for analysis, the baseline forecast in *LIFT* was calibrated to the Energy Information Administration's 2013 Annual Energy Outlook (AEO) for the years 2014 through 2040. We then introduced a series of data inputs into *LIFT* that reflected the four illustrative building blocks identified by EPA for states to meet their greenhouse gas emissions goals under the Clean Power Plan, as summarized in Chapter 1.

Based on these building blocks, the specific data inputs that we incorporated into *LIFT* to assess the proposed Plan's employment impacts are as follows:

- ***Changes in electricity, natural gas, and coal prices***. In *LIFT*, these changes affect household spending patterns and production costs for any industry that uses electricity, natural gas, or coal as an input.
- ***Efficiency improvements:*** Improvements in energy efficiency associated with the Clean Power Plan will reduce demand for electricity and, by extension, reduce electricity costs for households and businesses.

- ***Change in electricity generation mix:*** To achieve the CO_2 emission goals stipulated in the Clean Power Plan, states are likely to implement measures that would reallocate generation from more carbon-intensive sources to less carbon-intensive sources.
- ***Costs of attaining end use energy efficiency improvements:*** These costs represent expenditures on measures implemented by households, businesses, and other electricity customers to reduce their electricity consumption.
- ***Changes in power sector investment in generating capacity:*** To the extent that electricity consumption declines as a result of the Clean Power Plan, power producers may scale back or cancel investments in new generating capacity.
- ***Changes in power plant heat rates and the associated costs:*** In addition to end use energy efficiency and changes in the generation mix, improvements in power plant heat rates are likely to represent another important means of achieving the CO_2 emissions goals included in the Clean Power Plan.
- ***Direct employment impacts associated with changes in new capacity investments, early power plant retirements, and expenditures on air pollution control devices:*** To ensure that this analysis fully captures these direct employment impacts (most of which are negative, as detailed below), we add them to the employment impact estimates generated by *LIFT*.

To generate values for these variables, we used data from EPA's RIA for the proposed Clean Power Plan and the Integrated Planning Model (IPM)[3] results released by EPA for the baseline and Clean Power Plan scenarios.[4] More specifically, we used data from the RIA to generate estimates of retail electricity price impacts, the costs of end-use efficiency improvements, and the costs of power plant heat rate improvements. The IPM runs for the proposed rule served as our data source for changes in wholesale electricity prices, natural gas and coal prices, the electricity generation mix, new power plant capacity, early retirements, and installations of air pollution control devices. As noted above, both the RIA and the IPM runs were based on the four illustrative building blocks identified by EPA. States may use different measures than those implied by the building blocks to meet the carbon intensity requirements of the Clean Power Plan, which could lead to different impacts than those presented in this analysis.

In the remainder of this chapter, we present more detailed information on our approach, including an overview of the *LIFT* model itself, a summary of the AEO 2013 baseline in LIFT, and a detailed accounting of our approach for developing data inputs for *LIFT* and incorporating them into the model.

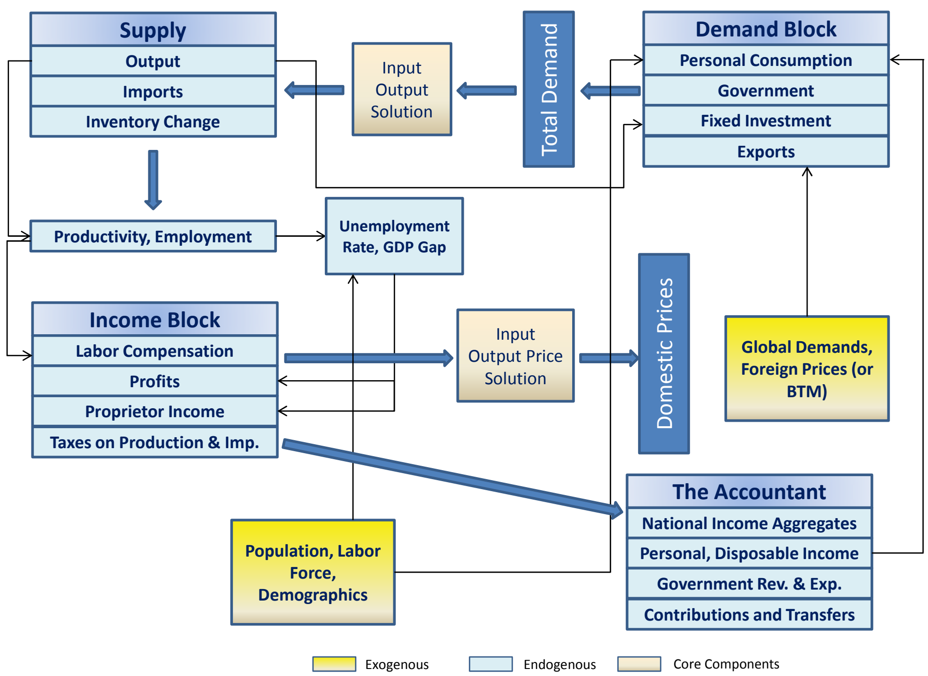
[3] IPM is the electricity sector model that EPA typically uses to assess the cost and emissions impacts of air regulations that affect the industry. The model optimizes the dispatch of power generation to minimize industry costs, subject to a series of user-specified constraints.

[4] For the Clean Power Plan, we used Option 1 (regional) as represented in the RIA and IPM outputs.

LIFT MODEL

The analysis presented in this paper applies Inforum's *LIFT* (Long-term Interindustry Forecasting Tool) model to assess the proposed rule's employment impacts. *LIFT* is unique among large-scale models of the U.S. economy in that it is based on an input-output (IO) core, and builds macroeconomic forecasts from the bottom up. Investments are made in individual firms in response to market conditions in the industries in which those firms produce and compete. Aggregate investment is simply the sum of these industry investment purchases. Decisions to hire and fire workers are made jointly with investment decisions with a view to the outlook for product demand in each industry. The net result of these hiring and firing decisions across all industries determines total employment, and hence the unemployment rate. The general structure of LIFT is shown in Exhibit 2-1.

EXHIBIT 2-1. FLOW DIAGRAM OF THE INFORUM LIFT MODEL



LIFT models 97 producing sectors. The energy sectors within the model include coal, natural gas extraction, crude petroleum, petroleum refining, fuel oil, electric utilities, and natural gas distribution. Despite its industry basis, *LIFT* is a full macroeconomic model with more than 1,200 macroeconomic variables determined either by econometric equation, exogenously or by identity. Certain macrovariables provide important levers for studying the effects of government policy. Examples include the monetary base and the personal tax rate. Other macrovariables, such as potential GDP and the associated GDP gap, provide a framework for perceiving tightness or slack in the economy.

In the last several years, the *LIFT* model has been extended through the incorporation of several modules that can be used to study energy demand and supply, and the implications of energy use on carbon emissions.

The model solves annually, and the extensive simultaneity in the model requires an iterative solution for each year. At the beginning of each year's solution, first guesses are made for some important endogenous variables, such as output and prices by industry, import shares, and many macro variables. Assumptions for exogenous variables are also established. Then the model loop runs, until outputs and other variables converge.

The key steps in the model loop include determining real final demand expenditures; solving the input-output (IO) equations jointly for output, imports, and inventory change; computing employment; and finally computing prices. Final demand expenditures include personal consumption, government expenditures, exports, equipment investment, and construction investment. Personal consumption of individual products is modeled in the consumer demand system known as the Perhaps Adequate Demand System (PADS). This system allows the classification of consumption goods into related expenditure groups, such as food, transportation or medical care. In the demand system, electricity prices affect the demand for natural gas since electricity and natural gas are substitutes in many cases. The demand system's parameters are estimated from historical consumption data. It is possible, however, to guide the level of consumption for individual products within the model. For example, if more efficient electric heat pumps are expected to come on line, the amount of electricity consumed can be reduced accordingly. For a more extensive discussion of the consumer demand system, see Almon (1996) and Almon (1979).

With respect to supply, the IO equations in *LIFT* are determined by the IO coefficients, which represent the quantity of an input per unit output of a product and are specified to change over time. Individual coefficients can also be modified, to model changes in price or technology.

Jobs in the *LIFT* model are calculated by 87 private industries, plus 6 government categories, and domestic and rest of world employment. In the private sector, jobs are derived as a combination of real output and labor productivity projections by industry. Output is a function of final and intermediate demand by industry. Labor productivity is projected using an equation that combines a time-trend and a cyclical component. Total jobs in the economy are equal to the sum of jobs by industry and public sector jobs.

For the purposes of assessing the employment and other macroeconomic impacts associated with an economic shock, LIFT was designed to track a long-term growth path such as potential GDP, and to return to a normal rate of unemployment after a shock. The model is not constrained to immediately return to the baseline growth path, as would perhaps be true of an equilibrium or classical model. However, the model is also not Keynesian, in that eventually the model crowds out certain sectors in response to additional stimulus, and the economy starts to return to the growth path again after a response to a negative shock. In short, the goal was to design the model to be Keynesian, or demand-responsive, in the short- to medium-term, but approaching classical response in the long run.

In the current study, a series of shocks are introduced into the model throughout most of the scenario time horizon. Some of these shocks are positive demand shocks from additional investments, while others are negative. Because these shocks persist over time (i.e., they are not one-time shocks), the model estimates substantive departures from the baseline forecast over the entire analytic time horizon.

REFERENCE CASE

The Reference Case for the Inforum *LIFT* model was calibrated to the *Annual Energy Outlook* (*AEO*) 2013 Reference Case, which was released in April 2013.[5] This calibration was done in two stages. In the first stage, industry variables, macroeconomic variables, and IO coefficients were modified to produce a macroeconomic forecast consistent with the *AEO*. In the second stage, imports, exports, personal consumption expenditures and IO coefficients were modified to calibrate to energy and carbon projections from the *AEO*. The current forecasting horizon of both *AEO* 2013 and *LIFT* is 2040.

The goal of the macroeconomic calibration is to produce a *LIFT* Reference Case that has the same overall GDP growth and composition as that of the *AEO* Reference Case. Although *LIFT* has detailed equations for the components of personal consumption, equipment investment, construction, and imports and exports, controls can be imposed on the model that bring the totals of these final demand categories into consistency with the AEO. The standard Inforum Reference Case also has a different projection of population, labor force, labor productivity, and total employment than the *AEO*. These demographic and employment variables are also modified so as to be consistent with *AEO*. Labor productivity by industry is modified to obtain the employment projection calibration. Exhibit 2-2 shows the projection for selected macroeconomic variables for the Reference Case used in this study.

EXHIBIT 2-2. REFERENCE CASE MACROECONOMIC VARIABLES

	2020	2025	2030	2035	2040
GDP and Macroeconomic Summary					
(Billions of chained 2011 dollars)					
Gross Domestic Product	19,155	21,693	24,081	27,177	31,267
Personal Consumption Expenditures	13,223	14,802	16,350	18,375	20,640
Gross Private Fixed Investment	3,121	3,626	4,071	4,769	5,720
Exports	3,502	4,680	5,767	6,958	8,932
Imports	3,574	4,278	4,952	5,743	6,760
Real Disp Income	14,246	16,016	17,630	19,802	22,518
Population and Employment (millions)					
Population	340.5	356.5	372.4	388.3	404.4
Total employment	158.8	168.4	174.6	184.2	196.7
Labor force	164.7	169.3	174.9	182.3	190.7

[5] The *AEO* 2013 is produced by the Department of Energy (DOE) Energy Information Administration (EIA) The *AEO* Reference Case and Side Cases are described and documented at http://www.eia.gov/forecasts/aeo/. For the Reference Case, and many of the side cases, detailed tables of results are available in Excel format, as well as in PDF.

The *LIFT* model can make projected calculations of prices by commodity based on input costs, labor costs and other value added components. However, the prices generated by the model can also be overridden to agree with prices specified by assumption, or calculated in another model. For the development of the Reference Case, producer price indexes in the model for coal, crude oil, natural gas, refined petroleum products, and electricity are controlled to grow like the corresponding prices in *AEO*, in nominal terms. Exhibit 2-3 shows the projections for selected energy prices[6].

