NRDC

MARCH 2017
IP: 17-03-B

APPENDIX

METHODOLOGY FOR NRDC ECONOMIC IMPACT ANALYSIS

This document details the methodology for the economic impact analysis of carbon emissions limits in the electric power sector, using the Regional Economic Modeling Inc.'s Policy Insight Plus model, referred to as the REMI model below. The first step of this analysis involves power sector analysis using the Integrated Planning Model (IPM®). In the second stage of this analysis, described here, outputs of this power sector modeling were then used as inputs into the REMI model. The methodology discussion is divided into two main sections: the Reference Case Calibration and Policy Simulations. Reference Case Calibration involves the recalibration of the REMI Standard Regional Control to more closely match the IPM Reference Case. The IPM Reference Case was developed by ICF in a separate analysis for NRDC and M.J. Bradley & Associates.[1] The calibration exercise makes adjustments for renewable jobs, coal mining, retirements (nuclear and coal), natural gas, utility jobs, and electricity prices. Policy Simulation involves the creation of policy variables in REMI using outputs from the relevant IPM runs. Policy Simulation contains Energy Efficiency, Retirements and Builds (Energy), Retrofits (Heat Rate Improvement (HRI) and other retrofits), and where applicable, Revenue Recycling, and Distributed Solar with Energy Efficiency further broken down into Spending on Equipment, Bill Savings, Lost Utility Revenue, and Customer Reallocation.

The REMI PI+ model is a structural economic forecasting and policy analysis model that integrates several analytic techniques including input-output, computable general equilibrium (CGE), econometric, and economic geography methodologies. The model is dynamic, with forecasts and simulations generated on an annual basis to include behavioral responses to wage, price, and other economic factors. REMI can be used for estimating national, regional, and state-level impacts of policy changes, such as the power sector carbon emissions limits analyzed in this study. The dynamic modeling framework supports the option to forecast how changes in the economy, and adjustments to those changes, will occur on a year-by-year basis. Three big advantages of teh REMI model over input-output models are that (1) it depicts the role that prices exert on household and business decisions; (2) prices 'adjust' to solve supply and demand imbalances for labor, capital, and other input markets; and (3) it allows for the estimation of year-by-year (annual) impacts and forecasts whereas other models only provide static representations of the economy. Finally, the REMI model allows us to identify the distributional impacts of policies across multiple states and regions.

The REMI model used in this analysis is a 16-region, 70-sector model of the continental United States. Our model contains regions for: Pennsylvania, Virginia, Ohio, Michigan, Missouri, Illinois, Iowa, Minnesota, Montana, Colorado, Nevada, Florida, New Hampshire, Maine, Georgia, and a single region (Rest of the U.S.) for all other states. CGE models incorporate interaction effects across each sector and each state. REMI allows three types of model closures: Keynesian, Historically Observed, and Anticipatory Fed. We used the Keynesian closure, meaning no central bank interest rate mechanism will be exerted to correct changes in U.S. employment that have been caused by a policy shock, because we are interested in finding the Keynesian multiplier effects of various policy changes.

1. REFERENCE CASE CALIBRATION

We determined that the Standard REMI Regional Control was not an accurate representation of the projections from the IPM Reference Case given significant recent changes in the energy sector and the age of the data used to generate the standard forecast. We focused on those variables for which the difference was most significant, given some of the recent changes occurring in the energy sector that were not captured in the REMI data. These variables are discussed below: For the purposes of the reference calibration, we compared the Annual Energy Outlook (AEO) for 2015, which was the basis for the IPM modeling, with AEO 2012, which served as one of the data sources for the REMI Standard Control. We compared AEO 2012 with AEO 2015 for Renewable and Natural Gas changes. For Coal Mining and Electricity Price changes, we directly compared the Standard REMI Regional Control values with AEO 2015. Finally, for Utility Employment changes, we compared the Standard REMI Regional Control values with the Bureau of Labor and Statistics (BLS) projections of employment.