EXHIBIT 2-3. SELECTED REFERENCE CASE ENERGY PRICES (2011$)

ENERGY TYPE	2020	2025	2030	2035	2040
Crude oil ($/bbl, Brent)	106.5	120.5	135.0	150.2	166.6
Natural gas ($/million Btu, as delivered)	5.55	6.33	6.87	7.90	9.40
Coal ($/million Btu, Minemouth)	1.68	1.81	1.93	2.02	2.10
Wholesale electricity price (mills/Kwh)	47.2	56.3	59.3	61.5	63.7
Retail electricity price (cents/Kwh)	10.4	10.8	10.9	12.5	14.8

The consumption of energy by sector by type is related to *LIFT* energy flows. The industrial and commercial sectors are defined according to *LIFT* industries, and commercial includes government. Residential energy consumption includes energy use associated with housing services. Transportation includes consumption by the transportation sectors in *LIFT*, consumption by the auto leasing sector, and personal consumption of gasoline and diesel fuel. Input-output coefficients are adjusted in the model to calibrate to the AEO control totals.

In the case of the household sector, the personal consumption equations for electricity, gas, and transportation fuels are left to operate normally, responding to income and price changes, but are adjusted multiplicatively to be consistent with the AEO. The same adjustments are made in the rules case, so the equations still respond to income and price effects.

Exhibit 2-4 shows a summary by sector of energy consumption, in quads of Btus.

EXHIBIT 2-4. SUMMARY OF REFERENCE CASE ENERGY CONSUMPTION BY SECTOR (QUADRILLION BTUs)

SECTOR	2020	2025	2030	2035	2040
Residential	20.8	21.3	21.9	22.5	23.3
Commercial	18.4	19.1	19.7	20.3	20.7
Industrial	33.9	34.6	34.1	34.1	34.8
Transportation	27.3	26.8	26.3	26.5	27.1
Total economy	**100.3**	**101.8**	**102.0**	**103.4**	**105.9**

[6] In 2011$, the *LIFT* prices are slightly different from the AEO, as the *LIFT* projection of the GDP deflator is used to convert to 2011$.

LIFT disaggregates the electric power sector into 8 different generation types. In developing the Reference Case, the AEO 2013 distribution and level of power production is targeted. This, in turn, affects the energy consumption of coal and natural gas, as well as other inputs used by the power sector. The distribution of generation across generation technologies is shown later in this report.

Unlike many energy and macroeconomic models, the energy sectors in *LIFT* are completely integrated. In other words, demand for energy products arises from the production of other energy using industries, and from consumers, government and net exports. As energy prices change, prices of the energy using industries are also affected, according to the share of energy in their cost of production. Conversely, production by the energy sectors generates demand for production of other sectors.

Jobs in the model are projected by industry, based on the level of production, and the growth of labor productivity in each sector. A switch from coal generation to natural gas generation reduces jobs in the coal mining sector, and increases jobs in natural gas extraction. A reduction in electric power production affects employment for all industries that provide inputs to the power sector, including coal and natural gas.[7]

CLEAN POWER PLAN CASE

As noted above, we modeled the Clean Power Plan (CPP) case in *LIFT* by introducing inputs into the model related to (1) the proposed rule's impact on electricity, natural gas, and coal prices; (2) energy efficiency effects; (3) the costs of end use energy efficiency measures implemented under the rule; (4) changes in the electricity production mix; (5) changes in power sector investment in response to the CPP; (6) the costs and productivity impacts of power plant heat rate improvements; and (7) direct employment impacts associated with early retirements, changes in capacity planning, and foregone air pollution control device retrofits. We describe the specification of each of these inputs below.

ELECTRICITY PRICES

The changes in electricity prices that result from the Clean Power Plan will reflect several aspects of the rule's implementation, some of which increase prices and others that, all else equal, drive prices downward. The shift in electricity production from relatively low-cost coal units to natural gas- and renewables-based generation will likely put upward pressure on prices. Similarly, expenditures by power producers to achieve heat rate improvements that reduce the carbon intensity of fossil-based power production also represent an increase in costs to power producers that will drive electricity prices upward. Costs incurred by distribution entities to encourage their customers to conserve will also be passed on to ratepayers in the form of higher distribution rates.

At least partially offsetting these factors, two aspects of the CPP may move prices downward. End use energy efficiency measures implemented by states to meet the CO_2 emission rate goals included in the CPP will lead to a downward shift in electricity

[7] The LIFT model is described in more detail in an appendix to this report.

demand that, all else equal, will reduce prices. In addition, the heat rate improvements described above will reduce the amount of fuel required per MWh of electricity produced. This change in power plant operations represents a productivity improvement that will put downward pressure on prices.

The overall impact of these influences may differ for wholesale versus retail electricity prices. While all of these factors will affect retail prices, costs incurred by distribution entities to encourage end use efficiency will affect retail prices only, as these costs are incurred downstream from wholesale markets. Thus, the factors putting upward pressure on electricity prices are stronger for retail prices than for wholesale prices.

To capture these price effects, we rely upon the wholesale and retail electricity price projections developed by EPA for its assessment of the CPP's impact on U.S. electricity markets. The IPM model runs conducted by EPA generated estimates of the CPP's impact on wholesale prices, while the RIA for the proposed rule reported the estimated retail price results from the Agency's Retail Price Model. We used these projections, as reported in Exhibit 2-5, to determine the percentage change in average electricity prices for the specific target years analyzed by EPA. The ratios of the price in the alternative cases to the base case were interpolated and extended over time, and these interpolated ratios were applied to the average wholesale and retail electricity prices from the AEO 2013 to use as the electricity price assumptions in the *LIFT* model.

EXHIBIT 2-5. ELECTRICITY PRICES UNDER THE BASELINE AND CPP CASES, BY IPM MODEL RUN YEAR (2011$)

	2020	2025	2030	2040[1]
Wholesale prices (mills/kWh)				
Base Case	47.16	56.25	59.27	63.72
Clean Power Plan Case	51.95	53.93	57.85	60.77
Percent Change	10.2%	-4.1%	-2.4%	-4.6%
Retail prices (cents/kWh)				
Base Case	10.40	10.80	10.90	14.80
Clean Power Plan Case	11.10	11.10	11.20	15.21
Percent Change	6.7%	2.8%	2.8%	2.8%

Sources: U.S. EPA, Regulatory Impact Analysis for the Proposed Carbon Pollution Guidelines for Existing Power Plants and Emission Standards for Modified and Reconstructed Power Plants, June 2014, and U.S. EPA, Integrated Planning Model run results for the proposed Clean Power Plan, 2014.

Notes:

1. Retail prices for 2040 were not reported in the sources listed above. To extrapolate beyond 2030, the previous base case projection was used to grow the IPM base price forward. The retail price for the rules case was constructed so as to be the same percentage above the base case as in 2030.

The projections in Exhibit 2-5 show that wholesale and retail electricity prices are expected to follow different trajectories as a result of the Clean Power Plan. In particular, while both wholesale and retail prices are projected to increase in 2020, the two prices move in opposite directions in 2025 and thereafter, with the wholesale price declining relative to the baseline and the retail price increasing. This pattern is consistent with the suggestion above that any upward pressure on electricity prices under the Clean Power Plan would be stronger in the retail market than in the wholesale market.

This analysis applies the projected percentage change in retail electricity prices to the residential and commercial sectors and the percentage change in wholesale prices to the industrial sector. This approach reflects how electricity is typically purchased by each customer class; residential and commercial customers typically purchase electricity through distribution entities, whereas industrial customers more often purchase directly on wholesale markets.

NATURAL GAS AND COAL PRICES

In addition to impacting electricity prices, the Clean Power Plan will also affect natural gas and coal prices. Similar to the effects described above for electricity prices, the proposed rule is likely to exert competing influences on natural gas prices. As electricity generation shifts from coal-based production to natural gas units, demand for natural gas will increase, which will drive up its price. Energy efficiency measures associated with the Clean Power Plan, however, will reduce the demand for natural gas for electric power generation, putting downward pressure on prices. Relative to these impacts for natural gas, the Clean Power Plan's impact on coal prices will likely be less complex. Both the shift away from coal-based generation and the reduction in electricity demand resulting from greater energy efficiency will lead to a reduction in coal prices.

To incorporate these price effects into LIFT, we relied upon the proportional changes in natural gas and coal prices projected by EPA's IPM model runs for the Clean Power Plan. More specifically, we estimated the ratio of the CPP price to the reference case for each IPM model run year and interpolated between these values to estimate ratios for the intervening years. We then applied these ratios to the baseline prices to generate estimates of prices under the CPP case.

Based on this approach, Exhibit 2-6 presents the estimated changes in natural gas and coal prices incorporated into LIFT for this analysis. As shown in the exhibit, natural gas prices are expected to increase by nearly 10 percent in 2020 before declining relative to the baseline over the 2025-2040 period. This pattern likely reflects differences in the timing of the competing influences of the Clean Power Plan. More specifically, while power generation is expected to shift to natural gas quickly as of 2020 (putting upward pressure on prices), the reduction in demand associated with increased energy efficiency builds over time (see Exhibit 2-10 below). For coal, the projected pattern of price impacts is more consistent over time, with the reduction in prices falling between 15 and 17 percent over the entire time horizon of the analysis.

EXHIBIT 2-6. NATURAL GAS AND COAL PRICES UNDER THE BASELINE AND CPP CASES, BY IPM MODEL RUN YEAR (2011$)

	2020	2025	2030	2040
Delivered Natural Gas Price ($/MMBtu)				
Base Case	5.55	6.33	6.87	9.40
Clean Power Plan Case	6.06	6.13	6.81	8.88
Percent Change	9.3%	-3.3%	-0.9%	-5.5%
Minemouth Coal Price ($/MMBtu)				
Base Case	1.68	1.81	1.93	2.10
Clean Power Plan Case	1.42	1.51	1.61	1.75
Percent Change	-15.6%	-16.5%	-16.5%	-16.8%
Sources: Derived from U.S. EPA, Integrated Planning Model run results for the proposed Clean Power Plan, 2014.				

EFFICIENCY RESPONSE

As noted above, improvements in end use energy efficiency represent one of the four building blocks for setting and meeting the CO_2 emissions goals outlined in the Clean Power Plan. To the extent that efficiency improvements reduce the demand for electricity, households will have additional resources to spend on other goods and services and businesses' costs will decline, enabling them to reduce prices.

These changes in household expenditure patterns and the prices that businesses charge for goods and services are likely to have spillover effects to multiple sectors of the economy. To capture these effects in the *LIFT* analysis, we superimposed the reductions in electricity demand estimated in EPA's regulatory impact analysis of the proposed rule, as summarized in Exhibit 2-7, on the model's Reference Case forecast of residential, commercial, and industrial electricity demand. Because EPA's analysis estimated the change in demand in aggregate across all three end-use sectors, we applied the same proportional reductions to each of these sectors in *LIFT*. Reductions in electricity demand for the commercial and industrial sectors were incorporated into *LIFT* through changes in the model's input-output coefficients. For the residential sector, household expenditures on electricity were adjusted downward to match the percentage reductions shown in Exhibit 2-7. Consumer spending was then reallocated to other goods and services based on LIFT's Reference Case distribution of spending across sectors and the sector-specific changes in prices projected by the model.

EXHIBIT 2-7. PROJECTED REDUCTION IN ELECTRICITY CONSUMPTION UNDER THE CLEAN POWER PLAN

	2020	2025	2030	2040
% Reduction	3.04%	7.92%	11.13%	11.13%[1]

Source: U.S. EPA (2014c).

Notes:

1. The EPA document did not report projections beyond 2030. For 2040, we assumed the same percentage change as in 2030.

COSTS OF ATTAINING ENERGY EFFICIENCY

While the improvements in energy efficiency described in the previous section lead to a cost savings for electricity consumers in the form of reduced electricity costs, these savings are achieved through expenditures on various measures to improve energy efficiency. These expenditures have a stimulative effect for the industries that provide energy efficiency goods and services, but they represent a cost for households and businesses. Thus, increased household spending on energy efficiency leads to reduced spending on other consumer goods and services, and industrial and commercial sector investments in energy efficiency lead to increases in prices.

Exhibit 2-8 summarizes the estimated cost of energy efficiency improvements, as presented in EPA's RIA for the proposed rule. Consistent with the RIA, we assume that half of this cost is a programmatic cost, which was distributed to power producers in *LIFT*, and the other half was the participant cost, distributed to consumers. Within the *LIFT* model, we distributed the participant cost evenly between the household sector and commercial & industrial customers. For households, costs were distributed equally between expenditures on major household appliances; household maintenance, which includes upgrades to energy-using equipment; and lighting fixtures. The costs to industrial and commercial producers were distributed between investments to upgrades in manufacturing buildings, commercial buildings, and stores and restaurants. These investments increase depreciation costs within *LIFT*, adding to producers' capital costs and thereby raising prices.

EXHIBIT 2-8. ESTIMATED COST OF ENERGY EFFICIENCY (MILLIONS OF 2011$)

	2020	2025	2030	2040
Annual Cost	$30,800	$43,800	$43,700	$43,700

Source: U.S. EPA (2014b), Table 6-6.

Notes:

1. The EPA document did not report projections beyond 2030. For 2040, we assumed the same value as in 2030.

CHANGE IN ELECTRICITY GENERATION MIX

Due to differences in the labor intensity of different power generation technologies, capturing the extent to which the Clean Power Plan shifts generation between technologies is important for fully understanding the employment impacts associated with the rule. To capture this effect, the *LIFT* analysis draws from the projections generated by IPM for the Reference Case and the Clean Power Plan. EPA's IPM runs for the proposed rule include detailed projections of generation by type, based on the model's detailed dispatch algorithms and the constraints associated with each scenario. The *LIFT* model does not maintain as much detail on generation by type as IPM, but it does include generation for the eight technologies in the left-hand column of Exhibit 2-9.

EXHIBIT 2-9. CROSSWALK BETWEEN LIFT AND IPM GENERATION TYPES

LIFT ELECTRICITY GENERATION TYPES	IPM ELECTRICITY GENERATION TYPES
Coal	Coal (PC, IGCC, IGCC-CCS)
Natural Gas	Natural Gas (CC, CC-CCS, CT, oil/gas steam)
Petroleum	None
Nuclear	Nuclear
Hydroelectric	Hydroelectric
Solar	Non-Hydro Renewables - Other
Wind	Non-Hydro Renewables - Wind
Geothermal and Other	Other, Biomass

We aggregated generation by type in IPM to the level available in *LIFT*, based on the crosswalk presented in Exhibit 2-9. Then, the ratios of generation in the CPP case relative to the base case were used to adjust the Reference Case values of generation in *LIFT*. Exhibit 2-10 shows the composition of generation by technology type and IPM target year for the Reference Case and CPP case over the 2020 to 2040 period. As indicated in the exhibit, the most significant changes are in coal- and natural gas-based generation, with the former declining as a percentage of total generation and the latter increasing. For example, in 2025 coal-based generation is projected to decrease from 1,702 billion kWh under the Reference Case, or 39 percent of all generation, to 1,275 billion kWh under the CPP case, accounting for 31 percent of all generation. In contrast, natural gas-based generation makes up 28 percent of generation under the baseline and 32 percent under the CPP case in 2025. Exhibit 2-10 also shows that the overall level of generation is projected to decline under the CPP case relative to the Reference Case. This reduction reflects the efficiency response described in the previous section.

EXHIBIT 2-10A. COMPOSITION OF GENERATION – REFERENCE CASE

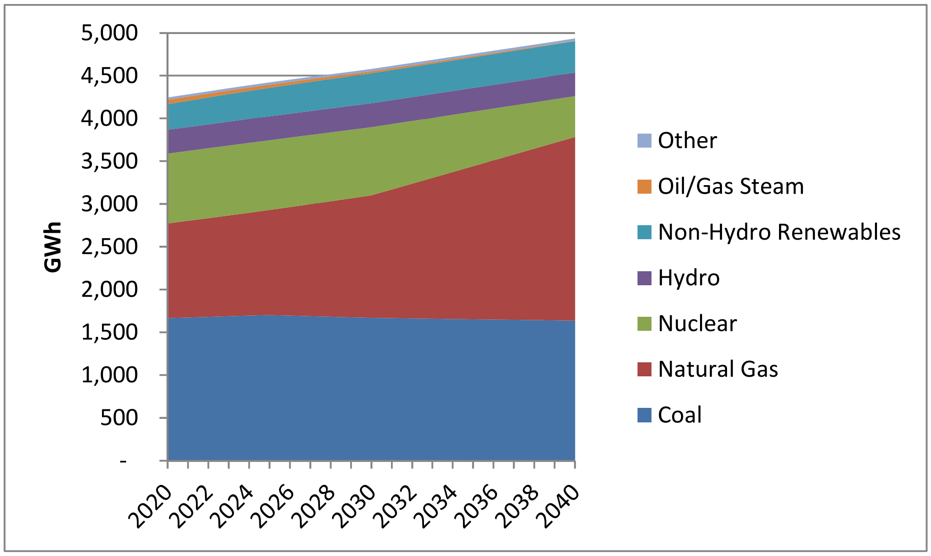
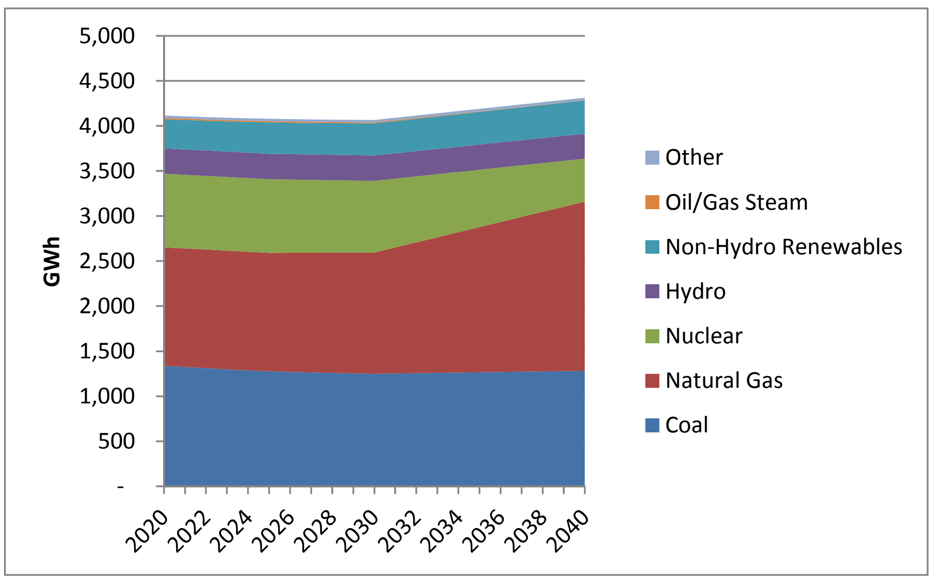


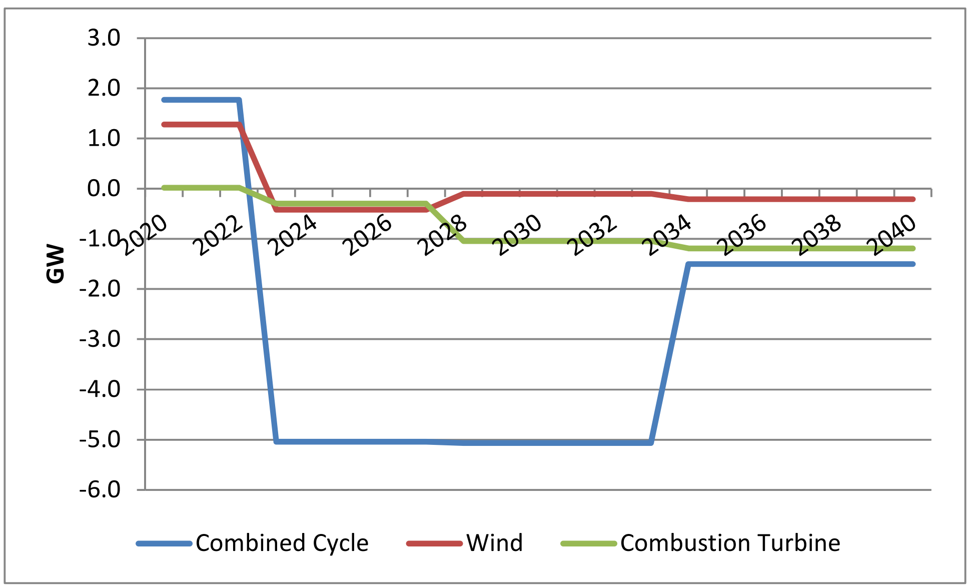
EXHIBIT 2-10B. COMPOSITION OF GENERATION – CLEAN POWER PLAN CASE



EFFECTS OF CHANGES IN ELECTRIC POWER SECTOR INVESTMENT

Due in large part to the projected shift in electricity generation from coal to natural gas and renewables and the projected reduction in electricity demand, investment within the electric power sector is expected to change in two important ways under the Clean Power Plan. First, the Plan will affect the overall level of investment in new generating capacity. The transition to greater reliance on natural gas and renewables will spur investment in these generating technologies, while reductions in electricity demand will have the opposite effect. Exhibit 2-11 shows the change in generating capacity for combined cycle, combustion turbine, and wind facilities under the Clean Power Plan, as projected in EPA's IPM runs for the proposed rule. The exhibit shows an increase in new combined cycle and wind capacity in the early years of the Clean Power Plan—to help meet CO_2 reduction goals—followed by a decline in new capacity that likely reflects the demand-side effects of energy efficiency.

EXHIBIT 2-11. PROJECTED CHANGE IN NEW CAPACITY UNDER THE CLEAN POWER PLAN, BY TECHNOLOGY TYPE



The changes in new capacity shown in Exhibit 2-11 were incorporated into LIFT as changes in investment. To estimate the specific level of investment associated with each technology, we assumed investment costs of $1,006 per kW for combined cycle plants, $664 for combustion turbines, and a declining scale for wind starting at $2,258 per kW in 2016 and ending at $1,864 in 2040 (all values in year 2011$).[8] Based on these values and the trend in new capacity projected by IPM, Exhibit 2-12 summarizes the change in new capacity investment for select years from 2020 through 2040.

[8] See U.S. EPA (2013), Tables 4-13 and 4-16.

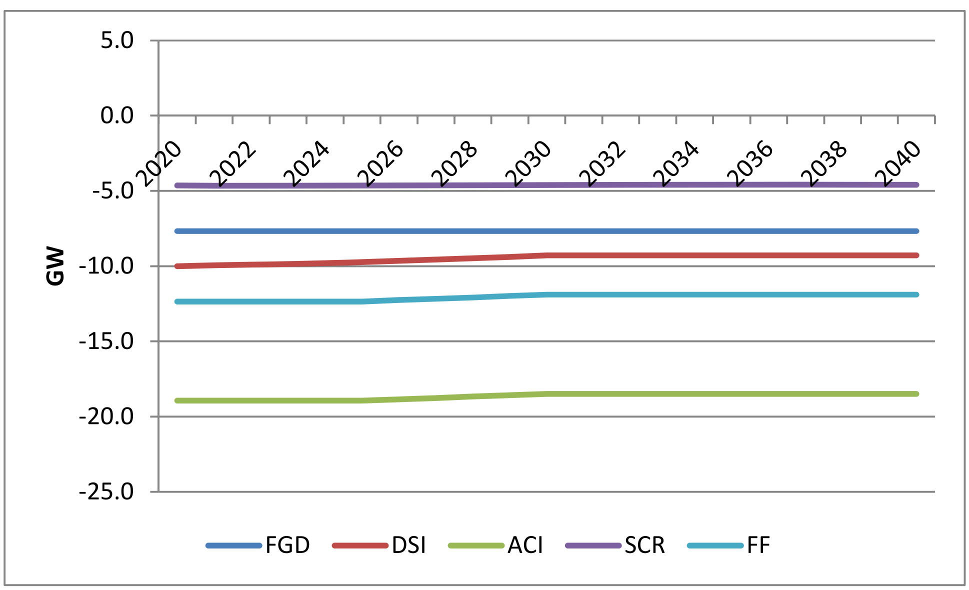
EXHIBIT 2-12. CHANGE IN INVESTMENT IN GENERATING CAPACITY (MILLIONS OF 2011$)

	2020	2025	2030	2040
Total Investment	$4,600	($6,300)	($6,300)	($3,100)

The second investment effect associated with the Clean Power Plan is its effect on emission control device retrofits. Because the proposed rule is expected to lead to reduced reliance on coal-fired power plants that install air pollution control devices under the Reference Case (e.g., many of these plants retire early), some of these plants will no longer find investment in air pollution control devices economical. Exhibit 2-13 illustrates the projected decline in retrofit capacity under the plan by control technology. To estimate the foregone investment associated with this reduction in new retrofits, we applied the following investment costs:[9]

- $522 per kW for scrubbers,
- $43 per kW for dry sorbet injection,
- $10 per kW for mercury controls,
- $192 per kW for fabric filters, and
- $269 per kW for SCR.