a. Renewable Jobs

IPM Reference Case projections for future renewable energy (RE) generation, which were based on recent AEO (2015) projections, were estimated to be 25 to 30 percent higher between 2016 and 2035 than those implied in REMI's Standard Regional Control projections. Therefore, we developed ways to properly adjust REMI to account for the increased manufacturing, construction, and professional and technical service jobs. Renewable jobs were calibrated in order to account for the significant increase in projected solar and wind generation. IPM does not provide job estimates directly, therefore, we estimated renewable jobs using the capital costs and fixed operations and maintenance (FOM) costs for solar and wind from IPM. The capital costs were assumed to be incurred by three sectors—manufacturing (44 percent), construction (10 percent), and professional, scientific, and technical services (47 percent). The FOM costs were assumed to be incurred by two sectors—manufacturing (45 percent) and utilities (55 percent). These assumptions are based on previous IMPLAN analysis which used the National Renewable Energy Laboratory (NREL) Jobs and Economic Development Impact (JEDI) models to assign shares to several categories. We converted energy investment into jobs changes using labor productivity rates from the BLS.[2] For more details see the relevant sectors below:

i. Manufacturing

To calibrate the manufacturing jobs, we estimated the number of solar-related jobs in IPM by applying 44 percent of the capital cost and 45 percent of the FOM cost (using data from the JEDI models discussed above) to the labor productivity of the computer and electric manufacturing sector (4.06).[3] These estimated national level jobs were then added to the REMI default jobs for computer and electronic product manufacturing. The maximum job increase was 4.6 percent in 2040 for the computer and manufacturing sector. We applied this increase uniformly under the assumption that the growth rates at the national and state level are equal.

We used the same approach to calibrate the inputs for wind-related manufacturing jobs; for wind, we applied the labor productivity for the "turbine and turbine generator set unit manufacturing," which is equal to 2.63. The maximum job increase across the U.S. was 3.1 percent in 2040 for the turbine and turbine generator set unit manufacturing sector.

ii. Construction

To calibrate the construction jobs, we estimated the number of solar and wind-related construction jobs in IPM by applying 10 percent of the capital cost of installations to the labor productivity of the construction sector (4.15). These estimated national level jobs were then added to the REMI default jobs for construction. The percent differences between the REMI default jobs and the newly adjusted REMI jobs were then used to calibrate REMI at the state-level. At most, we increased jobs by 0.1 percent for the construction sector in 2017 and 2018.

iii. Professional and Technical Services

To calibrate the professional and technical services jobs, we estimated the number of solar and wind-related professional and technical services jobs by applying 47 percent of the capital cost of installations to the labor productivity of the associated sector (5.19). These estimated national level jobs were then added to the REMI default jobs for professional and technical services. The percent differences between the REMI default jobs and the newly adjusted REMI jobs were then used to calibrate REMI at the state-level. The maximum increase in jobs yielded a 0.4 percent increase in professional and technical services in 2017 and 2018.

b. Coal Mining

Given that the REMI Standard Regional Control data vintage was from 2012, some of the more recent structural shifts affecting the coal-based generation fleet were not reflected in the REMI data and required updating. Comparing REMI's data with the more recent AEO data, we determined that coal employment was too high given recent mining prospects and the age of the REMI Standard Control data. To determine the necessary changes, we compared the REMI Standard Regional Control mining outputs with IPM coal consumption (assuming that coal mining is 40 percent of the mining industry using output dollars, based on relative output from the U.S. Mining Association) and with AEO 2012 estimates. We then subsequently decreased coal mining employment in REMI based on the coal consumption numbers from IPM. We dropped coal employment numbers in REMI by 7.9 percent in 2020 and further decreased numbers by 36 percent in 2040.

c. Retirements

We determined that the coal and nuclear retirements forecasted by IPM were greater than projected in the Standard REMI Regional Control. To calibrate the REMI Standard Control, we converted the retirements (in GW) predicted from IPM into job losses resulting from changes in FOM costs using average FOM per kW from AEO 2015 and labor productivity for the power generation from BLS. We then calibrated the REMI Standard Control based on these decreases. These losses entered the REMI model through the electric power generation, transmission, and distribution sector.

d. Natural Gas

To calibrate the REMI Standard Control to account for recent and projected future increases in natural gas demand, we compared natural gas consumption estimated in IPM with AEO 2012. As explained above, we compared IPM values (based on AEO 2015) with AEO 2012, which was used as one of the data sources for the REMI Standard Control. We estimated the difference in natural gas consumption (TBtu) between IPM and AEO and converted this to revenue using the delivered natural gas price from IPM ($/MMBtu). We then increased the output for the oil and gas extraction industry in REMI based on the difference between the REMI Standard Control and IPM values. This process is based on a similar rationale as the process used to adjust the coal industry consumption, except it results in an increase in the natural gas industry versus the decrease calculated for the coal industry.

e. Utility Jobs

To calibrate utility employment in the REMI Standard Control, we compared the raw employment with BLS National Employment Matrix (accessed August 2015) employment forecasts (which was 13 percent higher by 2022).[4] By comparing the REMI Standard Control with BLS out to 2040, we determined that the REMI Standard Control was underestimating the forecast, and we increased employment in the utility sector by 7 percent cumulatively between 2020 and 2040.

f. Price of Electricity

To equate the REMI Standard Control to IPM, we compared the state-level 2009 REMI prices (an index) with the IPM retail rates. Rather than compare exact values, we compared the trend across time intervals (for example, whether prices increase or decrease between 2020 and 2025), and then altered the index in REMI accordingly.

1.1 TREATMENT OF THE RENEWABLE ENERGY TAX CREDITS, AND ALTERNATE REFERENCE CASE

The Reference Case Calibration includes the December 2016 extensions of the renewable energy production tax credit (PTC) and a solar investment tax credit (ITC). To offset the government's declines in tax revenues as a result of these renewable energy tax credits (assuming no new revenue streams to account for the reduction in revenue from the credits), we assumed lower spending across the top ten areas of non-defense discretionary government spending: administrative and support services; ambulatory health care services; hospitals; miscellaneous manufacturing; nursing and residential care; oil and gas extraction; petroleum and coal products; scientific and professional services; real estate; and telecommunications.

We also estimated an alternate reference case for which there was no longer a PTC or ITC. The Alternate Reference Case uses the same methodology as the above Reference Case Calibrations, except for the tax credits described in the previous paragraph. While the exclusion of the PTC and ITC from the Alternate Reference Case resulted in difference in generation mixes, fossil fuel consumptions, and energy costs coming out of IPM, the methods and sources used remained the same.

2. SCENARIOS—METHODOLOGY FOR POLICY CASE MODELING

For each policy simulation, we used outputs from IPM to adjust the forecast based on a number of shocks. We modeled the following Scenarios (Policy Cases):

EXHIBIT 1: POLICY CASE SUMMARY INFORMATION

POLICY CASE	INCREMENTAL ENERGY EFFICIENCY	CARBON POLICY	REVENUE RECYCLING	TRADING LEVEL	OTHER SPECIFICATIONS
1	2%	CPP Mass	No	National	New +Existing
2	1%	CPP Mass	No	National	New +Existing
2A	1%	CPP Mass	Rebate	National	New +Existing
2B Lower Bound	1%	CPP Mass	Worker Retraining	National	New +Existing
2B Upper Bound	1%	CPP Mass	Worker Retraining	National	New +Existing
3	1%	CPP Dual Rate	No	National	
4	1%	CPP Mass, with 1% decline post-2030. The RGGI caps decline at 5%/year.*	No	National	DG Solar, relaxing generation caps 2040+, N+E

* In this scenario, the national Clean Power Plan (CPP) mass-based limits declined at 1%/year after 2030, to reflect a scenario in which the policy is strengthened to meet continued decarbonization goals.

In these policy cases we modeled the impacts of energy efficiency (spending, bill savings, lost utility revenue, and reallocation), retirements (coal and nuclear), new capacity builds (natural gas, wind, solar, rooftop solar (in case 4 only), and other renewables), retrofits, and revenue recycling (rebate and worker retraining) where appropriate.

a. Energy Efficiency

i. Spending

Spending on energy efficiency (EE) was broken down into program and participant spending, reflecting the assumptions specified for IPM. Program spending was derived from utility efficiency program budgets. Funding was assumed to accrue exclusively from utilities via electric customers, with no additional government support. Participant spending consists of copays as they are required by most efficiency programs. Both spending types were broken out into Residential, Commercial and Industrial (R, C, I) spending based on sales of electricity to ultimate customers by end-use sector from the Energy Information Administration (EIA) (Exhibit 2).

EXHIBIT 2: RETAIL SALES OF ELECTRICITY TO ULTIMATE CUSTOMERS BY END-USE SECTOR, BY STATE

STATE	RESIDENTIAL	COMMERCIAL	INDUSTRIAL
GA	41%	35%	24%
VA	41%	43%	16%
NH	41%	41%	18%
ME	39%	34%	27%
MI	33%	37%	30%
OH	35%	31%	34%
IL	33%	36%	31%
MT	35%	35%	30%
IA	31%	27%	42%
MN	33%	34%	33%
MO	42%	37%	21%
PA	37%	30%	33%
CO	35%	38%	28%
FL	51%	42%	7%
NV	34%	26%	39%
Rest of US	37%	36%	27%
Total US	38%	36%	26%

Source: EIA, 2013 data.