EXHIBIT 2-13. CHANGE IN CUMULATIVE CAPACITY RETROFIT WITH EMISSION CONTROL DEVICES, BY CONTROL TECHNOLOGY



[9] These values were obtained from U.S. EPA (2013).

Based on these values, Exhibit 2-14 summarizes the estimated change in retrofit expenditures, relative to the Reference Case, for select years during the 2020-2040 period. As shown in the exhibit, the most significant changes occur near the beginning of the period. This pattern is consistent with the relatively flat lines shown above in Exhibit 2-13, which shows the *cumulative* change in new retrofits over time. Within *LIFT*, these changes (mostly a decline) in retrofit investment expenditures lead to two countervailing effects on employment. The reduced expenditure leads to a reduction in employment associated with the retrofit itself. However, the reduced expenditure also leads to reduced depreciation over time that, all else equal, reduces prices and, by extension, has a stimulative effect.

EXHIBIT 2-14. CHANGE IN INVESTMENT IN AIR POLLUTION CONTROL RETROFITS (MILLIONS OF 2011$)

	2020	2025	2030	2040
Total Investment	($11.9)	$2.0	$21.4	$0.1

CHANGES IN HEAT RATE (GENERATION EFFICIENCY)

In addition to shifting the dispatch of power plants between plant types under the Clean Power Plan, the power sector may also make improvements to the efficiency of the fleet to reduce CO_2 emissions. Specifically, power plants may invest in heat rate improvements that reduce the amount of fuel required per MWh of electricity produced and, by extension, the carbon intensity of electricity production at a given power plant. These measures may include physical enhancements to power plants or changes in plant operations (e.g., changing to higher grade coal).

For the purposes of this analysis, we assume that power plants would make the heat rate improvements included in EPA’s regulatory impact analysis for the proposed rule. Exhibit 2-15 shows the projected heat rates for coal and natural gas-based generation under the Reference Case and the CPP case, as derived from EPA’s results. As shown in the exhibit, the heat rate is projected to improve for coal-fired plants over the entire time horizon of the analysis, whereas the heat rate for gas-fired plants is projected to improve in the 2020s before worsening in the 2030s. This trend for natural gas plants may reflect the reduced investment in new gas-fired capacity under the CPP case relative to the Reference Case. As demand for electricity is projected to decline in the 2030s, IPM also projects a decline in new gas-fired capacity. This new generating capacity may have required less energy input per MWh of electricity produced than some of the gas-fired power plants that increase their generation under the CPP case relative to the Reference Case.

EXHIBIT 2-15A. CHANGE IN EFFICIENCY - GAS-FIRED GENERATION

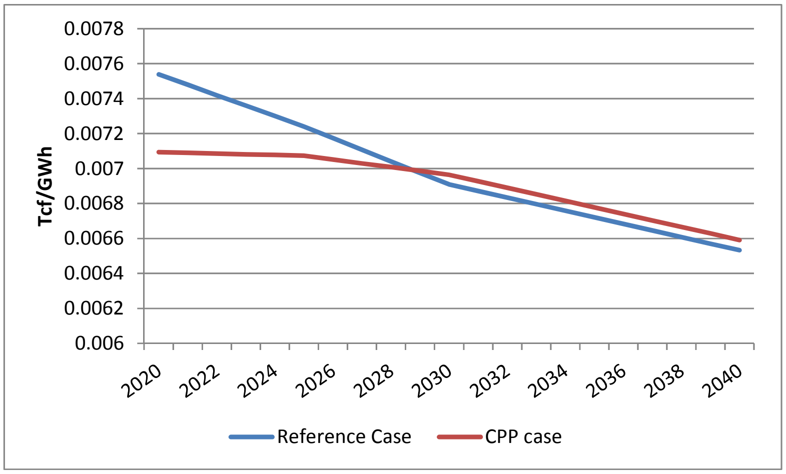
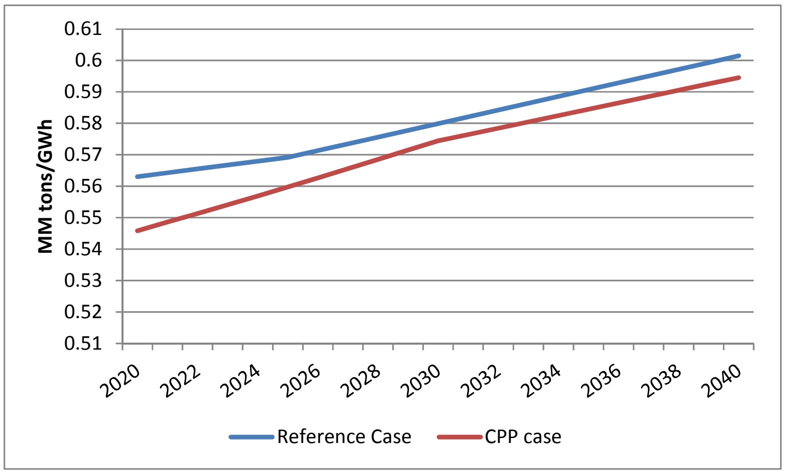


EXHIBIT 2-15B. CHANGE IN EFFICIENCY - COAL-FIRED GENERATION



In the *LIFT* model, the projected changes in heat rate are modeled as changes in the energy/output ratio, as embodied in the generation-specific input-output coefficients. For example, the change in the heat rate for coal-based generation shown in Exhibit 2-15A will, all else equal, put downward pressure on electricity prices. This change, however, will also result in slightly reduced production and employment in the coal industry, due to reduced demand from electric power.

The heat rate improvements shown in Exhibit 2-15 are attained through specific investments by electric power producers. Consistent with EPA's regulatory impact analysis for the proposed rule, we assume that this investment amounts to $4.4 billion per year (year 2011$) for four years following the promulgation of the rule. As with the efficiency investments discussed above, these investments have a stimulatory effect in the short run but over time must be depreciated, which raises industry capital costs and prices.

DIRECT JOB IMPACTS FROM CAPACITY CHANGES, RETIREMENTS, AND RETROFITS

Using data inputs developed from the methods described in the previous sections, *LIFT* estimates the economy-wide employment and output impacts associated with the Clean Power Plan. For power producers, this approach yields estimates of employment impacts that reflect LIFT's industry-wide specification of the capital and labor requirements per unit output. To complement LIFT's employment estimates for the power sector, we added micro-level jobs impacts estimated for the industry to the estimates generated by LIFT. These estimates reflect anticipated changes in (1) new capacity investment, (2) the timing of plant retirements, and (3) the installation of air pollution control retrofits.

Capacity Investment

As described above, the Clean Power Plan is anticipated to change the trajectory of investment in new generating capacity over time. Based on the IPM simulations performed for the Clean Power Plan, power producers are expected to make additional capacity investments during the first few years of the rule's implementation, but investment is expected to decline relative to the Reference Case starting in the mid-2020s, as shown in Exhibit 2-11. These changes in investment may lead to short-term employment impacts associated with construction and longer-term employment impacts related to the ongoing operations and maintenance (O&M) of power plants.

For a given year, we estimated the one-time employment impacts associated with construction according to the following equation:

$$(1)\ E_{c,t,y} = C_{t,y} \times e_{c,t}$$

Where $E_{c,t,y}$ = construction-related employment impact for technology *t* in year *y*;
$C_{t,y}$ = projected change in new capacity for technology *t* in year *y*; and
$e_{c,t}$ = one-time construction employment per GW of capacity constructed for generation technology *t*.

We obtained estimates of the projected change in new capacity for each technology ($C_{t,y}$) from the IPM runs performed by EPA for the proposed rule. Based on data presented in Bechtel (2009), $e_{c,t}$ was assumed to be 1,589 jobs per GW for natural gas power plants and 1,337 jobs per GW for wind-based generating capacity.

We follow a similar approach to estimate the ongoing O&M-related employment impacts associated with changes in capacity investments. The following equation summarizes our approach:

$$(2)\ E_{m,t,y} = P_{t,y} \times\ e_{m,t}$$

Where $E_{m,t,y}$ = O&M-related employment impact for technology *t* in year *y*;
$P_{t,y}$ = projected change in new number of power plants for technology *t* in year *y*; and
$e_{m,t}$ = annual O&M employment per new power plant for generation technology *t*.

Estimates of the number of new plants in operation relative to the Reference Case ($P_{t,y}$) were derived by dividing the number of GW by the average capacity of each new plant, both of which were obtained from EPA's IPM simulations for the proposed rule. Based on the IPM data, we estimated an average capacity of 935 MW for natural gas combined cycle plants, 130 MW for gas turbines, and 59 MW per wind installation.

Federal Energy Regulatory Commission (FERC) Form 1 data formed the basis of our estimates of O&M employment per plant ($e_{m,t}$). Designed to support electric rate regulation and financial audits, Form 1 includes annual operating and financial information for major electric plants in the U.S.[10], including plant name, capacity, net power generation, year constructed and average number of employees.[11] Focusing on plants in the Form 1 data with annual generation similar to the new plants projected by IPM, we estimated 31 O&M workers per new combined cycle plant, 8 O&M workers per gas turbine plant, and 3 workers per wind facility.

Applying these methods, we estimated the direct employment impacts presented in Exhibit 2-16. As these results show, the change in new power plant investment associated with the Clean Power Plan results in an increase in employment in 2020 before reversing sign to a reduction in employment in 2025. This pattern is consistent with the changes in new generating capacity projected by IPM.

EXHIBIT 2-16. INCREMENTAL EMPLOYMENT EFFECTS DUE TO CHANGES IN NEW CAPACITY

JOB CATEGORY	2020	2025	2030	2040
Employment impacts from manufacture and installation of generating capacity (FTEs)	4,600	(9,000)	(9,800)	(4,600)
Employment impacts from O&M of new generating capacity (FTEs)	1,100	100	(1,400)	(3,000)
Total (FTEs)	5,700	(9,000)	(11,200)	(7,600)

Early Retirements

The early retirement of less efficient (mostly coal-fired) power plants under the Clean Power Plan would likely displace workers employed at these plants. To estimate these job losses, we apply the following four-step approach:

1. First, using the FERC Form 1 data described above, we estimated the average employment per power plant by generating technology and annual generation. Exhibit 2-17 summarizes these data.

2. Applying the FERC Form 1 data shown in Exhibit 2-17 requires estimates of the annual generation of power plants projected to retire under the Clean Power Plan but not under the Reference Case. Using the parsed data files available for EPA's IPM runs, we identified such plants and estimated their average

[10] FERC defines major plants as those with: a) one million megawatt hours or more of total sales; b) 100 megawatt hours of annual sales for resale; c) 500 megawatt hours of annual power exchanges delivered; or d) 500 megawatt hours of annual wheeling for others (deliveries plus losses).

[11] Form 1 information and data accessed online at http://www.ferc.gov/docs-filing/forms.asp#1.

generation, by technology type, for the year 2020.[12] We did not generate estimates for later years because IPM parsed files are not available for all years.

EXHIBIT 2-17. ESTIMATES OF THE AVERAGE NUMBER OF EMPLOYEES BY PLANT TYPE AND NET GENERATION CATEGORY[1]

PLANT TYPE	NET GENERATION CLASS (GWH)[2]	AVERAGE NUMBER OF EMPLOYEES
Combined Cycle	700	14
	1,500	23
	3,400	26
	14,000	43
Coal	950	54
	2,300	97
	5,300	140
	26,000	230
Combustion Turbine	44	8
	350	12
	13,000	36
Oil & Gas	87	14
	290	35
	1,300	52
	4,800	63

Notes:

1. All values reported to two significant figures.
2. The break values for net generation classes correspond to the 25th, 50th, 75th, and 100th percentile net generation value for all plant types except combustion turbine where break values correspond to the 50th, 75th, and 100th percentile net generation value.

Source: FERC (2010).

3. To estimate employment losses for the year 2020, each power plant identified in Step 2 was assigned the employment value in Exhibit 2-17 corresponding to the plant's annual generation and its generation type.

4. To generate employment impacts post-2020, the values estimated for 2020 were scaled based on the ratio of the aggregate capacity of plants projected to retire in later years relative to the capacity of plants expected to retire in 2020. This step assumes that the annual generation of plants that retire post-2020 is similar to that of plants that retire in 2020. However, because most of the early retirement

[12] EPA's parsed IPM files for the Clean Power Plan include a base case file for the 2025 model year and a CPP file for the year 2020. Because aggregate retirements in the CPP case relative to the Reference Case are nearly identical in 2020 and 2025 (69 GW versus 68 GW), the 2025 parsed files provide a reasonable basis for estimating the average annual generation of plants that retired early in 2020 under the CPP case but not under the base case.

projected under the Clean Power Plan is expected to occur in 2020 or earlier, this assumption likely has minimal impact on our results.

Exhibit 2-18 presents the employment impact estimates that we estimated with this approach for each of the IPM target years. As shown in the exhibit, these impacts are fairly constant at nearly 9,000 lost jobs per year, the vast majority of which are associated with the early retirement of coal-fired power plants.

EXHIBIT 2-18. INCREMENTAL EMPLOYMENT EFFECTS DUE TO CHANGES IN EARLY PLANT RETIREMENTS

GENERATION TYPE	2020	2025	2030	2040
Coal	(8,000)	(8,100)	(8,000)	(8,000)
Combined Cycle	(100)	(100)	(100)	(100)
Combustion Turbine	<100	<100	<100	<100
Oil/Gas	(700)	(700)	(700)	(700)
Total (FTEs)	(8,800)	(8,900)	(8,800)	(8,800)

Pollution Control Retrofits

As described earlier in this report, investment in control devices to limit emissions of conventional criteria pollutants and mercury may decline as a result of the Clean Power Plan. With several (mostly coal-fired) power plants retiring early under the Clean Power Plan and electricity generation shifting from coal to natural gas, investment in these devices will no longer be economical for some plants. Because the manufacture, installation, and operation of these devices would have required a certain amount of labor, foregoing these installations will reduce the number of jobs associated with these devices. To capture these employment impacts, we rely upon the technology-specific unit employment values presented in Exhibit 2-19. These values were applied to data derived from EPA's IPM runs for the Clean Power Plan to generate estimates of the employment losses associated with foregone retrofits.

EXHIBIT 2-19. UNIT EMPLOYMENT VALUES BY POLLUTION CONTROL TECHNOLOGY

POLLUTION CONTROL TYPE	MANUFACTURE	INSTALLATION	ANNUAL O&M
Scrubbers (FGD)[1]	25-100 MW units: 71 FTE/system 100+ MW units: 144 FTE/system	25-100 MW units: 281 FTE/system 100+ MW units: 574 FTE/system	25-100 MW units: 8 FTE/system 100+ MW units: 20 FTE/system
Activated Carbon Injection	1.585 FTE/system[2]	1.035 FTE/system[2]	1.2×10^{-7} FTEs per kW-yr[3]
Dry Sorbent Injection	1.585 FTE/system[2]	1.035 FTE/system[2]	Operator: 1 FTE/system[4] Maintenance: 1.32×10^{-6} Annual FTEs per kW-yr[4] Administration: 2.11×10^{-7} Annual FTEs per kW-yr[4]
Fabric Filters	0.29 FTE/MW of installed capacity, plus 0.17 FTE per system[5]		1 FTE/system[6]
Selective Catalytic Reduction	0.34 FTE/MW[7]		0.5 FTE/system[8]

Notes:

1. All values represent the midpoints of the values reported in Price et al. (2011).
2. Midpoint of estimates derived from Martin (2011).
3. Value obtained from Sargent and Lundy (2011a).
4. Sargent and Lundy (2010).
5. Based on average of values obtained from U.S. EPA Clean Air Markets Division (2011) and Parsons (2011).
6. Estimate based on Parsons (2011).
7. U.S. EPA, Clean Air Markets Division. (2011). "Employment Estimates of Direct Labor in Response to the Proposed Toxics Rule in 2015." EPA Docket Number: EPA-HQ-OAR-2009-0234 March 2011.
8. U.S. EPA (2013).

Following this approach, Exhibit 2-20 summarizes the estimated direct employment impacts associated with the foregone manufacture, installation, and operation of air pollution control devices at some facilities. The data in Exhibit 2-20 show that O&M labor makes up most of the employment impacts associated with retrofits from 2020 through 2040. These O&M employment impacts largely reflect foregone retrofits during the early years of the Clean Power Plan's implementation.

EXHIBIT 2-20. INCREMENTAL EMPLOYMENT EFFECTS DUE TO CHANGES IN RETROFITS

JOB CATEGORY	2020	2025	2030	2040
Employment impacts from manufacture and installation of pollution control devices (FTEs)	100	0	<100	0
Employment impacts from O&M of pollution control devices (FTEs)	(500)	(500)	(500)	(500)
Total (FTEs)	**(400)**	**(500)**	**(500)**	**(500)**

CHAPTER 3 | RESULTS

Using the data inputs described in the previous chapter, *LIFT* projected the economy-wide impact of the Clean Power Plan on employment and several other macroeconomic variables. Exhibit 3-1 presents key variables of interest from the *LIFT* model runs from 2020, the first year in which the Clean Power Plan would be in full effect, through 2040. The first line for each variable shows its Reference Case values, while the second line for each variable shows the difference of the Clean Power Plan case relative to the Reference Case. Positive values in the second line for each variable represent an annual increase relative to the Reference Case, and negative values represent a reduction.

Over the full time horizon, the estimated GDP and employment effects of the Clean Power Plan are small but positive. By 2025, total annual employment in the CPP case increases by approximately 196,000 jobs relative to the Reference Case, and this increase grows to 273,000 by 2040. As described in the previous chapter, these results are the net outcome of both positive and negative impacts. For example, the improvements in end use efficiency associated with the Clean Power Plan represent increases in multi-factor productivity for electricity-consuming industries, which stimulates the economy by raising its potential supply (how much output can be produced with given resources). These efficiency investments, however, also represent a cost that, all else equal, may dampen growth.

Focusing on other key variables projected by *LIFT*, the results in Exhibit 3-1also suggest that the Clean Power Plan will have minimal impact on GDP. The $25 to $30 billion increases projected for the 2030 to 2040 period represent roughly a 0.1 percent change in GDP. The projected increase in investment, however, is more significant, ranging from a 1.0 to 1.4 percent increase during this period. This increase in investment reflects investments made to meet the CO_2 emissions targets of the Clean Power Plan plus any indirect changes in investments for sectors not directly affected by the Plan. Also related to CO_2 abatement, *LIFT* projects that CO_2 emissions will, as expected, be much lower under the Clean Power Plan than under the Reference Case, falling to 5,097 million tons by 2040, compared with 5,710 million tons in the Reference Case. Most of this reduction is in the electric power sector.

EXHIBIT 3-1. RESULTS SUMMARY - ECONOMIC IMPACTS OF THE CLEAN POWER PLAN

	2020	2025	2030	2035	2040
Employment (thousands)	158,797	168,353	174,628	184,203	196,662
	74.2	195.6	263.3	272.0	272.9
Other Macroeconomic Variables (Billions of dollars)					
Gross Domestic Product	19,155	21,693	24,081	27,177	31,267
	2.5	17.1	22.9	25.7	31.3
Personal Consumption	13,223	14,802	16,350	18,375	20,640
	(1.5)	(4.4)	(4.6)	(5.3)	(6.2)
Gross Private Fixed Investment	3,121	3,626	4,071	4,769	5,720
	30.7	47.4	57.4	63.6	63.7
Exports	3,502	4,680	5,767	6,958	8,932
	(4.8)	0.7	8.2	13.5	26.1
Imports	3,574	4,278	4,952	5,743	6,760
	17.0	25.8	34.6	41.7	45.7
Real Disposable Income	14,246	16,016	17,630	19,802	22,518
	(11.5)	(9.2)	(13.4)	(16.5)	(21.8)
Electricity Demand (bil kWh)					
Total generation	4,176	4,367	4,503	4,648	4,775
	(154.9)	(381.4)	(537.8)	(608.3)	(685.3)
Residential	1,431	1,508	1,593	1,685	1,784
	(69.5)	(154.6)	(207.6)	(241.7)	(279.3)
Commercial	1,384	1,460	1,530	1,597	1,652
	(40.8)	(112.2)	(169.0)	(189.1)	(209.0)
Industrial	1,145	1,170	1,136	1,113	1,101
	(31.8)	(86.9)	(122.2)	(127.6)	(134.6)
Carbon Dioxide Emissions (million tons)					
Total	5,438	5,529	5,604	5,736	5,710
	(362.8)	(504.2)	(590.5)	(622.2)	(612.8)
Electric power	2,067	2,183	2,310	2,431	2,349
	(353.7)	(506.5)	(590.0)	(627.0)	(622.4)
(tons per person)	16.0	15.5	15.1	14.8	14.1
	(1.1)	(1.4)	(1.6)	(1.6)	(1.5)

Notes:

1. All monetized values in year 2011$.
2. For each item, the first line represents the projected Reference Case value, and the second line represents the change from the Reference Case under the Clean Power Plan.

Exhibits 3-2 and 3-3 present additional detail on the projected employment impacts projected by *LIFT*. As shown in Exhibit 3-2, the increase in employment associated with the Clean Power Plan is projected to grow through the 2020s before plateauing around 2030. This plateau most likely reflects the flat trajectory assumed for many input variables post-2030 in cases where data were not available. For example, as described in Chapter 2, the 2030 estimates of the percentage change in the retail electricity price and the percent change in electricity consumption are both carried forward through 2040.