EXHIBIT 3: ENERGY EFFICIENCY PROGRAM AND PARTICIPANT SPENDING INDUSTRY ALLOCATION

INDUSTRY	PROGRAM SPENDING			PARTICIPANT SPENDING		
	R	C	I	R	C	I
Wood product manufacturing	1%	1%	0%	1%	0%	0%
Nonmetallic mineral product manufacturing	1%	1%	0%	1%	1%	0%
Paper	2%	0%	0%	2%	0%	0%
Machinery manufacturing	3%	8%	15%	3%	9%	17%
Computer and electronic product manufacturing	1%	3%	3%	1%	3%	3%
Electrical equipment manufacturing	2%	10%	15%	2%	11%	17%
Plastics and rubber product manufacturing	2%	2%	0%	2%	2%	0%
Wholesale trade	1%	2%	2%	1%	2%	2%
Construction	63%	54%	45%	70%	60%	50%
Retail	15%	0%	0%	17%	0%	0%
Professional Services	4%	14%	14%	0%	11%	11%
Utilities	6%	6%	6%	0%	0%	0%

Above values from the ENE report. Adjusted to account for REMI requirements of retail and wholesale margins.

With the IPM outputs divided into RCI, we used industry shares based on the Environment Northeast (ENE, now known as the Acadia Center) report (Exhibit 3)[5] to partition out the spending into industries.

For retail and wholesale trade, REMI requires only the margin value to be inserted. In input-output models, it is often necessary to insert only the markup or margin value for retail and wholesale trade because that is their value added contribution to the relevant economic activity. The remaining portion (i.e., 1-margin value) is typically a direct pass-through for these sectors and therefore should not be attributed to the retail/wholesale sectors. We assumed the margin value to be 30 percent for retail and 20 percent for wholesale based on Census Bureau estimates. To partition the 1-margin values for Residential retail trade, we used the National I-O matrix from REMI to determine sectors to allocate money based on personal consumption of household-appliances. For Commercial and Industrial retail trade, we used the original ENE shares to allocate funds. For wholesale trade, we inserted the margin into the wholesale industry; and then for the 1-margin, we used the Intermediate Use wholesale trade coefficients from the REMI National I-O matrix to allocate funds for RCI.

Spending was incorporated into REMI using the Exogenous Final Demand (amount) policy variables for the relevant sectors in exhibit 3 on page 4.

ii. Bill Savings

The category of Bill Savings reflects the amount of money saved (which can be negative in some years and some scenarios) on electricity bills due to the impacts of reduced consumption and funding for programs in each policy scenario. Bill savings were broken out into RCI in the same way as Spending (based on EIA data in Exhibit 2). ICF calculated bill savings by translating IPM outputs such as total capital costs, operations and maintenance costs (O&M), fuel costs, wholesale power prices, and quantities consumed into retail bill impacts.

IPM projects the wholesale prices paid to generators. The costs paid by retail customers can vary significantly from this wholesale price, since the retail rate typically also includes additional costs such as transmission and distribution costs to end-use customers. In order to capture these charges, ICF developed a measure of the representative retail electricity price in each state across the forecast period for each of the cases under study. The methodology for this calculation is derived from the Retail Price Model, developed by ICF for EPA.[6]

The Retail Price Model accounts for variations in regulated and deregulated markets by calculating cost-of-service and competitive retail prices for each region and then weighing and allocating both to individual IPM regions according to the market structure that best represents each region:

- Competitive retail power price is comprised of competitive generation cost and transmission and distribution charges.
- Cost-Of-Service retail power price includes the cost of generation and the recovery of costs associated with transmission and distribution facilities and services.

Electricity bills are then calculated as the product of the representative retail price and the retail sales of electricity for each region in that run year for each particular policy case. The bill savings reflect the change in this representative electricity bill in each policy case relative to the Reference Case. The retail bill savings can therefore be affected by:

- The level of Energy Efficiency: The cost of EE investments is offset by the lower demand for electricity, which tends to lower bills on net.
- CO_2 program design (Rate or Mass): A mass-based program will result in a different impact on wholesale power prices than an intensity-based standard
- CO_2 program design (Trading): The ability to trade allowances across state lines can result in some states being net sellers and some being net buyers of allowances, which has an impact on the retail bills.
- Changes in net exports: The imposition of a CO_2 program can lead to changes in dispatch across states, with corresponding changes in net exports. This can result in some movement in bill costs relative to a BAU scenario.