EXHIBIT 3-2. CHANGE IN EMPLOYMENT ASSOCIATED WITH THE CLEAN POWER PLAN

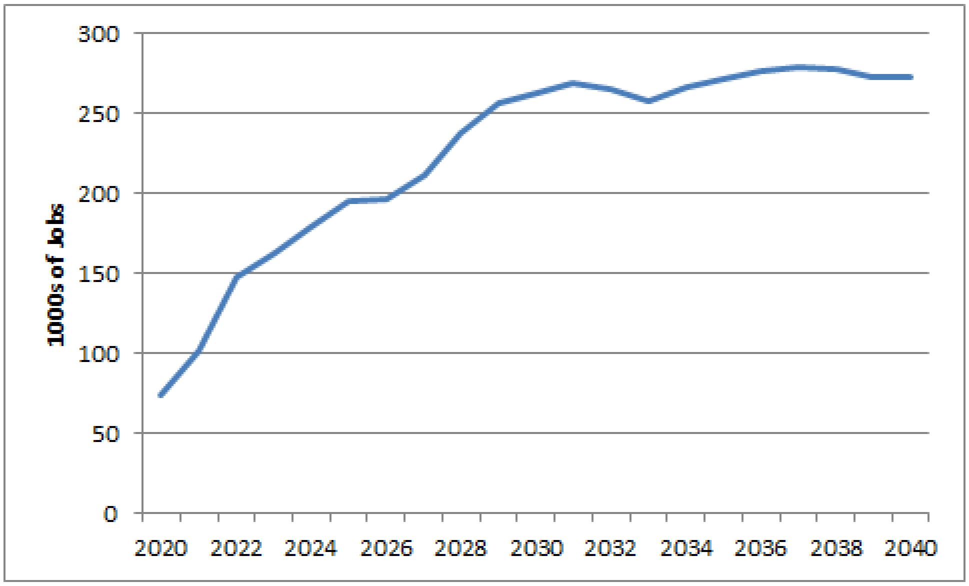


Exhibit 3-3 presents the projected change in employment by major industry sector. The results in the exhibit suggest that, post-2020, the employment gains associated with the Clean Power Plan will be most significant in the construction industry and retail, followed by the other services, durable goods, and wholesale sectors. The increase in the construction sector is consistent with the increase in investment projected by LIFT, specifically power sector investments in heat rate improvements and household investments in end use energy efficiency measures. In addition, while LIFT projects an overall increase in employment under the Clean Power Plan, some industries are projected to see a decline in employment, in particular the electric power industry. This reduction in employment for power producers reflects several effects, including the shift from coal-based power production to less labor-intensive generation technologies and the overall reduction in electricity demand associated with the improvements in energy efficiency projected under the Clean Power Plan. These same factors also contribute to the reduction in employment in coal mining. LIFT also projects a decline in employment in the construction industry in 2020, in contrast to the industry's projected gains in employment for later years. This decline in 2020 reflects the projected reduction in coal prices, which discourages construction activity in the coal sector that year. While the decline in coal prices persists for later years, other factors that become more significant over time, such as the efficiency response impact described in Chapter 2, mitigate this effect.

EXHIBIT 3-3. ESTIMATED EMPLOYMENT IMPACTS OF THE CLEAN POWER PLAN BY INDUSTRY (1,000S OF JOBS)

INDUSTRY	2020	2025	2030	2035	2040
Civilian jobs	74	196	263	272	273
Private sector	74	196	263	272	273
Agriculture, forestry and fisheries	3	6	7	7	8
Coal mining	(11)	(12)	(11)	(10)	(8)
Natural gas extraction	2	5	3	2	2
Other mining and extraction	7	11	11	12	13
Construction	(13)	58	57	49	43
Durable goods manufacturing	24	31	37	38	35
Non-durable goods manufacturing	11	18	21	22	24
Electric power	(13)	(28)	(36)	(36)	(37)
Gas utilities	1	3	1	1	1
Transportation, Communication, Other Utilities	3	4	10	12	16
Wholesale trade	17	25	31	32	32
Retail trade	7	55	62	64	69
Finance, Insurance, Real Estate	0	3	6	8	12
Health	(0)	(29)	(10)	(16)	(33)
Other services	37	52	78	87	97
Civilian government	-	-	-	-	-

Relative to the results presented in EPA's regulatory impact analysis for the Clean Power Plan, the estimates in Exhibit 3-3 suggest slightly larger employment impacts (e.g., 196,000 increase in jobs in 2025 versus an increase of 34,000 jobs). Because EPA does not report results by sector, a detailed comparison of industry level results is not possible, though EPA's RIA for the Clean Power Plan presents supply-side employment impacts for the coal, natural gas, and electric power industries. Overall, the job impacts that EPA projects for these industries are fairly similar to those presented in Exhibit 3-3. For example, our analysis estimates 12,000 job losses in the coal industry in 2025, while EPA estimates losses of 18,000 jobs. Both our analysis and EPA's project no more than 5,000 new jobs in the natural gas industry in 2025. For the electric power sector, EPA estimates a loss of approximately 57,000 jobs in 2025, compared to 28,000 in our analysis. Most of the difference between the two values reflects differences in the estimated job impacts associated with foregone capacity investments. As noted above, our analysis estimates these impacts based on the estimated jobs per GW constructed as reported by Bechtel (2009). In contrast, EPA's analysis distributes power plant investment costs between equipment, material, and labor and uses productivity data to translate labor costs into jobs.

For a different perspective on the results in Exhibit 3-3, Exhibit 3-4 presents the percentage change in employment by industry. As indicated in the exhibit, the coal mining and electric power industries are projected to experience the most significant proportional reductions in employment. Among those industries expected to experience an increase in employment, the percentage increase is most significant in natural gas extraction, natural gas utilities, and other mining and extraction. Across other industries projected to see a gain in employment, the percentage change is in the range of 0.1 to 0.5 percent.

EXHIBIT 3-4. ESTIMATED EMPLOYMENT IMPACTS OF THE CLEAN POWER PLAN BY INDUSTRY (PERCENT CHANGE RELATIVE TO REFERENCE CASE)

INDUSTRY	2020	2025	2030	2035	2040
Civilian jobs	0.0%	0.1%	0.2%	0.1%	0.1%
Private sector	0.1%	0.1%	0.2%	0.2%	0.2%
Agriculture, forestry and fisheries	0.1%	0.2%	0.3%	0.3%	0.3%
Coal mining	(15.8%)	(20.2%)	(20.3%)	(19.0%)	(17.7%)
Natural gas extraction	0.9%	2.2%	1.3%	1.1%	0.8%
Other mining and extraction	1.0%	1.7%	1.7%	1.8%	1.8%
Construction	(0.1%)	0.5%	0.5%	0.4%	0.3%
Durable goods manufacturing	0.3%	0.4%	0.5%	0.5%	0.4%
Non-durable goods manufacturing	0.2%	0.3%	0.4%	0.4%	0.4%
Electric power	(3.7%)	(8.7%)	(11.9%)	(13.1%)	(14.4%)
Gas utilities	1.2%	2.6%	1.5%	1.2%	0.9%
Transportation, Communication, Other Utilities	0.0%	0.1%	0.1%	0.1%	0.2%
Wholesale trade	0.2%	0.3%	0.4%	0.4%	0.4%
Retail trade	0.0%	0.2%	0.2%	0.2%	0.2%
Finance, Insurance, Real Estate	0.0%	0.0%	0.1%	0.1%	0.1%
Health	0.0%	(0.1%)	0.0%	(0.1%)	(0.1%)
Other services	0.1%	0.1%	0.2%	0.2%	0.2%
Civilian government	0.0%	0.0%	0.0%	0.0%	0.0%

CHAPTER 4 | DISCUSSION AND CONCLUSIONS

This study has provided an economy-wide assessment of the employment impacts associated with EPA's proposed Clean Power Plan. In addition to estimating employment impacts for directly affected firms, this study has examined how the proposed Plan might indirectly affect other industries and how these industries might change their use of labor. Our goal in performing this analysis was to capture the full range of effects that might influence the Plan's employment impacts. As described earlier in this report, these effects are many; they do not all move employment in the same direction; and they may influence employment in complex ways (e.g., changes in electricity prices affecting firms' production costs and thereby the prices they charge). Thus, at the outset of this study, we did not have any *a priori* expectations regarding the overall direction of employment impacts.

After accounting for all of the various effects described above in Chapter 2, our analysis found that the proposed Clean Power Plan is likely to increase U.S. employment by up to 273,000 jobs. For perspective, this is roughly the equivalent of one month of healthy job gains.[13] We emphasize, however, that this result is specific to the proposed Clean Power Plan. It does not imply that all greenhouse gas mitigation measures, or all emission control initiatives more broadly, will necessarily lead to an increase in employment. The direction and magnitude of employment impacts would depend on which of many factors affecting employment impacts are most significant. The relative strength of these factors would in large part reflect how the policy was structured. For example, the implementation of energy efficiency improvements at the retail level under the Clean Power Plan contributes to the estimated reduction in wholesale prices; the costs of these measures are not incurred by power producers but lead to a reduction in demand, causing wholesale prices to decline as well. This reduction in price would, all else equal, lead to increased employment, particularly for industrial electricity customers that purchase electricity on the wholesale market. Policy options that are structured differently, in the context of greenhouse gas regulation or conventional air pollutants, would not have this effect.

While employment is an important metric of regulatory impacts, we emphasize that it is but one of many metrics that provide useful information to policymakers and the public with respect to a rule's impacts. Estimates of a rule's employment impacts, therefore, should not be considered on their own but in conjunction with other impacts to gain a fuller understanding of a rule's implications for the economy and the public at large.

[13] According to the U.S. Department of Labor, approximately 295,000 jobs were added to the U.S. economy in February 2015.

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APPENDIX A | THE INFORUM LIFT MODEL

The national level model used for this study is the INFORUM LIFT[14] model. The features of the model that recommend it for this study include:

1. A consistent accounting for demand and supply for all industries.
2. Explicit modeling of the demand for energy by all industries, and for the household, government and foreign sectors.
3. The capability to model changes in patterns of energy use, such as those due to substitution or efficiency.
4. A detailed breakdown of the electric power sector into 8 generation types.
5. The ability to model GHG emissions by sector.
6. Dynamic modeling of employment and investment by sector.
7. A detailed set of consumer demand equations, which relate the demand for each good and service to real income and relative prices.
8. Consistent modeling of all major sectoral financial balances, including the government, business, household and foreign (external) sectors.
9. A flexible modeling environment, which allows for modification of parameters and variables in a transparent way.
10. Dynamic annual projections, normally out to 2040, but for a shorter or longer horizon if desired.

The interindustry input-output (IO) formulation of LIFT is not unique, as this is also a feature of many CGE models used for the study of energy and environmental policy issues. However, LIFT is quite different from most CGE models. Although LIFT is similar to a general equilibrium model, it is econometrically estimated, and works in many respects like other macroeconomic models, but with an IO core. Most parameters in LIFT were estimated using historical data, and the model "takes off" from the last historical data point, which may be different for different variables.

LIFT forms the macroeconomic aggregates for the most part from the bottom up, by aggregating detailed industry results. For example, aggregate investment, total exports, and employment are not determined directly, but are computed as the sum of detail: investment, employment and value added by industry, exports and imports by commodity, and personal consumption and construction by category. LIFT contains full

[14] Long-term Interindustry Forecasting Tool.

demand and supply accounting for 97 productive sectors. (See Table A-1 for the LIFT sector titles.)

This bottom-up technique carries several advantages for economic and policy analysis. First, the model describes how changes in one industry, such as increasing productivity or changing international trade patterns, affect related sectoral and aggregate variables. Second, parameters in the behavioral equations differ among products, reflecting differences in consumer preferences, price elasticities in foreign trade, and industrial structure. Third, the detailed level of disaggregation permits the modeling of prices by industry, allowing one to explore the causes and effects of relative price changes. For example, the differential effects of a carbon tax on the various producer and consumer prices can be calculated.

Another important feature of the model is the dynamic determination of endogenous variables. LIFT is an annual model, solving year by year, and incorporates key dynamics that include investment and capital stock formation. For example, investment depends on a distributed lag in the growth of investing industries, and international trade depends on a distributed lag of foreign price changes. Parameter estimates for structural equations largely are based on time-series regressions, thereby reflecting the dynamic behavior of the economic data underlying the model. So, model solutions are not static, but instead project a time path for the endogenous quantities. The LIFT model simulates the economy year-by-year, allowing analysts to examine both the ultimate economic impacts of projected energy or environmental policies and the dynamics of the economy's adjustment process over time.

Despite its industry basis, LIFT exhibits many of the same characteristics as a general equilibrium model, using bottom-up accounting to determine macroeconomic quantities consistent with the underlying industry detail. It includes more than 1200 macroeconomic variables consistent with the National Income and Product Accounts (NIPA) and other published data. Within the model, these variables are determined consistently with the underlying industry detail. This macroeconomic "superstructure" contains key functions for household savings behavior, interest rates, exchange rates, unemployment, taxes, government spending, and current account balances. Like many aggregate macroeconomic models, this structure is configured to make LIFT exhibit "Keynesian" demand driven behavior over the short-run, but neoclassical growth characteristics over the longer term. For example, while monetary and fiscal policies and changes in exchange rates can affect the level of output in the short- to intermediate-term, in the long-term, supply forces -- available labor, capital and technology -- will determine the level of output.