Commercial and Industrial bill savings were incorporated into REMI using Production Costs. Industry-specific savings were derived using energy use shares from the REMI National I-O Matrix. The values were broken into Industrial and Commercial sectors and normalized across each to attain industry-specific shares (presented in Exhibit 4).

EXHIBIT 4: REMI NATIONAL I-O MATRIX, USED TO ALLOCATE BILL SAVING IMPACTS ACROSS SECTORS

INDUSTRY	SHARE
INDUSTRIAL	
Forestry and logging; fishing, hunting, and trapping	0.1%
Agriculture and forestry support activities	0.2%
Oil and gas extraction	1.2%
Mining (except oil and gas)	12.5%
Support activities for mining	0.0%
Utilities	0.1%
Construction	0.7%
Wood product manufacturing	4.7%
Nonmetallic mineral product manufacturing	12.7%
Primary metal manufacturing	12.1%
Fabricated metal product manufacturing	3.4%
Machinery manufacturing	1.7%
Computer and electronic product manufacturing	0.7%
Electrical equipment and appliance manufacturing	1.8%
Motor vehicles, bodies and trailers, and parts manufacturing	2.0%
Other transportation equipment manufacturing	1.4%
Furniture and related product manufacturing	1.7%
Miscellaneous manufacturing	1.4%
Food manufacturing	5.6%
Beverage and tobacco product manufacturing	2.5%
Textile mills; textile product mills	4.8%
Apparel manufacturing	3.9%
Paper manufacturing	11.5%
Printing and related support activities	3.6%
Petroleum and coal products manufacturing	0.5%
Chemical manufacturing	5.3%
Plastics and rubber product manufacturing	3.7%
COMMERCIAL	
Wholesale trade	1.9%
Retail trade	3.2%
Air transportation	0.2%
Rail transportation	0.5%
Water transportation	1.3%

INDUSTRY	SHARE
Truck transportation	1.2%
Couriers and messengers	0.8%
Transit and ground passenger transportation	0.2%
Pipeline transportation	0.0%
Scenic and sightseeing transportation	1.5%
Warehousing and storage	4.1%
Publishing industries, except Internet	0.8%
Motion picture and sound recording industries	1.9%
Internet publishing and broadcasting	1.1%
Broadcasting, except Internet	1.0%
Telecommunications	2.0%
Monetary authorities - central bank	0.6%
Securities, commodity contracts, investments	1.1%
Insurance carriers and related activities	0.2%
Real estate	2.2%
Rental and leasing services	2.6%
Professional, scientific, and technical services	0.7%
Management of companies and enterprises	1.8%
Administrative and support services	1.4%
Waste management and remediation services	1.8%
Educational services	12.1%
Ambulatory health care services	1.1%
Hospitals	3.4%
Nursing and residential care facilities	5.1%
Social assistance	2.3%
Performing arts and spectator sports	1.4%
Museums, historical sites, zoos, and parks	11.3%
Amusement, gambling, and recreation	4.9%
Accommodation	12.0%
Food services and drinking places	6.5%
Repair and maintenance	2.1%
Personal and laundry services	2.1%
Membership associations and organizations	1.5%

Source: REMI National I-O Matrix (version 1.7.4). Totals may not add up to 100 due to rounding.

iii. Lost Utility Revenue

Lost utility revenue is the revenue utilities lose due to electricity demand reduction from energy efficiency. Lost revenue was calculated based on quantity and electricity price outputs of IPM and modeled as a loss for the utility sector (in terms of sales) in REMI.

iv. Spending Reallocation

Spending Reallocation represents the negative effects of EE customers' increased spending on EE equipment (Participant spending), assuming a constant overall budget for customers. Because Program spending is incorporated into wholesale prices in IPM, and is ultimately reflected in retail rates through the Retail Price Model, it was addressed internally in the model and did not need to be subtracted from the economy. Therefore, only Participant spending was entered into the model as a negative effect. It was broken out into RCI in the same manner as Spending and Bill Savings (Exhibit 2).

Reallocation was entered into the model using Consumption Reallocation (amount) for residential, and increased Production Cost for commercial and industrial. The value for C and I were distributed across all industries in proportion to their share of value-added output.

b. Retirements

i. By Energy Source

Increases or accelerations of coal, natural gas, and nuclear retirements were assumed to have negative economic effects (or positive impacts if retirements decreased relative to the Reference Case) and were modeled using changes in operation and maintenance and fuel costs from IPM. Decreasing FOM, variable operation and maintenance (VOM), and Fuel costs were factored into REMI using exogenous final demand (see Exhibit 5 below).

EXHIBIT 5: JEDI INDUSTRY SHARES (RETIREMENTS)

ENERGY	IPM OUTPUT	INDUSTRY	SHARE
Coal	Fixed O&M	Utilities	60%
		Electrical equipment and appliance manufacturing	25%
		Professional and technical Services	15%
	Variable O&M	Utilities	77%
		Chemical manufacturing	16%
		Waste Management and remediation services	7%
	Fuel Cost	Coal mining	60%
		Rail transportation	40%
Natural Gas	Fixed O&M	Utilities	80%
		Chemical manufacturing	10%
		Professional and technical Services	10%
	Variable O&M	Professional and technical Services	52%
		Utilities	48%
	Fuel Cost	Oil & gas extraction	78%
		Pipeline transportation	22%
Nuclear	Fixed O&M	Distribution and transmission	100%
	Variable O&M	Distribution and transmission	100%

Exhibit values (except for Nuclear) are originally from the National Renewable Energy Laboratory Jobs and Economic Development Impact models. For Nuclear we assume that changes affect only the distribution and transmission sectors.

c. New Builds

i. By Energy Source

We used capital, fixed and variable operation and maintenance, and fuel costs from IPM to determine the effect of incremental builds. REMI data for new builds came from two sources. All of the cost data came from the relevant IPM policy run outputs. In order to identify what economic sectors would benefit from these new build investments, we relied on the industry shares data from JEDI models for the relevant types of new builds (Exhibit 6). Builds were entered into REMI using Exogenous Final Demand for Natural Gas, Solar, Wind, and Other Renewables. Labor costs of Wind and Solar were entered into REMI using the compensation variable.

It is necessary to incorporate labor costs in REMI using the compensation variable in order to appropriately account for the labor payments, which can be thought of as increases in worker paychecks, resulting from new builds.

EXHIBIT 6: JEDI INDUSTRY SHARES (NEW BUILDS)

ENERGY	IPM OUTPUT	INDUSTRY	SHARE
Natural Gas	Capital Cost	Utilities	38%
		Construction	27%
		Machinery manufacturing	16%
		Fabricated metal product manufacturing	9%
		Professional services	3%
		Real estate	7%
	Fixed O&M	Utilities	80%
		Chemical manufacturing	10%
		Professional and technical Services	10%
	Variable O&M	Professional and technical Services	52%
		Utilities	48%
	Fuel Cost	Oil & gas extraction	78%
		Pipeline transportation	22%
Solar	Capital Cost	Computer and electronic manufacturing	41%
		Construction	22%
		Utilities	17%
		Professional services	10%
		Fabricated metals manufacturing	6%
		Real estate	5%
	Fixed O&M	Utilities	55%
		Computer and electronic manufacturing	41%
Wind	Capital Cost	Machinery manufacturing	45%
		Construction	23%
		Fabricated metal product manufacturing	12%
		Plastics & rubber products manufacturing	11%
		Truck transportation: couriers and messengers	8%
		Professional services	2%
	Fixed O&M	Electrical equipment & appliance manufacturing	56%
		Utilities	23%
		Insurance carriers & related activities	17%
		Repair & maintenance automotive repair & maintenance	2%
		Retail trade	1%

Source: National Renewable Energy Laboratory Jobs and Economic Development Impact Models.

Because the compensation variable was used to model labor costs, a post model adjustment was made to the employment results. The jobs created by compensation changes were calculated by dividing the compensation input by the annual compensation per worker from the REMI forecast. These jobs were then allocated back into the final aggregated and state results post REMI modeling.

d. Retrofits

i. Heat Rate Improvement

Heat Rate Improvement (HRI) was obtained from IPM as a quantity (GW). To enter the change into REMI, the amount of capacity that installed heat rate improvement measures was multiplied by the EPA estimated cost of HRI ($100/KW) and the subsequent amount was divided between professional, scientific, and technical services, construction, and machinery manufacturing sectors based on EPA 5.15 documentation by equal shares. HRI was factored into REMI using exogenous final demand for the three sectors.

ii. Other Retrofits

Investment in Other retrofits was obtained from IPM in annual investments ($millions). This investment was entered into REMI using Final Exogenous Demand for the chemical, construction, machinery manufacturing, and professional and technical services industries.

e. Revenue Recycling

To model the economic benefits of allowance revenue recycling, we first obtained the total revenues available from IPM for the relevant run, based on Policy Case 2 (2A, 2B LB, 2B UB; Exhibit 7). The estimate was based on the projected allowance prices and the capped emissions. We modeled revenue recycling effects using two alternative scenarios: lump sum rebates for all residents or investments in worker retraining and rehiring.