Finally, the LIFT model is linked to other, similar models with the Inforum Bilateral Trade Model (BTM). Countries included in this system include the U.S., Japan, China, and the major European economies. Through this system, commodity level exports and imports of the U.S. economy respond to demand and price variables projected by models of U.S. trading partners. In summary, the LIFT model is particularly suited for examining and assessing the macroeconomic and industry impacts of the changing composition of consumption, production, foreign trade, and employment as the economy grows through time.

A schematic diagram of LIFT is shown in Figure A-1. The interindustry framework underlying the model is composed of four blocks: the demand block, the supply block, the income block, and the accountant. The demand block of LIFT uses econometric equations to predict the behavior of real final demand (consumption, investment, imports, exports, government). The components are modeled at various levels of detail. For example, aggregate consumption is the sum of 92 consumption products. Demand by product, with product sectors consistent with the A matrix, is determined using bridge matrices to convert final demand to the commodity level. This equation is specified as:

$$f_{97\times1} = H^{c}_{97\times92}c_{92\times1} + H^{eq}_{97\times55}eq_{55\times1} + H^{s}_{97\times19}s_{19\times1} + i_{97\times1} + x_{97\times1} - m_{97\times1} + g_{97\times1}.$$

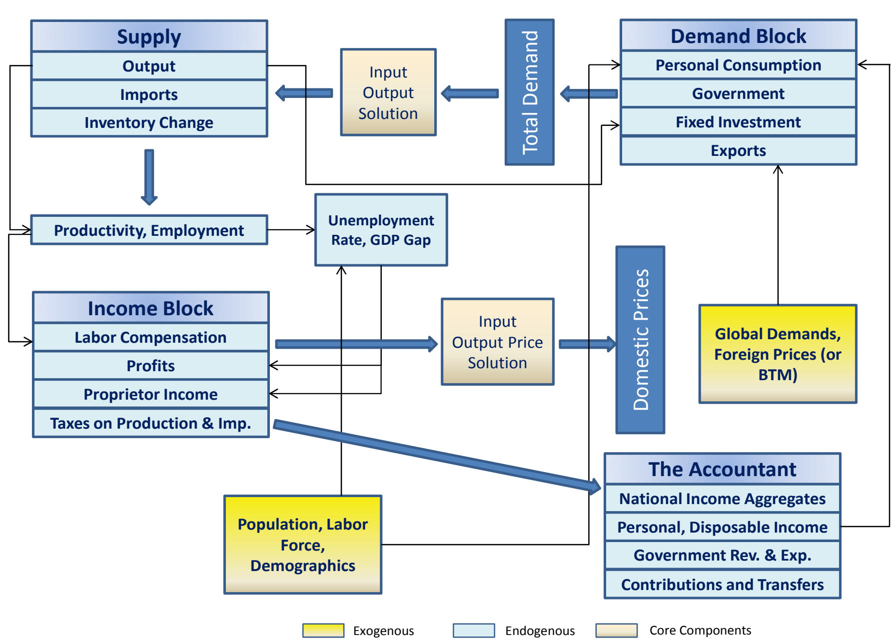
where H represents a bridge matrix for the various components: consumption, equipment investment by purchasing industry, expenditures by type of structures, inventory change, exports and imports, and government spending.

In the supply block, these detailed demand predictions then are used in an input-output production identity to generate real gross output demanded:

$$q = Aq + f$$

where q and f are vectors of output and final demand, respectively, each having 97 elements, and where A is a 97x97 matrix of input-output coefficients. Input-output coefficients and the bridge matrix coefficients vary over time according to historical trends evident in available data, and, in some cases, using assumptions about how technology and tastes might develop in the future.

FIGURE A-1. SUMMARY DIAGRAM OF THE LIFT MODEL



Commodity prices are determined in a similar fashion. In the income block, econometric behavioral equations predict each value-added component (including compensation, profits, interest, rent, and indirect taxes) by industry. Labor compensation depends on industry-specific wages which are determined by industry-specific factors as well as overall labor conditions. Profit margins are dependent on measures of industry slack (excess supply or demand) and, for tradable sectors, international prices. Depreciation depends on capital stock. Indirect taxes and subsidies are imposed, in most cases, through exogenous *ad-valorum* rates on overall nominal output.

The industry value added determined above is allocated to production commodities using a make matrix. Then the fundamental input-output price identity combines value added per unit of output with unit costs of intermediate goods and services to form an indicator of commodity prices:

$$p' = p'A + v'$$

where p and v have 97 elements to represent production prices and unit value added, respectively. This identity ensures that income, prices, and output by sector are directly related and are consistent. In turn, relative prices and income flows are included as independent variables in the regression equations for final demand, creating simultaneity between final demand and value added.

As noted above, LIFT also calculates all of the major nominal economic balances for an economy: personal income and expenditure, the government fiscal balance (at both the federal and state and local government levels), and the current account balance. It also contains a full accounting for population, the labor force and employment. This content is important for scenario-building, because it indicates the consistency between economic growth determined on the product side with the inflation and income components computed as it allows the model to examine how alternative microeconomic conditions or policies will affect other aspects of the economy.

As a result of this dynamic and bottom-up framework, LIFT is uniquely suited to explore many important economic relationships among industries, and their implications for the economy as a whole. The rich detail of the model supports a wide array of simulations that can be used for impact analysis and to address many types of policy questions, including analysis of shocks to particular industries. Because the input-output structure allows a bottom-up approach to modeling the macro economy, macroeconomic results are fully consistent with simulated industry changes.

We next turn to more detailed descriptions of some of the major components of LIFT.

The Personal Consumption Equations

Personal consumption is the largest single component of GDP. The pattern of consumer spending between the different categories of goods and services plays a large role in shaping the overall patterns of demand for domestic production and imports. The choice of a functional form and estimation technique for the consumption equations is crucial. The form must be able to accommodate significant growth in real income, such as what is likely to be realized in a long-term forecast. It must also be able to incorporate changes in relative prices and the effects of demographic and other trends. Both complementarity and substitution should be possible among different goods.

The equations are estimated as a demand system, using an estimation form called PADS. The estimation is done as a two-stage process. In the first stage, cross-sectional estimation is done to determine the impacts of age, geographic location, household size and education. In the second stage, the cross-section parameter results are combined with a time-series system estimation that relates real per-capita consumption of each good or service to real income and relative prices.

After consumption by category has been solved for in the model, this vector is passed through a consumption bridge, to obtain consumption by input-output commodity. This bridge also serves the function of stripping off trade and transportation margins to generate demand for the trade and transportation industries.

The Investment Equations

Equipment investment is also an important component of GDP, playing a major role in the medium-term cyclical behavior of the economy, as well as contributing to capacity for further long-term growth. LIFT forecasts purchases of equipment investment for 56 industries comprising the U.S. economy. Sales of investment goods at the 97 commodity level are then determined by passing equipment investment by buyer through the investment bridge matrix. Thus the model is capable of determining not only the direct and indirect impacts of a given increase in demand for some good, but also the investment purchases stimulated by that demand, and the capital goods inputs need to produce those investments.

The investment equations are estimated in a two-stage, three equation framework. Factor demands for equipment capital, labor and energy are estimated simultaneously. In the first stage, optimal capital-output, labor-output and energy-output ratios are estimated. In the second stage, the parameters from the first stage are treated as fixed, and equations for net investment, labor and energy are estimated. In this stage, investment is based upon a distributed lag on past changes in output, whereas labor and energy demand are based upon a distributed lag of levels of output. Replacement investment is determined by multiplying the optimal capital output ratio by the losses to capacity (as the level of optimal output given the current capital stock) occurring in the current year. Since the optimal capital-output ratio is a function of relative prices, price change affects both the demand for net investment and replacement investment.

The Construction Equations

The equations for private purchases of plant and other structures are for 19 categories of construction available from the NIPA. These purchases are generally aggregated into two major divisions. Residential construction consists of single- and multi-family homes, and additions and alterations. Non-residential construction is comprised of a motley of different types: hotels, industrial buildings, office buildings, schools, farm buildings, oil wells, railroads, telephone and communications, electric and gas utilities, and petroleum pipelines. The residential equations are estimated in per-capita form, and based on disposable income per capita, the mortgage interest rate, and the percent of households of home-buying age. The non-residential constructions are each unique, but often based on the output of the related industry or group of industries, the relative price of the related industry (especially in the case of oil and drilling rigs), interest rates, and a variety of demographic variables. Some of the equations also use a measure of capital stock of structures of that type, to model replacement investment needs.

Government Consumption and Investment

The NIPA divide government spending into consumption and investment categories, based on the average life of the good, as well as corresponding treatment of the good in private industry. For example, investment purchases of aircraft for defense are the new aircraft, as well as replacement components such as large engines or upgraded guidance systems. Consumption purchases include smaller replacement parts, tires and jet fuel.

Only consumption purchases are included in the presentation of the government revenues and expenditures. However, investment is accumulated into a book value stock, and the depreciation of this stock is the capital consumption of government. This capital consumption is part of current consumption expenditures.

LIFT has adopted this new accounting scheme, and we have developed an accounting for the government capital stock, and estimated capital consumption equations that relate capital consumption to the calculated depreciation from this stock. This capital consumption is part of the current government budget, and also shows up in the non-corporate capital consumption vector in the income side of the model.

Aside from capital consumption, the other categories of government consumption and investment are exogenous. However, these variables can be fixed at a fairly detailed level. For example, state and local purchases of structures can be fixed for 11 categories of construction, for education, health and other, for a total of 22 categories. If more aggregate control is desired, the total value of construction for each category of government can be fixed, and it will be allocated to construction by type by means of a bridge matrix.

There are four categories of government spending: federal defense, federal nondefense, state & local education, state & local health and other. For each category, there is a bridge that translates purchases by type to purchases by input-output commodity. For example, the bridge for federal defense spending has 97 rows and 25 columns.

Labor Productivity, Average Hours Worked and Employment

The growth of labor productivity is probably the single most important determinant of the growth of real per-capita income in the economy. The labor productivity equations used in LIFT are a combination of trend and cyclical factors.

The cyclical factor picks up the phenomenon of procyclical labor productivity, which is sometimes associated with “labor hoarding”. Firms are observed to retain trained workers in periods of slack output. When output increases again, they put the hoarded labor back to work before making new hires. There is a peak output variable used, which attempts to measure capacity output, both in the sense of capital and “hoarded” labor. Work is currently underway to estimate the effects of vintages of investment on labor productivity.

The equations for hours worked relate annual hours worked per employee to a time trend and cyclical changes in output, much like the labor productivity equations. Therefore, they are also essentially time trends.

Hours worked by industry can be obtained by dividing output by productivity. Then employment by industry is simply total hours divided by average hours worked per employee. This yields hours and employment for all industries comprising the private economy. Public sector employment, domestic employment and rest of world employment are specified exogenously.

Measures of Tightness

Before turning to some of the equations in the price-income side of the model, it would be helpful to discuss the alternative measures of tightness and slack in the economy. These are: the unemployment rate, or the difference of the unemployment rate from some specified “natural” rate; the GNP gap, which is an index that rises above 100 when the economy is tight; and capacity utilization, which is currently available from the Federal Reserve for only the mining, manufacturing and utilities sectors, and is a measure of how intensively the capital stock of various industries is being used. Although one may argue that the level of “core” inflation is determined generally by average money supply growth, the acceleration or deceleration of inflation around this core rate is surely determined by periods of relative tightness or slack.

The unemployment rate has long been considered a useful variable for indicating the pressure of aggregate demand relative to aggregate supply. Some variant of a Phillips curve has been included in the price equations of just about every macroeconomic model since the early aggregate Keynesian models. As a short-term indicator, the unemployment rate is extremely useful. Over a longer period however, the natural rate may drift, due to demographics and other factors. Therefore, when we use this variable, it is usually in reference to the natural rate, for which there are published historical time series. In the model forecast, the natural rate is exogenous, usually set to about 5.5.

The GDP gap is defined as $gdp/\overline{gdp}*100$, where $\overline{gdp}$ is potential GDP. The concept of potential GDP is simple: it is that level of GDP at which the economy is neither running above or below its capacity, as determined by labor force growth, labor participation, and labor productivity.