EXHIBIT 7: TOTAL REVENUES MODELED

POLICY CASE	TOTAL REVENUE (MILLION 2012 $)	REVENUE	RECYCLING METHOD
2A	$121,153	Allowance	Rebate
2B LB	$121,153	Allowance	Worker Retraining
2B UB	$121,153	Allowance	Worker Retraining

i. Rebate (Lump sum)

The revenue recycling numbers were broken into RCI based on state specific consumption shares from data on retail sales of electricity to different customer classes from EIA (see Exhibit 2). Rebates were entered into REMI as an annual lump sum payment for the residential sector, and by lowering production costs for the commercial and industrial sectors.

ii. Worker Retraining

In the alternative scenario for revenue recycling, we assumed that the available revenues can be used to retrain (and rehire) workers who lose their jobs because of the changes affecting the fossil fuel sectors. Based on the economic literature, we assumed the retraining investments would primarily go toward the education related sectors, whereas rehiring costs would be spent as hiring incentives. We estimated the number of workers needing retraining by examining the number of jobs lost due to fuel use changes in the recalibrated Reference Case (compared with the REMI Standard Control) as well as the jobs losses in the relevant policy case. We then determined the cost of reeducation as $15,000 per worker based on retraining estimates from Louie and Pearce (2016).[7] In addition to retraining costs, we estimated the costs of two rehiring incentives: an 'on the job training' (OJT) credit and an 'onboarding' credit. These credits, offered to employers to help offset the costs of hiring new employees, were estimated on a per person basis as 60 percent of the annual salary for six months and 1/3rd of the annual salary for OJT and onboarding, respectively. These estimates were based on information available from different BLS programs and initiatives.[8]

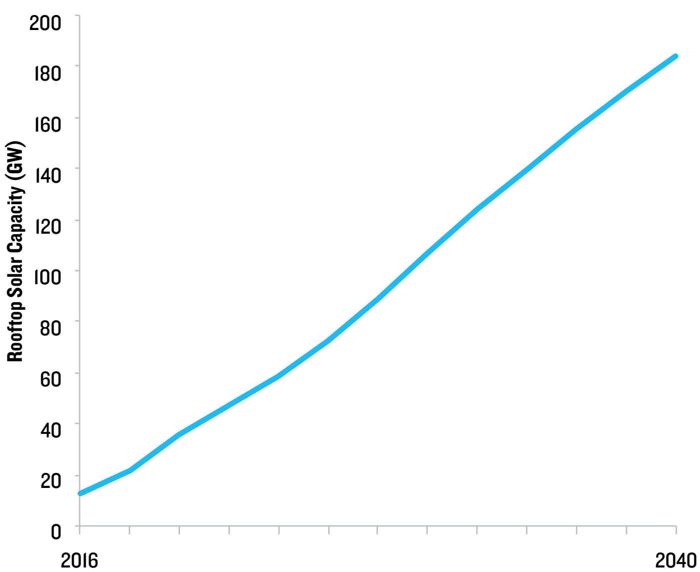
Because of the structuring of the revenue recycling program, there was significant revenue post 2025, but none prior. To allow for retraining and hiring incentives pre-2025, we assumed that the government will issue bonds to pay for the initial costs (in effect borrowing on expected future revenue streams), and then use the revenues generated later in the program to pay for the bonds as well as the costs of the program after 2025.[9] The amount borrowed and spent prior to 2025 represented less than 10 percent of total funds spent in the 2016-2040 period ($12 million is spent prior to 2025, compared with total revenues of $129 billion collected post-2025). To account for the borrowing costs for these investments—to offset the impact that this borrowing would have on other investments—we factored in changes to investment in the REMI policy variable non-residential investment spending. This offset reflects that there is borrowing to cover the cost of the retraining program, but there is a limited and fixed investment pool—government borrowing via issuing bonds to cover the retraining program will reduce available funds for private borrowing and raise their costs.