We have found the GDP gap to be a useful alternative to the unemployment rate in the price equations, the profit equations, and several others. The current version, which uses moving averages over five previous years, is backward-looking, and ignores capital stock. However, it is quite stable for long-term forecasting.

A third measure of tightness, for which data is available at the industry level, is the Federal Reserve measure of capacity utilization. The aggregate level of capacity utilization is a remarkably good indicator of the short-term cyclical prospects for inflation, performing better than the unemployment rate or the GDP gap. However, the definition and modeling of capacity is difficult, although we have made some experiments in this area.

The Wage Equations

In the price-income side of the model, the wage equations are really the backbone, for labor compensation comprises the largest share of income, and the most significant contributor to the core inflation rate is wage inflation. It is perhaps appropriate that it is here that we introduce the growth of money into the model, as the long-run determinant of average inflation.

The wage equations in LIFT are estimated in a stacked system, and the left-hand side variable is the percent change in the hourly labor compensation in each industry. The right hand side variables include the ratio of the money supply M2 divided by real GDP, and the percent change in industry labor productivity.

Although the main motive of introducing the monetary aggregate into this equation is to provide a mechanism whereby money affects prices, there is also a rationale supported by anecdotal evidence. This evidence suggests that when the money supply increases more rapidly, it stimulates aggregate demand. This creates pressure in the labor markets, which puts upward pressure on wages. An alternate story is the rational expectations version, that workers bid up wages in expectation of the higher inflation which they know will be generated by the money supply growth. From earlier experiments, we found that putting money supply growth in the demand equations, and the unemployment rate in the wage equations led to unsatisfactory results. The method we now use allows for a more direct and reliable influence of money on prices.

The Accountant

Even if forecasting the prices directly we still need to develop consistent estimates of the other components of income besides labor compensation. Rental income, interest income, proprietor's income and that part of profits paid out as dividends all contribute to personal income. Corporate profits taxes and indirect business taxes contribute to the revenue of governments. Capital consumption allowances and retained earnings are part of business savings, which is an important component of national savings. It is the job of the Accountant to aggregate the components of value added on the price-income side and obtain the aggregate variables needed to state the relationships between GNP, national income, personal income and disposable income. Along the way, the important components of the household and government balance sheets are obtained. The Accountant also forms aggregates of the expenditure vectors on the real side of the model, and forms implicit deflators from current and constant price aggregates.

The operation of the Accountant can be viewed in several stages. In the first stage, several aggregates of income are created from the price-income side, and summed to form nominal GNP. Factor imports are added and factor exports subtracted to obtain GDP. Supplements to labor compensation such as employer contributions are first aggregated across industries and then distributed to different funds based on exogenous ratios. Components of other labor income are also calculated in this stage. The second stage computes capital consumption adjustments, and forms proprietor's income, rental income and profits with and without capital consumption adjustments and inventory valuation adjustments. In the third stage, national income is formed by summing labor compensation, proprietor's income, rental income, corporate profits and interest income. Corporate profits, net interest and contributions for social insurance are subtracted, and transfer payments, personal interest income, personal dividend income, and business transfer payments are added back in to obtain personal income. This stage is quite lengthy due to a detailed set of identities and regression equations calculating the different components of transfer payments and interest payments. In the fourth stage, the components of federal and state and local receipts and expenditures are calculated. In the fifth and final stage, personal taxes and non-tax payments are removed to obtain disposable income. At this point, the loop in the model has been closed, and it returns to the real side, with the new guess at disposable income.

After prices have been computed, value added by commodity is recalculated as current price output less current price intermediate cost, and a discrepancy term. The product-industry bridge is used to recalculate value added by industry. Corporate profits, proprietors' income and capital consumption allowances are then scaled so that total value added by industry is correct. All that remains to be done in the price side is to calculate some other prices based on the domestic output prices. The price income loop is usually iterated at least twice, to make sure all parts are consistent with each other.

Once the price income loop has finished, it is now the job of the Accountant to summarize the industry results of the model, determine the household and government receipts and expenditures, and forecast important financial variables. For example, the Accountant forms personal income as the sum of wages and salaries, other labor income, proprietors' income, rental income, dividend income, interest income and transfer payments, less social insurance taxes. Then it subtracts personal tax and non-tax payments to arrive at personal disposable income. The model is now ready to return to the beginning of the real side, and solve again with this much better guess at disposable income.

Projections of Changes in IO Coefficients

The historical input-output database used for LIFT is built by Inforum based on the BEA Benchmark IO table, the time series of annual IO tables, BEA detailed gross output data, and Census exports and imports data. Inforum also compiles a database of domestic and import price deflators that are used to deflate the IO framework to constant prices. In the expenditure side of the model, which calculates output and imports, these constant price IO tables are used. The tables are not constant over time historically, and we don't expect constancy in the future either. Estimates are made of how average coefficients in a row of the table may be expected to change over the future, based on average changes in the recent past. A logistic, or "S-curve" equation is used, which will show average consumption of one commodity by other industries to be either rising or falling (or flat), but converging to a flat point in the future. The results of these equations are applied to the IO coefficients as the model moves forward in time.

These equations are estimated econometrically, but judgment must be applied in determining what form of equation to incorporate into the model for each row of the IO table. For some products, such as energy products, the projection of use by industry can be quite uncertain, since they are based on volatile supply and demand conditions affecting prices, as well as the adoption of technologies by the many different industries and consumers. Outside information may be incorporated instead, such as projections of energy use by the Energy Information Administration (EIA) *Annual Energy Outlook.* Through the modification of the IO coefficient projections for energy products, the model can be calibrated to agree with the AEO projection of industrial electricity consumption, for example.

IO coefficients can also be modified to implement a "what-if" scenario that examines the effects of a new technology or pattern of use. An example would be the modeling of increased use of corn or cellulosic ethanol as a blended ingredient into retail gasoline. In this case, the coefficient of agriculture to Other chemicals is increased, and then the coefficient of Other chemicals to Petroleum refining is increased. For one study, an ethanol submodel was joined to LIFT, which looked explicitly at alternate projections of corn or cellulosic ethanol, and determined impacts on agriculture markets of varying ethanol assumptions.

Energy Modeling in LIFT

While not an energy model *per se*, LIFT maintains detail for the following energy industries.

3. Coal
4. Natural gas extraction
5. Crude petroleum
24. Petroleum refining
25. Fuel oil
66. Electric utilities
67. Natural gas distribution

LIFT shows constant and current dollar sales of these industries to all other industries and to final demand, as well as showing the purchases of these industries from other industries in the economy.

The calculation of prices in LIFT is also based on IO relationships. Prices are based on the prices of domestic and imported inputs, and the value added generated in production, including labor compensation, gross operating surplus and indirect taxes. Energy taxes are implemented as indirect taxes, which affect the price of the target industry directly, and the prices of all other industries indirectly.

Residential energy demand, and household transportation are modeled as part of the system of personal consumption expenditure equations described above. These consumption equations respond to disposable income, relative prices and other variables. Industrial, commercial and non-household transportation energy demand is modeled via IO relationships. The IO relationships are not static, but may be modeled to incorporate efficiency improvements, price-induced substitution, or changes in structure due to technological change. The structure of the electric power generating industry is represented as a disaggregation into the following list of 8 separate components, based on the technology or fuel type.

Types of Electricity Generation

1. Coal
2. Natural gas
3. Petroleum
4. Nuclear
5. Hydro
6. Wind
7. Solar
8. Geothermal, biomass and other

Additional modules have been attached to LIFT, which perform side calculations. These modules take output, price and other variables from the model, solve, and then provide variables to feed back to the main model. Examples of modules now functioning with LIFT include:

- Biofuels
- Light-duty vehicles
- Buildings efficiency
- CCS
- Renewable power (wind and solar)
- Nuclear power
- Carbon and carbon tax calculator
- Electricity generation by type

A module such as the building efficiency or light duty vehicles calculates variables such as residential and commercial energy demand for which LIFT would normally use the personal consumption equations or the IO coefficients. With the addition of the module, these default calculations are either replaced or modified. Personal consumption expenditures on gasoline may then be calculated as the sum of fuels of vehicles of different types, based on MPG and vehicle miles traveled instead of the default equations which rely on income and price. Changes in commercial energy demand coming through building or vehicle efficiency are implemented as changes in IO coefficients.

Applications of LIFT

Here is a sample of recent Inforum projects that have used the LIFT model:

- Projecting National Health Expenditures (NHE) for the Centers for Medicare and Medicaid Services. In this project, the model is used to study questions concerned with financing present and future health programs, including evaluations of impacts of different macroeconomic and demographic assumptions, health policies, and health technologies.

- Determining the industrial and jobs impact of the Future Years' Defense Plan for the Department of Defense. This project also has a detailed industry (360) and state-level component which are not done by LIFT.
- Analysis of alternative scenarios for natural gas supply and demand for the Energy Modeling Forum. Inforum teamed with the Mitre Corporation, and LIFT is run with the MARKAL model in a loosely coupled framework.
- A study of the effects of removing the crude oil export ban on U.S. manufacturing, done for the Aspen Institute.
- Determining the costs and benefits of alternative levels of infrastructure investment, performed for the National Association of Manufacturers.
- Analysis of the effects of a west coast port stoppage, for the National Retail Federation.
- A historical and prospective analysis of the impact of U.S. oil dependence on the federal debt, for Securing America's Future Energy (SAFE).
- A study of the economic impact of the Transport Electrification Roadmap for the Electrification Coalition (EC).

Table A.1 Producing Sectors of the LIFT Model of the U.S. Economy

1 Agriculture, forestry, & fish

Mining
2 Metal mining
3 Coal mining
4 Natural gas extraction
5 Crude petroleum
6 Non-metallic mining

Construction
7 New construction
8 M & R construction

Non-Durables
9 Meat products
10 Dairy products
11 Canned & frozen foods
12 Bakery & grain mill product
13 Alcoholic beverages
14 Other food products
15 Tobacco products
16 Textiles and knitting
17 Apparel
18 Paper
19 Printing & publishing
20 Agric fertilizers & chemicals
21 Plastics & synthetics
22 Drugs
23 Other chemicals
24 Petroleum refining
25 Fuel oil
26 Rubber products
27 Plastic products
28 Shoes & leather

Durable Material & Products
29 Lumber
30 Furniture
31 Stone, clay & glass
32 Primary ferrous metals
33 Primary nonferrous metals
34 Metal products

Non-Electrical Machinery
35 Engines and turbines
36 Agr., constr., min & oil equip
37 Metalworking machinery
38 Special industry machinery
39 General & misc. industrial
40 Computers
41 Office equipment
42 Service industry machinery

Electrical Machinery
43 Elect. industry equipment
44 Household appliances
45 Elect. lighting & wiring eq
46 TV's, VCR's, radios
47 Communication equipment
48 Electronic components

Transportation Equipment
49 Motor vehicles
50 Motor vehicle parts
51 Aerospace
52 Ships & boats
53 Other transportation equip

Instruments, Misc. Manufacturing
54 Search & navigation equip
55 Medical instr & supplies
56 Opthalmic goods
57 Other instruments
58 Miscellaneous manufacturing

Transportation
59 Railroads
60 Truck, highway pass transit
61 Water transport
62 Air transport
63 Pipeline
64 Transportation services

Utilities
65 Communications services
66 Electric utilities
67 Gas utilities
68 Water and sanitary services

Trade
69 Wholesale trade
70 Retail trade
71 Restaurants and bars

Finance & Real Estate
72 Finance & insurance
73 Real estate and royalties
74 Owner-occupied housing

Services
75 Hotels
76 Personal & repair services
77 Professional services
78 Computer & data processing
79 Advertising
80 Other business services
81 Automobile services

82 Movies & amusements
83 Private hospitals
84 Physicians
85 Other medical serv & dentists
86 Nursing homes
87 Education, social serv, NPO

Miscellaneous
88 Government enterprises
89 Non-competitive imports
90 Miscellaneous tiny flows
91 Scrap & used goods
92 Rest of the world industry
93 Government industry
94 Domestic servants
95 Inforum statistic discrepancy
96 NIPA statistical discrepancy
97 Chain weighting residual