To estimate the economic impacts of the education investment and credits, we assessed a lower and an upper bound. For the lower bound, we included the education spending as exogenous final demand for education services. We then factored in the borrowing cost of the education spending using the investment spending variable in REMI. For the upper bound, we included the same values as the lower bound, offset additional investment from the credits, and then added jobs back into computer and electronic manufacturing, fabricated metal product manufacturing, machinery manufacturing, plastics and rubber product manufacturing, and professional and technical services. Using this approach we estimate a range for the effectiveness of worker retraining by estimating a lower bound at 0 percent rehiring and an upper bound at 100 percent rehiring. The UB represents 100 percent hiring because we force the model to hire all of the retrained mining workers that were displaced. For the lower bound, we do not force the model to hire any of these workers, and therefore it is as if they were retrained but none of them were hired.

f. Distributed Generation (DG) Solar

Policy case 4 explicitly models the impacts of distributed generation (DG) solar. DG solar estimates from IPM included capital and O&M costs, as well as bill savings, lost utility revenue, and reallocation values akin to those estimated under energy efficiency. We modeled new construction (Exhibit 8) of DG solar using JEDI and partitioned, similar to part (c) New Builds, the spending into relevant sectors (Exhibit 9).

EXHIBIT 8: CUMULATIVE DG SOLAR CAPACITY IN THE US (GW)[10]



Data source: National Renewable Energy Laboratory, 2016.

EXHIBIT 9: JEDI INDUSTRY SHARES (DG SOLAR)

ENERGY	IPM OUTPUT	INDUSTRY	SHARE
DG Solar	Capital Cost	Professional Services	47%
		Computer and Electronic Manufacturing	40%
		Construction	10%
		Fabricated Metals Manufacturing	3%

Exhibit values are originally from the National Renewable Energy Laboratory Jobs and Economic Development Impact models.

Similar to section (c) New Builds, it was necessary to post-model adjust the employment numbers to accurately reflect direct jobs.

We modeled bill savings, lost utility revenue, and reallocation akin to their energy efficiency counterparts (a) Energy Efficiency (ii-iv, above). The components reflect the savings accrued from less grid energy use by installing solar panels, the revenues lost to the utility sector as a result of reduced grid-produced energy consumption, and the budget offsets resulting from spending money on solar panels.

ENDNOTES

1 M.J. Bradley & Associates, *EPA's Clean Power Plan: Summary of IPM Modeling Results With ITC/PTC Extension* (2016). http://www.mjbradley.com/sites/default/files/MJBA_CPP_IPM_Report_III_2016-06-01_final_0.pdf.

2 We use value of production and number of employees from BLS, U.S. Labor Productivity (released May 18 2016) to determine labor productivity.

3 We assumed that the computer and electric manufacturing sector was associated with the manufacturing of renewable power plant components.

4 Available online at: https://www.bls.gov/emp/ep_table_108.htm

5 Jamie Howland et al., *Energy Efficient: Engine of Economic Growth: A Macroeconomic Modeling Assessment* (Environment Northeast, 2009). http://acadiacenter.org/wp-content/uploads/2014/10/ENE_EnergyEfficiencyEngineofEconomicGrowth_FINAL.pdf.

6 For more on the Retail Price Model, see https://www.epa.gov/sites/production/files/2015-08/documents/documentation_of_the_retail_price_model.pdf.

7 Edward P. Louis and Joshua M. Pearce, "Retraining investment for U.S. transition from coal to solar photovoltaic employment," *Energy Economics* 57, (2016), p. 295-302. http://www.sciencedirect.com/science/article/pii/S0140988316301347.

8 There are many sources of information for 'on the job training' and 'onboarding credits' including: the American Job Center at http://www.ewib.org/Portals/0/PDF/EWIB-OJT-Brochure--11-15.pdf and the Department of Labor, at: https://www.doleta.gov/Layoff/pdf/OJT_REQ.pdf and https://www.doleta.gov/business/incentives/opptax/.

9 For information on how the government borrows money, see: https://www.treasurydirect.gov/kids/what/what_borrow.htm. For information on how the U.S. Department of the Treasury issues debt see: https://fas.org/sgp/crs/misc/R40767.pdf.

10 The rooftop solar builds were exogenously specified in IPM, and the build levels were derived from the $10/ton Carbon Price case in: Pieter Gagnon and Ben Sigrin, *Distributed PV Adoption – Sensitivity to Market Factors* (National Renewable Energy Laboratory, 2016). http://www.nrel.gov/docs/fy16osti/65984.pdf.